Certified Personal Trainer

DOMAIN ONE

APPLIED SCIENCE

EXAM WEIGHT 25%

ISSA INTERNATIONAL SPORTS SCIENCES ASSOCIATION

"Applied Science" includes foundational information from which all other personal fitness training applications are built. In it, fitness professionals will learn the structure and function of different body systems such as the nervous, muscular, and skeletal systems. This domain will also include information on kinesiology and biomechanics, the study of human movement. These topics are important for a fitness professional's ongoing career so that they can easily learn new trends and styles of training by applying the cornerstones of exercise science to them.

To help clients reach their goals, it's important to understand the basic structure and function of the human body. The human body is organized as follows:

Atoms > Cells > Tissues > Organs > Organ Systems > Organism

The body has 11 organ systems (a group of organs working together to perform biological functions), but the nervous, muscular, and skeletal systems are the most prominent regarding human movement. Of those three systems, the nervous system is the most important as it is the control center of the body.

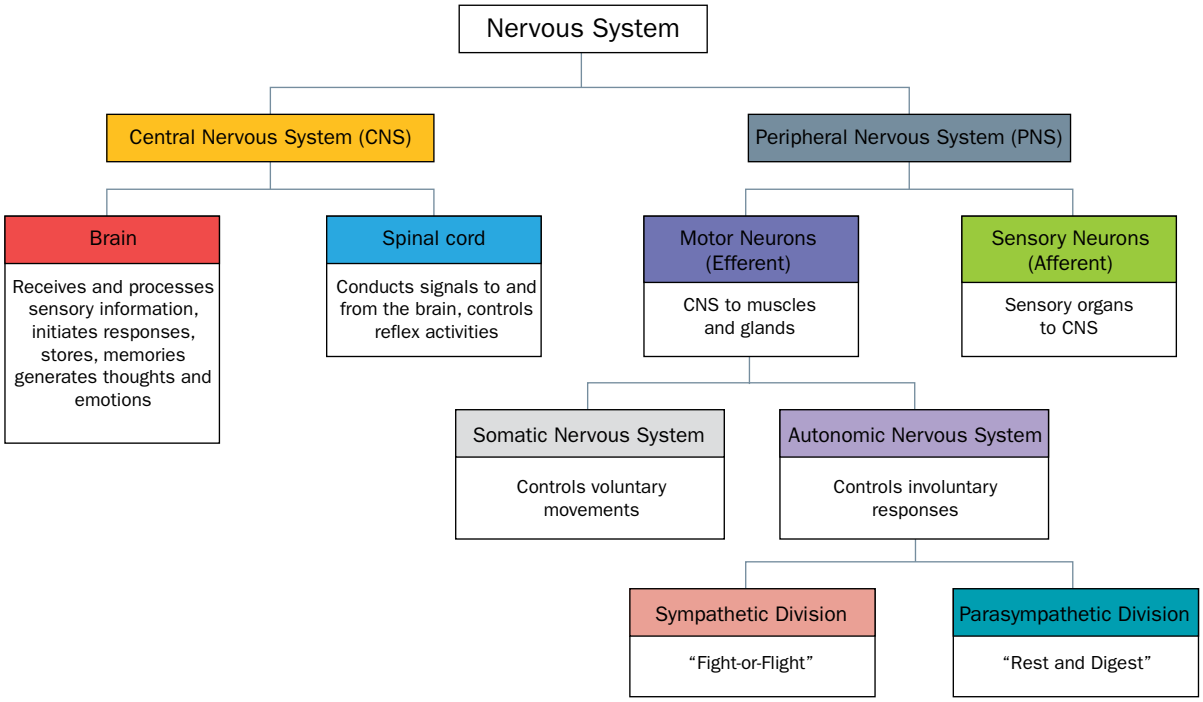
Nervous System - Chapter 3

The nervous system consists of the brain, spinal cord, and nerves and is responsible for controlling the voluntary (conscious or deliberate) and involuntary (automatic) functions of the body and the mind. The nervous system and all its divisions play a critical role in communicating with the muscles and initiating movement.

- Key terms
  - A neuron or nerve cell: the most fundamental component of the brain and nervous system
    - Cell body: the core and central structure of a neuron containing a nucleus and other specialized organelles that aid in nervous system function
    - Axon: the thin tail like structure of a neuron that generates and conducts nerve impulses
    - Dendrites: rootlike structures branching out from the cell body that receive and process signals from the axons of other neurons
  - Neurosecretory tissues: translate neural signals into chemical stimuli. These tissues make neurohormones, hormones produced and released by nerve cells that are released into the bloodstream.
  - Nervous tissue: tissue found in the brain, spinal cord, and nerves that coordinates body activities
  - Neuroglia: cells in the brain and spinal cord that form a supporting structure for the neurons and provide them with insulation
  - Neurosecretory tissues: neurons that translate neural signals into chemical stimuli
  - Decussation: the point of crossover of the nervous system in vertebrates located between the medulla oblongata and the spinal cord
  - Hypothalamus: the region at the base of the brain responsible for maintaining homeostasis
  - Homeostasis: a self-regulating process by which the body maintains the stability of its physiological processes for the purpose of optimal function

- Classifications of neurons
  - Sensory neurons: nerve cells involved in communicating tactile, auditory, or visual information
  - Motor neurons: nerve cells that initiate muscle contraction or activate glands
  - Interneurons: nerve cells that connect neurons to other neurons
- Lobes of the brain
  - Frontal lobe: the brain lobe involved in motor control, emotion, and language
  - Motor cortex: the region of the frontal lobe that plans and coordinates movement
  - Prefrontal cortex: the part of the frontal lobe responsible for high-level thinking and language
  - Parietal lobe: the brain lobe involved in processing sensory information
    - Somatosensory cortex: the region of the parietal lobe responsible for processing sensations such as pain, temperature, and touch
  - Temporal lobe: the lateral lobe of the brain responsible for hearing, memory, and emotion
    - Auditory cortex: the region of the temporal lobe responsible for hearing
  - Occipital lobe: the posterior lobe of the brain responsible for vision
    - Visual cortex: the specific region of the occipital lobe responsible for sight and visual perception
- Nervous system divisions
  - Central nervous system (CNS): the part of the nervous system consisting of the brain and spinal cord; receives sensory input and organizes, analyzes, and processes neural information
    - Cerebrum: the uppermost and largest part of the brain consisting of a left and right hemisphere, responsible for receiving and processing sensory information and controlling the body
    - Cerebellum: the region of the brain responsible for conscious motor coordination
    - Brain stem: the trunk of the brain, consisting of the medulla oblongata, pons, and midbrain that continues downward to form the spinal cord
    - Cerebral cortex: the part of the brain where most neural integration occurs
    - Midbrain: the brain region responsible for motor movement and processing auditory and visual information
    - Pons: the brain region responsible for posture, facial movement, and sleep
    - Medulla oblongata: the base of the brain stem, responsible for involuntary functions such as swallowing, sneezing, and heart function
    - Thalamus: the brain region responsible for relaying sensory and motor signals and regulating consciousness
    - Spinal cord: the neural tissue extending from the medulla oblongata to the lumbar region (lower back) of the vertebral column that connect the body and the brain
  - Peripheral nervous system (PNS): the nerves and ganglia (relay areas for nerve signals) outside of the brain and spinal cord
    - Reflexes are processed directly by the spinal cord (they do not travel to the brain).
    - The PNS consists of afferent and efferent neurons that are responsible for communication between the body and the brain.
      - Cranial nerves: the 12 sensory and motor nerves extending directly from the brain

- Spinal nerves: bundles of nerves connected to the spinal cord carrying information toward the periphery
- Afferent neurons: send information from the body toward the CNS
- Efferent neurons (motor neurons): carry signals from the CNS to the muscles to generate movement
  - Somatic nervous system: the part of the nervous system controlling voluntary movement
  - Autonomic nervous system: the part of the nervous system responsible for involuntary functions and movement
    - Sympathetic nervous system: the autonomic system responsible for "fight-or-flight"
    - Parasympathetic nervous system: the autonomic system responsible for "rest and digest"



- Functions of the nervous system
  - Sensory impulses
    - Internal stimuli: sensory input from within the body
    - External stimuli: sensory input from external sources
    - Mechanoreceptors: nervous system receptors responding to mechanical stimuli such as sound or touch
      - Tactile receptors: collect and communicate sensations of touch
      - Proprioceptors: communicate the position of the body and movement
      - Baroreceptors: collect and communicate changes in blood pressure
    - Proprioception: perception or awareness of body movement or position in space
    - Myelin sheath: the insulation of neuron axons, made of proteins and fats, which propagates neural impulses
  - Integration of sensory input

- Nerve impulses: the electrical signals used for nerve communication
- Sensory integration: the way the brain works to affect responses to neural input

- Motor function
  - Includes both voluntary and involuntary muscle contractions
    - Motor unit: a single motor neuron and the muscle fibers it controls
    - Motor unit pool: a group of motor units that work together
    - Extrafusal muscle fibers: fibers that cause muscle contraction and mechanical work
    - Alpha motor neurons: motor neurons originating in the brain stem and spinal cord that initiate muscle contraction
    - Excitation-contraction coupling: the physiological process of converting a neural impulse into a mechanical response
    - Action potential: an explosion of electrical activity caused by a neural impulse
    - All-or-none principle: the principle stating the strength of a neural electrical signal is independent of the magnitude of the stimulus so long as the neural threshold is achieved

Muscular System - Chapter 3

The muscular system also plays a critical role in human movement. Personal trainers need to know the structure, function, role, and anatomy of the muscles within the human body.

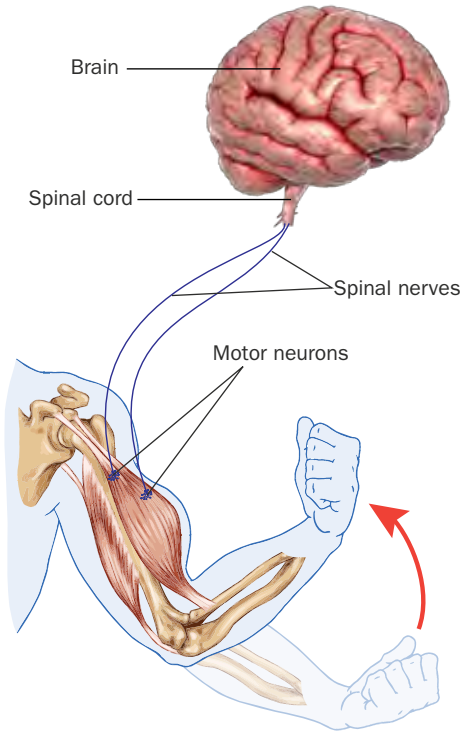
- There are three types of muscle tissue based on their structure and function. They include the following:

MUSCLE TISSUE TYPE	CHARACTERISTIC	EXAMPLE
Cardiac Muscle	Striated and involuntary	Makes up the wall of the heart
Smooth Muscle	Smooth and involuntary	Found in other organs such as those of the digestive system
Skeletal Muscle (most common muscle tissue in the human body)	Striated, voluntary, and fatigue easily	Attaches to bone, responsible for all movement

- Skeletal muscle structure
  - Sarcomere: the contractile unit of muscle tissue
  - Z line: the lateral boundary of the sarcomere where the myofilament actin attaches
  - Sarcoplasm: the cytoplasm of a muscle fiber (unique to muscle cells)
  - Glycogen: the stored form of glucose found in the liver and muscles
  - Myofibrils: parallel filaments that form muscle
  - Myofilaments: the filaments of myofibrils composed of actin and myosin
  - Actin: the thin filaments of muscle myofilaments where myosin binds to generate muscle contraction
  - Myosin: the thick filaments of myofilaments with a fibrous head, neck, and tail that binds to actin

- Endomysium: the connective tissue covering each muscle fiber
- Epimysium: fibrous elastic tissue that surrounds a muscle
- Fasciculi: bundles of muscle fibers; the singular is "fascicle"
- Perimysium: the connective tissue that covers a bundle of muscle fibers
- Tendon: a strong fibrous connective tissue that attaches muscle to bone
- Periosteum: a dense layer of vascular connective tissue enveloping the bones except at the surfaces of the joints

- Skeletal muscle contraction
  - Must receive a signal from the CNS
  - Neuromuscular junction: the space between a motor neuron and muscle fiber
  - Neurotransmitter: a chemical messenger that transmits messages between neurons or from neurons to muscles
  - Acetylcholine: the neurotransmitter (unique to the motor neuron) released by an action potential at the neuromuscular junction
  - Sliding-filament theory: the interaction of actin and myosin that describes the process of muscle contraction
    - Muscles are made up of sarcomeres—a contractile unit of a myofibril (muscle fiber).
    - The myofibrils have overlapping strands of protein polymers called actin (thin filaments) and myosin (thick filaments).
    - An electrical trigger stimulates the release of calcium, which binds to actin.
    - This then allows the interaction with the other contractile protein, myosin.
    - The myosin can now pull on the actin to begin shortening the muscle.
    - This series of interactions, the myosin pulling across the actin, is what causes shortening in the muscle and ultimately a muscle contraction.



1. Brain sends out electrical signal
2. Signal travels through the spinal cord
3. To the spinal nerves
4. To the motor neurons
5. Resulting in the propagation of an electrical current through the muscle fiber
6. Electrical signal triggers the release of calcium inside the muscle fiber
7. The released calcium binds to the contractile protein ACTIN
8. This permits its interaction with the MYOSIN contractile protein
9. ATP provides the energy that permits the "walking" of MYOSIN across the ACTIN
10. This pulling action of the MYOSIN across the ACTIN results in the shortening of the muscle fiber during MUSCLE CONTRACTION.

- Size principle of fiber recruitment (also called Henneman's size principle): principle stating that motor units are recruited in order according to their recruitment thresholds and firing rates
  - In other words, motor units will be recruited in order from smallest and slowest firing rate to largest and fastest firing rate.
- Types of muscle fibers
  - As a trainer, it's also important to understand the types of muscle fibers as they have different needs, capabilities, and purposes within the human body.
    - There are two main types of skeletal muscle fibers:
      - Type I: slow-twitch fibers and aerobic (good for endurance)
      - Type II: fast-twitch and anaerobic (good for power)
        - Type IIa fibers: fast-twitch, moderately fatigable muscle fibers with moderate mitochondrial density
        - Type IIx fibers: fast-twitch, fast-fatigable muscle fibers with low mitochondrial density (white in color)
          - Mitochondria (singular "mitochondrion"): an organelle with a double membrane and many folds inside responsible for generating the chemical energy needed for biochemical reactions; the "powerhouse of the cell"
- Muscles as movers
  - Muscles create movement by pulling on bones within the body. Muscles connect to bones, via tendons, at the origin and insertion.
    - Origin: the proximal (closer to the midline of the body) attachment
    - Insertion: the distal (farther from the midline) attachment
    - Action: the specific movements that each muscle is responsible for
    - Innervation: the specific distribution of nerves to a particular part of the body
- Muscle fiber arrangement (or the directions in which muscles run) will help fitness professionals learn how the muscles pull on the skeletal system to produce movement.
  - Fusiform muscle: spindle-shaped muscle
    - Example: Biceps brachii
  - Convergent muscle (triangular muscle): muscle fibers converging from a broad origin (fixed point where the muscle attaches closest to the torso) to a single tendon of insertion (fixed point where the muscle attaches farthest from the torso)
    - Example: Pectoralis
  - Circular muscle: muscle fibers surrounding an opening in the body
  - Parallel muscle: muscle fibers running parallel to the axis of the muscle
    - Example: Stylohyoid
  - Pennate muscle: muscles with fasciculi that attach obliquely (diagonally)
  - Unipennate muscle: muscle fibers extending from one side of a central tendon
    - Example: Flexor pollicis longus

- Bipennate muscle: muscle fibers extending from both sides of a central tendon
  - Example: Soleus
- Multipennate muscle: muscle fibers extending from both sides of multiple central tendons
  - Example: Deltoid

- A muscle produces three different types of actions:
  - Concentric: muscles that shorten to produce movement. For example, during the pressing motion of a bench press, the pectoralis is concentrically contracting.
  - Eccentric: muscles that lengthen to allow movement. For example, during the downward motion of a biceps curl, the biceps brachii is eccentrically contracting. When applying tempo training, this is the part of the movement that should be the focus and, therefore, the slowest portion of the repetition.
  - Isometric: muscles where the joint angle and muscle length do not change during movement. For example, the entire body works to maintain a stable position when performing a plank.
- Muscles typically work together in groups:

CLASSIFICATION	RESPONSIBILITY OF MUSCLE TYPE	EXAMPLE
Agonist	Main muscle responsible for movement; prime mover	Biceps brachii during a biceps curl
Synergist	Muscle that plays a secondary role in movement	Brachioradialis during a biceps curl
Antagonist	Muscle with an action directly opposite of the agonist	Triceps during a biceps curl

- Other key terms
  - All-or-none principle: The amplitude—or strength—of a nerve's action potential is independent of the strength—or magnitude—of the stimulus.
  - Stretch-shortening cycle (SSC): the cycling between the eccentric (stretch) action of a muscle and the concentric (shortening) action of the same muscle
    - Three (3) phases:
      - Eccentric, Amortization, Concentric

Skeletal System - Chapter 3

The skeletal system (about 206 bones) provides structure and support to the body and is made up of the axial skeletal system (80 bones including the skull, spine, and ribs) and the appendicular system (126 bones including all other extensions of the axial skeletal system).

- Divisions of the skeletal system
  - Axial skeleton
    - Skull
    - Spine
    - Ribs

- Appendicular skeleton
  - 60 in upper extremities
  - 60 in lower extremities
  - 2 in pelvic girdle
  - 4 in shoulder girdle

- Five main categories of bones

BONE CLASSIFICATION	CHARACTERISTIC	EXAMPLE
Flat Bones	Curved surface and provide protection for internal organs	Ribs, sternum, clavicle, and scapula
Short Bones	Small, cube shaped	Carpals and tarsals, calcaneus
Long Bones	Long, cylindrical shaft and provide structural support	Tibia, fibula, femur, radius, ulna, and humerus
Sesamoid Bones	Small bones in the tendon of a musculotendinous joint	Patella and flexor tendon of the foot and thumb
Irregular Bones	Serve a variety of purposes; includes the bones of the spine	Bones in the ischium and pubis

- Bone structure
  - Bone marrow: the soft, sponge like tissue in the center of most bones containing stem cells of red or white blood cells or platelets
  - Cancellous bone: the meshwork of spongy tissue (trabeculae) of mature adult bone, typically found at the core of vertebral bones and the ends of the long bones
  - Compact bone: a denser material, also known as cortical bone, making up the hard structure of the skeleton
- Bone formation
  - Osteogenesis: the process of bone formation or remodeling
  - Myositis ossificans: a condition when bone tissue forms within a muscle or other soft tissue as a result of trauma or injury
  - Cartilage: firm, flexible connective tissue that pads and protects joints and structural components of the body
  - Wolff's law: the explanation for bone adaptations as a result of the loads placed on them

Joints - Chapter 3

Joints are the points where two bones connect. Muscle mechanics for the major joints and muscle groups are an important concept for a personal trainer to know. Muscle mechanics look at joint action, joint makeup, muscle involvement, and the associated relationships between various muscle groups in the body.

- Joint classification
  - Fibrous joints: joints with fibrous connective tissue joining two bones that allow for very little movement
    - Sutures or synarthrodial joints: This type of joint is found in the skull. During birth, sutures are flexible to allow a baby to pass through the birth canal, and they become more rigid with age.
    - Syndesmosis: found between some long bones such as the tibia and fibula
    - Gomphosis joints: attach teeth to the sockets of the maxilla and mandible
  - Cartilaginous joints: moderately movable joints made of fibrocartilage or hyaline cartilage
    - Primary: epiphyseal (growth) plates
    - Secondary: intervertebral discs (layers of cartilage between vertebrae)
  - Synovial joints: fluid-filled joints found between bones that move against one another
    - The type of joint that allows movement
    - Example: Knee

TYPE OF SYNOVIAL JOINT	EXAMPLE
Gliding	Tarsals of the foot
Condyloid	Radiocarpal joint
Ball and Socket	Shoulder and hip
Hinge	Elbow, ankle, and knee
Saddle	Joint between the thumb and wrist
Pivot	Radioulnar joint

- Other key terms
  - Arthrokinematics: the broad term meaning joint motion that can be used in reference to all joint motions
  - Close-packed joint position: the most stable joint position, when the connective tissue is taut and neighboring bones have the most contact
  - Loose-packed joint position: the less stable joint position represented by any other joint position other than close packed

Tendons - Chapter 3

Tendons connect muscle to bone and serve as a mechanical bridge to transmit the force created by muscle contraction.

- Key terms
  - Receptors in the joints, muscles, and tendons help people know where their bodies are in space (proprioception).
    - Golgi tendon organs are at the junction of muscle and tendon and respond to mechanical stress such as pressure or muscle tension.
    - Muscle spindles are sensory receptors within the belly of a muscle that primarily detect changes in the length of this muscle (stretch).
      - Muscles responsible for fine movements contain more muscle spindles than muscles responsible for gross movements.

Ligaments - Chapter 3

Ligaments are tough bands of connective tissue made of collagen and elastin connecting bone to bone.

- Types
  - Extrinsic ligament: This type of ligament is located on the outside of a joint. An example is the lateral collateral ligament (LCL), which resists abnormal movement away from the midline, termed varus stress.
    - Varus: an abnormal joint movement away from the midline of the body (i.e., bowlegged)
  - Intrinsic ligament: The anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL) are situated inside the knee joint to resist anterior and posterior (forward and backward) movement of the tibia, respectively.
  - Capsular ligament: The medial collateral ligament (MCL) is a capsular ligament, so called because it is continuous with the joint capsule. It resists valgus stress at the knee by keeping the joint approximated.
    - Valgus: an abnormal joint movement toward the midline of the body (i.e., knock-kneed)
- Other key terms
  - Elastin: a highly elastic connective tissue allowing many tissues to retain their shape
  - Joint capsule: a thin, strong layer of connective tissue containing synovial fluid in freely moving joints

Cartilage - Chapter 3

Cartilage resists compressive forces, makes bones more resilient, and offers support and flexibility in some areas. There are no nerves or blood vessels in cartilage, making cartilage injury recovery a long, arduous process.

- Types of cartilage
  - Hyaline cartilage: a transparent cartilage found on most joint surfaces and in the respiratory tract, which contains no nerves or blood vessels
  - Fibrocartilage: an elastic and tough tissue containing type I and type II collagen
    - Meniscus: a form of fibrocartilage present in the knee, wrist, acromioclavicular, sternoclavicular, and temporomandibular joints
  - Elastic cartilage: flexible cartilage present in the outer ear, inner ear, and epiglottis
    - Epiglottis: a piece of elastic cartilage in the throat that opens during breathing and closes during swallowing
- Other key terms
  - Perichondrium: the connective tissue enveloping cartilage everywhere except at a joint
  - Articular cartilage: a form of hyaline cartilage located on the joint surface of bones
  - Nociceptors: pain-sensitive nerve endings

Supportive Systems - Chapter 4

Although the nervous, muscular, and skeletal systems are the most important organ systems regarding human movement, there are other systems in the body that a personal trainer should have foundational knowledge of.

- Circulatory system: the heart, arteries, and veins that act as a transport system

- Key structures
  - Arteries: blood vessels carrying oxygenated blood away from the heart and to the tissues
  - Veins: blood vessels carrying blood toward the heart to remove waste and pick up more oxygen
  - Capillaries: fine-branching blood vessels forming a network between the arterioles and venules, where transport of nutrients and oxygen or carbon dioxide occurs on a microscopic scale
  - Arterioles: the smaller branches of the arteries leading to the capillaries
  - Venules: the small branches of the veins gathering blood from the capillaries
  - Heart
    - The heart beats about 100,000 times per day.
    - For every minute of work, the heart pumps five (5) to six (6) quarts of blood around the body.
    - Atrium: one of the two upper cavities of the heart passing blood to the ventricles. The plural is “atria.”
    - Ventricle: one of the two lower cavities of the heart passing blood to the body or to the lungs
    - Pulmonary arteries: blood vessels moving blood from the heart to the lungs
    - Pulmonary veins: blood vessels returning oxygenated blood to the heart from the lungs
    - Aorta: the main artery in the body that supplies oxygenated blood to the circulatory system
    - Superior vena cava: the blood vessel moving blood from the upper body and head to the heart
    - Inferior vena cava: the blood vessel moving blood from the lower body to the heart
    - Atrioventricular (AV) valves: valves between the atria and ventricles preventing the backward flow of blood during cardiac contractions
    - Sinoatrial (SA) node: the pacemaker of the heart that generates the first electrical signal of a heartbeat and stimulates the atria to contract
    - Atrioventricular (AV) node: the nerve node between the right atrium and right ventricle that propagates the electrical signal from the SA note to more distal heart nerves that cause ventricular contraction
    - Movement of blood through the circulatory system: deoxygenated blood from body > right atrium > tricuspid valve > right ventricle > pulmonary artery (to lungs) > pulmonary vein (oxygenated) from lungs > left atrium > bicuspid valve > left ventricle > aorta (to body for circulation)
  - Blood cells
    - Red Blood cells
      - Erythrocytes: the most numerous of all blood cells (approx. 40 percent of blood volume) that transfer oxygen to the body tissues
    - White blood cells
      - Basophil: a large white blood cell that locates and destroys cancerous cells and is responsible for the histamine response during an allergic reaction
      - Neutrophil: the most numerous white blood cells responsible for the primary immune

response of the ingestion or enzymatic digestion of foreign microorganisms

- Eosinophil: white blood cells that play a role in allergic reactions and immune defense against multicellular parasites
- Monocyte: an immune cell that helps remove dead or damaged tissues and provides support to the other types of white blood cells
- Lymphocyte: white blood cells that include natural killer cells, B cells, and T cells, which kill tumor cells, produce antibodies, and kill infected or cancerous cells, respectively

- Key terms
  - Systole: the heartbeat phase where muscle contraction moves blood from the heart chambers to the arteries
  - Diastole: the heartbeat phase where the cardiac muscle relaxes and the heart chambers fill with blood
  - Stroke volume: the amount of blood pumped by the left ventricle of the heart in one contraction
  - Heart rate: the number of heartbeats per minute
    - Average human resting heart rate is 60 to 100 beats per minute
  - Pulmonary circulation: the blood flow between the heart and the lungs
  - Systemic circulation: the blood flow between the heart and the rest of the body
  - Cardiac cycle: the action of the heart from the start of one heartbeat to the beginning of the next
  - Pulse: a rhythmical throbbing of the arteries as blood is propelled through them
    - Measured at neck (carotid artery) or wrist (radial artery)
  - Blood pressure: the force of blood pushing against the walls of the arteries during the two phases of the cardiac cycle
    - 'Normal' range blood pressure: 120/80 mm Hg
    - Hypotension: low blood pressure measuring 90/60 mm Hg or lower
    - Hypertension: high blood pressure measuring more than 140/90 mm Hg
    - Systolic: the pressure in blood vessels when the heart beats (ventricular contraction)
    - Diastolic: the pressure in blood vessels when the heart rests (ventricular filling)
    - Factors influencing blood pressure
      - Cardiac output: how much blood the heart is pumping per minute
      - Blood volume: the total volume of blood contained in the circulatory system
      - Peripheral resistance of arteries: the elasticity (or lack thereof) of artery walls
      - Blood viscosity: the thickness of blood moving through circulation

- Lymphatic system
  - Key Structures
    - Lymph nodes
    - Tonsils
    - Spleen (largest)
    - Thymus

- Functions
  - Balancing interstitial fluids
  - Absorbing fats and fat-soluble vitamins
  - Defending against illness and disease
- Key terms
  - Lymph: the colorless fluid of the lymphatic system
  - Interstitial fluid: the fluid found between cells

- Respiratory system: the lungs and air passageways that supply oxygen to the body and remove carbon dioxide
  - Key structures
    - Nose and nasal cavities: The nose is made of bone and cartilage. Air and particles enter the body through the nose.
    - Pharynx: The pharynx is commonly called the throat and is a passageway for both air and food.
    - Larynx: This passageway is between the pharynx and trachea.
    - Trachea: This is the primary passageway for air moving into the lungs.
    - Bronchi: This is the passageway of air into the functional tissues of the lungs.
    - Lungs: The right lung has three lobes, while the left lung has two lobes. The lungs are separated by a membrane partition called the mediastinum, which is where the heart sits.
      - alveoli: the small sacs within the lungs where gas exchange occurs (by diffusion)
  - Functions
    - Providing oxygen for metabolic processes
    - Removing waste products of metabolism
    - Regulating the pH of blood
  - Key terms
    - Respiration: the intake of oxygen and subsequent release of carbon dioxide in an organism
    - Pulmonary ventilation: the process of exchanging air between the lungs and the ambient air
    - Inspiration: breathing air into the lungs
    - Expiration: breathing air out of the lungs
    - Diaphragm: the dome-shaped muscle that separates the lungs and pleural cavity from the abdomen; the primary muscle in pulmonary respiration
    - Diffusion: the passive movement of molecules or particles along a concentration gradient or from regions of higher concentration to regions of lower concentration
    - Thoracic cavity: the chest cavity enclosed by the ribs, sternum, and spinal column
    - Intra-alveolar pressure: the pressure within the alveoli that changes throughout respiration
    - External respiration: the exchange of gases between the lungs and the blood
    - Internal respiration: the process of diffusing oxygen from the blood into the interstitial fluid and into the cells

- Endocrine system: releases hormones and is responsible for metabolic activities (e.g., growth hormone [GH] is most abundantly produced by the pituitary gland)
    - Key structures
        - Hypothalamus: The main role of this gland is to maintain homeostasis. It either stimulates or inhibits heart rate, blood pressure, body temperature, fluid and electrolyte balance, thirst, appetite, body weight, glandular secretions of the stomach and intestines, the release of substances influencing the pituitary gland, and sleep cycles.
            - Electrolyte: Electrolytes are minerals in the body that have an electric charge.
        - Pineal gland: The only hormone this gland is known to secrete is melatonin.
        - Pituitary gland: Pituitary hormones control other parts of the endocrine system, including the thyroid gland, adrenal glands, ovaries, and testes.
        - Thyroid: The main function of the thyroid is to regulate metabolism.
        - Parathyroid: There are four parathyroid glands that help regulate calcium levels in the body.
        - Thymus: The thymus is only active until puberty. Before puberty, it stimulates the development of T lymphocytes, which play a role in the lymphatic system's defense against illness and infection.
        - Adrenal: The adrenal glands are attached to the kidneys and are made up of the adrenal cortex and adrenal medulla. Hormones secreted by the adrenal cortex are essential to life. Those secreted by the adrenal medulla are not.
        - Pancreas: The main role of the pancreas is to maintain blood glucose balance.
        - Ovaries: The ovaries secrete hormones essential for female reproductive development and fertility.
        - Testes: The testes are responsible for maintaining male reproductive health.

- Key terms
  - Hormones: chemical messengers stored, created, and released by endocrine glands

HOST	HORMONE	HORMONE FUNCTION	CONTROL OF HORMONE SECRETION	EFFECTS OF EXERCISE ON HORMONE SECRETION
Anterior pituitary	Growth hormone (GH)	Stimulates tissue growth; mobilizes fatty acids for energy; inhibits carbohydrate metabolism	Hypothalamic-releasing factor	↑ with increasing exercise
	Thyrotropin (TSH)	Stimulates production and release of thyroxine from thyroid gland	Hypothalamic TSH-releasing factor; thyroxine	↑ with increasing exercise
	Corticotropin (ACTH)	Stimulates production and release of cortisol, aldosterone, and other adrenal hormones	Hypothalamic ACTH-releasing factor; cortisol	Effects unknown
	Gonadotropin (FSH & LH)	FSH works with LH to stimulate production of estrogens and progesterone by ovaries and testosterone by male testes	Hypothalamic FSH- and LH-releasing factor; female: estrogen and progesterone; male: testosterone	No change
	Prolactin (PRL)	Inhibits testosterone; mobilizes fatty acids	Hypothalamic PRL-inhibiting factor	↑ with increasing exercise
	Endorphins	Block pain; promote euphoria; affect feeding and female menstrual cycle	Stress: physical/emotional	↑ with long-duration exercise
Posterior pituitary	Vasopressin (ADH)	Controls water excretion by kidneys	Hypothalamic secretory neurons	↑ with increasing exercise
	Oxytocin	Stimulates muscles in uterus and breasts; important in birth and lactation	Hypothalamic secretory neurons	Effects unknown

HOST	HORMONE	HORMONE FUNCTION	CONTROL OF HORMONE SECRETION	EFFECTS OF EXERCISE ON HORMONE SECRETION
Adrenal cortex	Cortisol Corticosterone	Promotes use of fatty acids and protein catabolism; conserves blood sugar: insulin antagonist; has anti-inflammatory effects with epinephrine	ACTH; stress	↑ in heavy exercise only
	Aldosterone	Promotes retention of sodium, potassium, and water by kidneys	Angiotensin and plasma potassium concentration; renin	↑ with increasing exercise
Adrenal medulla	Epinephrine Norepinephrine	Facilitates sympathetic activity, increases cardiac output, regulates blood vessels, increases glycogen catabolism and fatty acid release	Stress stimulates hypothalamic sympathetic nerves	Epinephrine: ↑ with heavy exercise; norepinephrine: ↑ with increasing exercise
Thyroid	Thyroxine (T4) Triiodothyronine (T3)	Stimulates metabolic rate; regulates cell growth and activity	TSH; whole-body metabolism	↑ with increasing exercise
Pancreas	Insulin	Promotes CHO transport into cells; increases CHO catabolism and decreases blood glucose; promotes fatty acid and amino acid transport into cells	Plasma glucose levels	↑ with increasing exercise
	Glucagon	Promotes release of glucose from liver to blood; increases fat metabolism	Plasma glucose levels	↑ with increasing exercise
Parathyroid	Parathormone	Raises blood calcium; lowers blood phosphate	Plasma calcium concentration	↑ with long-term exercise
Ovaries	Estrogen Progesterone	Controls menstrual cycle; increases fat deposition; promotes female sex characteristics	FSH, LH	↑ with exercise; depends on menstrual phase

HOST	HORMONE	HORMONE FUNCTION	CONTROL OF HORMONE SECRETION	EFFECTS OF EXERCISE ON HORMONE SECRETION
Testes	Testosterone	Controls muscle size; increases number of red blood cells; decreases bodyfat; promotes male sex characteristics	LH	↑ with exercise
Kidneys	Renin	Stimulates aldosterone secretion	Plasma sodium concentration	↑ with increasing exercise

- Endocrine glands: ductless glands releasing hormones that remain within the body
  - ENDOcrine glands produce substances that remain within the body
- Exocrine glands: glands that produce and release substances through ducts or openings on the body's surface
  - EXOcrine glands secrete substances that EXIT the body

- Hormonal response to exercise
  - Testosterone
    - A steroid hormone found in both males and females
  - Growth hormone (GH)
    - A hormone released by the pituitary gland that stimulates growth in animal cells
      - Increases protein synthesis
      - Increases fat breakdown
      - Increases collagen synthesis
      - Decreases glucose utilization
  - Insulin-like growth factor
    - A protein similar to insulin that stimulates the growth of cells
    - limited production when GH is absent
  - Insulin
    - A hormone produced in the pancreas to regulate blood sugar
    - Insulin promotes the uptake of glucose into target cells. Insulin = IN the cells
  - Cortisol
    - A catabolic hormone released in response to physical and emotional stress
    - Can be good or bad based on how long it remains elevated
      - Short-term cortisol elevation:
        - Increases blood sugar (glucose) levels
        - Enhances the brain's use of glucose
        - Reduces inflammation

        - Reduces unnecessary bodily functions during the fight-or-flight response
      - Extended-duration cortisol elevation:
        - Increases appetite
        - Increases blood pressure
        - Promotes weight gain
        - Contributes to type 2 diabetes
    - Catecholamines
      - Hormones released by the adrenal glands into the blood as a result of stress
  - Key terms
    - Anabolic: the process of creating larger molecules from smaller units
    - Catabolic: metabolic activity involving the breakdown of molecules such as proteins or lipids into smaller units
    - Protein synthesis: the process of arranging amino acids into protein structures
- Digestive system
  - Key structures
    - Mouth
      - Mastication: chewing
      - Bolus: food mixed with saliva to create a moist mass
    - Esophagus
      - Conduit for food between the pharynx and stomach
    - Stomach
      - 2 quarts in volume
      - Secretes several types of substances to aid in the breakdown of food
      - Chyme: a pulpy, acidic fluid that moves from the stomach to the small intestines, containing partially digested food and gastric juices
    - Small intestine
      - 12 feet long
      - Three main regions
        - Duodenum: some nutrient absorption, but mostly food storage and breakdown
        - Jejunum: nutrient absorption
        - Ileum: nutrient absorption
      - Lined with villi
      - Much of nutrient absorption happens here
    - Large intestine and rectum
      - 3 feet long
      - Some nutrient absorption happens here.
    - Liver

- Largest gland in the body
- Key functions
  - Secretion of plasma proteins, carrier proteins, hormones, prohormones, and apolipoprotein
  - Making and excreting bile salts
  - Storage of fat-soluble vitamins
  - Blood detoxification and filtration
  - Carbohydrate, protein, and lipid metabolism

- Gallbladder
  - Attached to liver
  - Stores bile
    - A bitter, greenish-brown alkaline fluid aiding digestion, secreted by the liver and stored in the gallbladder
- Pancreas
  - Behind the stomach
  - Endocrine and exocrine functions
  - Secretes the digestive enzymes amylase, trypsin, peptidase (protease), and lipase.

- Functions
  - Ingestion: taking food in through the mouth
  - Mechanical digestion: the process of chewing (mastication) and the churning and mixing actions of the stomach that further break down food
  - Chemical digestion: when enzymes are released throughout the digestive tract to break food into smaller molecules
  - Movements: food moving through the digestive system by the rhythmic contractions of the smooth muscle of the digestive tract—a process known as peristalsis
    - Peristalsis: the muscular contractions of the smooth muscle of the digestive tract, which moves food through the digestive tract
  - Absorption: when simple molecules get absorbed by the cell membranes in the lining of the small intestine into blood or lymph capillaries
  - Elimination: the removal of waste products and indigestible particles
    -

- Integumentary System
  - Largest human organ system
  - Skin, hair, and nails
  - Functions:
    - Protects internal organs from damage and disease
    - Prevents fluid loss

    - Regulates body temperature
- Layers:
    - Epidermis: outermost waterproof layer
    - Dermis: holds blood cells, sweat glands, hair, and connective tissues
    - Hypodermis: deepest layer holding subcutaneous fat and connective tissues

Principles of Biomechanics - Chapter 5

- Kinesiology is the study of the mechanics of human movement.
- Biomechanics is the study of the mechanical laws governing the movement of living organisms.
- Key terms
    - Force (the interaction that creates work or physical change) = mass x acceleration
    - Range of motion (ROM): the measurement of movement around a specific joint or body part
        - Human movement requires joints to be both mobile and stable (joints should have the ability to move through the proper ROM but with control).
    - Angle of muscle pull: the angle at which a muscle pulls relative to the long axis of the bone on which it pulls
    - Kinetics: the study of forces acting on a mechanism
    - Balance: an even distribution of weight enabling someone or something to maintain its center of gravity within a base of support
    - Equilibrium: a state in which opposing forces or influences are balanced
    - Stability: the ability to control and maintain control of joint movement or body position
    - Center of gravity: the hypothetical position in the body where the combined mass appears to be concentrated and the point around which gravity appears to act
    - Base of support: the area beneath an object or person that includes every point of contact that the object or person makes with the supporting surface
    - Gravity: the attraction between objects and the Earth
    - Muscular force: involves the contraction of a muscle while exerting a force and performing work. It can be concentric (shortening), eccentric (lengthening), or isometric (tension without joint movement).
    - Dynamic balance: the ability to remain upright and balanced when the body and/or arms and legs are in motion
    - Static balance: the ability to remain upright and balanced when the body is at rest
    - Mass: the amount of matter in an object
    - Weight: the gravitational force of attraction on an object
    - Line of gravity: a vertical line straight through the center of gravity
    - Joint mobility: the degree of movement around a joint before movement is restricted by surrounding tissues
        - Joints typically needing greater mobility: foot/ankle, hip, thoracic spine, shoulder, and wrist
    - Joint stability: the ability of the muscles around a joint to control movement or hold the joint in a fixed (stable) position

- Joints typically needing greater stability: knee, lumbar spine, cervical spine, and elbow

- Momentum: the quantity of motion of a moving body, measured as a product of its mass and velocity
- Muscular contraction: the shortening or resistance to lengthening of a muscle fiber
- Linear motion: movement along a line, straight or curved
- Angular motion: rotation around an axis
- Axis: point of rotation around which a lever moves
- Displacement: the distance an object is displaced from a starting point
- Distance: the total or sum of the length an object travels
- Angular displacement: the change of location of an object that is rotating about an axis
- Linear displacement: the distance an object moves in a straight line
- Mechanical advantage: the ratio of force that creates meaningful movement compared to the force applied to generate the movement
- Work: force times distance measured in foot-pounds
    - What happens when a force is applied to an object = force x distance
        - W = F x D
            - W is work, F is force, and D is distance or displacement.
- Power: the amount of force exerted by a muscle or group of muscles in a given amount of time
    - The work done in a unit of time = force x velocity
        - W = 300 pounds x 3 feet
        - W = 900 feet/pound
            - Assume it took 3 seconds to move a barbell.
                - 900 feet/pound divided by 3 seconds = 300 feet/pound of work per second
            - However, if it only took 2 seconds to move the load, the result is quite different.
                - 900 feet/pound divided by 2 seconds = 450 feet/pound of work per second
- Mechanical work: is the amount of energy transferred by a force, the product of force and distance.
- Torque: the turning effect of an eccentric force, the rotational analog of force
    - Torque is determined by multiplying the force (effort) by the length of the force arm.
        - Force arm: the distance between the fulcrum and the force or load application in a lever
- Rotary motion: the movement around a fixed axis moving in a curved path
- Length-tension relationship: the amount of tension a muscle can produce with respect to its length
- Force-couple relationship: two or more muscles acting in different directions that influence the rotation of a joint in a specific direction
- Muscle synergies: the activation of a group of muscles to generate movement around a particular joint
- Sustained force movement: movement that requires continuous muscle contractions to keep a load moving

There are specific terms fitness professionals use to understand and describe movement as well as different locations/positions on the body. The terms refer to the body when in anatomical position—facing forward with the arms at the sides of the body and palms and toes pointing straight ahead.

- Anatomical locations

ANATOMICAL LOCATION TERM	DEFINITION
Anterior or ventral	Front of the body or toward the front relative to another reference point
Posterior or dorsal	Back of the body or toward the back relative to another reference point
Superior	Above a reference point
Inferior	Below a reference point
Proximal	Position closer to the center of the body relative to a reference point
Distal	Position farther from the reference point
Medial	Position relatively closer to the midline of the body
Lateral	Position relatively farther from the midline of the body
Prone	Lying facedown

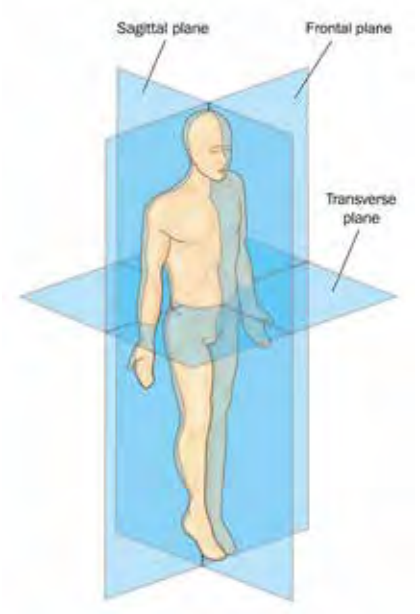
ANATOMICAL LOCATION TERM	DEFINITION
Supine	Lying on one's backside
Deep	Further beneath the surface relative to another reference point
Superficial	Closer to the surface relative to another reference point
Unilateral	Refers to only one side
Bilateral	Refers to both sides
Ipsilateral	On the same side
Contralateral	On the opposite side
Caudal	Toward the bottom
Cephalic	Toward the head
Volar	Relating to the palm of the hand or sole of the foot

- Anatomical movements

TERM	DEFINITION/ACTION
Abduction	Movement away from the midline
Adduction	Movement toward the midline
Flexion	Movement decreasing the angle between two body parts
Extension	Movement increasing the angle between two body parts
Lateral flexion	Flexion in the frontal plane
Protraction	Abduction of the scapula
Retraction	Adduction of the scapula
Elevation	Movement in a superior direction
Depression	Movement in an inferior direction
Plantar flexion	Extension of the foot downward (inferiorly)
Dorsiflexion	Flexion of the foot upward (superiorly)
External rotation	Rotational movement away from the midline
Internal rotation	Rotational movement toward the midline

TERM	DEFINITION/ACTION
Circumduction	Circular movement of a limb extending from the joint where the movement is controlled
Inversion	Movement of the sole of the foot toward the median plane
Eversion	Movement of the sole of the foot away from the median plane
Pronation	Turning the palm or arch of the foot down
Supination	Turning the palm or arch of the foot up
Hyperextension	Position that extends beyond anatomical neutral
Ipsilateral	Same-side movement
Contralateral	Opposite-side movement
Lateral	Situated away from the midline
Medial	Situated toward or closer to the midline

- Planes of motion
  - Frontal plane: an imaginary line that divides the body into anterior and posterior halves
    - Example movements in this plane include lateral raises, side lunges, and lateral flexion of the spine.
  - Sagittal plane: an imaginary line that divides the body into left and right halves
    - Example movements in this plane include lunges, biceps curls, squats, flexion or extension of the hip, and walking.
  - Transverse plane: an imaginary line that divides the body into inferior and superior halves
    - Example movements in this plane are rotational, such as a golf swing or internal rotation of the shoulder.

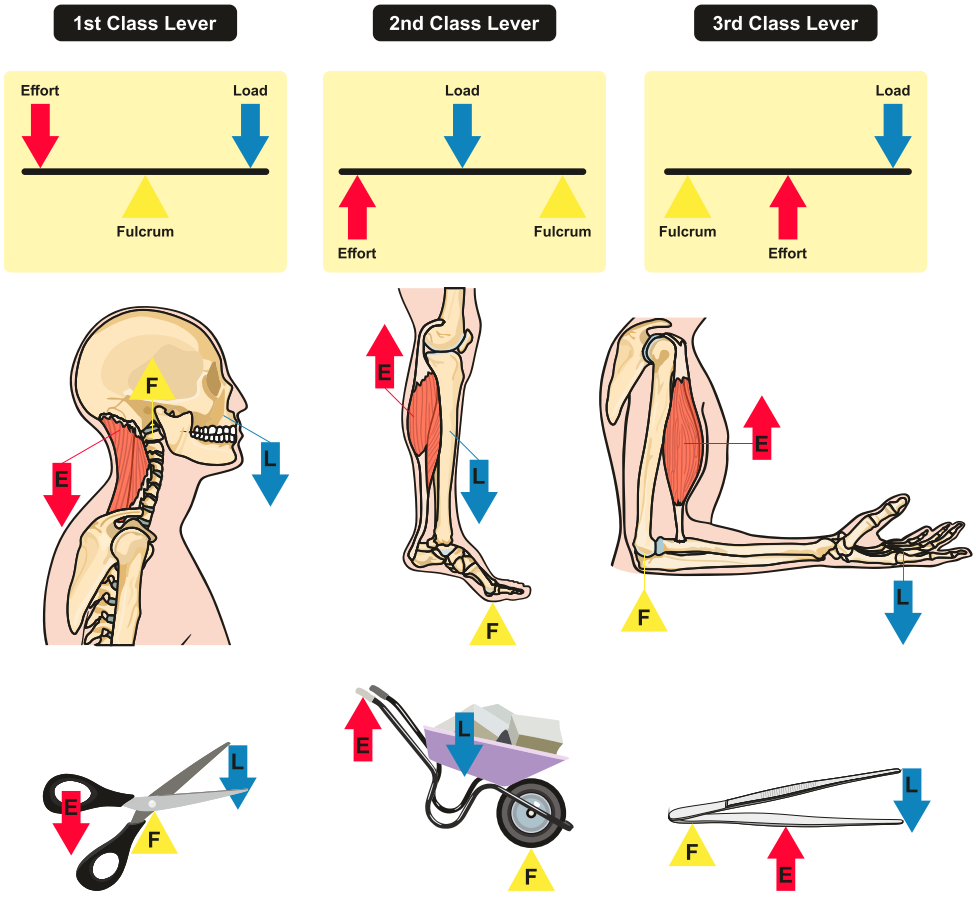


- Newton's law of motion
  - Newton's first law (inertia): A body in motion tends to stay in motion while a body at rest tends to stay at rest unless acted on by an outside force.
    - Inertia: the resistance to action or change and describes the acceleration and deceleration of the human body
    - Acceleration: the rate of change of velocity
    - Deceleration: a special type of acceleration where a person or object is slowing down
  - Newton's second law: A change in acceleration of mass occurs in the same direction of the force causing it, and the change of acceleration is directly proportional to the force causing it and inversely proportional to the mass of the body.
    - a = change in v / change in t
      - In this equation, a is acceleration, v is velocity, and t is time.
      - Velocity: the speed of an object and the direction it takes while moving
    - F = m x a
      - Force = mass x acceleration
    - F x velocity = P
      - F is force, and P is power.
      - Force-velocity curve: a representation of the inverse relationship between force and velocity in muscle contraction
    - F x D = W
      - F is force and D is distance
      - W is work: the energy that is transferred when force is applied to an object
  - Newton's third law: For every action, there is an opposite and equal reaction.
    - Speed: the ability to move the body in one direction as fast as possible
    - Ground reaction force (GRF): the force the ground exerts on a body it is in contact with
  - Friction: the resistance of relative motion that one surface or object encounters when moving over another
    - Static friction: the friction of an object that doesn't move
    - Sliding friction: the friction between two surfaces where one or both are moving against one another
    - Rolling friction:the force that resists a surface rolling across another surface
  - Compression force: the force of two surfaces pressing toward one another
  - Tensile force: the force when two surfaces pull apart from one another
  - Shear force: the force of two surfaces moving across one another
- Categories of biomechanics
  - Stability
  - Maximum effort (maximum amount of force or velocity)
  - Linear motion

- Angular motion

CATEGORY	PRINCIPLE(S)	DESCRIPTION	EXAMPLE
Stability	Stability	The ability to maintain control (i.e., resist change) of a joint or position.	Maintaining the positioning of the trunk, hips, and legs during a push-up.
Maximum effort	Production of maximum force	The maximum amount of force produced by a muscle or group of muscles.	Performing a one-rep maximum (1RM) for a barbell bench press.
	Production of maximum velocity	The maximum movement velocity, or muscular contraction speed, for a muscle or group of muscles.	Vertical jump. Throwing a baseball.
Linear	Force-velocity relationship	The greater the applied force on the same object, the greater the velocity.	A larger arc of a golf swing will produce greater force and therefore move the golf ball farther
	Direction of movement	Movement occurs in the direction opposite the applied force.	The body moves forward as the stroke applies force backward while swimming.
	Ground Reaction Forces (GRFs)	The force exerted by the ground to a body in contact with it. Because the ground does not move when applying force against a movable object, the object will move in the same direction of the force applied by the person.	In a barbell squat, the bar goes up when an exerciser applies force against it because the ground won't move. In a bench press, the bar goes in the same direction of the force the exerciser applies because the bench is solidly held by the ground. The exerciser is applying force down onto the bench rather than into the bar.
Angular motion	Angular motion	The motion of an object around a fixed point or axis. All lever actions are angular, and therefore most joint movements are angular.	A figure skater spinning. Elbow motion in a biceps curl because the ulna spins on the humerus.
	Conservation of angular momentum	Angular momentum is constant until an external force acts on it.	A figure skater during a triple-axel jump. In the air, there is very little acting against the skater's rotation. When gravity pulls the skater back down, the friction of the blade on the ice will stop the spin.

- Levers
  - A lever is a rigid bar that runs about an axis of rotation called a fulcrum. Having an understanding of levers is important because the rigid bar represents our bones and the fulcrum is the joints. The muscle contractions represent force.
  - Parts of a lever
    - Effort arm: the portion of the lever arm between the applied effort and the axis
    - Lever arm: the rigid bar portion of a lever that rotates around the fulcrum
    - Resistance arm: the portion of the lever arm between the load and the axis
    - Moment arm: the perpendicular distance between the fulcrum and the line of the force being applied



- Types of levers
  - First class
    - The fulcrum (axis) is located between the effort and the load (resistance).
      - Seesaw
      - Extension and flexion of the neck, with the fulcrum at the base of the skull
  - Second class
    - Load (resistance) is located between the fulcrum (axis) and the effort.
      - Wheelbarrow
      - Few instances of this type of lever can be found in the body.
        - Plantar flexion of the foot used to raise up to the toes, with the ball of the foot acting as the fulcrum
  - Third class
    - The effort is between the fulcrum (axis) and the load (resistance).
      - Shoveling
      - Most levers in the human body are of the third class.
        - Elbow flexion driven by the biceps brachii, with the elbow joint acting as the fulcrum

CLASS	DEFINITION	EXAMPLE
First-Class Lever	The fulcrum is between the force and resistance.	Seesaw
Second-Class Lever	Weight/resistance is between the fulcrum and application of force.	Wheelbarrow
Third-Class Lever	The force is between the fulcrum and resistance.	Shovel

- Muscle groupings/pairings
  - Agonist: the primary muscle used (prime mover) for a mechanical movement
  - Synergists: muscle(s) supporting the mechanical movement of a prime mover
  - Antagonist: muscle(s) opposing the mechanical movement of a prime mover
  - Stabilizer muscles: muscles playing the role of stabilizing or minimizing joint movement
  - Sherrington's law of reciprocal innervation: For every muscle activation, there is a corresponding inhibition of the opposing muscle.

- Muscles create movement by generating force and transferring that force to the attached bones via the connective tissue (tendons).
- Musculature
  - Muscles of the upper arm
    - Humerus (bone)
    - Biceps brachii (long head)
    - Biceps brachii (short head)
    - Triceps brachii (lateral head)
    - Triceps brachii (long head)
    - Triceps brachii (medial head)
    - Brachialis
  - Muscles of the forearm
    - Brachioradialis
    - Flexor pollicis longus
    - Pronator teres
    - Flexor digitorum profundus
    - Flexor carpi radialis
    - Pronator quadratus
    - Palmaris longus
    - Extensor carpi radialis longus
    - Flexor carpi ulnaris
    - Extensor carpi radialis brevis
    - Supinator
    - Extensor digitorum
  - Muscles of the shoulder
    - Humerus (bone)
    - Clavicle (bone)
    - Anterior deltoid
    - Lateral deltoid
    - Posterior deltoid
    - Supraspinatus
    - Infraspinatus
    - Subscapularis
    - Teres minor
  - Muscles of the back
    - Trapezius
    - Rhomboid minor

- Latissimus dorsi
- Rhomboid major
- External obliques
- Multifidus
- Semispinalis capitis
- Spinalis (erector spinae group)
- Semispinalis cervicis
- Longissimus (erector spinae group)
- Quadratus lumborum
- Iliocostalis (erector spinae group)

- Muscles of the midsection
  - Pectoralis major
  - Linea alba
  - Serratus anterior
  - Linea semilunaris
  - External oblique
  - Rectus sheath
  - Internal oblique
  - Quadratus lumborum
  - Rectus abdominis
  - Psoas
  - Transverse abdominis
  - Erector spinae
- Muscles of the chest
  - Pectoralis major
  - Subclavius
  - Pectoralis minor
- Muscles of the upper legs and hips
  - Psoas
  - Rectus femoris
  - Iliacus
  - Vastus lateralis
  - Gluteus medius
  - Vastus medialis
  - Gluteus minimus
  - Gluteus maximus

        - Tensor fasciae latae (TFL)
        - Biceps femoris
        - Sartorius
        - Semitendinosus
        - Adductor longus
        - Semimembranosus
        - Gracilis
    - Muscles of the lower leg
        - Tibialis anterior
        - Gastrocnemius
        - Peroneus longus
        - Soleus
        - Extensor digitorum longus
        - Peroneus brevis
        - Extensor hallucis longus
        - Tibialis posterior
- Kinetic chain: The kinetic chain checkpoints (foot and ankle, knee, hips, spine, shoulder, and head and neck) are important for fitness professionals to learn so that they know how to identify dysfunctional movement and make exercises more effective.
    - Foot and ankle
        - Made up of tibia and the talus bones, at the ankle, flexion and extension are possible and at the foot, inversion and eversion.
        - The foot and ankle are stabilized on the anterior side by the tibialis anterior and on the posterior side by the gastrocnemius and soleus (calf muscles).
    - Knee
        - The knee is stabilized on the anterior side by the quads, on the medial side by the sartorius and gracilis, on the lateral side by the TFL, and on the posterior side by the hamstrings.
        - The knee joint is at the end of the femur and tibia bones and primarily flexes and extends the lower leg.
    - Hips
        - The hip actions include flexion and extension, abduction and adduction, and internal and external rotation. Hip rotation can occur when the hip is neutral, flexed, or extended. The hip joint is one of the most flexible joints in the human body and a checkpoint a personal trainer must pay close attention to. Not only does this musculature support the stabilizing lumbopelvic hip complex (LPHC) but it also controls the movement of the lower extremities.
    - Spine
        - The spine includes the vertebral column (the most important functional unit of the body), and the spinous and transverse processes serve as attachments for deep and superficial muscles of the back.

Forward, backward, and lateral bending and some rotation are possible.

- The spine relies on ligaments and muscles for support. Supportive muscles include the rectus abdominus, internal/external obliques, and transverse abdominis.

- Shoulder
  - The shoulder is a multiaxial joint because it's a ball-and-socket joint and performs adduction and abduction, horizontal adduction and abduction, medial and lateral rotation, and circumduction.
    - The four muscles of the rotator cuff can easily be remembered by the acronym SITS and include the following:
      - Supraspinatus
      - Infraspinatus
      - Teres minor
      - Subscapularis
- Head and neck
  - The head and neck provide information along the kinetic chain about what is occurring at the shoulder girdle (clavicle, scapula, and coracoid bones of the appendicular skeleton), thoracic spine, rib cage, LPHC, and cervical spine.

Energy Systems - Chapter 6

The human body requires a constant supply of energy to move and function properly. The food we ingest must be broken down to be used at the cellular level for energy production.

- Cells: the building blocks of all living organisms
  - Organelles: tiny structures within cells, each with a unique function
  - Plasma membrane: the cellular membrane made of lipids and proteins that forms the external boundary of the cytoplasm and regulates the passage of molecules into and out of the cytoplasm
  - Cytoplasm: the viscous fluid inside a living cell excluding the nucleus
  - Phospholipid bilayer: the dual layer of lipids that make up the cell membrane of most human cells
  - Ribosomes: small cellular organelles involved in polypeptide and protein synthesis
  - Endoplasmic reticulum (ER): a network of tubules attached to the nuclear membrane in cells
  - Rough endoplasmic reticulum: endoplasmic reticulum with ribosomes attached
  - Smooth endoplasmic reticulum (SER): endoplasmic reticulum that lacks ribosomes
  - Golgi apparatus: an organelle of folded membranes responsible for packaging and transporting membrane-bound proteins
  - Glycoproteins: a class of proteins with at least one carbohydrate group attached
  - Lysosomes: an organelle filled with digestive enzymes that breaks down materials the cell has absorbed
  - Mitochondria (singular "mitochondrion"): an organelle with a double membrane and many folds inside responsible for generating the chemical energy needed for biochemical reactions; the "powerhouse of the

cell" where the aerobic processes the Kreb's cycle and electron transport chain occur

- Key terms
  - Fatty acids: the smaller, absorbable building blocks of the fat that is found in the body
  - Gluconeogenesis: the generation of new glucose molecules from non-carbohydrate carbon substrates
  - Glycolysis: the breakdown of glucose by enzymes, releasing energy and pyruvic acid
  - The nucleus of the cell also initiates cell division, known as mitosis. In this process, the cell divides itself to produce two cells from one.
    - Mitosis: cell division that results in two cells identical to the original cell
  - Glycogen: the stored form of glucose found in muscle tissue and the liver
  - Oxidative phosphorylation: the energy-producing process that occurs in mitochondria in the presence of oxygen
  - Glucose: a simple sugar the body uses for energy production on the cellular level
  - Triglycerides: the main component of adipose tissue made of three fatty acids and a glycerol
  - Respiratory quotient (RQ): a method of determining the fuel mix being used; a way to measure the relative amounts of fats, carbohydrates, and proteins being burned for energy
    - RQ = volume of carbon dioxide (CO_2) exhaled / volume of oxygen (O_2) inhaled
    - RQ for carbohydrate = 1.0
    - RQ for fat = 0.7
  - Indirect calorimetry: a way to measure energy expenditure by oxygen consumed and carbon dioxide produced
  - Adenosine triphosphate (ATP): an energy-carrying molecule ("energy currency") used to fuel body processes
    - Energy from ATP
      - The bond of the end phosphate (P) is broken, and energy, heat, and a hydrogen ion (H+) are released
        - ATP ADP + P + energy + heat + H+
      - ATP works with myosin in the sarcomere to contract and release the filaments.
      - During contraction, ATP is broken down by the enzyme ATPase.
        - This causes the phosphate group to split from ATP to generate energy and create adenosine diphosphate (ADP) and a free phosphate (P).
          - The ADP and P attach to the myosin head and bind to the actin filament.
  - Creatine phosphate (CP): a high-energy molecule stored in skeletal muscle cells, the myocardium, and the brain
  - Lactic acid (also called lactate): the chemical by-product of anaerobic glycolysis
    - Lactate is used in the body in three ways:
      - To make ATP
      - To make glucose in the liver
      - As a signaling molecule
    - Can promote the metabolism of glucose and glycogen (over fats) for faster energy production
  - Anaerobic threshold: the point at which the body switches from aerobic metabolism to primarily anaerobic metabolism
  - Lactate threshold: the maximum effort or intensity an individual can maintain for an extended time with

minimal effect on blood lactate levels. This is the point where muscle tissue begins to make large amounts of lactate

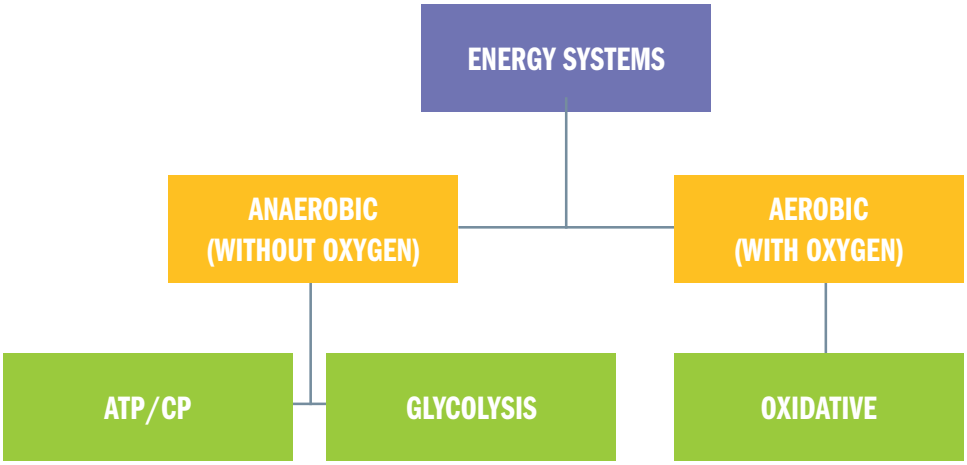
- Lactic acidosis: the accumulation of excess H+ causing muscle fatigue and soreness
- Steady-state exercise: exercise that maintains a steady level of exertion from start to finish
- Excess postexercise oxygen consumption (EPOC): the amount of oxygen required to restore normal metabolic status
- Calories (Cal): the amount of energy needed to raise the temperature of 1 kilogram of water by 1°C (4,184 joules) at a pressure of 1 atmosphere

- Macronutrients
  - Not directly used as energy, nor are the resulting substrates from digestion
    - Rather, these substrates (glucose and fatty acids) are converted into adenosine triphosphate (ATP), the energy currency of the cells.
  - Three main macronutrients:
    - Carbs
    - Proteins
    - Fats

SOURCE	CAL YIELD PER GRAM
Nutritional carbohydrate	4 Cal
Nutritional protein	4 Cal
Nutritional fat	9 Cal

- Metabolism
  - The chemical processes within the body that convert food into energy.
  - When the body is at rest:
    - Approximately 70 percent of the body's energy needs are met by fat sources
    - Approximately 30 percent of the energy need is met with carbohydrate sources
    - Carbohydrate and fat are the preferred energy sources in the body
  - Gluconeogenesis: the process of turing non-carbohydrate (like amino acids or lactate) substances into glucose for use as energy
    - Occurs during starvation, when blood glucose is low, or with a high protein meal
  - Energy pathways are the chemical-reaction pathways that supply the body with energy on a cellular level.
    - First energy source: ATP stored in the muscle cells
    - ATP/CP energy pathway: the anaerobic energy system that provides rapid energy using a phosphate phosphate group donated by CP to generate ATP.
      - Dominates for high-intensity activities lasting less than 10 seconds

  - Produces a small amount of ATP very quickly
  - The ATP/CP energy pathway is anaerobic, meaning oxygen isn't needed; for example, if a fitness professional is having their client do sprints or max powerlifting, they'd be using the ATP/CP energy pathway.
- Anaerobic glycolysis (Glycolytic): the anaerobic energy system converting glucose to lactate when oxygen is limited
  - Dominates for activities lasting 1 to 2 minutes
- Aerobic (Oxidative) energy pathways: cellular energy pathways that require oxygen for energy production
  - Dominates for activities lasting longer than 2 minutes
  - Produces the greatest amount of ATP, but does so the slowest
  - Beta-oxidation: the breakdown of triglycerides (fats) into fatty acids to be converted to acetyl-CoA (for the Kreb's Cycle)



- Energy balance
  - Energy balance: the state achieved when energy intake is equal to energy expenditure
  - Positive energy balance: more energy is consumed than expended
  - Negative energy balance: more energy is expended than consumed
  - Calorie surplus or deficit for weight management:
    - To gain muscle: 200 to 500 calories extra daily
    - To lose fat mass: reduce by 200 to 500 calories daily
  - Total daily energy expenditure (TDEE): the accumulated calorie burn made up of resting metabolic rate (RMR), the thermic effect of food (TEF), physical activity, and physical growth
  - Resting metabolic rate (RMR): the energy expenditure of metabolic and physical processes when the body is at rest (70 percent of TDEE)
    - Tells a trainer the minimum number of calories someone should be consuming daily
    - Bland-Altman analysis to calculate RMR:
      - Men's RMR = 66.4730 + (13.7516 x weight in kilograms [kg]) + (5.0033 x height in centimeters

[cm]) – (6.7550 x age in years)

- Women's RMR = 655.0955 + (9.5634 x weight in kg) + (1.8496 x height in cm) – (4.6756 x age in years)

- Thermic effect of food (TEF): the energy expenditure associated with food digestion and absorption
  - Diet-induced thermogenesis: the thermic effect of macronutrient digestion and absorption
- Physical activity
  - Exercise activity thermogenesis (EAT): energy expended as a result of planned, structured, and repetitive movement with the goal of improving or maintaining physical fitness
  - Non-exercise activity thermogenesis (NEAT): energy expended as a result of any movements of the body that require energy. This includes all activities of daily living outside of planned and structured workouts.
- Growth: The energetic cost of physical growth can be an important factor for a personal trainer to consider when creating exercise programming for a youth who is still growing and for a pregnant or lactating client.

- Daily calorie expenditure (DCE) is the total number of calories an individual expends including their RMR and activity level factor (multipliers that reflect varying levels of activity and the TEF)
  - Calculated with the Harris-Benedict equation

CALCULATING CALORIC EXPENDITURE	
MALE	metric: **DCE=ALF x [(13.75 x WKG) + (5 x HC) - (6.76 x age) + 66]** imperial: **DCE=ALF x [(6.25 x WP) + (12.7 x HI) - (6.76 x age) + 66]**
FEMALE	metric: **DCE=ALF x [(9.56 x WKG) + (1.85 x HC) - (4.68 x age) + 655]** imperial: **DCE=ALF x [(4.35 x WP) + (4.7 x HI) - (4.68 x age) + 66]**

WHERE	
ALF = Activity level factor	**AND ALF HAS THE FOLLOWING VALUES**
DCE = Daily caloric expenditure	Sedentary: ALF = 1.2
HC = Height in centimeters	Lightly active: ALF = 1.375
HI = Height in inches	Moderately active: ALF = 1.55
WKG - Weight in kilograms	Very active: ALF = 1.725
WP = Weight in pounds	Extremely active: ALF = 1.9

- Body types
  - Ectomorph: long and lean with little bodyfat and little muscle mass, narrow shoulders and hips
    - Training considerations: may have a hard time gaining weight

- Nutrition considerations: may require higher carbohydrate and protein in diet to maintain body weight and muscle mass

- Endomorph: Thicker, round build with lots of bodyfat and lots of muscle mass, large upper arms and thighs
  - Training considerations: gains weight easily
  - Nutrition considerations: may require a diet lower in carbohydrate and high in protein to prevent excess fat storage and support muscle mass
- Mesomorph: Athletic, muscular build with broad shoulders and a healthy body weight
  - Training considerations: may gain or lose weight without much effort
  - Nutrition considerations: may require a more balanced diet focused on daily caloric expenditure for energy balance

Exercise Adaptations - Chapter 9

A variety of changes occur within the body during aerobic and anaerobic exercise:

SPECIFIC ADAPTATIONS TO ANAEROBIC AND AEROBIC EXERCISE	ANAEROBIC TRAINING (HIGH POWER OUTPUT)	AEROBIC TRAINING (LOW POWER OUTPUT)
Performance		
Muscle endurance	Increases	Increases
Muscle strength	Increases	No change
Vertical jump	Increases	No change
Aerobic power	No/slight increase	Increases
Sprint speed	Increases	No/slight increase
Anaerobic power	Increases	No change
Body composition		
Fat-free mass	Increases	No change
Percent bodyfat	Decreases	Decreases
Muscle fiber		
Capillary density	No change or decreases	Increases

SPECIFIC ADAPTATIONS TO ANAEROBIC AND AEROBIC EXERCISE	ANAEROBIC TRAINING (HIGH POWER OUTPUT)	AEROBIC TRAINING (LOW POWER OUTPUT)
Fiber size	Increases	No change or slight increase
Fast heavy chain myosin	Increases	No change or decreases
Type II muscle fiber conversion	Almost all convert	Most convert
Mitochondrial density	Decreases	Increases
Bone and connective tissue		
Bone density	No change or increases	No change or increases
Collagen content	May increase	Varies
Ligament strength	Increases	Increases
Tendon strength	Increases	Increases
Metabolic energy stores		
Stored creatine phosphate	Increases	Increases
Stored adenosine triphosphate	Increases	Increases
Stored triglycerides	Increases	Increases
Stored glycogen	Increases	Increases
Enzyme activity		
Myokinase	Increases	Increases
Creatine phosphokinase	Increases	Increases
Lactate dehydrogenase	No change or varies	Varies
Phosphofructokinase	No change or varies	Varies

In addition, anaerobic adaptations can include increases in the body's functional capacity for explosive strength and maximized short-term energy systems. It's also important for fitness professionals to note that neural adaptations are primarily responsible for increased strength gains in beginning clients.