Chemical Coordination and Integration - Part 2

Objectives

After going through this lesson, the learners will be able to understand the following

- Hormones secreted by testes and their functions
- Hormones secreted by ovaries and their functions
- Hormones secreted by heart and kidney and their functions
- Hormones secreted by gastrointestinal tract and their functions

Content Outline

- Introduction
- Hormones produced by testes
- Hormones produced by ovaries
- Hormones produced by Heart, Kidney and Gastrointestinal (GI) Tract
    - Heart
    - Kidney
    - Gastrointestinal Tract
- Summary

Introduction

Reproductive system consists of gonads (testes and ovaries) and associated structures which assist in reproduction. Gonads are the main centers as they produce gametes as well as several hormones which help in the production of gametes and maintain secondary sexual characters. In males, testes produce male gametes i.e. spermatozoa or sperms and the androgens (testosterone and dihydrotestosterone). In females, ovaries produce female gamete i.e. ovum or eggs and estrogens and progesterone. The principal gonadal hormones are derived from cholesterol (a steroid) hence they are also known as **steroid hormones**. Thus, the process of synthesis of gonadal hormones is known as **steroidogenesis**.

Hormones Produced by Testes

Testes (singular = testis) or testicles are present as a pair in the scrotal sacs of the males (Figure). Scrotum is a skin sac and lies in the pelvic area between two legs in males. Testis performs two functions *viz.* it acts as a primary sex organ and also acts as endocrine gland. Testis is made up of several **seminiferous tubules** and **stromal or interstitial tissue** covered by a capsule (Figure).

The seminiferous tubules are the sites of development of male gametes (sperms) through a process known as **spermatogenesis** which is under the control of hormones from testis itself. The gonadal hormones in males i.e. **androgens**, are synthesized by special cells in the interstitial spaces in testes known as **Leydig cells** or **interstitial cells.** The principal androgen is **testosterone** but it can be converted to another potent androgen known as **dihydrotestosterone (DHT)**. DHT is primarily involved in the development of **virilizing characteristics** (male specific external characters).

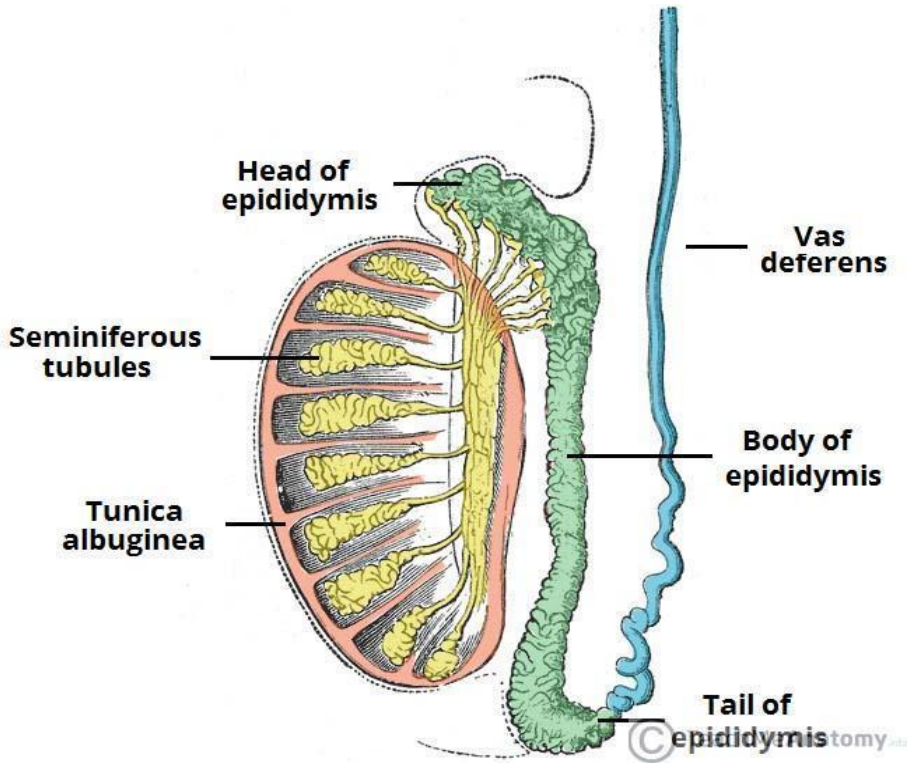

Figure 1: Structure of testis and associated structures (*This figure can be redrawn*)

Source:https://teachmeanatomy.info/pelvis/the-male-reproductive-system/testes-epididymis/

Figure 2: Transverse section of testis

Source:https://commons.wikimedia.org/wiki/File:Testicles_(26_2_11)_Cross-section.jpg

The transverse section of testis shows several seminiferous tubules and interstitial spaces (Figure). Each seminiferous tubule consists of a layer of cells at the periphery known as spermatogonia which are mother cells that give rise to spermatozoa. Spermatogonia undergo a series of changes within the seminiferous tubules, known as spermatogenesis, and release spermatozoa at the lumen of the tubule. During spermatogenesis, all the stages of development of spermatogonia are supported by nursing cells known as Sertoli cells. In addition to nursing and supporting the developing spermatogenic cells, Sertoli cells secrete a hormone known as **inhibin B** which inhibits the secretion of Follicle Stimulating Hormone (FSH) from anterior pituitary.

Testosterone in men causes characteristic pattern of distribution of body hair, regulates sex drive (libido), typical male voice, increases thickness of skin and causes acne to develop, increased musculature after puberty, bones grow thicker and deposit more calcium and increases basal metabolic rate. During embryonic development, the male embryo starts secreting testosterone, unlike female embryo which does not secrete any hormone, which causes the embryo to develop male specific genitalia and causes testes to descend in the scrotum.

Hormones Produced by Ovaries

Ovaries are located on either side of the abdomen in females. Ovaries contain follicles at different stages of development (Figure). Each month, one follicle from either of the ovaries starts its development and releases ovum i.e. ovulates. In the next month, the other ovary releases its egg. After ovulation, the follicle is converted into corpus luteum which secretes progesterone. If there is no pregnancy, the corpus luteum regresses and becomes corpus albicans which degrades subsequently. On the other hand, if pregnancy happens, corpus luteum becomes much larger in size and releases copious amounts of progesterone.

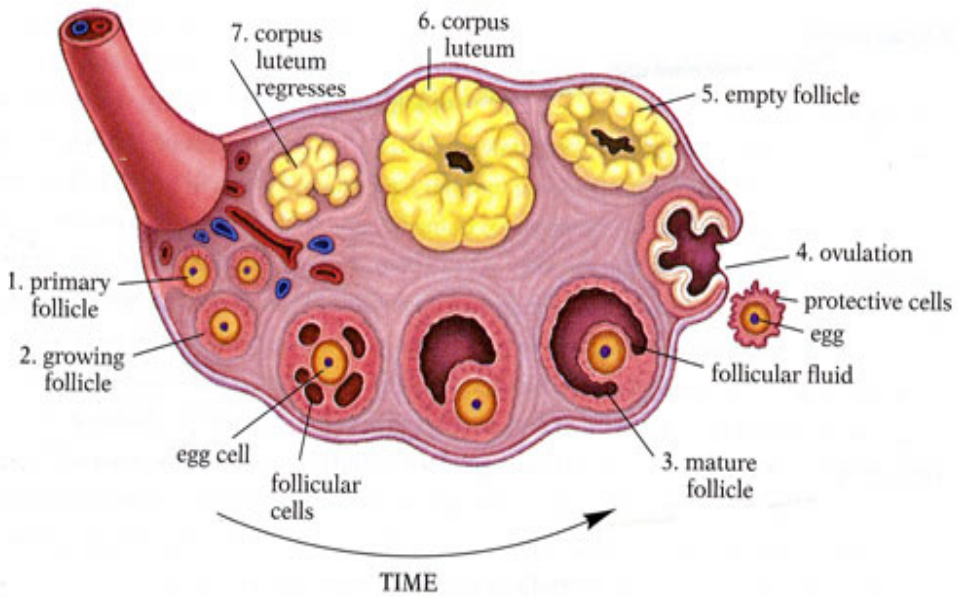

Figure 3: Structure of Ovary

https://commons.wikimedia.org/wiki/File:Anatomy_of_the_ovaries.jpg

Ovaries produce one egg (ovum) during the menstrual cycle each month. Thus, the ovary has two important functions to perform: (i) production of egg and (ii) production of steroid hormones. Ovaries produce two major hormones *viz*. estrogens and progesterone. There are four major types of estrogens: 17β-estradiol, estrone, estriol and estretrol. Estradiol is the most potent estrogen. Estrogens are secreted by granulosa cells of ovarian follicles, corpus luteum and placenta. Estrogen synthesis in the ovarian follicle depends on the coordinated biochemical activity of two types of cells: thecal cells and granulosa cells (Figure). This is known as the **two-cell model** of ovarian steroidogenesis**.** Figure (a) shows various stages of follicular development. The mature follicle is known as Graffian follicle and consists of an egg, surrounded by follicular cells, known as **granulosa cells**, which enclose a cavity at the

center known as **antrum**. The granulosa cells are surrounded by two layers of thecal cells which are known as **theca interna** (adjacent to granulosa cells) and **theca externa** (at the periphery).

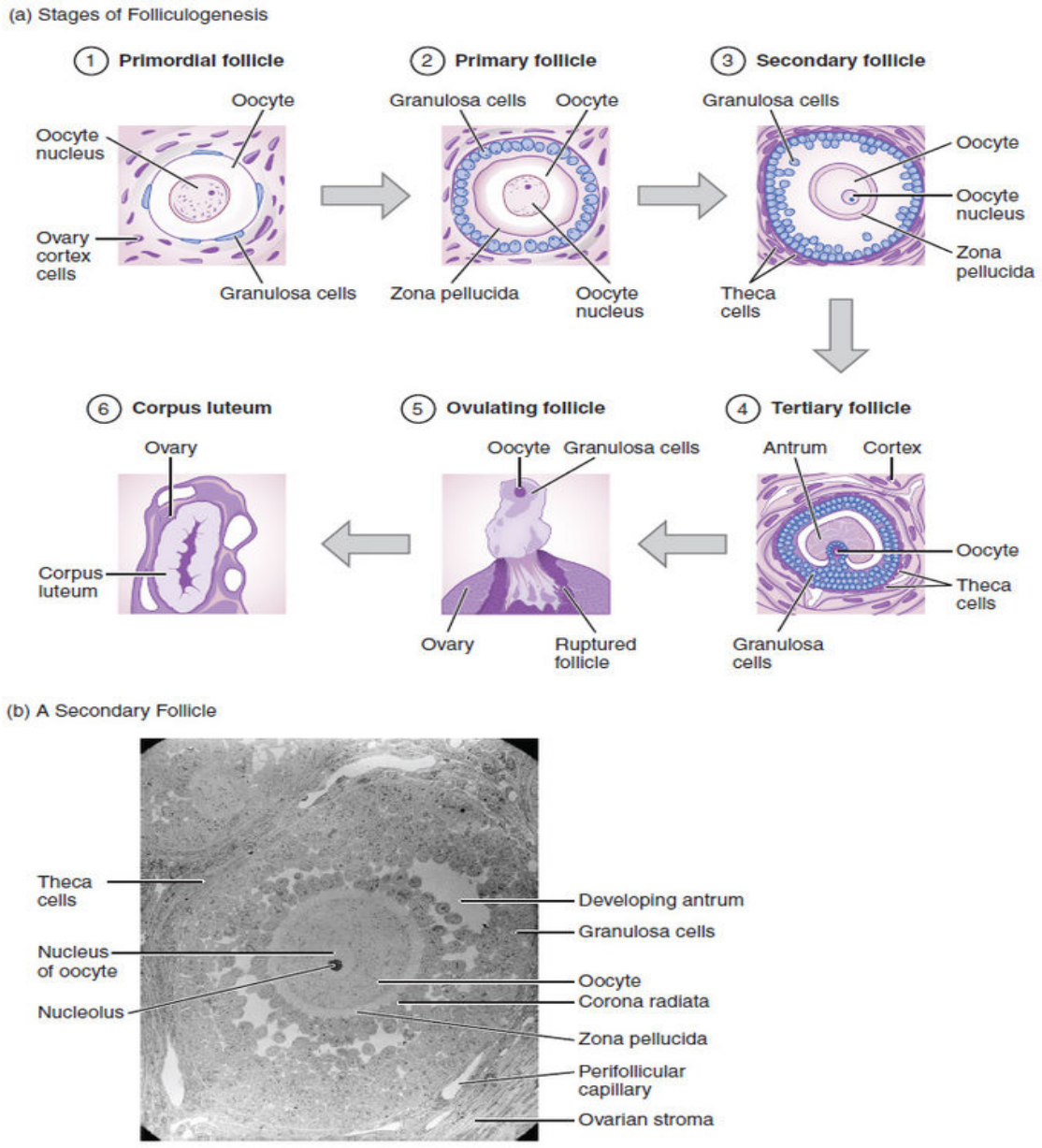

Figure 4: Development of ovarian follicles (Folliculogenesis)

Source:https://commons.wikimedia.org/wiki/File:Figure_28_02_04.JPG

Estrogens carry out several functions like facilitate growth of ovarian follicles, regulate secretions of LH and FSH, cause estrous behavior in animals, increase libido in humans and development of female secondary sex characteristics. Estrogens are responsible, in part, for the changes occurring in females during puberty like enlargement of breasts, uterus and vagina, distribution of fat in the body, high pitched voice, less body hair, more scalp hair etc.

Another hormone secreted by ovarian follicles is progesterone, however, progesterone is primarily secreted by corpus luteum and placenta. Progesterone secretion begins in late follicular phase i.e. when the ovarian follicles are about to ovulate (release the ovum) and later corpus luteum produces large quantities of progesterone. Progesterone performs two major functions i.e. first, it prepares the uterus for the implantation of the embryo and second, it prepares breasts for production of milk.

Hormones Produced by Heart, Kidney and Gastrointestinal (GI) Tract

Not all hormones are secreted by endocrine glands. Some hormones are also secreted by certain cells and/or tissues which are not endocrine glands. Let us discuss some of such organs which are not endocrine glands but secrete hormones.

a. Heart

The walls of the atrium in the heart secrete a hormone known as **atrial natriuretic factor (ANF)** or **atrial natriuretic peptide (ANP)**. It is a peptide hormone and maintains the extracellular fluid volume and thus, the blood pressure. When blood pressure increases, the arterial walls are stimulated to secrete ANF. ANF dilates the blood vessels and thus reduces the blood pressure.

b. Kidney

The kidney produces three hormones *viz.* **erythropoietin, calcitriol** and **renin**. They also secrete prostaglandins which act locally. Erythropoietin is a peptide hormone whose receptors are present on the erythrocyte precursors. The hormone prevents apoptosis of precursor cells and thus promotes **erythropoiesis** (formation of RBCs). The decrease in partial pressure of oxygen is the main stimulus for the release of erythropoietin.

Calcitriol is the active form of vitamin D and the final activation takes place in the kidney. It is produced in proximal tubular cells in the kidney. The main role of calcitriol is calcium absorption and bone mineralization.

Renin is an enzyme that converts angiotensinogen to angiotensin I, the rate limiting step of the renin-angiotensin system (physiological system that regulates blood pressure) as well as maintains sodium homeostasis. It is secreted from the juxtaglomerular cells of the kidney.

Gastrointestinal Tract (GI Tract)

Specialized endocrine cells scattered throughout the gastrointestinal tract secrete four major hormones *viz*. **gastrin, secretin, cholecystokinin (CCK)** and **gastric inhibitory peptide (GIP)**. Gastrin is secreted by the G cells located in the gastric pits of the stomach and lining of the upper part of the small intestine. When we eat, gastrin stimulates the parietal cells to secrete hydrochloric acid (HCl) which helps in the breakdown of proteins during digestion of food.

Secretin is the first peptide hormone (consisting of 27 amino acid residues) to be discovered. It is secreted by S cells of duodenum in crypts of Leiberkühn and proximal jejunum. Secretin influences the functions of many organs like heart, kidney, lung, brain etc. It stimulates secretion of bile from liver and water and bicarbonate ions from exocrine glands of pancreas. Secretin inhibits intestinal motility and secretion of gastric acid. The release of secretin is stimulated by secretion of gastric juice in the stomach. In addition to this, secretin is also produced by neurons in the brain. The levels of secretin in the body are used to assess pancreatic activity and test for pancreatic malignancy.

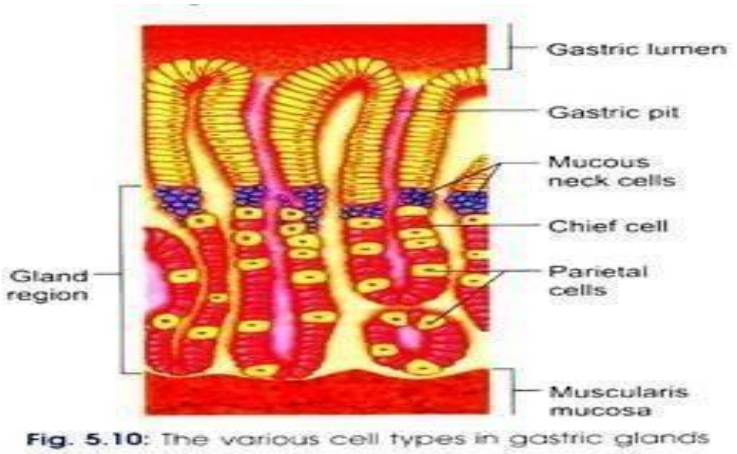

Figure 5: Mucosa of stomach showing different types of secretory cells. (*This figure can be redrawn*)

Source:http://www.biologydiscussion.com/human-physiology/digestive-system/structure-of-gastric-mucosa-digestive-system/62548

CCK is a neuropeptide (consisting of 33 amino acid residues) that is secreted primarily by I cells in duodenum and jejunum but also found in the peripheral and central nervous system. The two main functions of CCK are contraction of smooth muscles in gallbladder (leading to release of bile) and secretion of zymogens (inactive enzymes) by exocrine pancreas.

GIP is a peptide hormone (consisting of 43 amino acid residues) secreted by K cells of duodenum and jejunum. GIP performs two major functions: (i) stimulates pancreatic beta cells to secrete insulin and (ii) inhibits gastric secretion and motility.

Several other non-endocrine tissues secrete growth factors or growth hormones that are essential for the normal growth of tissues and their repair and/or regeneration. Some important growth factors include Epidermal Growth Factor (EGF), Platelet-derived Growth Factor (PDGF), Fibroblast Growth Factor (FGF), Nerve Growth factor (NGF), Transforming Growth Factor (TGF) etc.

Summary

Gonads are the main centers as they produce gametes as well as several hormones which help in the production of gametes and maintain secondary sexual characters. In males, testes produce male gametes i.e. spermatozoa or sperms and the androgens (testosterone and dihydrotestosterone).In females, ovaries produce female gamete i.e. ovum or eggs and estrogens and progesterone. The principal gonadal hormones are derived from cholesterol (a steroid) hence they are also known as steroid hormones. Thus, the process of synthesis of gonadal hormones is known as steroidogenesis. Testis consists of several seminiferous tubules and interstitial space. The interstitial space contains Leydig cells which secrete androgens i.e. testosterone and dihydrotestosterone (DHT). The Sertoli cells present in seminiferous tubules also secrete a hormone known as inhibin B. Inhibin B is known to act on anterior pituitary and stop secretion of FSH. The androgens are responsible for virilizing characters in males i.e. male specific characters. The secretion of testosterone starts during the development of male embryo as testosterone is necessary for differentiation of male genital organs. A pair of ovaries is located on either side of the abdomen. Each ovary contains several follicles and every month, one follicle starts its development and culminates in producing an egg. The granulosa cells in the growing follicles secrete estrogen which are responsible for female specific secondary sexual characters. After ovulation, the mature follicle is converted to corpus luteum which secretes another hormone called progesterone. Progesterone is required for maintaining the uterus for the implantation of the embryo and also prepares mammary glands (breasts) for milk production. The walls of the atrium in the heart secrete a hormone known as atrial natriuretic factor (ANF) or atrial natriuretic peptide (ANP). It is a peptide hormone and maintains the extracellular fluid volume and thus, the blood pressure. The kidney produces three hormones *viz.* erythropoietin (promotes

erythropoiesis), calcitriol (calcium absorption and bone mineralization) and renin (converts angiotensinogen to angiotensin I, the rate limiting step of renin-angiotensin system). Specialized endocrine cells scattered throughout the gastrointestinal tract secrete four major hormones *viz*. gastrin, secretin, cholecystokinin (CCK) and gastric inhibitory peptide (GIP).