Hole’s Essentials of Human Anatomy & Physiology

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Chapter 5-8
Chapter 5

Tissues
Introduction:

A. Cells are arranged in tissues that provide specific functions for the body.

B. Cells of different tissues are structured differently leading to differences in function.

C. Major types of human tissue are: epithelial, connective, muscle, and nervous.
Epithelial Tissues:

A. General Characteristics

1. Epithelial tissue
   1. widespread throughout the body
   2. covers organs
   3. lines body surfaces.

2. Anchored to a non-living basement membrane

3. Made up of tightly packed cells

4. Contain little intercellular material

5. Generally lack blood vessels
6. Replaced frequently.

7. Epithelial tissues function in:
   a) Protection
   b) Secretion
   c) Absorption
   d) Excretion
   e) Sensory reception
B. **Simple Squamous Epithelium**

1. Made up of a single layer of thin, flattened cells.
2. Well suited for diffusion so functions in:
   a) Gas exchange in the lungs
   b) Lines blood vessels, lymph vessels, body cavities, and hollow organs.

C. **Simple Cuboidal Epithelium**

1. Consists of a single layer of cube-shaped cells with centrally located nuclei.
2. Functions in secretion and absorption in the kidneys, and in secretion in glands.
D. **Simple Columnar Epithelium**

1. One row of elongated cells
2. Nuclei are all located near the basement membrane
3. May be ciliated
4. Lines the uterus, stomach, and intestines where it:
   a) protects underlying tissues
   b) secretes digestive fluids
   c) absorbs nutrients
   d) possess *microvilli* that increase the surface area available for absorption
   e) Mucus-secreting *goblet cells* can be found among columnar cells
E. Pseudostratified Columnar Epithelium

1. These cells appear layered due to the varying positions of their nuclei within the row of cells, but are not truly layered.

2. Cilia may be present, along with mucus-secreting globlet cells, that line and sweep debris from respiratory tubes.
F. **Stratified Squamous Epithelium**

1. Made up of layers of flattened cells that are designed to protect underlying layers.

2. It makes up the outer layer of skin, and lines the mouth, throat, vagina, and anal canal.

3. In the skin, outer layers of cells undergo *keratinization*; however, this process does not occur where tissues remain moist as in the throat, vagina, or anal canal.
G. Stratified Cuboidal Epithelium

1. This tissue consists of two to three layers of cuboidal cells lining a lumen of the mammary glands, sweat glands, salivary glands, and pancreas.

2. Several layers of cells provide greater protection than one single layer.

H. Stratified Columnar Epithelium

This tissue consists of several layers of cells and is found in the vas deferens, part of the male urethra, and parts of the pharynx.
I. **Transitional Epithelium**

1. Designed to distend and return to its normal size, as it does in the lining of the urinary bladder.

2. This design provides *distensibility* and keeps urine from diffusing back into the internal cavity.

J. **Glandular Epithelium**

1. Made up of cells designed to produce and secrete substances into ducts or body fluids.

2. Glands that secrete products into ducts are *exocrine*.

3. Those that secrete into body fluids and blood are called *endocrine*. 
3. Glands are classified by the ways the glands secrete their products.

a) **Merocrine** glands release fluid products by exocytosis (pancreas) and are grouped as:
   1) **serous** which produce a watery fluid or
   2) **mucus** which produce a thicker, protective substance.

b) **Apocrine** glands lose portions of their cell bodies during secretion (mammary glands).

c) **Holocrine** glands release entire cells (sebaceous glands).
Connective Tissues:

A. General Characteristics

1. Connective tissues:
   1. Bind
   2. Support
   3. Protect
   4. serve as frameworks
   5. fill spaces
   6. store fat
   7. produce blood cells
   8. protect against infection
   9. repair tissue damage

2. Have abundant *extracellular matrix* (intercellular material) throughout

3. Have good blood supplies (except cartilage).
B. Major Cell Types

1. **Fibroblasts** are the most common fixed cell type
   a) star-shaped
   b) large in size
   c) secretes protein fibers into matrix

2. Wandering **macrophages** function as scavenger cells and defend against infection by phagocytosis.

3. **Mast cells** are large and are located near blood vessels where they release:
   a) **Heparin**, an anticoagulant, and
   b) **Histamine** which promotes inflammation
C. **Connective Tissue Fibers**

1. **Strong** *collagenous* fibers (white fibers),
   a) made of the protein *collagen*
   b) add strength for holding body parts together.

2. **Elastic** fibers (yellow fibers)
   a) made of the protein *elastin*
   b) stretchy and add flexibility to certain types of connective tissues

3. **Reticular** fibers are thin *collagenous* fibers that form supportive networks in a variety of tissues.
D. **Loose Connective (areolar) Tissue**

1. Forms delicate, thin membranes throughout the body

2. Binds body parts together such as skin and underlying organs.

3. The majority of the cells are fibroblasts

4. Fibroblasts are separated by a gel-like ground substance containing collagenous and elastic fibers.
E. **Adipose Tissue**

1. Loose connective tissue designed to store fat.
2. Present:
   1. beneath the skin
   2. around joints
   3. padding internal organs (kidneys etc)
   4. in certain abdominal membranes.

F. **Dense Connective Tissue**

1. This tissue consists of densely packed collagenous fibers and is very strong but lacks a good blood supply.
2. It is found as part of **tendons** and **ligaments**.
G. **Cartilage**

1. Cartilage is a rigid connective tissue that provides a supportive framework for various structures.

2. It lacks a vascular system and so heals slowly.

3. Cartilage cells (**chondrocytes**) lie within **lacunae** in a gel-like fluid matrix.

4. Cartilaginous structures are enclosed within a connective tissue called the **perichondrium**.
5. **Hyaline cartilage**, the most common
   1. white
   2. Has abundant fine collagen fibers
   3. found at the ends of bones
   4. supports respiratory passages

6. **Elastic cartilage**, with elastic fibers
   1. provides a framework for the external ears and parts of the larynx.

7. **Fibrocartilage**, with many collagenous fibers
   1. tough tissue
   2. provides a shock-absorbing function in intervertebral disks and in the knees and pelvic girdle.
H. Bone

1. The most rigid connective tissue
2. Deposits of mineral salts and collagen within the matrix.
3. Hardness due to mineral salts
4. Internally supports the body
5. Protects
6. Forms muscle attachments
7. Site for blood cell formation
8. Osteocytes, bone cells
   1. lie within lacunae
   2. are arranged in concentric circles (osteons) around osteonic canals interconnected by canaliculi
9. Bone has a good blood supply, enabling rapid recovery after an injury
I. Blood

1. **Blood** is composed of cells suspended in a liquid matrix called **plasma**.

2. Cells include:
   1. Red blood cells
   2. White blood cells
   3. Platelets

3. **Functions to transport substances throughout the body.**
Membrane Types:

A. Epithelial membranes
   1. Thin and sheetlike
   2. Composed of epithelium and underlying connective tissues
   3. Cover body surfaces and line body cavities
   4. Three types:
      a) Serous membranes line cavities with no exterior openings including various pleura
      b) Mucous membranes line cavities with exterior openings including oral and nasal cavities
      c) Cutaneous membrane lines the exterior of the body AKA skin

B. Synovial membranes lines joints and is only composed of connective tissues
Muscle Tissues:

A. General Characteristics

1. Muscle cells, also called muscle fibers, contract and relax

2. Consist of three major types

B. Skeletal Muscle Tissue

1. Skeletal muscle is attached to bone and can be controlled by conscious effort (voluntary).

2. The cells (muscle fibers) are
   a) long and cylindrical,
   b) striated,
   c) have many nuclei, and
   d) contract from nervous impulse.
C. **Smooth Muscle Tissue**

1. **Smooth muscle tissue**
   a) lacks striations,
   b) is uninucleate, and
   c) consists of spindle-shaped cells.

2. **This involuntary muscle** is found in
   a) the walls of internal organs,
   b) the digestive tract,
   c) blood vessels, and
   d) urinary bladder.
D. **Cardiac Muscle Tissue**

1. Found only in the heart

2. *Involuntary* muscle

3. Consists of branching fibers that are connected to each other with *intervalated disks*.

4. Has a single nucleus in each cell but appears striated.
Nervous Tissues:

A. Nervous tissues are found in the brain, spinal cord, and nerves.

B. Neurons, or nerve cells, conduct nervous impulses while helper cells, or neuroglia, support and nourish the neurons.
Chapter 6

The Skin and Integumentary System
Introduction:

A. **Organs** are body structures composed of two or more different tissues.

B. The skin and its accessory organs make up the **integumentary system**.
Types of Membranes

A. **Serous membranes**

1. Line body cavities that lack openings to the outside.
2. They line the thorax and abdomen and cover the organs within these cavities.
3. Serous membranes are made up of epithelium and loose connective tissue and secrete serous fluid that acts as a lubricant.
B. **Mucous membranes**

1. Line the cavities and openings that lead outside of the body
2. Consist of epithelium and connective tissue with specialized mucus secreting cells
3. Include the oral and nasal cavities, and openings of the digestive, reproductive, respiratory, and urinary systems.
C. **Synovial membranes**

1. Line the joint cavities.
2. Consist of only connective tissues
3. Secrete synovial fluid, a lubricant

D. **Cutaneous membrane**

1. Consists of the skin
2. The subject of the remainder of this chapter.
The Skin and Its Tissues

A. Description of Skin

1. large organ

2. responsible for maintaining homeostasis through:
   a) temperature regulation
   b) protection of underlying tissues
   c) retardation of water loss
   d) housing sensory receptors
   e) synthesizing certain chemicals, and
   f) excreting wastes

B. Layers

1. Peripheral epidermis

2. Thick and complex dermis

3. connected to underlying tissue by the subcutaneous layer (hypodermis).
C. Epidermis

1. Protects against:
   a) Water loss
   b) Mechanical injury
   c) Chemicals, and
   d) Microorganisms

2. Lacks blood vessels.

3. Made up of stratified squamous epithelium

4. Cells are pushed outward as new cells are formed, become **keratinized**, and die.
5. **Four or five layers may be seen:**

   a) *stratum basale*
      1) layer of reproducing cells at the base of the epidermis
      2) well-nourished by dermal blood vessels

   b) *stratum spinosum*

   c) *stratum granulosum*

   d) *stratum corneum*

   e) *stratum lucidum*
      1) found on the thicker palms and soles.
6. **Melanocytes**
   
a) lie deep in the epidermis and underlying dermis

b) produce a pigment called **melanin** that protects deeper cells from UV rays.

c) pass melanin to nearby cells through **cytocrine secretion**
D. Skin Color

1. Results from a combination of genetic, environmental, and physiological factors.

2. Genetic differences result from differing amounts of melanin and in the size of melanin granules.

3. Exposure to sunlight causes darkening of skin as melanin production increases.

4. Circulation within dermal blood vessels affects skin color.
E. Dermis

1. Binds the epidermis to underlying tissues.

2. Epidermal ridges and dermal papillae cause the border to be uneven.

3. Consists of connective tissue with collagen and elastic fibers within a gel-like ground substance.

4. Contains blood vessels that:
   a) carry nutrients to upper layers of skin
   b) help to regulate temperature.

5. Also contains:
   a) nerve fibers,
   b) sensory fibers,
   c) hair follicles,
   d) sebaceous glands, and
   e) sweat glands.
F. Subcutaneous Layer (hypodermis)

1. Composed of:
   1. Loose connective tissue
   2. Insulating adipose tissue.

2. Binds the skin to underlying organs

3. Contains the blood vessels that supply the skin

4. No sharp boundary exists between the dermis and subcutaneous layer.
Accessory Organs of the Skin

A. **Nails**

1. Protective coverings over the ends of fingers and toes.

2. Consist of stratified squamous epithelial cells overlying the *nail bed*

3. Lunula is the most actively growing region of the nail root.

4. As new cells are produced, older ones are pushed outward and become keratinized.
B. **Hair Follicles**

1. Tube-like depressions extending from epidermal surface to dermis

2. Individual hairs develop from the hair root at the base of the *hair follicle*

3. As new cells are formed, old cells are pushed outward, become keratinized, then die forming the hair *shaft*.

4. Found on almost all skin surfaces
5. *Arrector pili muscles*
   
a) Bundles of smooth muscle fibers attached to each hair follicle.

b) Contract when cold or upset

c) Contraction causes hair to stand on end, “goose bumps”

6. Hair color is genetically programmed
   
a) Color determined by type and amount of pigment produced by *melanocytes*

b) Dark hair has *eumelanin*

c) Blonde and red hair have *pheomelanin*
C. Sebaceous Glands

1. **Holocrine** glands

2. Associated with hair follicles

3. Secrete **sebum**
   
   a) Mix of fatty material and cellular debris
   
   b) waterproofs
   
   c) moisturizes skin and hair shafts
D. **Sweat Glands** (sudoriferous glands)

1. Exocrine glands

2. Two types:
   
   a) **Eccrine**
      a) Most abundant
      b) Respond to body temperature

   b) **Apocrine**
      a) Activate at puberty
      b) respond to body temperature, stress, and sexual arousal.

3. **Ceruminous** glands are modified sweat glands that secrete wax in the ear canal.

4. **Mammary** glands, another modified type of sweat glands, secrete milk.
Regulation of Body Temperature

A. Proper temperature regulation is vital to maintaining metabolic reactions.

B. Hypothalamus regulates body temperature and the skin plays a major role in this regulation.

C. Active cells, such as heart and skeletal muscle, produce heat.

D. Heat is lost from the skin through radiation.

E. The body responds to excessive heat by:
   1) dilation of dermal blood vessels
   2) sweating

F. The body responds to excessive cooling by:
   1) constricting dermal blood vessels
   2) inactivating sweat glands
   3) shivering
Healing of Wounds and Burns

A. **Inflammation**
   1. Body's normal response to injury
   2. Blood vessels dilate (redness)
   3. Heat from increased blood flow
   4. Become more permeable (swelling)
   5. Pain caused by increased pressure and injury to neurons

B. Superficial cuts (epidermis) are filled in by reproducing epithelial cells.
C. Deeper cuts (into dermis)
1) Closed off by clots
2) Covered by scabs
3) Filled in by fibroblasts making connective tissue
4) Blood vessels extend into the area
5) Phagocytic cells digest dead cells and debris
6) Injured tissues are replaced
7) Then the scab falls off.

E. Large wounds
1. **granulations** may form
   a) New branch of blood vessels
   b) Cluster of collagen secreting fibroblasts
2. Scars composed primarily of collagenous fibers may remain.
Chapter 7

Skeletal System
Introduction:
A. Bones are the organs of the skeletal system
B. They are very active tissues
C. Functions include:
   1. muscle attachment
   2. protection
   3. support,
   4. blood cell production
   5. storage of minerals
Bone Structure

A. Bones are classified by size and shape

1. Long
   1. Long longitudinal axes
   2. Expanded ends (epiphysis)
   3. Femur, humerus

2. Short
   1. Length and width near equal
   2. Carpals, tarsals

3. Flat
   1. Platelike with broad surfaces
   2. Ribs, scapulae
4. Irregular
   1. Various shapes
   2. Vertebrae, nasal concha

5. Sesamoid
   1. Round
   2. Usually small
   3. Embedded within tendons adjacent to joints
   4. Patella
B. Structure of long bones

1. The **diaphysis**
   a) Bone shaft
   b) Long relative to its diameter
   c) Wall composed of **compact bone**
   d) Contains a hollow **medullary cavity**
      a) lined with **endosteum**
      b) filled with **marrow**

2. The **periosteum**
   a) Tough layer of **vascular connective tissue**
   b) Covers the bone
   c) Continuous with ligaments and tendons
3. **Epiphysis**
   a) Expanded ends of long bones
   b) Form joints with adjacent bones
   c) Filled with **spongy bone** to reduce weight
   d) Covered by **articular cartilages** (hyaline cartilage)

4. Shape makes function possible
   
   a) *Bony processes* or grooves provide places of attachment for muscles
   b) Epiphyses allow for ease of movement in joints
C. Microscopic Structure

1. **Osteocytes** (bone cells)
   a) Located within *lacunae*
   b) Pass nutrients and gasses in the matrix through *canaliculi*

2. Intercellular material consists of:
   a) Collagen – provides strength and durability
   b) Inorganic salts (CaPO₄) – hardness

3. Osteocytes and intercellular material
   a) Compact bone is organized into osteons that:
      1) Extend longitudinally through bone
      2) Lie in concentric circles around central *Haversian canals* *(osteonic canals)*
      3) Are interconnected by transverse *perforating canals*
      4) Contain blood vessels and nerve fibers
      5) Osteons are cemented together
   b) Spongy bone is not arranged into osteons
Bone Development and Growth

A. Bones form by replacing connective tissues in the fetus.

B. **Intramembranous bones**
   1. form within sheetlike layers of connective tissue
   2. **Osteoblasts**
      a) Deposit bony tissue around themselves
      b) Once osteoblasts are surrounded by extracellular matrix (lacunae) they are called osteocytes.
   3. Cells of membranous connective tissue outside the bone develop the periosteum.
   4. Include the flat bones of the skull
C. **Endochondral bones** replace masses of cartilage

1. Most skeletal bones
2. First develop as hyaline cartilage models
3. Cartilage is broken down in the diaphysis
4. Periosteum develops on the outside
5. Disintegrating tissue is invaded by blood vessels and osteoblasts
6. Spongy bone is formed at the *primary* ossification center
7. Bone tissue develops outward towards the ends
8. Osteoblasts from the periosteum lay down compact bone outside the spongy bone.
9. *Secondary ossification centers* appear in the epiphyses
10. **Epiphyseal plates** (metaphysis)
   a) Bands of hyaline cartilage
   b) Form between the two ossification centers
   c) Made up of layers of cartilage cells undergoing mitosis
   d) Responsible for lengthening bones

11. Increases in thickness are due to intramembranous ossification underneath the periosteum.

12. **Osteoclasts** break down the calcified matrix

13. Then replaced with bone-building **osteoblasts** that deposit bone in place of calcified cartilage.

14. A **medullary cavity** forms in the region of the diaphysis due to the activity of **osteoclasts**.
E. Homeostasis of Bone Tissue

1. **Osteoclasts** tear down (*resorption*)
2. **Osteoblasts** build bone (*deposition*)
3. Average of 3% to 5% of bone calcium exchanged annually
Bone Function

A. Support and Protection

1. Bones give shape to:
   a) Head
   b) Thorax
   c) limbs.

2. Bones such as the pelvis and lower limbs provide support for the body.

3. Bones of the skull protect:
   a) Brain
   b) Ears
   c) Eyes
B. Body Movement

1. Bones can act as **levers**

2. A lever has four components:
   a) a rigid bar (bone)
   b) a pivot or fulcrum (joint)
   c) an object that is moved against resistance (bone)
   d) a force that supplies energy (muscle)

C. Blood Cell Formation

1. Blood cells begin to form through **hematopoieses** in the yolk sac

2. Later manufactured in bone marrow
3. Two kinds of marrow occupy the medullary cavities of bone:

a) **Yellow marrow**
   1) occupies the cavities of most bones
   2) stores fat

b) **Red marrow**
   a) Functions in the formation of:
      a) red blood cells
      b) white blood cells
      c) Platelets
   b) Found in the spongy bone
   c) Red marrow can replace yellow when needed
D. Storage of Inorganic Salts

1. The inorganic matrix of bone stores inorganic mineral salts
   a) Calcium phosphate (CaPO$_4$)
   b) Important in many metabolic processes
   c) Bone calcium is a reservoir for body calcium
   d) Calcium is stored in bone under the influence of calcitonin when blood levels of calcium are high
   e) When blood levels are low, osteoclasts release calcium from bone

2. Bone also stores magnesium, sodium, potassium, and carbonate ions.

3. Bones can also accumulate harmful elements, such as lead, radium, and strontium
Skeletal Organization

A. The **axial skeleton** consists of the:
   1. Skull
   2. Hyoid bone
   3. Vertebral column
   4. Thorax

B. The **appendicular skeleton** consists of the:
   1. Pectoral girdle
   2. Upper limbs
   3. Pelvic girdle
   4. Lower limbs
The Skull

A. The skull is made up of 22 bones
   1. 8 cranial bones
   2. 13 facial bones, and
   3. the **mandible**

B. Cranium
   1. encloses and protects the brain
   2. provides attachments for muscles
   3. contains air-filled *sinuses* that reduce its weight.

C. Facial Skeleton
   1. The 13 immovable facial bones and mandible
      a) form the basic face
      b) provide attachments for muscles of mastication and expression
Vertebral Column

A. Cervical Vertebrae
   1. Seven bones
   2. Smallest of the vertebrae
   3. comprise the neck and support the head
   4. The bifid spinous processes and transverse foramina distinguish cervical vertebrae

B. Thoracic Vertebrae
   A. Twelve thoracic vertebrae
   B. articulate with the ribs.
   C. larger and stronger than the cervical vertebrae.
C. Lumbar Vertebrae

1. Five lumbar vertebrae
2. Massive
3. Support the weight of the body.

D. Sacrum

1. Triangular structure
2. Base of the vertebral column
3. Made up of five vertebrae fused into one bone

D. Coccyx

1. The lowermost portion of the vertebral column
2. Composed of four fused vertebrae
Thoracic Cage

A. The thoracic cage includes:
   1. Ribs
   2. Thoracic vertebrae
   3. Sternum
   4. Costal cartilages

B. It supports the pectoral girdle and upper limbs

C. Functions in breathing

D. Protects thoracic and upper abdominal organs

E. Ribs
   1. 12 pairs of ribs
   2. Attach to the thoracic vertebrae

F. Sternum (breastbone)
   1. located along the anterior midline of the thoracic cage
Pectoral Girdle
A. The **pectoral girdle** makes an incomplete ring that supports the upper limbs
B. It is made up of two **scapulae** and two **clavicles**

Upper Limb
A. Bones of the upper limb form framework for:
1. Arm - **Humerus**
2. Forearm – **Radius, Ulna**
3. Hand – **Carpals, Metacarpals, Phalanges**
Pelvic Girdle
A. Supports the trunk of the body on the lower limbs
B. Supports and protects lower abdominal and pelvic organs
C. consists of:
   1. two hip (innominate) bones
   2. Sacrum
   3. Each hip bone is made up of the Ilium, Ischium, and Pubis

Lower Limbs
A. The bones of the lower limbs provide the framework for
   1. Thigh (femur)
   2. Lower leg (tibia, fibula)
   3. Foot (tarsals, metatarsals, phalanges)
Joints (articulations)

A. Functional junctions between bones
B. Enable a wide variety of body movements
C. Can be classified according to degree of movement possible:
   1. Immovable
   2. Slightly movable
   3. Freely movable

D. Can also classified according to the type of tissue that binds them together
   1. Fibrous Joints
      a) Held close together by dense connective tissue
      b) Either immovable (sutures of skull)
      c) Or only slightly movable
         (joint between the distal tibia and fibula)
2. **Cartilaginous Joints**
   a) Hyaline cartilage or disks of fibrocartilage unite the bones
   b) help absorb shock and are slightly movable
   c) Ex/ Intervertebral disks, the first rib with the sternum

3. **Synovial Joints**
   a) Most joints of the skeleton
   b) More complex than fibrous or cartilaginous joints
   c) Articular ends of bone are covered with hyaline cartilage
   d) A joint capsule consists of:
      a) outer layer of dense connective tissue that joins the periosteum,
      b) an inner layer made up of **synovial membrane**
      c) **Synovial fluid** has the consistency of egg whites and lubricates articulating surfaces within the joint
   e) Some contain shock-absorbing pads of fibrocartilage called **menisci**
   f) Some contain fluid-filled sacs called **bursae**
g) Can be classified based on the shapes of their parts and the movements they permit:

1) **Ball-and-socket joint**
   a. bone with a globular or egg-shaped head
   b. articulates with the cup-shaped cavity of another bone
   c. a very wide range of motion is possible
   d. examples include the hip and shoulder joint

2) **Condyloid joint**
   a. consists of an ovoid condyle fitting into an elliptical cavity
   b. permits a variety of motions
   c. the joint between a metacarpal and a phalange

3) **Gliding joints**
   a. occur where articulating surfaces are nearly flat or slightly curved
   b. allowing a back-and-forth motion
   c. the joints of the wrist and ankle and between vertebrae are gliding joints
4) **Hinge joint**
   a. A convex surface fits into a concave surface
   b. Movement is in one plane only
   c. Found in the elbow and phalange joints

5) **Pivot joint**
   a. A cylindrical surface rotates within a ring of bone and fibrous tissue
   b. Examples include the joint between the proximal ends of the radius and ulna

6) **Saddle joint**
   a. Forms where articulating surfaces have both concave and convex areas
   b. Permits a wide range of movements
   c. Found in the joint between the trapezium and the metacarpal of the thumb
E. Types of Joint Movements

1. When a muscle contracts
2. its fibers pull its movable end (insertion)
3. toward its stationary end (origin)
4. causing movement at a joint
Chapter 8

Muscular System
Introduction:

A. Muscles are the organs of the muscular system.

B. All movements require muscle using chemical energy to contract.

C. The three types of muscle in the body are

1. **Skeletal muscle**
2. **Smooth muscle**
3. **Cardiac muscle**
**Structure of a Skeletal Muscle**

A. Each muscle is an organ, comprised of
   1. Skeletal muscle tissue
   2. Connective tissues
   3. Nervous tissue
   4. Blood

B. Connective Tissue Coverings
   1. **Fascia**, layers of dense connective tissue, surround and separate each muscle.
   2. Extends beyond the ends of the muscle
   3. Gives rise to tendons that are fused to the periosteum of bones.
4. **Aponeuroses** are broad sheets of connective tissue that sometimes connect muscles

5. An **epimysium** is a layer of connective tissue surrounding each whole muscle

6. A **perimysium** surround each **fascicle** (individual bundle) within each muscle

4. Each muscle cell (fiber) is covered by a connective tissue layer called **endomysium**
C. Skeletal Muscle Fibers

1. Each muscle fiber is a single, long, cylindrical muscle cell.

2. Beneath the sarcolemma (cell membrane) lies sarcoplasm (cytoplasm) with many mitochondria and nuclei

3. Myofibrils lie within the sarcoplasm
   
a) Thick filaments of myofibrils are made up of the protein myosin.

b) Thin filaments of myofibrils are made up of the protein actin.

c) The organization of these filaments produces striations.
4. A **sarcomere** extends from one **Z** line to the next.

a) **I bands**
   1) light bands
   2) made up of actin filaments
   3) anchored to **Z** lines

b) **A bands**
   1) dark bands
   2) made up of overlapping thick and thin filaments

c) **H zone**
   1) In the center of **A bands**
   2) Consists of myosin filaments only
5. **Transverse (T) tubules**

a) Invaginations of the sarcolemma

b) Open to the outside of the muscle fiber

c) Associated with the **sarcoplasmic reticulum** (endoplasmic reticulum)

d) Each T tubule lies between two cisternae of the sarcoplasmic reticulum

e) The sarcoplasmic reticulum and transverse tubules activate the muscle contraction mechanism when the fiber is stimulated.
D. Neuromuscular Junction
1. The site where the motor neuron and muscle fiber meet is the neuromuscular junction.
2. The muscle fiber membrane forms a motor end plate in which the sarcolemma is tightly folded and where nuclei and mitochondria are abundant.
3. The cytoplasm of the motor neuron contains numerous mitochondria and synaptic vesicles storing neurotransmitters.

E. Motor Units
1. A motor neuron and the muscle fibers it controls make up a motor unit
2. when stimulated to do so, the muscle fibers of the motor unit contract all at once
Skeletal Muscle Contraction

A. Muscle contraction results in:
   1. Shortening of sarcomeres
   2. Pulling of the muscle against its attachments

B. Role of Myosin and Actin
   1. **Myosin** consists of two twisted strands with globular cross-bridges projected outward along the strands.
   2. **Actin** is a globular protein with myosin binding sites; **tropomyosin** and **troponin** are two proteins associated with the surface of the actin filaments
3. According to the **sliding filament theory** of muscle contraction
   a) The myosin **crossbridge** attaches to the binding site on the actin filament
   b) Bends, pulling on the actin filament
   c) Then releases and attaches to the next binding site on the actin, pulling again.

4. Energy from the conversion of ATP to ADP is provided to the cross-bridges from the enzyme **ATPase**, causing them to be in a “cocked” position.
C. Stimulus for Contraction

1. The motor neuron releases the neurotransmitter acetylcholine from its synaptic vesicles into the synaptic cleft

2. Protein receptors in the motor end plate detect the neurotransmitters

3. A muscle impulse spreads over the surface of the sarcolemma and into the T tubules, where it reaches the sarcoplasmic reticulum.

4. The sarcoplasmic reticulum releases its stored calcium to the sarcoplasm of the muscle fiber
5. High concentration of calcium in the sarcoplasm cause the **troponin** and **tropomyosin** molecules to move aside exposing the myosin binding sites on the actin filaments.

6. Myosin cross-bridges bind and pull on the actin filaments, causing the sarcomeres to shorten.

7. After the nervous impulse has been received **acetylcholinesterase** rapidly decomposes the acetylcholine.

8. Calcium is returned to the sarcoplasmic reticulum and the linkages between myosin and actin are broken.
Muscle contraction
Release of Ca\(^{2+}\) from sarcoplasmic reticulum exposes binding sites on thin filament:
- Ca\(^{2+}\) binds to troponin complex
- Tropomyosin pulled aside
- Binding sites on actin filament exposed

Muscle relaxation
Active transport of Ca\(^{2+}\) into sarcoplasmic reticulum, which requires ATP, makes myosin binding sites unavailable.

1. Exposed binding sites on actin allow the muscle contraction cycle to occur

2. Cross-bridge binds actin to myosin

3. Cross-bridge pulls actin filament (power stroke), ADP and P released from myosin

4. New ATP binds to myosin, causing linkage to release

5. ATP splits, which provides power to "cock" the myosin cross-bridge

ADP + P

Actin filament
Tropomyosin
Troponin complex
Actin monomers
Myosin filament
<table>
<thead>
<tr>
<th>Table 8.1</th>
<th>Major Events of Muscle Contraction and Relaxation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Muscle Fiber Contraction</strong></td>
<td></td>
</tr>
<tr>
<td>1. A nerve impulse travels down a motor neuron axon.</td>
<td></td>
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<tr>
<td>2. The motor neuron terminal releases the neurotransmitter acetylcholine (ACh).</td>
<td></td>
</tr>
<tr>
<td>3. ACh binds to ACh receptors.</td>
<td></td>
</tr>
<tr>
<td>4. The sarcolemma is stimulated, and a muscle impulse travels over the surface of the muscle fiber and deep into the fiber through the transverse tubules.</td>
<td></td>
</tr>
<tr>
<td>5. The muscle impulse reaches the sarcoplasmic reticulum and calcium channels open.</td>
<td></td>
</tr>
<tr>
<td>6. Calcium ions diffuse from the sarcoplasmic reticulum into the sarcoplasm and bind to troponin molecules.</td>
<td></td>
</tr>
<tr>
<td>7. Tropomyosin molecules move and expose specific sites on actin.</td>
<td></td>
</tr>
<tr>
<td>8. Actin and myosin form linkages.</td>
<td></td>
</tr>
<tr>
<td>9. Thin (actin) filaments are pulled toward the center of the sarcomere by myosin cross-bridges.</td>
<td></td>
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<tr>
<td>10. The muscle fiber shortens as a contraction occurs.</td>
<td></td>
</tr>
<tr>
<td><strong>Muscle Fiber Relaxation</strong></td>
<td></td>
</tr>
<tr>
<td>1. Acetylcholinesterase decomposes acetylcholine, and the muscle fiber membrane is no longer stimulated.</td>
<td></td>
</tr>
<tr>
<td>2. Calcium ions are actively transported into the sarcoplasmic reticulum.</td>
<td></td>
</tr>
<tr>
<td>3. ATP breaks linkages between actin and myosin filaments without breakdown of the ATP itself.</td>
<td></td>
</tr>
<tr>
<td>4. Breakdown of ATP &quot;cocks&quot; the cross-bridges</td>
<td></td>
</tr>
<tr>
<td>5. Troponin and tropomyosin molecules inhibit the interaction between myosin and actin filaments.</td>
<td></td>
</tr>
<tr>
<td>6. The muscle fiber remains relaxed, yet ready, until stimulated again.</td>
<td></td>
</tr>
</tbody>
</table>
D. Energy Sources for Contraction

1. Energy for contraction comes from ATP.

2. Creatine phosphate stores excess energy released by the mitochondria.

3. Creatine phosphokinase promotes synthesis of creatine phosphate when the supply of ATP is sufficient.

4. As ATP decomposes, the energy from creatine phosphate can be transferred to ADP molecules regenerating ATP.
E. Oxygen Supply and Cellular Respiration

1. Muscle has a high requirement for oxygen to enable the complete breakdown of glucose to create ATP in the mitochondria.

2. Hemoglobin in red blood cells carries oxygen to muscle.

3. The pigment myoglobin stores oxygen in muscle tissues.
F. **Oxygen Debt**

1. During rest or moderate activity there is enough oxygen to support aerobic respiration.

2. During strenuous exercise oxygen deficiency may develop and lactic acid accumulates as an end product of anaerobic respiration.

3. **Lactic acid** diffuses out of muscle cells and is carried in the blood to the liver.

4. Oxygen debt refers to the amount of oxygen required by:
   a) Liver cells to convert accumulated lactic acid into glucose
   b) Muscle cells need to resynthesize ATP and creatine phosphate to their original concentrations

5. Repaying an oxygen debt may take several hours.
<table>
<thead>
<tr>
<th><strong>Type of Exercise</strong></th>
<th>Muscle Metabolism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low to moderate intensity: Blood flow provides sufficient oxygen for cellular requirements</td>
<td>High intensity: Oxygen supply is not sufficient for cellular requirement</td>
</tr>
<tr>
<td><strong>Pathway Used</strong></td>
<td>Muscle Metabolism</td>
</tr>
<tr>
<td>Glycolysis, leading to pyruvic acid formation and aerobic respiration</td>
<td>Glycolysis, leading to lactic acid formation</td>
</tr>
<tr>
<td><strong>ATP Production</strong></td>
<td>Muscle Metabolism</td>
</tr>
<tr>
<td>36 ATP per glucose for skeletal muscle</td>
<td>2 ATP per glucose</td>
</tr>
<tr>
<td><strong>Waste Product</strong></td>
<td>Muscle Metabolism</td>
</tr>
<tr>
<td>Carbon dioxide is exhaled</td>
<td>Lactic acid accumulates</td>
</tr>
</tbody>
</table>
G.  Muscle Fatigue

1. Muscle fatigue usually arises from the accumulation of lactic acid in the muscle.
2. Lowering of pH by accumulated lactic acid prevents the muscle from contracting.
3. When a muscle loses its ability to contract during strenuous exercise, it is referred to as *fatigue*.
4. A *muscle cramp* occurs due to a lack of ATP required to return calcium ions back to the sarcoplasmic reticulum so muscle fibers can relax.

H.  Heat Production

1. Contraction of skeletal muscle represents an important source of heat for the body.
2. Much of the energy produced through the reactions of cellular respiration is lost as heat (another source of heat for the body).
Muscular Responses

A. Muscle function is studied by
   1. Removing a single muscle fiber
   2. Connecting it to a device that records its responses to electrical stimulation
   3. Providing electrical stimuli
   4. A myogram is the recording of an electrically-stimulated muscle contraction

B. When a muscle fiber contracts, it always contracts to its full extent (all-or-none response); it cannot contract partially

C. A twitch is a single, short contraction involving only a few motor units

D. A muscle fiber remains unresponsive to stimulation unless the stimulus surpasses its threshold stimulus.
E. The **latent period** is the time delay between when the stimulus is applied and when the muscle contracts (less than *two* milliseconds)

F. The latent period is followed by a *period of contraction* and a *period of relaxation*.
G. Summation

1. A muscle fiber receiving a series of stimuli of increasing frequency reaches a point when it is unable to relax completely and the force of individual twitches combine by the process of summation.

2. If the sustained contraction lacks any relaxation, it is called a tetanic contraction.
Series of twitches

Summation

Tetanic contraction
H. Recruitment of Motor Units

1. An increase in the number of activated motor units within a muscle at higher intensities of stimulation is called recruitment.

2. Summation and recruitment together can produce a sustained contraction of increasing strength.

3. Muscle tone is achieved by a continuous state of sustained contraction of motor units within a muscle.
Smooth Muscles

A. Smooth Muscle Fibers

1. Elongated with tapered ends
2. Lack striations
3. Relatively undeveloped sarcoplasmic reticulum
4. Two types of smooth muscles:
   a) Multiunit smooth muscle
      1) fibers occur separately rather than as sheets
      2) blood vessels and iris of the eye
   b) Visceral muscle
      1) found in the walls of hollow organs
      2) occurs in sheets
      3) fibers can stimulate one another and display rhythmicity
      4) responsible for peristalsis in hollow organs
B. Smooth Muscle Contraction

1. The myosin-binding-to-actin mechanism is mostly the same for smooth muscles and skeletal muscles.

2. Both acetylcholine and norepinephrine stimulate and inhibit smooth muscle contraction, depending on the target muscle.

3. Hormones can also stimulate or inhibit contraction.

4. Smooth muscle is slower to contract and relax than is skeletal muscle, but can contract longer using the same amount of ATP.
Cardiac Muscle

A. The mechanism of contraction in cardiac muscle is essentially the same as that for skeletal and smooth muscle, but with some differences.

B. Cardiac muscle has transverse tubules that supply extra calcium and so can contract for longer periods.

C. Intercalated disks (complex membrane junctions)
   1. Join cells and transmit the force of contraction from one cell to the next
   2. Aid in the rapid transmission of impulses throughout the heart.

D. Cardiac muscle is self-exciting and rhythmic

E. The whole structure contracts as a unit
Skeletal Muscle Actions

A. Origin and Insertion

1. The immovable end of a muscle is the **origin**
2. The movable end is the **insertion**
3. Contraction pulls the **insertion** toward the origin
4. Some muscles have more than one insertion or origin.

B. Interaction of Skeletal Muscles

1. In a group of muscles, the one doing the majority of the work is the **prime mover**.
2. Helper muscles are called **synergists**
3. Opposing muscles are called **antagonists**
Major Skeletal Muscles

A. Muscles are named according to any of the following criteria:

1. Size
2. Shape
3. Location
4. Action
5. Number of attachments
6. Direction of its fibers
B. Muscles of Facial Expression

1. Are responsible for the variety of facial expressions possible in the human face
2. Muscles of facial expression attach to underlying bones and overlying connective tissue of skin

C. Muscles of Mastication

1. Chewing movements include up and down as well as side-to-side grinding motions of muscles attached to the skull and lower jaw.

D. Muscles that Move the Head

1. Paired muscles in the neck and back flex, extend, and turn the head.
E. Muscles that Move the Pectoral Girdle

1. The chest and shoulder muscles move the scapula.

F. Muscles that Move the Arm

1. Muscles allow the arm to move freely
2. They connect the arm to:
   a) pectoral girdle
   b) ribs
   c) vertebral column

4. Extensors
5. Abductors
6. Rotators
G. Muscles that Move the Forearm
   1. Arise from the humerus or pectoral girdle
   2. Connect to the ulna and radius.

H. Muscles that Move the Wrist, Hand, and Fingers
   1. Movements of the hand are caused by muscles originating from:
      a) the distal humerus
      b) radius
      c) ulna
I. **Muscles of the Abdominal Wall**

1. **This group of muscles connects the rib cage and vertebral column to the pelvic girdle.**

2. **A band of tough connective tissue, the **linea alba**, extending from the xiphoid process to the symphysis pubis, serves as an attachment for certain abdominal wall muscles.**
J. Muscles of the Pelvic Outlet

1. The superficial **urogenital diaphragm** fills the space within the pubic arch
2. The deeper **pelvic diaphragm** forms the floor of the pelvic cavity

K. Muscles that Move the Thigh

1. The muscles that move the thigh are attached to:
   a) femur
   b) pelvic girdle.

L. Muscles that Move the Leg

1. This group connects the tibia or fibula to the femur or pelvic girdle
Some more Latin (and Greek)

- adip- = fat
- ax- = axis
- -blast = bud
- calat- = something inserted
- carp- = wrist
- chondr- = cartilage
- -clast = break
- condyl- = knob
- corac- = crow’s beak
- cribr- = sieve
- crist- = crest
- cut- = skin
- -cyt = cell
- epi- = upon
- erg- = work
- derm- = skin
- follic- = small bag
- fov- = pit
- glen- = joint socket
and more Latin (and Greek)

- glia = glue
- inter- = between
- intra- = inside
- kerat- = horn
- macr- = large
- meat- = passage
- melan- = black
- myo- = muscle
- odont- = tooth
- os- = bone
- poie- = make, produce
- pseud- = false
- sarco- = flesh
- seb- = grease
- squam- = scale
- strat- = layer
- syn- = together
- tetan- = stiff
- -troph = well fed