See 2

INTRODUCTION

ANATOMIC PLANES & SECTIONS

CN: (1) Color the four body planes and related sections of the body in very light colors. (2) Take care not to color in areas marked by "do not color" (-;-) symbols.

Study of the human body (anatomy) requires visualization of internal regions or parts. Dissection (dis, apart; sect-, cut) is the name given to preparing the body for internal inspection. One method of dissection permits consistent visual orientation by cutting the body into parts or sections along fixed lines of reference called planes. Two of these planes are oriented along the long axis of the body or body part, one perpendicular to the other (longitudinal sections). The third plane is oriented perpendicular to or across the long axis of the body or body part (cross section). Such planes have application in medical imaging studies, such as computerized tomography (CT) and magnetic resonance imaging (MRI). Here the body interior is imaged as computerized "slices" of the body in sagittal, coronal and transverse planes.

MEDIAN A

The midline, longitudinal plane dividing the head and torso into right/left halves. The presence of the vertebral column and spinal cord is characteristic of the median plane of the torso. The median plane is the middle sagittal plane.

SAGITTAL B

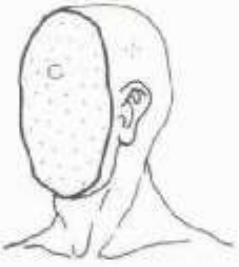
The longitudinal plane dividing the body into left and right parts. It is parallel to the median plane and may be applied to the head, torso and limbs.

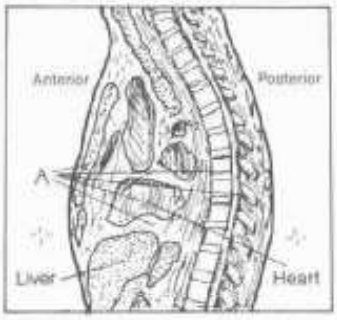
CORONAL, FRONTAL C

The longitudinal plane dividing the body into equal or unequal front and back parts. In CT and MRI, the term "coronal" is used by radiologists.

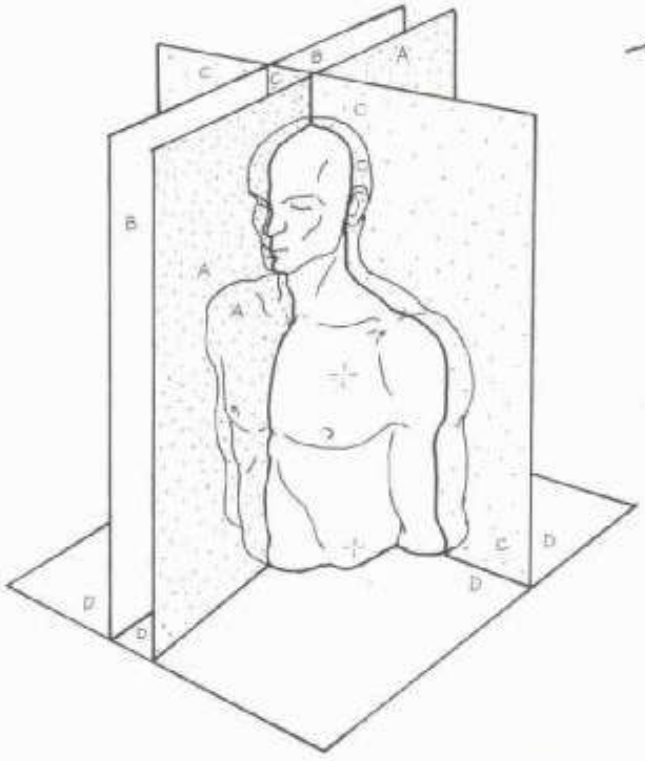
CROSS, TRANSVERSE D

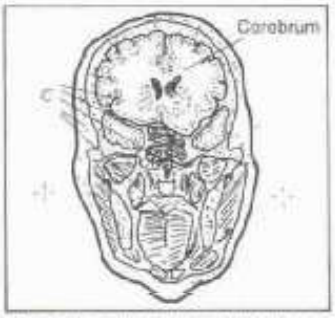
The transverse plane dividing the body or body parts into upper and lower segments. This plane is a cross section perpendicular to the longitudinal planes. Transverse planes of the body, called axial or transaxial sections by radiologists, are commonly seen in CT and MRI studies of the body.



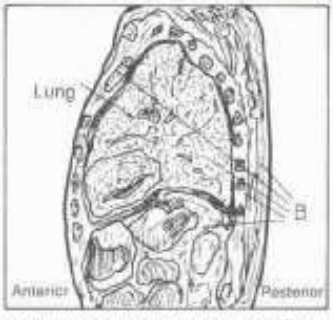


Median section through the thorax.

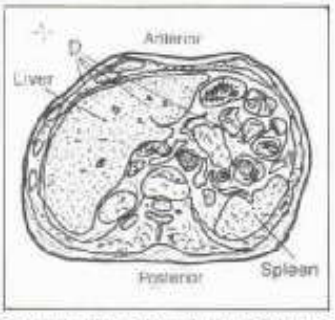




Coronal section through the head.



Sagittal section through the thorax.



Cross section through the abdomen.

INTRODUCTION
TERMS OF POSITION & DIRECTION

CN: (1) Use bright or dark colors for emphasis.
(2) Color the arrows but not the illustrations.

Terms of position and direction describe the relationship of one organ to another, usually along one of the three body planes illustrated in the previous plate. To avoid confusion, these terms are related to the standard *anatomical position*: body standing erect, limbs extended, palms of the hands forward.

CRANIAL, SUPERIOR, ROSTRAL A

These terms refer to a structure being closer to the head or higher than another structure of the body. See the quadruped in the right corner for a related application of the term "cranial."

ANTERIOR, VENTRAL B

These terms refer to a structure being more in front than another structure in the body. The term "anterior" is preferred. See the quadruped for another application of the term "ventral."

POSTERIOR, DORSAL C

These terms refer to a structure being more in back than another structure in the body. The term "posterior" is preferred. See the quadruped for another application of the term "dorsal."

MEDIAL D

This term refers to a structure that is closer to the median plane than another structure in the body. "Medial" is *not* synonymous with "median."

LATERAL E

This term refers to a structure that is further away from the median plane than another structure in the body.

PROXIMAL F

Employed only with reference to the limbs, this term refers to a structure being closer to the median plane or root of the limb than another structure in the limb.

DISTAL G

Employed only with reference to the limbs, this term refers to a structure being further away from the median plane or the root of the limb than another structure in the limb.

CAUDAL, INFERIOR H

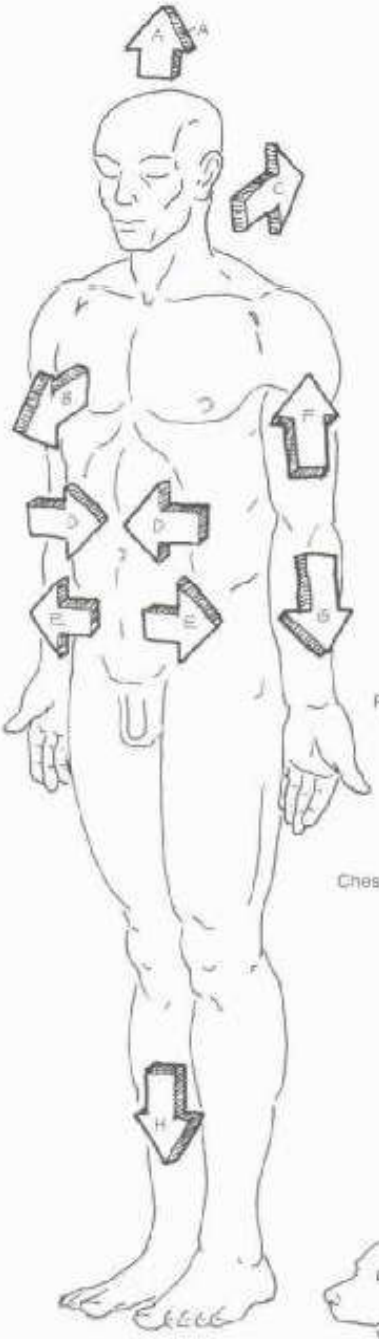
These terms refer to a structure being closer to the feet or the lower part of the body than another structure in the body. See the quadruped for a related application of the term "caudal."

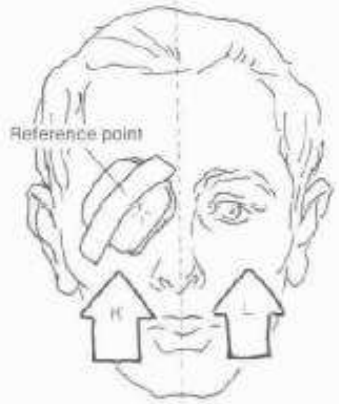
SUPERFICIAL I, DEEP J

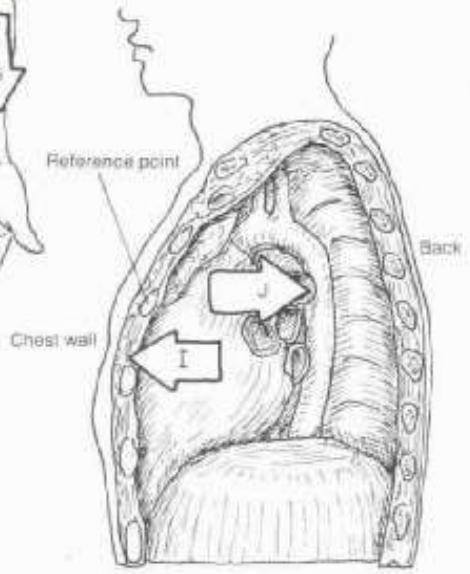
The term "superficial" is synonymous with external, and the term "deep" with internal. Related to the reference point on the chest wall, structure closer to the surface of the body is superficial; structure further away from the surface is deep.

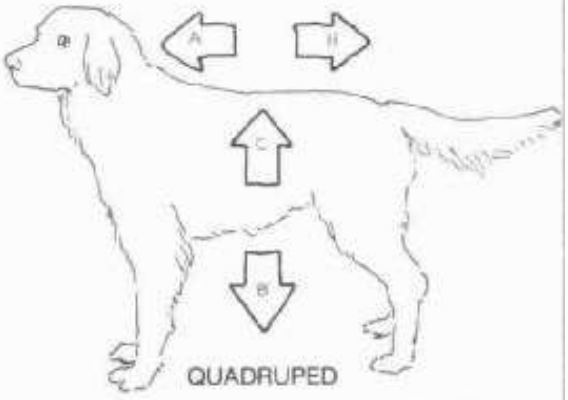
IPSILATERAL K, CONTRALATERAL L

The term "ipsilateral" means "on the same side" (in this case, as the reference point); "contralateral" means "on the opposite side" (of the reference point).









QUADRUPED

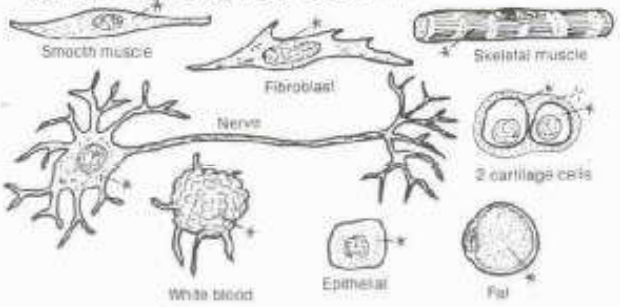
The quadruped presents four points of direction: head end (cranial), tail end (caudal), belly side (ventral), back side (dorsal). In the biped (e.g., human), the ventral side is also anterior, the dorsal side is also posterior, the cranial end is also superior, and the caudal end is inferior.

I. ORGANIZATION OF THE BODY

THE GENERALIZED CELL

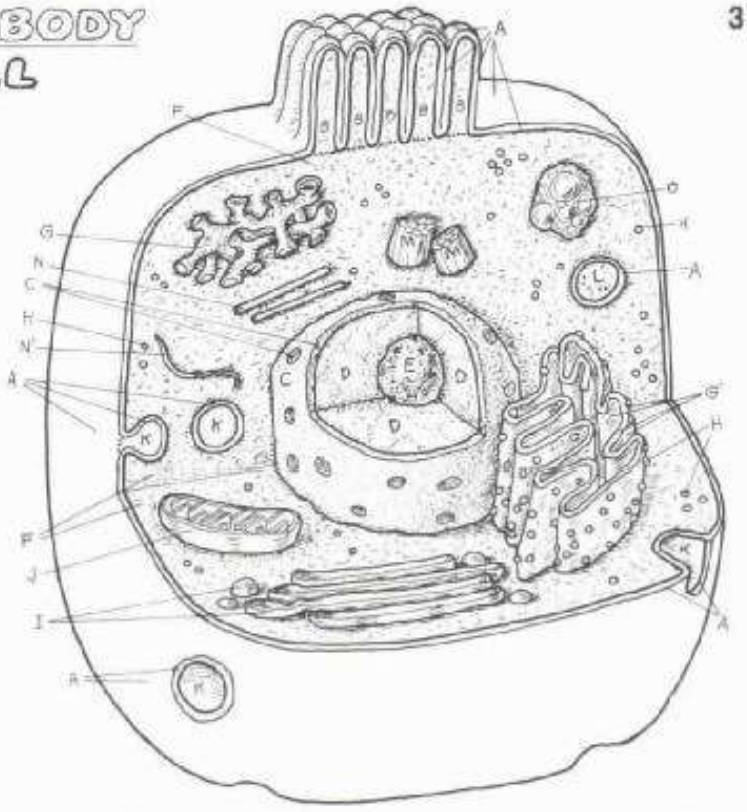
CN: Color gray the variety of cell shapes at upper left. Use lightest colors for A, B, C, D, F and G. (1) Small circles representing ribosomes (H) are found throughout the cytoplasm (F) and on the rough endoplasmic reticulum (G'); color those larger areas, including the ribosomes, first, and then color over the ribosomes again with a darker color. Each organelle shown is just one of many found in the living cell.

CELL SHAPES:



ORGANELLES:

CELL MEMBRANE A
MICROVILLI B
NUCLEAR MEMBRANE C
NUCLEOPLASM D
NUCLEOLUS E
CYTOPLASM F
ENDOPLASMIC RETICULUM
SMOOTH G ROUGH G'
RIBOSOME H
GOLGI COMPLEX I
MITOCHONDRION J
VACUOLE / PINOCYTOTIC
VESICLE K
LYSOSOME L
CENTRIOLE M
MICROTUBULE N
MICROFILAMENT N'
CELL INCLUSION O



The cell is the basic structural and functional unit of all living things. Living things are characterized by the ability to reproduce and grow, metabolize (transformation or production/consumption of energy), and adapt to limited changes in their internal and external environment. Body structure lacking these characteristics, such as connective tissue fibers, is not considered to be "alive." Body structure more complex than a cell consists of a collection of cells and their products.

The activities of cells constitute the life process, and include ingestion, assimilation, and digestion of nutrients, and excretion of the residue; respiration; synthesis and degradation of materials; movement; and excitability or response to stimuli. The impairment or cessation of these activities in normal cells, whether caused by trauma, infection, tumors, degeneration, or congenital defects, is the basis of a disordered or disease process.

The chemical composition of a cell is generally about 15% protein, 3% lipids, 1% carbohydrates, 1% nucleic acids and minerals, and 80% water (by volume). These compounds are integrated together into *organelles*, the working components of the cell. The basic function of cells is to produce protein, the structure of which is determined by DNA. The manifestation of this activity is the characteristic function of the cell (e.g., formation, repair, and breakdown of structure, secretion, absorption, contraction, conduction of electrochemical impulses, and so on).

Cell membrane: the limiting membrane of the cell; retains internal structure; permits exportation and importation of materials. Composed primarily of lipid and protein, and a smaller amount of carbohydrate.

Microvilli: finger-like extensions of the cell membrane covering the free surface of certain epithelial cells; they increase the surface area of the cell, enhancing secretion/absorption.

Nuclear membrane: porous membrane of similar construction to the cell membrane; the limiting membrane of the nucleus, separating it from the cytoplasm; regulates passage of molecules.

Nucleoplasm: the ground substance of the nucleus, containing the chromatin or thin threads of genetic material (DNA and related protein). During cell division, the chromatin transforms into chromosomes.

Nucleolus: a mass of largely RNA (and some DNA and protein) in the nucleus producing units of RNA which combine in the cytoplasm to form ribosomes.

Cytoplasm: the ground substance of the cell less the nucleus. Contains organelles and inclusions listed below.

Smooth/rough endoplasmic reticulum (ER): membrane-lined tubules to which ribosomes may be attached (rough ER; flattened tubules) or not (smooth ER; rounded tubules). Rough ER is concerned with transport of protein synthesized at the ribosomes. Smooth ER synthesizes complex molecules called steroids in some cells; stores calcium ions in muscle; breaks down toxins in liver.

Ribosome: the site of protein synthesis where amino acids are strung in sequence as directed by messenger RNA from the nucleus.

Golgi complex: flattened membrane-lined sacs which bud off small vesicles from the edges; collect secretory products and package them for export or cell use.

Mitochondrion: membranous, oblong structure in which the inner membrane is convoluted like a maze. Energy for cell operations is generated here through a complex series of reactions between oxygen and products of digestion.

Vacuoles/pinocytotic vesicles: membrane-lined containers which can merge with one another or other membrane-lined structure, such as the cell membrane. They function as transport vehicles.

Lysosome: membrane-lined container of enzymes with great capacity to break down structure, especially ingested foreign substances.

Centriole: bundle of microtubules in the shape of a short barrel; usually seen paired, perpendicular to one another. They give rise to spindles used by migrating chromatics during cell division.

Microtubule: microtubules are formed of protein and provide structural support for the cell.

Microfilament: microfilaments are support structures formed of protein different from that of microtubules. In skeletal muscle, the proteins actin and myosin are examples of thin and thick microfilaments.

Cell inclusion: aggregation of material within the cell that is not a functional part (organelle) of the cell, e.g., glycogen, fat, and so on.

See 3

I. ORGANIZATION OF THE BODY
CELL DIVISION / MITOSIS

CN: Use the colors you used on Plate 3 for cell membrane, nuclear membrane, nucleolus, and centriole for those titles on this plate, even though the previous letter labels may be different. Use contrasting colors for E–E² and F–F², and gray for D–D¹ to distinguish the latter from those with the contrasting colors. (1) Begin with the cell in interphase, reading the related text and completing each cell before going on to the next. (2) Color gray the name of each stage and its appropriate arrow of progression. Note that in interphase, the chromatin material within the nuclear membrane is in a thread-like state; color over the entire area with the appropriate color. Note that the starting chromatin (D* in interphase) is colored differently in the daughter cells (E², F²); it is the same chromatin.

CELL MEMBRANE A
NUCLEAR MEMBRANE B
NUCLEOLUS C
CHROMATIN D / CHROMOSOME D¹*
CHROMATID E / CHROMOSOME E¹
CHROMATIN E²
CHROMATID F / CHROMOSOME F¹
CHROMATIN F²
CENTROMERE G
CENTRIOLE H
ASTER I
SPINDLE J

The ability to reproduce its kind is a characteristic of living things. Cells reproduce in a process of duplication and division called mitosis. Epithelial and connective cells reproduce frequently; mature muscle cells not so frequently; mature nerve cells rarely if at all. Overactive mitoses may result in the formation of an encapsulated tumor, uncontrolled mitoses, associated with invasiveness and metastases, is called cancer.

As the main cellular changes during mitosis occur in the nucleus and surrounding area, only these parts of the cell are illustrated here. We are showing here how the nuclear chromatin (diffuse network of DNA and related protein), once duplicated, transforms into 46 chromosomes which divide into paired subunits (92 chromatids), and how those chromatids separate and move into opposite ends of the dividing cell, forming the 46 chromosomes of each of the newly formed daughter cells. For clarity, we show only 4 pairs of chromatids and chromosomes. The phases of the observed nuclear changes during mitosis are:

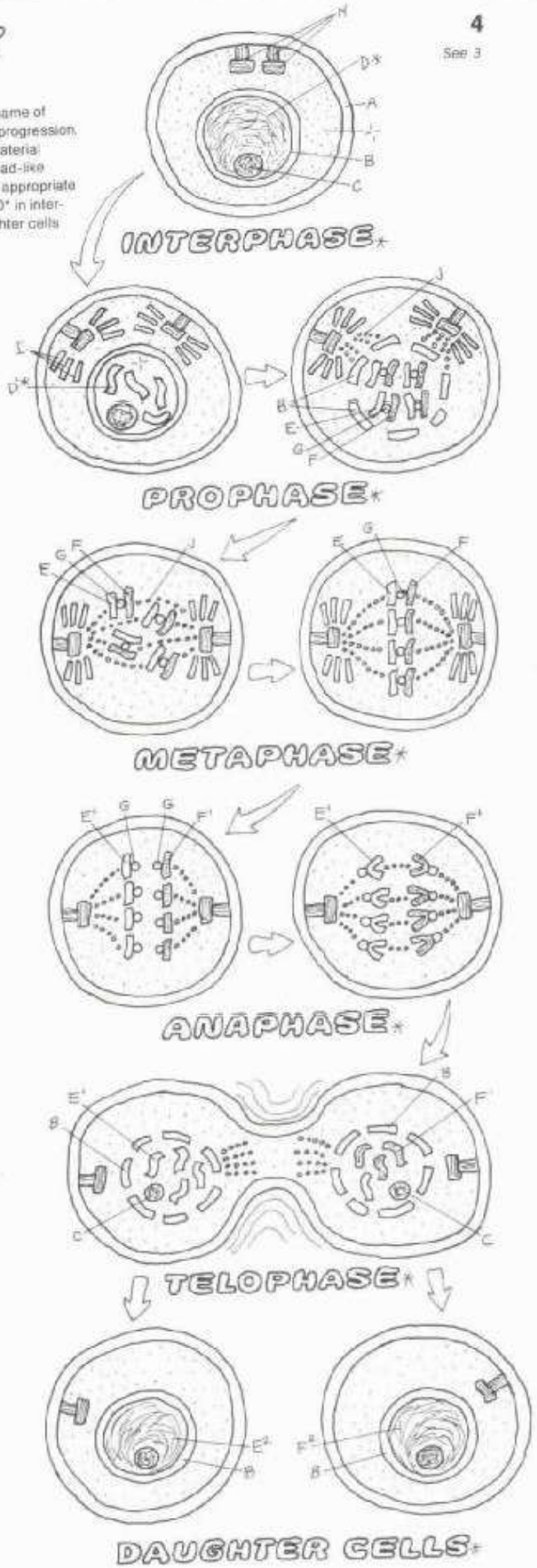
Interphase: the longest period of the reproductive cycle; the phase between successive divisions. Duplication of DNA (in chromatin) occurs during this phase. The dispersed chromatin (D*) here is a network of fine fibrils, not visible as discrete entities in the nucleoplasm. The cell membrane, nucleus, and nucleolus are intact. The centrioles are paired and adjacent to one another at one pole of the cell.

Prophase: the dispersed chromatin (D*) thickens, shortens, and coils to form condensed chromatin or chromosomes (D¹*). Each chromosome consists of 2 chromatids (E and F) connected by a centromere (G). Each chromatid has the equivalent amount of DNA of a chromosome. In the latter part of this phase, the nuclear membrane breaks up and dissolves, as does the nucleolus. The centrioles, having duplicated during interphase, separate, each pair going to opposite poles of the cell. They project microtubules called asters.

Metaphase: strands of spindle fibers project across the cell center from paired centricles. The chromatids attach to the spindle fibers at the centromere, and line up in the center, half (46) on one side, half (46) on the other.

Anaphase: the centromeres divide, each daughter centromere attached to one chromatid. Each centromere is drawn to the ipsilateral pole of the cell, along the track of the spindle fiber, and taking its chromatid with it. The separated chromatids now constitute chromosomes. Anaphase ends when the daughter chromosomes arrive at their respective poles (46 on each side).

Telophase: here the cell pinches off in the center, forming 2 daughter cells, each identical to the mother cell. The cytoplasm and organelles had duplicated earlier and are segregated each into their respective newly-forming cells. As the nucleus is reconstituted, and the nuclear membrane and nucleolus reappear in each new cell, the chromosomes fade into dispersed chromatin and the centromere disappears. Complete cleavage of the parent cell into daughter cells terminates the mitotic process. Each daughter cell enters interphase to start the process anew. The process of cell division serves to increase cell numbers, not change cellular content.



I. ORGANIZATION OF THE BODY

TISSUES: EPITHELIUM

CN: Use very light colors throughout. (1) Color the arrows pointing to the location of the epithelial tissues in the body organs.

There are four basic tissues of the body: epithelial, connective, muscle, and nervous. Epithelial tissues (epithelium) form the body's surface (skin), the surfaces of the body's cavities and their contained viscera, glands, and all tubular organs, e.g., ducts and vessels. Neuroepithelia convey sensations. Epithelia are arranged into single (simple) or several (stratified) layers; their cells are bound together by specialized fibers and substances (e.g., the basement membrane). Epithelial tissues are generally sensitive but avascular, and receive their nutrition by diffusion.

SIMPLE EPITHELIUM*

Surface tissue functioning in filtration, diffusion, secretion, and absorption.

SQUAMOUS A

Simple squamous epithelia line the heart cavities and the internal surfaces of all blood and lymph vessels (endothelia), the air cells of the lung, filtration capsules and thin tubules in the kidney, and the major body cavities (mesothelia). Rapid diffusion of gases in solution are characteristic activities in these cells.

CUBOIDAL B

Simple cuboidal epithelia are generally secretory cells, and make up glands throughout the body, tubules of the kidney, terminal bronchioles of the lungs, and ducts of the reproductive tracts.

COLUMNAR C

Simple columnar epithelia line the gastrointestinal tract and are concerned with secretion and absorption. Their free (apical) surface may be covered with finger-like projections of cell membrane called microvilli, increasing the cell's surface area for secretion/absorption.

PSEUDOSTRATIFIED COLUMNAR D

This tissue consists of simple columnar cells bunched together with irregularly placed nuclei giving the appearance of multiple cell layers. However, each of the cells is attached to the basement membrane. This tissue lines ducts of the reproductive tracts and air conduction pathways of the respiratory tract. They often exhibit cilia on their free surfaces and contain unicellular goblet-shaped (secretory) cells. The cilia collectively move surface material by virtue of undulating power strokes.

STRATIFIED EPITHELIUM*

Stratified epithelia are generally resistant to damage by wear and tear because of ready replacement of cells. Passive diffusion through these layers is slow but not impossible.

STRATIFIED SQUAMOUS E

These layers of cells line the skin, oral cavity, pharynx, vocal folds, esophagus, vagina, and anus. The basal cells are columnar and germinal. The outermost layers of skin epithelia are fibrous-like, flat, desiccated, non-nucleated cells containing keratin (a scleroprotein).

TRANSITIONAL F

Multiple layers of cells lining the urinary tract. In the empty (contracted) bladder, the fibromuscular layer is contracted due to resting tension of muscle cells, and the surface layer of rounded cells is closely concentrated, creating a bumpy surface. With distension of the bladder, all the cells stretch out to form a smooth, thin surface. The bladder can store volumes of urine up to 1000 milliliters or so.

GLANDULAR EPITHELIUM*

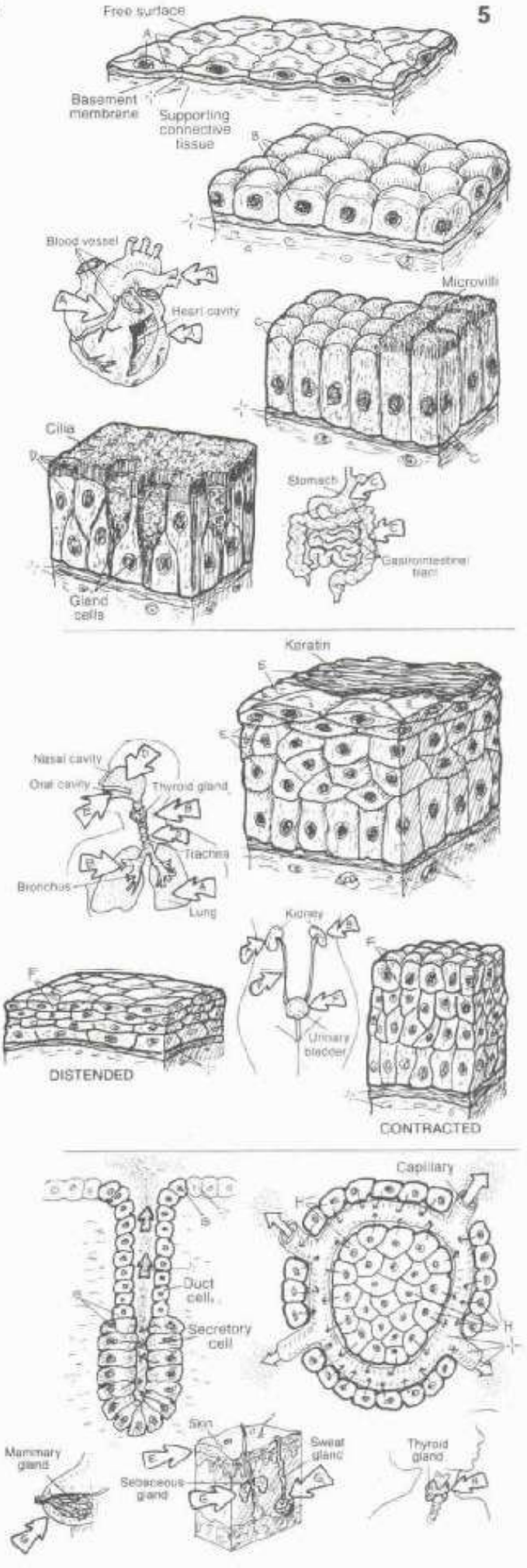
Glandular cells produce and secrete/excrete materials of varying composition, e.g., sweat, milk, sebum, cerumen, hormones, enzymes, and so on. Specialized contractile epithelial cells (myoepithelia) encourage discharge of the glandular material.

EXOCRINE G

Exocrine glands (e.g., sweat, sebaceous, pancreatic, mammary, and so on) arise as outpocketings of epithelial lining tissue, retain a duct to the free surface of the cavity or skin, and excrete/secrete some substance. Secretory portions may have one of several shapes (tubular, coiled, alveolar) connected to one or more ducts.

ENDOCRINE H

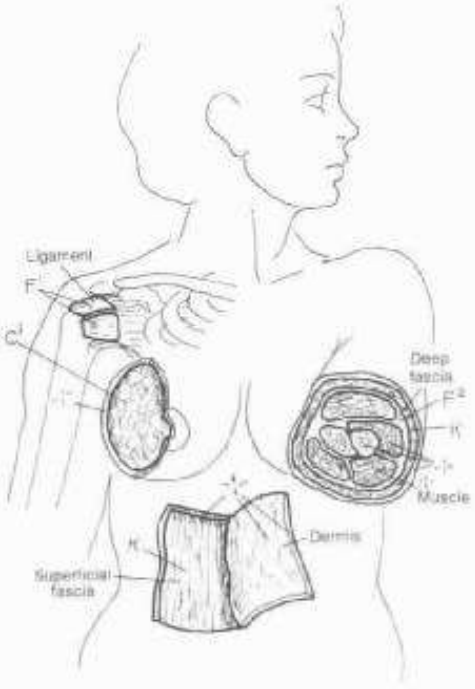
Endocrine glands arise as epithelial outgrowths but lose their connections to the surface during development. They are intimately associated with a dense capillary network and secrete their products into them. See Plate 128 for examples of these glands.



I. ORGANIZATION OF THE BODY TISSUES: FIBROUS CONNECTIVE TISSUES

CN: Use yellow for C and C', and red I. (1) Begin with the illustration at middle left, and the related titles (A through K). The titles and borders of the microscopic sections of dense regular/irregular c.t. (F^1, F^2) receive the color of collagen (F) as that is the dominant structure in both tissues. (2) Do not color the matrix.

The connective tissues (c.t.) connect, bind, and support body structure. They consist of variable numbers of cells, fibers, and ground substance (fluid, viscous sol/gel, or mineralized). At the microscopic level (here illustrated at about 600 x magnification), connective tissues range from blood (cells/fluid), through the fibrous tissues (cells/fibers/variable matrix) to the more stiff supporting tissues (cells/fibers/dense matrix) of cartilage and mineralized bone. Connective tissue can be seen at visible levels of body organization as well, in fascial layers of the body wall, tendons, ligaments, bone, and so on. This plate introduces the fibrous connective tissues (c.t. proper).



CELLS: *

- FIBROBLAST A
- MACROPHAGE B
- FAT CELL C
- PLASMA CELL D
- MAST CELL E

FIBERS: *

- COLLAGEN F
- ELASTIC G
- RETICULAR H

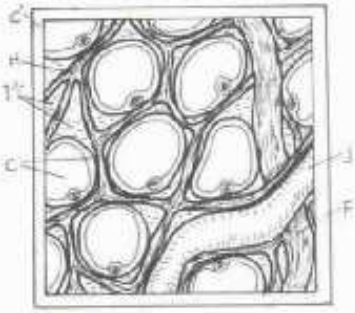
MATRIX, GROUND SUBSTANCE I, I'

CAPILLARY J

LOOSE, AREOLAR C.T. K

Loose, areolar connective tissue is characterized by many cells, a loose, irregular arrangement of fibers, and a moderately viscous fluid matrix. *Fibroblasts* secrete the fibers and ground substance of this tissue. Mobile *macrophages* engulf cell debris, foreign matter, and microorganisms. *Fat cells*, storing lipids, may be seen in small numbers or large (adipose tissue). *Plasma cells* secrete antibodies in response to infection. *Mast cells* contain heparin and other secretory products, some of which initiate allergic reactions when released. Numerous other cells may transit the loose fibrous tissues, including white blood cells (leukocytes). *Collagen* (linkages of protein exhibiting great tensile strength) and *elastic fibers* (made of the protein elastin) are the fibrous support elements in this tissue. *Reticular tissue* is a smaller form of collagen, forming supporting networks around cell groups of the blood-forming tissues, the lymphoid tissues, and adipose tissue. The *matrix* (consisting largely of water with glycoproteins and glycosaminoglycans in solution) is the intercellular ground substance in which all of the above function; it is fluid-like in the fibrous tissue. Numerous *capillaries* roam throughout this tissue. Loose connective tissue found deep to the skin is called superficial fascia, subcutaneous tissue, or hypodermis. It is found deep to the epithelial tissues of mucous and serous membranes of hollow organs.

ADIPOSE C.T. C'



Aggregations of *fat cells*, supported by reticular and collagenous fibers, and closely associated with both blood and lymph capillaries, constitute *adipose tissue*. The storage/release of fat in/from adipose tissue is regulated by hormones (including nutritional factors) and nervous stimuli. It is a source of fuel, an insulator, mechanical padding, and stores fat-soluble vitamins. Adipose tissue is located primarily in the superficial fasciae (largely breast, buttock, anterior abdominal wall, arm, and thigh), yellow marrow, and the surface of serous membranes.

DENSE REGULAR C.T. F

Dense, parallel-arranged, masses of collagenous/elastic fibers form ligaments and tendons that are powerfully resistant to axially loaded tension forces, yet permitting some stretch. Tendons/ligaments contain few cells; largely fibroblasts. Elastic, dense regular ligaments are found in the posterior neck and between vertebrae; the tendocalcaneus is the largest elastic structure (tendon or ligament) in the body, storing energy used in gait.

DENSE IRREGULAR C.T.

Dense, irregularly arranged masses of interwoven collagenous (and some elastic) fibers in a viscous matrix form capsules of joints, envelop muscle tissue (deep fasciae), encapsulate certain visceral organs (liver, spleen, and others) and largely make up the dermis of the skin. It is impact resistant (bearing stress omnidirectionally), contains few cells, and is minimally vascularized.

I. ORGANIZATION OF THE BODY

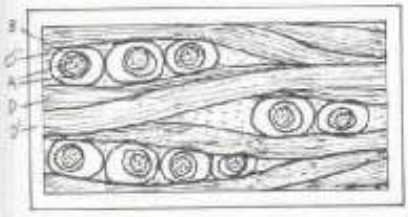
TISSUES: SUPPORTING CONNECTIVE TISSUES

CN: Use the same colors as used on the previous plate for collagen (D) and elastic (E) fibers. Use a light tan or yellow for F and red for L. Use light colors for A, B, G, I, and M. Complete the upper material before coloring the bone section.

The supporting connective tissues consist of cartilage and/or bone. Microscopic sections of cartilage tissue reveal cells (*chondrocytes*) in small cavities (*lacunae*) surrounded by a specialized, hard but flexible *matrix* consisting of water electrochemically bound to proteoglycans and very fine *collagen fibers*. Cartilage is avascular; it receives its nutrition by diffusion. It generally does not repair well after injury but does replace itself with wear, as on joint surfaces.

Bone is unique for its mineralized matrix (average bone is 65% mineral, 35% organic tissue by weight). Bone forms the skeleton of the body; it is a reservoir of calcium; it acts as an anchor for muscles, tendons, and ligaments; it harbors many internal viscera, including the central nervous system; it assists in the mechanism of respiration, and is a center of blood-forming (hemopoietic) activity and fat storage.

CARTILAGE: *
CHONDROCYTE A
LACUNA B
MATRIX C
COLLAGEN FIBER D
ELASTIC FIBER E



HYALINE CARTILAGE A'

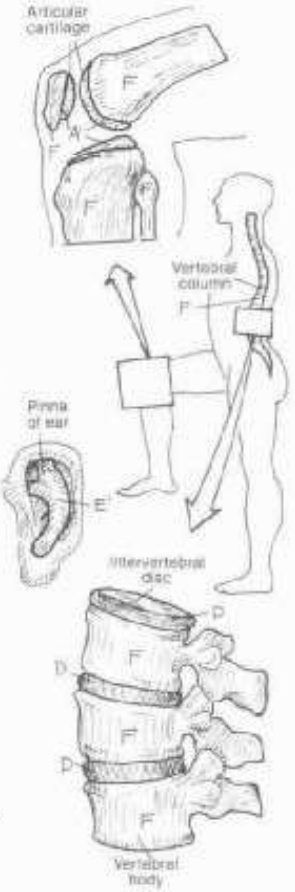
Hyaline cartilage is a flexible, avascular, insensitive, compressible cartilage, characterized by tiny pores. Its major significance is covering bone ends at synovial joints (articular cartilage). Joint movement enhances nutrition of the 1-3 mm thick articular cartilage, by pushing synovial fluid through the pores. Hyaline cartilage also supports the nose, contributes to the nasal septum, and is the main structural support of the larynx and lower respiratory tract. It forms the cartilage model for some bones in embryonic/fetal development; it is often a part of the intermediate framework (callus) in the healing process of fractured bone. Non-articular cartilage is generally ensheathed by perichondrium, a vascular fibrous tissue.

ELASTIC CARTILAGE C'

Elastic cartilage is essentially hyaline cartilage with elastic fibers and a slightly different type of collagen. It supports the external ear and contributes to the support of the larynx (epiglottis). It is remarkably flexible; test it on your external ear.

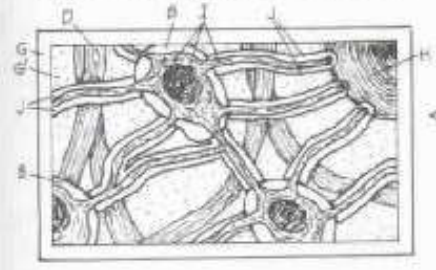
FIBROCARTILAGE D'

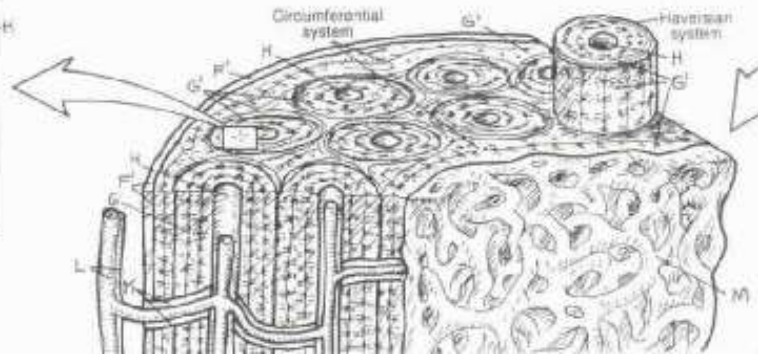
Fibrocartilage is dense fibrous tissue interspersed with chondrocytes in a reduced amount of intercellular matrix. It is found in intervertebral discs, the sacroiliac joint, pubic symphysis, and in several sites of ligamentous attachment to bone. Fibrocartilage enhances resistance to tensile and impact forces.



BONE F
PERIOSTEUM F'
COMPACT BONE G
HAVERSIAN SYS. I *
HAV. CANAL H
LAMELLAE G'
OSTEOCYTE I
LACUNA B
CANALICULI J
VOLKMANN CANAL K
BLOOD VESSEL L
SPONGY BONE M

Microscopic sections of *bone* consist of *osteocytes* in *lacunae*, supported by collagen fibers in a mineralized (calcium hydroxyapatite) matrix. Other bone cells (not shown) include bone forming cells (osteoprogenitor cells, osteoblasts) and bone-absorbing cells (osteoclasts). *Compact bone* is the outer, impact-resistant, weight-bearing shell of bone. It is surrounded on its outer surface by a fibrous, vascular, cellular *periosteum*. The matrix of compact bone occurs in two patterns: concentric layers (*lamellae*) with a central canal (*haversian system/canal*) arranged in columns; and layers between and around haversian systems (circumferential system). The canals are interconnected by *volkmann canals*; both conduct *blood vessels*. The bone internal to compact bone is trabecular, characterized by irregular and interwoven bony beams (*spongy bone*). These beams are constantly recrienting in response to the stress imposed on them. Unlike cartilage, bone is well-vascularized; bone cells reach for vascular nutrition by multiple long cellular processes threading through small canals (*canaliculi*), giving the cells an insect-like appearance.





See also 7

I. ORGANIZATION OF THE BODY
TISSUES: ENDOCHONDRAL OSSIFICATION

CN: Use the same colors as used on the previous plate for hyaline cartilage (A), periosteal bone (B) which was compact bone on Plate 7, and endochondral bone (E) which was spongy bone. Use red for D. Complete each stage before going on to the next. Do not color the periosteum which appears adjacent to periosteal bone in step 3 and continues to the end. Color the small shapes (E) that appear in the epiphyses and, to a lesser extent, the diaphyses (views 5–8). They represent spongy (cancellous) bone of endochondral origin.

Bone development occurs by intramembranous and/or endochondral ossification. Here we show longitudinal sections of developing long bone, demonstrating both forms of ossification, but emphasizing endochondral bone growth.

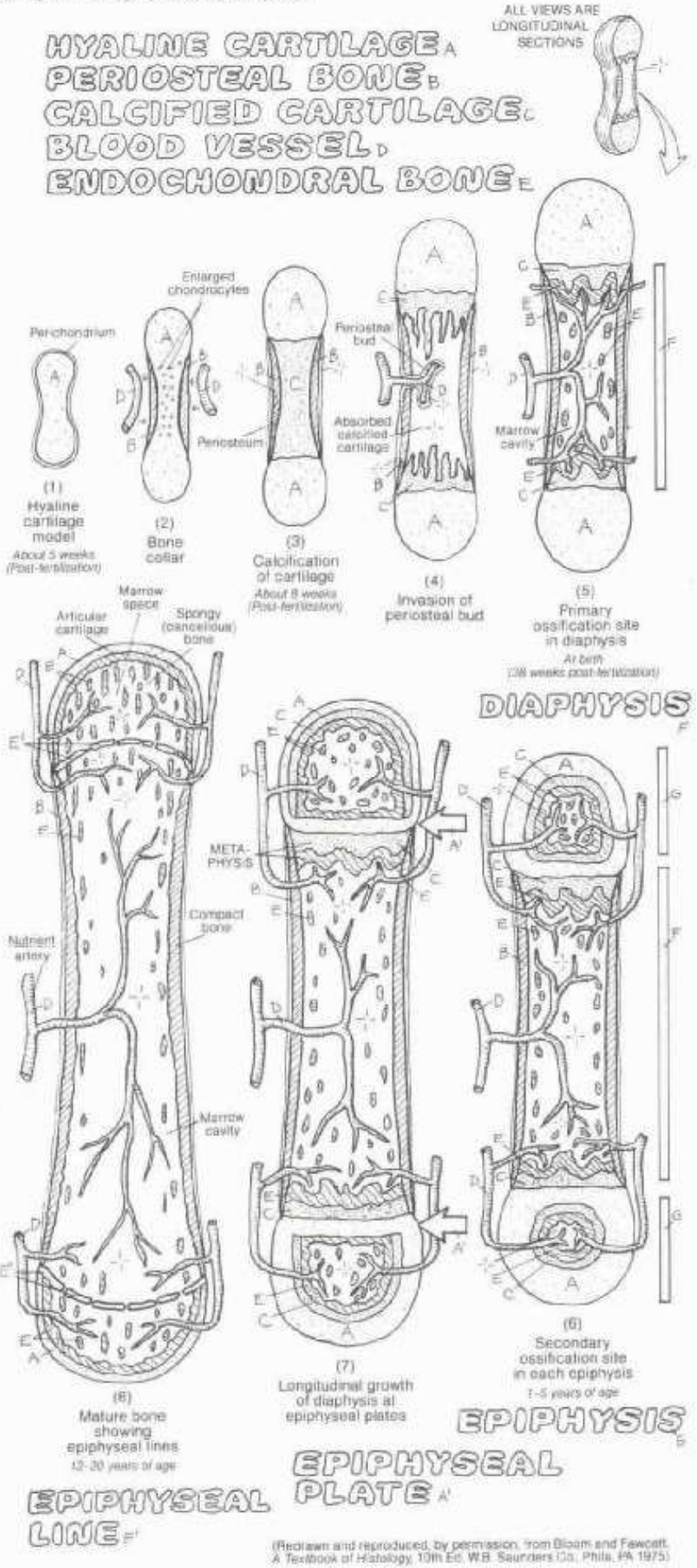
The endochondral process begins at about 5 weeks of post-fertilization age with formation of cartilage models (bone prototypes) from embryonic connective tissue. Subsequently (over the next 16–25 years), the cartilage is largely replaced by bone. The rate and duration of this process largely determines a person's standing height. Intramembranous bone development begins in embryonic connective tissue (membrane) and does not involve replacement of cartilage. The flat cranial bones, the clavicle, and the bone collar surrounding the shaft of cartilage models develop in this fashion.

Endochondral ossification begins with a *hyaline cartilage* model (1). As the cartilage structure grows, its central part dehydrates. The cartilage cells there begin to degenerate: enlarge, die and calcify (2). Concurrently, *blood vessels* bring bone-forming cells to the waist of the cartilage model and a collar of bone is formed around the cartilage shaft (2) within the membranous perichondrium (intramembranous ossification). This vascular, cellular, fibrous membrane around the bone collar is now called periosteum. The new bone collar (*periosteal bone*) becomes a supporting tubular shaft for the cartilage model, with a core of degenerating, calcifying cartilage (3).

Blood vessels from the fibrous periosteum penetrate the bone collar, enter the cartilage model (periosteal bud), and proliferate, conducting periosteal osteoblasts into the cartilage model (4). Starting at about 8 weeks post-fertilization, these bone-forming cells line up along peninsulas of *calcified cartilage* at the extremes of the shaft (*diaphysis*) and secrete new bone (5). The calcified cartilage degenerates and is absorbed into the blood: endochondral bone has now replaced the cartilage. The two sites of this activity are called primary centers of ossification (5). The direction of growth at these sites is toward the ends of the developing bone. The calcified cartilage and some endochondral bone of the diaphysis is subsequently absorbed, forming the medullary or marrow cavity (5). This cavity of the developing tubular bone shaft becomes filled with gelatinous red marrow in the fetus. Productive primary (diaphyseal) centers of ossification are well established at birth.

Beginning in the first few years after birth, secondary centers of ossification begin at the ends or *epiphyses* as blood vessels penetrate the cartilage there (6). The healthy cartilage between the epiphyseal and diaphyseal centers of ossification becomes the *epiphyseal plate* (7). It is the growth of this cartilage that is responsible for bone lengthening; it is the gradual replacement of this cartilage by bone cells in the metaphysis (7) that thins this plate and ultimately permits fusion of the epiphyseal and diaphyseal ossification centers (8), ending longitudinal bone growth (at 12–20 years of age). Dense areas of bone at the fusion site may remain into maturity (*epiphyseal line*). Epiphyseal bone is less structured (irregular beams) than that of the diaphysis (organized columns or osteons), and in maturity is called spongy or cancellous bone (recall Plate 7).

Intramembranous ossification of the diaphyseal shaft (bone collar to compact bone) is responsible for the widening of developing long bone. The ossification process is regulated by growth hormone (from the pituitary gland) and the sex hormones.



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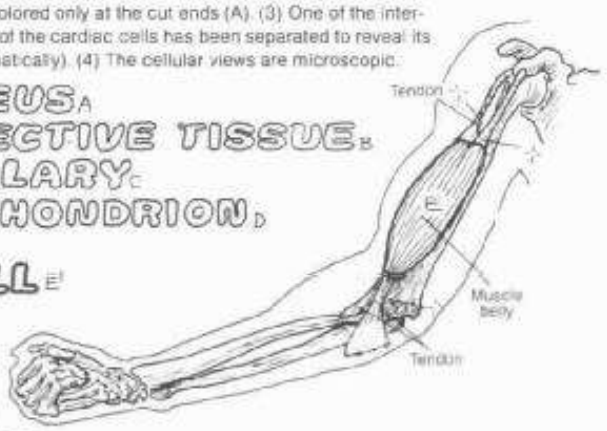
TISSUES: MUSCLE

Muscle tissue, one of the four basic tissue types of the body, consists of muscle cells ("fibers") and their fibrous connective tissue coverings. There are three kinds of muscle tissues: skeletal, cardiac, and smooth. Muscle tissue shortens (contracts) in response to nerve, nerve-like, or hormonal stimulation. Depending on their attachments, skeletal muscles move bones at joints, constrict cavities, and move the skin; cardiac muscle compresses a heart cavity or orchestrates the sequence of cardiac muscle contraction; and smooth muscle moves the contents of cavities by rhythmic contractions, constricts vessels they surround, and moves hairs/closes pores of the skin. The surrounding *connective tissue* transfers the force of contraction from cell to cell, and supports the muscle fibers and the many blood *capillaries* and nerves that supply them.

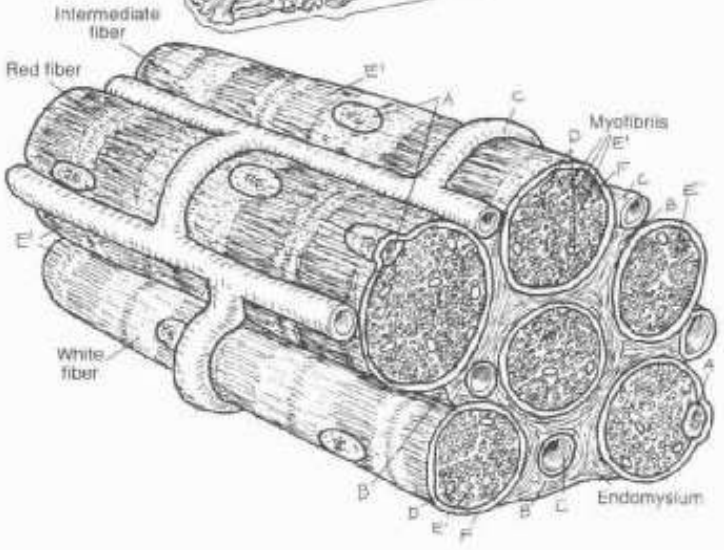
CN: Use red for C and your lightest colors for B, E, G, and I. (1) The sarcolemma (F), which covers each skeletal and cardiac muscle cell, is colored only at the cut ends. The plasmalemma (F'), which covers each smooth muscle cell, is colored only at the cut ends. (2) The nuclei of cardiac and smooth muscle cells, located deep within the cells, are to be colored only at the cut ends (A). (3) One of the intercalated discs (H) of the cardiac cells has been separated to reveal its structure (schematically). (4) The cellular views are microscopic.

NUCLEUS, A
CONNECTIVE TISSUE, B
CAPILLARY, C
MITOCHONDRION, D



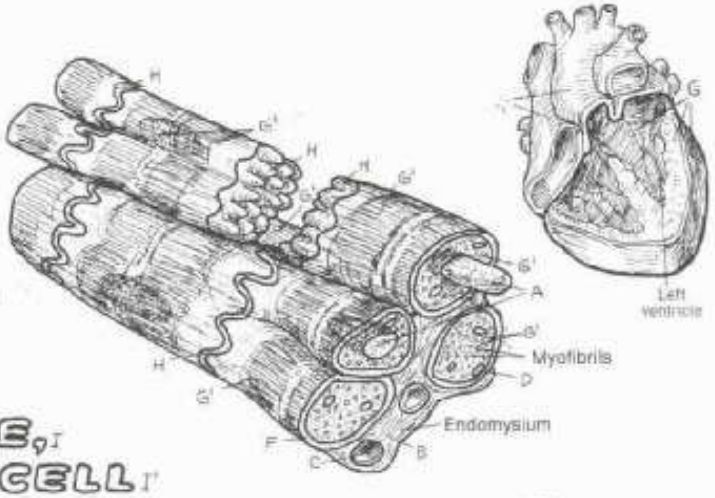
SKELETAL/STRIATED MUSCLE, E CELL E'
SARCOLEMMA F

Skeletal muscle cells are long, striated, and *multi-nucleated*, formed of myofibrils, *mitochondria*, and other organelles within the cytoplasm (sarcoplasm). Each cell is enveloped in cell membrane called *sarcolemma*. Collections of muscle cells make up the belly of a muscle. The highly vascularized skeletal muscles contribute greatly to the size and shape of the body. Skeletal muscles attach to bones or other muscles at their tendinous ends. Between bony attachments, muscles cross one or more joints, moving them. Muscles always pull . . . they never push. Skeletal muscle contractions consist of rapid, brief shortenings, often generating considerable force. Each contracting cell shortens maximally. Three kinds of skeletal muscle fibers are recognized: red (small, dark, long acting, slow contracting, postural muscle fibers with oxygen-rich myoglobin and many mitochondria), white (relatively large, pale, anaerobic, short acting, fast contracting muscle fibers with few mitochondria), and intermediate fibers. With exercise, fast fibers can convert to slow; slow fibers can convert to fast. Contraction of skeletal muscle requires nerves (innervation). Without a nerve supply (denervation), skeletal muscle cells cease to shorten; without reinnervation, the cells will die. A denervated portion of muscle loses its tone and becomes flaccid. In time, the entire muscle will become smaller (atrophy). Muscle contraction is generally under voluntary control, but the brain involuntarily maintains a degree of contraction among the body's skeletal muscles (muscle tone). After injury, skeletal muscle cells can regenerate from myoblasts with moderate functional significance; such regeneration may also occur in association with muscle cell hypertrophy in response to training/exercise.



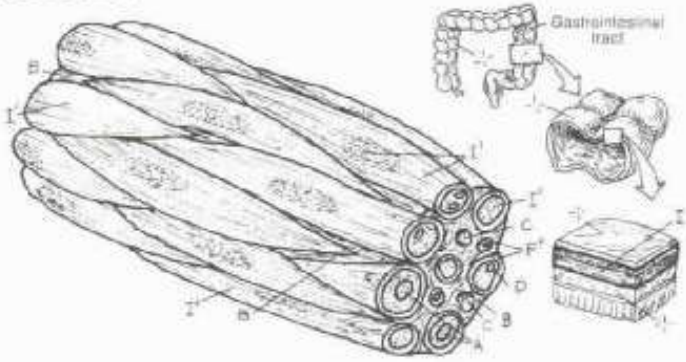
CARDIAC/STRIATED MUSCLE, G CELL G'
INTERCALATED DISC H

Cardiac muscle cells make up the heart muscle. They are branched, striated cells with one or two centrally located nuclei and a sarcolemma surrounding the sarcoplasm. They are connected to one another by junctional complexes called *intercalated discs*. Their structure is similar to skeletal muscle, but less organized. Cardiac muscle is highly vascularized, its contractions are rhythmic, strong, and well regulated by a special set of impulse-conducting muscle cells, not nerves. Rates of contraction of cardiac muscle are mediated by the autonomic (visceral) nervous system, the nerves of which increase/decrease heart rate. Cardiac muscle is probably not capable of regeneration.



VISCERAL/SMOOTH MUSCLE, I CELL I'
PLASMALEMMA F'

Smooth muscle cells are long, tapered cells with centrally placed nuclei. Each cell is surrounded by a *plasmalemma* (cell membrane). These cells are smooth (non-striated). Myofibrils are not seen; the myofilaments intersect with one another in a pattern less organized than that seen in skeletal muscle. Smooth muscle cells occupy the walls of organs with cavities (viscera) and serve to propel the contents along the length of those cavities by slow, sustained, often powerful rhythmic contractions (consider menstrual or intestinal cramps). Smooth muscle cells, oriented perpendicular to the flow of tubular contents, act as gates (sphincters) in specific sites, regulating the flow, as in delaying the flow of urine. Well-vascularized, smooth muscle fibers contract in response to both autonomic nerves and hormones. They are also capable of spontaneous contraction. Regeneration of smooth muscle, to some extent, is possible after injury.



TISSUES: SKELETAL MUSCLE STRUCTURE

CN: Use the same colors used on Plate 9 for sarcolemma (A) and mitochondrion (D). Use the same color used on the skeletal muscle cell for the myofibril (E) here. Use light colors for G and J, a dark color for H, and very dark colors for F and K. The cell nucleus is not shown here. (1) Begin with the drawing of the arm. (2) Color the parts of the muscle cell in the central illustration; note the presence of mitochondria (D) between the myofibrils. (3) Color the parts of the exposed (lowest) myofibril and the color-related letters, bands, lines, zone. Note that the cut end of this myofibril receives the color E, for identification purposes, and is part of the A band of the sarcomere adjacent to the one to be colored. (4) Color the relaxed and contracted sarcomere, the filaments, and the mechanism for contraction, noting the color relationship with the myofibril and its parts.

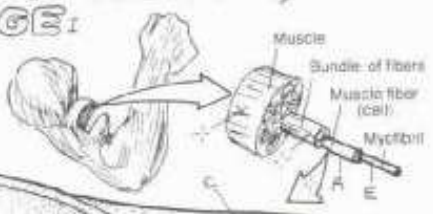
A part of a *skeletal muscle cell* is shown with the *sarcolemma* opened to reveal some cellular contents. The most visible of the contents are the *myofibrils*, the contractile units of the cell. They are enveloped by a flat tubular *sarcoplasmic reticulum* (SR) that, in part, regulates the distribution of calcium ions (Ca^{++}) into the myofibrils. Inward tubular extensions of the sarcolemma, called the *transverse tubule system* (TTS), run transversely across the SR, at the level of the Z lines of the myofibrils. The TTS, containing stores of sodium ions (Na^{+}) and calcium ions (Ca^{++}), conducts electrochemical excitation to the myofibrils from the sarcolemma. *Mitochondria* provide energy for the cell work.

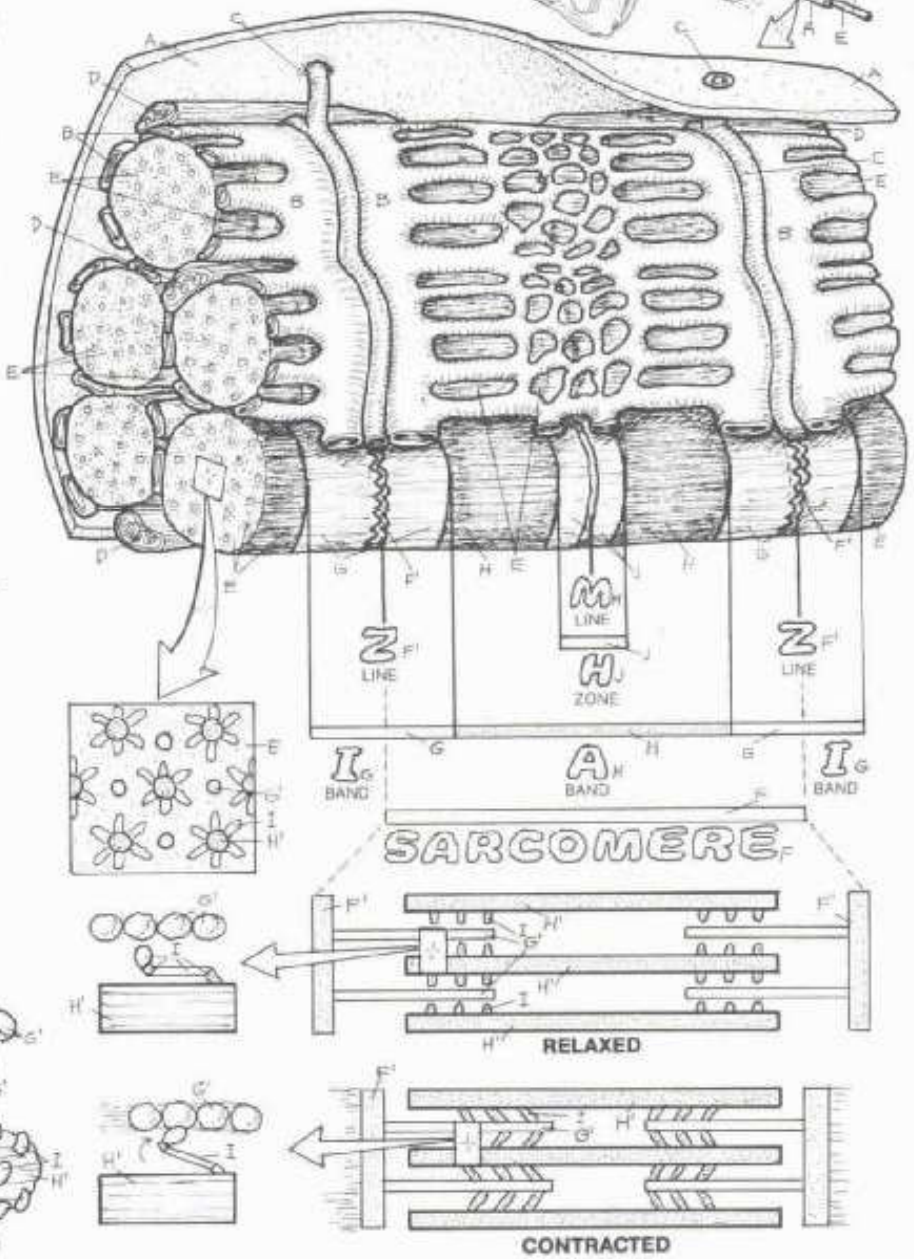
The myofibrils consist of myofilaments: *thick filaments* (largely myosin) with heads that project outward as *cross bridges*, and *thin filaments* (largely actin) composed of two interwoven strands. These two filament types are arranged into contractile units each of which is called a *sarcomere*. Each myofibril consists of several, radially arranged sarcomeres. At the end of each sarcomere, the thin filaments are permanently attached to the *Z line*, which separates one sarcomere from the next. The relative arrangement of the thick and thin filaments in the sarcomere creates light (*I*, *H*) and dark (*A*) *bands/zone* and the *M line*, all of which contribute to the appearance of cross striations in skeletal (and cardiac) muscles.

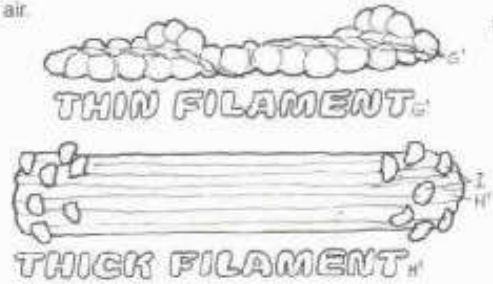
Shortening of a myofibril occurs when the thin filaments slide toward the center (H zone), bringing the Z lines closer together in each sarcomere. The filaments do not shorten; the myosin filaments do not move. The close relationship of the TTS to the Z lines suggests that this site is the "trigger area" for induction of the sliding mechanism. This sliding motion is induced by *cross bridges* (heads of the immovable thick filaments) that are connected to the thin filaments. Activated by high energy bonds from ATP, the paddle-like cross bridges swing in concert toward the H zone, drawing the thin filaments with them. The sarcomere shortens as the opposing thin filaments meet or even overlap at the M line.

Occurring simultaneously in all or most of the myofibrils of a muscle cell, shortening of sarcomeres translates to a variable shortening of the resting length of the muscle cell. Repeated in hundreds of thousands of conditioned muscle cells of a professional athlete, the resultant contractile force can pull a baseball bat through an arc sufficient to send a hardball a hundred meters or more through the air.

SKELETAL MUSCLE CELL:*
SARCOLEMMA A
SARCOPLASMIC RETICULUM B
TRANSVERSE TUBULE SYS. C
MITOCHONDRION D
MYOFIBRIL E
SARCOMERE F
I BAND G
THIN FILAMENT (ACTIN) G'
Z LINE F'
A BAND H
THICK FILAMENT (MYOSIN) H'
CROSS BRIDGE I
H ZONE J
M LINE K

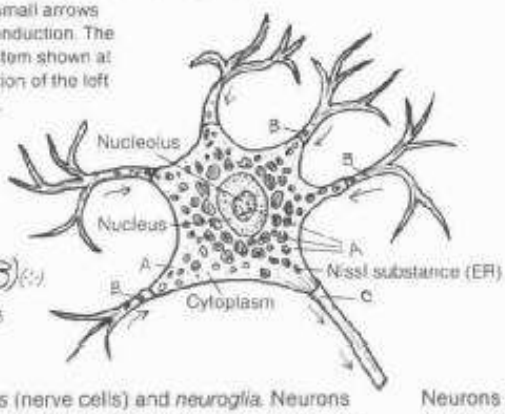






TISSUES: NERVOUS

CN: Use a light color for A. Note the small arrows which indicate direction of impulse conduction. The neurons of the peripheral nervous system shown at lower left are illustrated in the orientation of the left upper limb, although highly magnified.



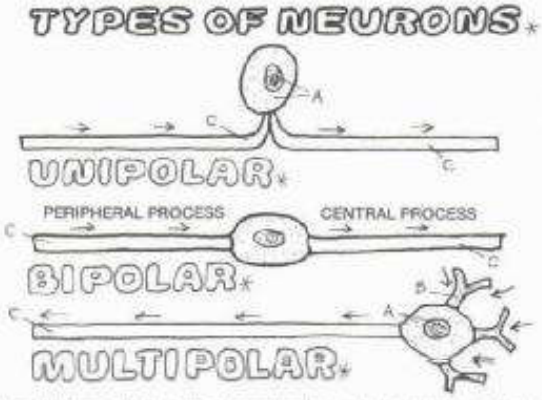
NEURON*

CELL BODY A

PROCESS(ES) (A)

DENDRITE B

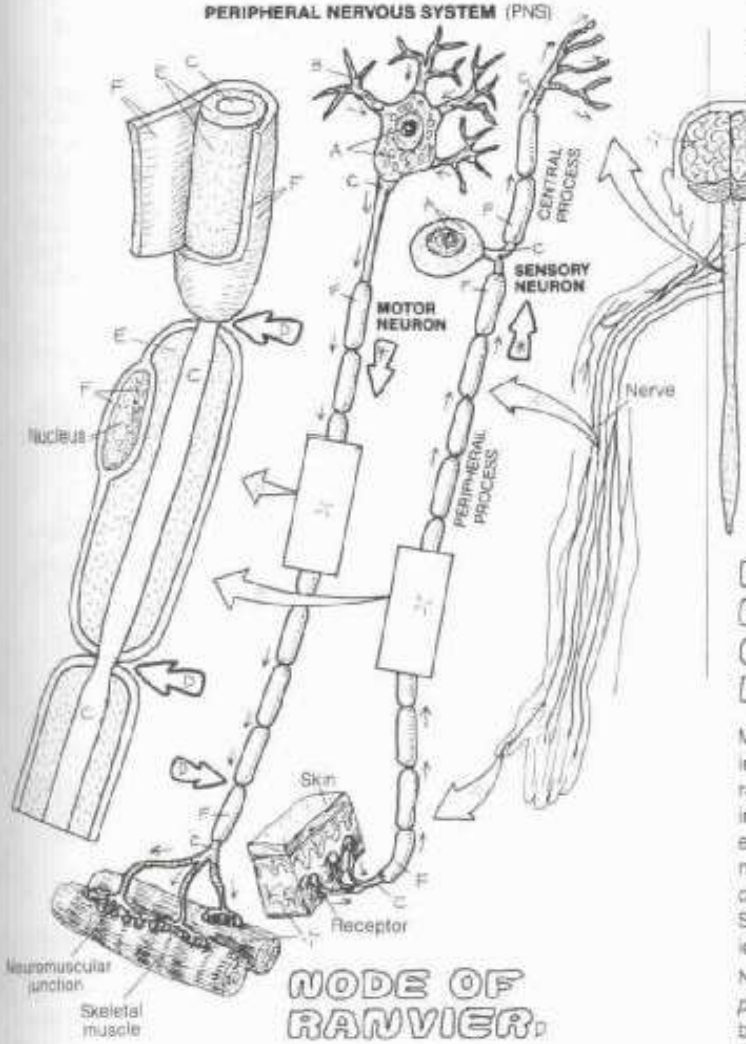
AXON C



Nervous tissue consists of *neurons* (nerve cells) and *neuroglia*. Neurons generate and conduct electrochemical impulses by way of neuronal (cellular) *processes*. Neuroglia are the supporting, non-impulse generating/conducting cells of the nervous system. The main, nucleus-bearing part of the neuron is the *cell body*. Its cytoplasm contains the usual cell organelles. Uniquely, the endoplasmic reticulum occurs in clusters called Nissl substance. Neurons do not undergo mitosis after birth, compromising their ability to regenerate after injury. Neuronal growth consists of migration and arborization of processes. Neurons are the impulse-conducting cells of the brain and spinal cord (central nervous system or CNS) and the spinal and cranial nerves (peripheral nervous system or PNS).

Neurons fall into three structural categories based on numbers of processes ("poles"). Processes that are highly branched (arborized) and uncovered are called *dendrites*. Slender, long, minimally branched processes are called *axons*. Within each category, there is a great variety of shape and size of neurons. *Unipolar* neurons have or appear to have (pseudounipolar) one process which splits near its cell body into a central and peripheral process. Both processes conduct impulses in the same direction, and each is termed an axon (see the sensory neuron at lower left). *Bipolar* neurons have two (central and peripheral) processes, called axons, conducting impulses in the same direction (see Plate 131). *Multipolar* neurons have three or more processes, one of which is an axon (see PNS motor neuron at lower left, and CNS neuron at lower right).

PERIPHERAL NERVOUS SYSTEM (PNS)



CENTRAL NERVOUS SYSTEM (CNS)

NEUROGLIA*

PROTOPLASMIC ASTROCYTE G

FIBROUS ASTROCYTE H

OLIGODENDROCYTE I

MICROGLIA J

NODE OF RANVIER D

AXON COVERINGS*

MYELIN E

SCHWANN CELL F

Most axons are enveloped in one or more (up to 200) layers of an insulating phospholipid (*myelin*) that enhances impulse conduction rates. In the CNS (lower right), myelin is produced by *oligodendrocytes*; in the PNS (lower left), by *Schwann cells*. All axons of the PNS are ensheathed by the cell membranes of Schwann cells (neurilemma) but not necessarily myelin. The gaps between Schwann cells are *nodes of Ranvier*, making possible rapid node-to-node impulse conduction. Schwann cells make possible axonal regeneration in the PNS. Significant axonal regeneration in the CNS has not been observed.

Neuroglia exist in both the CNS and PNS (Schwann cells). *Protoplasmic astrocytes* occur primarily in gray matter (dendrites, cell bodies) of the CNS, *fibrous astrocytes* in the white matter (myelinated axons). Their processes attach to both neurons and blood vessels and may offer metabolic, nutritional and physical support. They may play a role in the blood-brain barrier. Oligodendrocytes are smaller than astrocytes, have fewer processes, and are seen near neurons. *Microglia* are the small scavenger cells of the brain and spinal cord.

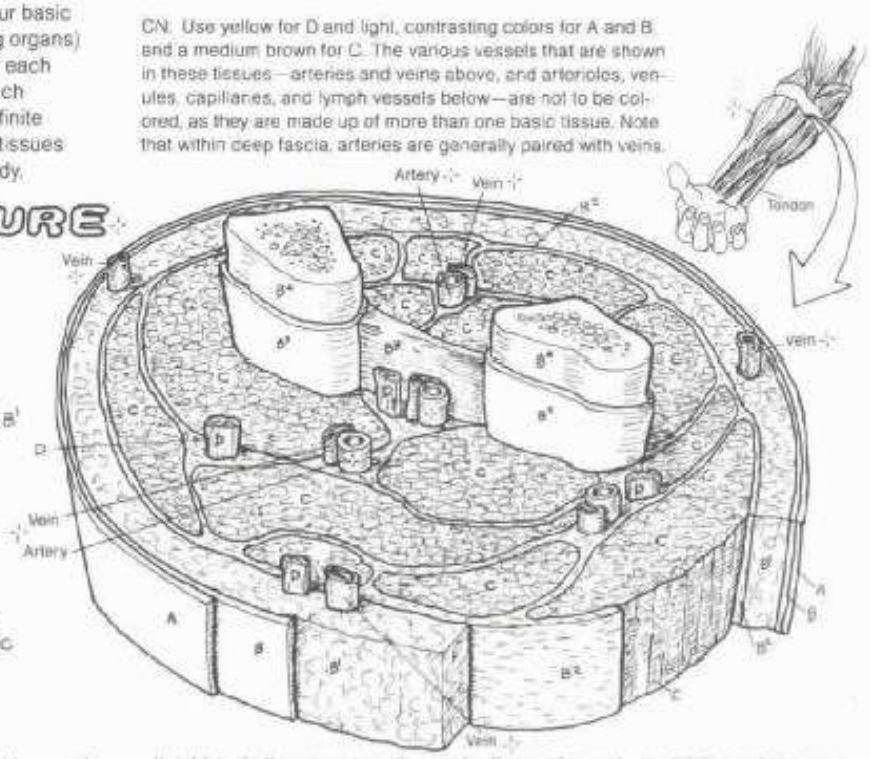
INTEGRATION OF TISSUES

This plate has one goal: to aid you in visually integrating the four basic tissues into somatic (body wall) and visceral (cavity-containing organs) structure. Concentrate on how the four tissues are arranged in each example of body structure. Consider the general function of each tissue in the overall function of the part/organ. There are an infinite number of functionally related variations in the way these four tissues form a discrete construction of the soma and viscera of the body.

SOMATIC STRUCTURE

- EPITHELIAL TISSUE *
  - SKIN (OUTER LAYER) A
- CONNECTIVE TISSUE *
  - SKIN (DEEP LAYER) B
  - SUPERFICIAL FASCIA B^1
  - DEEP FASCIA B^2
  - LIGAMENT B^3
  - BONE B^4
    - PERIOSTEUM B^5
- MUSCLE TISSUE *
  - SKELETAL MUSCLE C
- NERVOUS TISSUE *
  - NERVE D

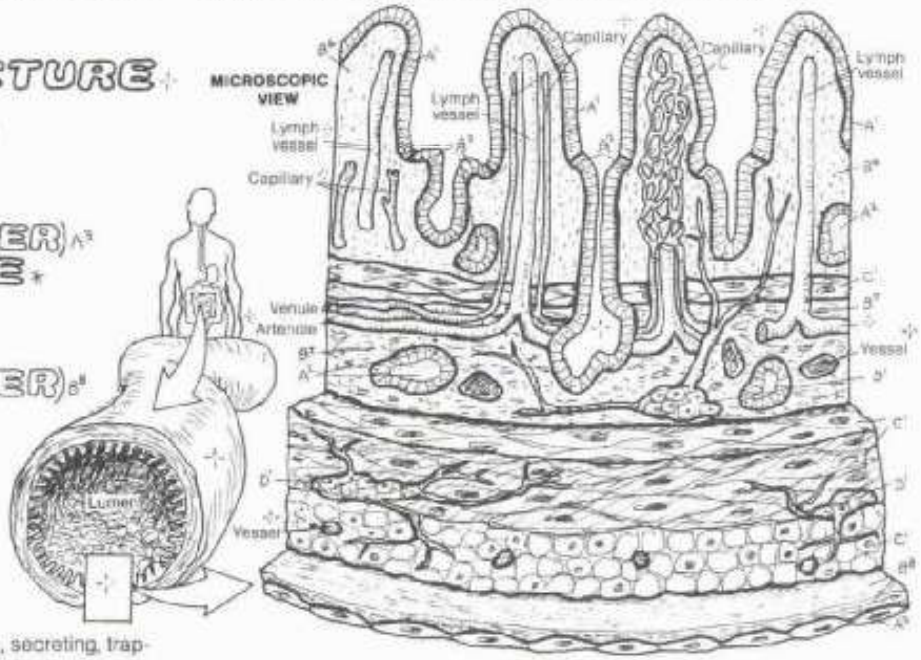
CN: Use yellow for D and light, contrasting colors for A and B and a medium brown for C. The various vessels that are shown in these tissues—arteries and veins above, and arterioles, venules, capillaries, and lymph vessels below—are not to be colored, as they are made up of more than one basic tissue. Note that within deep fascia, arteries are generally paired with veins.



Somatic structure, making up the skin-covered musculoskeletal frame of the body, is concerned with stability, movement, and protection. Its construction reflects these functions. The outermost covering of the body wall everywhere is a protective keratinized *stratified squamous epithelial tissue*, constituting the *outer layer of skin* (epidermis). Other epithelial tissues in somatic structure are the inner layers of blood vessels, and the glands (not shown). Connective tissue layers of the body wall include the *deep layer of skin* (dermis), consisting of dense, irregular fibrous *connective tissue*, and the sub-adjacent, variously mobile, subcutaneous *superficial fascia* (loose connective and adipose tissues), containing cutaneous nerves, small vessels, and occasional large veins. *Deep fascia*, a more vascular, sensitive, dense, irregular fibrous tissue, ensheaths skeletal muscle (myofascial tissue) as well as the supporting nerves and vessels. *Ligaments* (dense regular connective tissue) bind *bone* to bone by way of *periosteum* (vascular, cellular, dense, irregular, fibrous tissue). Skeletal *muscles* and their *nerves* are packaged in groups, separated by slippery septa of deep fascia securing neurovascular structure. The fibrous investments of skeletal muscle converge to form tendons of the muscle.

VISCERAL STRUCTURE

- EPITHELIAL TISSUE *
  - MUCOSAL LINING A^1
  - GLAND A^2
  - SEROSA (OUTER LAYER) A^3
- CONNECTIVE TISSUE *
  - LAMINA PROPIA B^6
  - SUBMUCOSA B^7
  - SEROSA (INNER LAYER) B^8
- MUSCLE TISSUE *
  - SMOOTH MUSCLE C^1
- NERVE TISSUE *
  - NERVE CELLS D^1



Visceral structure is generally concerned with absorbing, secreting, trapping, and/or moving food, air, secretions, and/or waste in its cavities. *Epithelial tissue* is the innermost layer (*mucosal lining*) of the thin and pliable visceral wall. It faces the lumen (cavity of the viscus); it is often a single layer of cells (esophagus, urinary tract, and reproductive tract excepted) and deals with the contents of the visceral cavity. *Glands*, unicellular or larger in the mucosa or submucosa, are epithelial, as are the inner layers of blood and lymph vessels. The mucosa includes a subepithelial layer of loose fibrous tissue (*lamina propria*), supporting mobile cells, glands, vessels and *nerves*. The deepest layer of the mucosa (when present) is a thin *smooth muscle* layer moving finger-like projections (villi) of the mucosal surface. Deep to the mucosa is a dense fibrous tissue (*submucosa*), replete with large vessels and small nerves/nerve cells (intramural ganglia) supplying the mucosa. Deeper yet, two or three layers of smooth muscle (tunica muscularis), innervated by local nerve cells, move the visceral wall in peristaltic contractions. The outermost layer of the gastrointestinal tract is the slippery *serosa*: an outer secretory simple squamous epithelial layer and an *inner* supporting layer of light fibrous tissue.

II. SYSTEMS AND REGIONS

SYSTEMS OF THE BODY (1)

CN: Use light colors on this and the next plate.
Color the entire skeleton (A); only the knee joint and shoulder joint show joint capsules (A'). Color the entire musculature (B) brown. Color all the vessels and heart (C): arteries and heart red, veins blue. Color all lymphatic vessels (D) green. Color all the nerves, as well as the brain and spinal cord (E), yellow. Do not color the background of the rectangular insets representing the endocrine system (F). Choose a skin color for the integument system (G).

Collections of similar cells constitute tissues. The four basic tissues are integrated into body wall and visceral structures/organs. A *system* is a collection of organs and structures sharing a common function. Organs and structures of a single system occupy diverse regions within the body and are not necessarily grouped together.

SKELETAL SYS. A
ARTICULAR SYS. A'

The *skeletal system* consists of the skeleton of bones and their periosteum, and the ligaments which secure the bones at joints. By extension, this system could include the varied fasciae which ensheath the body wall/skeletal muscles and contribute to the body's structural stability. The *articular system* comprises the joints, both movable and fixed, and the related structures, including joint capsules, synovial membranes, and discs/menisci.

MUSCULAR SYS. B

The *muscular system* includes the skeletal muscles which move the skeleton, the face, and other structures, and give form to the body; the cardiac muscle of the heart walls; and the smooth muscle of the walls of viscera and vessels, and in the skin.

CARDIOVASCULAR SYS. C

The *cardiovascular system* consists of the 4-chambered heart, arteries conducting blood to the tissues, capillaries through which nutrients, gases, and molecular material pass to and from the tissue, and veins returning blood from the tissues to the heart. Broadly interpreted, the cardiovascular system includes the lymphatic system.

LYMPHATIC SYS. D

The *lymphatic system* is a system of vessels assisting the veins in recovering the body's tissue fluids and returning them to the heart. The body is about 60% water, and the veins alone are generally incapable of meeting the demands of tissue drainage. Lymph nodes filter lymph and are located throughout the body.

NERVOUS SYS. E

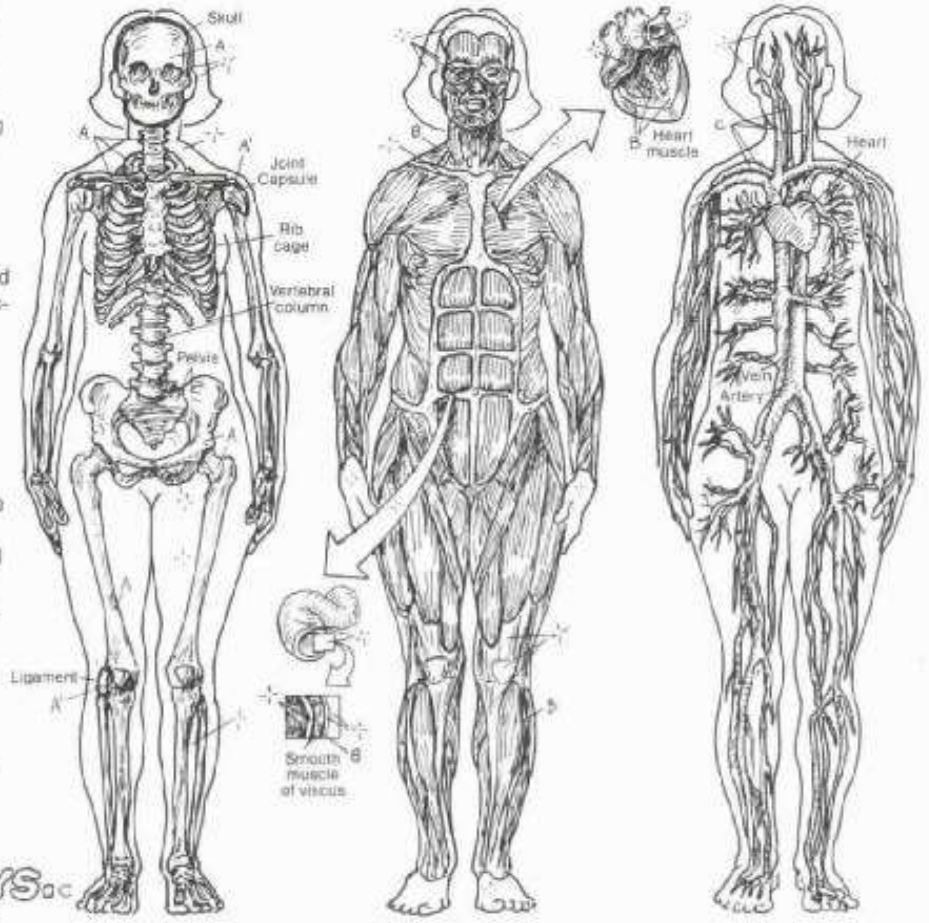
The *nervous system* consists of impulse-generating/conducting tissue organized into a central nervous system (brain and spinal cord), and a peripheral nervous system (nerves) that includes the visceral (autonomic) nervous system involved in involuntary "fight or flight" and vegetative responses.

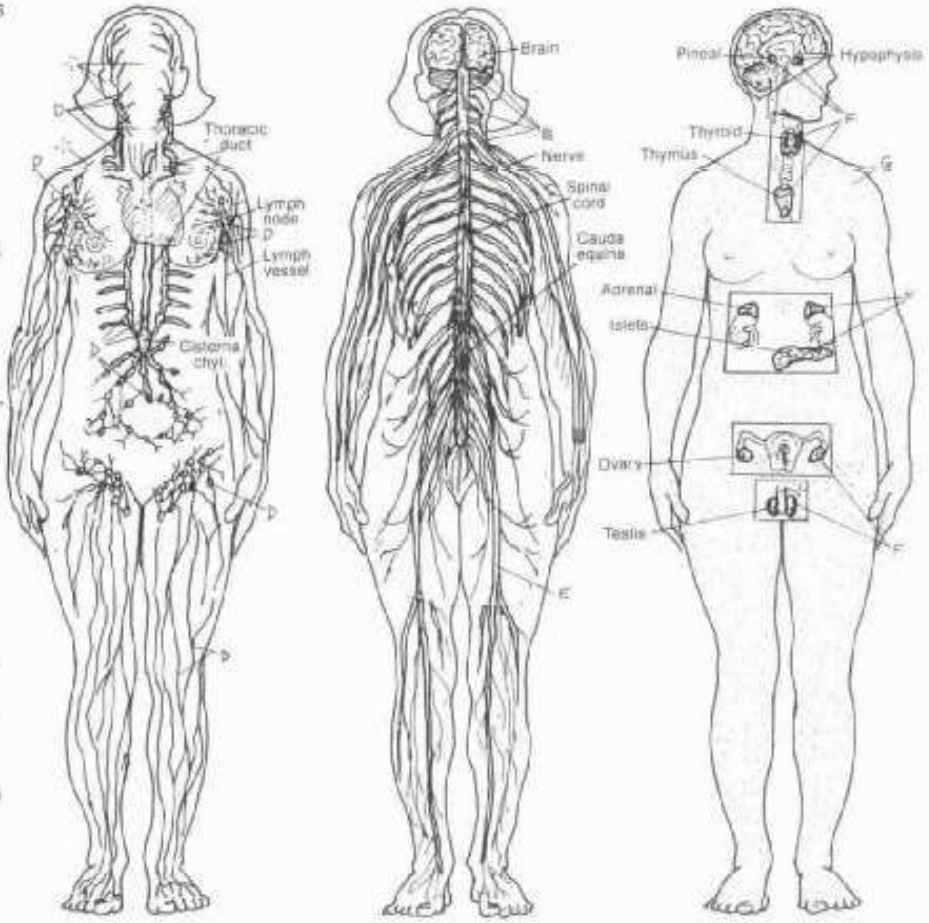
ENDOCRINE SYS. F

The *endocrine system* consists of glands which secrete chemical agents (hormones) into the tissue fluids and blood, affecting the function of multiple areas of the body. Many of these glands are under some control by the brain (hypothalamus). Hormones help maintain balanced metabolic functions in many of the body's systems.

INTEGUMENT. SYS. G

The *integumentary system* is the skin, replete with glands, sensory receptors, vessels, immune cells and antibodies, and layers of cells and keratin resisting environmental factors harmful to the body.





II. SYSTEMS AND REGIONS
SYSTEMS OF THE BODY (2)

CN: Use different light colors from those used on the preceding plate.

RESPIRATORY SYS. H

The *respiratory system* consists of the upper (nose through larynx) and lower respiratory tract (trachea through the air spaces of the lungs). Most of the tract is airway; only the air spaces (alveoli) and very small bronchioles exchange gases between alveoli and the lung capillaries.

DIGESTIVE SYS. I

The *digestive system* is concerned with the breakdown, digestion and assimilation of food, and excretion of the residua. Its tract begins with the mouth, continues down to the abdomen wherein it takes a convoluted course to open again at the anus. Associated glands include the liver and pancreas, including the biliary system (gall bladder and related ducts).

URINARY SYS. J

The *urinary system* is concerned with the conservation of water and maintenance of a neutral acid-base balance in the body fluids. The kidneys are the main functionaries of this system; residual fluid (urine) is excreted through ureters to the urinary bladder for retention, and discharged to the outside through the urethra.

IMMUNE / LYMPHOID SYS. K

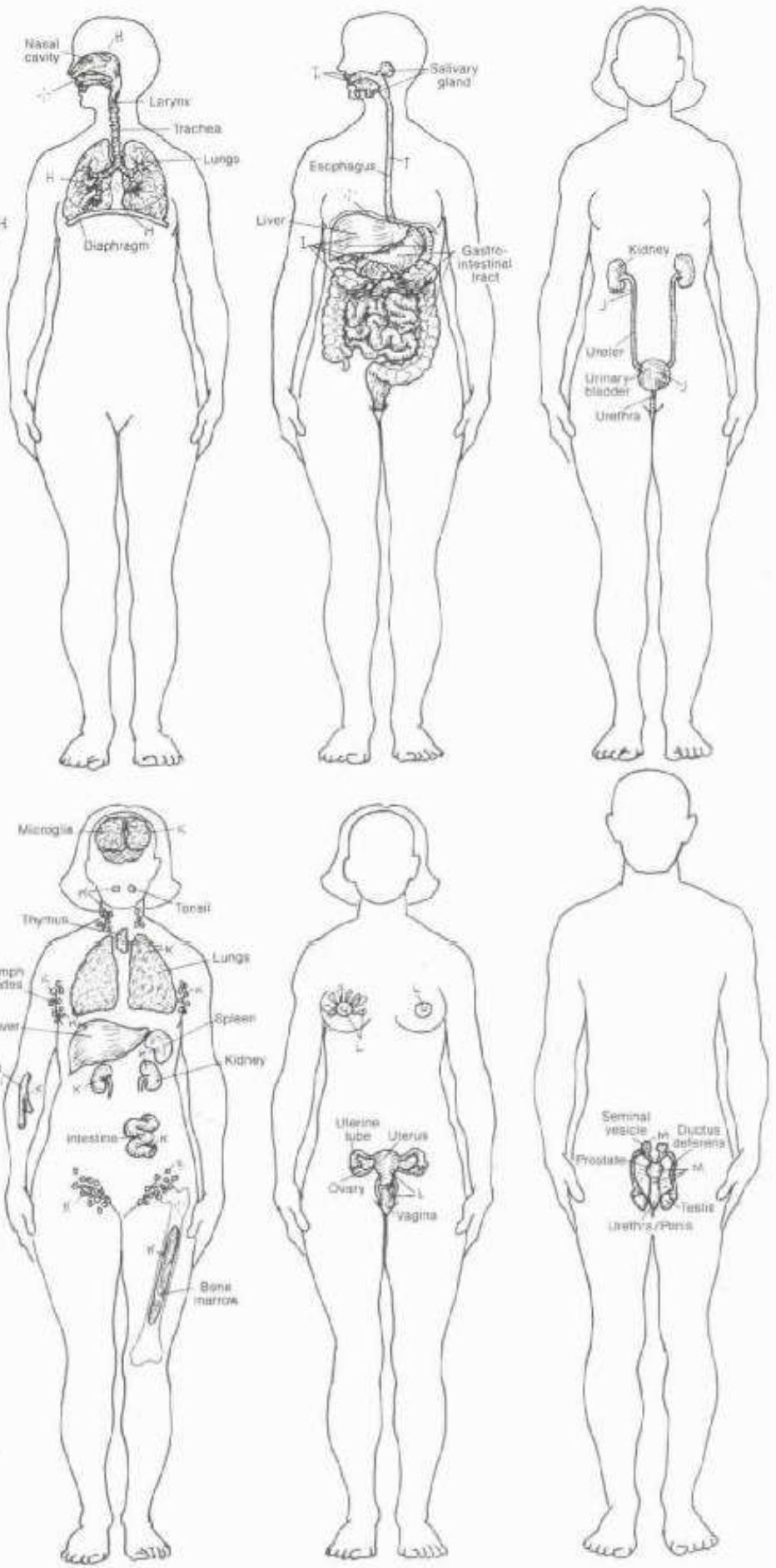
The *lymphoid system* consists of organs concerned with body defense: thymus, bone marrow, spleen, lymph nodes, tonsils, and smaller aggregates of lymphoid tissue. This system, including a diffuse arrangement of immune-related cells throughout the body, is concerned with resistance to invasive microorganisms, and the removal of damaged and/or otherwise abnormal cells.

REPRODUCTIVE SYS. / FEMALE L

The female reproductive system is concerned with the secretion of sex hormones, production and transportation of germ cells (ova), receipt and transport of male germ cells to the fertilization site, maintenance of the developing embryo/fetus, and initial sustenance of the newborn.

REPRODUCTIVE SYS. / MALE M

The male reproductive system is concerned with the secretion of male sex hormones, formation and maintenance of germ cells (sperm), and transport of germ cells to the female genital tract.



II. SYSTEMS AND REGIONS

REGIONS OF THE BODY

CN: You will most likely have to repeat colors among the arrows shown here. Consider a coloring pattern based on major regions (shades of red for head and neck, blues for upper limb, brown for lower limb, and so on).

HEAD/NECK:*
CRANIAL A
ORBITAL B
FACIAL C
MANDIBULAR D
CERVICAL E
SUPRACLAVICULAR F

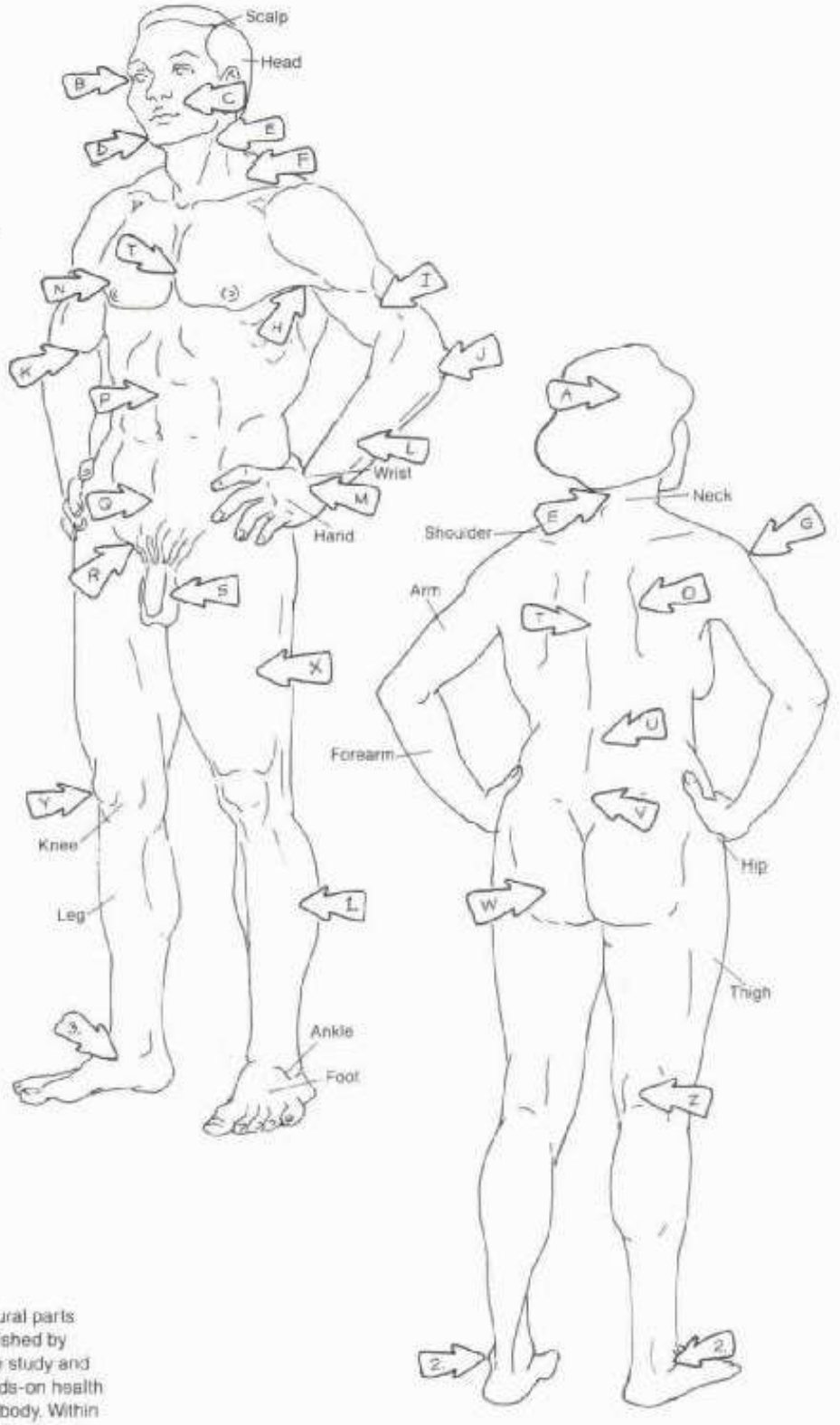
UPPER LIMB:*
DELTOID G
AXILLARY H
BRACHIAL I
CUBITAL J
ANTECUBITAL K
ANTEBRACHIAL L
CARPAL M

THORAX:*
PECTORAL N
SCAPULAR O

ABDOMINOPELVIC:*
ABDOMINAL P
PELVIC Q
INGUINAL R
PUDENDAL S

BACK:*
THORACIC T
LUMBAR U
SACROILIAC V

LOWER LIMB:*
GLUTEAL W
FEMORAL X
PATELLAR Y
POPLITEAL Z
CRURAL 1
MALLEOLAR 2
TARSAL 3



Regional anatomy is the organization of human structural parts by regions. The study of regional anatomy is accomplished by dissection of body parts in an embalmed cadaver. The study and awareness of regional anatomy is fundamental to hands-on health care providers who examine and evaluate the human body. Within each region, there are usually sub-divisions or sub-regions, e.g., within the cranial region, there are frontal, parietal, temporal, and occipital sub-regions. Characteristically, each region is composed of structures representing several systems.

II. SYSTEMS AND REGIONS

CAVITIES & LININGS

See 65, 95, 102

ON: Except for H, use light colors throughout. (1) Note that the linings for closed body cavities are all colored gray. (2) In the open visceral cavities shown below, the linings receive a darker color (H), and the closed cavities have their linings omitted.

CLOSED BODY CAVITIES:

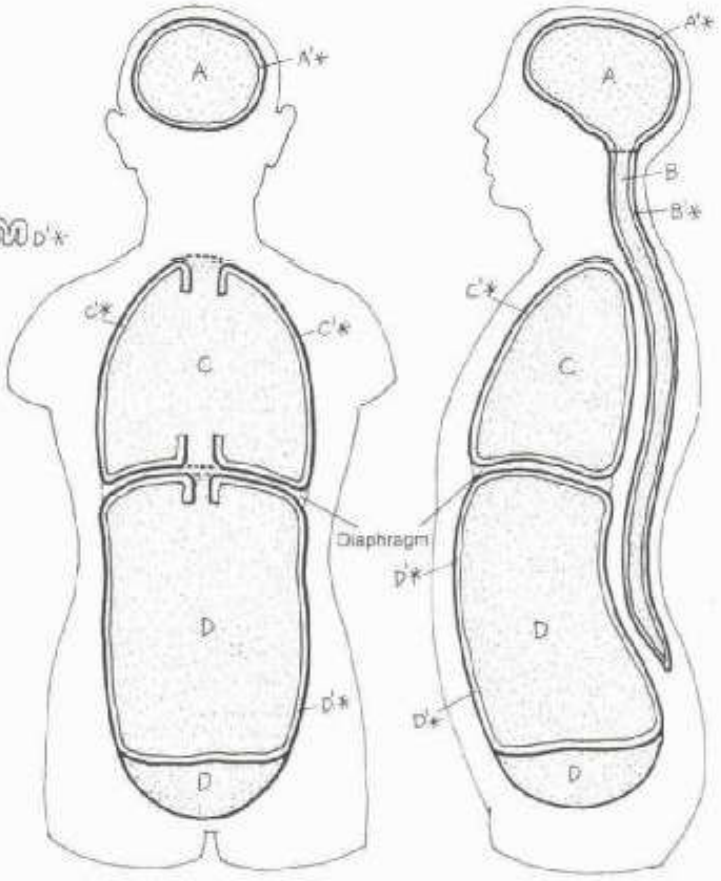
CRANIAL A / DURA MATER A'*
VERTEBRAL B / DURA MATER B'*
THORACIC C / PLEURA C'*
ABDOMINOPELVIC D / PERITONEUM D'*

Closed body cavities are not open to the outside of the body. The *cranial cavity* is located in the upper part of the skull and houses the brain and related structures. It is continuous with the *vertebral cavity* (canal) within the vertebral column. The vertebral cavity contains the spinal cord and related vessels and nerve roots. The tough, fibrous layer lining the cranial and vertebral cavities is called the *dura mater*. Portions of the dura envelop the brain and spinal cord; other parts are folded to form dividers (dural septa, not shown) separating parts of the brain.

The *thoracic cavity* is located in the thorax, surrounded by the rib cage and related muscles; its posterior wall is the vertebral column, its floor is the muscular thoracic diaphragm. The thoracic cavity is divided by a central set of structures (mediastinum) into left and right cavities for the lungs. These cavities are lined with a thin layer of simple squamous, secretory epithelium supported by fibrous tissue. Such a lining secretes a watery (serous) fluid and is called a serous membrane or serosa. The serosa lining the thoracic cavities for the lungs is called *pleura*, a subject to be developed in Plate 95.

The *abdominopelvic cavity* is located anterior to the posterior abdominal wall. It is surrounded anteriorly and laterally by muscle layers, the lower ribs and related muscles, and the bones of the pelvis. Its upper and lower boundaries are muscular (respiratory and pelvic) diaphragms. The abdominopelvic cavity contains the abdominal and pelvic viscera. The abdominal cavity is largely lined with a serous membrane called *peritoneum*, a subject to be developed in Plate 102.

There are a number of other cavities within the body that are closed, including the joint cavities, heart, vessels, ventricles of the brain, cavities/ducts of the eye and internal ear, and the potential cavities created by the foldings of serosal membranes (Plates 65, 95, and 102).



OPEN VISCERAL CAVITIES:

RESPIRATORY TRACT E
URINARY TRACT F
DIGESTIVE TRACT G
MUCOSA H

Open cavities, located within closed cavities, are open to the outside of the body. They are generally tubular cavities of viscera: the digestive, respiratory, reproductive, and urinary tracts. The digestive tract opens at the mouth superiorly and at the anus inferiorly. The respiratory tract opens at the mouth and nose. The reproductive tracts (not shown) open at the perineum; the urinary tract opens at the perineum as well. Not included in this category are glands of the skin and viscera whose ducts open on to the surface of the skin.

A variably-thick membrane covered with mucus (mucous membrane or *mucosa*) lines open cavities. It is continuous with skin at orifices. The mucosa is the working membrane of open cavities (secretion, absorption, protection), dealing with molecules placed before it (food, air, fluid, and so on).