# LIFE SCIENCE CONTENT SUMMARY

## III: Organ Systems

**Table of Contents**




The Content Summaries and SBD were developed by TERC and Lamar University and funded in part by the National Science Foundation, Award #1703343 and Award #2019843. All opinions, findings, conclusions, and recommendations expressed herein are those of the authors and do not necessarily reflect the views of the funders.

# III: Organ Systems

## IIIa) Human Body Organ Systems and Main Functions

An organ system is a group of organs that work together to perform certain main functions in an organism's body. The organ systems of the human body and their main components and functions are listed below:

***Digestive System***—mouth, pharynx, esophagus, stomach, intestines, liver, pancreas, anus—food processing (ingestion, digestion, absorption, elimination).

***Circulatory System***—heart, blood vessels, blood—internal distribution of materials.

***Respiratory System***—lungs, trachea, other breathing tubes and structures—gas exchange (uptake of oxygen; disposal of carbon dioxide).

***Immune and Lymphatic Systems***—bone marrow, lymph nodes, thymus, spleen lymph vessels, white blood cells—body defense (fighting infections and cancer).

***Excretory System***—kidneys, ureters, urinary bladder, urethra—disposal of metabolic wastes; regulation of osmotic balance of blood.

***Endocrine System***—pituitary, thyroid, pancreas, adrenal, and other hormone-secreting glands—coordination of body activities (digestion, metabolism etc.).

***Reproductive System***—ovaries or testes and associated organs—reproduction.

***Nervous System***—brain, spinal cord, nerves, sensory organs— coordination of body activities; detection of stimuli and formulation of response to them.

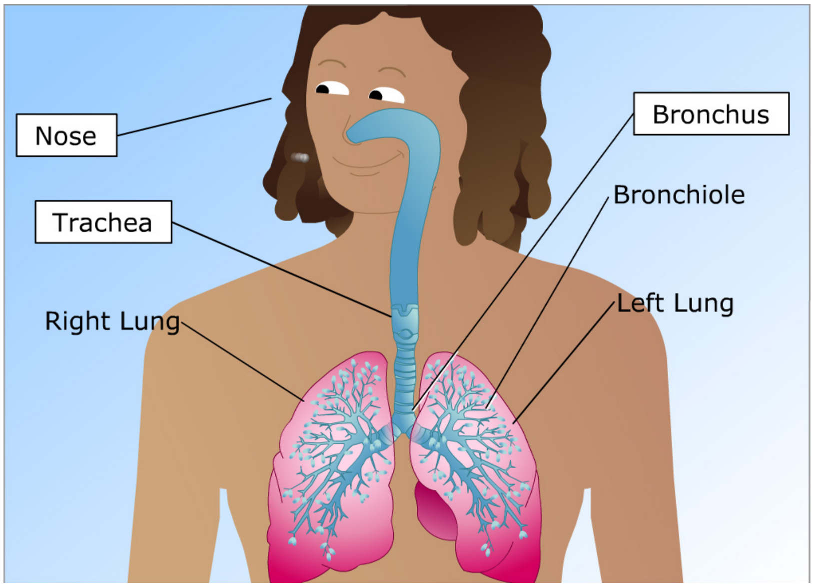
***Integumentary System***—skin and its derivatives (hair, skin etc.)—protection against mechanical injury, infection, dehydration; thermoregulation.

***Skeletal System***—skeleton (bones, tendons, ligaments, cartilage)—body support, protection of internal organs, movement.

***Muscular System***—skeletal muscles—locomotion and other movement.

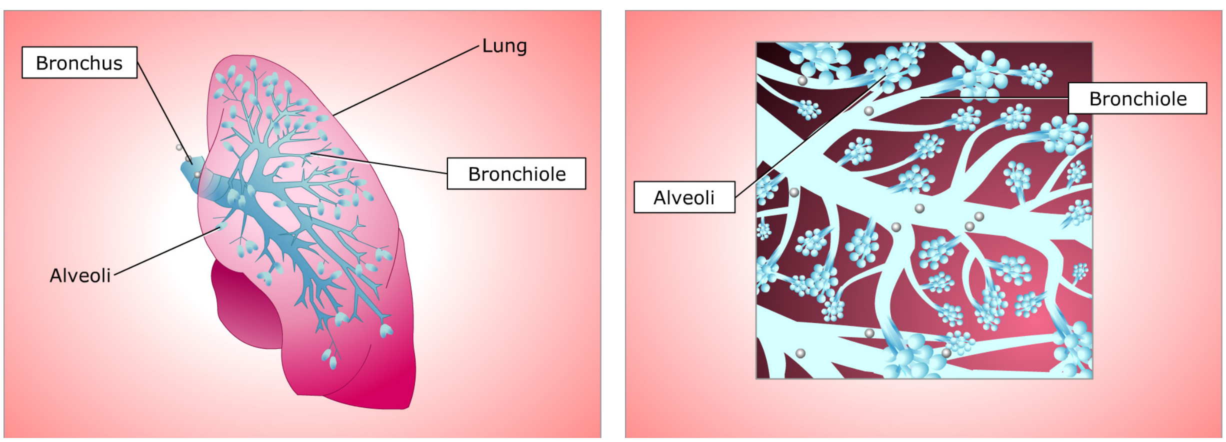
## IIIb) The Respiratory System

The respiratory system is made up of a group of organs that are integrated to perform the essential life process of respiration. The respiratory system functions—in combination with the circulatory system—to bring oxygen into the body and to eliminate waste carbon dioxide.



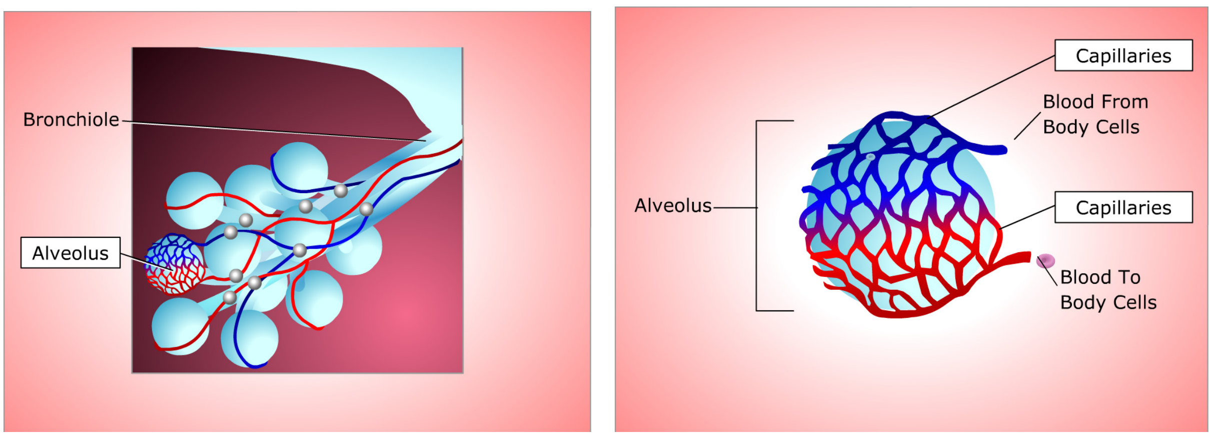
**Respiratory Organs and Breathing Tubes**

***The Carbon Dioxide-Oxygen Exchange***—When we inhale, oxygen-rich air enters the nose. The oxygen-rich air travels down the trachea, or windpipe, which splits into two bronchi that each carry air to a lung. Inside each lung, the bronchi branch into thousands of smaller bronchioles. Each bronchiole ends in a tiny structure that looks like a bunch of grapes. Each grape-like structure contains many air-filled sacs called alveoli. Each alveolus is moist with a network of capillaries surrounding it.



**Structures of the Lung**

Due to a process called diffusion, whereby the oxygen moves from a region of higher concentration to one that is lower, some of the oxygen in the inhaled air moves from the alveoli into the blood in the capillaries. This occurs because the concentration of oxygen in the alveoli is greater than in the blood, and the membranes separating the alveoli from the capillaries are only about one cell thick. The many alveoli of the lungs provide a large surface area over which diffusion can occur. This large surface area allows much of the oxygen taken in at each breath to be exchanged with the blood. As blood circulates away from the alveoli, red blood cells carry the oxygen to the heart, where it is pumped through arteries to capillaries surrounding nearly every cell in the body. When the oxygen-rich blood reaches body cells, the oxygen diffuses into the cells through the cell membrane (because there is a lower concentration of oxygen in the cells than in the blood). Carbon dioxide—produced as a waste product of respiration—diffuses from the cells into the blood because the concentration of carbon dioxide in the blood of the surrounding capillaries is less than that of the cells. As the blood circulates away from the cells, red blood cells carry the carbon dioxide to the heart, where it is pumped to capillaries surrounding the alveoli. Because the concentration of carbon dioxide in the capillaries is greater than inside the alveoli, it diffuses into the alveoli. When we exhale, the carbon dioxide and remaining oxygen that has not diffused into the blood moves from the bronchi in the lungs into the trachea and is exhaled out the nose.

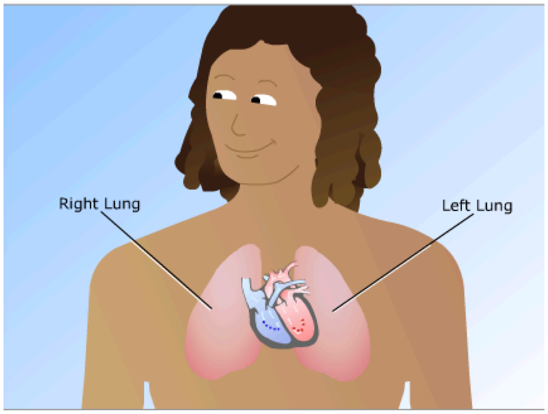



**Structure of the Alveoli**

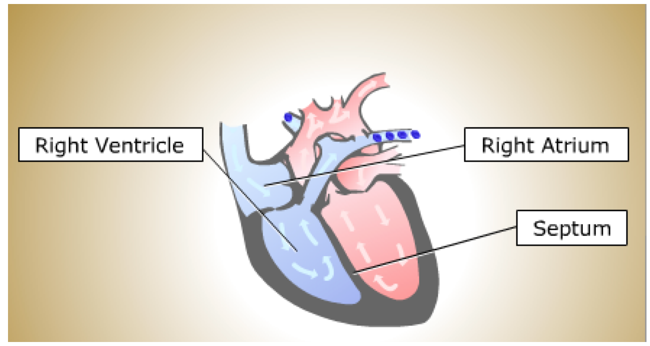
### IIIc) The Circulatory System

The circulatory system is made up of a group of organs that are integrated to perform the life process of circulation. One of the primary functions of the circulatory system—in combination with the respiratory system—is to circulate oxygen to body cells and waste carbon dioxide to the lungs. Using the heart as the starting point, whose primary function is to pump blood rich in oxygen to body cells and return blood rich in carbon dioxide to the lungs, this is accomplished as follows:

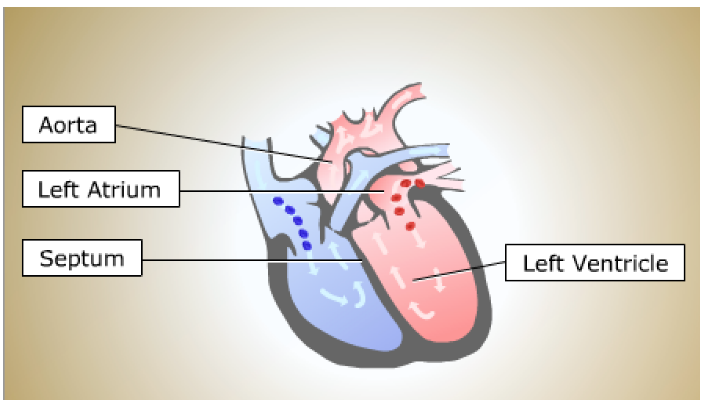
The heart is made up of two upper chambers and two lower chambers. The upper chambers are called atria. They are thin-walled structures that receive blood entering the heart from elsewhere in the body. The lower chambers are called ventricles. They are much larger and more muscular than the atria and pump blood away from the heart. The right and left sides of the heart are separated by a tough wall called the septum. The heart is connected to a network of tubes, or blood vessels, through which blood flows. These blood vessels are known as arteries, capillaries, and veins. Most arteries circulate oxygen-rich blood away from the heart. The aorta is the largest artery in the human body and connects to the left ventricle. As arteries get farther from the heart, they branch into smaller and smaller blood vessels. As arteries get closer to cells, they become extremely small and are known as capillaries. Capillaries circulating blood rich in carbon dioxide away from cells join back together to form veins. Most veins carry carbon dioxide-rich blood back to the heart where it enters the right atrium.



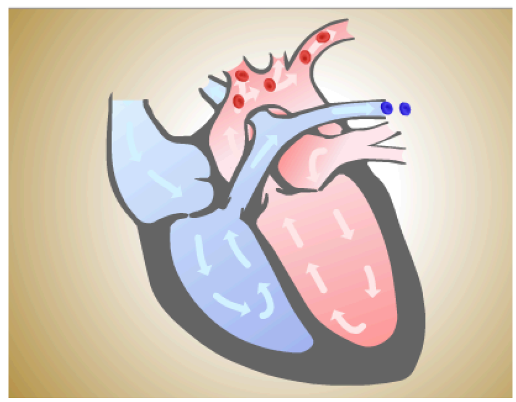

Location of the Heart




Right Side of the Heart




Left Side of the Heart

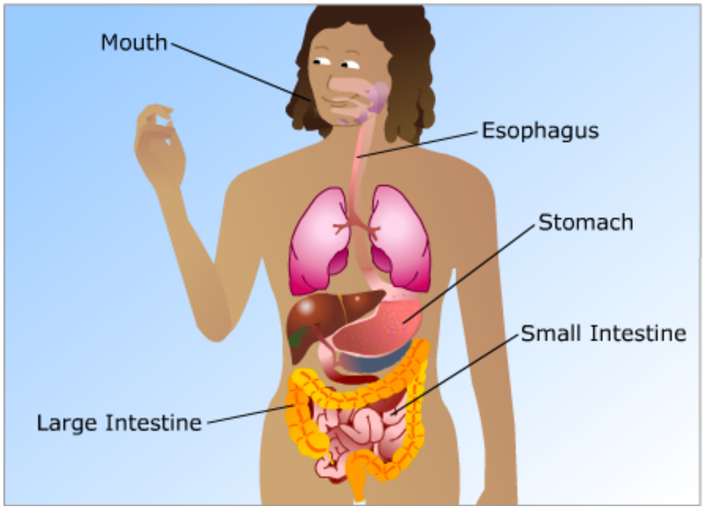


Blood Flow Through the Heart

The structure of the heart keeps oxygen-rich blood separate from blood rich in carbon dioxide. Blood carrying oxygen-rich air from the lungs enters the heart through a one-way valve into the left atrium. The left atrium contracts, forcing the blood through a one-way valve into the left ventricle. The left ventricle contracts and forces blood through a one-way valve into the aorta. From the aorta, the oxygen-rich blood circulates to almost every cell in the body. Blood rich in waste carbon dioxide circulates back to the heart from the body and enters the heart through a one-way valve into the right atrium. The right atrium contracts, forcing the blood through a one-way valve into the right ventricle. The right ventricle contracts, forcing blood rich in carbon dioxide into the lungs, where it is expelled in exhaled air.

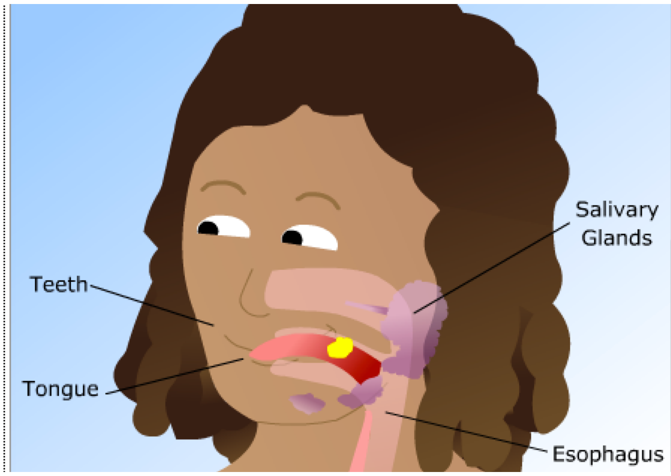
### IIId) The Digestive System

The digestive system, in combination with the respiratory and circulatory system, performs the life process of digestion. Digestion involves the breakdown of food—carbohydrates (starch and sugars), fats, and protein—into smaller products such as glucose, fatty acids, and amino acids that can pass into capillaries and be circulated to body cells. In humans, a continuous tube made up of a group of organs are integrated to perform the process of digestion. The organs that make up the food route (also called the alimentary canal and digestive tract) include the mouth, esophagus, stomach, small intestine, and large intestine.



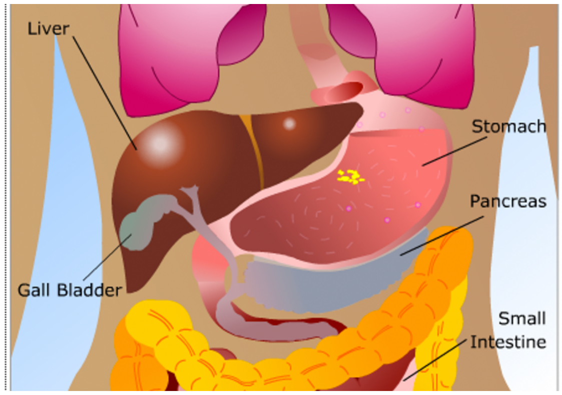
**The Food Route**

***The Process of Digestion***—In the mouth, the teeth break food apart. Saliva, from the salivary glands, makes food soft and moist for easy swallowing. It also contains an enzyme, called amylase, that speeds up the breakdown of starch to sugar. Enzymes are catalysts. They speed up reactions. Without them, reactions that take place in the body would occur so slowly that cells could not function, and the body could not survive. As food is swallowed, it moves down a long tube, called the esophagus, that connects the mouth to the stomach. Strong muscles in the esophagus move the food along in a wavelike motion called peristalsis.



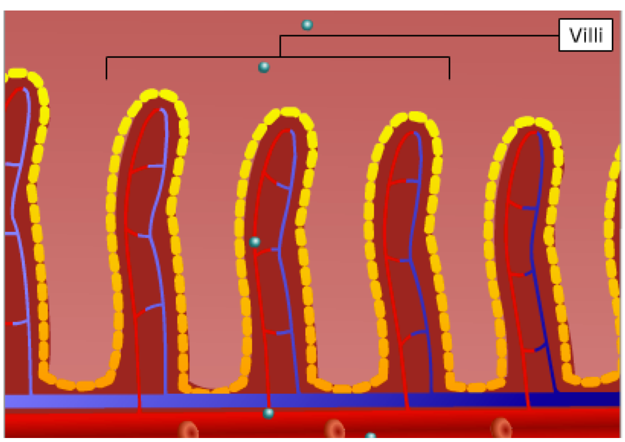
**The Mouth**

The stomach is a muscular organ. Muscles in the stomach mix the food with gastric juice that is mainly hydrochloric acid and enzymes (produced in the stomach lining). An important stomach enzyme, pepsin, functions under acid conditions to break down proteins. Digestion is completed in the small intestine. Bile, brought in from the liver via the gall bladder, is important for the breakdown of fats. Enzymes from the pancreas and the wall of the intestine are important for the breakdown of proteins, fats, and carbohydrates. In the small intestine, the products of digestion are transported to the blood in surrounding capillaries and circulated to body cells.

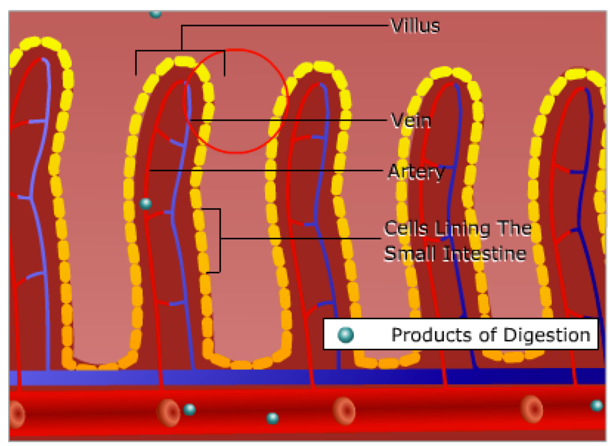



**Stomach-Small Intestine**

The interior of the small intestine is folded and has many fingerlike projections called villi. The folds and villi result in the small intestine having a large surface area that allows for the absorption of large amounts of the products of digestion. The products of digestion are transported into the blood through the cells of the small intestine.




**Villi (Singular Villus)**



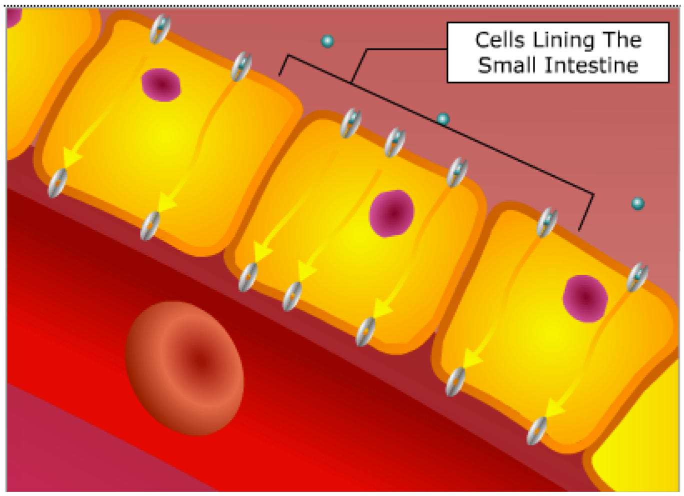

**Absorption and Transport of Products**

Most of the water remaining in the undigested food passes from the large intestine into capillaries and into the blood. Excess water exits the body through the skin and in exhaled air. It also circulates to the kidneys and is excreted in urine. Remaining solid waste is excreted through the rectum and anus.

***Utilizing the Products of Digestion***— Foods such as cereal, rice, bread, crackers, and potatoes contain starch, much of which is made in the chloroplasts as a storage product of photosynthesis. See Section Ib for more information about the process of photosynthesis. Starch is too large to pass into the bloodstream. During digestion, starch is broken down into glucose. Glucose is a simple sugar that can pass from the digestive system into capillaries and body cells. Foods such as meat, eggs, milk, and cheese contain protein. Foods such as butter, salad oil, and meat contain fats. During digestion, proteins are broken down into amino acids. Fats are broken down to form glycerol and fatty acids.

All the products are small enough to pass into the capillaries and circulate in the blood to body cells. In the cell, the glucose and fats interact with oxygen during the process of respiration to release energy, waste carbon dioxide, and water.

Unlike oxygen and carbon dioxide, which diffuse across the cell membrane, the products of digestion are not soluble in the cell's "oily layer." Therefore, they cannot diffuse across it. They enter the membrane across special "carriers" that function to "flip" the small products of digestion, such as glucose, across it. The cell membrane has many carriers, each of which can transfer only one, or very few kinds, of the products of digestion across the membrane.




**Cell Membrane with "Carriers"**

Blood circulating throughout the body picks up the products of digestion and transports them to cells. Upon reaching the cell, glucose and fats from fatty acids react with oxygen during the process of respiration to yield waste carbon dioxide and water. Energy is released during the process. The waste carbon dioxide produced is circulated back to the lungs, where it exits the body in exhaled air.

In addition to utilizing the immediate products of digestion, the body stores glucose (as glycogen) in the muscles and liver. Fat is stored in specialized fat cells. Alternatively, some of the products of digestion may be "remodeled" and used as building blocks to make the many complex products that are required for cell structure and function. These include chlorophyll (in plants), hemoglobin (in animals), enzymes, the genetic material DNA, cholesterol, and many others.

### IIIe) The Reproductive System

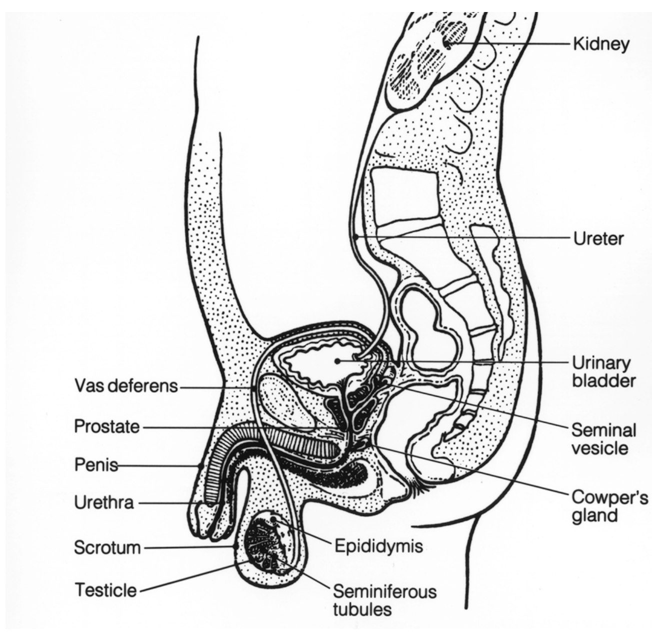
Reproduction is the process by which living things give rise to offspring (new individuals). Reproduction can be asexual or sexual.

***Asexual Reproduction***— Asexual reproduction requires only one parent organism. It usually results in an organism that is genetically and morphologically identical to the parent. The four major types of asexual reproduction are binary fission, budding, fragmentation, and parthenogenesis.

Budding occurs in yeast and some invertebrates such as hydra. It involves formation of a small outgrowth, or bud, that develops during cell division at a particular site and breaks off to become a new individual. Fragmentation occurs in many plants, as well as some invertebrates such as coral, sponges, and starfish. It involves the parent organism splitting into fragments. Each fragment develops into a new organism. Parthenogenesis occurs in invertebrates and in some vertebrates such as fish, amphibians, and reptiles. It involves growth and development of an embryo without fertilization by sperm. Many prokaryotes (unicellular organisms that do not have a nucleus such as bacteria) reproduce through binary fission. Binary fission involves a single parent cell dividing to produce two genetically identical daughter cells or organisms. See Section IId (Passing on of Genetic Information Through Asexual Reproduction) for more information about binary fission.

***Sexual Reproduction***—Many organisms, including humans, have sexes and pass information on through the process of sexual reproduction. This requires the union of two specialized cells, the sperm from the male and egg from the female. Most organisms, including humans, have separate sexes. However, some organisms do not have separate sexes. They are hermaphrodites. Hermaphroditic organisms have male and female organs within the same organism and exhibit some degree of self-fertilization. Snails and earthworms, some vertebrates such as fish, and most plants are hermaphroditic.

***The Human Male Reproductive System***—The male reproductive system is responsible for sexual function and urination. External organs include the penis, scrotum and testicles. Internal organs, also called accessory organs, include the vas deferens, prostate and urethra.




**Organs of the Male Reproductive System**

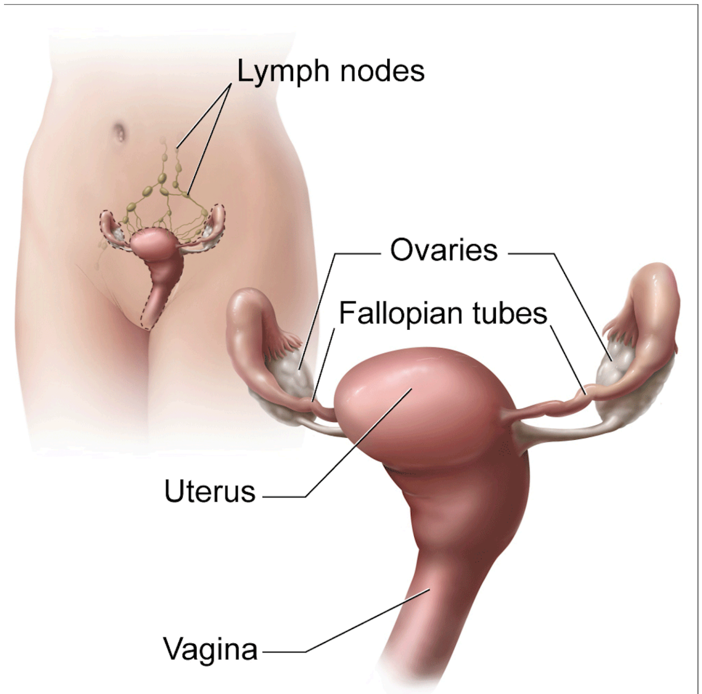
The testes (also called testicles) hang between the thighs in a pouch-like sac of skin called the scrotum. They are responsible for producing sperm and making the primary male sex hormone testosterone. Testosterone affects appearance and sexual development, stimulates sperm production and sex drive, and helps build muscle and bone mass. The scrotum protects the testes and maintains temperature so that it is appropriate for normal sperm development. Within the testes are coiled masses of tubes called seminiferous tubules. These tubules are responsible for producing the sperm cells through the process of spermatogenesis. The sperm that emerge from the testes are immature and incapable of fertilization. A long coiled called the epididymis tube rests on the backside of each testicle. It carries and stores sperm cells that are created in the testes. The epididymis is responsible for bringing the sperm to maturity.

The vas deferens, a long muscular tube that travels from the epididymis into the pelvic cavity, transports mature sperm from the epididymis to the urethra. The urethra is the tube that carries urine from the bladder to outside of the body. In males, it has the additional function of expelling (ejaculating) semen. Seminal vesicles, sac-like pouches that attach to the vas deferens near the base of the bladder, make a sugar-rich fluid (fructose) that provides sperm with a source of energy and helps with the sperms' ability to move (motility). The fluid of the seminal vesicles makes up most of the volume of the ejaculatory fluid, or ejaculate. The prostate gland, located below the urinary bladder in front of the rectum, contributes additional fluid to the ejaculate. Prostate fluids also help to nourish the sperm. The urethra is contained within the penis and runs through the center of the prostate gland. It carries the ejaculate to be expelled during orgasm, Bulbourethral glands, or Cowper's glands, located on the sides of the urethra, just below the prostate gland, produce a clear fluid that empties directly into the urethra and serves to lubricate the urethra and to neutralize any acidity that may be present due to residual drops of urine in the urethra.

Functioning of the male reproductive system is dependent on hormones. Hormones are chemicals that stimulate or regulate the activity of cells and organs. The primary hormones involved in the functioning of the male reproductive system are follicle-stimulating hormone (FSH), luteinizing hormone (LH) and testosterone. FSH and LH are secreted by the pituitary gland. The pituitary gland is located at the base of the brain and is part of the endocrine system. FSH is necessary for sperm production (spermatogenesis). LH stimulates the production of testosterone, which is necessary to continue the process of spermatogenesis. Testosterone is also important in the development of male characteristics, including muscle mass and strength, fat distribution, bone mass and sex drive.

***The Human Female Reproductive System***—The female reproductive system is designed to carry out several functions. The ovaries produce the egg cells, called the ova or oocytes that are then transported to the fallopian tube where fertilization by a sperm may occur. The egg then moves to the uterus, where the uterine lining has thickened in response to the normal hormones of the reproductive cycle. Once in the uterus, if fertilized, the egg can implant into thickened uterine lining and continue to develop. If implantation does not take place, the uterine lining is shed as menstrual flow. In addition, the female reproductive system produces female sex hormones that maintain the reproductive cycle.

The main organs of the female reproductive system lie within the abdominal cavity. They include the ovaries, Fallopian tubes, uterus, and vagina.




**Organs of the Female Reproductive System**

The ovaries are two oval-shaped glands located on either side of the uterus. They produce eggs and secrete the hormone estrogen. The Fallopian tubes are attached to the upper part of the uterus. Fertilization of an egg by a sperm normally occurs in the Fallopian tube. The uterus or womb is a hollow pear-shaped muscular organ that functions to carry a fetus until birth. The uterus is divided into two parts. The cervix is the lower part. It opens into the vagina. The main body of the uterus is the corpus. The corpus can easily expand to hold a developing baby. A canal through the cervix allows sperm to enter and menstrual blood to exit. The vagina is a tubular tract connecting the uterus to the outside of the body. The vagina is where sperm are usually deposited during sexual intercourse and ejaculation. The vagina is a canal that joins the cervix to the outside of the body. It is also called the birth canal.

Functioning of the female reproductive involves cycles of hormonal activity (menstrual cycles) that repeat at about one-month intervals. The average menstrual cycle takes about 28 days and occurs in phases that include the: follicular phase (development of the egg), ovulatory phase (release of the egg), and luteal phase (hormone levels decrease if the egg does not implant).

During the follicular phase follicle stimulating hormone (FSH) and luteinizing hormone (LH) are secreted from the pituitary gland and travel in the blood to the ovaries. The hormones stimulate the growth of about 15 to 20 eggs, each in its own "shell," called a follicle. They also trigger an increase in the production of the female hormone estrogen. As estrogen levels rise, production of FSH ceases. As the follicular phase progresses, one follicle in one ovary becomes dominant and continues to mature. This dominant follicle suppresses all of the other follicles in the group. As a result, they stop growing and die. The dominant follicle continues to produce estrogen.

The ovulatory phase (ovulation) usually begins about 14 days after the start of follicular phase. The rise in estrogen from the dominant follicle triggers a surge in the amount of luteinizing hormone that is produced. This causes the dominant follicle to release its egg from the ovary. As the egg is released (a process called ovulation) it is captured by finger-like projections on the end of the fallopian tubes that sweep the egg into the tube. Prior to this, there may be an increase in cervical mucus. This vaginal discharge helps to capture and nourish sperm on its way to meeting the egg for fertilization.

The luteal phase begins after ovulation. Once it releases its egg, the empty ovarian follicle develops into a new structure called the corpus luteum. The corpus luteum secretes the hormones estrogen and progesterone. Progesterone prepares the uterus for a fertilized egg to implant. If a sperm has fertilized the egg, the fertilized egg will travel through the fallopian tube to implant in the uterus. If the egg is not fertilized, it passes through the uterus, the lining of the uterus breaks down and sheds, and the next menstrual period begins.

See Section IId for more information about the passing on of genetic information through asexual reproduction. See Section IIe for more information about the passing on of genetic information through sexual reproduction.

**IIIf) Disease**

Disease is a breakdown in the body's structures and/or functions. The breakdown can result from intrinsic or extrinsic failures.

Diseases resulting from extrinsic failures result from bacteria or viruses entering the body that reproduce inside the body at a rapid rate, often numbering in the millions or billions within hours or days of infection. Its presence deprives the body of essential materials, disturbs the immune system, or releases toxins that interfere with the basic functioning of particular cells. Examples include bronchitis, the common cold, infectious food poisoning, influenza, mononucleosis, pneumonia, strep throat, meningitis, and COVID-19.

Diseases resulting from intrinsic failures can result from a defect in one of the cell types that make up one or several organ systems. Intrinsic failures often begin with an error (mutation) in the coded instructions that determine the organism's characteristics. (See Section IIf for more information about mutations as errors in genetic information.)

The first defense against bacteria or viruses is to prevent the organism from entering the body. For example, the skin serves as a barrier, and saliva secretes substances that can break down bacteria as they attempt to enter the body through the mouth. Bacteria and viruses that do manage to enter the body are generally recognized by the immune system as foreign and destroyed. Vaccines can serve to "prime" the immune system and enable it to respond more effectively when it encounters an invader that is identical to the material used to make the vaccine. Antibiotics and antiviral drugs block functions that are more or less specific to the bacterium or virus rather than to the human cell. For example, penicillin interferes with the synthesis of the cell wall of many bacteria, killing them, while sparing human cells.