**Endocrine System**

Fear and love, stress and success, sleep and wakefulness, thirst and saturation, shivering and sweating, courage and embarrassment, all are daily life events that we are able to get through and survive with the help of our precious endocrine system.

Endocrine is a word that describe the glands in our body that secrete **directly** into our blood or lymph; the other type of glands we have in our body are called exocrine (secrete their products through ducts associated with them).

Our endocrine system is divided into glands distributed all over our body and working together to maintain our homeostasis. In this brief handout we will go through many of our endocrine glands and describe their behavior in health vs. disease, an outline is given below.

Outline:

1. The three classes of hormones.
2. Mechanisms of hormone actions.
3. Pituitary gland:
   1. Anatomy and location in the body
   2. Hormones secreted and their physiological function
   3. Diseases of the pituitary:
      1. More or less secretion (hypersecretion or hyposecretion)
      2. Symptoms and signs (kids vs. Adults)
4. Thyroid gland:
   1. Anatomy and location in the body
   2. Hormones secreted and their physiological functions
   3. Diseases of the thyroid:
      1. More or less secretion (hypersecretion or hyposecretion)
      2. Goiter
      3. Graves disease
      4. Myxedema and its treatment **(national level only)**
      5. Symptoms and signs (kids vs. adults)
5. Parathyroid gland:
   1. Anatomy and location in the body
   2. Hormones secreted and their physiological functions
   3. Diseases of the parathyroid:
      1. More or less secretion (hypersecretion or hyposecretion)
      2. Symptoms and signs (kids vs. adults)
6. Adrenal gland:
   1. Anatomy and location in the body
   2. Hormones secreted and their physiological functions
   3. Diseases of the adrenal:
      1. More or less secretion (hypersecretion or hyposecretion)
      2. Addison’s disease and its treatment**(national levels)**
      3. Cushing disease and its treatment**(national level)**
7. Endocrine pancreas:
   1. Anatomy and location in the body
   2. Hormones secreted and their physiological functions
   3. Diseases of the endocrine pancreas:
      1. More or less secretion (hypersecretion or hyposecretion)
      2. Hypoglycemia
      3. Diabetes mellitus
      4. Symptoms and signs (kids vs. adults)
8. Gonads (ovary in females and testicles in males)
   1. Anatomy and location in the body
   2. Hormones secreted and their physiological functions
   3. Diseases of the gonads:
      1. More or less secretion (hypersecretion or hyposecretion)
9. Endocrine cycles and negative feedback **(national level only)**
10. Autonomic nervous system control of endocrine function **(national level only)**
11. The three classes of hormones:
    1. Peptide hormones: these are synthesized from amino acids hence the name peptide! Some examples are pituitary hormones such as GH, ACTH, LH, FSH, prolactin, ADH, and oxytocin. (these are water soluble hormones, so they can travel in the blood freely)
    2. Steroid hormones: these are synthesized from cholesterol, so they are fat soluble. Some examples are: corticosteroids, aldosterone, estrogen, and testosterone. (these are fat soluble, so they need a transporter to carry them in the blood)
    3. Amine hormones: these are derived from the amino acids tyrosine and tryptophan, some examples are catecholamines (epinephrine, norepinephrine, and dopamine), and thyroxin. (thyroxin is fat soluble while catecholamines are water soluble)
12. Mechanisms of hormone action:
    1. Water soluble hormones: As mentioned before, they can travel freely in the blood to reach their target tissues. Upon arrival to their destination they bind to their target receptors on the cell membrane (they cannot enter the cell). Binding to their receptors will cause intracellular changes mediated by second messenger system. A cascade of events will cause cell response.
    2. Fat or lipid soluble hormones: Blood is composed mainly of water; therefore fat soluble hormones will not be able to travel freely in blood (polar dissolves polar, nonpolar dissolves nonpolar). As a result most are carried by transporter proteins.

Upon their arrival to their destination they enter their target cells through diffusion across plasma membrane. Inside the target cells, fat soluble hormones find their target intracellular receptors to mediate their action or they cross the nuclear membrane together with the receptor and cause a change in DNA transcription.

**Glands**

1. Pituitary Gland
   1. Anatomy and location in the Body:

Ok this is the big one, remember this and you are in the money. The pituitary gland is located in a bony fossa at the base of the brain. It is divided into anterior and posterior sections and is under the control of a region of the brain called the hypothalamus.

* 1. Hormones secreted and their physiological function

All pituitary hormones are peptides

**Posterior pituitary hormones**

* + 1. Oxytocin: involved in the induction of labour following pregnancy.
    2. Vasopressin (anti diuretic hormone) primarily invoved in regulating the body’s retention of water. Acts on the collecting ducts of the kidneys. Inhibited by alcohol.

**Anterior pituitary hormones (there are lots so i’ll be brief)**

* + 1. Growth Hormone: stimulates bone elongation, muscle growth organ growth, acts on liver to produce IGF (insulin like growth factor)
    2. Prolactin: regulates milk production
    3. Thyrotropin: thyroid stimulating hormone
    4. Lutenising hormone (LH), Follicle stimulating hormone (FSH) and chorionic gonadotrophin: Involved in fertility
    5. Adrenocorticotrophic hormone: Regulated cortisol production by adrenal cortex
    6. Melanocyte stimulating hormone: Acts on melanocytes in the skin to regulate skin pigmentation.

**Hypothalamus**

* + 1. Growth hormone releasing hormone (GHRH)
    2. Gonadotrophin releasing hormone (GnRH)
    3. Thyroropin releasing hormone (TRH)
    4. Corticotropin releasing hormone (CRH)
    5. Somatostatin: Growth hormone inhibiting hormone.
  1. Diseases of the pituitary

Predominantly caused by tumours

Excess growth hormone will cause giantism in kids and acromegaly in adults.

Increased release of ACTH occurs in addisons disease (see adrenal glands).

Decreased production of fertility hormones can result in delayed adolescence and infertility.

1. Parathyroid glands
   1. Anatomy and location in the body

Four glands located behind the thyroid gland

* 1. Hormones secreted and their physiological function

Parathyroid hormone. Increases blood calcium by stimulating osteoclasts to break down bone, also increases calcium absorbtion by gut and reabsorbtion by the kidney

* 1. Diseases of the parathyroid

Hyperparathyroidism: moans, groans, stones and bones ie depression, kidney stones and osteoporosis.

Hypoparathyroidism low plasma calcium can be life threatening, cause mental retardation in kids and stunt tooth growth.

1. Thyroid gland:
   1. Anatomy and location in the body:

Is a butterfly shaped gland composed of two lobes (right and left) connected with a bridge called the isthmus, the gland is located in the anterior part of our neck inferior to Adams apple (thyroid cartilage).

* 1. Hormones secreted and their physiological functions:

1. Thyroxine (T4): The most abundant thyroid hormone, main target is our brain especially during maturation and development, also it controls the rate of metabolism in our body (the higher the T4, the higher is the metabolism), is secreted by the follicular cells.
2. Triiodothyronine (T3): the most powerful thyroid hormone, in fact most T4 is transformed into T3 before directly affecting their target tissues (brain development, growth, and metabolism), secreted by the follicular cells but most are the result of peripheral conversion.
3. Calcitonin: is one of the hormones involved in Ca+2 regulation; and is secreted by the parafollicular cells (C cells).

* 1. Diseases of the thyroid:
     1. More or less secretion (hypersecretion or hyposecretion):

Hyperthyroidism is defined as increasing the levels of total T4, T3 or both which can be caused by a defect in the gland itself (here is called primary hyperthyroidism) or it can be caused by increase stimulation of the gland (increase TSH, TRH, or both) and is called secondary hyperthyroidism.

On the other hand, hypothyroidism is defined as decreasing the levels of total T4, T3 or both, and can be caused by either a defect in the gland itself (primary hypothyroidism) or decrease In gland stimulation (low TSH, TRH, or both) and is called secondary hypothyroidism.

* + 1. Goiter: Is defined as the enlargement of the thyroid gland regardless of its functional status. The function can be increased, decreased, or the same. See figure.

* + 1. Graves disease: Is an autoimmune disease characterized by antibodies against the TSH receptors, these antibodies cause hyper-stimulation of the thyroid hence hyperthyroidism. Females are affected more than males. Note: Graves disease is a cause of diffuse goiter.
    2. Myxedema and its treatment **(national level only):**

**Is a skin and tissue disorder result from prolonged hypothyroidism; however it can be caused by Graves disease. The skin becomes dry, cold, coarse, and hair becomes brittle. This condition can be prevented or treated by proper control of thyroxin levels (replacement of thyroxin)**

* + 1. Symptoms and signs (kids vs. adults): In kids and infants, the main effect will be on the growth and development particularly brain development in newborn babies (some governments routinely screen for hypothyroidism in newborn babies).

In adults we have a large spectrum of symptoms and signs for both hyper and hypothyroidism. For hyperthyroidism; patients will have increase metabolism all over their bodies:

* + - 1. Heat intolerance (wearing short sleeves despite Ohio snow storms!)
      2. Diarrhea (gut hypermotility)
      3. Nervousness
      4. Eye disease especially in Graves
      5. Weight loss despite good appetite
      6. Feeling fast heart beats (palpitations)
      7. Irritability and weakness
      8. Excessive sweating
      9. Hair loss

In hypothyroidism patients will have slowing of their metabolism so they will have:

1. Cold intolerance (wearing several layers of cloth while walking on Miami Beach in August).
2. Constipation (everything is slow!)
3. Sluggishness
4. Weight gain despite normal or decreased appetite
5. Bradycardia (slow heart beat)
6. Weakness and depression
7. Brittle hair and nails
8. Slow movement and slow speech
9. Pancreas:
   1. Anatomy and location

Attached to the duodenum below the stomach

* 1. Hormones secreted and their physiological function (extremely simplified i advise you read more)

Glucagon from alpha cells, increase glucose in blood.

Insulin from beta cells, decrease glucose in blood.

* 1. Diseases of the pancreas

Diabetes mellitus: high blood sugar as not enough insulin is produced. **Type I** diabetes is cause by loss of beta cells and requires treatment with injectable insulin. **Type 2** diabetes results from insulin resistance in the body combined often with a reduced production of insulin.

Symptoms are polyurea, polydipsia and polyphagia, ketone breath and kussmaul breathing.

Glucagonoma-hyperglycemia

1. Adrenal gland:
   1. Anatomy and location in the body:

It is triangular in shape, divided into cortex and medulla, the cortex is further divided into three layers (zona glomerulosa, zona fasciculata, and zona reticularis). The gland is located above the kidneys in the retroperitoneal space (not totally covered with peritoneum) hence is called suprarenal gland.

* 1. Hormones secreted and their physiological functions:
     1. From the cortex:
        1. Mineralocorticoids mainly Aldosterone (from zona glomerulosa): function in blood pressure regulation through Na+ and water regulation. (hypersecretion causes hypertension, hyposecretion causes hypotension)
        2. Glucocorticoid mainly cortisol (from zona fasciculata): stress hormone! Released in response to stress. (hypersecretion causes Cushing disease see figure, while hyposecretion causes inability to tolerate stress and death)
        3. Androgens mainly Dehydroepiandrosterone DHEA (from zona reticularis): play major role in male development early in embryology; in larger individuals they play the major role in musculization (voice, body hair, and aggression!). hypersecretion causes male phenotypes in females “deep voice, abnormal hair growth, and increase sexual drive” while hyposecretion in males

causes feminization and loss of male characteristics. If the abnormality takes place during embryological development the result will be vague sexual characteristics of born kids.

* + 1. From the medulla:
       1. Epinephrine (adrenaline)
       2. Norepinephrine (noradrenaline)

These two hormones are responsible for the fight and flight response, they control heart rate, respiratory rate, alertness, and sweating, etc.)

Hypersecretion causes hypertension, tachycardia (increase heart rate), excessive sweating, and nervousness, while hyposecretion will cause the opposite but is rare to happen.

* 1. Diseases of the adrenal:
     1. More or less secretion (hypersecretion or hyposecretion): mentioned in the previous section.
     2. Addison’s disease and its treatment**(national levels):**

**Is called also chronic adrenal insufficiency, it can be an autoimmune disease or functional inability to produce steroids or adrenal dysgenesis (very rare). The main hormones affected are glucocorticoids and mineralocorticoids. Patients will have increase in pigmentation in primary disease (ACTH will be produced in response to low levels of adrenal hormones and its production will be accompanied by the release of Melanocyte-stimulating hormone (MSH)). The treatment is by replacing the hormones particularly cortisol to prevent death.**

* + 1. Cushing disease and its treatment**(national level):**

**Cushing syndrome results from the increase in the levels of glucocorticoids in the body, it can be due to primary increase in adrenal function, or due to pituitary ACTH increase (Cushing disease), or due to excessive exogenous intake of corticosteroids. See figure for the signs and symptoms. Treatment will be according to the cause, if primary disease due to tumor or hyperplasia, surgical removal of the affected gland can be implemented, Treatment of the pituitary pathology by surgery and/or drugs if secondary disease, and Tapering (gradual decrease) of the exogenous corticosteroids dose if iatrogenic (due to medical treatment).**

1. Gonads (ovary in females and testicles in males)
   1. Anatomy and location in the body:

Ovaries are oval shaped structures, located in the lateral walls of the pelvis, females have two ovaries.

Testicles are the reproductive organs in males and they are located outside the body in a sac called scrotum (to maintain lower than body temperature), males have two testicles.

* 1. Hormones secreted and their physiological functions:

Ovaries secrete estrogen and progesterone which work together to regulate ovulation and menstrual cycle, in addition these hormones are responsible for female sexual characteristics.

Testicles secrete androgens which define male sexual characteristics, and they are the factory of sperms.

* 1. Diseases of the gonads:
     1. More or less secretion (hypersecretion or hyposecretion)

Early hypersecretion of estrogen in females (before usual age of puberty) will cause early sexual development (precocious puberty), the same in young males.

Hyposecretion of estrogens and progesterone in females will lead to female musculization; on the other hand hyposecretion of androgens in males will lead to male feminization.

* Endocrine cycles and negative feedback **(national level only)**

**Please see the attached drawings.**

* Autonomic nervous system control of endocrine function **(national level only)**

The autonomic nervous system is divided into the sympathetic system and the parasympathetic system.

The sympathetic system works when you are walking alone in the middle of the night in the jungle, so your heart will be racing, your respiration is so fast, your pupil is dilated to see the farthest point possible, you are so alert, anxious, sweaty, no time to urinate or defecate, no time to digest food, and you are eager to either flee or if necessary fight......

The parasympathetic system works when you are sitting in the bathroom reading for your science Olympiad competition, here your heart is slow, breathing is normal, pupil is constricting and focusing on Wright State University handouts, you are relaxed, digestion is working, and all sphincters are open!

All of the previously mentioned responses are the result of the interactions between our autonomic nervous system in response to changes in surrounding environment and our endocrine system which is responsible for the hormones that directly mediate the actions listed above; main key players are adrenaline and noradrenaline.

The autonomic nervous system control our endocrine function by releasing neurotransmitters to induce changes in hormone secretion from our glands, such as increasing release of adrenaline and noradrenaline in response to stress, and regulation of insulin and glucagon secretion from the endocrine pancreas in response to food intake status.

In summary, our nervous system works hand in hand with our endocrine system to fight daily life stresses and to keep us in good shape and function.

**We wish you all the best in the upcoming competitions.**

**Wright State University Science clinic team.**