The endocrine system produces various secretions called hormones that serve as effectors to regulate the activities of various cells, tissues, and organs in the body. The endocrine system functions are essential in maintaining homeostasis and coordinating body growth and development and are similar to that of the nervous system: Both systems communicate information to peripheral cells and organs. However the communication in the nervous system takes place through transmission of neural impulses along nerve cell processes and the discharge of neurotransmitter. Communication in the endocrine system takes place through hormones, which are carried to their destination via connective tissue spaces and the vascular system.

The hormones are secretory products of endocrine cells and organs that pass into the bloodstream for transport to target cells. Each hormone acts on cells that bear specific receptors for it. These cells are called target cells. Some hormones act only on one organ or on one type of cells. But there are hormones which may have widespread effécts.

Endocrine glands are ductless glands, that release their secretory próducts or hormones directly into the blood or lymph.

Chemical nature of hormones

Chemically all hormones can be divided into three main classes:

1. Amino acid derivatives. They are synthesized and secreted by cells of the adrenal medulla, thyroid gland cells and many neurons;
2. Small peptides, polypeptides and proteines. They are synthesized and secreted by cells of the hypothalamus, pituitary gland, parathyroid gland, pancreas and scattered endocrine cells of the gastrointestinal tract and respiratory system.
3. Steroids or cholesterol-derived hormones. They are synthesized and secreted by cells of the ovaries, testes and adrenal cortex.

Hormonal contról mechanisms

There are three basic types of hormonal control mechanisms: endocrine, paracrine and autocrine.

1. In endocrine control mechanism, the hormone is discharged from a cell into the bloodstream and is transported to the target effector cells;
2. In paracrine control mechanism, the hormone is secreted from one cell and acts on adjacent target cells that express specific receptors for it;
3. In autocrine control mechanism, the hormone responds to the receptors located on the cell that produces it and regulate the cell's own activity.

Morphology of the endocrine cells

Endocrine cells have well developed synthetic apparatus. If endocrine cells release protein hormones they have an extensive rough endoplasmic reticulum and large Golgi complex. Steroid-secreting endocrine cells have abundant smooth endoplasmic reticulum, mitochondria with tubular cristae, large numbers of lipid droplets. Usually endocrine cells are characterized by the presence of abundant membrane-limited granules containing the hormonal secretory próduct.

Compónents of the endocrine system

The components of the endocrine system vary greatly in their organization and include:

1. The discrete endocrine glands such as hypóphysis, thyroid, parathyroid, adrenal and pineal glands. They are large parenchymal organs, covering with connective tissue's capsule from outside. A cómmon structural feature of these ductless glands is an exceptionally rich blood supply. Fenestrated or sinusoidal capillaries provide the transport of the released hormones. Endocrine glands are formed by glandular epithelium or nervous tissue.
2. Groups of endocrine cells may be présent in organs that have other functions. They include the islets of Langerhans in the pancreas, the follicles and corpora lutea of the ovaries and the placenta.

3. Scattered cells of different organs with endocrine function, that belong to the diffuse neuroendocrine system of our organism.

Diffuse neuroendocrine system (DNES)

Diffuse neuroendocrine system constitute a collection of endocrine cells in the body. In addition to their endocrine function, cells of DNES exercise autocrine and paracrine control of the activity of their own and adjacent epithelial cells. DNES includes the interstitial cells of the testes, some cells in the kidneys, thymus and the cells of APUD system.

A part of diffuse neuroendocrine system is APUD system (Amine Precursor Uptake and Decarboxylation). Cells of APUD system have neural origination and produce amines that have endocrine functions. Many of these amines also act as neurotransmitters or as neuromodulators. They are endocrine cells in the epithelium lining of the organs of the digestive, respiratory, urinary, and reproductive systems and also Merkel's cells of the skin, parafollicular cells of the thyroid gland, medulla of the adrenal glands and so on.

Pituitary gland (Hypophysis)

The hypophysis is a compound endocrine gland suspended from the hypothalamus and located in the sella turcica. The region, surrounding the floor of the third ventricle forms hypothalamus. A short stalk called the infundibulum attaches the hypophysis to the hypothalamus.

The hypophysis consists of 2 functional components:

1) Adenohypophysis which is the glandular epithelial tissue;

2) Neurohypophysis which is the neural tissue.

The adenohypophysis is divided into a pars distalis, a pars tuberalis, and a pars intermedia. The neurohypophysis is divided into a pars nervosa or infundibular process, infundibulum and the median eminence. But in clinical and endocrinological literature the terms anterior lobe and posterior lobe are

well established. The anterior lobe of hypophysis consists of pars distalis and pars tuberalis. The posterior lobe of hypophysis consists of pars intermedia and pars nervosa.

Embryonic development of hypophysis

The hypophysis is developed from two separate sources: the neural tube and the oral ectoderm. Therefore it may be divided into a glandular portion which has epithelial characteristics and a neural portion. The part that arises from oral ectoderm is the adenohypophysis. It is derived from an outpocketing called Rathke's pouch of the primitive oral cavity ectoderm. This diverticulum later becomes cut off from the ectoderm. The anterior wall of Rathke's pouch forms a large pars distalis of adenohypophysis. Some cells grow upwards along infundibulum and form a pars tuberalis. The posterior wall of Rathke's pouch remains thin and forms the pars intermedia, that closely fuses with the pars nervosa. The residual cleft is a remnant of Rathke's pouch cavity. It is separates the pars distalis and the pars intermedia.

The part of the hypophysis that develops from the neural tube is the neurohypophysis. The neurohypophysis arises from an outpocketing of the neuroectoderm of the primitive brain (specifically the diencephalon). It forms the pars nervosa and the infundibulum.

The embryological development of the hypophysis explains the presence of two different types of tissues in hypophysis.

Structure and function of adenohypophysis

The anterior lobe constitutes about 75 percent of the hypophysis. It is formed by glandular epithelium and surrounded by a dense connective tissue capsule. The anterior lobe contains cells arranged in cords and clumps, that are

separated by numerous sinusoidal and fenestrated capillaries. A little connective tissue is present among the cords of cells.

These secretory cells of adenohypophysis are called adenocytes.

According to staining all adenocytes can be divided into chromophil cells that have brightly stained granules in their cytoplasm and chromophobe cells in which granules are not prominent.

Chromophobes make up about 50% of adenocytes. These small cells have long, branching processes. They represént degranulated chromophil cells and stem cells that give rise to new chromophils.

The chromophils are large cells whose diameter from 12 to 15 mkm. Chromophil cells are classified into acidophils (40%) whose granules are stained with acid dyes (like eosin) and basophils (10%) whose granules are stained with basic dyes (like haematoxylin). The acidophil cells are often called alpha cells, and the basophlis are called beta cells.

Acidophils predominate in the periphery of adenohypophysis, whereas chromophobes and basophils show a preference for the more central part of the gland.

The chromophils have a well developed rough endoplasmic reticulum, a large Golgi complex, and numerous membrane-limited granules containing the hormonal secretory próduct. After appropriate stimulation, the hormone is released by exocytosis and can enter the capillary vessels for delivery to the target organs.

There are two types of acidophils: 1) somatotropes and 2) lactotropes and three types of basophils: 3)gonadotropes; 4) thyrotropes and 5) corticofipotropes.

Acidophils

The acidophils secrete simple proteins. They contain large eosinophilic granules with protein hormones.

1) Somatotropes (GH cells) are most commonly found within the pars distalis and constitute approximately 50% of the parenchymal cells in the anterior lobe of the pituitary gland. These medium-sized, oval cells exhibit round, centrally located nuclei and produce growth hormone (GH) or somatotropin. It acts on many metabolic processes, but its most marked effect is to stimulate the growth of the epiphyseal cartilages of long bones. It contróls body growth, especially before puberty.

Hormonally active tumors that originate from somatotropes are associated with hypersecretion of GH and cause gigantism in children and acromegaly in adults.

2) Lactotropes (PRL cells, mammotropes) constitute 15% to 20% of the parenchymal cells in the anterior lobe of the pituitary gland. These are large, polygonal cells with oval nuclei. They produce hormon called prolactin (PRL), which stimulates activity of the mammary gland. During pregnancy and lactation, these cells undergo hypertrophy and hyperplasia, causing the pituitary gland to increase in size. Prolactin also stimulates secretion of progesterone by the ovary corpus luteum and maternal behavior.

Basophils

The basophils secrete glycoproteins. These cells are large, but they have small granules.

3) Gonadotropes (FSH and LH cells) constitute about 10% of the parenchymal cells in the anterior lobe of the pituitary gland. These small, oval cells with round and eccentric nuclei produce both luteinizing hormone (LH) and follicle-stimulating hormone (FSH). Both FSH and LH play an important role in male and female reproduction and demonstrate changes in women during the menstrual cycle. FSH stimulates the growth of ovarian follicles and the secretion of estrogens in the female. In the male, it stimulates spermatogenesis. LH stimulates the

maturation of the corpus luteum in the female. In the male LH stimulates the production of androgens.

4) Thyrotropes (TSH cells) constitute about 5% of the parenchymal cells in the anterior lobe of the pituitary gland. These large, polygonal cells with round and eccentric nuclei produce thyrotropic hormone called thyroidstimulating hormone (TSH), which acts on the follicular cells of the thyroid gland to stimulate production of thyroglobulin and thyroid hormones.

5) Corticotropes (ACTH cells) constitute 15% to 20% of the parenchymal cells in the anterior lobe of the pituitary gland. These polygonal, medium-sized cells with round and eccentric nuclei produce a precursor molecule of adrenocorticotropic hormone (ACTH). ACTH stimulates production of glucocorticoids by cells of the adrenal gland cortex.

Thus, the adenohypophysis is one of the most important endocrine gland. It produces several hormones some of which profoundly influence on the activities of other endocrine glands. Its own activity is regulated by the hypothalamus.

Neurohypophysis (posterior lobe of the pituitary gland)

The neurohypophysis stores and releases secretory products from the hypothalamus. The neurohypophysis is not an endocrine gland, because it is a storage site for neurosecretions of the neurons whose bodies locate by groups called nuclei in hypothalamus anterior part.

The pars nervosa contains:

1) nonmyelinated axons and their nerve endings;
2) fenestrated capillary network (capillary plexus);
3) suppotive glial cells called pituicytes.

Hypothalamus

The hypothalamus is located in the middle of the base of the brain, and it encapsulates the ventral portion of the third ventricle. It coordinates most

endocrine functions of the body and serves as one of the major controlling centers of the autonomic nervous system.

The hypothalamus is represented by nervous tissue, producing by multipolar neurons. Some of neurons have capacity to produce hormones. These neurons are named neurosecretory cells. In hypothalamus, the cell bodies of neurosecretory neurons lie by groups called nuclei.

In anterior part of hypothalamus there are two important nuclei, producing by large neurosecretory neurons cell bodies. They are supraoptic nuclei and paraventricular nuclei of the hypothalamus.

Hormones called vasopressin or antidiuretic hormone (ADH) is produced mainly in supraoptic nuclei and hormone called oxytocin is produced mainly in paraventricular nuclei of the hypothalamus. Both they belong to the polypeptide hormones.

Main effects of ADH are:

1) Decreasing urine volume by stimulating reabsorption of water by collecting ducts of the kidney;

2) Increasing blood pressure by stimulating contractions of smooth muscle cells in the wall of arterioles.

Main effects of oxytocin are:

1) Stimulation of the uterine smooth muscle contraction during orgasm, menstruation and parturition;

2) Stimulation of the mammary gland myoepithelial cells contraction to eject milk from the glands.

In addition to oxytocin and ADH, hypothalamic neurosecretory neurons secrete polypeptide hypothalamic regulating hormones that promote and inhibit the secretion and release of hormones from the anterior lobe of the pituitary gland.

The hypothalamic regulating hormones are secreted in medio-basal zone of hypothalamus where the more small neurosecretory cells produce a group of nuclei (arcuate, ventromedial, dorsal) called mediobasal group of nuclei.

Hypothalamic regulating hormones are:

1) Somatostatin, which inhibits secretion of GH by somatotropes;

2) Dopamine, which inhibits secretion of PRL by lactotropes;

3) Corticotropin-releasing hormone (CRH) which stimulates secretion of ACTH by corticotropes;

4) Gonadotropin-releasing hormone (GnRH) which stimulates secretion of LH and FSH by gonadotropes;

5) Thyrotropin-releasing hormone (TRH) which stimulates secretion of TSH by thyrotropes and synthesis and secretion of PRL [Ross].

Hypothalamohypophyseal system

The pituitary gland anatomically and functionally is closely associated with the hupothalamus to form a common hypothalamohypophyseal system. This system can be divide into:

1) hypothalamoneurohypophyseal;

2) hypothalamoadenohypophyseal.

Hypothalamoneurohypophyseal system

The pars nervosa of the pituitary gland contains the nonmyelinated axons and their nerve endings of neurosecretory neurons whose cell bodies lie in the supraoptic and paraventricular nuclei of the hypothalamus anterior part. The axons of these neurons collect together to form the hypothalamohypophyseal tract passing down along infundlbulum to reach pars nervosa and to produce terminal endings on the fenestrated capillary network (axovasal synapses) of the pars nervosa.

Hormones ADH and oxytocin producing in the supraoptic and paraventricular nuclei of the hypothalamus move down along the axons of the hypothalamohypophyseal tract to reach the pars nervosa. Here neurosecretory granules are stored at the dilated endings of the axons near their terminals known as Herring bodies and then ADH and oxytocin are released into capillary plexus of the pars nervosa through axovasal synapses. Then hormones ADH and oxytocin are distributed to target organs, tissues, and cells via the systemic circulation.

Hypothalamoadenohypophysal system

Hypothalamic neurosecretory neurons, producing stimulatory and inhibitory polypeptide hormones are located in the medio-basal zone of hypothalamus where they form arcuate, ventromedial, dorsal nuclei. Axons of the medio-basal zone neurosecretory neurons pass to the median eminence to form here the axovasal synapses with capillaries of primary capillary plexus.

The capillaries of the primary plexus region collect to form long hypophyseal portal veins that traverse down along the infundibulum and reach pars distalis of adenohypophysis where they breake up into a secondary capillary plexus.

Hypothalamic regulating polypeptide hormones accumulate in nerve endings near the median eminence and infundibulum and, than they are released into the capillary bed of primary capillary plexus for transport to the pars distalis of the pituitary gland trough the hypothalamohypophyseal portal system.

Hormone regulation feedback mechanism

The level of hormones in the systemic circulation regulates the secretion of cells in the anterior lobe of the pituitary gland. This is primary achieved by negative feedback regulation of hormones secreted by the pituitary gland by target hormones.

A feedback mechanism regulates endocrine function at two levels: hormone production in the pituitary gland and hypothalamic releasing hormone production in the hypothalamus.

For example the secretion of thyroid hormones is controlled by the release of TSH from the anterior lobe of the pituitary gland into the bloodstream. If blood levels of T3 and T4 are high, TRH is not produced or released. If blood levels of T3 and T4 are low, the hypothalamus discharges TRH into the hypothalamohypophyseal portal system. Release of TRH stimulates specific cells within the anterior lobe of the pituitary gland to produce TSH, which in turn stimulates the thyroid to produce and release more thyroid hormones. As the thyroid hormone levels rise, the negative feedback system stops the hypothalamus from discharging TRH.

Pineal gland

The pineal gland (or pineal body, or epiphysis cerebri) is a small neuroendocrine organ present in relation в связи to the posterior wall of the third ventricle of the diencephalon. The pia mater covers its surface and forms a capsule from which connective tissue septa with fenestrated blood vessels, penetrate into the gland dividing it into lobules.

The pineal gland parenchyma presenting by nervous tissue consists of two basic cell types: pinealocytes and glial cells (interstitial cells).

Most numerous pinealocytes are separated from one another by supportive glial cells that resemble astrocytes in structure.

Pinealocytes are arranged in clumps and cords within the lobules. Each pinealocyte has a polyhedral cell body containing a large irregular nucleus and cytoplasmic granules filled with hormones. A long cytoplasmic process extends from pinealocyte cell body to the capillaries wall producing expanded terminal buds at it's end that serves to release hormones into bloodstream.

The human pineal gland contains irregular shape calcified concretions, known as corpora arenacea, or brain sand. They are concentric layers of calcium phosphates and carbonates within an organic matrix. The number of calcified concretions in organ increases with age.

The pinealocytes produce a number of hormones. These hormones have an important regulating influence (chiefly inhibitory) on many other endocrine organs: the adenohypophysis, the neurohypophysis, the thyroid, the parathyroids, the adrenal cortex and medulla, the gonads, and the pancreatic islets.

The best-known hormone of the pineal gland is the melatonin. Serotonin is a precursor of melatonin. Secretion of the melatonin is stimulated by darkness and inhibited by light. Thus the level of this hormone increases during sleep.

The pineal gland is a photosensitive organ that obtains information about light and dark cycles from the retina via the retinohypothalamic tract, including retina fibers passing to the suprachiasmatic nucleus of hypothalamus. Suprachiasmatic nucleus links to the pineal gland through sympathetic neural tracts.

Melatonin is important in the regulation of the day and night cycles of our organism called circadian rhythms. Melatonin inhibits the steroidogenic activity of the gonads by the inhibitory action of melatonin on neurosecretory neurons located in the hypothalamus (arcuate nucleus) that produce GnRH. Inhibition of GnRH causes a decrease in the release of FSH and LH from the anterior lobe of the pituitary gland.