Essentials of Oral Histology and Embryology

A Clinical Approach

James K. Avery

Essentials of Oral Histology and Embryology

A Clinical Approach

JAMES K. AVERY, D.D.S., Ph.D.

Professor of Dentistry, School of Dentistry;
Professor of Anatomy, Medical School
University of Michigan
Ann Arbor, Michigan

Edited by

PAULINE F. STEELE, B.S., R.D.H., B.S. (Educ.), M.A.

Director and Professor Emeritus—Dental Hygiene
University of Michigan, School of Dentistry
Ann Arbor, Michigan

Mosby Year Book

St. Louis Baltimore Boston Chicago London Philadelphia Sydney Toronto

Mosby Year Book
Dedicated to Publishing Excellence

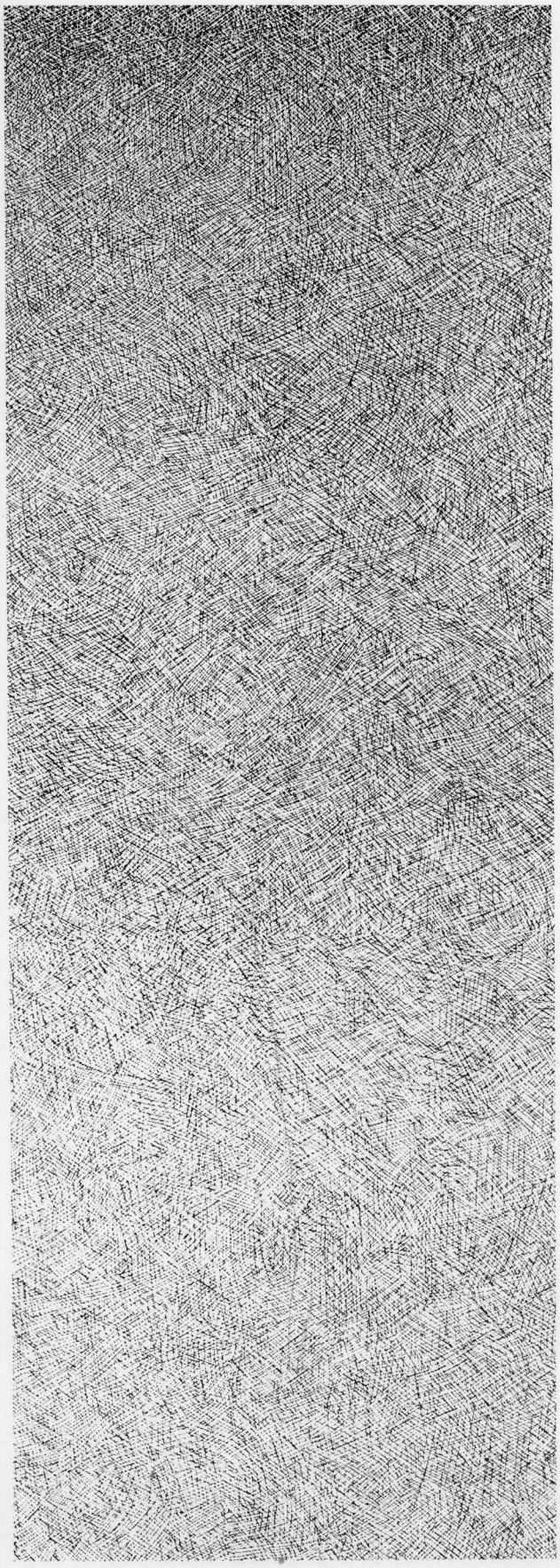
Editor: Robert Reinhardt
Project Manager: Barbara Merritt
Cover Design: Gail Morey Hudson

Printed in the United States of America

Mosby–Year Book, Inc.
11830 Westline Industrial Drive
St. Louis, MO 63146

International Standard Book Number: 0-8016-5868

92 93 94 95 96 CG/CD/WA 9 8 7 6 5 4 3 2 1



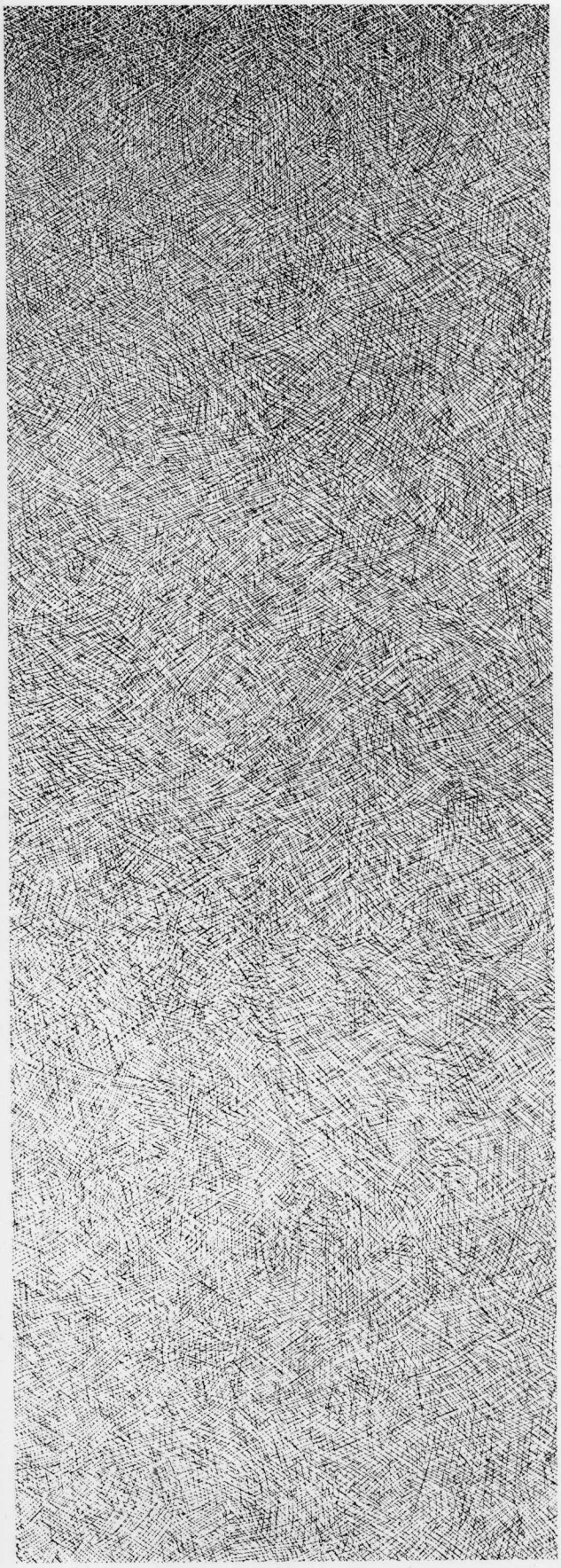
Acknowledgments

Numerous colleagues have provided valuable contributions in preparation of this textbook, *Essentials of Oral Histology and Embryology: A Clinical Approach*. I am indebted for their assistance and wish to acknowledge with gratitude each of these authors for their permission to use materials. Individual colleague contributions have been personally recognized in the respective chapter where it appears.

Through the interest and encouragement of colleagues and students at the University of Michigan, the concept of visual and didactic material being placed in proximity was initiated. Organizationally, a concerted effort was made to produce a book for the dental professional that includes fundamental theories of microscopic anatomy for this subject area.

I am most appreciative for the excellent artwork contributed to the book by Alayne Evans and Chris Jung, Medical Illustrators, at the School of Dentistry, University of Michigan. This book has been enhanced through Dr. Donald S. Strachan's expertise in scientific data presentation and analysis. I extend my sincere thanks to all who assisted with the publication. It is hoped that these efforts will provide worthwhile experiences for teachers, students, and practitioners using this text.

James K. Avery



Preface

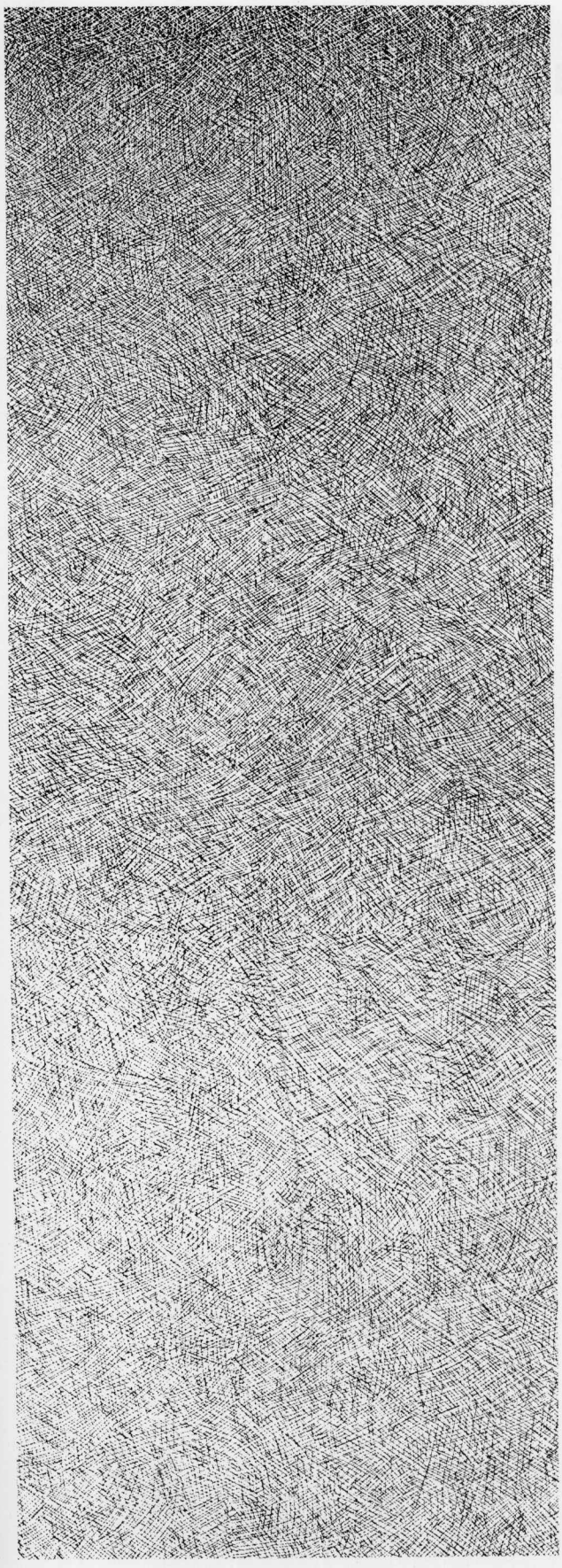
This textbook's purpose is to familiarize dental professionals with knowledge in the fields of oral histology and embryology pertinent to clinical dental hygiene and dental practice. Developmental and structural microscopic anatomy are significant sciences for the practitioner. In acquiring an understanding of how cells, tissues, and organs develop and function, one gains a clearer perspective of these structures and for the basis of their treatment.

Oral histology and embryology are most relevant sciences to the understanding of clinical oral manifestations. Therefore the text has been designed to encompass histologic and embryologic information with specific consideration of clinical connotations. This textbook has been written especially for dental hygiene students, practitioners, educators, and other co-associated professionals.

Several special features are found in this text. Numerous color photographs enhance visual learning. A concerted effort has been made to place all illustrative material as close as possible to the explanatory text. Each chapter has an overview to give a perspective of the chapter content, followed by more detailed descriptions of basic principles of oral histology and embryology and their relationships to clinical practice. This emphasis enables formation of both a practical and a theoretical approach to these essential sciences. Diagrams throughout the text facilitate further comprehension. Also included are low magnification light and high magnification electron microscopic photographs to assist with learning and clarify concepts. A glossary has been included to agument learning.

Professional competence connotes more than technical ability. Therefore an effort has been made to indicate those aspects of basic sciences that complement the technical procedures. Dental professionals must understand and appreciate these concepts involving clinical practice.

Pauline F. Steele



Contents

1

Development and Structure of Cells and Tissues

■ Overview

The smallest unit of structure is the cell, composed of a nucleus and cytoplasm. The nucleus contains the nucleic acids DNA and RNA, the fundamental structures of life. The cytoplasm functions in absorption and cell duplication, in which numerous organelles in the cytoplasm perform specific actions. The cell cycle is the time required for the DNA to duplicate before mitosis. This chapter discusses the four stages of mitosis—prophase, metaphase, anaphase, and telophase. Next, the three periods of prenatal development—proliferative, embryonic, and fetal—are described. The fertilization of the ovum and its implantation in the uterine wall are discussed. In addition, the origin of the human tissues—ectoderm, mesoderm, and endoderm—is presented, followed by the differentiation of tissue types, such as epithelium and skin with its derivatives, and the central and peripheral nervous systems. Finally, the development of connective tissues of the body such as fibrous tissue, cartilage, bone, muscles, and the cardiovascular system is delineated. After reading this chapter, one should better comprehend the origin, development, and organization of the various cells and tissues of the human body.

■ Cell Structure and Function

The human body is composed of cells, intercellular substance, or the products of these cells, and fluid that bathes tissues. Cells are the smallest living units capable of independent existence. They carry out functions of the vital processes of **absorption, assimilation, respiration, irritability, conductivity, growth, reproduction,** and **excretion.** Cells vary in size, shape, and structure, and these components relate to cell function. Regardless of function, each cell has a number of characteristics in common with other cells such as the nucleus and the cytoplasm. Cells are composed of a **nucleus,** containing a **nucleolus,** and the **cytoplasm,** which surrounds the nucleus. The shape of a cell may be related to its function. A cell on the surface of the skin, for example, serves best as a thin, flattened disc, whereas a respiratory cell is cuboidal or columnar to facilitate adsorption, with mobile cilia to move fluid from the lung to the oropharynx. Surrounding each cell is the **intercellular** material that provides the cell with nutrition and takes up waste products; it also provides the body with form. It may be as soft as loose connective tissue or as hard as bone cartilage or teeth. **Fluid,** the third component of the body, is the blood and lymph that travel throughout the body in vessels or the tissue fluid that bathes each cell and fiber of the body.

Cell Nucleus

A nucleus is found in all cells except mature red blood cells and blood platelets. The nucleus is usually round to ovoid, depending on the cell's shape. Ordinarily, a cell has a single nucleus; however, it may be binucleate, as are cardiac muscle and parenchymal liver cells, or multinucleate, as are osteoclasts and skeletal muscle cells. The nucleus contains nucleic acids, the basis of life, and is important in the production of **deoxyribonucleic acid (DNA)** and **ribonucleic acid (RNA).** DNA contains the genetic information in the cell, and RNA carries this information from the DNA to the sites of actual protein synthesis, which are located in the cell cytoplasm. The nucleus is bound by a membrane, the **nuclear envelope,** which has an opening at the nuclear pore. This envelope is associated with the endoplasmic reticulum of the surrounding cytoplasm, which forms at the end of each cell division. The nucleus contains from one to four nucleoli, which are round, dense bodies constituting the RNA contained in the nucleus. It has no limiting membrane (Figure 1.1).

Cell Cytoplasm

Cytoplasm contains structures necessary for the process of adsorption and production of the cell products. The cytoplasm contains **endoplasmic reticulum (ER),** a system of parallel membrane-bound cavities in the cytoplasm that contain newly acquired and synthesized protein. There are two types of ER: smooth-surfaced and granular or rough-surfaced. Smooth and granular ER can be found in the same cell. The rough surface is caused by the location of ribosomes on the surface of the reticulum and is the site protein production is initiated. Proteins are vital to the cell's metabolic processes, and each type of protein is made up of a number and variety of amino acids linked in a specific sequence. Amino acids form protein-containing groups, which in turn form acids or bases.

Ribosomes are particles that translate genetic codes for proteins and activate mechanisms for their production. They can be found free in the cytoplasm, clustered as polyribosomes, or attached to the ER membranes. Ribosomes are nonspecific as to what type of protein they synthesize. This specificity is dependent on messenger RNA (mRNA), which carries the message directly from DNA of the nucleus to the RNA of the ER. This molecule attaches to the ribosomes and gives orders on the formation of specific amino acids.

The ER transports substances in the cell. Then the ER is connected to the Golgi's apparatus via small vesicles. The **Golgi's apparatus** or **complex** functions in sorting, condensing, packaging, and delivering proteins arriving from the ER. The Golgi's apparatus is composed of cisternae (flat plates), or saccules; small vesicles; and large vacuoles. From here the secretory vesicles move or flow to the cell surface, where they fuse with the cell membrane, the plasmalemma, and release their contents by exocytosis.

Lysosomes are small membrane-bound bodies that contain a variety of acid hydrolase and digestive enzymes that function in breaking down substances both inside and outside the cell. They are in all cells except red blood cells but are prominent in macrophages and leukocytes.

Mitochondria are membrane-bound organelles that lie free in the cytoplasm and are present in all cells. They are important in generating energy and are a major source of adenosine triphosphate (ATP), and therefore the site of many metabolic reactions. These organelles appear as spheres, rods, ovoids, or threadlike bodies. Usually, the inner layer of their trilaminar bounding membrane inflects to form transverse-appearing plates, the cristae (Figure 1.1). Mitochondria lie adjacent to the area that requires their energy production.

Microtubules are small tubular structures in the cytoplasm and are composed of the protein tubulin. These structures may appear singular, as doublets, or as triplets. They likely have function as structural and force-generating elements, and they relate to cilia (motile cell processes) and to centrioles in relation to mitosis. They have cytoskeletal functions in maintaining cell shape. **Centrioles** are short cylinders appearing near the nucleus. Their walls are composed of nine triplets, sets of three microtubules. Centrioles are microtubule-generating centers and are important in mitosis, self-replicating before mitosis begins.

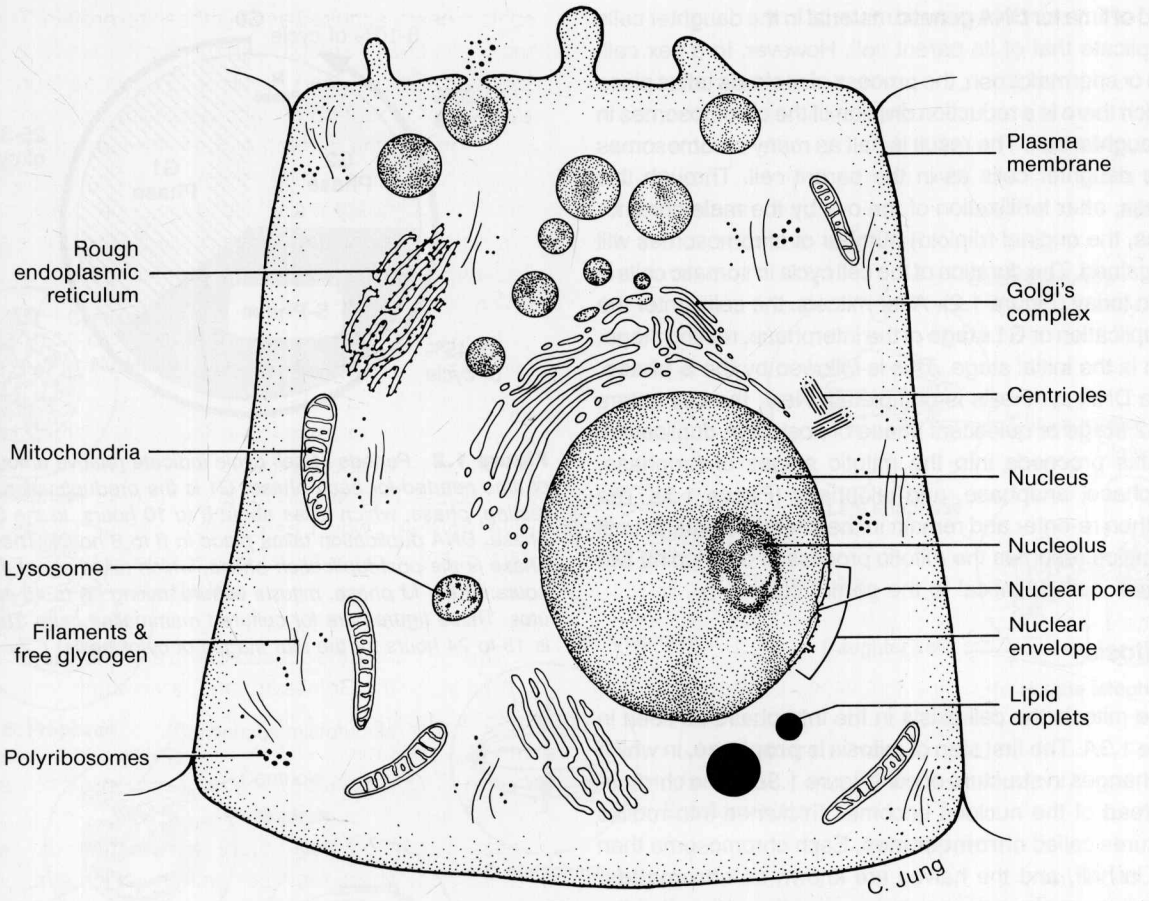


Figure 1.1 *Schematic diagram of cell structure illustrating components such as nucleus, rough endoplasmic reticulum, mitochondria, Golgi's complex, and centrioles as viewed by electron microscopy.*

Surrounding the cell is the **plasma membrane,** plasmalemma, which envelops the cell and provides a selective barrier that regulates transport of substances into and out of the cell. All membranes are composed mainly of lipid and protein with a small amount of carbohydrate. The plasma membrane also receives signals from hormones and neurotransmitters. In addition, cells contain proteins, lipids, or fatty substances that provide energy in the cell and are important components of cell membranes and permeability. Carbohydrates are also important in cells as the most available energy reserve in the body. They may exist as polysaccharides, polysaccharide-protein complexes, glycoproteins, and glycolipids. These compounds are important in cell function as well as in development of cell products such as supportive tissues and body lubricants.

■ *Cell Division*

Cell Cycle

Cell division is a continuous series of discrete steps by which the cell component divides. This function is related to the need for growth or replacement of tissues and is in part dependent on the length of the cells' life. Cells that are continually renewing are those lining the gastrointestinal tract, those composing the epidermis, and those of the bone marrow. A second type of cell is part of an expanding population—the cells of the kidney, liver, and some glands. The third type of cell does not undergo cell division or, therefore, DNA synthesis—for example, neurons of the adult nervous system. For a somatic cell to undergo cell division, it must pass through a **cell cycle,** which ensures a

period of time for DNA genetic material in the daughter cells to duplicate that of its parent cell. However, in a sex cell, ovum or spermatozoon, the process of **meiosis** takes place in which there is a reduction division of the chromosomes in the daughter cell. The result is half as many chromosomes in the daughter cells as in the parent cell. Through this process, after fertilization of the ova by the male chromosomes, the original (diploid) number of chromosomes will be regained. The duration of the cell cycle in somatic cells is known today (Figure 1.2). After mitosis, the cells enter the preduplication or **G1 stage** of the interphase, resting stage, which is the initial stage. This is followed by the **S phase,** where DNA synthesis is completed. Next, the cell enters the **G2 stage** or quiescent phase of post-DNA duplication, and this proceeds into the mitotic stages of prophase, metaphase, anaphase, and telophase (Figure 1.3). The cells then re-enter and remain in the interphase stage until duplication resumes the mitotic process of developing two daughter cells identical to the parent cells.

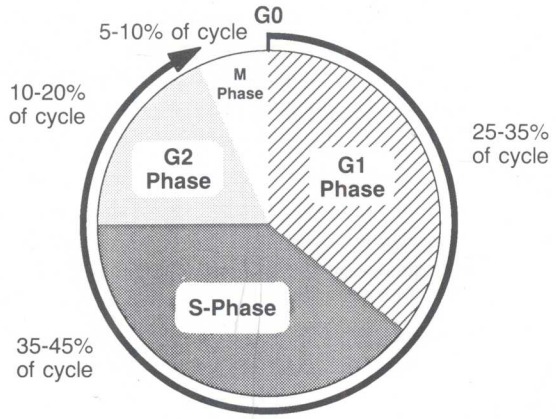


Figure 1.2 *Periods of cell cycle indicate relative amounts of time needed for each phase. G1 is the preduplication, or resting, phase, which takes about 8 to 10 hours. In the S phase, DNA duplication takes place in 6 to 8 hours. The G2 phase is the postduplication phase, which takes about 4 to 6 hours. In the M phase, mitosis occurs, taking 30 to 45 minutes. These figures are for cultured mammalian cells. The total is 18 to 24 hours for the four stages of cytokinesis.*

Mitosis

Before mitosis the cell exists in the interphase as seen in Figure 1.3*A*. The first step of mitosis is **prophase,** in which four changes in structure occur (Figure 1.3*B*). The chromatin thread of the nucleus becomes thickened into rodlike structures called **chromosomes.** Each chromosome then splits in half, and the halves are known as **chromatids.** These line up along the central area of the cell, called the **equatorial plate.** Each chromatid pair is attached to a spherical body termed a **centromere.** As the centriole pair duplicates, there is migration to opposite ends of the cell, accompanied by the chromatids. Those fibers not formed between the migrating centrioles are termed **spindle fibers,** and those that form around each pair of centrioles are termed **astral rays** or **asters** (Figure 1.3*C*). At this time, the nucleolus disappears, and its components become attached to the chromatids. Finally, the nuclear envelope breaks down, changing into granular elements like the endoplasmic reticulum (Figure 1.3*D*).

Upon reaching the **metaphase** stage, the chromatids have moved to the cell center and become arranged along an equatorial plate at right angles to the long axis of the spindle (Figure 1.3*E*). The two chromatids of each chromosome become attached centrally at the equatorial plate to a centromere, with their arms sticking outward. These chromatids then split at the centromere into two sets of chromosomes.

In **anaphase,** the daughter chromosomes move to the opposite poles of the cell, with the full complement of 46 at each end (Figure 1.3*F* and *G*). This is thought to occur by movement of the chromosomal microtubules that attract the chromatids toward the poles. A constriction begins to appear around the midbody of the cell (Figure 1.3*G*).

In **telophase,** the chromosomes detach from the chromosomal microtubules, and the microtubules disintegrate (Figure 1.3*H*). The chromosomes next elongate and disperse, losing their identity and regaining the chromatin thread appearance. Both the nucleoli within the nucleus and the nuclear envelope then reappear. As each nucleus matures, the cleavage furrow deepens in the midcell until the two daughter cells separate (Figure 1.3*H*).

Clinical Comment

All cells have a limited lifetime. For example, the life span of white blood cells is only a few hours to a few days. However, the red blood cells live approximately 120 days and then are ingested by macrophages. Surface covering cells, such as those of the skin, hair, or nails, renew as they are replaced, as do cells lining the respiratory, urinary, and gastrointestinal tracts. Other cells in the body do not normally renew after maturity unless they are injured, such as the cells of the liver, kidneys, and thyroid gland.

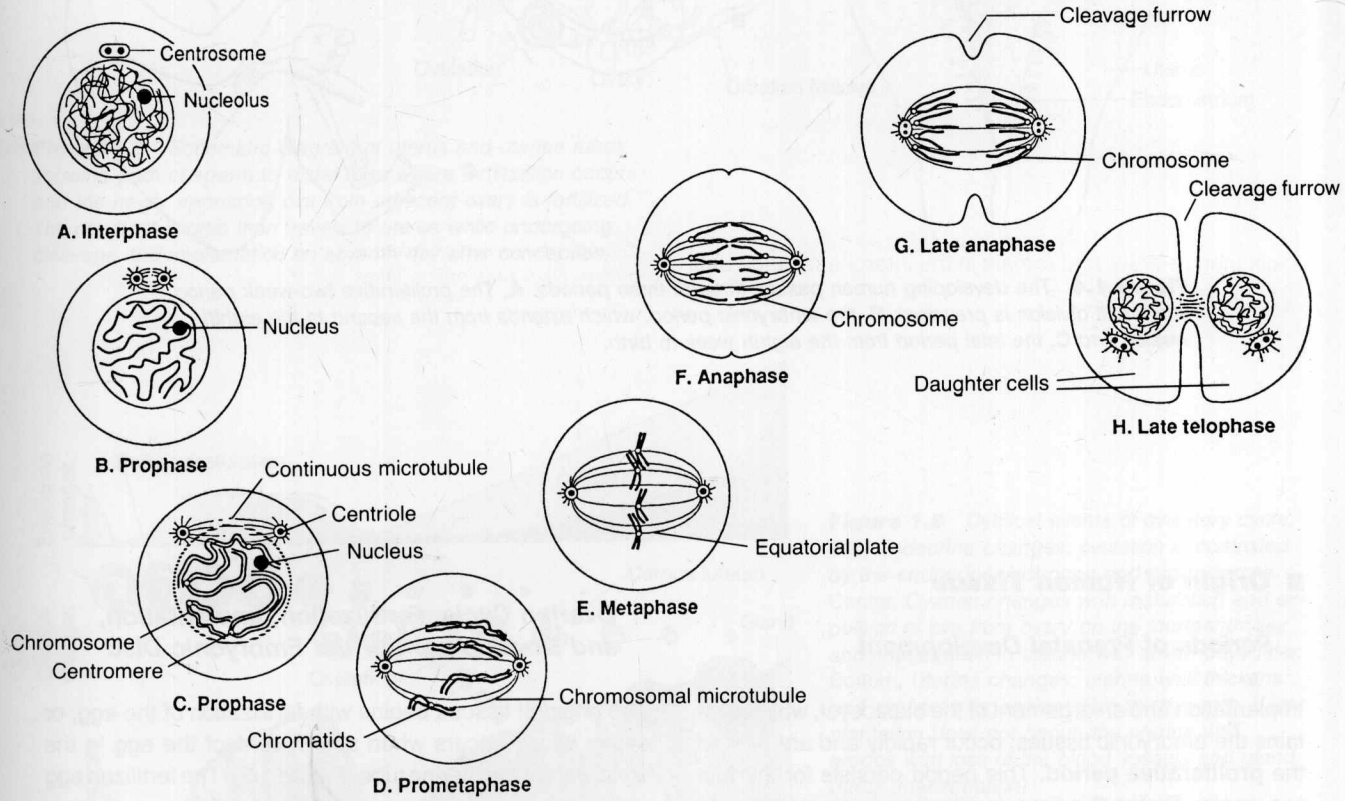


Figure 1.3 *Mitosis of somatic cell. The continuous process of cell division is shown in* A *to* H. *Mitosis is replication of parent chromosomes and distribution of two sets of chromosomes into two separate and equal nuclei. The stages are as follows:* (A) *Interphase, the resting cell.* (B and C) *During prophase, the chromatin thread shortens, thickens, and becomes chromosomes, which then split into pairs or chromatids. The nuclear membrane disappears, and the centrioles appear and begin migration to the opposite poles of the cell.* (D) *In the prometaphase, or early metaphase, the chromatid pairs attach to centromere and line up in the equatorial plate of the cell.* (E) *Metaphase occurs when the centromeres and chromatids line up in middle of cell. Centrioles are at opposite ends of cell and attach to chromosomes by mitotic spindles.* (F) *Anaphase is a division of centromeres and movement of the completed identical sets of chromatids (chromosomes) to opposite ends of the cells.* (G) *In late anaphase, identical sets of chromosomes have reached the opposite pole and cell cleavage begins.* (H) *In telophase, a nuclear membrane reappears, nucleoli appear, and chromosomes lengthen and form a chromatin thread. Mitotic spindles disappear, and centrioles duplicate so that each cell has completely identical properties.*

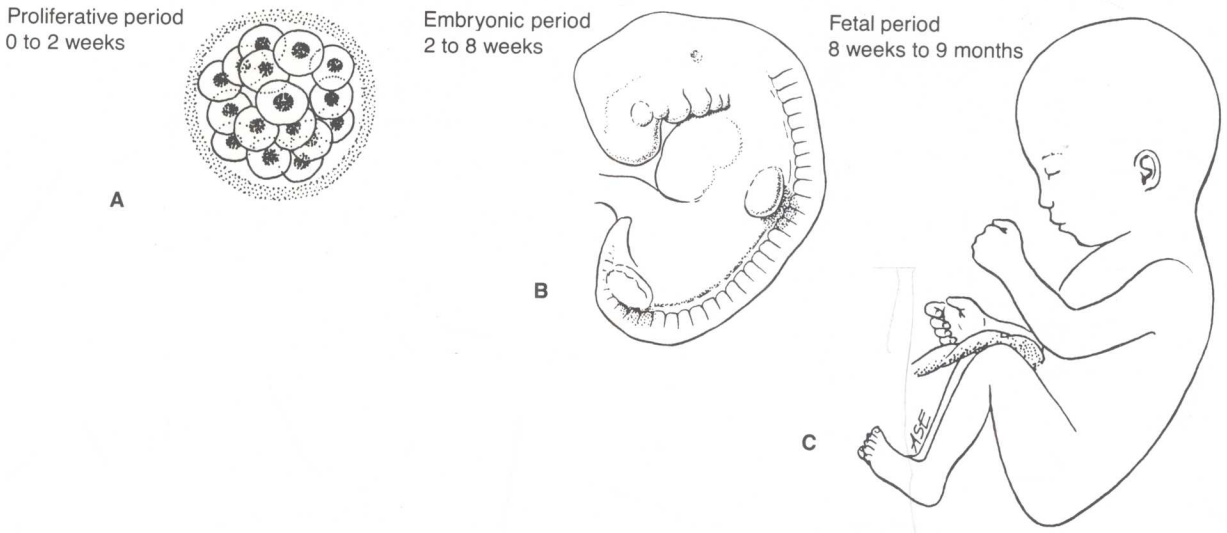


Figure 1.4 *The developing human passes through three periods:* **A,** *The proliferative two-week period, when cell division is prevalent;* **B,** *the embryonic period, which extends from the second to the eighth weeks, and* **C,** *the fetal period from the eighth week to birth.*

■ Origin of Human Tissue

Periods of Prenatal Development

Implantation and enlargement of the blastocyst, which contains the embryonic tissues, occur rapidly and are termed the **proliferative period.** This period persists for the first two weeks. During this time, fertilization, implantation, and formation of the embryonic disc takes place. After the second week, this mass of cells begins to take the form of an embryo, so the period of two to eight weeks is appropriately termed the **embryonic period.** During this period, the different types of tissues develop, organizing to form organ systems located in various areas of the embryo. The heart forms and begins to beat. The face and oral structures develop. At eight weeks, the embryo takes on a more human appearance and passes into the **fetal period,** which extends until birth (Figure 1.4). The increase in body weight and size reflects the beginning of various organs and systems.

Ovarian Cycle, Fertilization, Implantation, and Development of the Embryonic Disc

The origin of tissues begins with fertilization of the egg, or ovum, which occurs when sperm contact the egg in the distal part of the uterine tube (Figure 1.5). The fertilized egg grows and is termed the **zygote.** The cell mass produces a ball of cells, the **morula,** in the uterine tube. The morula begins migration medially to the uterus, reaching it at the end of the first week. The uterine cavity meanwhile was preparing for the arrival of the fertilized ovum by a thickening of the uterine lining, or **endometrium,** and the development of capillaries and glands to nourish the ovum. This cyclical event is under the control of the hormones estrogen and progesterone (Figure 1.6). The morula increases in size and is termed a **blastocyst.** As it swells, it becomes hollow and develops a small inner cell mass. When this ball of cells reaches the uterine cavity, it attaches to the sticky wall and becomes embedded as the surface cells of the zygote digest the endometrium, permitting deeper penetration. This process is known as **implantation** (Figures 1.5 to 1.7).

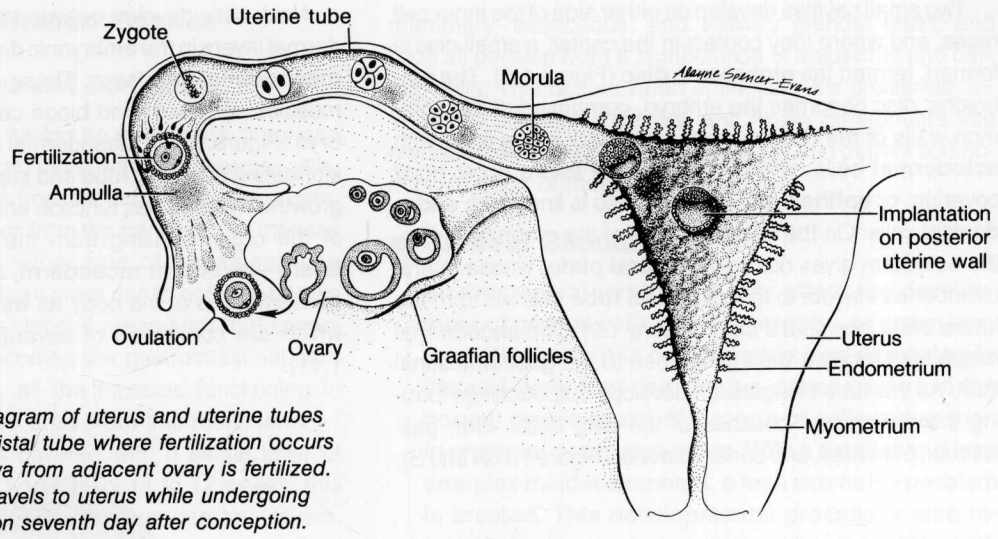


Figure 1.5 *Schematic diagram of uterus and uterine tubes showing path of sperm to distal tube where fertilization occurs and the newly appearing ova from adjacent ovary is fertilized. The resultant zygote then travels to uterus while undergoing cleavage and implantation on seventh day after conception.*

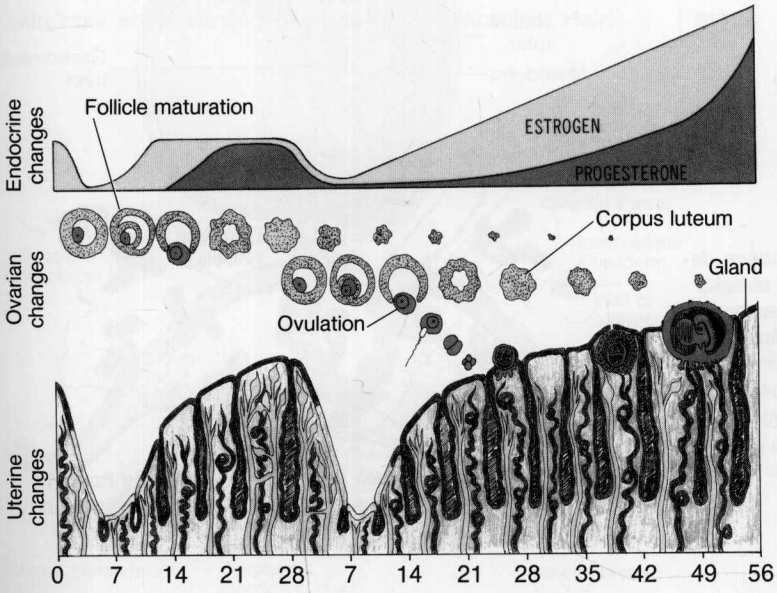


Figure 1.6 *Cyclical events of ovulatory cycle.* Top, *Endocrine changes: ovulation is controlled by the endocrines estrogen and progesterone.* Center, *Ovarian changes with maturation and expulsion of ova from ovary on the fourteenth day and implantation in uterine wall seven days later.* Bottom, *Uterine changes: uterine wall thickens and prepares for implantation each month. If implantation does not occur, the uterine wall erodes with loss of the blood vessels and gland ducts (menstruation).*

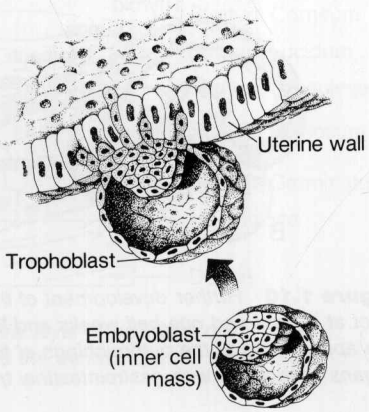


Figure 1.7 *Implantation of fertilized ovum (zygote) in wall of uterus. Outer cells of trophoblast digest uterine cells in order to implant. Embryoblast develops within cell mass and, as cell mass expands, forms a surrounding cavity.*

Two small cavities develop on either side of the inner cell mass, and where they contact in the center, a small disc is formed, termed the **embryonic disc** (Figure 1.8). The embryonic disc becomes the embryo, composed of the common walls of the two adjacent sacs. One sac is lined with **ectodermal** cells, which will form the future outer body covering, or **epithelium.** The other sac is lined with **endodermal** cells. On the dorsal surface of the embryonic disc, the ectoderm gives rise to the **neural plate,** whose lateral boundaries elevate to form a **neural tube** that will form the future brain and spinal cord (Figure 1.9). The endodermal tissue also forms a tube giving rise to the gastrointestinal tract. As this tube elongates, it develops outpouchings forming the pharyngeal pouches of the lung buds, liver, gallbladder, pancreas, and urinary bladder (Figure 1.10*A* and *B*).

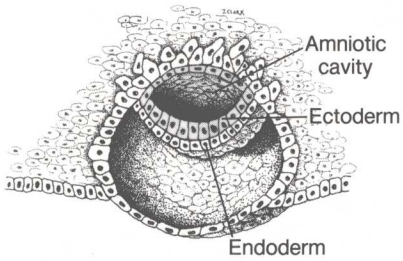


Figure 1.8 *A second small cavity lined with ectoderm develops (amniotic cavity). The other cavity (yolk sac) is lined with endoderm. The two cell layers contact in the center to form an area of ectoderm and endoderm (embryonic disc).*

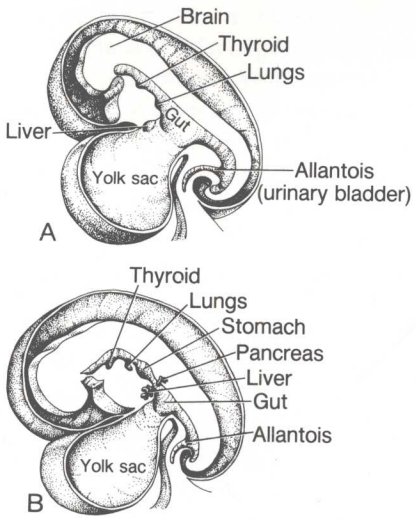


Figure 1.10 *Further development of the gastrointestinal tract at* **A,** *four and one-half weeks and* **B,** *five weeks. Note the appearance of the outpouchings of tube that will form the organs associated with gastrointestinal tract.*

Next, cells develop between the ectodermal and endodermal layers in the embryonic disc. This area becomes the **mesodermal cell layer.** These cells will develop into the muscles, skeleton, and blood cells of the developing embryo (Figure 1.11). Mesodermal cells also accompany the elongating digestive tube and support its walls with muscle growth. This enables function and aids in the development of the organs arising from the tract. From these three layers—**ectoderm mesoderm,** and **endoderm**—develop all the tissues of the body as well as the complex organs, which are composed of several types of tissue (Figure 1.11).

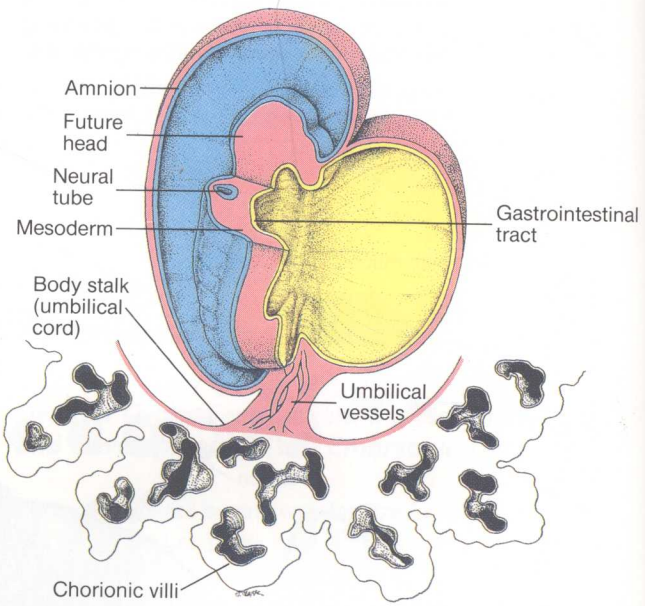


Figure 1.9 *A three-week human embryo, viewed from the ventral aspect, illustrating an elongating gastrointestinal tube and dorsally located neural tube.*

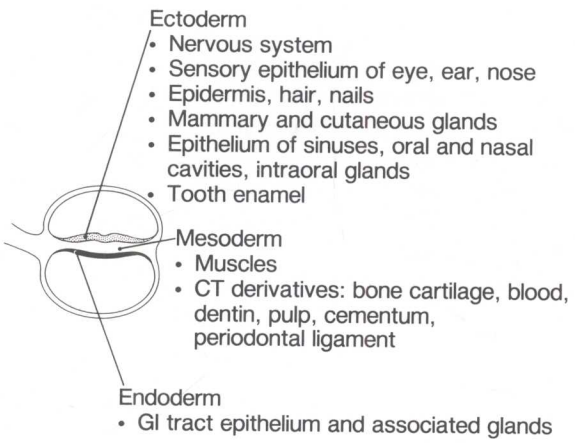


Figure 1.11 *Derivatives of ectoderm, mesoderm, and endoderm germ layers.*

■ Development of Human Tissues

Epithelial Structures and Derivatives

The skin is of dual origin, having an **epidermis,** a surface cell layer that develops from the surface ectodermal cells, and a **dermis,** which arises from the underlying mesoderm. The dermis originally comes from the **somites,** the masses of mesoderm that lie on either side of the neural tube (Figure 1.12). This mesoderm gives rise to both the dermis of the epithelium and the visceral mesoderm that covers the yolk sac and later becomes the gastrointestinal tract (Figure 1.12). Therefore, all the muscles functioning in peristalsis of the intestines arise from this mesoderm.

Initially, the embryo is covered with a single layer of ectodermal cells (Figure 1.13*A*.). By 11 to 12 weeks, this ectodermal layer or epithelium thickens into four layers. The basal layer of cells gives rise to the more superficial cells of the epithelium (Figure 1.13*B*). Later, **melanocytes** invade and pigment the skin (Figure 1.13*B*). At birth, the skin may show varying degrees of keratinization. Hair; mammary, sebaceous, and salivary glands; teeth, and nails all develop from a combination of epidermal and dermal cells. This occurs when epithelial cells proliferate, invade the underlying dermis, and finally differentiate into glands or teeth, with both the epidermis and dermis contributing to each of these structures.

■ Clinical Comment

Environmental teratogens may affect the development of normal cells, tissues, organs, or organ systems. However, it is considerably less damaging to life and body function when a defect occurs in the normal development of a group of cells rather than in an organ or organ system. With a smaller and less complex maldevelopment, a less extensive problem is created. This developmental process is also related to timing, and when tissues begin to differentiate in the embryonic period (four to eight) weeks, they are the most susceptible to defective development.

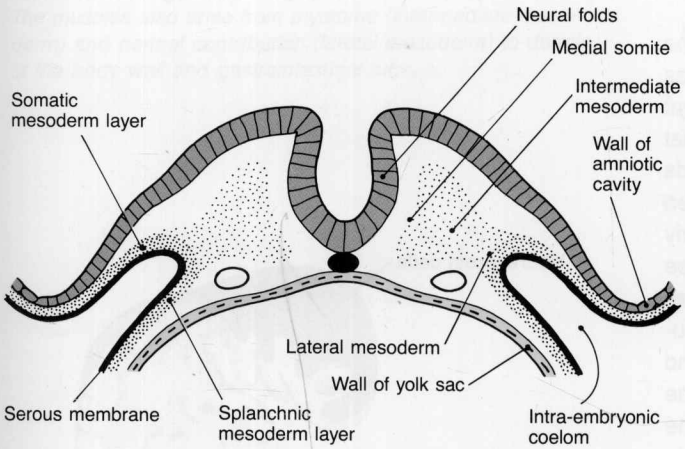


Figure 1.12 *The neural folds and somites in transverse section at approximately 20 days after conception. The medial somite, or mesoderm, forms the axial skeletal surrounding the neural tube. The intermediate mesoderm forms the striated muscle of the body, and the lateral mesoderm forms the dermis of the epithelium of the body wall (somatic) and of the gastrointestinal tract (splanchnic).*

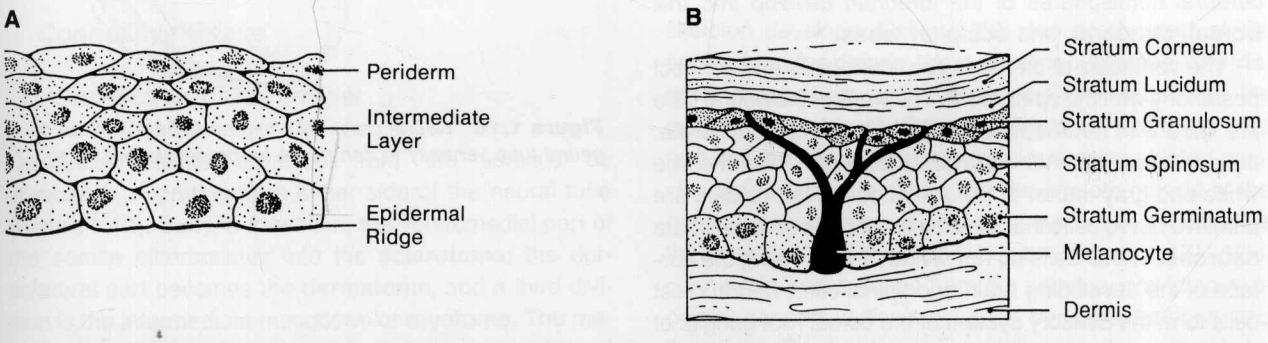


Figure 1.13 *Development of skin* **A,** *at four weeks and* **B,** *36 weeks. Initial layer of epithelial cells thickens into multiple layers, and the underlying connective tissue becomes the dermis. Dermis and epithelium combine to become skin.*

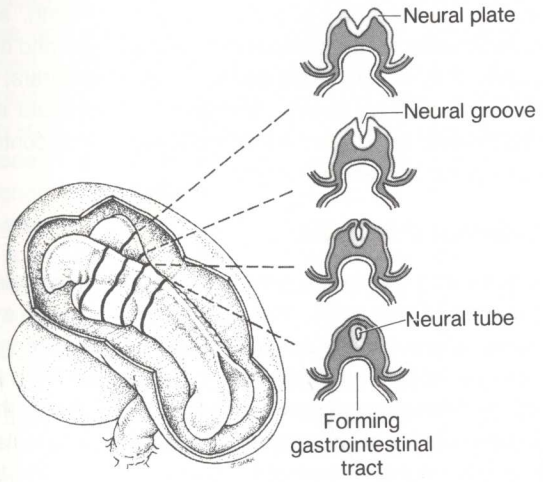


Figure 1.14 Left, *Dorsal view of the closing neural tube of a three-week human embryo. Note closure occurs initially in dorsal central area and then anteriorly and posteriorly.* Right, *Transverse sections of neural folds appear anteriorly, and those of the closed neural tube are in the midregion.*

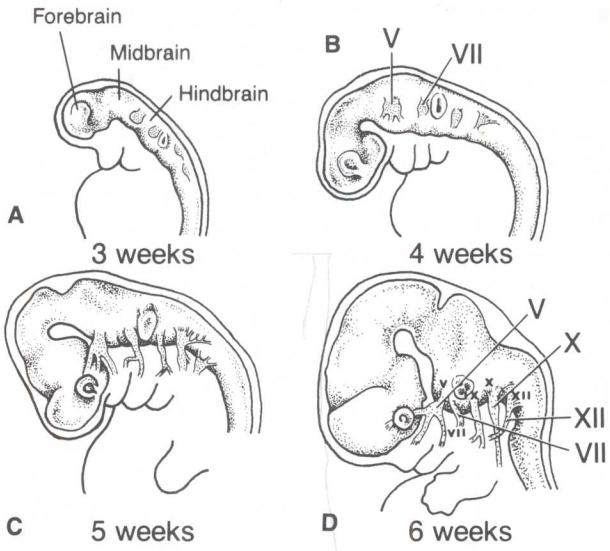


Figure 1.15 *Development of the cranial nerves at* **A,** *three weeks,* **B,** *four weeks,* **C,** *five weeks, and* **D,** *six weeks. At three weeks, the forebrain has enlarged and the sensory vesicles are laterally located. At four and five weeks, the forebrain has bent forward, and cranial nerves have grown into tissues they innervate. At six weeks, anterior brain has enlarged and bent back on the posteriorly located cerebellum.*

Nervous System

The neural folds appear during the third prenatal week. The lateral edges of the neural plate then begin to elevate as folds that arise dorsally (Figure 1.9). These folds represent the first change in shape of the embryo's body from the flat sheet of cells described earlier (Figure 1.8). These folds contact in the midline, first in the cervical region, and then the neural tube closes both anteriorly and posteriorly (Figure 1.14). When the anterior tube closes, it shows three dilations that form the primary brain vesicles—the **forebrain, midbrain,** and **hindbrain** (Figure 1.15*A*). The neural tube then bends forward just behind the midbrain and backward behind the hindbrain (Figure 1.15*C* and *D*). The **cerebral hemispheres** develop from the forebrain. The midbrain is a pathway from the cerebral cortex to centers in the **pons** and **cerebellum** in the hindbrain. The fifth cranial nerve develops in the midbrain (Figure 1.15*B* to *D*). The cerebral hemispheres of the forebrain develop into the **frontal, temporal,** and **occipital lobes.**

The ventricles of the brain are continuous and connect posteriorly with the spinal cord. The walls of the neural tube are lined with neuroepithelium. As these cells proliferate, they differentiate into **neuroblasts,** which become the white and gray matter of the spinal cord. Neuroblasts are primitive nerve cells that develop into adult nerve cells, the **neurons.** These cells do not divide further. Along the surface of the developing brain and spinal cord, neural crest cells form the sensory system of the dorsal root ganglia of the cranial and spinal nerves (Figure 1.16). The neural crest cells also contribute to tissues of the face, such as cartilages, bones, muscles, teeth, and ligaments.

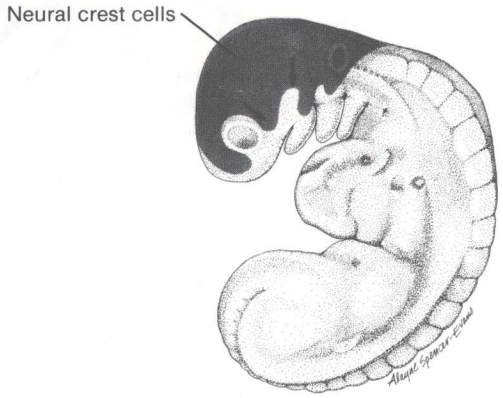
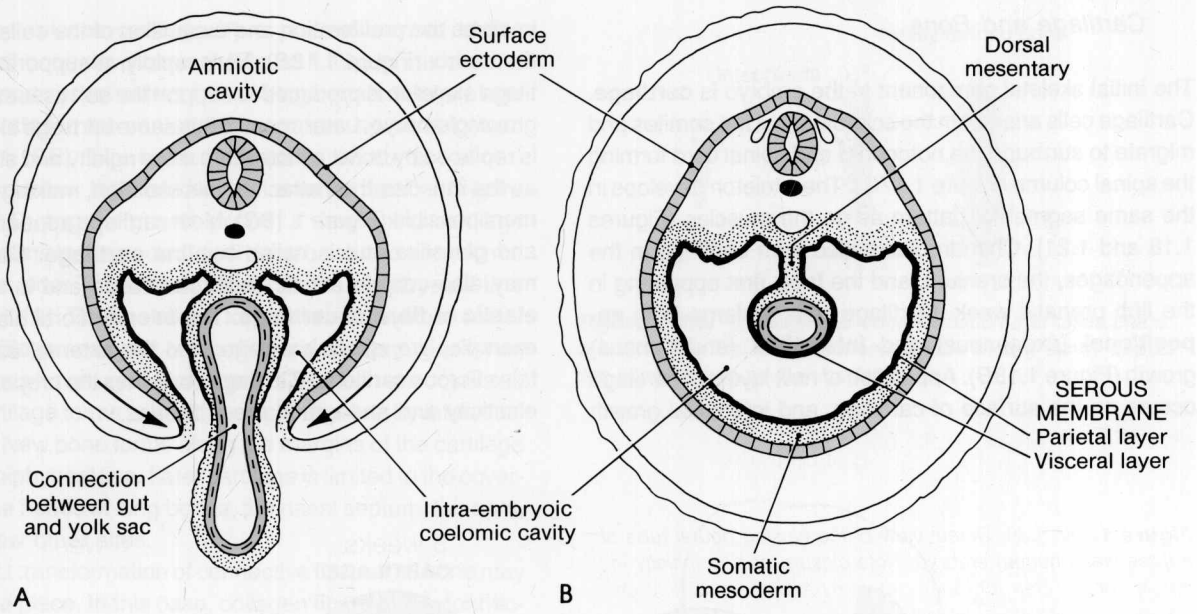


Figure 1.16 *Neural crest cells migrating from surface of neural tube ventrally to contribute to the developing face.*



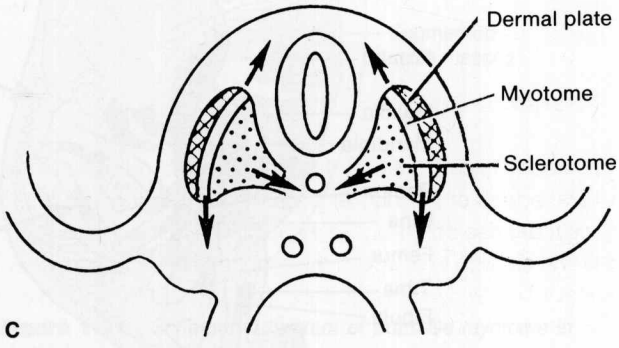


Figure 1.17 **A** *and* **B,** *Cross-sections of an embryo illustrating how yolk sac is incorporated into the elongating body as a gastrointestinal tube, and the elongating neural tube and enlarging brain at four weeks.* **C,** *The contribution of the somite to cartilage support of spinal column (the sclerotome). The muscles also arise from myotome (intermediate mesoderm) and dermal contribution (lateral mesoderm) to dermis of the body wall and gastrointestinal tube.*

Connective Tissue

Connective Tissue Proper

Connective tissue develops from the somites as fibroblasts, migrating from either side of the neural tube (Figure 1.12). Early in formation, the ventromedial part of the somite differentiates into the **sclerotome;** the dorsolateral part becomes the **dermatome,** and a third division is the intermediate mesoderm or **myotome.** The medial sclerotome portion differentiates into **mesenchymal cells,** which become **osteoblasts, chondroblasts,** and **fibroblasts.** From these cells, a large part of the embryonic skeleton develops. Cells of the dermatome part of the somite form the dermis, the subcutaneous tissue, and **visceral mesoderm,** which supports the endoderm of the gastrointestinal tract (Figure 1.17*A* to *C*). From the third part, the myotome develops muscle, such as striated muscles of the body and limbs and the smooth muscle of the gastrointestinal tract, as well as a system of mesenteries that stabilize and support this tube (Figure 1.17). Also, connective tissue arises from the somites, providing supporting connective tissues, bones, cartilage, tendons, and ligaments. The tendons connect the muscles to the skeleton as they develop. Connective tissue also functions as capsules of glands and the supporting tissues within them.