Learning Outcome B4

Connective Tissue
- Is the most abundant tissue type and is widely distributed throughout the body.
- Found in blood, under skin, in bone, and around many organs.
- Connects, binds together parts of the body.
- Also functions in support and protection, allows the storage of fat, and the transport of substances.

Most connective tissues share two similar characteristics:
- Both have a good blood supply.
  - Ligaments, tendons, and cartilage are also types of connective tissue but they do not have a blood supply.
  - This is the reason why injuries to these areas heal very slowly.
  - Have an abundance of intracellular matrix.

Intercellular Matrix is what makes types of connective tissue so different.
- Located outside cells and fills spaces between cells.
- Cells secrete matrix and it fills intercellular spaces.
- Hardness of intercellular matrix varies from cell to cell.

Matrix may be liquid as in blood, gel-like as in fat tissue, or hard as in bone.
- Amount of matrix also varies between cell types.
  - In fat tissue the cells are close together; with very little intercellular matrix.
  - Bone and cartilage have very few cells and large amounts of intercellular matrix.
  - Also in the matrix of most connective tissue is protein fibers:

- **Collagen** – strong and flexible but only slightly elastic, white in color.
- **Elastin** – not very strong but stretchy, yellow in color.
- **Reticular fibers (fine collagen)** – also strong and very flexible.
Collagen Injections
- Used to remove unwanted wrinkles and lines
- Use cattle collagen or patient's collagen from hips, thighs or abdomen.
- Injected under skin and fills unwanted wrinkles

Collagen

Types of Connective Tissue

Loose (areolar) Connective Tissue
- Is beneath skin and most epithelial tissue
- Also found between muscle
- Functions to bind together, cushions, protects and acts as tissue glue.
- Made up of collagen and elastic fibers in an intercellular matrix.
- Soft and protects and cushions many organs.
- Holds organs in position.
- A layer underlies all mucous membranes.

Adipose Connective Tissue
- Is located beneath skin (subcutaneous layer), around the heart and kidneys, behind the eyeballs.
- Functions to cushion insulate and stores fat.
- A type of loose connective tissue that supports fat.
- Can insulate body and prevent heat loss.
- Deposited around certain organs.
  - Example holds kidneys in place.

Dense fibrous Connective Tissue
- Makes up tendons, ligaments, and skin (dermis).
- Functions to bind structures together.
- Contains many collagen and elastic fibers.
- The main type of fiber is collagen; it forms strong supporting structures: tendons, ligaments and fascia.
  - Tendons are cord-like structures that attach muscle to bone.
  - Ligaments are dense fibrous connective tissue that cross joints and attach bone to bone.

Types of Connective Tissue

Ligaments contain more elastic fibers than tendons; therefore have a greater ability to stretch.
- Ability to stretch: prevents tearing of ligaments when joints bend.
  - Fascia are bands and/or sheets of dense fibrous connective tissue.
- Covers muscle, blood vessels and nerves.
- Functions to cover, support and anchors the organs to nearby structures.
**Types of Connective Tissue**

- Tendons and ligaments can tear and stretch with excessive stretching.
- Example a torn Achilles tendon causes loss of movement because tendons attach the leg muscle to the heel.

**Types of Connective Tissue**

- Reticular Connective Tissue
  - Makes lymphoid tissue; make up lymph nodes, spleen and bone marrow.
  - Functions to form internal framework of lymphoid organs.

**Types of Connective Tissue**

- Cartilage
  - Formed by cells known as chondrocytes.
  - Chondrocytes secrete a protein that is put into the intercellular matrix, this allows the matrix to be firm, smooth and flexible.
  - Although the matrix is solid it is not as hard as the matrix of bone.

**Types of Connective Tissue**

- Most cartilage is covered by a perichondrium.
- Perichondrium is a layer of connective tissue that carries blood vessels to the cartilage.
- The perichondrium supplies oxygen and nutrients to the cartilage.
- Cartilage does not have its own blood supply.

**Types of Connective Tissue**

a. Hyaline Cartilage
  - Located at the end of long bones and at joints.
  - Also connects ribs to sternum
  - Makes up rings in trachea
  - Makes up nose and fetal skeleton
  - Function to support, protect and provide framework for the body.
**Types of Connective Tissue**

b. **Fibrocartilage**
- Makes up intervertebral discs, pads in the knee joint and the pads within pubic bones.
- Functions to cushion and support
Types of Connective Tissue

c. Elastic Cartilage
- Makes up external ear and part of the larynx.
- Functions to support and provides framework of the body

Elastic Cartilage

Bone
- Makes up skeleton
- Functions to support the body and provide the framework
- Also known as osseous tissue.
- Bone cells are called osteocytes
- Bones cells secrete an intercellular matrix made up of collagen, calcium salts and other minerals.

Types of Connective Tissue

Osteocytes

Types of Connective Tissue

- Collagen provides flexibility and strength
- A matrix becomes hard, such as in bone when minerals are deposited.
- Hardness of bone lets it protect organs such as the brain
- Bone also acts as a storage site for mineral salts such as calcium.
When mineralization of bone tissue is diminished, the bone is weakened and tends to break easily. This is known as osteoporosis.

Calcium is the most important mineral especially through childhood and menopause due to lack of estrogen. Estrogen helps calcium deposit into bone; so do weight bearing activities.

Blood

Function to transport nutrients, hormones, respiratory gases ($O_2$ and $CO_2$) and wastes.

Lymph

Makes up all lymphatic vessels. Functions to drain all interstitial fluid and functions in immunity. Blood and lymph are two type so connective tissue that have a watery intercellular matrix. Blood is surrounded by and intercellular matrix is known as plasma. Plasma does not contain elastin or collagen; it contains a non fibrous plasma protein. Lymph is found in lymphatic tissue.

Nervous System

Neurons are composed of three parts:

- Dendrites – receive information from other neurons and then transmits info towards the cell body.
- Cell body – contains the nucleus and is essential for life.
- Single axon – transmits info away from the cell body.

Nervous System

Neurons

Makes up the brain, spinal cord and nerves. Made up of two types of cells: neurons and neuroglia. Neurons transmit electrical signals to the brain and spinal cord. Neurons have many shapes and sizes.
Neuroglia are cells that support and take care neurons. These cells support and stick together the vast network of neuron. Neuroglia do not transmit electrical signals.

Neuroglia are composed of cells that shorten and contract. Cells are long and slender; so they are called fibers instead of cells. There are three types of muscle fibers:

1. **Skeletal** — attached to bone
   - Also known as striated (aka stripes)
   - Striations are due to proteins within the muscle tissue
   - Function to move the skeleton; and maintains posture and stabilizes joints.

Skeletal Muscle
**Muscle Tissue**

2. **Smooth muscle** – found in the walls of viscera and organs.
   - Example – stomach, intestine, urinary bladder.
   - Also make up the walls of bronchioles and blood vessels.
   - Function is related to location
     - Small muscle in stomach helps mash and turn food
     - Smooth muscle in bladder helps expel urine
   - Smooth muscle is not voluntarily controlled, so it is known as involuntary muscle.
   - Not striated; therefore known as non-striated muscle

**Smooth Muscle**

- Smooth muscle cells cut in long/oblique section

**Muscle Tissue**

3. **Cardiac Muscle** – found only in the heart and pumps blood through blood vessels.
   - Cardiac muscle is striated
   - Muscle fibers are long branching fibers that fit together tightly at junctions.
   - Tight junctions are called intercalated discs and promote rapid conduction of electrical signals through the heart.

**Cardiac Muscle**

- Cardiac muscle with intercalated discs

**Review of Muscle Types**

- Cardiac muscle cell
- Skeletal muscle cell
- Smooth muscle cell

**Tissue Repair**

- There are two types of tissue repair:
  1. **Regeneration** – replacement of tissue by cells that are identical to the original cells
    - This occurs only in cells that undergo mitosis, such as epithelial cells
  2. **Fibrosis** – is the replacement of injured tissue by the formation of fibrous connective tissue or scar tissue
    - The fibers of scar tissue pull the edges of a wound together and strengthen the area.
    - Damaged skeletal, cardiac and nervous tissue does not undergo mitosis and must be replaced by scar tissue.
Steps in Tissue Repair

1. Deep wound in the skin severs blood vessels; causing blood to fill the wound.
2. A blood clot forms and as it dries a scab is formed.
3. Tissue repair begins; scar tissue forms in the deep layer.
4. At the same time surface epithelial cells multiply and fill the area between the scar tissue and the scab.
5. When the epithelium is completed the scab detaches.
6. A fully generated layer of epithelium over an underlying area of scar tissue.

Structure of Muscles

Belly – refers to the enlarged fleshy part of a muscle between the points of attachment.
- Each muscle is composed of thousands of single muscle fibers (aka muscle cells)
- Large skeletal muscles are surrounded by a layer of tough connective tissue known as fascia.

Epimysium – is the outer layer of fascia.
- Fascia extends and attaches to the bone as tendon.

Structure of Muscles

Perimysium – is another layer of connective tissue that surrounds smaller bundles of muscle fibers.

Fascicles – are small bundles of muscle fibers.

Endomysium – is the third layer of connective tissue that surrounds the fascicles that contains individual muscle fibers.
- Muscles form attachments to other structures in three ways:
  - Tendons attach muscle to bone
  - Muscle attaches directly to bone
  - Aponeurosis is a flat sheet-like fascia that connects muscle to muscle and muscle to bone.

Structure of Muscles

Muscle fibers have more than one nucleus and are surrounded by a cell membrane known as a sarcolemma.
At several points the cell membrane penetrates deep into the interior of the muscle fibers forming transverse tubules (T-tubules).
- Muscle fibers have a specialized endoplasmic reticulum known as sarcoplasmic reticulum.
- Each muscle fiber is made up of a long cylindrical structure called myofibrils.

Structure of Muscles

Sarcomeres – are small contractile units that make-up myofibrils.
- Each sarcomere extends from a Z-line to Z-line and is formed by a unique arrangement of two contractile proteins: actin and myosin.
- Z-line occurs at the end of each sarcomere
- Thin actin filaments extend from the Z-line towards the centre of the sarcomere.
- Thicker myosin filaments sit between the actin filaments.
- Arrangement of myosin and actin gives skeletal and cardiac muscle its striped appearance.
When muscles contract, they shorten. They shorten because the sarcomeres shorten. The sarcomeres shorten because actin and myosin filaments slide past one another. The sarcomeres shorten when the myosin head makes contact with the actin; forming a temporary cross bridge.

Once the cross bridge forms; the myosin head rotates; pulling the actin towards and centre of the sarcomere. The rotation of the myosin head causes the actin to slide past the myosin. Muscle relaxation occurs when the cross bridges are broken and the actin and myosin return to their original position.
Rigo Mortis
- Formation of cross bridges and detachment depends on ATP.
- When a person dies, cells no longer make ATP.
- Prevents detachment of some muscles, becoming stiff.
- Helps determine time of death, as rigor begins two hours after death; peaks at 12 hours and is over in 36 hours.

Role of Calcium & ATP in Muscle Contraction and Relaxation
- ATP helps myosin heads form and break cross bridges with actin.
- ATP only works in the presence of calcium.
- When the muscle is relaxed; calcium is stored in the SR away from the actin and myosin.
- When the muscle is stimulated; calcium is released from the SR and causes actin; myosin and ATP to interact.
- When calcium is pumped back into the SR away from the actin and myosin and ATP, the cross bridges are broken and the muscle relaxes.
- Calcium is essential for muscle contractions.

Skeletal Muscles & Nerves
- Skeletal muscle contraction occurs only in muscle that has been stimulated by a nerve.
  Somatic (motor) nerve – supplies skeletal muscle
- A somatic nerve comes from the spinal cord and supplies several muscles with nerve stimulation.
- Neuromuscular Junction - is an area where the motor nerve meets the muscle.
- Structures within the NMJ are:
  - Membrane at the end of the nerve
  - A space between the nerve ending and muscle membrane
  - Receptors site on the muscle membrane.

Neuromuscular Junction

Neurotransmitter
The Neuromuscular Junction

- Stimulated nerve causes a release of chemical substances that diffuse across the NMJ and stimulates the muscle membranes.
- There are four steps involved in the transfer of info from nerve to muscle at the NMJ:
  1. Stimulation of a nerve causes an electrical signal to move along the nerve toward the nerve ending.
  2. The nerves endings contain membranous pouches known as vesicles filled with substances known as neurotransmitters.

3. The transmitter at the NMJ is acetylcholine (Ach)
4. Nerve impulses cause the vesicle to move forward and fuse with the nerve endings
5. Ach is released into the space between the nerve endings

6. Ach diffuses across the space and binds to the receptor sites on the muscle membrane.
7. Ach stimulates the receptor and causes an electrical signal to develop along the muscle membranes.
8. Ach leaves the binding site and is immediately destroyed by an enzyme; that is found in the NMJ.

9. The enzyme is called acetylcholinesterase
10. Free binding sites are ready for additional ach when the nerve is stimulated again.

The Stimulated Muscle Membrane

- When the electrical signal reaches the muscle membrane it travels along the membrane and triggers a series of events that results in muscle contractions.
- The electrical signal travels across the membrane and penetrates into the interior through T-tubules.
- The electrical signal causes the SR to release calcium.
- The calcium flows into the sarcomeres and allows the interaction of actin, myosin and ATP, which is the energy used to produce muscle contraction.
- Eventually calcium is pumped back into the SR and muscle relaxation can occur.

Disorders of the NMJ

Myasthenia Gravis - symptoms of this disease are due to damaged receptor sites on the muscle membranes.
- Prevents the binding of Ach
- Impairs muscle contraction; results in extreme muscle weakness.
- Results in low tolerance to exercise; difficulty rising eyelids and trouble breathing.
- Neurotoxins are chemical substances that disrupt normal function of the nervous system.
- Neurotoxins are produced by bacteria.
Disorders of NMJ
- Example: *Clostridium tetani* – secretes a neurotoxin; that causes excessive firing of motor neurons.
- This causes an excessive release of Ach, the overstimulation of the muscle membrane, causing severe muscle spasms and titanic contractions.
- Causing tetanus
- Disease is often called lockjaw, because the jaw muscle are often the first affected.

Disorders of the NMJ
- Example: *Clostridium botulinum* – bacterium appears when food has been improperly processed or canned.
- Causes botulism; which is a very serious form of food poisoning.
- Neurotoxins prevents the release of Ach at the ends of nerves.
- No Ach; means the muscles cannot contract.
- Muscles including breathing muscles become paralyzed.

Response of Whole Muscle
- Contraction of a whole muscle versus a single muscle fiber
- A single muscle fiber contracts completely not partially or it does not contract at all.
- A whole muscle can contract partially depending on what the purpose of the contractions is.
- Muscles can vary in strength and contraction; due to the number of muscle fibers being used.

Response of Whole Muscle
- *Example*
- Lifting a pencil activates several hundred fibers
- Lifting a 100lb weight activates several thousands of fibers
- All muscle fibers contract completely; additional force is provided by recruiting additional muscle fibers.

Twitch & Tetanum
- Used to describe whole muscle contractions
  - *Twitch* - if a single stimulus is delivered to a muscle; the muscle contracts and fully relaxes.
  - *Tetanus* - the muscle is stimulated repeatedly with no time to relax.
- The muscle remains contracted.
- Titanic muscle contractions are sustained and smooth; and play an important role in maintaining posture.
- If the muscles that maintained posture only twitched, we would not be able to stand.
- Not lockjaw

Muscle Tone
- *Is the continuous state of partial muscle contraction*
- *Tone is due to the contraction of different groups of muscle fibers within a whole muscle.*
- To maintain tone; one groups of muscle fibers contracts.
- As these fibers relax a second group of muscle fibers contracts.
- Muscle tone of smooth muscle in blood vessels help maintain blood pressure.
Energy for Muscle Contraction
- ATP is consumed by the contracting of muscle and it is replaced in three ways
  - Aerobic metabolism is the presence of oxygen; fuels such as glycogen, glucose and fats can be completely broken down to yield energy (ATP)
  - Anaerobic metabolism is when the body can metabolize fuels in the absence of oxygen.
- Without oxygen the complete breakdown of fuel is not possible and lactic acid is produced.
- Accumulation of lactic acid is the cause of muscle soreness after heavy exercise.

Describing Muscle Movement
- Origin and insertion refers to the site of muscle attachment
- When a muscle contracts across a joint; one bone remains stationary.
  - Origin – muscle that attaches to a stationary bone
  - Insertion muscle that attaches to the more moveable bone

Metabolism of Creatine Phosphate
- Creatine phosphate contains energy that the body can use to replenish ATP quickly during muscle contraction.
- Storage form of energy

Describing Muscle Movement
- Example - the origin of the biceps brachii is the scapula while the insertion is on the radius
- One contraction of the biceps brachii the radius is pulled toward the scapula
- Movement is generally accomplished by the group of muscles, but a single muscle is responsible for most of the movement.
- Prime movers are the “chief muscle” responsible for most of the movement.
- Synergists are the “helper muscles” that help move the prime mover.
- Antagonists are muscles that oppose the motion of another muscle.

Describing Muscle Movement
- Example - the contraction of the biceps brachii; the prime mover, pulls the lower arm towards the shoulder. The triceps brachii is the antagonists. it opposes the action of the biceps brachii by pulling the lower arm away from the scapula.

Overuse & Underuse of Muscles
- Hypertrophy
  - Overused muscles will increase in size.
  - Cardiac muscle can also undergo hypertrophy; this generally indicates the heart is working too hard.
  - Example - hypertension
    - Causes the heart to push blood into blood vessels that are resistant to the flow of blood
    - This extra work causes the heart to enlarge.
**Atrophy**
- Occurs if muscles are not used.
- They decrease in size.
- *Example* - a person with a broken leg

**Contracture**
- Occurs if the muscle is immobilized for a long period of time.
- Is an abnormal formation of fibrous tissue within a muscle, causes muscles to freeze in flexed position and severely restricts joint mobility.

**Naming of Skeletal Muscle**
- Name is based on the following characteristics:
  - Shape
  - Size
  - Direction of fibers
  - Location of fibers
  - Number of origins
  - Origin and insertion
  - Muscle action.

**Shape**
- Deltoid - triangular
- Latissimus - wide
- Trapezius - trapezoid
- Rhomboideus - rhomboid
- Teres - round

**Size**
- Vastus - huge
- Maximum - large
- Longus - long
- Minimus - small
- Brevis - short

**Direction of Fibers**
- Rectus - straight
- Oblique - diagonal
- Transverse - across
- Circularis - circular
**Location**
- Pectoralis - chest
- Gluteus - buttocks
- Brachii - arm
- Supra - above
- Infra - below
- Sub - underneath
- Lateralis - lateral

**Number of Origins**
- Number of sites at which the muscle is anchored
  - 2 biceps
  - 3 triceps
  - 4 quadriceps

**Muscle Anchors**
- Number of sites at which the muscle is anchored
  - 2 biceps
  - 3 triceps
  - 4 quadriceps

**Muscle Action**
- Abductor muscle moves away from midline
- Adductor muscle moves toward midline
- Flexor causes flexion
- Extension straightens limb
- Levator elevates a structure
- Masseter enables to chew

**Muscles of Head**
- There are two categories:
  - Facial muscles
  - Chewing muscles

  Facial Muscles
  - Inserted directly into the soft tissue of skin and other muscles of skin
  - When facial muscles contract; they pull of the soft tissue.

**Facial Muscles**
- *Frontalis*
  - Is a flat muscle that covers the frontal bone
  - Extends from the cranial aponeurosis to the skin of the eyebrows
  - Function is contraction, which raises the eyebrow and wrinkles the forehead