THE INTEGUMENTARY SYSTEM

The most important function of the skin (integument) is that it acts as the first line of defense in protecting the body from disease by providing an external barrier. It also helps regulate the temperature of the body, provides information about the environment through the sense of touch, assists in the synthesis of vitamin D (essential for the normal formation of bones and teeth), and helps eliminate waste products from the body. It is the largest organ of the body and accomplishes its diverse functions with assistance from its accessory structures, which include the hair, nails, and two types of glands: sebaceous (oil) and sudoriferous (sweat). Any impairment of the skin has the potential to lessen its ability to carry out these functions, which can lead to disease.

The skin is composed of two layers: the epidermis, which forms the outermost layer, and the dermis or corium, the inner layer. The dermis is attached to a layer of connective tissue called the hypodermis or the subcutaneous layer, which is mainly composed of fat (adipose tissue).

The epidermis is composed of several different layers, or strata, of epithelial tissue. Epithelial tissue covers many of the external and internal surfaces of the body. Because the type of epithelial tissue that covers the body has a microscopic layered, scaly appearance, it is referred to as stratified squamous epithelium.

Although there is a limited blood supply to the epidermis (it is avascular—that is, it contains no blood vessels), constant activity is taking place. New skin cells are formed in the basal (bottom) layer of the epidermis, the stratum germinativum (also called the stratum basale). The term germinativum is derived from germ/i meaning sprout and nat/o meaning birth. So this is where the skin cells “sprout” and are “born,” that is to say, where they develop, or germinate. This layer is also the site where melanin (a black pigment) is produced by melanocytes. When the skin is
exposed to ultraviolet light, the melanocytes secrete more melanin. Birthmarks, age spots, and freckles result from the clumping of melanocytes in the basal layer of the skin. Individuals have different skin colors because of varying numbers of melanocytes.

The dermis, or corium, is the thick, underlying layer of the skin that is composed of vascular connective tissue arranged in two layers. The papillary layer is the thin upper layer composed of fibers made from protein and collagen that serves to regulate blood flow through its extensive vascular supply. The reticular layer is the lower, thicker layer, which also is composed of collagen fibers. This layer holds the hair follicles, sudoriferous and sebaceous glands, and the sensory receptors. Meissner’s corpuscles provide sensitivity to light touch, while Pacinian’s corpuscles sense pressure. Specialized heat and cold receptors relay information to the brain for regulating body temperature (thermoregulation).

Accessory glands

The sudoriferous, or sweat, glands are located in the dermis and provide one means of thermoregulation for the body. Eccrine glands, most densely in the hands, feet, and forehead, secrete sweat through tiny openings in the surface of the skin called pores. Eccrine glands are principally responsible for cooling the body. Apocrine glands, located in the armpits and groin, begin secretion after puberty, and aside from discharging sweat through the hair follicles, may be responsible for an individual’s unpleasant body odor. Eccrine glands are named for secreting their sweat directly to the outside (ec-) of the body. Apocrine glands are named for a separation (apo-) of part of the secreting cell that enters the gland before it is discharged to the surface of the body. The secretion of sweat is called perspiration. The sebaceous glands secrete an oily, acidic substance called sebum, which helps to lubricate hair and the surface of the skin. The acidic nature of sebum is key in inhibiting the growth of bacteria.

Hair has its roots in the dermis; these roots, together with their coverings, are called hair follicles. The visible part is called the hair shaft. Underneath the follicle is a nipple-shaped structure that encloses the capillaries called the papilla. Epithelial cells on top of the papilla are responsible for the formation of the hair shaft. When these cells die, hair can no longer regenerate, and hair loss occurs. Like skin, hair is colored by melanin, but in hair, there are two types. Eumelanin gives hair a black or brown color, while pheomelanin results in red or blond hair. Individuals who have very little melanin will have gray hair, while those with no melanin have white hair.

The main function of hair is to assist in thermoregulation by holding heat near the body. When cold, hair stands on end (piloerection), holding a layer of air as insulation near the body.

Nails cover and thus protect the dorsal surfaces of the distal bones of the fingers and toes. The part that is visible is the nail body (also called the nail plate), whereas the nail root (matrix) is in a groove under a small fold of skin at the base of the nail. The nail bed is the highly vascular tissue under the nail that appears pink when the blood is oxygenated or blue/purple when it is oxygen deficient. The moonlike white area in the base of the nail is called the lunula (meaning little moon), behind which new growth occurs.
THE URINARY SYSTEM

The major function of the urinary system is to continually maintain a healthy balance of the amount and content of extracellular fluids within the body. Biologists use the term homeostasis to describe this important process. The process of metabolism changes food and liquid (with its requisite fats, carbohydrates, and proteins) into building blocks, energy sources, and waste products. To operate efficiently, the body needs to constantly monitor and rebalance the amounts of these substances in the bloodstream. The breakdown of proteins and amino acids in the liver leaves chemical wastes, such as urea, creatinine, and uric acid, in the bloodstream. These wastes are toxic, nitrogenous substances that must be excreted in the urine. The act of releasing urine is called urination, voiding, or micturition.

Because the kidneys are primarily responsible for the functioning of the urinary system, it is helpful to look at them in greater detail. Each of the two kidneys is located high in the abdominal cavity, tucked under the ribs in the back and behind the lining of the abdominal cavity (retroperitoneal). The normal human kidney is about the size of a fist. The tough outer covering of the kidney is the renal capsule. If a kidney were sliced open, the outer portion, the cortex (pl. cortices), and the inner portion, called the medulla (pl. medullae), would be visible. The renal pelvis and calyces (sing. calyx) are an extension of the ureter inside the kidney. The renal pyramids are triangular sections that extend from the renal medulla toward the renal pelvis. The downward point of the pyramid is referred to as the papilla. The term renal means pertaining to
the kidneys. The ureteropelvic junction (UPJ) is the area where the ureter joins the renal pelvis. It is a common site of obstruction of the outward flow of urine from the kidney.

The hilum (pl. hila) is the location on the kidney where the ureter and renal vein leave the kidney and the renal artery enters. The cortex contains tissue with millions of microscopic units called nephrons. Here in the tiny nephrons, blood passes through a continuous system of urinary filtration, reabsorption, and secretion that measures, monitors, and adjusts the levels of substances in the extracellular fluid.
The nephrons filter all the blood in the body approximately every 5 minutes. The **renal afferent arteries** transport unfiltered blood to the kidneys. Once in the kidneys, the blood travels through small arteries called **arterioles** and finally into tiny balls of renal capillaries, called **glomeruli** (sing. glomerulus). These glomeruli cluster at the entrance to each nephron. It is here that the process of filtering the blood to form urine begins. The nephron consists of four parts: (1) the **renal corpuscle**, which is composed of the glomerulus and its surrounding Bowman’s capsule; (2) a **proximal convoluted tubule**; (3) the **nephronic loop**, also known as the Loop of Henle; and (4) the **distal convoluted tubule**. As blood flows through the capillaries, water, electrolytes, glucose, and nitrogenous wastes are passed through the glomerular membrane and collected. The most common electrolytes are sodium (Na), chloride (Cl), and potassium (K). Blood cells and proteins are too large to pass through the glomerular membrane. Selective filtration and reabsorption continue along the renal tubules, with the end result of **urine** concentration and subsequent dilution occurring in the renal medulla. From there, the urine flows to the calyces and exits the kidney, flowing through the ureter into the bladder, where it is stored until it can be expelled from the body through the urethra.

### THE ENDOCRINE SYSTEM

The **endocrine** and nervous systems work together and separately to achieve the delicate physiologic balance necessary for survival termed homeostasis. While the nervous system uses electrical impulses and chemicals termed neurotransmitters, the endocrine system secretes chemical messengers into the bloodstream called **hormones**. Hormones play a major role in the regulation of **metabolism** (the conversion of energy) and nutritional disorders may be a cause or result of endocrine dysfunction. The term neuroendocrine, as in the term neuroendocrine tumors, is recognition of the close relationship between the two systems. Nervous stimulation of the posterior lobe of the pituitary (neurohypophysis) causes secretion of hormones ADH and oxytocin.

The endocrine system is composed of several single and paired ductless glands that secrete hormones into the bloodstream. The hormones regulate specific body functions by acting on target cells with receptor sites for those particular hormones only.

The **pituitary gland**, also known as the **hypophysis**, is a tiny gland located behind the optic nerve in the cranial cavity in a depression in the sphenoid bone called the sella turcica. The **infundibulum**, named for its funnel-like appearance, is the structure that attaches the pituitary to the hypothalamus directly superior to it in the brain. Sometimes called the **master gland** because of its role in controlling the functions of other endocrine glands, the hypophysis is composed of anterior and posterior lobes, each with their own function.

The **anterior lobe**, or **adenohypophysis**, is composed of glandular tissue and secretes hormones in response to stimulation by the hypothalamus. The **hypothalamus** sends hormones through blood vessels, which cause the adenohypophysis either to release or to inhibit the release
of specific hormones. The adenohypophysis has a wide range of effects on the body, as Fig. 15-2 and the table below illustrate.

The **posterior lobe (neurohypophysis)** of the pituitary gland is composed of nervous tissue. The hormones that it secretes are produced in the hypothalamus, transported to the neurohypophysis directly through the tissue connecting the organs, and released from storage in the posterior lobe by neural stimulation from the hypothalamus. The two hormones released by this lobe are **antidiuretic hormone (ADH)** and **oxytocin (OT)**.

### Adenohypophysis Hormones and Their Effects

<table>
<thead>
<tr>
<th>Adenohypophysis Hormones</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Adrenocorticotropic hormone (ACTH)</strong></td>
<td>Stimulates the adrenal cortex to release steroids.</td>
</tr>
<tr>
<td><strong>Gonadotropic hormones</strong>&lt;br&gt;(include follicle-stimulating hormone [FSH], luteinizing hormone [LH], and interstitial cell-stimulating hormone [ICSH])&lt;br&gt;</td>
<td>FSH stimulates the development of gametes in the respective sexes. LH stimulates ovulation in the female and the secretion of sex hormones in both the male and the female. ICSH stimulates production of reproductive cells in the male.</td>
</tr>
<tr>
<td><strong>Growth hormone (GH)</strong>&lt;br&gt;(also called human growth hormone [hGH] or somatotropin hormone [STH])&lt;br&gt;</td>
<td>Stimulates growth of long bones and skeletal muscle; converts proteins to glucose.</td>
</tr>
<tr>
<td><strong>Prolactin (PRL)</strong>?&lt;br&gt;(also called lactogenic hormone)&lt;br&gt;</td>
<td>Stimulates milk production in the breast.</td>
</tr>
<tr>
<td><strong>Thyrotropin</strong>&lt;br&gt;(also called thyroid-stimulating hormone [TSH])&lt;br&gt;</td>
<td>Stimulates thyroid to release two other thyroid hormones.</td>
</tr>
</tbody>
</table>
The thyroid gland is a single organ, but is divided into right and left lobes that are joined by a thin structure termed the isthmus. It is located in the anterior part of the neck and is bounded by the trachea behind it and the thyroid cartilage above it. It regulates the metabolism of the body and normal growth and development, and controls the amount of calcium (Ca) deposited into bone. The thyroid gland is composed of small sacs called follicles that absorb iodine. The sacs are surrounded by follicular cells that produce triiodothyronine (T3) and thyroxine (T4). Parafollicular cells in the thyroid produce and secrete calcitonin, which controls the amount of calcium in the blood. Thyroid-stimulating hormone (TSH), released by the anterior pituitary gland, causes the thyroid to release T3 and T4.

The parathyroids are four small glands (right and left, superior and inferior) located on the posterior surface of the thyroid gland in the neck. They secrete parathyroid hormone (PTH) in response to a low level of calcium in the blood. When low calcium is detected, the PTH increases calcium by causing it to be released from the bone, which results in calcium reabsorption by the kidneys and the digestive system. PTH is inhibited by high levels of calcium.
The **adrenal glands**, also called the **suprarenals**, are paired, one on top of each kidney. Different hormones are secreted by the two different parts of these glands: the external portion called the **adrenal cortex** and an internal portion called the **adrenal medulla**.

The adrenal cortex secretes three hormones that are called steroids. The adrenal medulla is the inner portion of the adrenal gland. It produces sympathomimetic hormones that stimulate the fight-or-flight response to stress, similar to the action of the sympathetic nervous system.

### Adrenal Cortex Hormones and Their Effects

<table>
<thead>
<tr>
<th>Adrenal Cortex Hormones</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glucocorticoids (e.g., cortisol [hydrocortisone])</td>
<td>Respond to stress; have antiinflammatory properties.</td>
</tr>
<tr>
<td>Mineralocorticoids (e.g., aldosterone)</td>
<td>Regulate blood volume, blood pressure, and electrolytes.</td>
</tr>
<tr>
<td>Sex hormones (e.g., estrogen, androgen)</td>
<td>Responsible for secondary sex characteristics.</td>
</tr>
</tbody>
</table>

### Adrenal Medulla Hormones and Their Effects

<table>
<thead>
<tr>
<th>Adrenal Medulla Hormones (Catecholamines)</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dopamine</td>
<td>Dilates arteries and increases production of urine, blood pressure, and cardiac rate. Acts as a neurotransmitter in the nervous system.</td>
</tr>
<tr>
<td>Epinephrine (also called adrenaline)</td>
<td>Dilates bronchi, increases heart rate, raises blood pressure, dilates pupils, and elevates blood sugar levels.</td>
</tr>
<tr>
<td>Norepinephrine (also called noradrenaline)</td>
<td>Increases heart rate and blood pressure and elevates blood sugar levels for energy use.</td>
</tr>
</tbody>
</table>

The pancreas, located inferior and posterior to the stomach, is a gland with both exocrine and endocrine functions. The **exocrine function** is to release digestive enzymes through a duct into the small intestines. The **endocrine function**, accomplished through a variety of types of cells called **islets of Langerhans**, is to regulate the level of glucose in the blood by stimulating the liver. The two main types of islets of Langerhans cells are alpha and beta cells. **Alpha cells** produce the hormone glucagon that increases the level of glucose in the blood when levels are low. **Beta cells** secrete **insulin** that decreases the level of glucose in the blood when levels are high. Insulin is needed to transport glucose out of the bloodstream and into the cells. In the absence of glucose in the cells, proteins and fats are broken down, causing excessive fatty acids
and ketones in the blood. Normally, these hormones regulate glucose levels through the metabolism of fats, carbohydrates, and proteins.

THE MALE REPRODUCTIVE SYSTEM

The function of the male reproductive system is to reproduce. In the process of providing half of the genetic material (in the form of spermatozoa) necessary to form a new person—and then successfully storing, transporting, and delivering this material to fertilize the female counterpart, the ovum—the species survives.

Both male and female anatomy can be divided into two parts: parenchymal, or primary tissue, which produces sex cells for reproduction; and stromal, or secondary tissue, which includes all of the glands, nerves, ducts, and other tissues that serve a supportive function in producing, maintaining, and transmitting these sex cells. Together these types of reproductive tissue, in
either sex, are called **genitalia**. The parenchymal organs that produce the sex cells in both sexes are called **gonads**. The sex cells themselves are called **gametes**.

In the male, the gonads are the **testes** (sing. testis) or **testicles**, paired organs that produce the gametes called **spermatozoa** (sing. spermatozoon). The testes are suspended in a sac called the **scrotum** (pl. scrota) outside the body’s trunk.

At **puberty**, the stage of life in which males and females become functionally capable of sexual reproduction, the interstitial cells in the testicles begin to produce **testosterone**, a sex hormone responsible for the growth and development of male sex characteristics. The spermatozoa are formed in a series of tightly coiled, tiny tubes in each testis called the **seminiferous tubules**. The formation of sperm is called **spermatogenesis**. The serous membrane that surrounds the front and sides of the testicle is called the **tunica vaginalis testis**. From the seminiferous tubules, the formed spermatozoa travel to the **epididymis** (pl. epididymides), where they are stored.

When the seminal fluid is about to be ejected from the urethra (ejaculation), the spermatozoa travel through the left and right **vas deferens**, also called the **ductus deferens**, from the epididymides, around the bladder. The **spermatic cord** is an enclosed sheath that includes the vas deferens, along with arteries, veins, and nerves.
To survive and thrive, the sperm are nourished by fluid from a series of glands. The seminal vesicles, Cowper’s (or bulbourethral) glands, and the prostate gland provide fluid either to nourish or to aid in motility and lubrication. The sperm and the fluid together make up a substance called semen. The ejaculatory duct begins where the seminal vesicles join the vas deferens, and this “tube” joins the urethra. Once the sperm reach the urethra, they travel out through the shaft, or body, of the penis, which is composed of three columns of highly vascular erectile tissue. There are two columns of corpora cavernosa and one of corpus spongiosum that fill with blood through the dorsal veins during sexual arousal. Two leglike extensions of the corpus cavernosa, the crura, attach the penis to the pubic bone on either side. During ejaculation, the sperm exit through the enlarged tip of the penis, the glans penis. At birth, the glans penis is surrounded by a fold of skin called the prepuce, or foreskin. The removal of this skin is termed circumcision.

When ejaculation occurs during sexual intercourse (coitus or copulation), the sperm then race toward the female sex cell, or ovum. If a specific sperm penetrates and unites with the ovum, conception takes place, and formation of an embryo begins.

THE FEMALE REPRODUCTIVE SYSTEM

The role of the female reproductive system is to keep one’s genetic material in the world’s gene pool. Through sexual reproduction, the 23 pairs of chromosomes of the female must join with 23 pairs of chromosomes from a male to create new life. To do this, the system must produce the hormones necessary to provide a hospitable environment for the ovum (OH vum) (pl. ova), the female gamete, to connect with the spermatozoon, the male gamete, for fertilization to occur. Once an egg is fertilized, it is nurtured throughout its growth process until the delivery of the neonate (newborn).

Because the primary function of the female reproductive system is to create new life through the successful fertilization of an ovum, discussion of this system begins with this very important germ cell.

From menarche, the first menstrual period, to menopause (the climacteric), the cessation of menstruation, mature ova are produced by the female gonads, the ovaries. The ovaries are small, almond-shaped, paired organs located on either side of the uterus in the female pelvic cavity. They are attached to the uterus by the ovarian ligaments and lie close to the opening of the fallopian tubes, the ducts that convey the ova from the ovaries to the uterus. Approximately every 28 days, in response to hormonal stimulation, the ovaries alternate releasing one ovum. This egg matures in one of the follicles, which are tiny, secretory sacs within an ovary. Graafian follicles are the result of a monthly maturation of these structures that occurs between puberty and menopause. The pituitary gland, an endocrine gland located in the cranial cavity, secretes two hormones that influence the activity of the ovaries. Follicle-stimulating hormone (FSH) causes the ovarian follicles to begin to mature and secrete estrogen. Because of the increase of estrogen in the bloodstream, luteinizing hormone (LH) is released by the anterior lobe of the pituitary gland. LH then stimulates the follicle to mature and release its ovum (ovulation) and aids in the development of the corpus luteum. The corpus luteum, a tiny, yellow endocrine structure,
then responsible for secreting **estrogen** and **progesterone**, hormones responsible for female secondary sex characteristics and the cyclical maintenance of the uterus for pregnancy. If two eggs are released and fertilized, the resulting twins will be termed **fraternal**, because they will be no more or less alike in appearance than brothers (or sisters) occurring in sequential pregnancies. If, however, one of the fertilized eggs divides and forms two infants, these are **identical** twins, who share the same appearance and genetic material.
Once the mature ovum has been released, it is drawn into the fimbriae (sing. fimbria), the feathery ends of the fallopian tube. These tubes, about the width of a pencil, and about as long (10 to 12 cm), transport the ovum to the uterus. Along the length of the tube are structures with names that indicate their shape or location: the infundibulum is the funnel-shaped area adjacent to each fimbria; the ampulla follows, named for its bottle shape, and the fallopian isthmus is the narrowed area close to the uterus. The fallopian tubes (also called oviducts or uterine tubes) and the ovaries make up what is called the uterine adnexa, or accessory organs of the uterus.

Once the ovum has traversed the fallopian tube, it is secreted into the uterus, or womb, a pear-shaped organ that is designed to nurture a developing embryo/fetus. The uterus is composed of three layers: the outer layer, called the perimetrium, or serosa; the myometrium, or muscle layer; and the endometrium, the lining of the uterus. Disorders that involve the layers of the uterus are termed intramural. As a whole, the uterus can be divided into several areas. The corpus (which means body in Latin) is the large central area; the fundus is the raised area at the top of the uterus between the outlets for the fallopian tubes; and the cervix is the narrowed lower area, often referred to as the neck of the uterus. Note that there are two openings of the cervix: the internal os and the external os. The area in between is termed the cervical canal.
The external female genitalia collectively are called the **vulva**. The vulva consists of the vaginal opening, or **orifice**; the membrane covering the opening, or **hymen**; the two folds of skin surrounding the opening, or **labia majora** (the larger folds) and **labia minora** (the smaller folds); the **clitoris**, which is sensitive, erectile tissue; and the **perineum**, the area between the opening of the vagina and the anus. The **vestibular glands**, located in or near the opening of the vagina are divided into two types. The greater vestibular glands (also called **Bartholin’s glands**) are the paired glands in the vulva that secrete a mucous lubricant for the vagina. The lesser vestibular glands (also called **Skene’s** or **paraurethral glands**) are located in the vagina near the outlet of the urethra and have a function similar to the male prostate, providing fluid during ejaculation.

The Breast

The **breasts**, or mammary glands, are composed of fatty (adipose) tissue, fibrous connective tissue, milk-producing glands and ducts, lymphatic tissue, and blood vessels. Pectoral muscles lie beneath the breast tissue and the suspensory (Coopers) ligaments attach the breast to the chest wall.

The **nipple** of the breast is the **mammary papilla** (pl. papillae), and the darker-colored skin surrounding the nipple is the areola (pl. areolae). Internally, the breast is composed of 15 to 20 sections that radiate around the nipple. Each of the sections is made up of several segments called **lobules**, each of which ends in a bulblike cavity termed an **alveolus**. Thin passageways called **ducts** carry milk from the lobules to the nipple. Small dilations of the duct close to the nipple that serve to hold milk prior to being expressed are termed **lactiferous sinuses** or **ampullae**.

Lymph vessels surround and drain the breast into axillary and mediastinal lymph nodes. **Prolactin**, released by the anterior pituitary, is the main hormone associated with the formation and production of milk (**lactogenesis**); whereas the hormone **oxytocin** is produced by the posterior lobe of the pituitary and is responsible for the release of the milk produced.