CHAPTER 2

THE DIGESTIVE SYSTEM

Animals, like plants, absorb their food in fluid form. In order that solid food shall become fluid, preparatory to being taken into the blood stream, it must undergo certain mechanical and chemical changes. The parts of the body set aside for this purpose are known as the digestive or alimentary system. This is essentially (1) a long hollow tube, the digestive passage, through which food is propelled, and (2) certain accessory glands (*fig. 45*).

The *digestive passage* (alimentary canal) begins at the lips, traverses the neck, thorax, abdomen and pelvis, and ends at the anus. Its successive parts are: the mouth, pharynx, esophagus, stomach, small intestine (subdivided into duodenum, jejunum, and ileum) and large intestine (subdivided into appendix, cecum, colon, rectum, and anal canal).

The *accessory glands* are: the salivary glands (parotid, submandibular, and sublingual), the liver and pancreas. Associated with these is the spleen.

The Mouth. To survive, animals must eat. And, in search for food, they advance, mouth-end foremost. Around the mouth the organs of special sense are developed: the eyes to locate food by *sight*, the nose by *smell*, and the lips and tongue by *touch*. When the food is in the mouth, the *taste buds* decide if it is good, in which case it is swallowed; if not, it is rejected. The ears advise if there is *sound* of danger, when safety may be sought in flight. Hence, the brain establishes itself at the mouth end of the body.

The mouth or buccal cavity is bounded externally by the lips and cheeks. The cleft between the upper and lower lips is the *rima oris* or *aperture* of the mouth. The *teeth* are arranged in the form of an upper and a lower dental arch, 16 in each arch, and are set in the upper jaw or maxillae and lower jaw or mandible. The horseshoe-shaped space between the lips and cheeks externally and the teeth and gums internally is the *vestibule* of the mouth. The space bounded externally by the teeth and gums is the *mouth proper*. From the floor of the mouth rises the *tongue*; the roof comprises the *hard* and *soft palates* and the median finger-like process, the *uvula* in which the soft palate ends.

From near the posterior free border of the soft palate two folds descend on each side. The anterior fold, the *palato-glossal arch*, descends to the side of the tongue at the junction of its anterior ⅔ and posterior ⅓. The posterior fold, the *palato-pharyngeal arch*, descends on the side wall of the pharynx. The triangular space between the two folds and the side of the tongue is occupied by the palatine *tonsil*. (*fig. 779*).

The mouth is limited posteriorly at the *isthmus of the fauces* (oro-pharyngeal isthmus) by the soft palate, the palato-glossal arches, and a V-shaped groove, the *sulcus terminalis*, that crosses the dorsum of the tongue between the right and left palato-glossal arches. The tonsils and the posterior third of the tongue are, therefore, situated behind the mouth in the oral part of the pharynx.

Mastication. It is the duty of the incisor teeth (L. incidere = to cut) to bite off pieces of food, and of the molar teeth (L. mola = a millstone) to grind them. The food is commonly coarse; so, the mouth requires a protective lining. It is lined with stratified squamous epithelium, resembling epidermis, but the surface cells, though flattened, retain their nuclei and do not cornify. The epithelium is lubricated and kept moist by the mucous and serous secretions of small glands, the size of pin-heads, that line the palate, lips and cheeks. These glands do for this epithelium what sebaceous and sweat glands do for the epidermis; they are aided by the secretions of the 3 paired **Salivary Glands** (parotid, submandibular, sublingual).

The **Parotid Gland** (Gk. para = beside; ous (otos) = the ear) lies below the ear in the space between the ramus of the jaw and the mastoid process; its duct opens into the vestibule of the mouth beside the 2nd upper molar tooth.

The **Submandibular** (SUBMAXILLARY) **Gland** lies under shelter of the mandible; its duct opens on to a papilla beside its fellow, behind the lower incisor teeth. On opening your mouth and raising the tip of the tongue, water secretion may be seen welling up from the orifices.

Each **Sublingual Gland** produces a ridge on the side of the floor of the mouth beneath the tongue; it has many fine ducts which open on to the ridge. (*Figs. 659, 785.*)

The salivary glands have a mucous secretion or a serous secretion or both; the serous secretion (ptyalin) digests free starch, but cannot break down cellulose. The saliva moistens the food which has been ground into small particles by the teeth. This the tongue rolls into a bolus or lubricated mass easily swallowed—dry food is swallowed with difficulty. Saliva keps the lips and mouth pliable in speaking. It also aids in the healing of wounds (e.g., a bitten tongue or the empty socket of an extracted tooth heals readily). The amount secreted is about 1 liter daily.

The **Nerves** of general sensation for

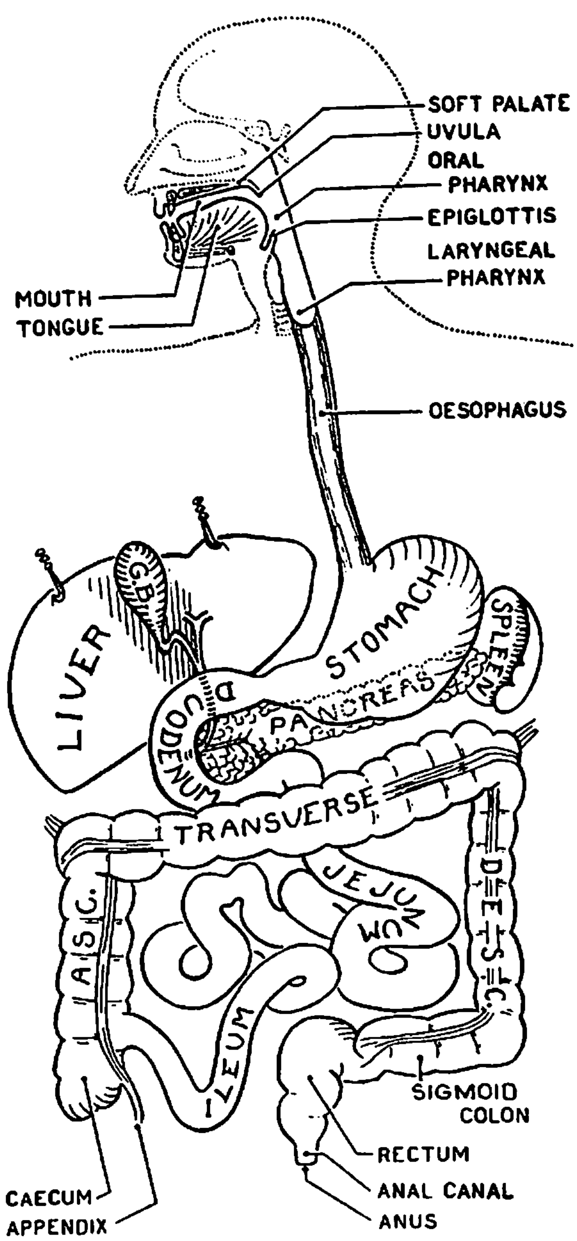

FIG. 45. Diagram of the digestive system.

the roof of the mouth and upper teeth are derived from the *maxillary nerve*, and for the floor of the mouth, anterior ⅔ of the tongue and lower teeth from the *mandibular nerve*. The *facial nerve* (via the nervus intermedius) carries secretory fibers to the submandibular and sublingual glands and assists the *glosso-pharyngeal nerve* to supply the parotid gland.

Sucking. Place a finger in your mouth and, while sucking it, note that your lips grasp it, that a groove forms along the middle of the tongue, and that the tongue recedes from the palate, thereby creating a vacuum. Note also that, while sucking fluid through a straw, you can breathe in and out through the nose. This is possible, since the Palato-glossi shut the mouth off from the pharynx. A child with a cleft palate cannot suck effectively, because air, drawn in through the cleft, prevents the formation of a vacuum within the mouth.

Swallowing. While food is in the mouth, it is under voluntary control, but when it enters the pharynx this control is lost and it is propelled onwards through the esophagus to the stomach, where digestion begins. During the act of swallowing, the pharyngeal wall contracts against the soft palate which rises to meet it, thereby shutting off the naso-pharynx (region above the soft palate). Hence, breathing is suspended temporarily and food cannot be forced into the naso-pharynx (p. 752).

The Pharynx and Esophagus are merely passages and, like the mouth, are protected by stratified squamous epithelium. The muscle coat of the pharynx and upper half of the esophagus, though voluntary in structure, is not under voluntary control; in the lower half of the esophagus (and onwards to the anus) it is involuntary or smooth. In the pharynx the muscle coat consists of three *Constrictors (fig. 711)*. In the esophagus (and onwards to the anus) the muscle coat has 2 layers: an inner circular and an outer longitudinal. Throughout the esophagus (and onwards to the anus) the muscle coat is separated from the epithelial lining by a thick tunic of areolar tissue. This is split into an inner and an outer part by a thin layer of smooth muscle, the *lamina muscularis mucosae*: (a) the inner part, called the *lamina propria*, with the epithelial lining and the lamina muscularis mucosae constitute the *mucous membrane* or *tunica mucosa*; (b) the outer part is called the *submucous coat* or *tela submucosa*.

The Stomach lies in the abdomen and, being a receptacle for food and requiring to expand, to contract and to move about, it possesses a serous (peritoneal) coat, such as the relatively inexpansible pharynx and esophagus do not require. It thus possesses the same 3 coats as the esophagus (mucous—submucous—muscular) plus a serous coat—as do the intestines also. The lining epithelium is a single layer of clear, columnar cells which secrete a protective mucus. About 3,000,000 test-tube-like glands pervade the lamina propria and open at the apices of conical evaginations of the mucous coat. The peripheral cells of the glands secrete hydrochloric acid which is necessary to the action of the pepsin secreted by the remaining cells. Pepsin initiates the digestion of proteins. The outlet of the stomach, the **Pylorus** (Gk. = a gate-keeper) is guarded by a strong sphincter of circular fibers, the *pyloric sphincter*. Absorption is not a notable feature of the stomach, though alcohol, sugar and water are to some extent absorbed. (*Figs. 233, 280.*)

The Intestine or gut is divisible into two parts: (1) the small intestine, about 20 feet long, and (2) the large intestine, about 6 feet long.

STRUCTURE. The intestine has four coats (a) serous and subserous, (b) muscular, (c) submucous and (d) mucous. The *serous* or *peritoneal coat* over-lies a fine, subserous layer in which fat may appear, as in the appendices epiploicae of the large gut. The *muscle coat* consists of two tubes, an outer thin longitudinal and an inner thick circular, separated from each other by enough areolar tissue to allow each tube some independent movement. The longitudinal muscle forms a complete coat for the small gut and for the extreme ends of the large gut (appendix and anal canal), but in the cecum and colon it is disposed in three equally spaced bands or taeniae, each about ⅓″ wide, and it clothes the rectum completely in front and behind, but meagerly at the sides. The circular muscle is complete throughout the small and large guts. As at the outlet of the stomach (pylorus) so at the outlet of the intestine (anal canal) the circular muscle is thickened to form an involuntary sphincter, the *sphincter ani internus.* The *submucous coat* is areolar and strong. In it the main vessels and nerves run; on it—not on the muscle coats—the strength of the gut depends; in fact, it is from this coat that catgut (violin strings and surgical sutures) is made. The *mucous coat* throughout the entire gut is lined with a single layer of columnar cells, and between these are numerous goblet cells. In the outer part of the mucous coat there is a thin layer or tube of smooth muscle, the *lamina muscularis mucosae.* This extends throughout the gut, applied to the submucous coat. Between the epithelium internally and the muscularis mucosae externally there is a thick layer of special connective tissue, the *lamina propria,* in which lymphocytes are diffused. Straight test-tube-like evaginations of the epithelial surface, the *intestinal glands,* project outwards into the propria; these are closely packed together and are lined chiefly with *columnar* and *goblet cells.* Finger-like processes of the propria, the *villi,* 0.5 to 1.5 mm. long and covered with columnar and goblet cells, project freely into the lumen of the gut. These villi extend throughout the small gut, from pylorus to ileo-cecal valve, but in the fetus they are present in the large gut also. Running down the middle of each villus there is a lymph vessel, a *lacteal*; at one end it is blind; at the other it opens into the lymph plexus of the mucosa.

FUNCTIONS. The structure of the mucous membrane of the gut is related to its functions. Thus, the partially digested food leaving the stomach is mixed with hydrochloric acid and pepsin, is fluid, and is relatively free from bacteria. In the upper part of the small gut (3″ beyond the pylorus) the ferments of the pancreas and the bile are added to the intestinal ferments. Here digestion continues and absorption of water and digested products begins. These processes are most active in the duodenum and they diminish as the large gut is approached. The essential function of the large gut is to dehydrate the intestinal contents; the bacteria present break down cellulose.

Accordingly, the mucous surface of the small gut is enormously increased by permanent folds of mucous membrane, the *plicae circulares,* which run circularly (actually spirally) for short distances. These begin 1 or 2″ beyond the pylorus, are closely packed, and about 6 mm. high. Gradually they become fewer and lower, and finally disappear about the lower part of the ileum. (*fig. 301*).

As the distance from the entrance of the pancreatic juices and the bile increases (a) the intestinal contents become less fluid and their progress more slow; hence, in the large gut more lubricating mucus being required, goblet cells are more plentiful; and (b) the antiseptic properties of the ferments become weaker; hence, the lymphocytes, which everywhere pervade the lamina propria, also accumulate in *solitary* follicles, 1–2 mm. in diameter; these are plentiful in the ileum and numerous in the colon. Large accumulations of lymphocytes, *aggregated* follicles (*Peyer's patches*), about ½″ wide by 1″ to 2″ long occur within the ileum at the antimesenteric border.

The *ileo-cecal valve* (ileo-colic valve). In the last few inches of the ileum, the circular muscle, though not thickened, behaves as a sphincter retarding the too rapid emptying of the small gut. The end of the sphincter pouts into the cecum and, when the cecum is distended, has an upper lip which overhangs a lower lip and apparently directs the emitted contents downwards into the cecum. From each of the two commissures of the lips a mucous fold, a *frenulum,* extends transversely round the gut (*fig. 290,* p. 272).

The mucous coat of the appendix is practically a continuous series of solitary lymph follicles, hence the *appendix* has been called the "intestinal tonsil". In dissecting room subjects the lumen is commonly partly occluded and so cannot be injected.

Around the *anal canal* there are two sphincters: (1) involuntary, consisting of a thickening of the circular muscle, and (2) voluntary, consisting of skeletal muscle (*fig. 370,* p. 353).

Nerve Supply. The intestinal canal is supplied by sympathetic and parasympathetic nerves. These take part in two plexuses (1) placed between the longitudinal and circular layers of the muscle coat, and (2) placed within the submucous coat. The sympathetic nerves are connected with cord segments Th. 9 to L.2. The parasympathetic nerves supplying parts cranial to the left colic flexure are derived from the vagus nerves; those to parts caudal to the flexure are derived from the pelvic splanchnic nerves (*fig. 826*). The nerves reach the intestine with the blood vessels. The stomach is supplied in a similar way. The stomach and intestines continue to function even after the nerves are divided.

The Liver (Hepar)

The liver is the largest organ in the body. Attached to its under surface is the *gall bladder*; this extends backwards to a transverse fissure, the *porta hepatis,* through which the *hepatic ducts* conduct bile from the liver and through which the *portal vein* (conducting blood laden with products of digestion) and the *hepatic artery* (conducting oxygenated blood) enter the liver. After the blood has circulated through the liver, it leaves the posterior surface via the hepatic veins to enter the inferior vena cava.

The liver is a gland of compound tubular design. The cells of the tubules elaborate an *exocrine* (*external*) *secretion,* called bile, into the tiny lumina of the tubules. Each tubule, called a *bile capillary* or *canaliculus,* is really a continuous series of minute spaces between two contiguous rows of liver cells. At the periphery of the lobule (see below) it drains into a system of ducts, the *bile passages,* which communicate with the gall bladder and with the duodenum (*fig. 274,* p. 255).

The same liver cells also elaborate an *endocrine* (*internal*) *secretion.* This is possible, since the surfaces of the cells not forming canaliculi are in apposition with blood capillaries. These are not simple capillaries but *sinusoids* (p. 37). Helping to line the sinusoids are phagocytic cells, *Kupffer's cells.*

The tubules (cords of cells) and the sinusoids lying between them are arranged in polyhedral prisms, called *lobules.* These are 1–2 mm. in diameter and are somewhat longer than they are wide (*fig. 46*). Through the center of each lobule runs a vein, the *central vein.* The cords of cells and the sinusoids radiate from the central vein to the periphery of the lobule which, though not conspicuous in man, is clearly outlined in the pig by connective tissue septa.

The *classical lobule* of the liver, illustrated in figure 46, has a central vein at its center. The pathologist, however, recognizes another lobule—one in which central veins occupy the periphery and at the center lie a branch of the portal vein, of the hepatic artery, and of the bile passages. To this, Rappaport has given the name *"liver acinus".*

The Blood Flow through the Liver. The branches of the portal vein spread out between the lobules as *interlobular veins.* Thence *sinusoids* converge on the the *central vein.* The central veins drain into *sublobular veins* which unite to form *hepatic veins* which open into the i. v. cava. Small branches of the *hepatic artery* accompany the portal and interlobular veins, nourish the areolar sheaths and end in the sinusoids.

The *bile passages* conduct bile in the reverse direction (i.e., towards the porta). *Lymph vessels* run both with the portal vein and the hepatic veins.

Functions. As the blood moves leisurely though the sinusoids, the cells of the liver elaborate bile. They also regulate the amount of sugar (glucose) in the blood by removing the excess after a meal and temporarily storing it as glycogen. They also store vitamin A. They elaborate urea which the kidneys dispose of, also fibrinogen and heparin.

The Kupffer cells, like similar reticuloendothelial cells in the spleen and bone marrow, help to dispose of effete red blood cells, and are concerned with resistance to disease and with immunity.

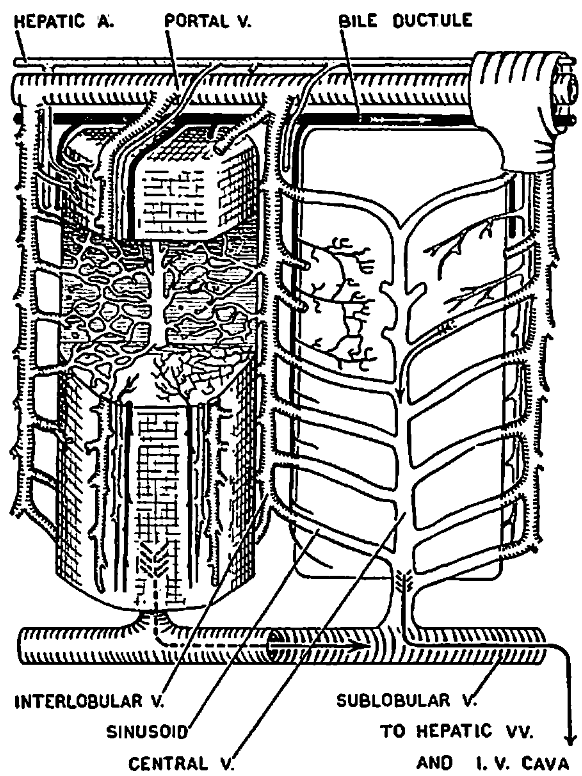

FIG. 46. Diagram of the blood flow through two lobules of the liver and of the course of the bile.

The Pancreas

The pancreas (Gk. pan = all; kreas = flesh), called the sweetbread in animals, has smooth polyhedral surface areas, each about 1 cm. in diameter, called *lobules,* separated from each other by fine areolar septa (*fig. 282*). It has an exocrine (external) and an endocrine (internal) secretion. The exocrine secretion is drained into the duodenum by a "herring-bone" duct system; that is, a large main duct runs through the gland and receives many fine ducts, but there are no ducts of intermediate size—a distinguishing feature of the pancreas. The endocrine secretion enters the capillaries. Unlike the liver, where the same cells make both the exocrine and the endocrine secretions, here there is a division of labor.

The *exocrine secretion* is the precursor of several ferments which act upon carbohydrates, proteins, and fats. Its liberation is under the control of a hormone, *secretin,* which is formed in the duodenal mucosa when the acid contents of the stomach flow over it. Secretin is absorbed into the blood stream and so passes by a round-about way to the cells of the pancreas and provokes them to secrete. Stimulation of the vagus, however, also provokes them to secrete.

The *endocrine secretion* is formed by clusters of cells, the *islets of Langerhans,* which manufacture *insulin,* a hormone concerned with carbohydrate metabolism and employed in the control of diabetes.

The Spleen (Lien)

The spleen is described here for convenience, but its association with the digestive system is incidental. It is a soft sponge filled with blood, about the size of a clenched fist, and colored like the liver (*fig. 282*). It is covered with *peritoneum,* except at the hilum where vessels and nerves enter it, and it is free to move.

Structure. The spleen has a capsule of white fibers, elastic fibers and smooth muscle fibers which allow it to expand and contract. Supporting *trabeculae* of the same materials spread inwards from the capsule. The spaces between the trabeculae contain a supporting *sponge-work* of reticular fibers and reticulo-endothelial cells and are filled with blood. About one sixth of the total volume of blood in the body can thus be stored in the spleen, which accordingly varies greatly in size.

Function. The spleen is the largest of the lymphocyte producing organs. It is the main store-house of blood. It is the chief depot of reticulo-endothelial cells, which break down the hemoglobin of effete red cells and in so doing produce bile pigment, they also rid the blood of other debris including probably effete blood-platelets and they are concerned with resistance to disease and with immunity.

The spleen is not essential to life; in fact, in certain conditions it is advisable to remove it.

THE RESPIRATORY SYSTEM

Respiration is a chemical reaction essential to life; it involves the taking up of oxygen and giving off of carbon dioxide. In unicellular organisms this interchange of gases (O_2 and CO_2) takes place directly between the cell and the medium (which in all cases is water) in which the cell lives. But in a large multicellular organism, such as man, all cells, except the external ones, being removed from the surrounding medium (in this case air), require that the oxygen shall be brought to them from the exterior and that the carbon dioxide shall in turn be taken away. The transfer is made in two stages: the first stage is from the exterior via the air passages to the lungs, which act as a halfway house; the second stage is via the bloodstream to the watery medium (tissue fluids) that bathes the cells. Two systems, then, the respiratory and the circulatory, are here allied in the common purpose of permitting the individual cells to breathe (exchange gases) like unicellular organisms. The lungs are sponges filled with air; their septa being thin, moist, and membranous, allow transfusion of gases in solution. Being removed from the surface of the body they are, in a measure, protected from mechanical injury and from desiccation; moreover, the air reaching them is warmed and moistened by the air passages.

The respiratory system is developmentally an offshoot from the digestive system. The urinary and genital systems also are closely allied. Of these 4 tubular systems, the respiratory and digestive have absorptive functions; the urinary and genital have not—they are excretory. The walls of the digestive and respiratory passages, being thus exposed to germs from without, are protected by a barrier of lymphocytes, such as the urinary and genital passages do not possess. The digestive system absorbs food; the respiratory system absorbs oxygen, the absorption taking place in the alveoli of the lungs. The products of digestion and the oxygen (which combines loosely with the hemoglobin pigment in the red blood cells to form oxyhemoglobin) are conveyed by the blood to the tissues of the body where the products of digestion are oxidized and energy thereby released. The carbon dioxide, formed in the process, returns in the blood to the lungs and is there eliminated.

The respiratory system has two portions: (1) conducting, (2) respiratory. *The Conducting Portion*, or air passages, comprises: the nasal cavities, pharynx, larynx, trachea, bronchi, and bronchioli; *the Respiratory Portion* comprises: the alveolar sacs and alveoli of the lungs (*fig. 590*).

The Nasal Cavities, a right and a left, are separated from each other by a thin median partition, the *nasal septum*. The entrance to each cavity, called the *vestibule*, is lined with skin which bears hairs, sebaceous glands, and sweat glands. From the side wall of each cavity three downwardly curved shelves, the superior, middle, and inferior *conchae* (turbinals), conceal three antero-posteriorly running passages, the superior, middle, and inferior *meatuses*. Opening into the inferior meatus is the *tear duct* (naso-lacrimal

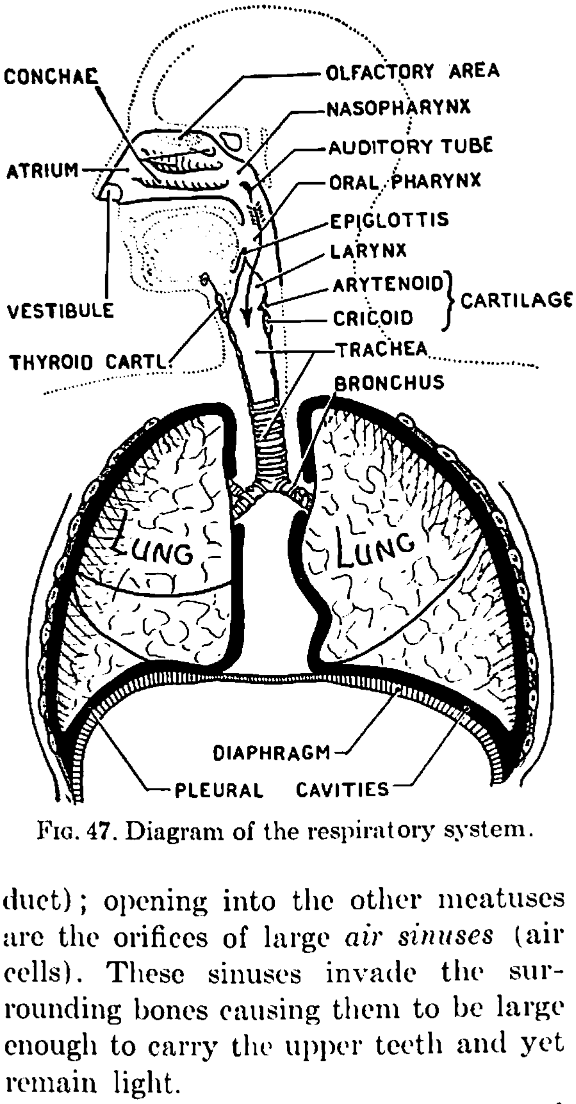

FIG. 47. Diagram of the respiratory system.

duct); opening into the other meatuses are the orifices of large *air sinuses* (air cells). These sinuses invade the surrounding bones causing them to be large enough to carry the upper teeth and yet remain light.

The mucous membrane lining the nasal cavities and air sinuses is almost inseparable from the periosteum; hence, the two collectively are called *muco-periosteum*. The muco-periosteum covering the inferior concha, and to a lesser extent that covering the middle concha, contains dilatable *venous sinuses* which warm and humidify the inhaled air. The muco-periosteum has a covering of stratified ciliated epithelium with scattered goblet cells, and in it are mucous and serous glands, diffuse lymphoid tissue, and lymphoid follicles. The mucus catches inhaled dust and bacteria, and acts a sterilizing agent. The cilia waft the mucus, and the foreign matter entangled in it, backwards to the pharynx.

The uppermost part (2 square cm. in each nasal cavity) of the medial and lateral walls is the *olfactory area.* Here the olfactory nerves, which stream through the thin perforated roof, *cribriform plate,* of the nasal cavity, end freely among the epithelial cells. This area is much more extensive in certain lower animals, such as the dog. The olfactory area is above the level reached by the air passing to and from the lungs, but eddies of air can be made to circulate here on sniffing, so that weaker stimuli may be appreciated. The *naris or anterior nasal aperture* of each side is oval, mobile, bounded by soft parts (so it can dilate on taking a deep breath) and downwardly directed. The *choana or posterior nasal aperture* of each side is oblong, rigid, bounded by four bony margins, and directed backwards towards the naso-pharynx (*fig. 772*) and it is functionally continuous with the latter.

The Pharynx is a fibro-muscular chamber, 5″ long. It is attached above to the base of the skull; it lies in front of the upper six cervical vertebrae; and it is continuous below with the esophagus. Communicating with it in front are the nasal cavities, mouth, and larynx. Accordingly, it is divisible into 3 parts (upper, middle, and lower), called the nasal, oral, and laryngeal parts respectively.

The nasal part or *naso-pharynx* is the backward extension of the nasal cavities, and it cannot be shut off from these cavities, but it can be, and is, shut off from the oral part by the soft palate and uvula during the act of swallowing. Were it not so, food would be forced from the oral part into the nasal part and so to the nasal cavities—a person with a paralyzed soft palate (e.g., after diphtheria) may find this may happen.

An air duct, the **Auditory Tube** (pharyngo-tympanic or Eustachian tube) opens by a funnel-shaped orifice on to each side of the naso-pharynx. Each tube is 1½″ long, and, by bringing the pharynx into communication with the tympanic cavity (middle ear) of the corresponding side, serves to keep the air pressure on the two sides of the tympanic membrane (ear drum) equal under changing atmospheric conditions. Normally the tubes are closed, but the act of swallowing opens them; hence, persons ascending or descending heights, as in an aeroplane, find relief through performing the movement of swallowing. The tubes also allow infection to spread from the naso-pharynx to the middle ear and beyond it to the air cells in the mastoid bone (*fig. 817*). The orifice of the tube is directed forwards towards the nasal cavity; so, fluid syringed along the cavity may enter the tube and carry infection to the middle ear.

A collection of lymphoid tissue, the *pharyngeal tonsil,* lies in the posterior wall of the naso-pharynx and extends laterally behind the orifices of the tubes. When enlarged, this tonsil is referred to as "adenoids". By obstructing the free flow of air through the naso-pharynx, adenoids cause mouth-breathing and collapse of the anterior nasal apertures. They may also obstruct the tubes, thereby preventing access of air to the middle ear with resulting indrawing of the ear drums and deafness. (*Fig. 798.*)

On each side of the entrance to the oral pharynx, and visible from the mouth, is a mass of lymphoid tissue, the size and shape of half a walnut, called "*the tonsil*" or the palatine tonsil. Its upper pole extends upwards from the side of the tongue into the soft palate; its lower pole cannot be seen unless the tongue is depressed.

The nasal part of the pharynx is, then, part of the respiratory passage; the oral part and the upper half of the laryngeal part are common to the respiratory and digestive passages.

The Larynx or voice box opens off the lowest part of the pharynx and is continuous below with the trachea. This box is kept rigid by a number of hyaline and elastic cartilages which are united by membranes. It is lined with mucous membrane internally and covered with voluntary muscles externally (*fig. 810*).

The chief cartilages of the larynx are: (a) The *thyroid cartilage* which resembles an angular shield, has two perpendicular *laminae* which meet in front in the median plane, the prominent upper end of the angle of meeting being conspicuous as the *laryngeal prominence* (Adam's apple). The posterior borders of the laminae are free and rounded, and below they grip and articulate with the cricoid cartilage as the knees of a horseman grip a saddle. (b) The *cricoid cartilage* is a complete ring expanded posteriorly into a lamina or plate and so resembles a signet ring; it keeps the lower part of the larynx perpetually open. (c) The *arytenoid cartilages* are paired, small, and pyramidal; their bases articulate with the upper border of the lamina of the cricoid, each articulation being capable of the movements of a universal (ball and socket) joint, such as the hip and shoulder. The *vocal cords* extend from half way down the angle between the laminae of the thyroid to the anterior tips (vocal processes) of the arytenoid cartilages. When the arytenoids rotate medially the cords are approximated (adducted), as when talking and singing; and separated (abducted), as when taking a deep breath. (d) The *epiglottic cartilage* is shaped like a bicycle saddle, its stalk being attached to the angle of the thyroid cartilage just above the vocal cords.

The epiglottis was at one time thought to act as a lid that, during the act of swallowing, folded backwards over the entrance to the larynx in order to prevent the entry of food. However, during the act of swallowing; (a) the larynx rather is drawn upwards under shelter of the root of the tongue; (b) its entrance or upper aperture is closed by the sphincteric muscles that surround it and tilt the arytenoid cartilages forwards, and (c) the arytenoid cartilages are at the same time adducted and the rima glottidis (i.e., space between the cords anteriorly and the arytenoids posteriorly) is closed. By these means food is prevented from entering the larynx. By palpating the thyroid cartilage while performing the act of swallowing, the larynx can be felt to be drawn upwards and forwards.

The Trachea or windpipe is an elastic tube over 4″ long, with a caliber equal to the root of the index finger. It is kept patent by about 20 U-shaped rings of hyaline cartilage which are open posteriorly. Involuntary muscle fibers, embedded in the elastic tube, unite the free ends of the U-shaped rings. Half of the trachea is in the neck, half in the thorax; and immediately behind it is the esophagus. When you throw back your head you can readily feel the thyroid and cricoid cartilages rise, and perhaps feel the tracheal rings separate. It is the elastic tissue between the rings that allows the trachea so to lengthen. At the level of the sternal angle, 2″ below the suprasternal notch, the trachea bifurcates into a right and a left bronchus.

The Bronchi have the same structure as the trachea. After an oblique course of 2″, each enters the respective lung at the hilum and descends towards the base, giving off branches which in turn branch and rebranch like a tree (*fig. 585–589*). Within the lung the U-shaped rings give place to flakes of hyaline cartilage which surround the tube. When the bronchi are reduced to the diameter of 1.0 mm., they are called *bronchioles*. Here the cartilage ceases; just beyond, the mucous glands cease and the ciliated cells become cubical. Around the bronchi and bronchioles involuntary muscle fibers are wound spirally. The terminal bronchioles divide into a number (2 to 11) of alveolar ducts which end in dilated air sacs, *alveolar sacs*. The walls of these sacs being themselves sacculated, resemble a bunch of grapes, and hence they are called alveoli (L. alveolus = a bunch of grapes) (*fig. 590*). Adjacent *alveolar* sacs are practically contiguous—between them there is room only for a close-meshed network of capillaries through which the blood cells hurry in single file giving off CO_2 and taking up O_2 from the alveoli on each side with a resulting change in the color of the blood from relatively blue to red. This being the aim and object of respiration, the alveoli are the essential constituents of the lung. Since alveoli also occur on the bronchioles immediately preceding the alveolar ducts, they are termed *respiratory bronchioles*.

The Lungs, a right and a left, are spongeworks of elastic tissue which on section and in consistency resemble rubber sponges. In this highly elastic framework a bronchus and a pulmonary artery and a pulmonary vein ramify, the bronchus conducting air to and from the alveoli, the vessels conducting blood.

The lungs occupy the conical thorax, each lung forming half a cone. The right lung is divided by two complete fissures into three separate lobes; the left is divided by one fissure into two lobes.

Each lobe of each lung has a delicate and inseparable "skin", the *visceral pleura*. This is a perfectly smooth, moist, serous membrane, identical in structure and in origin with peritoneum, i.e., a fine areolar sheet with a surface of squamous (mesothelial) cells. Another layer of pleura lines the ribs, diaphragm, and mediastinum (containing the heart); this is *parietal pleura*. Between the visceral and parietal layers of pleura there is a potential space, the *pleural cavity*, best explained by figure 561. It allows the lung to expand and contract without friction.

The Respiratory Act has 2 phases—inspiration and expiration. On inspiration the diaphragm descends, thereby increasing the vertical diameter of the thorax; and the ribs rise from a sloping to a more horizontal position, thereby increasing the antero-posterior and the side-to-side diameter, as you can determine by palpation. The atmospheric pressure is 14.7 lbs. to the square inch at sea level; therefore on enlarging the thorax (inspiration) air rushes down the trachea and bronchi into the lungs so that they expand, thereby avoiding the formation of vacua in the pleural cavities. Expiration is largely a matter of elastic recoil; that is, the highly elastic tissue contracts, the stretched abdominal muscles act like an elastic belt on the abdominal contents forcing the diaphragm upwards; and the cartilages of the ribs, which underwent twisting during inspiration, now untwist.

The respiratory act has aptly been likened to a fire-bellows in action, the thoracic cage being the framework of the bellows, the trachea the nozzle.

As the table shows, during quiet respiration about 500 cc. of air are inspired and expired. On full inspiration about an extra 2500 cc. can be taken in; and on full expiration an extra 1000 cc. can be forced out. Even then there remain in the alveolar sacs, trachea, and bronchi about 1000 cc. which cannot be expelled.

	cc.		
Total capacity	2500	Complemental air	Vital capacity
	500	Tidal air	
	1000	Supplemental air	
	1000	Residual air	

Nerve Supply. The respiratory center is located diffusely in the reticular formation of the medulla oblongata. If the center is destroyed or if the spinal cord between the center and the origin of the phrenic nerves, which supply the diaphragm, is severed, respiration ceases. The normal stimulus to the center is the excess CO_2 in the circulating blood. Efferent impulses descend from the center to the motor nuclei of the phrenic (C.3, 4, 5) and intercostal nerves (Th. 1–11) in the spinal cord and along these nerves to the diaphragm and intercostal muscles, causing them to contract. When the lung is distended, afferent impulses ascending in the vagus nerve inhibit further inspiration and provoke expiration.

The bronchial muscles (circular) are made to contract by the vagus nerves and to relax by the sympathetic, hence in asthma the spasms of these muscles are relieved by adrenalin.

Epithelial Surfaces. The respiratory passages as far as the bronchioles of 1 mm. in diameter are lined with stratified columnar, ciliated epithelium containing scattered goblet cells. In the mucous membrane are mucous and serous glands, also lymphoid tissue both diffuse and aggregated.

In the protective mucus that lines the larynx, trachea, and bronchi inhaled dust and other foreign material is caught and entangled. The cilia cause the lining tube of mucus to move ever upwards, like a moving carpet or escalator, to the entrance of the larynx where it spills over into the pharynx and is swallowed. The other method of expelling foreign material is by coughing. The lymphoid tissue also is defensive against foreign invasion.

Exceptional Areas. (1) The vestibule of the nose is lined with skin, possessing hairs, sweat glands, and sebaceous glands; (2) areas subjected to pressure or friction, where cilia could not survive, are protected by stratified squamous epithelium, viz.—(a) the parts of the upper surface of the soft palate and uvula which are applied to the pharyngeal wall during swallowing; (b) areas against which the food comes into contact, namely, the entire oral and laryngeal parts of the pharynx and also the dorsal aspect of the upper half of the epiglottis; (c) the vocal cords, which vibrate and strike each other; (3) the terminal and respiratory bronchioles, whose epithelium is cubical; (4) the alveoli, whose lining epithelium is by some thought to be partly squamous and partly cubical; by others, absent; (5) the olfactory (smell) epithelium.

The cilia in the nasal cavities sweep backwards towards the pharynx; those in the trachea and bronchi upwards towards the pharynx; those in the air sinuses spirally around the walls to the orifices.

Coughing is a defensive act, an attempt to blast a foreign body out of the trachea and larynx. Thus, following an inspiration, the vocal cords are approximated and kept approximated (adducted) while the movements of expiration are begun; the cords then suddenly relax (abduction), whereupon by the force of the air the irritant is blown out of the larynx. The afferent impulses travel in the internal laryngeal branch of the vagus when the source of irritation is above the vocal cords and in the recurrent laryngeal branch when below. Coughing may also result from inflammation of the pleura, but as there is then nothing to be expelled, the coughing is profitless and it may be wise to arrest it by means of drugs.

Sneezing likewise is a defensive act, an attempt to blast a foreign body out of the nasal cavity. The act is preceded by a deep inspiration and the mouth usually kept closed during forceful expiration. The afferent impulses travel in the maxillary branches of the trigeminal nerve.

THE URINARY SYSTEM

The urinary system and the genital system are closely associated in their development and are commonly described together as the *urogenital system.* In the human male, but not in the female, the urethra serves as a common outlet for the products of both systems.

The urinary system comprises the following parts:

(1) Kidneys }
(2) Ureters } bilateral and paired
(3) Bladder }
(4) Urethra } median and unpaired

The *kidneys* excrete urine. This passes down two muscular tubes, one on each side, the *ureters,* into a muscular reservoir, the *urinary bladder,* where it is stored until such time as it may conveniently be discharged through the *urethra.*

Kidneys. Each of the two kidneys is of conventional kidney-shape, is about 4½″ long and weighs about 4½ oz. Its function is to keep the composition of the blood plasma constant. This it does by removing the excess of water and the waste products, especially those resulting from the metabolism of nitrogenous substances. It also maintains the alkalinity of the blood (a) by manufacturing ammonia, which combines with the surplus acid radicle of the salts of the blood to form ammonia salts, which are then excreted by the kidneys, whereas the bases are retained; and (b) by excreting NaH_2PO_4 instead of Na_2HPO_4. To the former salt the urine owes its acid reaction.

Structure (*fig. 48*). A kidney contains about 1,000,000 microscopical units. Each unit or *nephron* has two parts (1) a *glomerulus,* and (2) a *uriniferous tubule.*

A glomerulus (L. glomus = a ball) is a spherical bunch of looped capillaries about 200μ in diameter, which invaginates the expanded blind end of a uriniferous tubule, called a *glomerular capsule* or *Bowman's capsule,* much as the lens of the developing eye invaginates the optic vesicle to form the optic cup, but with this difference—the invaginated layer of the capsule covers the individual loops of capillaries and dips into the crevices between them, thereby creating an extensive surface, estimated to be 0.3813 sq. millimeters per glomerulus or 0.3813 sq. meters per kidney (M. H. Book). The two layers of glomerular capsule, outer and inner or invaginated, and the glomerulus are known as a *renal* or *Malpighian corpuscle,* but the term is variously applied. Malpighi, who first saw the corpuscles, likened them to apples hanging from a tree. The capsule is succeeded by the 1st (proximal) convoluted tubule, the descending and ascending limbs of Henle's loop, the 2nd (distal) convoluted tubule and finally the junctional tubule which discharges into a system of collecting tubules. About a dozen collecting tubules open on to the papilla of each pyramid (*fig. 309*) and discharge their contents into the pelvis of the kidney.

Each named part of the tubule has a distinctive epithelium and, accordingly, a different function. The glomeruli and the convoluted tubules occupy the labyrinth of the kidney; the limbs of Henle's loops and the collecting tubules occupy the pyramids.

Vessels. The renal vessels are exceptionally large. The artery generally breaks up into 3 *main branches*, of which 2 pass in front of the pelvis and 1 behind it. These send branches into the renal columns, situated between the pyramids, and, because the pyramids are spoken of as the lobes of the kidney, they are called *interlobar arteries*. At the junction between the medulla and cortex these divide into branches (arcuate arteries) which curve between these two parts. From these branches, *interlobular arteries* pass radially towards the capsule. Each interlobular artery gives off many short arterioles, vasa afferentia, which pass at right angles into the labyrinth where the glomeruli lie. Each *vas afferens* enters a glomerulus and there branches to form capillary loops, as described above. These reunite and leave the glomerulus as a single vessel, the *vas efferens*, which is of smaller lumen than the vas afferens. The vas efferens now breaks up into capillaries which ramify among the convoluted tubules. These reunite to form venules, which in turn become interlobular (arcuate), interlobar and main veins. The pyramids are supplied by long parallel meshed vessels, *arteriolae rectae*, which proceed from the glomeruli situated near the border zone.

Note: (1) The renal artery is disproportionately large; its branches are large; and each vas afferens is larger than the corresponding vas efferens. All this makes for high arterial pressure within the glomeruli. (2) The blood flowing through

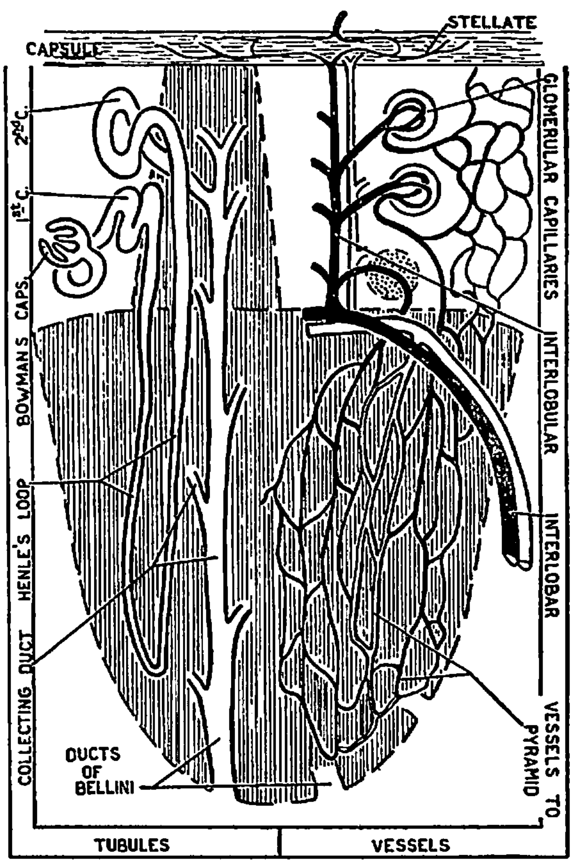

FIG. 48. Diagram of the tubules and blood supply of the kidney. (*see also fig. 309*).

the renal artery passes first through the glomerular capillaries, which are filters, and then through a second set of capillaries, which are nutrient to the renal tissues. (3) But, certain arteries of clinical importance omit the glomerular capillaries, viz. (a) the twigs that leave the artery in the renal sinus for the supply of the pelvis and the fibrous and fatty capsules of the kidney; (b) the terminal twigs, *stellate arteries*, of the interlobular arteries that radiate under the capsule; and (c) a few *arteriolae rectae* to the pyramids, which pass through atrophic glomeruli (*fig. 48*).

The interlobular veins begin under the capsule as stellate veins and may be seen on stripping it off. The tributaries of the renal veins anastomose freely.

Urine is not a secretion but a concentrated filtrate, the glomeruli doing the filtering, the tubules the concentrating. Since the blood is circulating under pressure through the glomerular capillaries, water, salts in solution and substances of small molecular size filter through into the glomerular capsule (Bowman's capsule). Of course, the blood cells remain within the blood vessels; so do the blood proteins, for they are of large molecular size, and there they exert an osmotic pressure which tends to retain water and dissolved substances within the blood stream. For the "excretion" of urine the blood pressure must exceed the osmotic pressure within the vessels. The quantity of filtrate that passes daily into the glomerular capsule is estimated to be about 100 liters, but an average amount of urine voided daily is a little more than one liter. All but a fraction, then, of the water filtered is reabsorbed as it passes down the tubules and is restored to the blood. Some constituents of the filtrate (e.g., glucose, sodium chloride) are entirely reabsorbed; others (e.g., urea, uric acid, and phosphates) are reabsorbed to a slight extent; others (e.g., creatine and sulphates) are not reabsorbed.

Ureters, Urinary Bladder and Urethra. From the kidney the urine is propelled by peristaltic action along a 10-inch muscular tube, the *ureter,* into a hollow muscular reservoir, the *urinary bladder.* Through a urethroscope introduced into the bladder, jets of urine are seen to leave the urethral orifices two or three times a minute. The bladder has a capacity of ½ to 1 pint. From it a fibro-muscular tube, the *urethra,* leads to the exterior of the body. It is about 6″ to 8″ long in the male, 1¼″ in the female. At the junction of the bladder and urethra (i.e., at the neck of the bladder) the bladder is guarded by a sphincter of involuntary muscle, the *sphincter vesicae,* and beyond this (i.e., between the fasciae of the urogenital diaphragm) it is guarded by a sphincter of voluntary muscle, the *sphincter urethrae.*

Micturition. As urine gradually collects within the bladder, the muscle wall adapts itself to the increasing volume without appreciable increase in internal pressure until 200 to 300 cc. have collected. The internal pressure then begins to rise and rhythmical contractions of the bladder wall begin. These, increasing, culminate in a strong reflex contraction of the wall and an associated relaxation of the sphincter, and so the bladder is emptied. Though micturition is essentially a reflex act, it can be, and is, both initiated and inhibited at will, until a suitable occasion presents.

Nerve Supply. The Kidney. The strong clinical evidence is that the kidney receives sympathetic fibers that pass via the lowest splanchnic nerve and the visceral rami of ganglion L. 1 to the renal plexus and thence along the renal vessels to the kidney. The nerve fibers are vasoconstrictor, vasodilator, and afferent. Cutting posterior nerve roots of T. 12, L. 1, and L. 2 relieves renal pain. (White and Smithwick.) A denervated kidney continues to excrete normal urine.

The Ureter. In its upper part the ureter receives *Sympathetic* nerve fibers from the renal and intermesenteric plexuses; in its middle part from the superior hypogastric plexus (and hypogastric nerve) in association with the spermatic plexus; and in its lower part from the inf. hypogastric plexus [pelvic plexus] which lies at the side of the bladder, vesicle and prostate. (Mitchell.) Its spinal or cord segments are L. 1 and 2. The peristalsis of the ureter is not disturbed by lumbar sympathectomy; in fact, by the withdrawal of inhibitory sympathetic influences the functions of a dilated (hydronephrotic) ureter and of a dilated colon (megacolon) are improved.

Parasympathetic. Vagal fibers via the coeliac plexus may be supposed for the kidney and upper part of the ureter, and pelvic splanchnic nerve fibers for the lower part.

THE BLADDER AND URETHRA (*fig. 49*).

Parasympathetic. The pelvic splanchnic nerves (S. 2, 3, 4) are the motor nerves to the bladder; when they are stimulated the bladder empties, the blood vessels dilate, and the penis becomes erect. They are also the sensory nerves to the bladder.

Sympathetic, through the superior hypogastric plexus (presacral nerve; Th. lower, L. 1, 2, 3) is motor to a continuous muscle sheet comprising the ureteric musculature, the trigonal muscle, and the muscle of the urethral crest. It also supplies the muscle of the epididymis, ductus (vas) deferens, seminal vesicle, and prostate. When the plexus is stimulated, the seminal fluid is ejaculated into the urethra but is hindered from entering the bladder perhaps by the muscle sheet which is drawn towards the internal urethral orifice. The sympathetic is also vaso-constrictor and to some slight extent it is sensory to the trigonal region.

The pudendal nerve is motor to the sphincter urethrae and sensory to the glans penis and the urethra.

It would seem that the sympathetic supply to the bladder has a vaso-constrictor and a sexual effect and that as regards micturition it is not antagonistic to the parasympathetic supply. (Learmonth; Langworthy and others.)

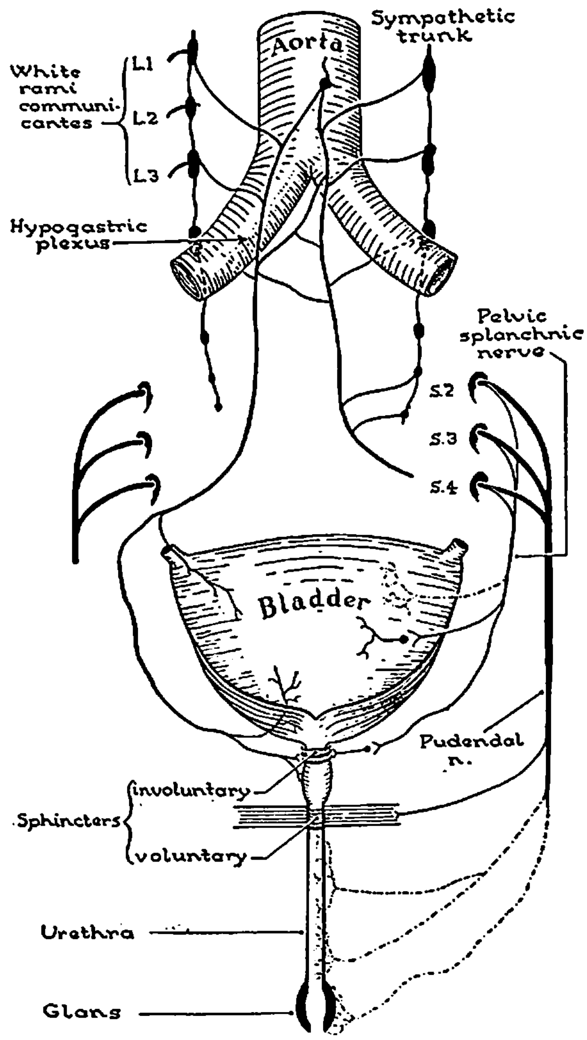

FIG. 49. Diagram of the nerve supply of the bladder and urethra.

THE GENITAL SYSTEM

The male and female organs of reproduction are fundamentally the same, and in early fetal life are very similar. In both sexes they pass through an indifferent stage during which there is a pair of parallel ducts—the Wolffian or mesonephric and the Müllerian or paramesonephric—on each side of the body. In the male, the Wolffian ducts are utilised as genital ducts and the Müllerian ducts largely disappear or remain vestigial; in the female the converse is true (*figs. 50, 51*).

Each sex has (1) a symmetrical pair of reproductory or sex glands, which produce germ cells—spermatozoa in the male and ova in the female; (2) passages through which these germ cells find their way to the exterior of the body; (3) vestigial parts (well developed in the opposite sex); (4) accessory glands; and (5) external genitals or pudenda.

Corresponding Male and Female Parts

	Male	Female
Sex Gland	Testis............	Ovary
Passages	Epididymis........	*Appendix (W)*, *Epoophoron*, *Paroophoron*
	Ductus Deferens	*Duct of Gartner*
	Urethra	—
Vestigial Parts	*Appendix (M)*.....	Uterine Tube
	Prostatic Utricle...	Uterus
	—	Vagina
Accessory Glands	Seminal Vesicle	—
	Prostate...........	Para-urethral Glands
	Bulbo-urethral Gland...........	Greater Vestibular Gland
	Urethral Glands..	Lesser Vestibular Glands
External Genitals	Penis, Scrotum..........	Pudenda

The Male Genital System

The Testes or male sex glands, one on each side, lie in the scrotum. (*Figs. 225, 226, 227.*) Each testis is oval, slightly flattened from side to side, and 1½″ long. Like the eyeball it has a thick, white, inelastic, fibrous outer covering, the *tunica albuginea*. Within this covering are about 250 delicate pyramidal compartments, each containing from 1 to 3 greatly convoluted threadlike tubules, the *seminiferous tubules*, which are from 1 to 2 feet long, so the total length of the tubules in each testis is about 250 yards. These tubules open into an anastomosing network, the *rete testis*, near the posterior border of the testis. The seminiferous tubules produce *spermatozoa* or male gametes—little tadpole-like cells with a head much smaller than a red blood cell, a body of the same length, and a long motile tail.

The testis is covered in front and at the sides with a bursal sac, the *tunica vaginalis testis*, which before birth was continuous with the peritoneal cavity.

The Ducts of the Testis. From 6–12 fine coiled tubules, the *efferent ductules*, each about 8″ long, lead out of the upper part of the rete testis into the *canal of the epididymis*. This canal, though about 20 feet long, is so folded as to form a compact body, the *epididymis* (Gk. epi = upon; didumos = a twin; i.e., the testes are twins), which caps the upper pole of the testis and is applied to its posterior border. The ductus or vas deferens connects the canal of the epididymis to the urethra, and so leads away from the testis. It is about 18″ long. It ascends first behind the testis and then through the upper part of the scrotum to the abdominal wall. This it pierces obliquely. Continuing, it runs under cover of the peritoneum to the base of the bladder, and then descends between the bladder and the rectum. Its terminal ¾″, the *ejaculatory duct*, pierces the prostate and opens into the urethra close to its fellow, about an inch beyond the bladder. From this point onwards the male urethra is the common duct of the urinary and genital systems.

STRUCTURE. The efferent ductules are lined with ciliated epithelium and mucus-secreting cells. The canal of the epi-lumen large, whereas the ductus or vas feels like a whipcord because the muscle didymis and the vas have a circular muscle coat with longitudinal muscle fibers both inside and out. The epididymis feels soft, because the muscle is thin and the

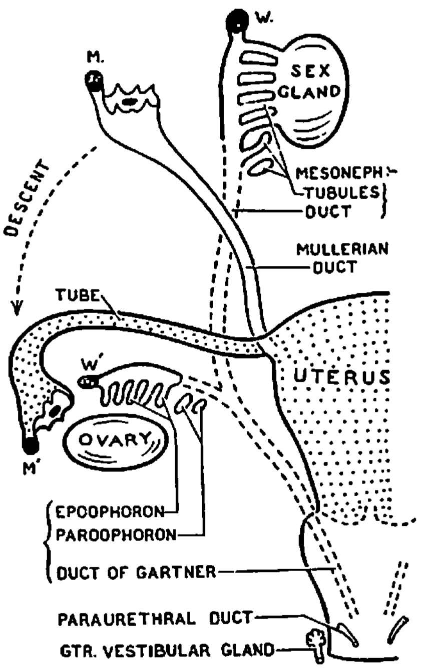

FIG. 50
Diagram of the female genital system (front view).

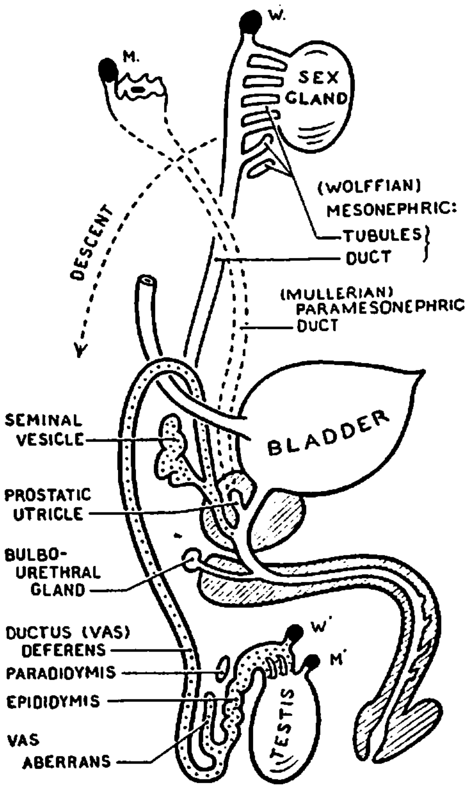

FIG. 51
Diagram of the male genital system (side view).

The parts of the Müllerian duct in the male and of the mesonephric duct in the female, shown in broken lines, disappear. In the upper halves of both figures the parts are shown in their early fetal or indifferent state. M = Müllerian appendage; W = Wolffian (mesonephric) appendage.

is so thick and the lumen so small. Each has a mucous coat. The cells lining the canal of the epididymis discharge a mucoid secretion. The part of the vas behind the bladder, the *ampulla of the vas,* is dilated, thin-walled and easily torn. Within it are septa and secretory outpouchings.

Accessory Glands. The **Seminal Vesicles,** one on each side, are tubular outgrowths from the ampullary ends of deferent ducts, which they resemble in structure (*figs. 367, 368*). They secrete a yellowish sticky liquid.

The **Prostate** (Gk. pro = before, istanai = to stand), the size and shape of a large chestnut, surrounds the first 1¼″ of the urethra just beyond the bladder. It is partly glandular, partly muscular and partly fibro-areolar. It secretes into the urethra an opalescent liquid, free from mucus. It is pierced by the ejaculatory ducts.

The **Bulbo-urethral Glands** (of Cowper), the size of a pea, lie one on each side of the membranous urethra. Their ducts are 1″ long and open into the spongy urethra. They secrete a mucus-like substance.

The **Urethral Glands** (p. 349).

The Penis (L. penis = a tail) is the male organ of copulation (*see fig. 333*). It comprises 3 parallel fibrous tubes, 2 paired and 1 unpaired, which are filled with cavernous tissue and are enclosed in a single loosely-fitting tube of skin and subcutaneous tissue. The paired tubes, the right and left *corpora cavernosa penis,* are fused side by side. In front they present a rounded end; behind they diverge into right and left *crura* (L. crus = a leg) which are firmly attached to the pubic arch. The c. cavernosa are the "supporting skeleton" of the penis. The unpaired tube, the *corpus spongiosum penis* (c. cavernosum urethrae) occupies a groove below the united c. cavernosa; it is traversed by the urethra. Its expanded hinder end is fixed to the membrane (perineal membrane) which stretches between the sides of the pubic arch; its expanded anterior end, the *glans* (L. glans = an acorn), fits like a cap on the ends of the c. cavernosa. The redundant skin covering the glans is the *prepuce.* The operation of circumcision consists in removing the prepuce.

The Scrotum is the bag of skin and laminated subcutaneous tissue in which the testes lie. Like the penis it is free from fat, but it contains a layer of smooth muscle, the *dartos,* which causes wrinkling of the skin when cold.

Semen (L. = seed) is composed of spermatozoa suspended in the secretions of the ducts of the testes and of the accessory glands. The spermatozoa are formed in the testis, whose walls are inelastic; and they overflow into the efferent ductules, whose cilia waft them on into the epididymis with whose secretion they mix and where they are stored until emitted. The number of spermatozoa in an emission is estimated to be 300,000,000; but only one ovum is shed by an ovary each month.

Erection. Stimulation of the pelvic splanchnic nerves produces erection of the penis—hence the term "nervi erigentes" originally given to these nerves—by causing dilatation of the arteries and cavernous tissue of the penis and constriction of the veins. In the normal reflex act the afferent limb is the pudendal nerve (S. 2, 3, 4); the efferent is the pelvic splanchnic (S. 2, 3, 4) (*see fig. 49*). This is brought about by stimulation of the pudendal nerve endings in the glans penis. The fibers of the pelvic splanchnics pass through the prostatic nerve plexus and under the pubic arch to join the vessels of the penis.

Ejaculation. The impulse spreading, sympathetic nerves are stimulated to cause closure of the internal urethral orifice, to set up peristaltic waves which empty the epididymis and propel its contents through the vas to the urethra, and to empty the seminal vesicles and prostate of their secretions. The cord segment is L. 1. The path is probably via the intermesenteric and hypogastric plexuses, because the usual operation for removal of the lumbar sympathetic does not impair ejaculation, but removal of the hypogastric plexus does so permanently (Learmonth). By causing the Bulbospongiosus to contract the pudendal nerve is responsible for emptying the spongy urethra.

The Female Genital System

The Ovaries or female sex glands, one on each side, lie on the side wall of the pelvis (*see fig. 384*). Each ovary is a solid body about half the size of a testis and more flattened. It has an attached border; elsewhere it projects into the peritoneal cavity. It is covered, however, not with squamous peritoneal cells but with a cubical epithelium (germinal). Its surface is scarred and pitted due to the shedding of ova. At birth each ovary contains about 200,000 (immature) ova. From puberty to the end of the reproductive period (15th to 45th year) an ovum is shed into the peritoneal cavity about once a lunar month, and, having no motive power, there it lies at large. In all about 400 ova are shed; the rest are absorbed in the ovary.

The Ducts or Passages that conduct the ova to the exterior of the body are the uterine tubes, which are paired, and the uterus and vagina, which are unpaired (*fig. 50*). The **Uterine Tube** (Fallopian Tube) is about 4½″ long, is as large as a pencil, lies in the free edge of a fold of peritoneum, the *broad ligament*, and takes a twisted course from ovary to uterus. Its ovarian end opens by a trumpet-shaped mouth (infundibulum) into the peritoneal cavity beside the ovary. Its other end opens into the cavity of the uterus.

Structure and Function. The tube has thin outer longitudinal and inner circular muscle coats, a mucosa thrown into numerous longitudinal folds, and a lining of columnar cells in part ciliated, in part secretory. When an ovum is about to be shed the mouth of the tube is turned and likely applied to the ovary ready to receive the ovum. Peristaltic action propels it along the tube, the cilia perhaps helping, and the secretion of the tube nourishing. In the tube the ovum may be met and fertilized by a spermatozoon, which is able to propel itself through the uterus in about 6 hours.

The Uterus is a thick-walled, hollow, muscular organ placed near the center of the pelvis and projecting upwards into the peritoneal cavity between the bladder and the rectum (*see fig. 379*). It is shaped like an inverted pear, somewhat flattened from before backwards so that its cavity is collapsed, and is 3″ long. Above, a uterine tube opens into it on each side; below, it opens into the vagina. The upper 2″ are the *body;* the lower 1″ is the *cervix*; the part of the body above the entrance to the tubes is the *fundus*. The peritoneum covering the body and fundus stretches from each side of the uterus as a fold, the *broad ligament,* that rises from the pelvic floor, extends to the side wall of the pelvis and contains the uterine tube in its upper free edge. Its function is to harbor a fertilized ovum for nine months. During the first two months the ovum is in the indifferent or embryonic stage; during the last seven it is in the formed or fetal stage.

Structure. Under a *peritoneal covering* there is a coat, ½″ thick, of interlacing *smooth muscle fibers* which by contracting not only expel the uterine contents (e.g., fetus and placenta) but also compress the branches of the uterine vessels which pass between them, and so arrest postpartum hemorrhage. Internally there is a thick *mucous coat* (endometrium) pervaded by tubular pits. The mucous coat and the pits are lined with a columnar epithelium, largely ciliated.

In the cervix the muscle fibers are chiefly circular, forming, as it were, a sphincter; the mucous membrane possesses branched mucus-secreting glands, and is lined with an epithelium which is columnar except at the external orifice of the cervix where it is stratified squamous.

The Vagina (L. = a sheath) is a relatively thin-walled collapsed tube, about 3½″ long. The cervix projects into its upper end; below, it opens into the vestibule. It has a coat of smooth muscle fibers, mostly longitudinal except below, where many are circular, an outer fibro-areolar coat, and a mucous membrane which is thrown into ridges or rugae and is lined with stratified squamous epithelium. The vagina having no glands, any mucus present within it comes from the cervix.

Accessory Glands. THE PARAURETHRAL GLANDS (paired) have ducts which open at the side of the urethral orifice. THE GREATER VESTIBULAR GLANDS (of Bartholin) are paired like their homologues in the male, the bulbo-urethral glands, and like them have long ducts, well seen in figure 340. THE LESSER VESTIBULAR GLANDS are a few small mucous glands surrounding the urethral orifice.

The External Genitalia (pudenda) have their homologous parts in the male, see pages **326–328**.

Nerve Supply. The ovaries, like the testes, are supplied by (?) T.10; the fibers travel with the ovarian vessels through the suspensory ligaments, and some of them supply the *uterine tubes.* The *uterus* is supplied by the hypogastric plexus and the pelvic splanchnic nerves which pass through the utero-vaginal plexuses in the broad ligaments. The afferent fibers from the fundus and body pass through the hypogastric plexus and enter the spinal cord via T. 11, 12; those from the cervix and vagina via the pelvic splanchnic nerves (S. 2, 3, 4); but the lowest part of the vagina is supplied by the pudendal nerve.

THE SKIN AND ITS APPENDAGES AND THE FASCIAE

The skin or cutis has four appendages: hairs, nails, sweat glands, and sebaceous glands.

Do not misconceive the skin to be merely an envelope wrapped around our bodies like paper around a parcel. It is, indeed, a wrapping but it is more than a wrapping—it is one of our most versatile organs. As an *envelope* it has admirable properties: being waterproof it prevents the evaporation and escape of tissue fluids; it becomes thick where it is subject to rough treatment; it is fastened down where it is most liable to be pulled off; it has friction ridges where it is most liable to slip; "—even with our ingenious modern machinery we cannot create a tough but highly elastic fabric that will withstand heat and cold, wet and drought, acid and alkali, microbic invasion, and the wear and tear of three score years and ten, yet effect its own repairs throughout, and even present a seasonable protection of pigment against the sun's rays. It is indeed the finest fighting tissue" (Whitnall). As an *organ* it is the regulator of the body temperature; it is an excretory organ capable of relieving the kidneys in time of need; it is a storehouse for chlorides; it is the factory for antirachitic vitamin D (ergosterol) formed by the action of the ultraviolet rays of the sun on the sterols in the skin, and necessary for the mineralization of bones and teeth; and it is the most extensive and varied of the sense organs.

In an average adult man the skin covers a body surface of 1.7 sq. meters. At the orifices of the body it is continuous with the mucous membranes. The skin, somewhat modified, forms the conjunctiva and the outer layer of the ear drum.

The Skin or cutis (L. cutis = skin) has two parts (*fig. 52*): (1) the dermis (Gk. derma = skin) and (2) the epidermis.

The **Dermis or Corium** is of mesodermal origin. It is a feltwork of bundles of white fibers and of elastic fibers. Superficially the feltwork is of fine texture; deeply it is coarse and more open and its spaces contain pellets of fat, hair follicles, sweat glands and sebaceous glands. It is in general 1 to 2 mm. thick, but is thicker on the palms and soles and back, and is thinner on the eyelids and external genital organs. The spaces in the felt-work are lozenge-shaped, hence a needle puncture does not remain a round hole. The long axes of the lozenges are differently directed in different parts, usually being parallel to the lines of tension of the skin. A cut across the long axes of these **Lines of Cleavage** (Langer's Lines) will gape. (Cox.)

It is due to the presence of elastic fibers that the skin, after being stretched or pinched into a fold, returns to normal. Dermis, when tanned, is called leather.

The **Epidermis** is a non-vascular stratified epithelium of ectodermal origin. The deeper layer, the *germinative layer,* is living. It consists of several strata of polyhedral cells resting on a single stratum of columnar cells. The superficial layer, the horny layer or *stratum corneum,* is dead. It consists of several strata of dry, flattened, scaly cells without visible nuclei. The surface cells are perpetually being rubbed away and are perpetually being replaced by cells of the germinative layer.

Finger-like processes of the dermis, *papillae,* protrude into the epidermis anchoring it in the same manner as the tubercular surface of the diaphysis of a bone anchors the epiphysis.

For *Finger Prints* see figure 142, and p. 145, and consult Cummins and Midlo.

The **Nails** are thickenings of the deeper layers of the stratum corneum. A nail has a free end which projects, a root which extends proximally deep to the overhanging nail fold, two lateral borders, a free surface and a deep one. The white crescent appearing distal to the nail fold is the *lunule.* The deep surface rests on and adheres to the *nail bed.* This largely consists of bundles of white fibers which attach the dermis to the periosteum.

Growth takes place at the root and from the bed as far distally as the lunule; beyond this the nail probably slides distally on its bed, adhering to it. Toxins,

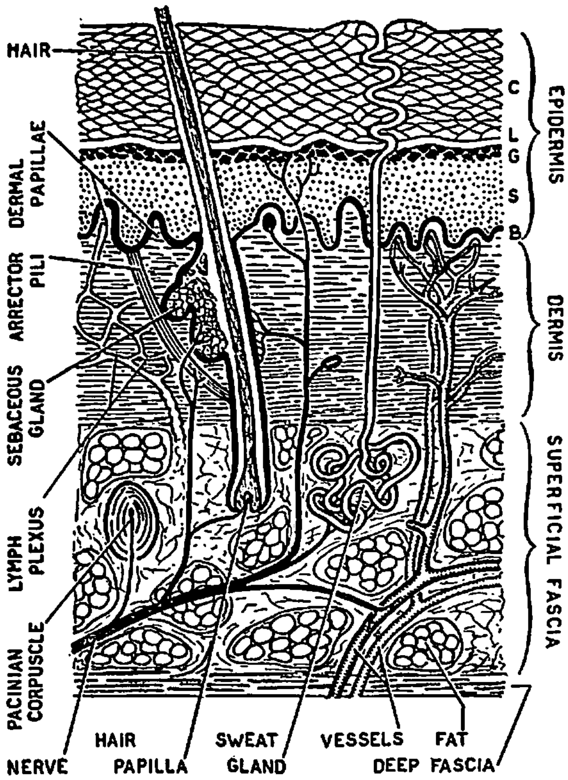

FIG. 52. Section of thick skin, superficial fascia and deep fascia. C = stratum corneum; L = stratum lucidum; G = stratum granulosum; S = germinative layer; B = basal layer of columnar cells. (After Appleton, Hamilton and Tchaperoff.)

arising in an acute illness, temporarily arrest the growth of the nails (as they do of the bones, *see fig. 15*) and a transverse ridge appearing on each nail when growth is resumed is evidence of a past illness. Seeing that the average rate of nail growth is 0.1 mm. a day or 3 mm. a month (i.e., about 1½" a year) the date of a past illness can be estimated. The nail of digit III consistently grows fastest, that of digit V, slowest. Nails grow rapidly in "nail biters"; in immobilized limbs they grow slowly. (Le Gros Clark and Buxton.)

The Hairs are distributed over the entire surface of the body except the palms and soles, dorsum of the last segment of the digits of the hand and foot, red of the lips, parts of the external genitals and the conjunctiva. They are also present in the vestibule of the nasal cavity and in the outer part of the external auditory meatus.

Hairs may be short (a few mm.) or long. Long hairs are present in the scalp, eyebrows, margins of the eyelids, vestibule of the nose, outer part of the external auditory meatus; and at puberty they appear on the pubes, external genitals, axillae, and in the male on the face.

A hair has a *shaft* or part that projects beyond the skin surface, a *root* that lies in a follicle of the skin, and at the end of the root there is a swelling, the *bulb*, which is moulded over a dermal papilla. The life of a hair on the head is about 2–4 years; of an eyelash about 3 to 5 months. Like the leaves of an evergreen tree, old hairs are constantly falling out and new ones taking their place.

The Arrectores Pilorum Muscles are bundles of smooth muscle that pass obliquely from the epidermis to the slanting surface of the hair follicles deep to the sebaceous glands. By contracting they cause the hairs to stand erect. In birds, by erecting the feathers, they increase the air spaces between them thereby preserving heat; hence sparrows look plump in cold weather. In man, spasm of the Arrectores produces "goose skin".

Sebaceous Glands are simple alveolar glands, bottle-shaped, and filled with polyhedral cells which break down into a fatty secretion, called sebum, into the hair follicles. The glands develop as outgrowths of hair follicles into the dermis, one or more being associated with each hair. Commonly the glands are largest where the hairs are shortest (e.g., end of nose, and outer part of the external auditory meatus.) They make the skin waterproof—"like water off a duck's back" is a common expression. Fortunately there are no hairs on the palms and soles, neither are there sebaceous glands to make the surfaces greasy. Independently of hairs, sebaceous glands are present on the inner surface of the prepuce, on the labia minora, and on the areolae of the mammae. The tarsal glands of the eyelids also are modified sebaceous glands (*fig. 655*).

Boils (and carbuncles) start in hair follicles and sebaceous glands and are therefore possible, indeed common, in the vestibule of the nose and outer part of the external auditory meatus.

Sweat Glands are present in the skin of all parts of the body (red of the lips and glans penis excepted), being most numerous on the palms and soles. They are simple tubular glands. The secretory part is coiled to form a ball (0.3 to 0.4 mm. in diameter) situated in the fat of the deepest part of the dermis. The duct runs tortuously through the dermis, enters the epidermis between two papillae, and proceeds spirally to the skin surface. In the stratum corneum it is represented merely by a cleft between the cells. The resemblance to the "intestines of a fairy" was fancifully suggested by Oliver Wendell Holmes.

The ceruminous glands in the outer parts of the external auditory meatus and the ciliary glands of the eyelids are modified "disintegrating" sweat glands. In the axilla, about the external genitals, and around the anus are long, large (3 to 5 mm. in diameter) "disintegrating" sweat glands that produce an odor. They are spoken of as "sexual skin glands".

Sweating lowers the temperature. In man at rest, sweating is observed to begin abruptly when the body temperature is elevated as much as 0.2 to 0.5°F. This is due to the action of the heated blood on the brain centers, and therefore does not occur in the distribution of a peripheral nerve that is severed.

Sweat glands are excretory organs—accessory to the kidneys. The salt taste of sweat is due to sodium chloride. The normal sweat secretion is important in keeping the thick horny layers of the palms and soles supple, and it increases the friction between the skin and an object grasped. In dogs, sweat glands are confined to the foot pads; so, being unable to sweat, dogs pant.

Vessels. The vessels for the supply of the skin run in the subcutaneous fatty tissue. From these the dermis receives two arterial plexuses: one is deeply seated near the subcutaneous tissue; the other is in the subpapillary layer. This sends capillary loops into the papillae. The returning blood passes through several layers of thin-walled subpapillary venous plexuses, thence through a deep venous plexus, and so to the subcutaneous veins. Arterio-venous anastomoses, which are sometimes open and sometimes closed, connect some of these arterioles and venules.

The *lymph vessels* of the skin form a plexus at the junction of the dermis and the superficial fascia. This plexus receives blind fingerlike vessels (or networks) from the papillae and it drains into lymph vessels that accompany the subcutaneous arteries and veins.

Nerves. The cutaneous nerves have (1) *efferent* autonomic fibers for the supply of: the blood vessels, arrectores pilorum, sweat and sebaceous glands, and (2) *afferent* somatic fibers of general sensation, namely touch, pain, heat, cold, and pressure (*fig. 43*, p. 44).

As figure 52 indicates, free fibers end between the cells of the germinative layer (and intra-epidermal injections may cause pain), and around the hair follicle and beside it (probably touch fibers); tactile corpuscles occupy occasional papillae (for touch); Pacinian corpuscles lie in the superficial fascia and are plentiful along the sides of the digits (for pressure). The anatomical basis for heat, cold, and pain is not yet determined.

Superficial Fascia or Tela Subcutanea

Superficial fascia is a subcutaneous layer of **Loose Areolar Tissue** which unites the corium of the skin to the underlying deep fascia. It consists of (a) bundles of *white* or *collagenous fibers* which, by branching and uniting with other bundles, form an open webbing, filled with (b) *tissue fluid*; (c) a slender network of *yellow elastic fibers*, and scattered amongst all this lie (d) *connective tissue cells* (*fig. 53*). When areolar tissue is exposed to the air, the tissue fluids rapidly evaporate with consequent drying and shrinking. Fortunately, the addition of an (antiseptic) saline solution will restore to areolar tissue its original fluffy texture, but once other tissues have become dry and shrunken they remain so.

Areolar tissue is derived from those portions of mesoderm that remain after bones, ligaments, tendons, muscles, and vessels have taken form. It is, therefore, not confined to the superficial fascia but is diffusely spread; for example, it forms the sheaths of muscles, vessels, nerves, and viscera, and it fills up the spaces

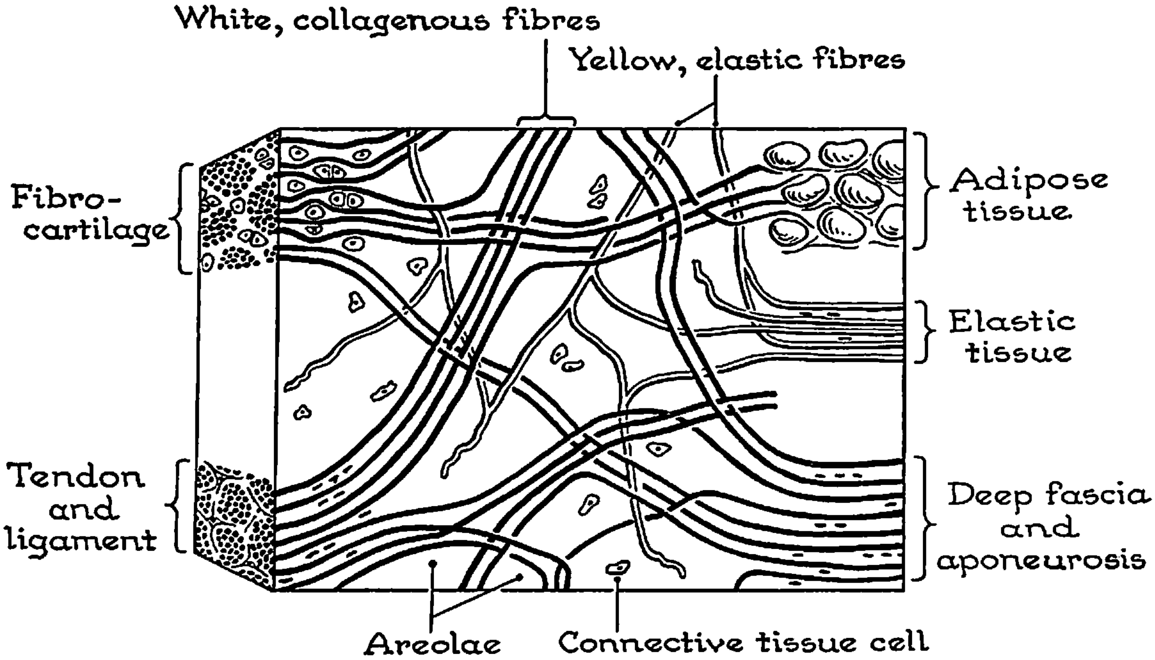

FIG. 53. A diagram of areolar tissue demonstrating that its 4 ingredients when mixed in different proportions form other tissues.

between them; it forms the basis of the mucous, submucous, and subserous coats of the hollow viscera; the serous membranes (i.e. peritoneum, pleura, pericardium, and tunica vaginalis testis) are but areolar membranes lined with flat mesothelial cells.

Areolar tissue is potentially **Adipose Tissue** or fat, and wherever areolar tissue occurs, there fat also may occur. The fat accumulates in the connective tissue cells. Fat is fluid at body temperature but, because each drop of fat is imprisoned in a cell, it does not gravitate to lower levels or flow from a wound.

Distribution. The superficial fascia almost everywhere contains fat—except in the eyelids, external ear, penis and scrotum, and at the flexion creases of the digits. In the palms and soles it forms a protective cushion; here and still more so in the breast and scalp it is loculated (*fig. 661*). It is most abundant in the buttocks. *In the female,* fat is most extensively deposited in the gluteal and lumbar regions, front of the thigh, anterior abdominal wall below the navel, mammae, postdeltoid region and cervicothoracic regions.

Adipose or fatty tissue, as mentioned, is modified areolar tissue, and is notably present in the superficial fascia, the subserous layer of the abdominal wall and in the omenta and mesenteries. It covers parts of the urinary tract (e.g. kidney, ureter, sides of the bladder), but it leaves free the gastro-intestinal tract, liver, spleen, testis, ovary, uterus, and lung. It is odd, then, that it should be present in the sulci of the heart. There is no fat within the cranial cavity to dispute possession with the brain, nor within the dura mater covering the spinal medulla. The eyeball moves in fluid fat.

Deep Fascia

Deep fascia is the membranous investment of the body deep to the superficial fascia (*figs. 53, 54*). Like tendons, aponeuroses, and ligaments it contains the same four ingredients as areolar tissue, but in different proportions; and, like them, being subjected to tensile strains, the white collagenous fibers form parallel bundles; the tissue fluids are at a minimum; and the cells are distorted from pressure.

Deep fascia is best marked in the limbs and neck, where it is wrapped around the muscles, vessels, and nerves like a bandage, the fibers being chiefly circularly arranged. Around the thorax and abdomen, which require to expand and contract, there may be a film of areolar tissue but there can be no true deep fascia; nor is there any covering flat muscles (e.g., Trapezius, Pectoralis Major) since there it would have no useful function; nor on the face, since the facial muscles, like the Platysma, are cutaneous muscles.

The deep fascia sends septa, *intermuscular septa,* between various muscles and groups of muscles (*fig. 54*).

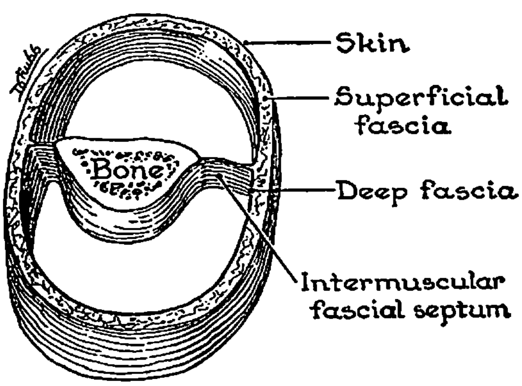

FIG. 54. An intermuscular septum passing from deep fascia to bone.

Where deep fascia encounters bone, it does not cross it, but attaches itself to it, for the simple reason that both have a common derivation; so, unless some muscle during development intervenes and detaches the fascia from the bone, the two remain attached. At the wrist and ankles there are exceptions to this generalization.

The deep fascia is thickened where muscles are attached to it, and the direction of its fibers takes the line of pull. It is also thickened about the wrist and ankle to form, as it were, bracelets and anklets, called *retinacula,* which prevent the tendons of muscles from bowstringing (*fig. 55*).

FIG. 55. Demonstrating the function of a retinaculum (annular ligament). (After Andreas Vesalius—De Humani Corporis Fabrica, 1568 edition: first published in 1543.) (By the courtesy of the Toronto Academy of Medicine.)

Subcutaneous Bursae are present (a) at the convex surface of joints which undergo acute flexion, because here the skin requires to move very freely, e.g., behind the elbow (olecranon b.), in front of the knee (prepatellar b.) and, sometimes, dorsal to the metacarpo-phalangeal and interphalangeal joints; (b) over bony and ligamentous points subjected to considerable pressure and friction. Most of these, being acquired or occupational, are inconstant, e.g., those lying superficial to: acromion, ischial tuberosity, lig. patellae, tubercle of the tibia, malleoli, insertion of the tendo calcaneus, and head of the first metatarsal (medial side).