Section 3: Basic and Applied Sciences and Nutritional Concepts

Chapter 5. The Nervous, Muscular, and Skeletal Systems Summary

Nervous System

- The human movement system includes an integration of the nervous, skeletal, and muscular systems.
- The nervous system provides sensory (afferent) and motor (efferent) information.
- The neuron is the functional unit of the nervous system.
- The nervous system includes the CNS (brain and spinal cord) and PNS (somatic and autonomic nervous system).
- The PNS contains different types of sensory receptors such as mechanoreceptors, nociceptors, chemoreceptors, and photoreceptors.
- The muscle spindle and Golgi tendon organ are two important sensory receptors (mechanoreceptors).
- The PNS contains two subdivisions: the somatic and autonomic nervous systems.
- The nervous system requires different electrolytes for proper function, which include sodium, potassium, magnesium, and water.
- Motor skill development often occurs in three stages: cognitive, associative, and autonomous.
- The nervous system develops as humans age from childhood to adulthood.

Important Concepts (not an exhaustive list)	
Human movement system (HMS)	The collective components and structures that work together to move the body: muscular, skeletal, and nervous systems.
Neuron	Specialized cell that is the functional unit of the nervous system.
Three components of a neuron	Neurons are composed of three main parts: cell body, axon, and dendrites.
Central nervous system (CNS)	A division of the nervous system that includes the brain and spinal cord.
Peripheral nervous system (PNS)	Nerves that connect the rest of the body to the central nervous system.
Afferent pathway	Sensory pathway that relays information to the central nervous system.
Efferent pathway	A motor pathway that relays information from the central nervous system to the rest of the body.

Mechanoreceptors	Specialized structures that respond to mechanical forces (touch and pressure) within tissues and then transmit signals through sensory nerves.
Somatic nervous system	Nerves that serve the outer areas of the body and skeletal muscle and are largely responsible for the voluntary control of movement.
Autonomic nervous system	A division of the peripheral nervous system that supplies neural input to organs that run the involuntary processes of the body (e.g., circulating blood, digesting food, producing hormones).
Sympathetic nervous system	Subdivision of the autonomic nervous system that works to increase neural activity and put the body in a heightened state.
Parasympathetic nervous system	Subdivision of the autonomic nervous system that works to decrease neural activity and put the body in a more relaxed state.
Proprioception	The body's ability to naturally sense its general orientation and relative position of its parts.
Muscle spindles** very important	Sensory receptors sensitive to change in **length** of the muscle and the rate of that change.
Golgi tendon organ (GTO) ** very important	A specialized sensory receptor located at the point where skeletal muscle fibers insert into the tendons of skeletal muscle; sensitive to changes in muscular **tension** and rate of tension change.
Three stages of motor skill development	• During stage 1 (cognitive), you may need to use simple instructions and break down the skill into smaller steps so your clients will be able to understand the goals of the movement. • During stage 2 (associative), you may need to help refine your clients' skills through practice and regular feedback. • During stage 3 (autonomous), you may be able to teach your clients new versions of the skill to further challenge them.

Skeletal System

- The skeletal system provides support for the body and protects the internal organs.
- The skeletal system has two divisions: axial and appendicular.
- Human bones act as attachment sites and levers (rigid rods) to produce movement when muscles contract.
- Bone growth occurs throughout life and remodels itself with specialized cells called osteoblasts and osteoclasts.
- There are five categories of bones: long, short, flat, irregular, and sesamoid.
- The vertebral column has five distinct regions: cervical, thoracic, lumbar, sacrum, and coccyx.
- In between each vertebra is an intervertebral disc that acts as a shock absorber and assists with movement.
- Joints are formed by one bone articulating with another and can be categorized by their shape, structure, and function.

- Osteokinematic describes bone movement, and arthrokinematic describes movement at the joint surface.
- Synovial joints are unique with a synovial capsule but also contain other connective tissues, such as ligaments and fascia that provide support.
- Synovial joints have six classifications: gliding (plane), condyloid, hinge, saddle, pivot, and ball-and-socket joints.
- Exercise and proper nutrition can have a major positive impact on bone mass with the aging adult.

<table>
<tr><th colspan="2">Important Concepts (not an exhaustive list)</th></tr>
<tr><td>Skeletal system</td><td>A description of the bones of the body. In the human skeletal system, there are 206 bones of which approximately 177 are used in voluntary movement.</td></tr>
<tr><td>Axial skeleton</td><td>A division of the skeletal system consisting of the skull, the rib cage, and the vertebral column. There are approximately 80 bones in the axial skeleton.</td></tr>
<tr><td>Appendicular skeleton</td><td>A division of the skeletal system consisting of the arms, legs, and pelvic girdle. The appendicular skeleton encompasses approximately 126 bones.</td></tr>
<tr><td>Remodeling</td><td>The process by which bone is constantly renewed by the resorption and formation of the bone structure.</td></tr>
<tr><td>Osteoclasts</td><td>Special cells that break down and remove old bone tissue.</td></tr>
<tr><td>Osteoblasts</td><td>Special cells that form and lay down new bone tissue.</td></tr>
<tr><td>Types of Bones</td><td>
<table>
<tr><th>Bone Type</th><th>Characteristic</th><th>Example</th></tr>
<tr><td>Long</td><td>Long, cylindrical shaft with irregular or widened ends</td><td>• Humerus (i.e., the upper arm bone)
• Femur (i.e., the thigh bone)</td></tr>
<tr><td>Short</td><td>Similar in length and width and appear somewhat cubical in shape</td><td>• Carpals of the wrist
• Tarsals of the ankle</td></tr>
<tr><td>Flat</td><td>Thin, protective surfaces that provide broad surfaces for muscles to attach</td><td>• Scapulae (i.e., the shoulder blades)
• Sternum (i.e., the breast plate)
• Ribs</td></tr>
<tr><td>Irregular</td><td>Unique shape and function from all other bone types</td><td>• Vertebrae (i.e., the spinal column)</td></tr>
<tr><td>Sesamoid</td><td>Small, often round bones embedded in a joint capsule or found in locations where a tendon passes over a joint</td><td>• Patella (i.e., the kneecap)</td></tr>
</table>
</td></tr>
<tr><td>Depressions</td><td>Flattened or indented portions of bone.</td></tr>
<tr><td>Processes</td><td>Projections protruding from the bone where tendons and ligaments can attach.</td></tr>
</table>

<table>
<tr><td>Segments of Vertebral Column</td><td>
<table>
<tr><th>Segment</th><th>Description</th></tr>
<tr><td>Cervical spine (C1–C7)</td><td>• First seven vertebrae starting at the top of the spinal column
• Form a flexible framework and provide support and motion for the head</td></tr>
<tr><td>Thoracic spine (T1–T12)</td><td>• Twelve vertebrae located in the upper and middle back behind the ribs
• Each vertebra articulates with a rib helping form the rear anchor of the rib cage
• Larger than cervical vertebrae and increase in size from top to bottom</td></tr>
<tr><td>Lumbar spine (L1–L5)</td><td>• Five vertebrae of the low-back below the thoracic spine
• Largest segments in the spinal column
• Support most of the body’s weight and are attached to many back muscles</td></tr>
<tr><td>Sacrum</td><td>• Triangular bone located below the lumbar spine
• Composed of five vertebrae that fuse together as the body develops into adulthood</td></tr>
<tr><td>Coccyx</td><td>• Located below the sacrum, more commonly known as the tailbone
• Composed of three to five small fused bones</td></tr>
</table>
</td></tr>
<tr><td>Osteokinematics</td><td>Movement of a limb that is visible.</td></tr>
<tr><td>Arthrokinematics</td><td>The description of joint surface movement; consists of three major types: roll, slide, and spin.</td></tr>
<tr><td>Synovial joints</td><td>A joint with a fluid-filled joint capsule.</td></tr>
<tr><td>Nonaxial</td><td>A gliding joint that moves in only one plane, either back and forth or side to side.</td></tr>
<tr><td>Nonsynovial joints</td><td>Joints that have no joint capsule, fibrous connective tissue, or cartilage in the uniting structure.</td></tr>
</table>

Muscular System

- The muscular system links the nervous and skeletal systems and generates force to move the human body.
- Muscles have a complex structure that includes different layers of connective tissue that surround the contractile muscle fibers.
- Myofibrils consist of repeating sarcomeres and the myofilaments actin and myosin, which create the muscle contraction called the sliding filament theory. Adenosine triphosphate is also needed to create energy for this process.
- Excitation-contraction coupling describes the steps in the muscle contraction process involving the nervous and muscular systems.
- The electrolyte calcium and neurotransmitter acetylcholine are involved in the excitation-contraction coupling process.

- The all-or-nothing principle describes how a motor unit either maximally contracts or does not contract at all.
- Muscles involved with fine motor skills have motor units with fewer innervated fibers. Motor units involved in gross motor control have motor units with more innervated fibers.
- Type I, slow-twitch, muscle fibers are smaller in size, produce less force, and are fatigue resistant.
- Type II, fast-twitch, muscle fibers are larger in size, produce more force, and fatigue quickly.

Important Concepts (not an exhaustive list)	
Three types of muscles	The three types of muscles in the body are skeletal, cardiac, and smooth.
Skeletal muscle	The type of muscle tissue that connects to bones and generates the forces that create movement.
Fascia	Connective tissue that surrounds muscles and bones.
Epimysium	Inner layer of fascia that directly surrounds an entire muscle, commonly referred to as the "deep fascia."
Fascicles	Largest bundles of fibers within a muscle. Fascicles are surrounded by perimysium.
Perimysium	Connective tissue surrounding a muscle fascicle.
Endomysium	Connective tissue that wraps around individual muscle fibers within a fascicle.
Tendons v. Ligaments	• Tendons connect muscles to bones. Commonly discussed tendons include the Achilles tendon at the ankle and the patellar tendon of the knee. When a tendon is overstretched or torn, this is known as a strain. • Ligaments connect bones to bones. A commonly discussed ligament is the anterior cruciate ligament of the knee that connects the tibia to the femur. When a ligament is overstretched or torn, it is known as a sprain.
Myofibrils	The contractile components of a muscle cell; the myofilaments (actin and myosin) are contained within a myofibril.
Myofilaments	The filaments of a myofibril; include actin and myosin.
Actin	The thin, stringlike, myofilament that acts along with myosin to produce muscular contraction.
Myosin	The thick myofilament that acts along with actin to produce muscular contraction.
Sarcomere	The structural unit of a myofibril composed of actin and myosin filaments between two Z-lines.
Motor unit	A motor neuron and all of the muscle fibers that it innervates.

Sliding filament theory	The series of steps in muscle contraction involving how myosin (thick) and actin (thin) filaments slide past one another to produce a muscle contraction, shortening the entire length of the sarcomere.
Type I muscle fibers** very important	Muscle fibers that are small in size, generate lower amounts of force, and are more resistant to fatigue.
Type II muscle fibers** very important	Muscle fibers that are larger in size, generate higher amounts of force, and are faster to fatigue.

Chapter 6. The Cardiorespiratory, Endocrine, and Digestive Systems Summary

- The cardiorespiratory system is comprised of the heart, blood, blood vessels, and lungs.
- The respiratory system is comprised of the respiratory airways, lungs, and respiratory muscles.
- The heart is contained in an area referred to as the mediastinum.
- A normal heart rate ranges from 60 to 100 beats per minute.
- Each side of the heart has two chambers: an atrium and a ventricle.
- The body will increase the heart rate in response to exercise and decrease the heart rate during sleep.
- The electrical conduction system of the heart is responsible for its function and begins with the sinoatrial node, which is in the right atrium.
- The sinoatrial node is referred to as the pacemaker of the heart and sends the electrical signal to the atrioventricular node and ultimately into the ventricles.
- The right atrium gathers deoxygenated blood returning to the heart from the body and then sends it to the right ventricle and to the lungs for oxygenation.
- The left atrium receives oxygenated blood from the lungs and sends it to the left ventricle to be pumped out into the body.
- Special valves are present in the heart to ensure that blood is pumped in a one-way fashion.
- The pulmonary artery transports deoxygenated blood from the right ventricles to the lungs, whereas the pulmonary vein transports oxygenated blood from the lungs to the left atrium.
- As part of the normal integrated functioning of the cardiorespiratory system, the carbon dioxide from the deoxygenated blood pumped into the lungs from the right ventricle is ultimately expelled to the environment through normal expiration.
- Stroke volume is the amount of blood pumped out of the heart with each contraction.
- End-diastolic volume is the volume of blood in the ventricle prior to contraction, whereas the end-systolic volume is the amount of blood present in the ventricle after contraction.

- Stroke volume is ultimately a product of end-diastolic volume minus end-systolic volume.
- Cardiac output is the volume of blood pumped out of the heart in a minute and is a function of both heart rate and stroke volume.
- Normal blood pressure is a systolic less than 120 mm Hg with a diastolic of less than 80 mm Hg.
- Arteries transport blood away from the heart to the body, whereas veins transport blood back to the heart, and capillaries function as an exchange channel between the vessels and bodily tissues.
- Breathing (ventilation) is divided into two phases, referred to as inspiration and expiration.
- The respiratory system is tasked with bringing in oxygen, filtering air from inspiration, and subsequently oxygenating blood from the heart as well as exhaling carbon dioxide.
- A normal respiratory rate is 12 to 16 breaths per minute and relies on the primary respiratory muscles (diaphragm and intercostals).
- During normal inspiration, active contraction of respiratory muscles occurs, whereas relaxation occurs during expiration.
- During forced or heavy breathing, expiratory ventilation relies on secondary muscles to compress the thoracic cavity and force air out.
- *Diffusion* is a term used to describe the process of getting oxygen from the environment to the body's tissues.
- Abnormal breathing patterns will affect exercise performance and may be identified by shallow breaths, which often are associated with the use of secondary respiratory muscles (sternocleidomastoid, upper trapezius, or scalenes).
- A respiratory rate of less than 8 breaths per minute would be considered too slow (bradypnea), whereas a rate of greater than 24 breaths per minute is considered too high (tachypnea).
- The endocrine system is comprised of glands that secrete hormones.
- When hormones are released into the bloodstream, they are protected by transporters, which carry them to the intended organ or structure, where they bind with a receptor to stimulate a particular function.
- The hypothalamus and pituitary gland control a majority of functions for the endocrine system.
- Cortisol, which is stimulated by the adrenal cortex, may be used to aid in recovery from exercise and as a marker of overtraining.
- Insulin and glucagon both function to control blood glucose levels and work opposite to each other; glucagon aids in the metabolism of glucose, and insulin aids in the cellular uptake and storage of glucose.

- The catecholamines, which consist of epinephrine and norepinephrine, are immediately stimulated from the adrenal medulla in response to exercise.
- Cortisol, considered a catabolic hormone, is produced by the adrenal cortex and is sensitive to blood sugar and sleep.
- Although testosterone levels decline with age, they can be stimulated through intense exercise.
- Growth hormones are responsible for growth and development as well as lipolysis and are produced from the pituitary gland.
- One of the most potent of the anabolic hormones is insulin-like growth factor, which is produced by the liver in response to growth hormones binding on liver receptors.
- Testosterone, growth hormones, and insulin-like growth factors are stimulated in response to anaerobic resistance training as well as vigorous aerobic activity (e.g., high-intensity training styles).
- Thyroid hormones serve numerous functions in the body, including metabolism and increasing bone mineral density through the secretion of calcitonin.
- Adequate sleep is a necessary requirement for glucose metabolism, hormone function, and muscle recovery.
- The digestive system consists of the oral cavity (head and mouth), the upper GI system (stomach, small intestine [duodenum, jejunum, and ileum], and the lower GI tract (large intestine, rectum, and anus), as well as the liver, gall bladder, and pancreas.
- Ingested foods and liquids are first processed in the oral cavity where mastication (the mechanical process of chewing and breaking down food) begins the digestive process.
- Once food is broken down, it passes through the esophagus into the stomach where gastric juices aid in digestion, kill bacteria, and turn food into chyme, which is then passed into the small intestine.
- The small intestine has a key function of absorption of carbohydrates, lipids, calcium, amino acids, and iron. Additionally, electrolytes including water, are absorbed into the small intestines.
- The large intestine absorbs electrolytes and vitamins, and serves to pass waste from nondigested food into the rectum.
- While fluids are absorbed into both the small and large intestine, the large intestine uses water to help pass waste into the rectum.
- The liver, gall bladder, and pancreas produce and store digestive juices, which are secreted into the small intestine to help with digestion.
- Evidence suggests that exercise can improve digestive function by increasing transit time of food from the upper to the lower GI tracts.

Important Concepts (not an exhaustive list)
Cardiovascular System

<table>
<tr><td>Atrium (atria)</td><td>Superior chamber(s) of the heart that gathers blood returning to the heart.</td></tr>
<tr><td>Ventricle</td><td>Inferior chamber of the heart that pumps blood to the lungs and body.</td></tr>
<tr><td>Blood flow through the heart** very important</td><td>• Right atrium: receives deoxygenated blood returning from the body and sends it to the right ventricle.
• Right ventricle: receives deoxygenated blood from the right atrium and sends it to the lungs.
• Left atrium: receives oxygenated blood from the lungs and sends it to the left ventricle.
• Left ventricle: receives oxygenated blood from the left atrium and sends it to the body.</td></tr>
<tr><td>Resting heart rate</td><td>Resting heart rates for most of the population are between 60 and 100 beats per minute</td></tr>
<tr><td>Sinoatrial (SA) node</td><td>Located in the right atrium, this node initiates an electrical signal that causes the heart to beat.</td></tr>
<tr><td>Atrioventricular (AV) node</td><td>Located between the atria and ventricles, this node delays the impulse from the sinoatrial node before allowing it to pass to the ventricles.</td></tr>
<tr><td>Stroke volume</td><td>The amount of blood pumped out of the heart with each contraction.</td></tr>
<tr><td>End-diastolic volume</td><td>The filled volume of the ventricle before contraction.</td></tr>
<tr><td>End-systolic volume</td><td>The volume of blood remaining in the ventricle after ejection.</td></tr>
<tr><td>Bradycardia</td><td>When the heart rate is less than 60 beats per minute.</td></tr>
<tr><td>Tachycardia</td><td>When the heart rate is greater than 100 beats per minute.</td></tr>
<tr><td>Cardiac output** very important</td><td>The overall performance of the heart (heart rate × stroke volume).</td></tr>
<tr><td>Arteries</td><td>Vessels that transport blood away from the heart.</td></tr>
<tr><td>Capillaries</td><td>The smallest blood vessels and the site of exchange of elements between the blood and the tissues.</td></tr>
<tr><td>Veins</td><td>Vessels that transport blood back to the heart.</td></tr>
<tr><td>Arterioles</td><td>Small arteries that eventually divide into capillaries</td></tr>
<tr><td>Venules</td><td>Small veins that allows blood to drain from capillaries into the larger veins.</td></tr>
<tr><td>Venous pooling</td><td>The accumulation of blood into the extremities due to slow blood flow though the veins (venous return) or backflow.</td></tr>
<tr><td>Stages of hypertension** very important</td><td>
<table>
<tr><th>American Heart Association Blood Pressure Classification</th><th>Criteria (mm Hg)</th></tr>
<tr><td>Normal</td><td>Systolic <120 and diastolic <80</td></tr>
<tr><td>Elevated</td><td>Systolic 120–129 and diastolic <80</td></tr>
<tr><td>Stage 1</td><td>Systolic 130–139 or diastolic 80–89</td></tr>
<tr><td>Stage 2</td><td>Systolic ≥140 or diastolic ≥90</td></tr>
<tr><td>Hypertensive crisis</td><td>Systolic >180 and/or diastolic >120</td></tr>
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<tr><td colspan="2">Respiratory System</td></tr>
</table>

Structures of respiratory pump	**Bones**: Sternum (breastbone); Ribs; Vertebrae (spine) **Inspiration Muscles**: Diaphragm; External intercostals (muscles between individual ribs); Scalenes (side of neck muscles); Sternocleidomastoid (front of neck muscle); Pectoralis minor (smaller chest muscle) **Expiration Muscles**: Internal intercostals (muscles between individual ribs); Abdominals
Valsalva maneuver	A process that involves expiring against a closed windpipe, creating additional intra-abdominal pressure and spinal stability.
Structures of respiratory passages	**Conducting Airways**: Nasal cavity; Oral cavity; Pharynx; Larynx; Trachea; Right and left pulmonary bronchi; Bronchioles **Respiratory Airways**: Alveoli; Alveolar sacs
Tachypnea	Respiratory rate that is too fast; greater than 24 breaths per minute.
Bradypnea	Respiratory rate that is too slow; fewer than 8 breaths per minute.
Dyspnea	Shortness of breath or labored breathing.
Endorcine System	
Lipolysis	The breakdown and utilization of fat for energy.
Insulin	A hormone secreted by the pancreas that is responsible for glucose metabolism.
Glucagon	A hormone secreted by the pancreas that regulates blood glucose and functions opposite to insulin.
Glycogen	Glucose that is deposited and stored in bodily tissues, such as the liver and muscle cells; the storage form of carbohydrate.
Growth hormone	An anabolic hormone produced by the pituitary gland that is responsible for growth and development.
Catecholamines	Hormones produced by the adrenal glands that are part of the stress response known as the fight-or-flight response.
Catabolic	Metabolic process that breaks down molecules into smaller units used for energy.
Gluconeogenesis	The formation of glucose from noncarbohydrate sources (proteins and fats).
Testosterone	A hormone producing secondary male sex characteristics.
Anabolic	Metabolic process that synthesizes smaller molecules into larger units used for building and repairing tissues.

Insulin-like growth factors (IGF)	Anabolic hormone produced by the liver, which is responsible for growth and development.
Calcitonin	Thyroid hormone that helps the body use calcium properly to aid with maintaining bone mineral density.
Glucose intolerance	A condition that results in elevated blood glucose levels.

Chapter 7. Human Movement Science Summary

- Movement is described in three dimensions that are based on planes, which include the sagittal, frontal, and transverse planes.
- Osteokinematic describes the observable movement of a limb, whereas arthrokinematic describes the movement taking place at the joint itself.
- Movement is described using biomechanical terminology that is universal to all professions in the allied health industry.
- The sagittal plane is an imaginary line that bisects the body into right and left sides. Movements in the sagittal plane include flexion and extension and plantar flexion and dorsiflexion of the foot and ankle.
- The frontal plane bisects the body to create front and back halves. Movements in the frontal plane include abduction and adduction of the limbs (relative to the trunk), lateral flexion of the spine, and eversion and inversion at the foot and ankle complex.
- The transverse plane bisects the body to create upper and lower halves. Movements in the transverse plane include internal rotation and external rotation for the limbs, right and left rotation for the head and trunk, horizontal abduction and horizontal adduction of the limbs, and radioulnar pronation and supination.
- Motions of the scapulae include scapular retraction, scapular protraction, scapular depression, and scapular elevation.
- Muscle actions are described as isotonic, isometric, and isokinetic.
- Isotonic muscle actions can be broken down into the concentric and eccentric phases.
- Muscles can play the role of agonist, synergist, stabilizer, or antagonist depending on the movement being performed.
- Closed-chain movements anchor the body to the ground or immovable object, whereas open-chain movement involves the distal limb moving freely in space.
- Placing a muscle in a shortened position or lengthening a muscle beyond optimal length may reduce force output, because optimal length is the position with maximal overlap of actin and myosin filaments.
- The stretch-shortening cycle involves three phases, which include the eccentric phase, amortization phase, and concentric phase.

- The term *force-couple* is used to describe muscles that work in a synergistic function around a joint.
- The local muscular system involves muscles that generally attach on or near the spine and provide stability for the LPHC.
- The global muscle system can be broken down into subsystems, which include the deep longitudinal, posterior oblique, anterior oblique, and lateral subsystems.
- The subsystems describe the integrated function of muscle groups to transfer force for complex multijoint movements and stabilization of the HMS.
- The amount of force produced by the HMS relies on not only muscle recruitment but also the lever type of the joint that is moving.
- Lever systems are classified as first, second, and third class. Third-class levers are the most predominate levers in the human body.
- Muscle synergies describe the cooperative function of multiple muscles recruited by the nervous system to complete a given movement pattern.
- Proprioception is the intrinsic awareness of movement and bodily position in space.
- Feedback can come from internal or external sources and aids the process of motor learning.
- Motor learning is the integration of motor control processes, with practice and experience, leading to a relatively permanent change in the capacity to produce skilled movements.

Important Concepts (not an exhaustive list)

Anatomic locations** very important

Anatomic Location	**Definition**
Medial	Relatively closer to the midline of the body
Lateral	Relatively farther away from the midline or toward the outside of the body
Contralateral	Positioned on the opposite side of the body
Ipsilateral	Positioned on the same side of the body
Anterior	Positioned on or toward the front of the body
Posterior	Positioned on or toward the back of the body
Proximal	Positioned nearest to the center of the body or other identified reference point
Distal	Positioned farthest from the center of the body or other identified reference point
Inferior	Positioned below an identified reference point
Superior	Positioned above an identified reference point

<table>
<tr><td>Dorsiflexion</td><td>Flexion occurring at the ankle (i.e., top of the foot moves toward the shin).</td></tr>
<tr><td>Plantar flexion</td><td>Extension occurring at the ankle. Pointing the foot downwards.</td></tr>
<tr><td>Muscle actions** very important</td><td>
<table>
<tr><th>Action</th><th>Performance</th></tr>
<tr><td>Isotonic</td><td>Force is produced, muscle tension is developed, and movement occurs through a given range of motion. Isotonic muscle actions are subdivided into concentric and eccentric muscle actions.</td></tr>
<tr><td>Isometric</td><td>Muscle tension is created without a change in muscle length and no visible movement of the joint.</td></tr>
<tr><td>Isokinetic</td><td>The speed of movement is fixed, and resistance varies with the force exerted.

It requires sophisticated training equipment often seen in rehabilitation or exercise physiology laboratories.</td></tr>
</table>
</td></tr>
<tr><td>Agonists** very important</td><td>The primary muscles providing force for a movement. Examples include:
The gluteus maximus is the agonist for hip extension (i.e., squats).
The anterior deltoid is the agonist for shoulder flexion (i.e., shoulder presses).
The biceps brachii is the agonist for elbow flexion (i.e., biceps curls).
The triceps brachii is the agonist for elbow extension(i.e., triceps pushdowns).</td></tr>
<tr><td>Synergists** very important</td><td>Muscles that assist agonists to produce a movement. Examples include:
The hamstring complex and the erector spinae are synergistic with the gluteus maximus during hip extension (i.e., squats).
The brachioradialis and brachialis (forearm muscles) assist the biceps brachii during a biceps curl.
The triceps brachii assist the pectoral muscles during a chest press.
The biceps brachii assist the latissimus dorsi during a pull-up.</td></tr>
<tr><td>Stabilizers** very important</td><td>Muscles that contract isometrically to stabilize the trunk and joints as the body moves. Examples include:
The transversus abdominis (a deep abdominal muscle), internal obliques, and multifidus (deep muscles of the spine) stabilize the LPHC during hip extension (i.e., squats).
The rotator cuff muscles (supraspinatus, infraspinatus, teres minor, and subscapularis), stabilize the shoulder during upper extremity movements.</td></tr>
<tr><td>Antagonists** very important</td><td>Muscles on the opposite side of a joint that are in direct opposition of agonist muscles. Examples include:
The biceps brachii (an elbow flexor) is an antagonist to the triceps brachii during elbow extension (i.e., triceps pushdown).
During elbow flexion, the triceps become the antagonist to the biceps (i.e., biceps curl).
The hip flexor complex is antagonistic to the gluteus maximus during hip extension (i.e., squats).
The latissimus dorsi is antagonistic to the deltoids during a shoulder press.</td></tr>
</table>

Example closed-chain exercises** very important	• Push-ups • Pull-ups • Squats • Lunges
Example open-chain exercises** very important	• Biceps curls • Lat pulldowns • Bench presses • Leg curls • Leg extensions
Length-tension relationship** very important	The resting length of a muscle and the tension the muscle can produce at this resting length.
Altered length-tension relationship** very important	When a muscle's resting length is too short or too long, reducing the amount of force it can produce.
Reciprocal inhibition** very important	When an agonist receives a signal to contract, its functional antagonist also receives an inhibitory signal allowing it to lengthen.
Altered reciprocal inhibition** very important	Occurs when an overactive agonist muscle decreases the neural drive to its functional antagonist.
Muscle imbalance	When muscles on each side of a joint have altered length-tension relationships.
Integrated performance paradigm	To move with efficiency, forces must be dampened (eccentrically), stabilized (isometrically), and then accelerated (concentrically).
Force-couple relationship** very important	The synergistic action of multiple muscles working together to produce movement around a joint
First-class levers	First-class levers have the fulcrum in the middle, like a seesaw. Nodding the head is an example of a first-class lever, with the top of the spinal column as the fulcrum.

Second-class levers	Second-class levers have a resistance in the middle with the fulcrum and effort on either side, similar to a load in a wheelbarrow where the axle and wheel are the fulcrum points. The body acts as a second-class lever when one engages in a full-body push-up or calf raise.
Third-class levers	Third-class levers have the effort placed between the resistance and the fulcrum. The effort always travels a shorter distance and must be greater than the resistance. Most limbs of the human body operate as third-class levers. An example of a third-class lever is the human forearm; the fulcrum is the elbow, the effort is applied by the biceps brachii muscle, and the load is in the hand, such as a dumbbell when performing a biceps curl. Another example of a third-class lever is the standing hamstring curl, whereby the knee joint is the fulcrum, hamstring muscle is the effort, and resistance is at the ankle.
Motor behavior	Motor response to internal and external environmental stimuli.
Motor control	How the central nervous system integrates internal and external sensory information with previous experiences to produce a motor response.
Motor learning	Integration of motor control processes through practice and experience, leading to a relatively permanent change in the capacity to produce skilled motor behavior.
Motor development	Change in skilled motor behavior over time throughout the life span.
Internal feedback	Process whereby sensory information is used by the body to reactively monitor movement and the environment.
External feedback	Information provided by some external source, such as a fitness professional, video, mirror, or heart rate monitor, to supplement the internal environment.

Chapter 8. Exercise Metabolism and Bioenergetics Summary

- The human body needs a constant supply of energy to function properly and meet the demands of exercise.
- The energy molecule used to do cellular work is called adenosine triphosphate (ATP), and it is made from food substrates consumed in the diet.
- The first law of thermodynamics states that energy can neither be created nor destroyed, only converted from one form into another.
- The fuels used to create ATP are glucose from carbohydrates, free fatty acids from fat, amino acids from protein, and ketone bodies. These fuels are mostly obtained through the diet.
- Carbohydrates in the diet are broken down into glucose, which can produce ATP quickly via the process of glycolysis.
- Glucose is stored in the form of glycogen; the amount of glycogen that can be stored in the body is much less than the amount of fat that can be stored.
- Free fatty acids are the by-products of the breakdown of stored or consumed fats. They are oxidized exclusively via the aerobic pathway, which uses oxygen to create ATP.
- Amino acids are the by-product of protein breakdown or digestion.

- Amino acids can be metabolized via oxidative phosphorylation, but this is not typical in healthy people because protein is usually reserved for muscle building rather than ATP production.
- Ketone bodies are produced by the liver during periods of low energy intake or low carbohydrate availability. They can be oxidized via the oxidative phosphorylation pathway to create ATP.
- Exercise is categorized by two factors: intensity and duration. The higher the intensity of the activity, the shorter the duration must be.
- To perform exercise, the body needs fuel, which comes from food that is broken down through a series of chemical reactions to provide energy (ATP) and heat.
- The ATP-PC pathway is the simplest and fastest way to generate ATP. This system can only support short duration activities because the supply of PC is limited.
- Glycolysis is an anaerobic process and generates ATP quickly, but not a tremendous amount. The end products of glycolysis are ATP and pyruvate, which can become lactate under anaerobic conditions.
- Oxidative phosphorylation is a process that uses oxygen to create ATP from substrate molecules at a relatively slow rate.
- Oxidative phosphorylation can use pyruvate (starting from glucose), fatty acids, amino acids, or ketone bodies as substrate molecules. This oxidative metabolism produces carbon dioxide as a by-product, which is then exhaled.
- The most important factors determining the type of energy use during exercise are intensity and duration.
- The intensity and duration of an activity are inversely related, which means that as intensity goes up, duration must go down.
- Steady-state exercise is defined as a situation in which a person engages in the same level of activity, without increases or decreases in intensity, for several minutes.
- Intermittent exercise is defined as frequent changes in the work requirement (intensity) during an activity.
- Exercise increases metabolic rate, and breathing rate increases in proportion with it.
- When breathing rate becomes too rapid to allow talking, the body has shifted to oxidizing almost exclusively carbohydrate to fuel the activity.
- Lower-intensity activities use a higher percentage of fat as a fuel but generally do not burn a lot of calories unless performed for a very long time.
- Higher-intensity activities have a higher percentage of energy coming from carbohydrate and usually burn more total calories in a given time.
- Daily food (energy) intake needs to be adequate to maintain a healthy body weight, allow for proper bodily function, and support physical activity.
- If daily food intake is matched to energy needs, a person is said to be in energy balance.

- Calories are the basic unit of energy provided by food, and the total number of calories that a person burns in a day is called the total daily energy expenditure (TDEE).
- The resting metabolic rate (RMR) is the minimum number of calories needed at rest to keep a person alive and meet all functional needs of the body.
- The thermic effect of food (TEF) is the number of calories that are used to digest a meal.
- Nonexercise activity thermogenesis (NEAT) involves burning calories in activities that are not structured exercise.
- Exercise activity thermogenesis (EAT) is the calories burned during structured physical activity or purposeful exercise.

Important Concepts (not an exhaustive list)	
First law of thermodynamics	Energy cannot be created or destroyed but merely converted from one form to another.
Glucose	The simplest form of carbohydrate used by the body for energy.
Glycogen	Glucose that is deposited and stored in bodily tissues, such as the liver and muscle cells; the storage form of carbohydrate.
Triglyceride	The chemical or substrate form in which most fat exists in food as well as in the body.
Essential amino acid (EAA)	Amino acid that must be obtained through the diet as the body does not make it; there are nine essential amino acids.
Nonessential amino acids	Amino acids that can be synthesized by the body and do not, under normal circumstances, need to be obtained in the diet.
Gluconeogenesis	The formation of glucose from noncarbohydrate sources (proteins and fats).
Aerobic	Processes relating to, involving, or requiring oxygen.
Anaerobic	Processes relating to the absence of oxygen.

ATP-PC system** very important	An energy system that provides energy very rapidly, for approximately 10–15 seconds, via anaerobic metabolism.
	• Example exercises that predominately use the ATP-PC system include:
	  ○ Short sprints
	  ○ Olympic weightlifting
	  ○ Jumping and plyometrics

Glycolytic system** very important	A metabolic process that occurs in the cytosol of a cell that converts glucose into pyruvate and adenosine triphosphate. Anaerobic glycolysis refers to when this process occurs in the absence of oxygen. It lasts longer, with a capacity of approximately 30 to 60 seconds of duration. • Example exercises that predominately use the glycolytic system include: ○ Strength training (8-12 repetitions)
Oxidative system** very important	The most complex of the three energy systems is the oxidative system—a process that uses oxygen to convert food substrates into ATP. This process is called oxidative phosphorylation, and it is defined as an aerobic process because it needs oxygen to complete the reactions. • Example exercises that predominately use the oxidative system include: ○ Jogging and running for an extended period

Electron transport chain (ETC)	A series of protein complexes that transfer protons and electrons received from the citric acid cycle through a series of reactions to create adenosine triphosphate.
Excess postexercise oxygen consumption (EPOC)	The state in which the body's metabolism is elevated after exercise.
Resting metabolic rate (RMR)	The rate at which the body expends energy (calories) when fasted and at complete rest, such as asleep or lying quietly.
Exercise activity thermogenesis (EAT)	The calories expended through structured exercise or training.
Thermic effect of food (TEF)	The energy required to digest, absorb, and process nutrients that are consumed.
Nonexercise activity thermogenesis (NEAT)	Energy expenditure through daily activities outside of structured exercise, such as walking, completing household chores, and taking the stairs.

Chapter 9. Nutrition Summary

- Registered and licensed dietitians and nutritionists are authorized to provide nutrition counseling, medical nutrition therapy, and meal plans.
- Fitness professionals (who are not also registered or licensed dietitians or nutritionists) can provide general nutrition guidelines, direct clients to credible nutrition resources, refer clients to dietitians and nutritionists, and provide accountability and support with dietary changes.
- Credible and reliable nutrition information includes peer-reviewed research and scholarly sources.
- Protein is comprised of 20 amino acids; 9 are essential and must be obtained via the diet.
- The role of protein is the synthesis of tissues, organs, hormones, enzymes, and peptides.
- Dietary sources of complete proteins include soy and animal foods, such as meat, poultry, seafood, and dairy. Plant-based, incomplete protein foods include legumes, grains, and vegetables.
- Protein contains 4 calories per gram.
- The RDA for protein is 0.8 g/kg bodyweight (considered a minimum to maintain nitrogen balance).
- The AMDR for protein is 10% to 35% of total calories.
- Carbohydrates include simple sugars, complex carbohydrates, glycogen, and fiber.
- Carbohydrates are an important energy source of exercising individuals and athletes.
- Dietary sources of carbohydrates include plant foods and dairy, including grains, vegetables, legumes, fruit, milk, and yogurt.

- Simple sugars include the monosaccharides (glucose, fructose, galactose) and disaccharides (lactose, sucrose, maltose).
- Complex carbohydrates are long chains of glucose units called polysaccharides, which are slower to digest and raise blood glucose levels slowly.
- Sources of complex carbohydrates include starches, legumes, and vegetables.
- The glycemic index reflects the effect of a carbohydrate on blood sugar levels; low GI foods cause smaller rises in blood glucose compared to high GI foods.
- Glycemic load is a better indicator of a carbohydrate's effect on blood sugar levels, because it accounts for the glycemic index and the quantity of carbohydrates consumed.
- Carbohydrates contain 4 calories per gram.
- Glycogen is the storage form of carbohydrates in animals and humans. Glycogen is stored in the liver and skeletal muscle.
- Fiber is indigestible carbohydrates associated with various health benefits and includes both soluble and insoluble fiber.
- The AMDR for carbohydrate is 45% to 65% of calories in the diet.
- Fiber recommendations: 25–28 g of fiber a day for women (aged 19–50 years) and 30–34 g of fiber a day for men aged 19–50 years.
- Lipids are commonly referred to as fats and include triglycerides, phospholipids, and sterols.
- Saturated fat sources include animal fats, full-fat dairy, coconut, and palm oil.
- Polyunsaturated fat sources include omega-6 (nuts, seeds, oils), omega-3 (fatty fish, flaxseed, walnuts, chia seeds, fortified milk/eggs, dairy from grass-fed cows, and green vegetables).
- Monounsaturated fat sources include olives, olive oil, avocado, peanuts, and canola.
- Phospholipid sources include meats, egg yolks, seafood, poultry, soybeans, and grains.
- Sterols sources include cholesterol from animal foods, egg yolks, and plant sterols.
- Lipids contain 9 calories per gram.
- The AMDR for lipids is 20% to 35% of total calories.
- Vitamins and minerals are compounds essential to regulating metabolic processes, such as energy metabolism. Deficiencies and insufficiencies can contribute to health issues.
- Vitamins include two groups: fat soluble and water soluble.
- Vitamins A, D, E, and K are fat soluble.
- Water-soluble vitamins include vitamin C and B vitamins (thiamin, riboflavin, niacin, folate, B12, pantothenic acid, biotin).
- A balanced diet with a wide variety of minimally processed foods will likely supply adequate vitamins.
- Minerals include major minerals and trace minerals.

- Fluid recommendations (general population): approximately 11.5 cups a day (2.7 L) of fluid for women and approximately 15.5 cups (3.7 L) for men.
- Hydration guidelines for athletes include 12–16 oz of fluid every 10–15 minutes for activities longer than 60 minutes.
- Athletes should replace fluid at 1.25 times the amount of body weight lost during an event.
- Sports drinks may be hypotonic (lower concentration than body fluids), isotonic (similar concentration as body fluids), or hypertonic (higher concentration than body fluids).
- Sports drinks are likely unnecessary for short-duration exercise lasting less than 60 minutes (unless in hot or humid temperatures).
- Strategy combinations are used to help clients achieve their weight goals, primarily including modification of energy intake and physical activity.
- The first law of thermodynamics states that energy cannot be created or destroyed but only converted from one form to another.
- Weight gain is the result of energy intake exceeding energy output, whereas weight loss is the result of energy output exceeding energy intake.
- Other factors that influence weight include sleep, medications, and endocrine disorders.
- Food labels convey information on the nutritional value and content of products via the nutrition facts panel and the ingredients list.
- Food labels can help clients make informed decisions about how a food item contributes to their nutrition and fitness goals.
- Fat loss requires a net calorie deficit but with the goal of minimizing loss of lean body mass and any reduction in TDEE due to adaptive thermogenesis.
- Adequate caloric intake, especially adequate protein intake combined with resistance training, remains an essential element for increasing muscle mass.
- Nutrition strategies for improved sports performance are numerous and include ensuring adequate energy (calories) and macronutrient intake. Meal timing and hydration are also important to maximize sport performance.

<table>
<tr><th colspan="4">Important Concepts (not an exhaustive list)</th></tr>
<tr><td>Macronutrients and alcohol energy** very important</td><td colspan="3">Protein: 4 calories per gram
Carbohydrate: 4 calories per gram
Lipid (fat): 9 calories per gram
Alcohol: 7 calories per gram</td></tr>
<tr><td>Amino acids</td><td>Essential</td><td>Nonessential</td><td>Conditionally Essential</td></tr>
</table>

	• Leucine • Isoleucine • Valine • Methionine • Phenylalanine • Threonine • Tryptophan • Lysine • Histidine	• Alanine • Arginine • Aspartic acid • Asparagine • Cysteine • Glutamic acid • Glutamine • Glycine • Proline • Serine • Tyrosine	• Histidine • Arginine • Glutamine
Complete protein	A protein source that provides all essential amino acids.		
Incomplete protein	A protein that lacks one or more of the amino acids required to build cells.		
RDA for protein	0.8 g/kg of body weight		
Acceptable macronutrient distribution ranges (AMDR) ** very important	• Protein: 10% to 35% of total calories • Carbohydrate: 45% to 65% of total calories • Lipid (fat): 20% to 35% of total calories		
Triglycerides	The triglyceride family is composed of fats and oils; it comprises 98% of the stored lipids in the body and approximately 95% of the lipids in foods.		
Fat-soluble vitamins** very important	A, D, E, K		
Water-soluble vitamins** very important	C, B-vitamins		
Fluid intake	• Women: 11.5 cups per day (2.7 L) • Men: 15.5 cups per day (3.7 L)		

Chapter 10. Supplementation Summary

- Dietary supplements are products (other than tobacco) intended to supplement the diet that bears or contains one or more of the following dietary ingredients: vitamins; minerals; herbs or other botanicals; amino acids; dietary supplements used by humans to supplement the diet by increasing the total dietary intake; or concentrates, metabolites, constituents, extracts, or combination of any previously described ingredient.
- In the United States, dietary supplements are regulated by the FDA according to the Dietary Supplement Health and Education Act. However, supplements do not require review or approval prior to being marketed and sold.

- The fitness professional should understand the required components of the dietary supplement label, including the active ingredients, other ingredients, pertinent warnings, total contents, usage instructions, and serving size.
- Dietary supplements may be used for health and/or performance goals.
- Dietary supplements used specifically for performance are classified as ergogenic aids.
- Vitamin and mineral supplements may be used by individuals to correct or supply insufficient dietary intake in an effort to consume the DV each day.
- Vitamin and mineral intake should not exceed the UL unless by the direction of a dietitian or physician.
- Dietary supplements and other ergogenic aids may produce adverse effects or serious adverse effects. Such effects may arise from the dietary supplements themselves or from a change to or the contamination of the products.
- Protein supplements are convenient methods to increase total daily protein intake, the most important consideration for protein intake. Protein needs depend on the activity level, body size, and body composition goal of the individual.
- An effective dose of creatine is at least 0.03 g per kg body weight, but a typical dose at 5 g per day ensures complete muscle saturation.
- An effective dose of caffeine is 3 to 6 mg/kg (1.4–2.7 mg/lb) per day.
- Banned substances may not always be illegal substances, and athletes must check with their governing body (such as the NCAA or WADA) prior to consuming a dietary supplement. It is also wise for athletes to choose a supplement with third-party verification from Informed Choice or NSF.
- It is beyond the scope of practice for a fitness professional to prescribe dietary supplements to clients to treat a medical condition or disease. It is appropriate for the fitness professional to provide general education about supplements or to direct a client to consult with a dietitian or medical professional.

Important Concepts (not an exhaustive list)	
Dietary supplement	A product (other than tobacco) intended to supplement the diet that bears or contains one or more of the following dietary ingredients: vitamin; mineral; herb or other botanical; amino acid; substance used by man to supplement the diet by increasing the total dietary intake; or concentrate, metabolite, constituent, extract, or combination of any previously described ingredient.
Dietary Supplement Health and Education Act of 1994	The primary legislation of the U.S. government regulating dietary supplements.
Tolerable upper limit	The greatest quantity of a vitamin or mineral that may be consumed in a day without risk of an adverse health effect.

<table>
<tr><td>Ergogenic aid</td><td colspan="2">A dietary supplement that may enhance performance or body composition; it may also be referred to as a performance supplement.</td></tr>
<tr><td>Adverse effects of anabolic steroids</td><td colspan="2"><table>
<tr><th>Men</th><th>Women</th></tr>
<tr><td>Acne</td><td>Development of masculine features</td></tr>
<tr><td>Loss of head hair</td><td>Increased body and facial hair</td></tr>
<tr><td>Gynecomastia (development of breasts)</td><td>Deepening of voice</td></tr>
<tr><td>Irritability and aggression</td><td>Irritability and aggression</td></tr>
<tr><td>Altered sex drive (increased or decreased)</td><td>Altered sex drive (increased or decreased)</td></tr>
<tr><td>Sleeplessness</td><td>Fluid retention</td></tr>
<tr><td>Testicular atrophy</td><td>Menstruation irregularities</td></tr>
<tr><td>Decreased sperm count</td><td>Breast atrophy</td></tr>
<tr><td>Worsened cholesterol profiles</td><td>Clitoral enlargement</td></tr>
<tr><td>Prostate enlargement</td><td>Acne</td></tr>
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