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An embryo represents the initial stage of development in a multicellular organism. This period is characterized by rapid cell division and the establishment of the basic body plan. In organisms that reproduce sexually, this phase begins after fertilization, transforming a single cell into a complex structure with the potential to form specialized tissues and organs. In humans, the developing organism is referred to as an embryo from the first cell division until about the eighth week after fertilization. The Beginning of Embryonic Life The journey of an embryo starts with fertilization, the fusion of two specialized sex cells, known as gametes—a sperm from the male and an egg from the female. This union creates a single diploid cell called a zygote, which contains a complete set of genetic material from both parents. This event typically occurs in the fallopian tube. Shortly after fertilization, the zygote begins a process of rapid cell division known as cleavage. During this phase, the single cell divides into two, then four, then eight cells, and so on, without a significant increase in the overall size of the organism. This cluster of cells, now termed an embryo, continues its journey toward the uterus. Key Stages of Embryonic Development After the initial cell divisions, the embryo develops into a blastocyst around five to six days after fertilization. The blastocyst is a hollow ball of cells with two distinct parts: an outer layer that will eventually form the placenta and an inner cell mass that will develop into the fetus itself. This structure travels to the uterus, where it must attach to and embed within the uterine wall, a process called implantation, which generally completes around 9 or 10 days after fertilization. Once implanted, the embryo undergoes a transformative process called gastrulation, which begins around the third week. During gastrulation, the inner cell mass reorganizes itself into three primary germ layers. These layers are the ectoderm, the mesoderm, and the endoderm. Each layer is destined to give rise to specific tissues and organs. The ectoderm, or outer layer, is responsible for forming the epidermis, which includes the skin, hair, and nails. It also gives rise to the entire nervous system, including the brain and spinal cord, as well as various sensory organs. The middle layer, the mesoderm, develops into the body’s structural components, such as the skeleton, muscles, and connective tissues. It also forms the circulatory system, including the heart and blood vessels, and the urogenital system. The innermost layer, the endoderm, forms the epithelial lining of the digestive and respiratory tracts and associated organs like the liver and pancreas. The formation of these germ layers sets the stage for organogenesis, which starts around the third week and continues through the eighth week. The heart is one of the first functional organs to develop, beginning to beat and pump blood around day 22. By the end of the embryonic period, the rudimentary forms of all major organ systems have been established. From Embryo to Fetus The transition from an embryo to a fetus occurs at the end of the eighth week after fertilization, which corresponds to about the tenth week of pregnancy. By this point, the developing organism has established recognizable human features, such as limbs, fingers, and a more defined facial structure. The primary distinction between the embryonic and fetal stages lies in the nature of development. The embryonic stage is defined by the formation of structures and organ systems. In contrast, the fetal stage is primarily focused on growth and maturation. From the ninth week onward, the now-called fetus will continue to grow in size and weight, and its organs will mature and become functional. Embryonic Development in Other Species While the basic principles of embryogenesis, such as cell division and differentiation, are common across the animal kingdom, the specifics of development can vary significantly between species. These differences are often tied to the environment in which the embryo develops. For example, the development of a chick embryo inside an egg is supported by a large yolk, which provides all the necessary nutrients until hatching. In contrast, mammalian embryos, including humans, develop inside the mother’s body and rely on a placenta for nourishment and waste exchange. Although mammals do not have a large yolk, their embryonic development retains features from their reptilian ancestors, such as the formation of a yolk sac in early stages, even though it serves different functions. By the end of this section, you will be able to: Describe how, when, and why the body metabolizes proteins Describe how the body digests proteins Explain how the urea cycle prevents toxic concentrations of nitrogen Differentiate between glucogenic and ketogenic amino acids Explain how protein can be used for energy Much of the body is made of protein, and these proteins take on a myriad of forms. They represent cell signaling receptors, signaling molecules, structural members, enzymes, intracellular trafficking components, extracellular matrix scaffolds, ion pumps, ion channels, oxygen and CO_2 transporters (hemoglobin). That is not even the complete list! There is protein in bones (collagen), muscles, and tendons; the hemoglobin that transports oxygen; and enzymes that catalyze all biochemical reactions. Protein is also used for growth and repair. Amid all these necessary functions, proteins also hold the potential to serve as a metabolic fuel source. Proteins are not stored for later use, so excess proteins must be converted into glucose or triglycerides, and used to supply energy or build energy reserves. Although the body can synthesize proteins from amino acids, food is an important source of those amino acids, especially because humans cannot synthesize all of the 20 amino acids used to build proteins. The digestion of proteins begins in the stomach. When protein-rich foods enter the stomach, they are greeted by a mixture of the enzyme pepsin and hydrochloric acid (HCl; 0.5 percent). The latter produces an environmental pH of 1.5–3.5 that denatures proteins within food. Pepsin cuts proteins into smaller polypeptides and their constituent amino acids. When the food-gastric juice mixture (chyme) enters the small intestine, the pancreas releases sodium bicarbonate to neutralize the HCl. This helps to protect the lining of the intestine. The small intestine also releases digestive hormones, including secretin and CCK, which stimulate digestive processes to break down the proteins further. Secretin also stimulates the pancreas to release sodium bicarbonate. The pancreas releases most of the digestive enzymes, including the proteases trypsin, chymotrypsin, carboxypeptidase, and elastase, which aid protein digestion. Together, all of these enzymes break complex proteins into smaller individual amino acids (Figure 24.4.1), which are then transported across the intestinal mucosa to be used to create new proteins, or to be converted into fats or acetyl CoA and used in the Krebs cycle. Figure 24.4.1 – Digestive Enzymes and Hormones: Enzymes in the stomach and small intestine break down proteins into amino acids. HCl in the stomach aids in proteolysis by denaturing proteins, and hormones secreted by intestinal cells direct the digestive processes. In order to avoid breaking down the proteins that make up the pancreas and small intestine, pancreatic enzymes are released as inactive proenzymes that are only activated in the small intestine. In the pancreas, vesicles store trypsin, chymotrypsin, and carboxypeptidase as trypsinogen, chymotrypsinogen, and procarboxypeptidase. Once released into the small intestine, an enzyme found in the wall of the small intestine, called enterokinase, binds to trypsinogen and converts it into its active form, trypsin. Trypsin then binds to chymotrypsinogen and procarboxypeptidase to convert it into the active chymotrypsin and carboxypeptidase. Trypsin, chymotrypsin, and carboxypeptidase break down large proteins into smaller peptides, a process called proteolysis. These smaller peptides are catabolized into their constituent amino acids by the brush border enzymes, aminopeptidase and dipeptidase. The free amino acids are then transported across the apical surface of the intestinal mucosa in a process that is mediated by secondary active transport using sodium-amino acid transporters. These transporters bind sodium and then bind the amino acid to transport it across the membrane. At the basal surface of the mucosal cells, the sodium and amino acid are released. The sodium can be reused in the transporter, whereas the amino acids are transferred into the bloodstream to be transported to the liver and cells throughout the body for protein synthesis. Freely available amino acids are used to create proteins. If amino acids exist in excess, the body has no capacity or mechanism for their storage; thus, they are converted into glucose or ketones, or they are decomposed. Amino acid decomposition results in hydrocarbons and nitrogenous waste. However, high concentrations of nitrogen are toxic as they produce ammonium ions. The urea cycle processes nitrogen and facilitates its excretion from the body. The urea cycle is a set of biochemical reactions that produces urea from ammonium ions in order to prevent a toxic level of ammonium in the body. It occurs primarily in the liver and, to a lesser extent, in the kidney. Prior to the urea cycle, ammonium ions are produced from the breakdown of amino acids. In these reactions, an amine group, or ammonium ion, from the amino acid is exchanged with a keto group on another molecule. This transamination event creates a molecule that is necessary for the Krebs cycle and an ammonium ion that enters into the urea cycle to be eliminated. In the urea cycle, ammonium is combined with CO_2, resulting in urea and water. The urea is eliminated through the kidneys in the urine (Figure 24.4.2). Figure 24.4.2 – Urea Cycle: Nitrogen is transaminated, creating ammonia and intermediates of the Krebs cycle. Ammonia is processed in the urea cycle to produce urea that is eliminated through the kidneys. Amino acids can also be used as a source of energy, especially in times of starvation. Because the processing of amino acids results in the creation of metabolic intermediates, including pyruvate, acetyl CoA, acetoacyl CoA, oxaloacetate, and α-ketoglutarate, amino acids can serve as a source of energy production through the Krebs cycle (Figure 24.4.3). Figure 24.4.4 summarizes the pathways of catabolism and anabolism for carbohydrates, lipids, and proteins. Figure 24.4.3 – Energy from Amino Acids: Amino acids can be broken down into precursors for glycolysis or the Krebs cycle. Amino acids (in bold) can enter the cycle through more than one pathway. Figure 24.4.4 – Catabolic and Anabolic Pathways: Nutrients follow a complex pathway from ingestion through anabolism and catabolism to energy production. Disorders of the…Metabolism: Pyruvate Dehydrogenase Complex Deficiency and Phenylketonuria Pyruvate dehydrogenase complex deficiency (PDCD) and phenylketonuria (PKU) are genetic disorders. Pyruvate dehydrogenase is the enzyme that converts pyruvate into acetyl CoA, the molecule necessary to begin the Krebs cycle to produce ATP. With low levels of the pyruvate dehydrogenase complex (PDC), the rate of cycling through the Krebs cycle is dramatically reduced. This results in a decrease in the total amount of energy that is produced by the cells of the body. PDC deficiency results in a neurodegenerative disease that ranges in severity, depending on the levels of the PDC enzyme. It may cause developmental defects, muscle spasms, and death. Treatments can include diet modification, vitamin supplementation, and gene therapy; however, damage to the central nervous system usually cannot be reversed. PKU affects about 1 in every 15,000 births in the United States. People afflicted with PKU lack sufficient activity of the enzyme phenylalanine hydroxylase and are therefore unable to break down phenylalanine into tyrosine adequately. Because of this, levels of phenylalanine rise to toxic levels in the body, which results in damage to the central nervous system and brain. Symptoms include delayed neurological development, hyperactivity, mental retardation, seizures, skin rash, tremors, and uncontrolled movements of the arms and legs. Pregnant women with PKU are at a high risk for exposing the fetus to too much phenylalanine, which can cross the placenta and affect fetal development. Babies exposed to excess phenylalanine in utero may present with heart defects, physical and/or mental retardation, and microcephaly. Every infant in the United States and Canada is tested at birth to determine whether PKU is present. The earlier a modified diet is begun, the less severe the symptoms will be. The person must closely follow a strict diet that is low in phenylalanine to avoid symptoms and damage. Phenylalanine is found in high concentrations in artificial sweeteners, including aspartame. Therefore, these sweeteners must be avoided. Some animal products and certain starches are also high in phenylalanine, and intake of these foods should be carefully monitored. Digestion of proteins begins in the stomach, where HCl and pepsin begin the process of breaking down proteins into their constituent amino acids. As the chyme enters the small intestine, it mixes with bicarbonate and digestive enzymes. The bicarbonate neutralizes the acidic HCl, and the digestive enzymes break down the proteins into smaller peptides and amino acids. Digestive hormones secretin and CCK are released from the small intestine to aid in digestive processes, and digestive proenzymes are released from the pancreas (trypsinogen and chymotrypsinogen). Enterokinase, an enzyme located in the wall of the small intestine, activates trypsin, which in turn activates chymotrypsin. These enzymes liberate the individual amino acids that are then transported via sodium-amino acid transporters across the intestinal wall into the cell. The amino acids are then transported into the bloodstream for dispersal to the liver and cells throughout the body to be used to create new proteins. When in excess, the amino acids are processed and stored as glucose or ketones. The nitrogen waste that is liberated in this process is converted to urea in the urea acid cycle and eliminated in the urine. In times of starvation, amino acids can be used as an energy source and processed through the Krebs cycle. chymotrypsin pancreatic enzyme that digests protein chymotrypsinogen proenzyme that is activated by trypsin into chymotrypsin elastase pancreatic enzyme that digests protein enterokinase enzyme located in the wall of the small intestine that activates trypsin inactive proenzymes forms in which proteases are stored and released to prevent the inappropriate digestion of the native proteins of the stomach, pancreas, and small intestine pepsin enzyme that begins to break down proteins in the stomach proteolysis process of breaking proteins into smaller peptides secretin hormone released in the small intestine to aid in digestion sodium bicarbonate anion released into the small intestine to neutralize the pH of the food from the stomach transamination transfer of an amine group from one molecule to another as a way to turn nitrogen waste into ammonia so that it can enter the urea cycle trypsin pancreatic enzyme that activates chymotrypsin and digests protein trypsinogen proenzyme form of trypsin urea cycle process that converts potentially toxic nitrogen waste into urea that can be eliminated through the kidneys This work, Anatomy & Physiology, is adapted from Anatomy & Physiology by OpenStax, licensed under CC BY. This edition, with revised content and artwork, is licensed under CC BY-SA except where otherwise noted. Images, from Anatomy & Physiology by OpenStax, are licensed under CC BY except where otherwise noted. Access the original for free at . Written By Shreya_S Last Modified 24-01-2023 Development of Human Embryo: For decades, researchers could only guess at the early stages of the development of human embryos using animal studies and rare tissue samples as guides. The initial eight weeks of development after fertilisation, known as embryogenesis, are a complicated process. It’s incredible to think that humans go from a single cell to an organism with a multi-level body plan in just eight weeks. During this stage, the circulatory, excretory, and neurologic systems all begin to develop. Fertilization, like many other complicated biological concepts, may be broken down into smaller, simpler concepts. Going from a single cell to a ball of cells to a set of tubes is the central concept of embryogenesis. Plants and mammals have different embryonic development. In mammals, embryonic development takes place in the uterus; nevertheless, the uterus’ development and role in gestation varies greatly among mammalian taxa. Read on to explore more about embryo development in human beings. The study of embryo development is known as Embryology. This covers the transformation of a single-cell embryo into a newborn. Embryology is the study of a foetus’ development before birth. Embryology is a crucial area of study for understanding the effects of mutation and the evolution of genetic disorders. Stem cell research is an important element of embryology. The fertilisation of an egg cell (ovum) by a sperm cell initiates embryonic development (spermatozoon). A zygote is a single diploid cell that develops from a fertilised ovum. The zygote undergoes mitotic divisions with no considerable growth (a process known as cleavage) and cellular differentiation after passing through an organisational barrier during mid-embryogenesis, resulting in the development of a multicellular embryo. In humans, prenatal development, also known as antenatal development, is the process that spans the time between the formation of an embryo and the delivery of a foetus (or parturition). Cell proliferation, cell specialisation, cell interaction, and cell mobility are all dependent on the machinery. It begins with fertilisation and finishes with the end of the second week of intrauterine life (IUL).Fertilization, zygote transportation via the uterine tube, mitotic divisions/cleavage, implantation, and development of primordial embryonic tissues are all morphogenetic phenomena that occur during this time.Fertilization happens when a sperm cell enters and merges with an egg cell successfully (ovum). It takes place in the ampulla, a part of the oviduct.The sperm and egg genetic material combines to form a single cell known as a zygote, and the germinal stage of development begins.The embryo takes 5 days to enter the uterine lumen. The zygote goes through cleavage divisions, which are mitotic divisions that occur without the formation of daughter cells. These cells are called blastomeres.At the 8-cell stage, the embryo undergoes a peculiar process known as compaction, leaving a portion of the blastomeres facing the external side.The outer trophoblast, which becomes the foetal component of the placenta, and the inner cell mass, which forms the embryo proper and extraembryonic membranes, are the two cellular lineages that result from compaction.Once within the uterus, the embryo and the uterine lining recognise each other biochemically, allowing the embryo to be attached and implanted with precision.At implantation, the inner cell mass reorganises into a two-layered embryo: the epithelial epiblast, which forms the embryo and amniotic membrane, and the hypoblast, which aids in yolk sac formation and embryonic axes alignment. The zygote begins to divide at this point, a process known as cleavage. Fig: Cleavage Cleavage is an embryological process in which a single-celled zygote is transformed into a multicellular structure called a blastula through a series of rapid mitotic divisions.Holoblastic and equal cleavages occur in the human zygote. The fallopian tube is the site where cleavage happens.Cleavage increases the number of cells but does not cause them to grow. It restores the cell size and nucleocytoplasmic ratio, which are both species-specific characteristics.Cleavage brings about the distribution of the cytoplasm of the zygote, amongst the blastomeres.It increases the mobility of the protoplasm, which facilitates morphogenetic movements necessary for cell differentiation, germ layer formation, and the formation of tissue and organs.The unicellular zygote is converted into a multicellular embryo. Fig: Stages of cleavage Fig: Morula Formation Stage of Embryo Development By repeated cleavage divisions, the ovum forms a solid mass of cells(Blastomeres) called Morula (meaning mulberry, because of its appearance).It is formed within the fallopian tube after fertilization.Morula is made up of 16-32 cells from the inner cell mass and the surrounding cell mass that are grouped together in the centre.The inner cell mass gives rise to the embryo’s tissues, while the outside cell mass gives rise to the trophoblast, which eventually develops into the placenta.After fertilisation, the morula reaches the uterus about 4-6 days later, with the zona pellucida intact.The morula enters the uterine cavity at a time when the endometrial lining is in a quite suitable stage to accept it.Within the uterine cavity, the morula floats for about two days and implants into the endometrium on the seventh day. Fig: Blastocyst Formation Stage of Embryo Development The development of morula into a blastodermic vesicle or blastocoel begins with the rearranging of tiny blastomeres.A blastocyst is an embryo that is made up of an exterior layer of cells called the trophoblast or trophectoderm and an inner cell mass called the embryoblast.The embryonic or animal pole is the side of the blastocyst to which the inner cell mass is linked, while the abembryonic pole is the opposite side. The blastocoel and inner cell mass are encircled by the trophoblast. The embryo is formed from the inner cell mass.The trophoblast’s cells help in the nourishment of the embryo. Extraembryonic membranes, chorion, and amnion, as well as a part of the placenta, are formed by them.The cells of the trophoblast that are attached with the inner cell mass are called cells of Rauber.The cells of the inner cell mass are differentiated into two layers: A. Layered small, cuboidal cells known as the hypoblast layerB. Layered high columnar cells, the epiblast layer. Both the hypoblast and epiblast form a flat disc called the embryonic disc. Fig: Implantation of Embryo Implantation is the process of attaching the blastocyst to the uterine wall. It happens seven days after fertilisation.In the zone of contact between the blastocyst and the endometrium, the trophoblast produces two layers: syncytiotrophoblast and cytotrophoblast.The blastocyst falls into a depression produced in the endometrium and is entirely encircled by it. To obtain nourishment, it develops villi.The inner cell mass’s cells divide into two layers: hypoblast and epiblast.The embryonic disc is a flat disc formed by the hypoblast and epiblast.Human chorionic gonadotropin is a hormone secreted by the chorionic cells of the placenta (HCG). It has a wide range of functions:a. Maintains corpus luteum. b. The corpus luteum stimulates the secretion of progesterone.c. Maintains the endometrial lining of the uterus and helps in its growth during the period of pregnancy.The placenta begins to produce enough progesterone by the 16th week of pregnancy, and the corpus luteum begins to recede. The invasive syncytial trophoblast’s irregular strands are the first stage in the development of true villi, which are part of the placenta and are briefly discussed below.The chorionic plate of the developing placenta is formed by the deepest embedded section of the chorionic wall.The placenta assists the foetus in a variety of ways, the majority of which involve the exchange of materials carried in the mother’s and foetus’ bloodstreams. These functions are classified as follows:a. Nutritionb. Respirationc. Excretiond. Barrier action (e.g., prevention of intrusions by bacteria)e. Synthesis of hormones and enzymes. Fig: Gastrulation stages of embryo development Gastrulation is the process of transforming a blastocyst into a gastrula with primary germ layers by cell rearrangement.It involves morphogenetic movements, which are cell movements that assist the embryo in taking on a new shape and morphology. The various stages of gastrulation are: Formation of Embryonic Disc: Inner cell mass and trophoblast make up the early blastocyst. The hypoblast and epiblast cells combine to form a two-layered embryonic disc.Formation of Extra Embryonic Coelom: The trophoblast cells give rise to the extraembryonic mesoderm, which is a mass of cells. Because it sits outside the embryonic disc, this mesoderm is called extraembryonic. It does not result in the formation of embryonic tissue.Formation of Chorion and Amnion: The chorion and amnion, two crucial embryonic membranes, are formed at this stage. The somatopleuric extraembryonic mesoderm inside the chorion and the trophoblast outside form the chorion. Amniogenic cells inside the amnion and somatopleuric extraembryonic mesoderm outside produce the amnion. The chorion eventually becomes the placenta’s major embryonic part. Human chorionic gonadotropin (hCG), a crucial pregnancy hormone, is also produced by the chorion. The amniotic cavity, which is filled with amniotic fluid, is formed by the amnion surrounding the embryo. The amniotic fluid protects the foetus by acting as a shock absorber, regulating body temperature, and preventing desiccation.Formation of Yolk SacA. Inside the blastocoel, flattened cells emerging from the hypoblast spread and line. The major yolk sac is lined by endodermal cells.B. The yolk sac (embryonic membrane) becomes much smaller than before with the formation of the extraembryonic mesoderm and later the extraembryonic coelom, and is now known as the secondary yolk sac.C. The outer splanchnopleuric extraembryonic mesoderm and inner endodermal cells make up the secondary yolk sac.D. The yolk sac is a source of blood cells. It also functions as a shock absorber and helps prevent desiccation of the embryo.Formation of Primitive StreakGastrulation is the process of cells from the epiblast rearranging and migrating. The epiblast forms a primitive streak, which is a faint groove on the dorsal surface. The embryo’s head and tail ends, as well as its right and left sides, are all clearly defined by the primitive stripe. The epiblast cells move inward below the primitive streak and detach from the epiblast after the development of the primitive streak. Invagination is the term for this inverting movement. When the cells invaginate, some of them displace the hypoblast, resulting in the formation of the endoderm. During embryonic development, the endoderm develops initially.The mesoderm is formed by cells that stay between the epiblast and the newly developed endoderm.Ectoderm is formed by cells that stay in the epiblast. Fig: Formation of Germ/Embryonic Layers Endoderm, mesoderm, and ectoderm are the three germ layers that give rise to all of the body’s tissues and organs. The fate of Three Germ Layers: Each germ layer gives rise to specific tissues, organs, and organ systems. The germ layers have a similar fate in various animals. Derivatives of Ectoderm: The ectoderm gives rise to the central nervous system (brain and spinal cord), peripheral nervous system, sensory epithelia of the eye, ear, and nose, epidermis and its appendages (nails and hair), mammary glands, hypophysis, subcutaneous glands, and tooth enamel, the epidermis of the skin, hair, arrector pili muscles, nails, sudoriferous (sweat) and sebaceous (oil) glands and chromatophores (pigment cells) of skin. Derivatives of Mesoderm: The mesoderm gives rise to connective tissue, cartilage, and bone; striated and smooth muscles; the heart walls, blood and lymph vessels, and cells; the kidneys; the gonads (ovaries and testes) and genital ducts; the serous membranes lining the body cavities; the spleen; and the suprarenal (adrenal) and connective tissues including loose areolar tissue, ligaments, tendons and the dermis of the skin. Derivatives of Endoderm: Epithelium of mouth, part of palate, tongue, tonsils, Epithelium of Eustachian tube, middle ear, Epithelium of larynx, trachea, bronchi, and lungs. Epithelium of the gallbladder, liver, pancreas, including islets of Langerhans, gastric and intestinal glands. Epithelium of thyroid, parathyroid, and thymus glands. Fig: Neurulation Neurulation commences the construction of central nervous system structures, while organogenesis develops the basic design for all organ systems. The ectoderm produces epithelial and neural tissue after gastrulation, and the gastrula is now known as the neurula.The neural plate, which began as a thicker ectoderm plate, continues to spread, and its ends begin to fold upwards as neural folds.The folding process that transforms the neural plate into the neural tube is known as neurulation, and it occurs during the fourth week.They fold along a shallow neural groove in the neural plate that has evolved as a dividing median line.As the folds grow in height, they will eventually meet and close together at the neural crest.The embryonic disc starts off flat and spherical, but as it grows longer, it develops a wider cephalic portion and a narrow-shaped caudal end. The neural tube is formed when the cranial and caudal neuropores gradually shrink until they close entirely (by day 26). Organogenesis is the process of organ development that begins in the third week and lasts until birth.During development, the circulatory, excretory, and nervous systems all begin to develop.The mesoderm produces hematopoietic stem cells, which give rise to all blood cells.At roughly 21 or 22 days, the heart becomes a functioning organ and begins to beat and pump blood.The process of vasculogenesis (the formation of the cardiovascular system) begins. On day 18, cells in the splanchnopleuric mesoderm start to differentiate into angioblasts, which eventually become flattened endothelial cells.The digestive system begins to grow in the third week, and the organs have correctly positioned themselves by the twelfth week.The respiratory system begins with the lung bud, which appears about four weeks into development in the ventral wall of the foregut. The lung bud forms the trachea as well as two lateral growths known as bronchial buds, which increase at the start of the fifth week to produce the left and right main bronchi. Secondary (lobar) bronchi are formed by these bronchi; three on the right and two on the left (reflecting the number of lung lobes). Secondary bronchi give rise to tertiary bronchi.The urogenital system starts to take shape.The epidermis begins to form in the second month of development and takes on its definitive arrangement by the fourth month. Fertilization is the first step in embryonic development. During its development, the embryo travels through several stages. A zygote is formed when an unfertilized egg is released from the ovary following fertilization. The single-celled zygote splits into the morula, a spherical mass of cells. The morula then splits to produce a blastocyst, a hollow sphere with a single layer enclosing it called the trophoblast and cells projecting from within. The blastocysts attach themselves to the uterine wall. The embryo, which is three weeks old, looks to be a little organism. The heart and blood vessels develop after five weeks. After eight weeks, the organisms begin to grow limbs and take on the appearance of a human being. Following the completion of 40 weeks, an infant is born. Q.1. What is the development of an embryo?Ans: Embryonic development, also known as embryogenesis in developmental biology, is the growth of an animal or plant embryo. The fertilisation of an egg cell (ovum) by a sperm cell initiates embryonic development (spermatozoon). The fertilised ovum develops into a single diploid cell called a zygote. Q.2. How many weeks is the embryonic stage?Ans: Following conception, the zygote enters the embryonic stage, which is a period of rapid development. This period lasts from the fifth to the tenth week of pregnancy. The infant is known as an embryo at this time. Q.3. What is the difference between embryo and fetus?Ans: The embryonic stage is all about the development of the body’s major systems. The foetal phase, on the other hand, is more about your baby’s growth and development so that the newborn may survive in the world. Q.4. What is gastrulation, and what are the 3 layers?Ans: The single-layered blastula is rearranged into a trilaminar (three-layered) structure known as the gastrula during the early stages of embryonic development. The ectoderm, mesoderm, and endoderm are the three germ layers. Q.5. How are embryos formed in humans?Ans: Initially, the zygote forms a solid ball of cells. The blastocyst, a hollow ball of cells, is then formed. The blastocyst implants in the uterine wall and develops into an embryo that is attached to the placenta and surrounded by fluid-filled membranes. We hope this detailed article on the Development of Human Embryo will be helpful to you in your preparation. If you have any doubts please reach out to us through the comments section, and we will get back to you as soon as possible. Fetal development is an orderly and intricate process. It begins before you even know you’re pregnant and ends with the birth of your baby. Between conception and delivery, there are many detailed steps that have to occur.There are three stages of fetal development: germinal, embryonic and fetal. Most people don’t talk about their pregnancy in these terms, but it can be helpful to know.Germinal stageThe germinal stage is the shortest stage of fetal development. It begins at conception when a sperm and egg join in your fallopian tube. The sperm fertilizes the egg and creates a zygote. The zygote begins its journey down to your uterus over the course of about one week. During this journey, the zygote divides many times, eventually creating two separate structures. One structure eventually becomes the embryo (and later, the fetus) and the other becomes the placenta. Cell division continues at a rapid pace. Eventually, the zygote turns into a blastocyst. The blastocyst arrives at your uterus and implants into your uterine lining. If implantation is successful, your body immediately begins producing hormones to support a pregnancy. This also stops your menstrual period.Embryonic stageThe embryonic stage lasts from about the third week of pregnancy until the end of the eighth week of pregnancy. The blastocyst begins to take on distinct human characteristics. It’s now called an embryo. Structures and organs like the neural tube (which later becomes the brain and spinal cord), head, eyes, mouth and limbs form. The cells that will form the fetal heart begin to cluster around five to six weeks and can pulse. Buds that will become arms and legs also form around the sixth week. By the end of the eighth week, most of the embryo’s organs and systems take shape. For a lot of people, this is the point in pregnancy where morning sickness begins.Fetal stageThe fetal stage of development begins around the ninth week and lasts until birth. This is when the embryo officially turns into a fetus. The fetus gets its assigned sex around nine weeks of pregnancy, although your healthcare provider can’t detect it on ultrasound yet. The fetus’s major organs and body systems continue to grow and mature. Things like fingernails, eyelashes and hair also grow. The fetus is able to move its limbs, although you may not feel it until 20 weeks of pregnancy. The majority of growth — in both weight and length — happens in the fetal stage.When does a pregnancy start?The start of pregnancy is actually the first day of your last menstrual period (LMP). This is the gestational age of the fetus. It’s about two weeks ahead of when conception actually occurs. Though it may seem strange, the date of the first day of your last period will be an important date when determining your due date. Your healthcare provider will ask you about this date and will use it to figure out how far along you are in your pregnancy.How does conception work?Each month, your body goes through a reproductive cycle that can end in one of two ways. You’ll either have a menstrual period or become pregnant. This cycle is continuously happening during your reproductive years — from starting your period to menopause around age 50.In a cycle that ends with pregnancy, there are several steps. First, a group of eggs (called oocytes) gets ready to leave your ovary for ovulation (release of the egg). The eggs develop in small, fluid-filled cysts called follicles. Think of these follicles as small containers for each immature egg. Out of this group of eggs, one will become mature and continue through the cycle.The mature follicle now opens and releases the egg from your ovary. This is ovulation.After ovulation, the opened follicle develops into a structure called the corpus luteum. This releases the hormones progesterone and estrogen. Progesterone helps prepare your uterine lining for pregnancy. If you don’t become pregnant during a cycle, this lining is what your body sheds during your period. If sperm fertilizes the egg, conception occurs and the fertilized egg begins its journey to your uterus, where it will implant.How long is a pregnancy?Traditionally, we think of pregnancy as a nine-month process. However, this isn’t always the case. A full-term pregnancy is 40 weeks, or 280 days. Depending on what months you’re pregnant during (some are shorter and some longer) and what week you deliver, you could be pregnant for either nine months or 10 months. This is completely normal and healthy.Stages of Growth Month-by-Month in PregnancyThe fetus will change a lot throughout a typical pregnancy. This time is divided into three stages, called trimesters. Each trimester is a set of about three months. Your healthcare provider will probably talk to you about fetal development in terms of weeks. So, if you’re three months pregnant, you’re about 12 weeks.You’ll see distinct changes in the fetus, and yourself, during each trimester of pregnancy.First trimesterThe first trimester will span from conception to 12 weeks. This is generally the first three months of pregnancy. During this trimester, the fertilized egg will change from a small grouping of cells to a fetus that begins to have human features. The first trimester is exciting, but also when most people develop unpleasant symptoms like morning sickness and fatigue.Month 1 (weeks 1 through 4)Although it’s strange, the first two weeks of pregnancy are a “getting ready” period. Your body slowly releases more hormones and your uterus prepares for a potential pregnancy. At the end of the second week, your ovary releases an egg (ovulation). If sperm meets an egg just after ovulation, the process to pregnancy continues.Week 3: Fertilization occurs during the third week. A sperm and egg join and create a zygote.Week 4: The tiny bundle of cells turns into a blastocyst and implants into your uterine lining. The beginning of what will become the placenta forms. A water-tight sac forms around the blastocyst. This is the amniotic sac, and it provides cushioning to a fetus during pregnancy.By the end of the fourth week, the blastocyst is about 2 millimeters (mm) long — the size of a poppy seed.Month 2 (weeks 5 through 8)The second month of pregnancy is when most people realize they’re pregnant. Pregnancy hormones go into overdrive, and by about the fifth week, an at-home pregnancy test will show as positive. This is when many people begin to feel symptoms of pregnancy.Week 5: The neural tube (brain, spinal cord and other neural tissue of the central nervous system) forms. The tiny “heart” tube will pulse 110 times a minute by the end of the fifth week.Week 6: Tiny buds that become arms and legs also develop. Blood cells are taking shape, and circulation will begin. Structures that’ll become the ears, eyes and mouth take form. Your healthcare provider can probably detect pulses in the cluster of cells that will form the heart on a vaginal ultrasound.Week 7: Bones begin replacing soft cartilage and genitals begin to form. The embryo’s head is large in proportion to the rest of its body. Some people think the embryo resembles a small tadpole or seahorse due to its prominent tail (which recedes) and large head.Week 8: All of the major organs and body systems are developing. The embryo has web-like hands and feet. Eyes become visible and ears begin to form. The umbilical cord is fully developed and helps to transport oxygen and blood to the embryo.After the 8th week, healthcare providers refer to the embryo as a fetus. It will remain a fetus until birth.By the end of the second month, the fetus is about 0.5 to 1 inch (in) long — about the size of a black bean.Month 3 (weeks 9 through 12)The third month of pregnancy is when an embryo becomes a fetus. It’s a period of rapid growth and development. The fetus develops distinct facial features, limbs, organs, bones and muscles. By the end of the 12th week, the fetus has an assigned sex, but it won’t be visible on ultrasound for several more weeks.Week 9: The beginnings of teeth and taste buds are forming. Its muscles are forming and its body shape takes on more of a human appearance. But, its head is still 50% of its length. Your provider may be able to hear its heartbeat with a Doppler ultrasound.Week 10: The arms, hands, fingers, feet and toes are fully formed (no more webbed fingers). Fingernails and toenails are beginning to develop and the external ears form. The external genitals also begin to form, but it’s too soon to see them on an ultrasound.Week 11: The fetus is starting to explore a bit by doing things like opening and closing its fists and mouth. Its knees, elbows and ankles are working, but it’s too soon to feel any kicks. The bones are hardening, but its skin is still see-through. Facial features are more prominent.Week 12: All the organs, limbs, bones and muscles are present and will continue to develop in order to become fully functional. The circulatory, digestive and urinary systems are also working and the liver produces bile. The fetus is drinking and peeing amniotic fluid.Since the most critical development has taken place, your chance of miscarriage drops considerably after 12 weeks (the end of the first trimester). Most people begin feeling some relief from morning sickness now, too.At the end of the third month, the fetus is about 2.5 to 3 inches long — about the size of a plum.Second trimesterThe second trimester of pregnancy is often thought of as the best part of the experience. By this time, any morning sickness is probably gone and the discomfort of early pregnancy has faded. You may also start to feel movement as the fetus flips and turns in your uterus. During this trimester, many people find out about the fetus’s assigned sex. This is typically done during an anatomy scan (an ultrasound that checks physical development) at around 20 weeks.Month 4 (weeks 13 through 16)Many people begin showing signs of being pregnant at this point in pregnancy, especially if you’ve been pregnant before. Your pregnancy care provider can hear the fetal heartbeat loud and clear on a Doppler ultrasound. The fetus can even suck its thumb, yawn, stretch and make faces.Week 13: Vocal cords form and the fetus’s large head begins to grow proportionate to its body.Week 14: The fetus’s skin starts to thicken and fine hair begins to grow. It can start bringing its fingers to its mouth and turn its head. External genitals are fully developed and fingerprints begin to form.Week 15: Some organs, like intestines and ears, are moving to their permanent location. The fetus still uses amniotic fluid to practice breathing, but its lungs are beginning to develop. The fetus begins to make more purposeful movements, like sucking its thumb or smiling.Week 16: The fetus has lips and its ears are developed enough that it can hear you talk. Even though its eyes are closed, the fetus can react to light by turning away from it.By the end of the fourth month, the fetus is about 5 inches long and weighs about 4 ounces. For reference, that’s about as big as an avocado.Month 5 (weeks 17 through 20)By the end of the fifth month of pregnancy, most people begin to feel the fetus moving around. The first movements are called quickening and can feel like a flutter. If your pregnancy has been healthy to this point, you’ll finally get your first ultrasound. You may even get to find out the fetus’s assigned sex.Week 17: The fetus still has thin skin, but will start to put on fat. Its skin is covered with a whitish coating called vernix. This “cheesy” substance is thought to protect fetal skin from long-term exposure to amniotic fluid.Week 18: The fetus is covered in lanugo, a peach fuzz-like hair. It helps keep the fetus warm and provides another layer of protection. The fetus may have a sleep-wake cycle, and loud noises may wake the fetus if it’s asleep.Week 19: The fetus is getting stronger and most people begin to feel kicks and punches. The fetus also has its own unique set of fingerprints and can hiccup.Week 20: The fetus’s nails grow towards the end of its fingers. The area of the brain responsible for its five senses begins to develop.By the end of the fifth month, the fetus is about 9 to 10 inches long and weighs about 1 pound.Month 6 (weeks 21 through 24)If you could look inside your uterus right now, you’d see that the fetus’s skin is reddish in color, wrinkled and veins are visible through translucent skin. In the sixth month of pregnancy, its eyelids begin to part and you may notice regular, jerky movements. The fetus responds to sounds by moving or increasing its pulse.Week 21: Limb movements are coordinated and frequent. The fetus has bone marrow that helps it produce blood cells.Week 22: The fetus’s grasp is getting stronger and it can touch its ears and the umbilical cord. It can hear your heartbeat, your stomach rumble and your breathing.Week 23: If born prematurely, the fetus may survive after the 23rd week with intensive care. It will begin rapidly adding fat to its body.Week 24: The fetus’s lungs are fully developed, but not well enough to work outside your uterus.By the end of the sixth month, the fetus is about 12 inches long and weighs about 2 pounds.Month 7 (weeks 25 through 28)The fetus continues to mature and develop reserves of body fat. The fetus changes position frequently and responds to stimuli, including sound, pain and light. The amniotic fluid begins to diminish.Week 25: More body fat makes the fetus’s skin less wrinkled and plumper. Its nervous system is quickly maturing.Week 26: The fetus makes melanin, the substance that gives skin and eyes their color. The fetus’s lungs start to make surfactant, a substance that helps it breathe after birth.Week 27: The fetus can open its eyes and blink. It also has eyelashes.Week 28: The fetus may begin turning head-down in your uterus as it gets ready for birth. At the end of the seventh month, the fetus is about 14 to 15 inches long and weighs between 2 and 3 pounds.Third trimesterThis is the final part of your pregnancy. You may be tempted to start counting down the days to your due date and hope that it comes early, but each week of this final stage of development helps the fetus prepare for birth. Throughout the third trimester, the fetus gains weight quickly, adding body fat that’ll help after birth.Your healthcare provider will monitor you closely as you approach your due date. You’ll visit your provider biweekly and then weekly. Make sure to ask your provider any questions you have about labor and delivery.Month 8 (weeks 29 through 32)The fetus continues to mature and develop reserves of body fat. The brain develops most rapidly during this time. The fetus can see and hear most stimuli. Most internal systems are well-developed, but the lungs may still be immature.Week 29: You may notice the kicks and jabs feel more like pokes now that the fetus is getting cramped in the amniotic sac.Week 30: The fetus can control its own body heat. Its brain is maturing and growing rapidly.Week 31: The fetus can process more information and stimuli. You can probably notice more distinct patterns in when it’s awake and when it’s asleep.Week 32: The fetus’s skin isn’t translucent anymore. Other than the lungs and brain, most other organs are well-formed and ready for birth.The fetus is about 17 to 18 inches long and weighs as much as 5 pounds.Month 9 (weeks 33 through 36)During this stage, the fetus continues to grow and mature. The lungs are close to being fully developed at this point in pregnancy. The ninth month is mostly about putting the finishing touch on growth and brain development.Week 33: The fetus’s bones are hardening, with exception of the cranial bones around its brain, which needs to be soft to descend the birth canal.Week 34: The vernix that protects the fetus’s skin starts to get thicker.Week 35: The fetus’s brain continues to grow, but still only weighs two-thirds of what it should at birth.Week 36: The fetus loses its lanugo and it has hair on its head.The fetus is about 17 to 19 inches long and weighs from 6 to 7 pounds.Month 10 (Weeks 37 through 40)In this final month, you could go into labor at any time. At this point, the fetus’s position may have changed to prepare for birth. Ideally, it’s head-down in your uterus. You may feel very uncomfortable in this final stretch of time as the fetus drops down into your pelvis and prepares for birth. Your provider may encourage you to perform kick counts, which is a way to track how much the fetus moves.Week 37: The fetus’s toenails reach the end of its toes. You may start to feel the fetus drop into your pelvis.Week 38: The fetus is packing on 0.5 pounds per week to get to its final size.Week 39: The fetus is full-term and ready to meet the world!Week 40: It’s your due date week. Call your pregnancy care provider if you notice any signs of labor.The fetus is about 18 to 20 inches long and weighs about 7 to 9 pounds. By the end of this section, you will be able to: Describe the overall function of the lung Summarize the blood flow pattern associated with the lungs Outline the anatomy of the blood supply to the lungs Describe the pleura of the lungs and their function A major organ of the respiratory system, each lung houses structures of both the conducting and respiratory zones. The main function of the lungs is to perform the exchange of oxygen and carbon dioxide with air from the atmosphere. To this end, the lungs exchange respiratory gases across a very large epithelial surface area—about 70 square meters—that is highly permeable to gases. The lungs are pyramid-shaped, paired organs that are connected to the trachea by the right and left bronchi; on the inferior surface, the lungs are bordered by the diaphragm. The diaphragm is the flat, dome-shaped muscle located at the base of the lungs and thoracic cavity. The lungs are enclosed by the pleurae, which are attached to the mediastinum. The right lung is shorter and wider than the left lung, and the left lung occupies a smaller volume than the right. The cardiac notch is an indentation on the surface of the left lung, and it allows space for the heart (Figure 22.2.1). The apex of the lung is the superior region, whereas the base is the opposite region near the diaphragm. The costal surface of the lung borders the ribs. The mediastinal surface faces the midline. Figure 22.2.1 Gross Anatomy of the Lungs. Each lung is composed of smaller units called lobes. Fissures separate these lobes from each other. The right lung consists of three lobes: the superior, middle, and inferior lobes. The left lung consists of two lobes: the superior and inferior lobes. A bronchopulmonary segment is a division of a lobe, and each lobe houses multiple bronchopulmonary segments. Each segment receives air from its own tertiary bronchus and is supplied with blood by its own artery. Some diseases of the lungs typically affect one or more bronchopulmonary segments, and in some cases, the diseased segments can be surgically removed with little influence on neighboring segments. A pulmonary lobule is a subdivision formed as the bronchi branch into bronchioles. Each lobule receives its own large bronchiole that has multiple branches. An interlobular septum is a wall, composed of connective tissue, which separates lobules from one another. The blood supply of the lungs plays an important role in gas exchange and serves as a transport system for gases throughout the body. In addition, innervation by the both the parasympathetic and sympathetic nervous systems provides an important level of control through dilation and constriction of the airway. The major function of the lungs is to perform gas exchange, which requires blood from the pulmonary circulation. This blood supply contains deoxygenated blood and travels to the lungs where erythrocytes, also known as red blood cells, pick up oxygen to be transported to tissues throughout the body. The pulmonary artery is an artery that arises from the pulmonary trunk and carries deoxygenated, arterial blood to the alveoli. The pulmonary artery branches multiple times as it follows the bronchi, and each branch becomes progressively smaller in diameter. One arteriole and an accompanying venule supply and drain one pulmonary lobule. As they near the alveoli, the pulmonary arteries become the pulmonary capillary network. The pulmonary capillary network consists of tiny vessels with very thin walls that lack smooth muscle fibers. The capillaries branch and follow the bronchioles and structure of the alveoli. It is at this point that the capillary wall meets the alveolar wall, creating the respiratory membrane. Once the blood is oxygenated, it drains from the alveoli by way of multiple pulmonary veins, which exit the lungs through the hilum. Dilation and constriction of the airway are achieved through nervous control by the parasympathetic and sympathetic nervous systems. The parasympathetic system causes bronchoconstriction, whereas the sympathetic nervous system stimulates bronchodilation. Reflexes such as coughing, and the ability of the lungs to regulate oxygen and carbon dioxide levels, also result from this autonomic nervous system control. Sensory nerve fibers arise from the vagus nerve, and from the second to fifth thoracic ganglia. The pulmonary plexus is a region on the lung root formed by the entrance of the nerves at the hilum. The nerves then follow the bronchi in the lungs and branch to innervate muscle fibers, glands, and blood vessels. Each lung is enclosed within a cavity that is surrounded by the pleura. The pleura (plural = pleurae) is a serous membrane that surrounds the lung. The right and left pleurae, which enclose the right and left lungs, respectively, are separated by the mediastinum. The pleurae consist of two layers. The visceral pleura is the layer that is superficial to the lungs, and extends into and lines the lung fissures (Figure 22.2.2). In contrast, the parietal pleura is the outer layer that connects to the thoracic wall, the mediastinum, and the diaphragm. The visceral and parietal pleurae connect to each other at the hilum. The pleural cavity is the space between the visceral and parietal layers. Figure 22.2.2 Parietal and Visceral Pleurae of the Lungs. The pleurae perform two major functions: They produce pleural fluid and create cavities that separate the major organs. Pleural fluid is secreted by mesothelial cells from both pleural layers and acts to lubricate their surfaces. This lubrication reduces friction between the two layers to prevent trauma during breathing, and creates surface tension that helps maintain the position of the lungs against the thoracic wall. This adhesive characteristic of the pleural fluid causes the lungs to enlarge when the thoracic wall expands during ventilation, allowing the lungs to fill with air. The pleurae also create a division between major organs that prevents interference due to the movement of the organs, while preventing the spread of infection. The burning of a tobacco cigarette creates multiple chemical compounds that are released through mainstream smoke, which is inhaled by the smoker, and through sidestream smoke, which is the smoke that is given off by the burning cigarette. Second-hand smoke, which is a combination of sidestream smoke and the mainstream smoke that is exhaled by the smoker, has

been demonstrated by numerous scientific studies to cause disease. At least 40 chemicals in sidestream smoke have been identified that negatively impact human health, leading to the development of cancer or other conditions, such as immune system dysfunction, liver toxicity, cardiac arrhythmias, pulmonary edema, and neurological dysfunction. Furthermore, second-hand smoke has been found to harbor at least 250 compounds that are known to be toxic, carcinogenic, or both. Some major classes of carcinogens in second-hand smoke are polyaromatic hydrocarbons (PAHs), N-nitrosamines, aromatic amines, formaldehyde, and acetaldehyde. Tobacco and second-hand smoke are considered to be carcinogenic. Exposure to second-hand smoke can cause lung cancer in individuals who are not tobacco users themselves. It is estimated that the risk of developing lung cancer is increased by up to 30 percent in nonsmokers who live with an individual who smokes in the house, as compared to nonsmokers who are not regularly exposed to second-hand smoke. Children are especially affected by second-hand smoke. Children who live with an individual who smokes inside the home have a larger number of lower respiratory infections, which are associated with hospitalizations, and higher risk of sudden infant death syndrome (SIDS). Second-hand smoke in the home has also been linked to a greater number of ear infections in children, as well as worsening symptoms of asthma. The lungs are the major organs of the respiratory system and are responsible for performing gas exchange. The lungs are paired and separated into lobes; The left lung consists of two lobes, whereas the right lung consists of three lobes. Blood circulation is very important, as blood is required to transport oxygen from the lungs to other tissues throughout the body. The function of the pulmonary circulation is to aid in gas exchange. The pulmonary artery provides deoxygenated blood to the capillaries that form respiratory membranes with the alveoli, and the pulmonary veins return newly oxygenated blood to the heart for further transport throughout the body. The lungs are innervated by the parasympathetic and sympathetic nervous systems, which coordinate the bronchodilation and bronchoconstriction of the airways. The lungs are enclosed by the pleura, a membrane that is composed of visceral and parietal pleural layers. The space between these two layers is called the pleural cavity. The mesothelial cells of the pleural membrane create pleural fluid, which serves as both a lubricant (to reduce friction during breathing) and as an adhesive to adhere the lungs to the thoracic wall (to facilitate movement of the lungs during ventilation). bronchoconstriction decrease in the size of the bronchiole due to contraction of the muscular wall bronchodilation increase in the size of the bronchiole due to contraction of the muscular wall cardiac notch indentation on the surface of the left lung that allows space for the heart hilum concave structure on the mediastinal surface of the lungs where blood vessels, lymphatic vessels, nerves, and a bronchus enter the lung lung organ of the respiratory system that performs gas exchange parietal pleura outermost layer of the pleura that connects to the thoracic wall, mediastinum, and diaphragm pleural cavity space between the visceral and parietal pleurae pleural fluid substance that acts as a lubricant for the visceral and parietal layers of the pleura during the movement of breathing pulmonary artery artery that arises from the pulmonary trunk and carries deoxygenated, arterial blood to the alveoli pulmonary plexus network of autonomic nervous system fibers found near the hilum of the lung visceral pleura innermost layer of the pleura that is superficial to the lungs and extends into the lung fissures This work, Anatomy & Physiology, is adapted from Anatomy & Physiology by OpenStax, licensed under CC BY. This edition, with revised content and artwork, is licensed under CC BY-SA except where otherwise noted. Images, from Anatomy & Physiology by OpenStax, are licensed under CC BY except where otherwise noted. Access the original for free at . Author Comments Start here by looking at the external appearance of embryos in sequence from 1 to 23. It is not so important to memorise the dates, as they are only approximate, but more important to understand growth (size changes) and the development (overall sequence of events) during this period. Clicking the Carnegie stage numbers opens a page dedicated to describing that single stage and the associated developmental events. This page shows some key events of human development during the embryonic period of the first eight weeks (weeks 1 - 8) following fertilization. This period is also considered the organogenic period, when most organs within the embryo have begun to form. There are links to more detailed descriptions which can be viewed in a week by week format, by the Carnegie stages or integrated into a Timeline of human development. Online resources include: individual images of all Carnegie stages, scanning electron micrographs of the earlier stages, cross-sections showing internal structures at mid- and late-embryonic, 3D reconstructions of internal structures, animations of processes, ultrasound scans and information about abnormalites of development. Note that there is variability in the actual timing of specific events and at the end of this period fetal development begins. Human Embryo - Biological definition Modern Definition The following biological definition comes from the Australian National Health and Medical Research Council (NHMRC) discussion paper (2006). "human embryo means a discrete entity that has arisen from either: (a) the first mitotic division when fertilisation of a human oocyte by a human sperm is complete; or (b) any other process that initiates organised development of a biological entity with a human nuclear genome or altered human nuclear genome that has the potential to develop up to, or beyond, the stage at which the primitive streak appears; and has not yet reached 8 weeks of development since the first mitotic division." This definition was also published later by the same group in 2007.[1] Historical Definition "The distinction between the embryonic and the fetal periods at 8 postovulatory weeks has proved valuable. It is based primarily on the probability that more than 90 percent of the more than 4,500 named structures of the adult body have appeared by that time."[2][3] Links: Embryonic Development | Fertilization | NHMRC paper PDF Kyoto Collection Carnegie Collection Human Embryo, Carnegie stages 1-23 Human Embryo, Carnegie stages 10-23 Carnegie stages stage 1 stage 2 stage 3 stage 4 Week 2 Carnegie stages stage 4 stage 5 stage 6 Week 3 Week 3 - Carnegie stage - 7 | 8 | 9 Carnegie stages stage 7 stage 8 stage 9 Week 4 Week 4 - The heart begins Week 4 - Carnegie stage - 10 | 11 | 12 | 13 Heart Placodes Pharyngeal arches Carnegie stages stage 10 stage 11 stage 12 stage 13 Week 5 Week 5 - Carnegie stage - 14 to 15 Carnegie stages stage 14 stage 15 Week 6 Week 6 - Early face deevelopment Week 6 - Carnegie stage - 16 to 17 Carnegie stages stage 16 stage 17 Week 7 Week 7 - Head and limb development Week 7 - Carnegie stage - 18 to 19 Carnegie stages stage 18 stage 19 Week 8 Week 8 - Last embryonic stage 23 Week 8 - Carnegie stage - 20 | 21 | 22 | 23 Last week of embryonic development. Carnegie stages stage 20 stage 21 stage 22 stage 23 Carnegie Stages: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | About Stages | Timeline Carnegie Stage Table Weeks shown in the table below are embryonic post ovulation age, for clinical Gestational Age (GA) measured from last menstrual period, add 2 weeks. Stage Days (approx) Size (mm) Images(not to scale) Events 1 1 (week 1) 0.1 - 0.15 fertilized oocyte, zygote, pronuclei 2 2 - 3 0.1 - 0.2 morula cell division with reduction in cytoplasmic volume, blastocyst formation of inner and outer cell mass 3 4 - 5 0.1 - 0.2 loss of zona pellucida, free blastocyst 4 5 - 6 0.1 - 0.2 attaching blastocyst 5 7 - 12 (week 2) 0.1 - 0.2 implantation 6 13 - 15 0.2 extraembryonic mesoderm, primitive streak, gastrulation 7 15 - 17 (week 3) 0.4 gastrulation, notochordal process 8 17 - 19 1.0 - 1.5 primitive pit, notochordal canal 9 19 - 21 1.5 - 2.5 Somitogenesis Somite Number 1 - 3 neural folds, cardiac primordium, head fold 10 22 - 23 (week 4) 2 - 3.5 Somite Number 4 - 12 neural fold fuses 11 23 - 26 2.5 - 4.5 Somite Number 13 - 20 rostral neuropore closes 12 26 - 30 3 - 5 Somite Number 21 - 29 caudal neuropore closes 13 28 - 32 (week 5) 4 - 6 Somite Number 30 leg buds, lens placode, pharyngeal arches Stage 13/14 shown in serial embryo sections series of Embryology Program 14 31 - 35 5 - 7 lens pit, optic cup 15 35 - 38 7 - 9 lens vesicle, nasal pit, hand plate 16 37 - 42 (week 6) 8 - 11 nasal pits moved ventrally, auricular hillocks, foot plate 17 42 - 44 11 - 14 finger rays 18 44 - 48 (week 7) 13 - 17 ossification commences 19 48 - 51 16 - 18 straightening of trunk 20 51 - 53 (week 8) 18 - 22 upper limbs longer and bent at elbow 21 53 - 54 22 - 24 hands and feet turned inward Stage 22 shown in serial embryo sections series of Embryology Program 22 54 - 56 23 - 28 eyelids, external ears 23 56 - 60 27 - 31 rounded head, body and limbs Following this stage Fetal Development occurs until birth (approx 37 weeks) The embryos shown in the table are from the Kyoto and Carnegie collection and other sources. 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Adapt — remix, transform, and build upon the material for any purpose, even commercially. The licensor cannot revoke these freedoms as long as you follow the license terms. Attribution — You must give appropriate credit , provide a link to the license, and indicate if changes were made . You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use. ShareAlike — If you remix, transform, or build upon the material, you must distribute your contributions under the same license as the original. No additional restrictions — You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits. You do not have to comply with the license for elements of the material in the public domain or where your use is permitted by an applicable exception or limitation . No warranties are given. The license may not give you all of the permissions necessary for your intended use. For example, other rights such as publicity, privacy, or moral rights may limit how you use the material. Embryonic development, also known as ontogeny, refers to the series of processes that occur during the formation and growth of an organism from a single cell, the fertilized egg. It encompasses various stages, each marked by distinct changes in morphology and functionality. This intricate journey from a simple cell to a complex organism involves cell division, differentiation, morphogenesis, and organogenesis. The different stages of development can be broadly categorized as early and late embryogenesis, with each phase characterized by unique events and milestones. Early embryogenesis, consisting of cleavage and blastula formation, is a period of intense cell division, in which the fertilized egg undergoes multiple rounds of replication. During this stage, the embryo is comprised of a cluster of cells called the blastomeres, which eventually form a hollow sphere known as the blastula. This early phase sets the foundation for subsequent events and serves as a crucial time for determining the basic body plan and cell fate. Morphogenesis, a critical process during embryonic development, defines the shaping and arrangement of cells and tissues to form the distinct structures of an organism. It involves the precise movements, changes in cell shape, and cell migration, orchestrated by an exquisite interplay of signal molecules, genetic programs, and mechanical forces. The fine-tuned interconnections between cells and tissues during morphogenesis give rise to the organs and body structures that define the specific characteristics of an organism. Organogenesis is the stage of embryonic development during which the rudimentary organs and organ systems begin to form. This intricate process involves the coordinated development and differentiation of various cell types to ultimately give rise to functional organs, such as the heart, brain, liver, and limbs. Each organogenesis phase follows a specific timeline and involves the precise spatiotemporal expression of critical genes and the interaction between different tissues and cell populations. The establishment of functional organs is a major milestone in embryonic development and sets the stage for further growth, maturation, and functionality. Understanding the stages and processes involved in embryonic development is not only a fascinating area of study but also essential for numerous fields, including medicine, genetics, and evolutionary biology. Insights gained from studying embryo development can provide valuable knowledge about the origins of developmental disorders, birth defects, and the evolutionary relationships between different species. Additionally, advances in our understanding of embryonic development have significant implications for regenerative medicine and tissue engineering, opening up new possibilities for treating diseases and injuries. Early Stages of Development Embryonic development encompasses a series of intricate processes that occur in the early stages of an organism’s life. These stages are characterized by differentiation, morphogenesis, and organogenesis, which ultimately lead to the growth and development of a fully-formed fetus. During the early stages of development, embryos undergo various transformations and acquire distinct cell types through a process called differentiation. This process involves the specialization of cells into specific cell types and tissues, such as muscle cells, nerve cells, or skin cells. Embryos also go through stages of growth and morphogenesis, during which their shape and structure change. This process involves the formation of different body systems and organs, as well as the establishment of their basic functional characteristics. For example, during organogenesis, the heart, lungs, brain, and other vital organs begin to develop and take shape. Fetal development is a crucial period, as it sets the foundation for the future growth and health of the organism. Early stages of development lay the groundwork for the overall structure and function of the organism, and any abnormalities or disruptions during these stages can have long-lasting effects on the individual’s health. Understanding the early stages of development is essential for researchers and healthcare professionals, as it provides insights into the formation and organization of tissues and organs. This knowledge is instrumental in identifying and addressing developmental disorders and birth defects, as well as in developing potential treatments and interventions. Process of Embryonic Development The process of embryonic development consists of various stages of morphogenesis and growth. It begins with the fertilization of an egg by sperm, resulting in the formation of a zygote. The zygote then undergoes a series of divisions to form a blastocyst, which is a multicellular structure composed of an outer layer of cells called the trophoblast and an inner cell mass. During the early stages of development, the cells of the blastocyst begin to differentiate and specialize into different cell types. This process, known as cell differentiation, is regulated by genetic and environmental factors. As the embryo continues to develop, it undergoes further growth and organogenesis, where the different organs and tissues of the body start to form. Embryos go through a series of critical stages during development, each with its own significance. The formation of the neural tube, for example, is a crucial stage that occurs early in embryonic development and gives rise to the central nervous system. The formation of limbs is another important stage that occurs later in development, allowing the fetus to acquire its distinct body shape. As development progresses, the embryo undergoes more complex processes, such as gastrulation, where the three primary germ layers – ectoderm, mesoderm, and endoderm – are established. These germ layers will give rise to different tissues and organs in the body. This stage marks an important milestone in embryonic development. Overall, embryonic development is a dynamic and intricate process characterized by various stages and processes. It is a remarkable journey from a fertilized egg to a fully formed fetus, with each step contributing to the formation and differentiation of different cell types and structures in the body. Significance of Embryonic Development The embryonic development is a critical stage in the life cycle of all organisms, including humans. During this process, a fertilized egg (zygote) undergoes a series of complex and highly coordinated events that lead to the formation of an embryo. The embryo then continues to develop, eventually becoming a fetus. Growth and Morphogenesis One of the key aspects of embryonic development is growth and morphogenesis. Embryos go through different stages, each marked by significant changes in size and shape. These changes are controlled by genetic programs that dictate cell proliferation, migration, and differentiation. As the embryo grows, cells organize themselves into distinct tissues and organs, giving rise to the overall body plan of the organism. Development and Differentiation Embryonic development is also crucial for the process of cell specialization and differentiation. As the embryo develops, cells acquire specific functions and characteristics, becoming specialized for particular roles in the body. This is achieved through the activation and repression of specific genes, which direct cells towards specific fates and functions. The proper development and differentiation of cells are essential for the formation of functional tissues and organs. Organogenesis and Tissue Formation Organogenesis is another significant aspect of embryonic development. During this stage, the rudiments of various organs and tissues are formed. This involves the coordinated growth, folding, and remodeling of embryonic tissues to create complex structures such as the brain, heart, lungs, and limbs. Defects in organogenesis can lead to severe developmental abnormalities and congenital disorders. Overall, embryonic development plays a critical role in shaping the structure and function of an organism. It is a highly regulated and intricate process that ensures the proper growth, differentiation, and formation of tissues and organs. Understanding the different stages and mechanisms involved in embryonic development is essential for comprehending normal development and identifying potential causes of developmental disorders. Development of Embryos Embryonic development is a complex process that goes through different stages, starting from the fertilized egg to the formation of a fully developed organism. It involves a series of coordinated cellular events, including differentiation, growth, and morphogenesis, which ultimately lead to the formation of tissues, organs, and body structures. During the early stages of embryonic development, the fertilized egg undergoes rapid cell division and differentiation. The cells start to specialize and take on specific roles to form different tissues and organs. This process is crucial for the proper development and function of the organism. Organogenesis, another significant stage of embryonic development, occurs when the basic organ structures start to form. Cells continue to differentiate, migrate, and organize themselves to create the foundation of various organ systems, such as the respiratory, cardiovascular, and nervous systems. Morphogenesis, the final stage of embryonic development, involves the shaping and positioning of cells, tissues, and organs to create a recognizable and functional organism. This process includes cell movement, interactions, and changes in cell shape and size, contributing to the overall development and growth of the embryo. The development of embryos is a tightly regulated and highly orchestrated process. Any disruptions or abnormalities during embryonic development can lead to birth defects or developmental disorders. Understanding the stages and processes of embryonic development is crucial for comprehending how organisms develop and for identifying potential interventions or treatments for developmental disorders. Cell Division and Differentiation Growth and development of embryos and fetal morphogenesis occur through a highly complex process known as embryonic development. The early stages of development involve cell division and differentiation, which play crucial roles in shaping the various tissues and organs of the growing organism. Cell division occurs as the fertilized egg, or zygote, undergoes successive rounds of mitotic divisions. This process results in the formation of more cells, creating a multicellular structure. The cells produced during this stage are undifferentiated and have the potential to become any cell type in the body. As development proceeds, cells begin to differentiate into specific cell types, acquiring distinct functions and morphologies. This process of differentiation is tightly regulated by various signaling pathways and gene expression patterns. Differentiation enables the formation of specialized tissues and organs, such as the nervous system, heart, and lungs. The timing and coordination of cell division and differentiation are critical for the proper development of an organism. Disruptions in these processes can lead to developmental abnormalities and birth defects. Understanding the underlying mechanisms of cell division and differentiation during embryonic development is essential for identifying potential therapeutic targets and improving our knowledge of human development. Morphogenesis in Embryo Morphogenesis is the process of the development and growth of embryos, which involves multiple stages of differentiation and organogenesis. During the early stages of embryonic development, the cells undergo various changes in shape, size, and position to form the basic body plan of the organism. This process is crucial for the proper formation of tissues, organs, and structures that will be present in the fetal stage. Formation of Germ Layers During embryonic development, the process of morphogenesis involves the formation of three distinct layers of cells known as germ layers. These germ layers give rise to the various tissues and organs in the body. The formation of germ layers is a crucial stage in the early development of embryos, and it sets the foundation for further growth and differentiation. Stages of Germ Layer Formation The formation of germ layers occurs during the early stages of embryonic development. It begins with the process of gastrulation, where the embryo transforms from a simple ball of cells into a three-layered structure. This process involves the movement and rearrangement of cells, resulting in the formation of the three germ layers. During gastrulation, the outer layer of cells, known as the ectoderm, forms. This layer gives rise to the nervous system, skin, and other external structures. The innermost layer, called the endoderm, develops into the lining of the digestive system, as well as other internal organs. Finally, the middle layer, known as the mesoderm, gives rise to the muscles, bones, blood vessels, and other connective tissues. Significance of Germ Layer Formation The formation of germ layers is significant as it establishes the basic blueprint for fetal development. Each germ layer gives rise to specific cell types and tissues, which ultimately form the different organs and systems in the body. Any disruptions or abnormalities during germ layer formation can lead to congenital defects and developmental disorders. Understanding the process of germ layer formation is essential for studying embryonic development and its implications on health and disease. It provides insights into how different cell types arise and how they interact to form complex structures. This knowledge is vital for advancing regenerative medicine, tissue engineering, and other therapeutic approaches that aim to repair or replace damaged tissues. In conclusion, the formation of germ layers is a crucial stage in early embryonic development. It involves the differentiation and growth of cells into three distinct layers, namely the ectoderm, endoderm, and mesoderm. This process sets the foundation for the development of the various tissues and organs in the body, making it an essential area of study in developmental biology. Organogenesis in Embryo Organogenesis is a critical process during early embryonic development, where the differentiation and growth of various organs and tissues take place. It is a complex process that involves the precise coordination of cellular activities, such as morphogenesis and tissue specialization, leading to the formation of different organ systems in the developing fetus. Organogenesis occurs during specific stages of embryonic development, with each stage marked by the formation and differentiation of specific organs. These stages include the formation of the neural tube and the development of the central nervous system, the development of the heart and circulatory system, the development of the digestive and respiratory systems, and the formation of the limbs and other appendages. During organogenesis, different cell types emerge from embryonic stem cells through a process called cell differentiation. This process involves changes in gene expression that lead to the development of specialized cell types with distinct functions. For example, during heart development, certain cells differentiate into cardiomyocytes, which are responsible for the contraction and pumping of blood. Morphogenesis, another crucial aspect of organogenesis, refers to the shaping and organizing of tissues and organs. It involves intricate cellular movements, rearrangements, and interactions that establish the correct structure and architecture of each organ. The precise timing and coordination of these cellular events are essential for the proper formation of organs and their subsequent functionality. The significance of organogenesis in embryonic development cannot be overstated. It lays the foundation for the future growth and functionality of organs, allowing them to perform vital functions in the developing fetus. Any disruptions or abnormalities during organogenesis can lead to congenital malformations or developmental disorders that can have serious consequences for the individual’s health and well-being. In conclusion, organogenesis is a fascinating and intricate process that occurs during early embryonic development. It involves the differentiation, growth, and morphogenesis of various organs and tissues. Understanding the stages and processes involved in organogenesis is crucial for unraveling the complexities of human development and identifying potential interventions for developmental disorders. Formation of Major Organ Systems During embryonic development, the growth and morphogenesis of embryos occur through a series of complex processes. One of the most critical stages in this process is the formation of major organ systems. This process, known as organogenesis, is characterized by the early differentiation and development of various organ systems within the developing fetus. Organogenesis involves the coordinated development of different types of tissues and cells to form specific organs. This intricate process begins during the early stages of embryonic development and continues throughout fetal development. It is during this time that the rudiments of major organ systems begin to form, including the cardiovascular system, nervous system, digestive system, respiratory system, and musculoskeletal system. Each major organ system follows a unique and highly regulated developmental pathway. For example, the cardiovascular system starts forming as early as the third week of embryonic development, with the development of the heart tube and the differentiation of blood vessels. Similarly, the nervous system begins to develop during the third week, with the formation of the neural tube, which eventually gives rise to the brain and spinal cord. Organ System Timeline of Development Cardiovascular System Third week of embryonic development Nervous System Third week of embryonic development Digestive System Fourth week of embryonic development Respiratory System Fifth week of embryonic development Musculoskeletal System Sixth week of embryonic development Understanding the formation of major organ systems is crucial, as any disruptions or abnormalities during this process can lead to congenital malformations or birth defects. By studying the intricate mechanisms involved in organogenesis, scientists and healthcare professionals can gain insights into the potential causes and prevention of these conditions, ultimately improving the overall health and well-being of future generations. Development of Nervous System The development of the nervous system is a complex and intricate process that occurs during embryogenesis and continues throughout the fetal stages. It involves the growth, morphogenesis, and organogenesis of the early embryonic neural tube, which eventually gives rise to the brain and spinal cord. During the early stages of embryonic development, the neural tube forms from the ectoderm, a single layer of cells on the dorsal side of the embryo. This process is known as neurulation and is essential for the initial establishment of the nervous system. As the embryo grows, the neural tube begins to differentiate into different regions, giving rise to the various parts of the brain and spinal cord. As the development progresses, neural crest cells also migrate from the neural tube to different regions of the embryo. These cells have the ability to give rise to a variety of cell types, including neurons, glial cells, and other supporting cells of the nervous system. Throughout the fetal stages, the nervous system undergoes substantial growth and further refinement. Neurons continue to form connections with each other, allowing for the communication and transmission of signals. This process, known as neural circuit formation, is critical for the proper functioning of the nervous system. The development of the nervous system is a highly coordinated and regulated process. Slight disruptions or malformations during this period can lead to significant neurodevelopmental disorders or congenital abnormalities. Therefore, understanding the various stages and mechanisms involved in the development of the nervous system is of great significance for both basic research and clinical applications. Key Points – The development of the nervous system involves the growth, morphogenesis, and organogenesis of the early embryonic neural tube. – Neurulation is the process by which the neural tube forms from the ectoderm during early embryonic development. – Neural crest cells migrate from the neural tube and give rise to various types of cells in the nervous system. – Throughout the fetal stages, the nervous system undergoes substantial growth and neural circuit formation. – Disruptions during the development of the nervous system can lead to neurodevelopmental disorders and congenital abnormalities. Embryo Implantation and Placenta Formation Embryo implantation and placenta formation are crucial stages in the development of embryos. After the process of fertilization, the zygote undergoes a series of developmental stages to form an embryo. These stages include organogenesis, morphogenesis, and differentiation. Embryo Development Stages During the early stages of embryonic development, the embryo grows and differentiates into different cell types. This process is known as organogenesis, where the major organs and body systems start to form. The embryo goes through various morphogenetic changes, such as gastrulation, neurulation, and limb formation, to acquire its shape and structure. Embryo Implantation Embryo implantation is the process by which the developing embryo attaches itself to the uterine wall. This usually occurs around seven to ten days after fertilization. The embryo enters the uterus, and the outer layer of cells, known as the trophoblast, begins to invade the endometrium, the lining of the uterus. Once the trophoblast cells penetrate the endometrium, they form small spaces, called lacunae, which will later become the maternal blood vessels. These blood vessels provide nutrients and oxygen to the growing embryo. The trophoblast also secretes enzymes that help it further invade the uterine wall and establish a connection with the maternal blood supply. Placenta Formation During embryo implantation, the trophoblast cells divide and differentiate into two distinct layers: the cytotrophoblast and the syncytiotrophoblast. The cytotrophoblast is the inner layer and gives rise to the chorionic villi, finger-like projections that will later form the placenta. The syncytiotrophoblast is the outer layer and directly contacts the maternal blood. It secretes hormones, such as human chorionic gonadotropin (hCG), which helps maintain pregnancy. The syncytiotrophoblast also facilitates the exchange of gases, nutrients, and waste between the maternal and fetal bloodstreams. As the pregnancy progresses, the placenta continues to develop, providing essential support and nourishment to the growing fetus. It acts as a barrier, filtering out harmful substances and protecting the fetus from infections. In summary, embryo implantation and placenta formation are crucial processes in the development of embryos. During these stages, the embryo attaches itself to the uterine wall and establishes a connection with the maternal blood supply. The placenta then forms, providing vital support and nourishment to the developing fetus throughout pregnancy. Developmental Disorders The development of a fetus is a complex and intricate process that involves the growth, organogenesis, and morphogenesis of early embryos. However, this delicate process can sometimes be disrupted, leading to developmental disorders. Causes of Developmental Disorders There are various factors that can contribute to the occurrence of developmental disorders. Genetic abnormalities, environmental factors, and maternal health issues are just a few examples. These factors can interfere with the normal development of an embryo, leading to structural abnormalities and functional impairments. Types of Developmental Disorders Developmental disorders can manifest in various ways, affecting different aspects of an individual’s growth and development. Some common types of developmental disorders include: Neural tube defects, such as spina bifida Chromosomal abnormalities, such as Down syndrome Autism spectrum disorders Cleft lip and palate These disorders can have significant impacts on an individual’s physical, mental, and emotional well-being. They may require specialized medical care and interventions to address the specific challenges faced by individuals with developmental disorders. Evaluation and Treatment Early identification and intervention are important for individuals with developmental disorders. Diagnostic tests, such as genetic testing and imaging techniques, can help identify the underlying causes and provide valuable information for developing a treatment plan. Treatment options for developmental disorders vary depending on the specific disorder and its severity. In some cases, surgical procedures may be required to correct structural abnormalities. Therapies, such as physical therapy, speech therapy, and occupational therapy, can help improve functional abilities and quality of life for individuals with developmental disorders. Overall, understanding developmental disorders is crucial for healthcare professionals, parents, and society as a whole. By recognizing and addressing these disorders early on, we can provide support and resources to individuals with developmental disorders, helping them thrive and reach their full potential. Teratogens and their Effects Teratogens are substances or factors that can disrupt the normal differentiation, growth, and morphogenesis of embryos, leading to structural and functional abnormalities. The effects of teratogens can vary depending on the timing and duration of exposure during early stages of fetal development. It is important to note that not all teratogens have the same effects on embryonic development. Some may cause malformations in specific organ systems, while others may have a broader impact on overall growth and development. The effects of teratogens can be classified into different categories: Category Examples Effects Chemical teratogens Alcohol, certain medications, environmental pollutants Can lead to facial dysmorphology, central nervous system abnormalities, and growth restriction Infectious teratogens Rubella, cytomegalovirus, toxoplasmosis Can cause congenital infections, central nervous system abnormalities, and organ damage Physical teratogens Radiation, heat, trauma Can result in structural abnormalities, organ dysfunction, and growth restriction It is worth noting that the effects of teratogens can be dose-dependent and may differ depending on the susceptibility of the developing embryo. Some teratogens may only have an effect if exposure occurs during specific stages of embryonic development. Understanding the potential teratogenic effects of various substances and factors is crucial for preventing and minimizing the risk of developmental abnormalities. Healthcare professionals, parents, and individuals should be aware of the potential risks associated with certain medications, substances, and environmental factors during pregnancy to ensure the healthy development of the fetus. Genetic and Environmental Factors The development of an embryo is a complex process that is influenced by both genetic and environmental factors. These factors play a crucial role in determining the growth and differentiation of cells during organogenesis and morphogenesis. Genetic Factors Genetic factors refer to the inherited traits and characteristics that are passed down from parents to their offspring. The genetic information encoded in the DNA of the embryo’s cells provides the blueprint for its development. This genetic blueprint determines the basic body plan and structure of the organism. It also influences the timing and sequence of developmental events and the formation of different tissues and organs. During early stages of embryonic development, specific genes are activated or repressed to initiate various signaling pathways and cell differentiation processes. These genetic factors regulate the proliferation and migration of cells, as well as the assembly and organization of tissues and organs. Mutations or aberrations in these genes can lead to developmental abnormalities or disorders. Environmental Factors Environmental factors, on the other hand, encompass all non-genetic influences that affect embryonic development. These factors include the physical conditions and chemical substances present in the embryo’s immediate environment, as well as the maternal and external factors that the embryo is exposed to. Environmental factors can have a significant impact on the growth and development of embryos. For example, exposure to certain drugs, toxins, or infections during pregnancy can interfere with normal development and increase the risk of birth defects. The availability of nutrients, oxygen, and hormones in the environment also plays a crucial role in supporting the growth and differentiation of cells. In conclusion, the development of embryos is influenced by both genetic and environmental factors. Genetic factors provide the foundation for the development of an organism, while environmental factors shape and modify this development. Understanding the interplay between these factors is essential for comprehending embryonic development and how it can be influenced or disrupted. Factors Affecting Embryonic Development Embryonic development is a complex and highly regulated process that involves a series of stages from fertilization through to the formation of a fully developed fetus. During this early period of growth and morphogenesis, various factors can influence the development of embryos and impact their subsequent differentiation and organogenesis. One of the key factors affecting embryonic development is the genetic makeup of the embryo itself. The genes inherited from the parents play a crucial role in directing the cellular processes that occur during development. Mutations or abnormalities in these genes can lead to developmental disorders or birth defects. The environment in which the embryo develops can also have a significant impact on its development. Factors such as maternal nutrition, exposure to toxins or drugs, and even stress levels can influence the growth and development of the embryo. For example, inadequate maternal nutrition can lead to insufficient nutrient supply to the developing fetus, potentially resulting in developmental delays or abnormalities. The timing and sequence of developmental events are another important factor. The different stages of embryonic development must occur in a specific order for proper organogenesis and tissue differentiation to take place. Any disruption or delay in these stages can have profound effects on the overall development of the embryo. In addition to genetic and environmental factors, interactions between cells and signaling molecules also play a crucial role in embryonic development. These interactions, known as cell-cell communication, guide the formation and patterning of tissues and organs. Signals from neighboring cells and molecules such as growth factors and hormones can influence cell behavior and determine the fate of cells during differentiation. Understanding the factors that affect embryonic development is essential for researchers and healthcare professionals. By studying these factors, scientists can gain insights into the mechanisms underlying normal and abnormal development, which can help improve our understanding of developmental disorders and potentially lead to the development of new treatments and interventions. Fetal Development The process of fetal development follows the early stages of embryonic development, which include fertilization, cleavage, implantation, and gastrulation. After gastrulation, the embryo enters the fetal stage, which is characterized by the growth and development of organ systems. During the fetal stage, organogenesis takes place, wherein the major organs and systems begin to form and develop. This process involves the differentiation and specialization of cells into specific tissues and structures. The organs continue to grow and mature, acquiring their distinct features and functions. Morphogenesis, another important aspect of fetal development, refers to the shaping and structuring of the organs and body. This includes the development of body symmetry, the formation of limbs and digits, and the establishment of facial features. Throughout fetal development, the embryo undergoes rapid growth. It gains weight and size, with the organs and body structures becoming more defined. The fetus moves and responds to external stimuli, exhibiting signs of life and activity. The fetal stage is a critical period in human development as it lays the foundation for the individual's future health and well-being. Any disruptions or abnormalities during this stage can have long-lasting effects on the individual's overall growth and development. Stages of Fetal Development First Trimester Embryonic period (weeks 1-8) Organogenesis occurs, and major organ systems develop. External structures, such as limbs and facial features, start to form. Second Trimester Fetal period (weeks 9-23) Rapid growth and development of organs, muscles, and bones. Movement becomes more pronounced. Third Trimester Fetal period (weeks 24-40) Continued growth and maturation of organs, especially the lungs. Fetus gains weight and prepares for life outside the womb. Welcome to the Biology Library. This Living Library is a principal hub of the LibreTexts project, which is a multi-institutional collaborative venture to develop the next generation of open-access texts to improve postsecondary education at all levels of higher learning. The LibreTexts approach is highly collaborative where an Open Access textbook environment is under constant revision by students, faculty, and outside experts to supplant conventional paper-based books. Campus BookshelvesBookshelvesLearning Objects Home is shared under a not declared license and was authored, remixed, and/or curated by LibreTexts. By the end of this section, you will be able to: Describe the microscopic and gross anatomical structures of bones Identify the gross anatomical features of a bone Describe the histology of bone tissue, including the function of bone cells and matrix Compare and contrast compact and spongy bone Identify the structures that compose compact and spongy bone Describe how bones are nourished and innervated function? Bone tissue (osseous tissue) differs greatly from other tissues in the body. Bone is hard and many of its functions depend on that characteristic hardness. Later discussions in this chapter will show that bone is also dynamic in that its shape adjusts to accommodate stresses. This section will examine the gross anatomy of bone first and then move on to its histology. A long bone has two main regions: the diaphysis and the epiphysis (Figure 6.3.1). The diaphysis is the hollow, tubular shaft that runs between the proximal and distal ends of the bone. Inside the diaphysis is the medullary cavity, which is filled with yellow bone marrow in an adult. The outer walls of the diaphysis (cortex, cortical bone) are composed of dense and hard compact bone, a form of osseous tissue. Figure 6.3.1 – Anatomy of a Long Bone: A typical long bone showing gross anatomical features. The wider section at each end of the bone is called the epiphysis (plural = epiphyses), which is filled internally with spongy bone, another type of osseous tissue. Red bone marrow fills the spaces between the spongy bone in some long bones. Each epiphysis meets the diaphysis at the metaphysis. During growth, the metaphysis contains the epiphyseal plate, the site of long bone elongation described later in the chapter. When the bone stops growing in early adulthood (approximately 18-21 years), the epiphyseal plate becomes an epiphyseal line seen in the figure. Lining the inside of the bone adjacent to the medullary cavity is a layer of bone cells called the endosteum (endo- = "inside"; osteo- = "bone"). These bone cells (described later) cause the bone to grow, repair, and remodel throughout life. On the outside of bones there is another layer of cells that grow, repair and remodel bone as well. These cells are part of the outer double layered structure called the periosteum (peri– = "around" or "surrounding"). The cellular layer is adjacent to the cortical bone and is covered by an outer fibrous layer of dense irregular connective tissue (see Figure 6.3.4a). The periosteum also contains blood vessels, nerves, and lymphatic vessels that nourish compact bone. Tendons and ligaments attach to bones at the periosteum. The periosteum covers the entire outer surface except where the epiphyses meet other bones to form joints (Figure 6.3.2). In this region, the epiphyses are covered with articular cartilage, a thin layer of hyaline cartilage that reduces friction and acts as a shock absorber. Figure 6.32 – Periosteum and Endosteum: The periosteum forms the outer surface of bone, and the endosteum lines the medullary cavity. Flat bones, like those of the cranium, consist of a layer of diploë (spongy bone), covered on either side by a layer of compact bone (Figure 6.3.3). The two layers of compact bone and the interior spongy bone work together to protect the internal organs. If the outer layer of a cranial bone fractures, the brain is still protected by the intact inner layer. Figure 6.3.3 – Anatomy of a Flat Bone: This cross-section of a flat bone shows the spongy bone (diploë) covered on either side by a layer of compact bone. Bone Matrix Osseous tissue is a connective tissue and like all connective tissues contains relatively few cells and large amounts of extracellular matrix. By mass, osseous tissue matrix consists of 1/3rd collagen fibers and 2/3rds calcium phosphate salt. The collagen provides a scaffolding surface for inorganic salt crystals to adhere (see Figure 6.3.4a). These salt crystals form when calcium phosphate and calcium carbonate combine to create hydroxyapatite. Hydroxyapatite also incorporates other inorganic salts like magnesium hydroxide, fluoride, and sulfate as it crystallizes, or calcifies, on the collagen fibers. The hydroxyapatite crystals give bones their hardness and strength, while the collagen fibers give them a framework for calcification and gives the bone flexibility so that it can bend without being brittle. For example, if you removed all the organic matrix (collagen) from a bone, it would crumble and shatter readily (see Figure 6.3.4b, upper panel). Conversely, if you remove all the inorganic matrix (minerals) from bone and leave the collagen, the bone becomes overly flexible and cannot bear weight (see Figure 6.3.4b, lower panel). Figure 6.3.4a Calcified collagen fibers from bone (scanning electron micrograph, 10,000 X, By Sbertazzo – Own work, CC BY-SA 3.0, Figure 6.3.4b Contributions of the organic and inorganic matrices of bone. Image from Ammerman figure 6-5, Pearson Bone Cells Although bone cells compose less than 2% of the bone mass, they are crucial to the function of bones. Four types of cells are found within bone tissue: osteoblasts, osteocytes, osteogenic cells, and osteoclasts (Figure 6.3.5). Figure 6.3.5 – Bone Cells: Four types of cells are found within bone tissue. Osteogenic cells are undifferentiated and develop into osteoblasts. Osteoblasts deposit bone matrix. When osteoblasts get trapped within the calcified matrix, they become osteocytes. Osteoclasts develop from a different cell lineage and act to resorb bone. The osteoblast is the bone cell responsible for forming new bone and is found in the growing portions of bone, including the endosteum and the cellular layer of the periosteum. Osteoblasts, which do not divide, synthesize and secrete the collagen matrix and other proteins. As the secreted matrix surrounding the osteoblast calcifies, the osteoblast become trapped within it; as a result, it changes in structure and becomes an osteocyte, the primary cell of mature bone and the most common type of bone cell. Each osteocyte is located in a small cavity in the bone tissue called a lacuna (lacunae for plural). Osteocytes maintain the mineral concentration of the matrix via the secretion of enzymes. Like osteoblasts, osteocytes lack mitotic activity. They can communicate with each other and receive nutrients via long cytoplasmic processes that extend through canaliculi (singular = canaliculus), channels within the bone matrix. Osteocytes are connected to one another within the canaliculi via gap junctions. If osteoblasts and osteocytes are incapable of mitosis, then how are they replenished when old ones die? The answer lies in the properties of a third category of bone cells—the osteogenic (osteoprogenitor) cell. These osteogenic cells are undifferentiated with high mitotic activity and they are the only bone cells that divide. Immature osteogenic cells are found in the cellular layer of the periosteum and the endosteum. They differentiate and develop into osteoblasts. The dynamic nature of bone means that new tissue is constantly formed, and old, injured, or unnecessary bone is dissolved for repair or for calcium release. The cells responsible for bone resorption, or breakdown, are the osteoclasts. These multinucleated cells originate from monocytes and macrophages, two types of white blood cells, not from osteogenic cells. Osteoclasts are continually breaking down old bone while osteoblasts are continually forming new bone. The ongoing balance between osteoblasts and osteoclasts is responsible for the constant but subtle reshaping of bone. Table 6.3 reviews the bone cells, their functions, and locations. Bone Cells (Table 6.3) Cell type Function Location Osteogenic cells Develop into osteoblasts Endosteum, cellular layer of the periosteum Osteoblasts Bone formation Endosteum, cellular layer of the periosteum, growing portions of bone Osteocytes Maintain mineral concentration of matrix Entrapped in matrix Osteoclasts Bone resorption Endosteum, cellular layer of the periosteum, at sites of old, injured, or unneeded bone Most bones contain compact and spongy osseous tissue, but their distribution and concentration vary based on the bone's overall function. Although compact and spongy bone are made of the same matrix materials and cells, they are different in how they are organized. Compact bone is dense so that it can withstand compressive forces, while spongy bone (also called cancellous bone) has open spaces and is supportive, but also lightweight and can be readily remodeled to accommodate changing body needs. Compact bone is the denser, stronger of the two types of osseous tissue (Figure 6.3.6). It makes up the outer cortex of all bones and is in immediate contact with the periosteum. In long bones, as you move from the outer cortical compact bone to the inner medullary cavity, the bone transitions to spongy bone. Figure 6.3.6 – Diagram of Compact Bone: (a) This cross-sectional view of compact bone shows several osteons, the basic structural unit of compact bone. (b) In this micrograph of the osteon, you can see the concentric lamellae around the central canals. LM × 40. (Micrograph provided by the Regents of University of Michigan Medical School © 2012) Figure 6.3.7 Osteon If you look at compact bone under the microscope, you will observe a highly organized arrangement of concentric circles that look like tree trunks. Each group of concentric circles (each "tree") makes up the microscopic structural unit of compact bone called an osteon (this is also called a Haversian system). Each ring of the osteon is made of collagen and calcified matrix and is called a lamella (plural = lamellae). The collagen fibers of adjacent lamellae run at perpendicular angles to each other, allowing osteons to resist twisting forces in multiple directions (see Figure 6.34a). Running down the center of each osteon is the central canal, or Haversian canal, which contains blood vessels, nerves, and lymphatic vessels. These vessels and nerves branch off at right angles through a perforating canal, also known as Volkmann's canals, to extend to the periosteum and endosteum. The endosteum also lines each central canal, allowing osteons to be removed, remodeled and rebuilt over time. The osteocytes are trapped within their lacunae, found at the borders of adjacent lamellae. As described earlier, canaliculi connect with the canaliculi of other lacunae and eventually with the central canal. This system allows nutrients to be transported to the osteocytes and wastes to be removed from them despite the impervious calcified matrix. Like compact bone, spongy bone, also known as cancellous bone, contains osteocytes housed in lacunae, but they are not arranged in concentric circles. Instead, the lacunae and osteocytes are found in a lattice-like network of matrix spikes called trabeculae (singular = trabecula) (Figure 6.3.8). The trabeculae are covered by the endosteum, which can readily remodel them. The trabeculae may appear to be a random network, but each trabecula forms along lines of stress to direct forces out to the more solid compact bone providing strength to the bone. Spongy bone provides balance to the dense and heavy compact bone by making bones lighter so that muscles can move them more easily. In addition, the spaces in some spongy bones contain red bone marrow, protected by the trabeculae, where hematopoiesis occurs. Figure 6.3.8 – Diagram of Spongy Bone: Spongy bone is composed of trabeculae that contain the osteocytes. Red marrow fills the spaces in some bones. Aging and the...Skeletal System: Paget's DiseasePaget's disease usually occurs in adults over age 40. It is a disorder of the bone remodeling process that begins with overactive osteoclasts. This means more bone is resorbed than is laid down. The osteoblasts try to compensate but the new bone they lay down is weak and brittle and therefore prone to fracture. While some people with Paget's disease have no symptoms, others experience pain, bone fractures, and bone deformities (Figure 6.3.9). Bones of the pelvis, skull, spine, and legs are the most commonly affected. When occurring in the skull, Paget's disease can cause headaches and hearing loss. Figure 6.3.9 – Paget's Disease: Normal leg bones are relatively straight, but those affected by Paget's disease are porous and curved. What causes the osteoclasts to become overactive? The answer is still unknown, but hereditary factors seem to play a role. Some scientists believe Paget's disease is due to an as-yet-unidentified virus. Paget's disease is diagnosed via imaging studies and lab tests. X-rays may show bone deformities or areas of bone resorption. Bone scans are also useful. In these studies, a dye containing a radioactive ion is injected into the body. Areas of bone resorption have an affinity for the ion, so they will light up on the scan if the ions are absorbed. In addition, blood levels of an enzyme called alkaline phosphatase are typically elevated in people with Paget's disease. Bisphosphonates, drugs that decrease the activity of osteoclasts, are often used in the treatment of Paget's disease. The spongy bone and medullary cavity receive nourishment from arteries that pass through the compact bone. The arteries enter through the nutrient foramen (plural = foramina), small openings in the diaphysis (Figure 6.3.10). The osteocytes in spongy bone are nourished by blood vessels of the periosteum that penetrate spongy bone and blood that circulates in the marrow cavities. As the blood passes through the marrow cavities, it is collected by veins, which then pass out of the bone through the foramina. In addition to the blood vessels, nerves follow the same paths into the bone where they tend to concentrate in the more metabolically active regions of the bone. The nerves sense pain, and it appears the nerves also play roles in regulating blood supplies and in bone growth, hence their concentrations in metabolically active sites of the bone. Figure 6.3.10 – Diagram of Blood and Nerve Supply to Bone: Blood vessels and nerves enter the bone through the nutrient foramen. Watch this video to see the microscopic features of a bone. A hollow medullary cavity filled with yellow marrow runs the length of the diaphysis of a long bone. The walls of the diaphysis are compact bone. The epiphyses, which are wider sections at each end of a long bone, are filled with spongy bone and red marrow. The epiphyseal plate, a layer of hyaline cartilage, is replaced by osseous tissue as the organ grows in length. The medullary cavity has a delicate membranous lining called the endosteum. The outer surface of bone, except in regions covered with articular cartilage, is covered with a fibrous membrane called the periosteum. Flat bones consist of two layers of compact bone surrounding a layer of spongy bone. Bone markings depend on the function and location of bones. Articulations are places where two bones meet. Projections stick out from the surface of the bone and provide attachment points for tendons and ligaments. Holes are openings or depressions in the bones. Bone matrix consists of collagen fibers and organic ground substance, primarily hydroxyapatite formed from calcium salts. Osteogenic cells develop into osteoblasts. Osteoblasts are cells that make new bone. They become osteocytes, the cells of mature bone, when they get trapped in the matrix. Osteoclasts engage in bone resorption. Compact bone is dense and composed of osteons, while spongy bone is less dense and made up of trabeculae. Blood vessels and nerves enter the bone through the nutrient foramina to nourish and innervate bones. articular cartilage thin layer of cartilage covering an epiphysis; reduces friction and acts as a shock absorber articulation where two bone surfaces meet canaliculi (singular = canaliculus) channels within the bone matrix that house one of an osteocyte's many cytoplasmic extensions that it uses to communicate and receive nutrients central canal longitudinal channel in the center of each osteon; contains blood vessels, nerves, and lymphatic vessels; also known as the Haversian canal compact bone dense osseous tissue that can withstand compressive forces diaphysis tubular shaft that runs between the proximal and distal ends of a long bone diploë layer of spongy bone, that is sandwiched between two the layers of compact bone found in flat bones endosteum delicate membranous lining of a bone's medullary cavity epiphyseal plate (also, growth plate) sheet of hyaline cartilage in the metaphysis of an immature bone; replaced by bone tissue as the organ grows in length epiphysis wide section at each end of a long bone; filled with spongy bone and red marrow hole opening or depression in a bone lacunae (singular = lacuna) spaces in a bone that house an osteocyte medullary cavity hollow region of the diaphysis; filled with yellow marrow nutrient foramen small opening in the middle of the external surface of the diaphysis, through which an artery enters the bone to provide nourishment osteoblast cell responsible for forming new bone osteoclast cell responsible for resorbing bone osteocyte primary cell in mature bone; responsible for maintaining the matrix osteogenic cell undifferentiated cell with high mitotic activity; the only bone cells that divide; they differentiate and develop into osteoblasts osteon (also, Haversian system) basic structural unit of compact bone; made of concentric layers of calcified matrix perforating canal (also, Volkmann's canal) channel that branches off from the central canal and houses vessels and nerves that extend to the periosteum and endosteum periosteum fibrous membrane covering the outer surface of bone and continuous with ligaments projection bone markings where part of the surface sticks out above the rest of the surface, where tendons and ligaments attach spongy bone (also, cancellous bone) trabeculated osseous tissue that supports shifts in weight distribution trabeculae (singular = trabecula) spikes or sections of the lattice-like matrix in spongy bone