Lesson 1.1: Identity: Humans

Understandings
1. The human body is made up of complex systems functioning together to maintain homeostasis.
2. Directional terms describe the position of anatomical structures in relation to other structures or locations in the body, and regional terms specify distinct anatomical landmarks on the body.

Knowledge and Skills
It is expected that students will:
- Identify the systems and structures involved in basic body processes.
- Explain the functions of different human body systems, and list the major organs within each system.
- Describe how multiple body systems are interconnected and how those interconnections and interactions are necessary for life.
- Show the relationship between multiple human body systems.
- Explain how directional terms and regional terms can be used to pinpoint location on the body.
- Demonstrate the correct use of directional and regional terms.
- Illustrate key directional term pairs on a model of the human body.

1.1.a. In what ways do the parts of a human body system work together to carry out a specific function?

1.1.b. In what ways do different human body systems work together to complete specific functions?

### Urinary System
- **Kidneys** (filter blood & make pee) → **Ureters** (transport pee) → **Bladder** (holds pee) → **Urethra** (releases pee)

### Nervous System
- **Brain** (control center) → **Spinal Cord** (information highway) → **Peripheral Nerves** (carry signals to and from limbs) → **Eyes, Ears, Taste Buds**, etc (collect sensory info and send to brain)

### Immune System
- **Thymus** (promotes production of WBCs) → **Tonsils** (trap pathogens) → **Appendix** (stores good bacteria) → **Spleen** (filters blood) → **Lymph Nodes** ("water knots") → **Skin** (prevents pathogens entering body)

### Digestive System
- **Teeth/Tongue** (breaks down and pushes down) → **Pharynx** (food/air tube) → **Esophagus** ("eater within"—food tube) → **Stomach** (breaks down food) → **Small Intestine** (absorbs nutrients) → **Large Intestine** (absorbs water) → **Rectum** (holds poo) → **Anus** (releases poo)

- **Accessory organs** → **Gall Bladder** (stores bile, releases into small intestine) → **Liver** (makes bile for the small intestine)

### Respiratory System
- **Nasal cavity** (opening to outside) ←→ **Pharynx** (air & food tube) ←→ **Larynx** (voice box, Adam’s apple) ←→ **Trachea** ("windpipe"—air tube) ←→ **Epiglottis** ("tongue on top"—prevents food entering air tube) ←→ **Bronchi** (branch into lungs) ←→ **Alveoli** ("hollow"—site of gas exchange w/ blood) ←→
1.1.c. **How can directional terms and regional terms help describe location in the body?**

<table>
<thead>
<tr>
<th>Directional Terms</th>
<th>Regional Terms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior (&quot;after&quot;)</td>
<td>Front</td>
</tr>
<tr>
<td>Ventral (&quot;belly&quot;)</td>
<td></td>
</tr>
<tr>
<td>Posterior (&quot;after&quot;)</td>
<td>Back</td>
</tr>
<tr>
<td>Dorsal (&quot;back&quot;)</td>
<td></td>
</tr>
<tr>
<td>Superior (&quot;above&quot;)</td>
<td>Higher</td>
</tr>
<tr>
<td>Inferior (&quot;below&quot;)</td>
<td>Lower</td>
</tr>
<tr>
<td>Lateral (&quot;side&quot;)</td>
<td>Toward the side</td>
</tr>
<tr>
<td>Medial (&quot;middle&quot;)</td>
<td>Toward the middle</td>
</tr>
<tr>
<td>Proximal (&quot;far&quot;)</td>
<td>On limb, nearer to attachment point</td>
</tr>
<tr>
<td>Distal (&quot;near&quot;)</td>
<td>On limb, farther from attachment point</td>
</tr>
<tr>
<td>Superficial (&quot;above&quot;)</td>
<td>more external, surface of body</td>
</tr>
<tr>
<td>Deep</td>
<td>more internal</td>
</tr>
</tbody>
</table>

1.1.d. **What features of structure and function are common to all humans?**

Humans can be told apart by the <0.1% that is different about us. That’s what gives us each our unique identity. However, we share most of our features in common. Here are examples.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 tissue types</td>
<td>Connective, epithelial, muscle &amp; nervous</td>
</tr>
<tr>
<td>23 pairs of chromosomes</td>
<td>46 total, 23 from each parent</td>
</tr>
<tr>
<td>206 bones at maturity</td>
<td>Roughly, bone number decreases with age (as they fuse)</td>
</tr>
<tr>
<td>DNA as identity molecule</td>
<td>Some organisms use RNA, but all humans have DNA</td>
</tr>
<tr>
<td>Bipedal</td>
<td>Two legs</td>
</tr>
<tr>
<td>Opposable thumbs</td>
<td>Used for grasping</td>
</tr>
</tbody>
</table>
Lesson 1.2: Identity: Tissue

Understanding

- A tissue is a group of similar cells designed to carry out a specific function.
- The bones of the human skeletal system protect the body’s internal organs while allowing for movement and great range of mobility.
- The specific structure of bone reveals information about a person’s gender, stature, age, and ethnicity.
- The length of long bones in the human body can be used to mathematically predict the overall height of an individual.

Knowledge and Skills

It is expected that students will:

- Identify characteristics of the four categories of human tissue.
- Describe the functions of the human skeletal system.
- Recognize that differences in bone structure contribute to a person’s unique identity.
- Recognize that there is a relationship between the length of long bones and the overall height of an individual.
- Analyze the structure of various human tissue types to infer function.
- Identify and locate bones of the human skeletal system.
- Interpret bone markings, bone landmarks, and bone measurements to determine a person’s gender, age, stature, and ethnicity.
- Derive and analyze a linear equation.

1.2.a. What are the main types of tissue in the human body?

1.2.b. How does the structure of a type of human tissue relate to its function in the body?

Tissues are collections of similar cells that help perform a common function. A group of tissues is called an organ.

<table>
<thead>
<tr>
<th>Epithelial</th>
<th>Muscle</th>
<th>Nervous</th>
<th>Connective</th>
</tr>
</thead>
<tbody>
<tr>
<td>(<em>to cover the top</em>)</td>
<td><em>full of nerves</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Covers</td>
<td>Moves</td>
<td>Signals</td>
<td>Joins</td>
</tr>
<tr>
<td>lines organs &amp; body cavities</td>
<td>makes up all muscles, including the heart</td>
<td>includes neurons &amp; neuroglia</td>
<td>adipose (&quot;fat&quot;), blood, bone, cartilage, etc.</td>
</tr>
<tr>
<td>layers (one kind of cells inside &amp; a different kind outside)</td>
<td>long and narrow so they can contract to allow movement</td>
<td>long axons to allow signals to travel distances, branches for connections</td>
<td>fairly consistent matrix to allow it to fill spaces of various shapes/sizes</td>
</tr>
</tbody>
</table>

1.2.c. How does the distribution and structure of different types of tissue in the body contribute to personal identity?

Some people have more muscle & some have less. Differences in nerves & nerve connections affect the way our brains interpret different stimuli. Does it make sense that certain cells or their connections are distinct for each individual?
1.2 Identity: Tissues

1.2.a. What are the main types of tissue in the human body?

1.2.b. How does the structure of a type of human tissue relate to its function in the body?

Tissues are collections of similar cells that help perform a common function. A group of tissues is called an organ.

- **Epithelial** ("to cover the top")
  - Covers
  - Moves

- **Muscle**
  - Long and narrow so they can contract to allow movement

- **Nervous** ("full of nerves")
  - Long axons to allow signals to travel distances, branches for connections

- **Connective**
  - Fairly consistent matrix to allow it to fill spaces of various shapes/sizes

1.2.c. How does the distribution and structure of different types of tissue in the body contribute to personal identity?

Some people have more muscle & some have less. Differences in nerves & nerve connections affect the way our minds work and the ways we make decisions. Some people have more connective tissue. For instance, an obese person has much more adipose than a thin person. Most cells contain a central nucleus that contains DNA and every person's DNA is completely unique (except identical twins).

1.2.d. What are the functions of the human skeletal system?

The **axial skeleton** (skull and trunk) protect soft organs such as the brain, heart, lungs, etc. The **appendicular skeleton** (arms and legs) provides attachment points for muscles that allow movement.

1.2.e. What are the main bones of the human skeletal system?

1.2.f. What is forensic anthropology and how does this field relate to human body systems?

**Forensic** ("to seek truth") **anthropology** ("study of mankind") is the study of human bones to determine information about the deceased and decide cause of death & whether a crime was committed. One aspect of the job is testifying in court. **Forensic anthropologists** are not generally medical doctors, but instead usually have a PhD. They tend to be college professors and have 12+ years of education. When a deceased person still had flesh, the job usually goes to a Medical Examiner, but when only bones are located, the job is done by a **Forensic Anthropologist**. Dr. Brennan on "Bones" is an example. They have played roles in cases such as Waco, TX and the twin tower victims from 9/11.

1.2.g. How can features of bone be used to determine information about a person’s gender, ethnicity, age or stature?

<table>
<thead>
<tr>
<th>Gender can best be determined from skull or pelvis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Male</strong></td>
</tr>
<tr>
<td>Males square eye sockets</td>
</tr>
<tr>
<td>u-shaped mandible</td>
</tr>
<tr>
<td>brow ridges &amp; sharper</td>
</tr>
<tr>
<td>heart-shaped pelvis</td>
</tr>
<tr>
<td>angled-in coccyx</td>
</tr>
</tbody>
</table>

Gender can best be determined from skull or pelvis.

**Male**
- Square eye sockets
- U-shaped mandible
- Brow ridges & sharper
- Heart-shaped pelvis
- Angled-in coccyx

**Female**
- Round eye sockets
- V-shaped mandible
- Smoother bones
- Rounded pelvis
- Wider pubic arch
Lesson 1.3: Identity: Molecules and Cells

Understandings

- Human DNA is a unique code of over three billion base pairs that provides a genetic blueprint of an individual.
- Restriction enzymes recognize and cut specific sequences in DNA.
- Gel electrophoresis separates DNA fragments based on size and is used in Restriction Fragment Length Polymorphism (RFLP) analysis.
- Physical characteristics can be used to confirm or authenticate identity.

Knowledge and Skills

It is expected that students will:

- Explain how restriction enzymes cut DNA.
- Describe how gel electrophoresis separates DNA fragments.
- Recognize that gel electrophoresis can be used to examine DNA differences between individuals.
- Outline current biometrics technology.
- Digest DNA samples using restriction enzymes.
- Demonstrate the steps of gel electrophoresis and analyze the resulting restriction fragment length polymorphisms (RFLPs).

1.3.a. What is the structure and function of DNA?

DNA stands for **deoxyribonucleic acid**. Its name comes from the fact that the sugar in it is deoxyribose and it is made up of building blocks of nucleic acids (just like RNA). It is a double-stranded helical molecule that the chromosomes in the nucleus of our cells are made of. DNA makes up genes, which make up chromosomes. Each gene codes for a protein (like hemoglobin), and each protein determines a trait (like oxygen-carrying red blood cells).
1.3.b  How does DNA differ from person to person?  1.3.c  What role does DNA play in our identity?  1.3.i  How can the field of biometrics be used to verify and protect identity?

More than 99.9% of the DNA of each person matches the DNA of every other person. Scientists can analyze the small bits that differ to determine who DNA came from, though.

DNA analysis is one form of biometrics ("life measurement") and can be used to tell individuals apart. Only identical twins have 100% identical DNA, so for everyone else our DNA is as unique as our fingerprints.

Other forms of biometrics include iris scans, voice analysis, fingerprinting, gait measurement, facial recognition, etc. They can be used to protect accounts, keep babies from being taken from the wrong parents out of hospitals, protect national security, etc.

1.3.d  How can tools of molecular biology be used to compare the DNA of two individuals?

DNA can be extracted from a person & then scientists can perform PCR (polymerase chain reactions) to amplify the DNA, making a sample millions of times bigger than the original sample. They can then cut the DNA with restriction enzymes and run the samples through gel electrophoresis to analyze the size of each DNA fragment. Because the DNA of each individual is unique, the restriction enzymes will cut each person’s DNA in a different place, so the RFLPs will look different on the gels.

1.3.f  What are restriction enzymes?

Restriction enzymes come from bacteria (mostly) and are chemicals they are thought to use to break down the DNA of invading viruses. Geneticists use them to cut DNA into smaller fragments called Restriction Length Polymorphisms.

<table>
<thead>
<tr>
<th>Restriction enzyme</th>
<th>Source organism</th>
<th>Restriction recognition site in double-stranded DNA</th>
<th>Structure of the cleaved products</th>
</tr>
</thead>
<tbody>
<tr>
<td>EcoRI</td>
<td>Escherichia coli</td>
<td>TTAGAATCC</td>
<td>5' overhang</td>
</tr>
<tr>
<td>PstI</td>
<td>Providencia stuartii</td>
<td>TCTGAG</td>
<td>3' overhang</td>
</tr>
<tr>
<td>Smal</td>
<td>Serratia marcescens</td>
<td>CCCGCG</td>
<td>Blunt ends</td>
</tr>
<tr>
<td>(b)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NcoI</td>
<td>Haemophilus sapiens</td>
<td>CCGGG</td>
<td>5' overhang</td>
</tr>
<tr>
<td>NheI</td>
<td>Haemophilus parainfluenza</td>
<td>CCGC</td>
<td>Blunt ends</td>
</tr>
</tbody>
</table>

1.3.g  What are restriction fragment length polymorphisms?

Restriction fragment length polymorphisms are also called RFLPs and are the bits of DNA after the long strand has been cut by restriction enzymes. They're what we see on the electrophoresis gel.

1.3.h  What is gel electrophoresis and how can the results of this technique be interpreted?

Gel electrophoresis ("to carry across with electricity") is how RFLPs get separated. DNA molecules have a negative charge (because of the phosphates). They are attracted to a positive charge. DNA samples are placed in wells within an agarose gel and the DNA is near a negative electrode. When the electricity is started, they move toward the positive electrode. Smaller bits are lighter and travel faster, so the bits get separated by size. This makes it possible to tell individuals apart.
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Lesson 2.1: The Brain

Understandings

- Communication between body systems is crucial to maintaining homeostasis.
- The brain receives stimuli from the outside world, interprets this information, and generates an appropriate response.
- Each region within the brain helps control and regulate specific functions in the body.

Knowledge and Skills

It is expected that students will:

- Describe the structure and function of the central nervous system and the peripheral nervous system.
- Identify major regions of the human brain.
- Match regions of the brain with their primary function in the human body.
- Apply knowledge of brain structure and function to determine the parts of the brain related to specific human actions, emotions, and/or dysfunctions.
- Interpret how a breakdown in communication in the central nervous system would impact the function of the human body.

2.1.a.  What is communication?

Communication is messages passing from one entity to another & being understood by the 2nd entity.

2.1.b.  What are ways communication occurs in machines and in the human body?

Machines → My computer is powered by electricity. Somehow the vibrating electrons cause the computer to turn on & the binary code stores and transmits messages for how programs run.

Human Body → Communication can be chemical (endocrine system, hormones) or electrical (nervous system, impulses)
2.1. What are consequences of miscommunication in the body?

When there is miscommunication within our central nervous system (brain, brain stem and spinal cord) we might misunderstand sensory input or (more often) our body’s might do things we don’t want them to (uncontrolled movements, lack of balance, paralysis, mental illness, etc).

2.1.d. How do the central nervous system & the peripheral nervous system work together to control the body?

Sensory input—sense information is carried to the brain. Information from the eyes/ears goes directly to the brain. However, information from the lower body is first picked up by the peripheral “outer” nervous system (PNS) & then passed into the spinal cord, then through the brain stem & then into the brain (all parts of the central “middle” nervous system or CNS)

Motor output—muscle movement is most started in the CNS (unless it’s a reflex response) and then the impulses travel through the brainstem into the spinal cord and to the PNS to activate the neurons in the muscles that need to move.

2.1.f. How do scientists determine which areas of the brain are associated with specific actions, emotions or functions?

Earliest attempts → based on phrenology (“study of the mind”), which used bumps on the skull to determine personality traits. It was very flawed but did initiate the idea that different parts of the brain had different functions.

Then & now → both in the past and today patients with brain injuries are studied. The area of the injury can be linked to changes in behavior or abilities (i.e. Phineas Gage’s damaged frontal lobe caused personality changes)

Now → MRIs & electrodes directly implanted into the brain can show which areas of the brain are active during which activities or even when people are thinking about various things.

2.1.e. What are the functions of the main regions of the brain?

- **Cerebellum**: mostly controls fine motor movement & balance.
- **Cerebrum**: higher thought.
- **Gyri**: are the ridge/s between grooves/furrows (sulci) and get deeper with learning.
- **Limbic System (lower/mammalian Brain)**: controls emotions & motivation.
- **4 major lobes** (divisions): frontal, occipital, temporal & parietal.

- **Frontal Lobe**: higher thought, planning, action, personality.
- **Occipital Lobe**: visual processing, memory.
- **Temporal Lobe**: hearing, memory, speech perception.
- **Parietal Lobe**: sense & speech.
- **Motor Cortex**: voluntary movement.
- **Sensory Cortex**: sense.
- **Broca’s Area**: speech production.
- **Wernicke’s Area**: speech comprehension.
- **Amygdala**: fear, emotions.
- **Hippocampus**: memory.
- **Neocortex (new covering)”Primitive Brain”**: Inhibits urges, allows abstract thought, extremely flexible, allows consciousness.

**HIGH LEVEL “Human” FUNCTIONS (abstract thought, imagination, consciousness, language)**

- **Sight and visual memory & reading**
- **Hearing and speech memory**
Lesson 2.2: Electrical Communication

Understandings

- Neurons convey information using electrical and chemical signals.
- The body’s reaction time to reflex and voluntary actions is related to processing in the nervous system.
- Errors in electrical communication can impact homeostasis in the human body.

Knowledge and Skills

It is expected that students will:

- Recognize that the nervous system relies on specialized cells called neurons to pass signals to and from the brain and spinal cord.
- Describe how the movement of ions across the cell membrane of a neuron generates an action potential and propagates electrical signals.
- Explain how neurons communicate at the synapse.
- Describe how brain processing differs in reflex and voluntary responses.
- Outline what goes on in the human body from an initial stimulus to a response.
- Analyze experimental data to explore reaction time and reflexes in the human body.
- Design an experiment to test factors that impact reaction time.
- Analyze case studies to determine the effects of a communication breakdown in the nervous system on the human body.

2.2.a How does communication happen within the body?

| Electrical Signals | Nervous System | Chemical Signals | Endocrine System |
2.2.b  What is the basic structure and function of a neuron?

<table>
<thead>
<tr>
<th>Function</th>
<th>Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sends electrical signals through body</td>
<td>NEURON</td>
</tr>
<tr>
<td><strong>Dendrites (&quot;trees&quot;)</strong>—pick up signal</td>
<td>Dendrites (receptors)</td>
</tr>
<tr>
<td><strong>Axon</strong>—carry signal long distances (up to 3 ft)</td>
<td>Axon (transmitters)</td>
</tr>
<tr>
<td><strong>Myelin Sheath</strong>—insulates axon</td>
<td>Schwann's Sheath (Insulating fatty layer that speeds transmission)</td>
</tr>
<tr>
<td><strong>Nodes (&quot;knots&quot;) of Ranvier</strong>—allow nutrients in, waste out</td>
<td>Node of Ranvier (Insulating fatty layer that speeds transmission)</td>
</tr>
<tr>
<td><strong>Axon Terminals (&quot;ends&quot;)</strong>—branch to meet other neurons</td>
<td>Axon Terminals (transmitters)</td>
</tr>
<tr>
<td><strong>Synapses</strong>—place one neuron connects to next neuron</td>
<td>Synapses</td>
</tr>
<tr>
<td><strong>Synaptic Cleft</strong>—joint between neurons</td>
<td>Synaptic Cleft</td>
</tr>
<tr>
<td><strong>Neurotransmitters</strong> (&quot;to carry across a nerve&quot;) — chemicals that allow neurons to communicate with each other</td>
<td>Neurotransmitters (transmitters)</td>
</tr>
</tbody>
</table>

2.2.c  How do the different types of neurons work together to send and receive signals?

<table>
<thead>
<tr>
<th>Sensory Neuron</th>
<th>Interneuron</th>
<th>Motor Neuron</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pick up signals through senses (sight, smell, touch, etc)</td>
<td>Connect sensory neurons to motor neurons</td>
<td>Receive signals from CNS, causing movement</td>
</tr>
<tr>
<td>Send info from PNS to CNS</td>
<td>Found in CNS</td>
<td>In PNS, receive info from CNS</td>
</tr>
</tbody>
</table>

2.2.d  How are electrical impulses created in the human body?

Na+/K+ pump keeps outside of membrane + and inside – by pumping positive ions out of the membrane, priming the membrane to carry charges

During an action potential, there’s a sudden reversal of charge, carrying a message down the axis
How are electrical impulses created in the human body?

Na+/K+ pump keeps outside of membrane + and inside – by pumping positive ions out of the membrane, priming the membrane to carry charges.

During an action potential, there’s a sudden reversal of charge, carrying a message down the axis.

How do neurons convey information using both electrical and chemical signals?

Electrical ➔ Action potentials down axis of each neuron (WITHIN each neuron)

Chemical ➔ Neurotransmitters conduct signal BETWEEN neurons

What factors impact our ability to react to a stimulus?

How and why does reaction time differ in reflex and voluntary actions?

Reflex—reflex responses simply go to the spinal cord and don’t involve the brain, so the reaction time is VERY fast (example: blinking when something comes at you, kicking when hit with reflex hammer)

Voluntary—Voluntary responses must travel to the brain, take longer. The more thought that is required (i.e. doing the OPPOSITE of what asked), the slower the reaction time.

How do errors in communication impact homeostasis in the human body?

Epilepsy: Bursts of electricity cause involuntary responses (seizures, odd smells, etc)

Parkinson’s: Cells that make dopamine die (no one knows why). The lack of this neurotransmitter causes problems in communication between neurons in the two brain regions that must communicate to allow smooth, controlled movements

Huntington’s: Genetic defect on chromosome 4 (excess CAG repeats) causes synthesis of abnormal protein—the protein disrupts function of certain nerve cells, ultimately leading to their deaths (dead cells can’t communicate)

Alzheimer’s: Brain cells die (cause unknown) and dead cells can’t communicate—communication breaks down, getting worse with time and eventually causing death

Multiple Sclerosis: The immune system attacks the myelin around nerve axes in the brain, spinal cord and optic nerves, causing nerves to be unable to transmit messages due to a buildup of scar tissue (sclerosis).

Amyotrophic lateral sclerosis (Lou Gehrig’s): The name is a (without) myo (muscle) trophic (nourishment) lateral (side) scler (hardening) osis (abnormal condition). Nerve cells waste away or die and can’t send messages to the lower motor neurons. Movement becomes less and less controlled. Eventually the lung muscles cannot contract, causing death.

How can biomedical professionals help treat, cure and improve the quality of life of those suffering from nervous system disorders?

The main person that treats neurological disorders is a Neurologist (one who studies nerves). That’s a special kind of doctor that specializes in the nervous system. People with these disorders also rely on Pharmacists to dispense their medication, Nurses to care for them, Pharmacologists to produce new medications, researchers to help understand causes and possible treatments, Brain Surgeons if surgery is possible, Psychiatrists if they are depressed, Physical Therapists to maintain movement, etc.
Lesson 2.3: Chemical Communication

Understandings
- The endocrine system helps the body communicate through the use of chemical signals called hormones.
- Hormones help maintain homeostasis through feedback loops.
- A hormone imbalance can lead to disease or dysfunction.

Knowledge and Skills
It is expected that students will:
- Describe the way in which hormones interact with target cells.
- Recognize that the human body uses feedback mechanisms to maintain proper hormone levels.
- Model a feedback loop that shows how the body maintains homeostasis.
- Analyze physical symptoms of a patient and relate these symptoms to errors in chemical communication.

2.3.a What is a hormone?

A hormone is a chemical (specifically a protein) secreted by an endocrine gland (gland is just a name for an organ that secretes something) that signals a system to do something.

- Some hormones are short-term (like adrenalin speeding up heart rate) and some are long term (like growth hormone)
- The same hormone can be secreted by multiple organs (for example, the ovaries and adrenal glands both make estrogen).
- Very small amounts of hormones can have very large effects.

Endocrine glands is another name for endocrine organs and they are found in the endocrine system.

- They include the pancreas, thymus, thyroid, pituitary gland, pineal gland, adrenal glands, ovaries and testes.
- Endocrine glands are found throughout the body, but are all ultimately controlled by the hypothalamus and pituitary gland in the brain.

Below are examples of hormones and what they do.

<table>
<thead>
<tr>
<th>Hormone</th>
<th>Secreted by</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>insulin</td>
<td>pancreas</td>
<td>regulates blood sugar levels by allowing cells to take in sugar</td>
</tr>
<tr>
<td>GH (growth hormone)</td>
<td>pituitary</td>
<td>stimulates growth</td>
</tr>
<tr>
<td>FSH (follicle stimulating hormone)</td>
<td>anterior pituitary</td>
<td>stimulates maturity, including sexual maturity</td>
</tr>
<tr>
<td>glucagon</td>
<td>pancreas</td>
<td>increases sugar levels in blood</td>
</tr>
<tr>
<td>TRH</td>
<td>hypothalamus</td>
<td>triggers pituitary gland to secrete TSH</td>
</tr>
<tr>
<td>TSH</td>
<td>pituitary gland</td>
<td>triggers thyroid gland to secrete T3/T4</td>
</tr>
<tr>
<td>T3/T4</td>
<td>thyroid gland</td>
<td>regulates metabolism</td>
</tr>
</tbody>
</table>
2.3 Chemical Communication

2.3.a What is a hormone?

A hormone is a chemical (specifically a protein) secreted by an endocrine gland (gland is just a name for an organ that secretes something) that signals a system to do something.

- Some hormones are short-term (like adrenalin speeding up heart rate) and some are long-term (like growth hormone).
- The same hormone can be secreted by multiple organs (for example, the ovaries and adrenal glands both make estradiol).
- Very small amounts of hormones can have very large effects.

Endocrine glands is another name for endocrine organs and they are found in the endocrine system.

- They include the pancreas, thymus, thyroid, pituitary gland, pineal gland, adrenal glands, ovaries and testes.
- Endocrine glands are found throughout the body, but are all ultimately controlled by the hypothalamus and pituitary gland in the brain.

Below are examples of hormones and what they do.

- **Insulin**, secreted by pancreas → regulates blood sugar levels by allowing cells to take in sugar
- **GH (growth hormone)**, secreted by pituitary → stimulates growth
- **FSH (follicle stimulating hormone)**, secreted by anterior pituitary → stimulates maturity, including sexual maturity
- **Glucagon**, secreted by pancreas → increases sugar levels in blood
- **TRH**, secreted by hypothalamus → triggers pituitary gland to secrete TSH
- **TSH**, secreted by pituitary gland → triggers thyroid gland to secrete T3/T4
- **T3/T4**, secreted by thyroid gland → regulate metabolism

2.3.b How do hormones interact with target cells?

Each hormone travels in the blood looking for target cells. Target cells have receptors that the hormone fits into, like a key. For example, a male sex hormone would only fit receptors in cells in the male sex organ and would have no effect on other cells.

2.3.c What are examples of endocrine glands and exocrine glands in the human body?

**Endocrine (“secrete within”) glands**

- Sweat glands
- Cowper’s glands
- Cobelli’s glands
- Mammary glands

**Exocrine (“secrete outside”) glands**

Below are examples

- **Gland**
  - Sweat glands
  - Cowper’s glands
  - Cobelli’s glands
  - Mammary glands
- **Product & Location**
  - Sweat, skin
  - Pre-ejaculate, penis
  - Mucus, esophagus,
  - Milk, breasts

Excretes products through a duct to the outside, usually of the body, but sometimes just outside an organ

2.3.d How do feedback loops help regulate the action of hormones?

Feedback loops keep hormones in balance.

- When hormone levels go ABOVE homeostasis, feedback loops REDUCE hormone levels.
- When hormone levels drop BELOW homeostasis, feedback loops bring them back up to normal levels.

Examples of this include:

- Insulin & blood sugar
- T3/T4 & metabolism
- Growth hormone & growth
Lesson 2.4: Communication with the Outside World

Understandings

- The structures within the human eye work to focus and process light.
- The eye allows perception of color, depth, brightness, and optical illusions.
- Errors in the structure and function of the eye can lead to problems in acuity or dysfunction.
- Problems with focusing light in the eye can be corrected with lenses.

Knowledge and Skills

_it is expected that students will:_

- Identify the key structures of the eye.
- Demonstrate how light is processed in the eye in a person with normal vision, as well as a person with myopia or hyperopia.
- Explain the tests and procedures in a typical eye exam.
- Diagram the path of light as it enters the eyes and travels to the brain for processing.
- Evaluate visual perception by testing depth perception, peripheral vision, color vision, and visual acuity.
- Experiment with lenses to refocus light and correct problems with vision.

2.4.a. How do humans communicate with the world around them?

Humans take in information using their senses (sight, hearing, touch, taste & smell) & send out information using their ability to speak or using body language or movement.

2.4.b. How does the power of sight allow humans to communicate with the outside world?

>80% of the data that we take in comes from our power of sight. Sight lets us take in 180° of images, perceive 1 million different colors, adjust what we see based on level of light & focus close up or miles away. Our vision is more detailed than any digital camera.

2.4.c. How is light focused by the eye?

<table>
<thead>
<tr>
<th>Eye part</th>
<th>Analogy</th>
<th>What it does</th>
</tr>
</thead>
<tbody>
<tr>
<td>cornea</td>
<td>front window of eye</td>
<td>bends light rays so they can pass through pupil</td>
</tr>
<tr>
<td></td>
<td></td>
<td>keeps foreign particles out of eye</td>
</tr>
<tr>
<td></td>
<td></td>
<td>where refraction (light bending) mostly occurs</td>
</tr>
<tr>
<td>aqueous humor</td>
<td>air in a basketball</td>
<td>gives nutrients to eye and maintains pressure</td>
</tr>
<tr>
<td>(<em>&quot;water-like&quot;</em>)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>iris</td>
<td>shutter of camera</td>
<td>can enlarge or shrink to allow more or less light into eye</td>
</tr>
<tr>
<td>pupil</td>
<td>keyhole into dark room</td>
<td>opening in the iris, grows or shrinks based on light levels</td>
</tr>
<tr>
<td>lens</td>
<td>lens in camera</td>
<td>shortens and lengthens width to focus light rays (<strong>accommodation</strong>)</td>
</tr>
<tr>
<td>vitreous humor</td>
<td>air in a basketball</td>
<td>let's light pass through while helping eye keep its shape</td>
</tr>
<tr>
<td>(<em>&quot;having nature of giving life&quot;</em>)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>retina</td>
<td>film on camera</td>
<td>captures light rays &amp; processes them w/ millions of nerve endings</td>
</tr>
<tr>
<td></td>
<td></td>
<td>send light impulses through &gt;1 million nerve fibers to optic nerve</td>
</tr>
</tbody>
</table>
2.4.d. How do the eye and the brain work together to process what we see? 2.4.i. How does the eye perceive depth, color and optical illusions?

Messages from the retina pass into the optic nerve and are carried to the visual cortex in the occipital lobe. There the image is flipped over and gaps (such as the blind spot where the optic nerve meets the retina) are filled in. Our visual database (built during childhood) helps us interpret images.

The retina is
- >95% rods (found all over retina & used for seeing B/W, peripheral vision & low light viewing)
- <5% cones (for COLOR PERCEPTION, concentrated in fovea, tiny spot with detailed vision)

**DEPTH PERCEPTION** → Depends on retina: The visual database contains information about size of objects from previous experience & gauges size based on that. Moving the head from side to side allows you to see how far objects move (less movement means farther away). Comparing the image from one eye to the combined images tells retina how far away something is.

**OPTICAL ILLUSIONS** → These are examples of "visual deception" & trick the brain by using arrangement of images, color effects & light source impact to mislead the brain.

2.4.e. How does what we see impact other human body systems?

Most of what we do is in response to what we see. From basic movements like walking (using skeletal and muscular system) to emotional responses to what we see (limbic system & endocrine responses), our sight guides our actions in many ways.

2.4.f. What is visual perception?

Visual perception is the combination of what we see and how we interpret it. Sight without a visual database is useless (no sense can be made) and a visual database without sight is also useless (no input). Examples →

- Color perception
- Visual acuity
- Depth perception
- Peripheral vision

2.4.g. What does it mean to have 20/20 vision?

20/20 is considered "normal" visual acuity (not PERFECT). It means that at 20 feet you can see what humans should see at 20 feet away. WORSE → If your vision is 20/200 (like mine), it means that you have to be 20 ft away to see something a human SHOULD be able to interpret from 200 feet away. Pretty bad! BETTER → It’s possible to have vision that’s better than 20/20. 20/15 vision means that from 20 ft away, you can see what most people have to be 15 ft away to see.

2.4.h. How can corrective lenses be used to refocus light and resolve myopia and hyperopia?

<table>
<thead>
<tr>
<th>Disorder</th>
<th>What's happening</th>
<th>Effect</th>
<th>Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Astigmatism</td>
<td>Rays don’t meet at focal point because of deformation of lens</td>
<td>Blurry/imperfect image</td>
<td>glasses or contacts with a cylinder curve turn 2 focal points into 1</td>
</tr>
<tr>
<td>Hyperopia</td>
<td>Image comes to focus BEHIND RETINA to more common with age</td>
<td>Far-sightedness → Vision ok for distant objects, blurry up close</td>
<td>Bifocals (there’s a small plus lens in them that moves the image forward) OR glasses with a full plus lens</td>
</tr>
<tr>
<td>Myopia</td>
<td>Image comes to focus IN FRONT OF RETINA</td>
<td>Near-sightedness → Vision ok up close, blurry for distant objects (near-sighted)</td>
<td>A minus lens moves the image farther back</td>
</tr>
</tbody>
</table>
### Knowledge and Skills

**Lesson 3.1: Introduction to Power**

**Understandings**

- Many human body systems work to create, process, and distribute the body's main resources – food, water, and oxygen.

**Knowledge and Skills**

*It is expected that students will:*

- List and describe the human body systems that create, process, and distribute food, water, and oxygen.
- Recognize that factors unique to the person, such as age, weight, and overall health affect the body's ability to utilize biological resources and maintain homeostasis.
- Recognize that factors in the environment, such as climate or temperature, affect the body's ability to utilize biological resources and maintain homeostasis.
- Estimate how long the human body can last without food, without water, and without oxygen.

#### 3.1.a. What are the resources the human body needs to survive?

<table>
<thead>
<tr>
<th>Food</th>
<th>Water</th>
<th>Oxygen</th>
</tr>
</thead>
<tbody>
<tr>
<td>This includes <strong>macromolecules</strong> (Lipids, Carbohydrates &amp; Proteins), as well as vitamins &amp; minerals</td>
<td>Can be taken in through foods or drinks—the body is ¾ water!</td>
<td>The air around us is about 20% oxygen—the gas humans need to survive</td>
</tr>
</tbody>
</table>

### Table

<table>
<thead>
<tr>
<th>Condition</th>
<th>Description</th>
<th>Vision Effect</th>
<th>Interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-flexible lens</td>
<td>The lens cannot perform accommodation (changing shape) to focus light, occurs mostly with age</td>
<td>Blurry vision</td>
<td>The lens can be dissolved, extracted &amp; replaced by an artificial lens</td>
</tr>
<tr>
<td>Malformed cornea</td>
<td>Cornea is shaped wrong</td>
<td>Blurry vision</td>
<td>Corneal replacement (mostly from cadavers)</td>
</tr>
<tr>
<td>Cataracts</td>
<td>The lens is becoming blurry</td>
<td>Blurry vision</td>
<td>Same as for non-flexible lens</td>
</tr>
<tr>
<td>Crossed eyes</td>
<td>The eyes do not focus together</td>
<td>Double vision</td>
<td>Lenses move the image to match the &quot;wayward&quot; eye, correcting double vision</td>
</tr>
</tbody>
</table>

Source: [http://science.howstuffworks.com/innovation/everyday-innovations/lens2.htm](http://science.howstuffworks.com/innovation/everyday-innovations/lens2.htm)

#### 2.4.1. What are the tests and procedures in a routine eye exam?

<table>
<thead>
<tr>
<th>Test/Procedure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual acuity test</td>
<td>Read the Snellen chart from across the room to measure clarity of view (acuity)</td>
</tr>
<tr>
<td>Automated perimetry</td>
<td>Push a button when you see a flash to measure peripheral vision</td>
</tr>
<tr>
<td>Refraction assessment</td>
<td>Look through Phoroptor to determine which lens works best for each eye</td>
</tr>
<tr>
<td>Slit-lamp examination</td>
<td>Slit lamp focuses intense light on eye to determine abnormalities</td>
</tr>
<tr>
<td>Indirect ophthalmoscopy</td>
<td>Doctor holds eye open &amp; examines with bright light (shows great detail and 3 dimensions)</td>
</tr>
<tr>
<td>Applanation tonometry</td>
<td>Measures pressure needed to flatten part of cornea, tests for glaucoma</td>
</tr>
</tbody>
</table>

3.1 Introduction to Power

Study Guide by Hisrich

3.1.a. What are the resources the human body needs to survive?

- Food
- Water
- Oxygen

This includes macromolecules (Lipids, Carbohydrates & Proteins), as well as vitamins & minerals—can be taken in through foods or drinks. The body is ¾ water! The air around us is about 20% oxygen—the gas humans need to survive.

3.1.b. What role does food play in the human body?

- Carbohydrates: Quick energy source
- Lipids: Long term energy source, cushioning of organs, makes up much of brain
- Proteins: Build & repair body tissues

3.1.c. What role does water play in the human body?

1. Dissolves other materials & allows them to flow (in blood)
2. Gives cells structure (just right amount needed to prevent shrinking and exploding)
3. Allows food to digest & pass through intestinal walls into bloodstream
4. Carries waste products out of body (in urine)
5. Helps send electrical messages
6. Regulates homeostasis of body temperature (evaporation/sweating)
7. Lubricates structures (i.e. allows fecal matter to pass through large intestine)
8. Protective barrier around organs

3.1.d. What role does oxygen play in the human body?

Oxygen allows humans to metabolize (burn) fuel (food), creating energy. Every cell in the human body needs oxygen to survive. Cells turn glucose and oxygen into energy within their mitochondria, in a process called “cellular respiration.” Without oxygen, we can’t process food or make energy.

3.1.e. What human body systems work to create, process or distribute the body’s main power sources?

<table>
<thead>
<tr>
<th></th>
<th>Food</th>
<th>Water</th>
<th>Oxygen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taken in through</td>
<td>DIGESTIVE system (absorbed through</td>
<td>DIGESTIVE system, passes to the</td>
<td>RESPIRATORY system, passes to the</td>
</tr>
<tr>
<td>the</td>
<td>small intestine walls), passes to</td>
<td>CARDIOVASCULAR system for</td>
<td>CARDIOVASCULAR system</td>
</tr>
<tr>
<td>DIGESTIVE system</td>
<td>the CARDIOVASCULAR system for</td>
<td>distribution to all cells. filtered</td>
<td>through the capillaries that coat</td>
</tr>
<tr>
<td>for</td>
<td>distribution to all cells. filtered</td>
<td></td>
<td>the</td>
</tr>
</tbody>
</table>
distribution to all cells where it’s let into the cells by insulin (made in the **ENDOCRINE** system) and processed within the **mitochondria**. Through the kidneys of the **URINARY** system to remove waste and maintain **homeostasis** of fluid levels. Alveoli (for distribution to all cells, where it’s processed within the mitochondria.

### 3.1.f. How do personal factors and environmental factors impact the body’s ability to survive without air, food or water?

<table>
<thead>
<tr>
<th>Environmental</th>
<th>Personal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presence of dangerous animals (i.e. sharks or poisonous spiders), temperature of air, humidity of air, presence of protective clothing, etc</td>
<td>Fitness level, age, will to survive, amount of fat, genes, metabolism, etc</td>
</tr>
</tbody>
</table>

### Lesson 3.2: Food

**Understandings**

- Enzymes are usually proteins and act as catalysts which speed up chemical reactions in the human body.
- The digestive system consists of the gastrointestinal tract and the accessory digestive organs which function together to chemically and mechanically digest food, absorb water and nutrients, and remove wastes.
- Metabolism, the sum of all the chemical reactions that occur within the body, is required to maintain homeostasis.
- When a process in the body requires energy, ATP is broken down to liberate energy stored in its chemical bonds.

**Knowledge and Skills**

**It is expected that students will:**

- Recognize that enzymes are designed to be highly specific, and the structure of the enzyme’s active site determines the substrate it acts upon.
- Recognize that factors such as temperature, pH, and enzyme and substrate concentration affect the rate of an enzyme-catalyzed reaction.
- List specific enzymes that digest carbohydrates, fats, and proteins at sites along the digestive tract.
- Describe the structure and function of the organs in the digestive system.
- Explain how energy is stored in ATP.
- Model the interaction between enzymes and their corresponding substrates.
- Outline what happens to a bite of food as it travels down the digestive tract.
- Design a laboratory experiment investigating the impact that environmental changes can have on enzyme function and analyze the results.
- Analyze energy inputs and outputs in the body to assess overall health.

### 3.2.a. What are the functions of the digestive system?

The **digestive system** takes in food & water and breaks down food & allows its absorption into the bloodstream. It breaks down **polymers** like carbohydrates and proteins into **monomers** like sugars & amino acids, in the process releasing energy. The process of breaking molecules down is called **catabolism**. It also gets rid of unusable materials in the form of feces.
3.2.b. How does the structure of each organ in the digestive system relate to its function? 3.2.c. How does the digestive system assist in maintaining the water balance in the body?

<table>
<thead>
<tr>
<th>Oral Cavity &amp; Salivary Glands</th>
<th>Pharynx</th>
<th>Esophagus</th>
<th>Stomach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salivary glands are exocrine glands that secrete materials to lubricate &amp; break down food. Salivary amylase is one of the enzymes secreted to begin the breakdown of starch.</td>
<td>A hollow tube found in both the digestive &amp; respiratory system—allows the passage of food, water &amp; air. A bolus is a soft mass of food formed in the oral cavity that travels down the pharynx.</td>
<td>Hollow tube, pushes food &amp; water to the stomach using peristalsis</td>
<td>Sac in which foods are broken down into nutrients—it makes up ⅛ of the gastrointestinal tract</td>
</tr>
</tbody>
</table>

Liver & Gall Bladder

The liver makes bile needed for digestion & the gall bladder is a sac that stores it & passes it into the small intestine to help break down fats

Pancreas

It secretes digestive enzymes into the small intestine (digestive function), but also makes insulin to control blood sugar (endocrine function).

Small Intestine

Long, narrow, has villi that absorb nutrients into bloodstream—it makes up ⅛ of the gastrointestinal tract

Large Intestine

Wider/shorter than small intestine, reabsorbs water and produces feces

3.2.d. How do enzymes assist the process of digestion? 3.2.e. How do factors such as temperature, pH and concentration of enzyme or substrate affect the rate of enzyme-catalyzed reactions?

| Enzymes are proteins that help speed up or initiate chemical reactions, including digestion. An example of an enzyme is salivary amylase, secreted by the salivary glands to begin the digestion of the polymer starch. | Enzymes work best within a particular range of temperatures & pH values. For instance, salivary amylase works best at 37°C (body temperature) and a pH of 6.8 (barely acidic). The higher the enzyme: substrate ratio, the more effective the enzyme will be. |

3.2.f. What are BMI and BMR? 3.2.g. How can BMI and BMR help assess healthy diet and weight?

<table>
<thead>
<tr>
<th>Body mass index (BMI)</th>
<th>Basal metabolic rate (BMR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio of weight (kg) to height (m)—used to determine whether a person is at a healthy weight</td>
<td>Metabolism (total chemical reactions) while at complete rest. It is combined with a person’s activity level to plan a healthy caloric intake.</td>
</tr>
</tbody>
</table>
Lesson 3.3: Oxygen

Understandings

• The structure of the lungs and the close association between the lungs and the vessels of the cardiovascular system facilitate the transport of oxygen to all cells in the body.
• During normal breathing, a healthy individual is using only a small percentage of the total capacity of his or her lungs.
• The amount of oxygen required by the cells in a body depends on the activity level of the cells.

Knowledge and Skills

It is expected that students will:

• Describe the structure of the respiratory system, especially the lungs, and the basic mechanics of breathing.
• Explain how the structure of the lungs facilitates the exchange of oxygen and carbon dioxide between air and the body.
• Use sensors to measure lung capacity.
• Analyze data collected using a spirometer to determine tidal volume, vital capacity, and minute volume.
• Describe the action of specific medications on the body and investigate how this action helps treat and control disease.

### 3.3.a. Why do we need oxygen?

Oxygen is needed for cell respiration & energy metabolism.

### 3.3.b. How do we breathe?

We take in air through our nasal cavity. It then passes through the pharynx (along with food) and through the larynx (voice box) into the trachea (wind pipe). The trachea branches into a left and right bronchus, which enter the left and right lung, respectively. The 2 bronchi branch into smaller bronchioles, much like the branches of a tree get smaller as the extend away from the trunk. The bronchioles get smaller and smaller, ending in 300-500 alveoli (the "hollow" sites of gas exchange). The alveoli are wrapped in capillaries that carry oxygen away from the alveoli (to all the body tissues) and bring carbon dioxide to the alveoli (for removal from the body).

### 3.3.c. How does the oxygen we inhale get to all of our cells?

Our respiratory system, found in our abdominal cavity (along with parts of the digestive, excretory, and reproductive systems) brings in oxygen. The lungs are found in the thoracic cavity, along with the heart. The diaphragm is a sheet of muscles that contracts to let us breathe in and relaxes to let us exhale. The intercostal ("between ribs") muscles also help with the process. The oxygen is carried away from the alveoli by the hemoglobin in the red blood cells to capillary beds that are found in all the body tissues. The capillaries ("hairlike") are tiny vessels where arterioles ("little arteries") meet venules ("little veins") & are the place where oxygen, nutrients and hormones get dropped off & cellular waste gets picked up and carried away.

### 3.3.d. How much air do we normally breathe in and out?

We breathe in and out 15-20x/min, ~22,000x/day. We process ~300 cubic feet (2,100-2,400 gallons) of air per day.

### 3.3.g. How efficient are our lungs at capturing oxygen from the air?

Normal humans use about 10% of their lung capacity at rest. 21% of the air around us is oxygen & the air we breathe out is about 15% oxygen, so we use about 25% of the oxygen in the air & expel about 75% of it.

### 3.3.e. How much air can our lungs actually hold? 3.3.f. How do we measure lung capacity? 3.3.i. How do we measure oxygen capture?

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal Volume (TV)</td>
<td>air breathed in/out without conscious effort</td>
</tr>
<tr>
<td>Reserve Volume (RV)</td>
<td>air that can be inhaled/exhaled with max. effort</td>
</tr>
<tr>
<td>Lung capacity</td>
<td>measured using a spirometer: It can also be used to measure oxygen content of inhalations (~20.8%) &amp; oxygen content of exhalations (~15.3%) &amp; the difference is oxygen capture (~5.5%)</td>
</tr>
</tbody>
</table>
Lesson 3.4: Water
Understandings

- The urinary system helps maintain homeostasis in the body by filtering the blood, regulating water and electrolyte concentration, maintaining the pH balance of the blood, and ridding the body of liquid waste called urine.
- Through filtration, reabsorption, and secretion, the nephron assists in maintaining normal values of water, electrolytes, pH, and blood pressure in the body.
- The hormones aldosterone and antidiuretic hormone (ADH) both help regulate the amount of water in the body.
- Malfunctions in the body can be identified through noticeable changes in the composition of urine, and these changes can be detected through urinalysis.

Vital Capacity (VC): air that can be exhaled after maximal inhalation = TV + IRV + ERV

Residual Volume (RV): air in lungs after max. exhalation

Total Lung Capacity (TLC): VC + RV

Minute Volume: air breathed in one min. w/out conscious effort TV x (breaths/minute).

3.3.h. Why might some people be more efficient at capturing oxygen than others? 3.3.k. How does a respiratory therapist assist patients with ventilation and utilization of oxygen?

Efficiency is increased by:
1) Regular cardiovascular exercise
2) Daily deep breathing
3) Avoiding cleaners, pollution & smoke
4) Eating fruits/veggies with antioxidants

Source: Livestrong.com

3.3.j. What are examples of diseases or medical conditions that would affect breathing and/or oxygen capture?

<table>
<thead>
<tr>
<th>Disease/Condition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bronchitis (&quot;inflammation of bronchi&quot;)</td>
<td>Bronchial tubes are inflamed, irritated membrane swells &amp; blocks air flow</td>
</tr>
<tr>
<td>Emphysema</td>
<td>The alveoli are destroyed, smoking is the primary cause (can also be genetic), causes shortness of breath</td>
</tr>
<tr>
<td>Lung cancer</td>
<td>There’s uncontrolled growth of tissue, persistent coughing is common sign, main causes is smoking</td>
</tr>
<tr>
<td>Asthma</td>
<td>Environmental triggers cause inflammation or tightening of bronchial tubes and/or excess mucus production, blocking air flow</td>
</tr>
</tbody>
</table>

3.3.l. What are the components of an effective resume?

It should be concise, targeted to the specific job & should list education, professional qualifications and relevant experiences in a reader-friendly format.

3.3.i. What are the components of an effective resume?

It should be concise, targeted to the specific job & should list education, professional qualifications and relevant experiences in a reader-friendly format.
Knowledge and Skills

It is expected that students will:

- Describe the structure and function of the human urinary system.
- Describe how the structure of the kidney relates to its function in the body.
- Recognize that the nephron is the structural and functional unit of the kidney.
- Describe the connections between urine and blood and the exchange of ions and fluids that occurs across the nephron.
- Illustrate the path of urine formation through the kidney.
- Estimate the filtration rate of the glomerulus and relate mathematical estimates to the function of the human kidney.
- Analyze urinalysis results to diagnose disease and dysfunction in human body systems.

3.4.a. What are the functions of the urinary system?  3.4.b. What are the major organs of the urinary system?

The **urinary system** helps maintain fluid homeostasis (blood volume) in the body. The **kidneys** assist in vitamin D production, maintain blood calcium levels, control extracellular fluid volume and composition (lymph fluids) & assist in control of pH of internal environment. They filter 20% of blood pumped by the heart.

**Urine** is created in the **kidneys** and then passes through the **ureters** into the bladder. The bladder stores the urine until the body is ready to release it, at which point a sphincter muscle relaxes and the urine passes out of the body through the **urethra**.

3.4.c. What is the general structure of the **kidney** and how does this structure relate to kidney function?

![Components of the Urinary System](image)

The **kidneys** receive blood through the renal artery, process it, and return the processed blood to the body through the renal vein.

The **kidneys** also make a protein (BMP-7) that stimulates bone growth.

The renal capsule is a membrane that protects the organ.

The cortex is the lightly colored outer region and the medulla is the darker colored inner region.

The renal pelvis collects the urine that has formed and directs it into the **ureter**.

3.4.d. How does the **kidney** form **urine**?  3.4.e. What is the relationship between blood and urine?  3.4.f. What is the function of the **nephron**?

| The **kidneys** filter 20% of the plasma and non-cell parts of blood, reabsorbing the components the body needs back into the blood and secreting the unwanted portions. | The **nephron** is the basic filtering unit of the **kidney** and there are about a million of them in each **kidney**. They filter every bit of blood about 20-25 times per day! | Unwanted materials (ions, small molecules, waste products, extra fluids) turn into filtrate (urine) in the **nephrons** and leave the body. No red blood cells get filtered out, so there should never be blood in the urine. |
### 3.4.h. How do the hormones ADH and aldosterone affect the nephron and the body’s overall water balance?

<table>
<thead>
<tr>
<th>ADH (antidiuretic hormone, vasopressin)</th>
<th>aldosterone</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Made by</strong></td>
<td><strong>Adrenal Glands</strong> (adrenal cortex)</td>
</tr>
<tr>
<td><strong>Job</strong></td>
<td>Promotes sodium and water reabsorption in nephrons</td>
</tr>
<tr>
<td><strong>Both</strong></td>
<td>Hormones that promote fluid retention, thereby increasing blood volume &amp; pressure (act in response to situations like dehydration or high salt levels in blood)</td>
</tr>
</tbody>
</table>

### 3.4.g. How do filtration, secretion and reabsorption in the nephron help maintain a fluid and electrolyte balance in the body?

#### Filtration

- The blood volume undergoes **glomerular filtration** where it gets filtered under pressure in the **glomerulus** (capillaries surrounded by Bowman’s capsule). The filtrate becomes urine (made of excess fluids and unneeded particles) and passes into the proximal tube.

#### Secretion

- Waste substances like ammonia, ions (H⁺, K⁺ & HCO₃⁻), urea, creatinine, and certain drugs move into the distal and collecting tubules for removal from the body. Secretion is the opposite of reabsorption, moving substances out of the blood and turning them into urine. Secretion helps maintain pH balance by removing excess ions.

#### Reabsorption

- **Happens in these places:**
  - Proximal tubule - reabsorbs 65 percent of filtered Na + 2/3 of water most other stuff
  - Loop of Henle - reabsorbs 25 percent of filtered Na.
  - Distal tubule - reabsorbs 8 percent of filtered Na.
  - Collecting duct - reabsorbs the remaining 2 percent only if the hormone **aldosterone** is present.

This process moves substances back into the blood.

- Small molecules like glucose, amino acids, vitamin C, and ions (K⁺, Ca²⁺, Cl⁻ & Na⁺) get grabbed by transporter proteins (located in the proximal tubule) and reabsorbed out of the filtrate. Some act passively, but some require active transport. Water is reabsorbed through osmosis. The reabsorption of sodium controls the reabsorption of most other substances (including water).

- The higher the concentration of a molecule & the slower the rate of flow, the more that is reabsorbed.

### 3.4.i. What is urinalysis? 3.4.j. How can the composition of urine provide clues about problems in other human body systems?

#### Urinalysis measures the products excreted from the body via urine & can be used to detect many different diseases in the body (see graphic left).
Lesson 4.1: Joints and Motion

Understandings
- The skeletal system works with the muscular system to move the human body.
- The types of joints found in the human body differ in both structure and function and are classified as such. Understanding of Flexion and Extension.
- Range of motion describes a joint’s possible movements as well as provides a measure of overall flexibility at a joint.

Knowledge and Skills

It is expected that students will:
- Recognize that a joint is the location at which two or more bones connect, allowing movement and providing support to the human skeleton.
- Describe the motion at joints, such as flexion and extension.
- Demonstrate the types of movement possible at a joint and match range of motion photographs to specific actions.
- Measure range of motion of human joints using a goniometer.

4.1.a. What role do joints play in the human body?

Joints are the places where two bones meet and allow movement & flexibility.

4.1.b. How are joints classified by both structure and function?

<table>
<thead>
<tr>
<th>Immovable/Fibrous</th>
<th>Partially Moveable/Cartilaginous</th>
<th>Freely Moveable/Synovial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do not move—EX: joints in dome of skull and between teeth and jawbone</td>
<td>Move little—linked by cartilage—EX: vertebrae in spine</td>
<td>Move in many directions—found at the hip, shoulders, elbows, knees, wrists, and ankles—filled with synovial fluid (acts as lubricant)—these joints have synovial cavities</td>
</tr>
</tbody>
</table>

4.1.c. What are the different types of synovial joints?

<table>
<thead>
<tr>
<th>Hinge</th>
<th>Pivot</th>
<th>Ball and Socket</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elbow &amp; knee—movement in one direction only</td>
<td>Head &amp; distal radial-ulna—rotating/twisting movement</td>
<td>Hips &amp; shoulders—allows movement in any direction, round end of long bone fits into hollow of another bone</td>
</tr>
</tbody>
</table>

The way in which the parts come together at a joint is called the articulation.

4.1.d. What role do cartilage, tendons, and ligaments play at a joint?

<table>
<thead>
<tr>
<th>Cartilage</th>
<th>Tendons</th>
<th>Ligaments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cushions/protects bones where they meet and rub against each other. The cartilage found in joints is hyaline cartilage—the same kind found in a fetal skeleton &amp; it’s referred to as articular cartilage where it attaches to articular bone surfaces.</td>
<td>Fibrous tissue that connects muscles to bones</td>
<td>Fibrous straps that fasten bones to other bones</td>
</tr>
</tbody>
</table>
4.1.f. What is range of motion?

**Range of motion** is the range through which a joint can be moved & can be measured using a goniometer to determine angles.

4.1.g. How do you measure the range of motion of a particular joint movement?

<table>
<thead>
<tr>
<th>Abduction</th>
<th>Adduction</th>
<th>Circumduction</th>
<th>Rotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Movement away from body’s midline</td>
<td>Movement toward body’s midline</td>
<td>Movement at <a href="#">synovial joint</a> in which distal end moves in circle and proximal end remains in one place</td>
<td>Moving bone around its own axis</td>
</tr>
</tbody>
</table>

- **Abduction**
- **Adduction**
- **Circumduction**
- **Rotation**

4.1.h. How do bones, muscles and joints work together to enable movement and locomotion for the human body?

Our bones provide support and give our bodies shape, but cannot move on their own. The muscles provide the movement. The joints help attach bones to one another to provide flexibility & allow the muscles to help give the bones a way to move.

Lesson 4.2: Muscles

Understandings
Through contraction and relaxation, the three different types of muscle tissue - skeletal, cardiac, and smooth - produce body movements, stabilize body position, move substances within the body, and regulate heat.

The structure of the muscle and attachment of this muscle to bone directly relates to the function of each skeletal muscle.

Muscles are composed of units called sarcomeres, which contract and shorten when exposed to electrical stimuli.

Calcium ions and ATP play a role in the contraction of muscle fibers.

Neurons are packed together in wiring called nerves, and these nerves take electrical messages from the brain to muscle.

Knowledge and Skills

*It is expected that students will:*

- Describe how the three types of muscle tissue differ in structure and function.
- Explain the sliding filament mechanism of muscle contraction.
- Recognize the connection between nerves and muscle.
- Analyze muscle tissue structure using a microscope.
- Interpret muscle function by examining its structure and its attachment to bones.
- Test the effect of varying solutions of ATP on the contraction of muscle tissue.
- Demonstrate the process of muscle contraction as well as the phenomenon of rigor mortis.

**4.2. a  How do muscles assist with movement of the body and of substances around the body?**

Our *muscles* are what allow all movement of our bodies (and within our bodies). They help us involuntarily by helping food move down the esophagus and into the stomach (peristalsis) and helping blood move through our bodies (the heart is a muscle). They also help us move our bodies voluntarily from place to place (the muscles in our limbs). Our bodies each have about 650 muscles & are ~ 50% muscle by weight!

**4.2. b  How do the structure and function of the three types of muscle tissue compare?**

<table>
<thead>
<tr>
<th>Cardiac</th>
<th>Skeletal</th>
<th>Smooth</th>
</tr>
</thead>
<tbody>
<tr>
<td>They are <em>striated muscle</em> fibers form the wall of the heart &amp; function involuntarily.</td>
<td>They are attached to bone, mostly in the legs, arms, abdomen, chest, neck and face. They are <em>striated muscle</em> fibers (lined under microscope) &amp; attach to bone by a tendon. They hold the skeleton together and give the body shape. They are voluntary (we control them) and contract quickly and powerfully, but they tire easily.</td>
<td>They are smooth (not <em>striated</em>) &amp; are controlled automatically by our nervous system. They are also called “involuntary” muscles. They make up the walls of the stomach and intestine to help break down and move food. They also line the walls of blood vessels. They take longer to contract than skeletal muscles, but also don’t tire as easily.</td>
</tr>
</tbody>
</table>

**4.2.c  How are muscle fibers and membranes organized to form a whole skeletal muscle?**

**Structure of a Skeletal Muscle**

```
<table>
<thead>
<tr>
<th>Bone</th>
<th>Epimysium</th>
<th>Perimysium</th>
<th>Fascicle</th>
<th>Blood vessel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tendon</td>
<td>Endomysium</td>
<td>Muscle fiber</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

The *epimysium* ("upon muscle") is the outermost layer of connective tissue. The *perimysium* ("around muscle") is made of connective tissue and forms casings for bundles of muscle fibers. The *endomysium* ("within muscle") is connective tissue surrounding each individual muscle fiber. Each *fascicle* is a small cluster of muscle fibers, with *endomysium* between the individual fibers. Blood vessels run between the *fascicles*, bringing the tissue nutrients & removing waste. Nerves also run throughout, controlling the movement of the muscles. Together, the network of nerves and blood vessels are referred to as the *plexus*. 
4.2.e  How are muscles named?  4.2.d  What do skeletal muscle structure and attachment to bones tell you about function?

Several factors are considered when naming a muscle, including 1) Location (EX: tibialis anterior is on the front of the tibia) 2) Shape (EX: deltoid “resembles” -oid) a “triangle” - (delt)) 3) Points of attachment (EX: sternocleidomastoid—the muscle attaches to the sternum and the tendons attach to the mastoid process of the skull.) 4) Relative size (EX: gluteal or “rump” region – the gluteus maximus is bigger and the gluteus minimus smaller). 5) Number of muscle “heads” or divisions (EX: Biceps means “two-headed” and has two divisions) 6) Direction of muscle fibers (EX: the rectus abdominis muscle is located in the front of the abdomen and its fibers are oriented in a “straight” (rect), vertical direction). 7) Association with characters (EX: sartorius means “presence of” (-us) a “tailor” (sartori!) Tailors used to sit cross-legged upon the ground. The sartorius is actually located along the inner aspect of each thigh. Thus, when it contracts, it flexes (bends) the lower leg like an ancient tailor.

4.2.f  What are the requirements for muscle contraction?  4.2.h  What is a sarcomere?  4.2.i  How does a sarcomere contract and lengthen to cause muscle contraction?  4.2.k  How do nerves interact with muscles?

In order for muscles to contract (shorten and thicken), they must receive a message from the CNS to do so. The messages come through efferent neurons (nerves that move away from the CNS). The sliding filament mechanism explains muscle contractions. Muscle fibers contain many myofibrils (“muscle fibers”) that allow the muscle cells to contract. The myofibrils contain thick and thin filaments attached to the Z disk (Z line). Thick filaments are made of myosin protein and thin ones of actin protein. The two proteins can twist around each other, shortening the sarcomere during contraction. Tropomyosin and troponin are proteins that control how actin and myosin interact—when they contract and twist and when they unravel and relax. Afferent neurons send messages back from muscles to the CNS. If there are problems with nerves, it can lead to issues with muscle function (i.e. Carpal Tunnel Syndrome)

4.2.g  What role do calcium and ATP play in muscle contraction?

1) Calcium ions cause troponin and tropomyosin to shift, exposing myosin binding sites 2) Myosin heads connect with actin binding sites & move the thin filament, contracting the muscle 3) The ADP & P that caused the myosin heads to cock back are left behind during the power stroke 4) Introduction of ATP causes myosin heads to release the actin 5) ATP is broken down into ADP & P, causing myosin heads to cock back and prepare for another power stroke
4.2.j How is the condition rigor mortis related to muscle contraction?

After death the muscle’s membranes become more permeable to calcium ions. Those ions promote the cross bridges of actin and myosin, shortening muscle fibers. ATP is needed to release the myosin heads from the actin fibers and allow muscles to relax, but ATP reserves are quickly depleted, causing muscles to remain contracted. It can take 10 minutes to hours to occur, with maximum stiffness 12-24 hours after death. Eventually tissue decays and lysosomal enzymes leak and cause muscles to relax.

4.2.i How can we assess muscle function?

Heart rate can help assess cardiac muscle function. Strength tests can help assess function of voluntary muscles.

Lesson 4.3: Blood Flow

Understandings

- The heart pumps blood to the lungs to pick up oxygen and to the body to deliver this oxygen.
- The structure of arteries, veins, and capillaries relates directly to the function of each vessel and to the amount of pressure exerted on the vessel walls.
- Changes in cardiac output, the amount of blood that is pumped out by the ventricles per minute, often signal diseases of the heart, and these changes can impact the function of other body systems.
- Increased blood pressure in vessels can indicate possible blockages, and these blockages can interrupt blood flow to an organ or limb.

Knowledge and Skills

It is expected that students will:

- Explain the relationship between the heart and the lungs.
- Identify the body’s major arteries and veins and name the body region supplied by each.
- Recognize that unlike arteries, veins contain valves that prevent the backflow of blood.
- Describe pulse and blood pressure as they relate to cardiovascular health.
- Recognize that lifestyle choices, such as poor diet and smoking, can lead to the developing blood flow disorders.
- Trace blood flow in pulmonary and systemic circulation.
- Calculate and interpret cardiac output values and relate the amount of blood pumped by the heart to the health of other body systems and organs.
- Measure peripheral pulses using Doppler ultrasound and calculate an ankle brachial index (ABI).
- Interpret the ankle brachial index (ABI) to determine possible blockages in blood vessels.

4.3.a What types of muscle help move blood around the body?

The heart is the primary muscle that helps move blood & is made of cardiac muscle tissue. It is responsible for the circulation of blood & all the materials in it.

4.3.b What is the relationship between the heart and the lungs? 4.3.c What is the pathway of blood in and out of the heart in pulmonary and systemic circulation?

**Pulmonary Circulation**: The right side of the heart collects deoxygenated blood into its atrium & then passes it into the ventricle. The right ventricle then pushes the blood to the lungs, where the CO₂ is dropped off and O₂ is picked up.

**Systemic Circulation**: The blood from the lungs comes back to the left side of the heart through the left atrium. It then moves into the left ventricle and the ventricle pushes it out through the aorta (biggest artery) and into the rest of the arteries. The arteries carry oxygenated blood to all of the body’s tissues. As they reach the tissues, they turn into tiny arteries called arterioles, which then become capillaries. The capillaries are the place where oxygen, nutrients and hormones are dropped off and waste products are picked up. The capillaries then turn into venules, which turn into veins, which come together as the vena cavas (biggest veins) and carry deoxygenated blood back into the right atrium of the heart.
### 4.3.d How do the structure of arteries, veins, and capillaries relate to their function in the body?

<table>
<thead>
<tr>
<th>Arteries</th>
<th>Capillaries</th>
<th>Veins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three layers of thick, fairly rigid walls to allow them to expand/contract &amp; to handle high pressure (blood has greatest pressure as it's leaving the heart)— one layer is smooth muscle</td>
<td>Thin walled (one cell layer thick) &amp; microscopic in size to allow exchange of materials, often have pores to allow movement of materials</td>
<td>Three layers of elastic/collapsible walls with valves to prevent the backflow of blood as it moves toward the heart—one layer is smooth muscle</td>
</tr>
</tbody>
</table>

### 4.3.f What are varicose veins? 4.3.g Why don’t we ever hear about varicose arteries?

**Varicose veins** are big, twisty veins near the skin’s surface that are caused by weakened valves. When the valves don’t work (keep blood moving), blood collects in the veins and the pressure builds up, causing them to become weak, large and twisted. They can run in families, but are also caused by age, being overweight and standing for long periods of time.

**Arteries** don’t do this because they have higher pressure in them & therefore do not need valves to keep the blood moving.

### 4.3.h What are the major arteries and veins in the body and which regions do they serve?

<table>
<thead>
<tr>
<th>Major Arteries</th>
<th>Major Veins</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aorta</strong>—blood is pushed out of the aorta by the left ventricle &amp; then the aorta branches into all other arteries in the body</td>
<td><strong>Superior Vena Cava</strong>—carries deoxygenated blood from the upper body (arms and head) back to the heart</td>
</tr>
<tr>
<td><strong>Coronary Artery</strong>—this is the artery that runs across the ventral side of the heart, nourishing the cardiac tissue itself</td>
<td><strong>Inferior Vena Cava</strong>—carries deoxygenated blood from the lower body (abdomen and legs) back to the heart</td>
</tr>
<tr>
<td><strong>Pulmonary Arteries</strong>—carry blood from the right ventricle to the lungs to pick up oxygen</td>
<td><strong>Pulmonary Veins</strong>—carry newly oxygenated blood from the lungs back to the left atrium</td>
</tr>
</tbody>
</table>

### 4.3.i What is cardiac output? 4.3.j How does cardiac output help assess overall heart health? 4.3.k How does an increased or decreased cardiac output impact the body?

**Cardiac output** is the volume of blood the heart pumps per minute (mL/min) out of the left side. It’s calculated by multiplying heart rate (beats/min) by stroke volume (mL/beat). **Stroke volume** is how much blood is pushed out by the left ventricle with each beat. An average person has a resting heart rate of 70 beats/min and resting stroke volume of 70 mL/beat, leading to a typical cardiac output of 4,900 mL/min. The total volume of blood in an average person is 5,000 mL (5 L), so the whole volume of blood is pumped through the heart about once each minute. During vigorous exercise, it can increase 4–7 fold.

Normal cardiac output is needed to move oxygen and nutrients to all the body’s tissues. If a person’s cardiac output is lower than normal, the tissues can suffer or blood pressure can become unhealthy. An increased cardiac output from exercise can help strengthen the heart.
4.3.1 What is blood pressure?

Blood pressure is a measure of how fast the molecules in blood are hitting the walls of the arteries. It increases with increased blood volume & with increased heart rate. It is an important indicator of cardiac health and should be under 120/80 at rest.

4.3.m How can the measurement of blood pressure in the legs be used to assess circulation? 4.3.n What is peripheral artery disease?

The blood pressure in the legs can be taken to measure how well blood is circulating to those limbs. To take the pressure, a person listens to the pulse in that region. Arteriosclerosis (“abnormal condition of hard arteries”) & atherosclerosis (“hard arteries due to fat deposits”) can both impede blood flow by making the arteries more narrow (that’s atherosclerosis) and less flexible (that’s arteriosclerosis). That can lead to peripheral vascular disease (PAD), in which blood vessels supplying the extremities do not work as well as they should. The most extreme form of peripheral vascular disease is peripheral artery disease, in which there is partial or total blockage of an artery, usually one leading to an arm or leg. It causes pain and eventually can even lead to loss of partial or total limbs.

4.3.o Why can smoking lead to peripheral artery disease?

Smoking raises the risk of atherosclerosis and therefore the risk of PAD. It’s thought to do so by damaging the endothelium (innermost layer of the artery), which allows plaque to build up on the artery walls.

Lesson 4.4: Exercise Physiology

Understandings
- Exercise requires the coordinated effort of many human body systems, including the nervous system, the muscular system, the skeletal system, the cardiovascular system, and the respiratory system.
- An athlete training for an intense physical event needs to consider diet, exercise, hydration, and injury prevention as well as track his or her progress and modify the plan to meet the demands of exercise.

Knowledge and Skills
It is expected that students will:
- Recognize that the body uses high energy molecules such as creatine phosphate, glycogen, and glucose to supply ATP to working muscle.
- Recognize that muscle fatigue occurs with prolonged or repetitive use of a muscle group.
- Describe ways in which an athlete can prepare his or her body for the stress of an athletic event.
- Illustrate the body’s response to the stages of exercise.
- Design an experiment to test the effect of feedback, coaching, or competition on muscle fatigue.
- Interpret EMG and grip strength data to assess muscle fatigue.
- Apply knowledge of power and movement in the body to design a comprehensive training plan for an athlete.
4.4 Exercise Physiology

4.4.a What is the connection between power and movement in the body?

Movement requires power (fueled by energy). The energy comes from cellular respiration. Respiration can be aerobic ("with oxygen"—the source of long term energy) or anaerobic ("without oxygen"—the source of short term energy).

4.4.b How does the body maintain a supply of ATP during exercise?

**Phosphagen System**
Muscles use creatine phosphate to make energy for 8-10 seconds. An enzyme (creatine kinase) breaks the ATP into ADP, releasing energy & the ADP is quickly recharged back into ATP.

**Glycogen-Lactic Acid System**
Muscles store carbs as glycogen (chains of glucose) and can use anaerobic respiration to turn glycogen into glucose and then convert the glucose into ATP and lactic acid. The process is slower, but longer lasting than the Phosphagen system. The lactic acid builds up and makes muscles sore (causing muscle fatigue).

**Aerobic Respiration**
After about 2 minutes of exercise, the body is able to get oxygen to the muscles so that glucose can be fully broken down aerobically. The glucose can come from these places: 1) glycogen in muscles 2) glycogen in the liver 3) absorption of glucose from food in the intestine. After “hitting the wall” (depleting all glucose reserves), the body switches to burning fat reserves. When all fat is exhausted, the body can break proteins into amino acids & convert them into ATP. It works slower than the other processes, but is extremely long-lasting.

4.4.c What body systems are involved with powering an athlete through a running race?

<table>
<thead>
<tr>
<th>System</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digestive</td>
<td>Absorbs glucose through intestines and releases stored glucose from liver</td>
</tr>
<tr>
<td>Respiratory</td>
<td>Brings in steady supply of oxygen needed to combust glucose</td>
</tr>
<tr>
<td>Cardiovascular</td>
<td>Carries O₂ &amp; glucose to the cells to be converted into energy within the mitochondria</td>
</tr>
</tbody>
</table>

4.4.f What are performance-enhancing drugs?

Performance enhancing drugs are artificial ways of making the body function better during competition.

4.4.g How do specific performance-enhancing drugs affect the human body?

**Anabolic Steroids** promote tissue growth (esp. muscle) & improve endurance. Blood doping is loading an athlete’s blood with his/her own RBCs so blood carries more oxygen. **Erythropoietin** can be injected into the athlete to promote RBC production & increase O₂ carrying capacity.

4.4.h Why should certain performance-enhancing drugs be banned from athletic competition?

These drugs can make for an "unleveled playing field" & some can harm health (steroids). Not everyone agrees that they should be banned however. Is there any such thing as “a level field”?
**4.4.d What is muscle fatigue? 4.4.e How are we able to overcome muscle fatigue?**

Muscle cells rely upon a flow of electricity from the brain. It tells them to contract by signaling the sarcoplasmic reticulum to release calcium. Muscle fatigue is when the muscles can’t generate force.

Nerves are typically able to provide the necessary signals, but after a time of maximum contraction (such as strength training), the nerve’s signal reduces in frequency and contraction is reduced. There’s no pain, but the muscle seems to no longer listen to the brain & sometimes moves backwards. Continued strength training can increase the nerve’s ability to sustain high frequency signals for longer time periods, helping a person overcome muscle fatigue.

A new explanation is shown to the right→

**A New Explanation of Muscle Fatigue**

Muscle contraction and relaxation are controlled by the release and storage of calcium ions within muscle fibers. Scientists at Columbia University say that muscle fatigue, largely misunderstood for decades, is caused by calcium leaking into muscle cells.

**MUSCLE CONTRACTION**

Calcium ions are released into the cell, causing filaments in the muscle fiber to contract.

**MUSCLE RELAXATION**

Calcium ions are pumped into storage, allowing the muscle filaments to relax.

Muscles can also fatigue when there’s a lack of oxygen, water, vitamins or nutrients or when there’s a build-up of lactic acid.

1. **Lack of oxygen**—During hard/fast exercise (like sprinting) the body may not be able to provide enough oxygen to the muscles to break down glucose and produce energy. That results in a build-up of lactic acid, causing fatigue.

2. **Lack of fluid & electrolytes**—If a person doesn’t drink enough fluids & taking in enough electrolytes during exercise, the muscles will cramp and fatigue. The blood won’t be able to carry oxygen/nutrients to muscles & won’t be able to carry away the waste products (CO₂ and lactic acid).

3. **Lack of sleep**—Without adequate sleep, the muscles won’t be able to recover from the day before and will fatigue more quickly.

4. **Poor nutrition**—A lack of calcium, or an imbalance of carbs, proteins and fats can lead to muscle fatigue.

**4.4.i What are areas to consider when designing a training plan for an athlete?**

The trainer should first consider the background and current condition of the athlete. She should then help the athlete set a goal. The trainer and athlete can develop plans for the following areas in order to help meet the goals.

- Diet
- Exercise
- Hydration
- Injury Prevention
- Tracking Progress
- Medications, Vitamins or Supplements
• The skin is a dynamic organ that functions in protection, temperature regulation, sensation, excretion, and absorption in the human body.
• Burn damage to skin can impact numerous body functions and body systems.
• Both the body’s ability to sense pain and to suppress pain help protect the human body from injury and death.

Knowledge and Skills
It is expected that students will:
• Describe the structure and function of the two main layers and the accessory organs of the skin.
• Explain how different degrees of burns damage layers of the skin.
• Explain how the human body senses and processes signals of pain.
• Interpret how burn damage to the skin will affect the function of the organ and overall homeostasis in the body.
• Outline what happens inside the body when a person feels pain.

5.1.a. What are the functions of skin?
<table>
<thead>
<tr>
<th>Protection</th>
<th>Sensation</th>
<th>Temperature Regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>It is the first defense against pathogens.</td>
<td>It alerts the body of danger through the sensation of pain.</td>
<td>It insulates us to maintain our internal temperature. It also allows us to lose or retain heat, mainly by shifting the diameter of the blood vessels in the skin.</td>
</tr>
</tbody>
</table>

5.1.b. What types of tissue make up the layers of the skin?

The skin is made of epithelial ("having the nature of covering a surface") tissue. The top layer is the epidermis ("top skin")—which is neither sensitive nor vascular—and the next layer is the dermis ("skin"). It is also referred to as the mesoderm ("middle skin") and is very sensitive. Below that is the hypodermis ("below the skin"). The blood vessels penetrate the hypodermis and dermis. The hypodermis has fat tissue, blood vessels & connective tissue. The hair follicles begin in the hypodermis & the tips of the hair extend beyond the epidermis. Collagen and elastin are proteins found in the dermis. Together, they give the skin its smooth structure & make the skin look young. Keratin ("horny") is a fibrous protein that is part of the epidermis & the main component of hair.

5.1.c. What role do accessory organs such as sweat glands and sebaceous glands play in the skin?

<table>
<thead>
<tr>
<th>Sweat Glands</th>
<th>Sebaceous Glands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweat glands begin in the superficial hypodermis and extend through the dermis and empty out of the epidermis. They are exocrine (&quot;secrete outside&quot;) glands &amp; the primary function of most humans sweat glands is to cool the body (eccrine glands, found all over). Humans also have larger apocrine sweat glands in their armpits and perianal regions (i.e. crotch). They secrete an oily, milky substance that coats hair so odor-causing bacteria can grow on it. All sweat glands have specialized myoepithelial cells (&quot;muscle covering surface&quot;) that help to squeeze the glands and push out the secretions &amp; they are controlled by the nervous system &amp; hormones from the endocrine system.</td>
<td>The sebaceous (&quot;full of fat&quot;) glands begin in the hypodermis and empty through pores in the epidermis. They are exocrine (&quot;secrete outside&quot;) glands that secrete and oily/waxy material (sebum) to lubricate and waterproof skin and hair. Humans have the greatest density of these glands on tier faces and scalps. The only place they do NOT exist in humans is on the palms and soles. Eyelids have special sebaceous glands that secrete tears (a type of sebum).</td>
</tr>
</tbody>
</table>
5.1.d. What happens to skin as it is exposed to sunlight and as a person ages?

<table>
<thead>
<tr>
<th>Aging</th>
<th>Sunlight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skin changes over time due to exposure to the sun’s UV rays, which damage the fibers in skin called elastin, that helps give skin its flexibility. As elastin deteriorates, the skin starts to sag and stretch and become unable to go back into place after stretching. That makes skin bruise and tear more easily &amp; take longer to heal.</td>
<td>Most wrinkles and spots are caused by sunlight. Sunlight speeds the aging process of skin &amp; increases risk of skin cancer. Exposure to the sun causes skin lesions, tumors, wrinkles, freckles, discolored areas, yellowing &amp; destruction of elastin and collagen tissues. UV light from the sun is the #1 cause of skin cancer (tanning beds are just as harmful). Melanin is a natural pigment that the skin produces when exposed to UVB radiation. It helps disperse about 99.9% of UV radiation as heat, protecting the skin from skin cancer. That’s why people with darker skin (more melanin) are at lower risk of skin cancer.</td>
</tr>
</tbody>
</table>

5.1.e. Which layers of the skin are damaged in different types of burns? (info from http://hospitals.unm.edu/burn/classification.shtml)

| 1st Degree Burn—damages Epithelium, painful/tender | 2nd Degree Burn—damages Epithelium & top of dermis, very painful | 3rd Degree Burn—damages epithelium and dermis—little to no pain |

5.1.f. How does burn damage in the skin affect other functions in the body?

<table>
<thead>
<tr>
<th>Skeletal</th>
<th>Circulatory</th>
<th>Muscle</th>
<th>Nervous</th>
<th>Respiratory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bone marrow works to replace RBCs destroyed by burnt skin—blood transfusions may be needed</td>
<td>BP and blood volume drop, decreasing blood flow and oxygenation—can lead to shock/death</td>
<td>Metabolism increases and the body starts to consume muscle mass</td>
<td>K+ levels become abnormal makes nerve transmissions irregular (faster, slower or not at all)</td>
<td>Rate of breathing can increase from higher metabolism &amp; edema—edema of throat can also obstruct the airway</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Endocrine</th>
<th>Lymphatic</th>
<th>Immune</th>
<th>Digestive</th>
<th>Urinary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adrenalin secretions can raise body temperature &amp; increase metabolism</td>
<td>System under strain from inflammation (due to damaged tissues)</td>
<td>Becomes less effective because 1st line of defense (skin) compromised</td>
<td>Intestinal lining increases absorption of nutrients to support metabolism and repair cells</td>
<td>Kidneys increase reabsorption to compensate for lost fluid (can damage kidneys)</td>
</tr>
</tbody>
</table>

5.1.g. What role does pain play in the human body? 5.1.h. How does the body interpret and process pain? 5.1.i. Why would the inability to feel pain actually put the human body in danger?

<table>
<thead>
<tr>
<th>Role of Pain</th>
<th>Processing of Pain</th>
<th>Risk from Lack of Pain</th>
</tr>
</thead>
</table>
The survival purpose of pain is to alert the body to a risk of tissue damage so the person can take action to remove the risk (i.e. touching a hot stove—pull hand away). The higher the risk, the greater the pain.

Pain is received by naked nerve endings (dendrites of sensory nerves) & is often experienced as physical discomfort (pricking, throbbing or aching). A person typically responds by taking action to remove the source of the pain. The brain secretes endorphins (a type of hormone made in the pituitary gland) in response to stress and pain. Endorphins can act in a similar way to morphine, reducing perception of pain as well as to feelings of euphoria and an increased immune response. (May be responsible for "runner's high")

Acute (short term) pain is necessary to survival. If a human felt no risk from pain (i.e. touching a hot stove), he would take no action to remove the threat (i.e. pulling hand away) and would suffer more damage. There is not thought to be any survival benefit to chronic (long term) pain (i.e. cancer pain), however.

Lesson 5.2: Bones

Understandings

- Bones assist muscles with movement of the body and protect the internal organs from damage and injury.
- Damage to bone, through a sprain or a fracture, can impact the function of other body organs and systems.
- Osteoclasts and osteoblasts are specialized bone cells that function to break down and build bone tissue.
- Bone is constantly being broken down and reformed through the process of bone remodeling.

Knowledge and Skills

It is expected that students will:

- Recall the four main types of bone.
- Recognize that bone is a living connective tissue composed of cells and protein fibers wrapped in hard mineral salts that can adapt and change to fit the needs of the person.
- Describe the structure and function of compact and spongy bone.
- Describe the types of bone fractures.
- Analyze bone structure using a microscope.
- Interpret X-rays to determine specific types of bone fractures.
- Apply knowledge of hormones and of bone remodeling to explain calcium balance in the body.
- Diagram the stages of bone healing after injury

1. How does the skeletal system assist with protection in the body?

   The bone marrow produces blood, including the white blood cells that are part of the immune system. Bones also protect internal organs (heart, lungs, brain) from damage.

2. How does the structure of compact bone differ from the structure of spongy bone?

<table>
<thead>
<tr>
<th>Compact Bone</th>
<th>Spongy (cancellus) Bone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forms the outside of bones and most of the <strong>diaphysis</strong> (&quot;nature of being across&quot; shaft), osteons are close together.</td>
<td></td>
</tr>
<tr>
<td>Found inside short, flat &amp; irregular bones and in the <strong>epiphyses</strong> (&quot;nature of being on top&quot; ends) of long bones.</td>
<td></td>
</tr>
</tbody>
</table>


   Bone is stronger than concrete (pound for pound) and stronger than any other natural material. Cells are hollow and have paper-thin walls, giving bone its lightweight structure. Calcium and phosphorus give bone its rigid strength, but ~ ½ of bone mass is soft and alive, allowing bones flexibility to bend. Every bone cell is replaced every 7 seven years, keeping bone strong.
4. **What is an X-ray?**

An x-ray is an invisible type of high energy radiation. Soft tissues are made of smaller atoms and don’t absorb x-ray photons well. The calcium atoms in bone are larger and absorb x-rays better. That causes a picture of the bone to show up.

5. **What are the four main stages of healing that occur after a bone fracture?**

<table>
<thead>
<tr>
<th>Comminuted</th>
<th>Depression</th>
<th>Compression</th>
</tr>
</thead>
<tbody>
<tr>
<td>Break in several pieces, splintered/crushed</td>
<td>Fragment is pushed down, typically due to a blow to the skull</td>
<td>Collapse of vertebra, often due to osteoporosis (“holes in bones”) or tumors or to being ejected from an ejection seat</td>
</tr>
<tr>
<td>Transverse</td>
<td>Oblique</td>
<td>Spiral</td>
</tr>
<tr>
<td>Complete break at right angle to bone axis, often from direct blow</td>
<td>Break has curved/sloped pattern, often caused by slanted blow</td>
<td>Caused by twisting force on bone, such as rotation to leg during skiing</td>
</tr>
<tr>
<td>Greenstick</td>
<td>Open</td>
<td>Closed</td>
</tr>
<tr>
<td>Incomplete, bone is bent &amp; partially broken, most common form in kids</td>
<td>Bone breaks through skin—greater risk of infection</td>
<td>Bone breaks, but doesn’t puncture skin</td>
</tr>
</tbody>
</table>

6. **How can damage to a bone affect other human body systems?**

Fat tissue from the bone marrow can leak into the blood, causing fat embolism syndrome, which can cause lung problems and seizures. If the skin breaks (open fracture), pathogens can enter the body and cause an infection.

7. **What is bone remodeling?**

Bone remodeling happens throughout life and is also called “bone metabolism.” It’s the process by which bone tissue is removed and new tissue forms (ossification). It increases after a fracture and is the method by which the bone heals. Remodeling is rapid early in life (100% replacement during first year of life) and then slows (10% yearly for adult). An imbalance in the process can lead to bone diseases like osteoporosis.

8. **How do osteoblasts and osteoclasts assist with bone remodeling and overall bone homeostasis?**

**Osteoblasts** ("bone sprouts")

Osteoblasts form new bone tissue, to replace those reabsorbed by osteoclasts—produce the organic part of bone (osteoid), made mostly of collagen protein, that inorganic minerals crystallize around—many of them turn into mature osteocytes

**Osteoclasts** ("bone breakers")

Osteoclasts break down and reabsorb bone tissue—come from monocytes in bone marrow, release minerals (calcium phosphate) and other stored materials (like growth factors)

9. **What is the relationship between bone remodeling and blood calcium levels?**

<table>
<thead>
<tr>
<th>Low blood calcium</th>
<th>High blood calcium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glands in the parathyroid release <strong>parathyroid hormone</strong> (PTH), causing osteoclasts to break down bone matrix and release calcium ions into blood.</td>
<td>C cells in the thyroid release <strong>calcitonin</strong> &amp; that stimulates storage of calcium in bones</td>
</tr>
</tbody>
</table>
11. What are the four main stages of healing that occur after a bone fracture?

<table>
<thead>
<tr>
<th>Inflammation</th>
<th>Soft Callus Formation</th>
<th>Hard Callus Formation</th>
<th>Remodeling</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-5 days</td>
<td>4 days-3 weeks</td>
<td>2 weeks-6-12 weeks</td>
<td>6-12 weeks +</td>
</tr>
<tr>
<td>There’s bleeding in the tissue and the trauma doctor must return bone fragments to place to stem blood flow. A mesh of blood clots between the fragments.</td>
<td>Fibroblast cells start to form cartilage to fill the gap—but it’s fragile, fracture must be kept immobile (sling or cast)—new blood vessels start to form</td>
<td>Cartilage begins to transform into woven bone. It takes longer for lower limbs than upper limbs. It’s controlled by release of calcium and phosphorus minerals into the cartilage, forming a hard callus over the fracture site. The end of this is called “fracture union.” Gentle weight bearing encourages this process, so removable cast walkers are suggested.</td>
<td>The body lays more hard callus than necessary during bone healing, enlarging the bone. After uniting, bone remodeling occurs and the bone shape becomes normal. The osteoclasts remove unneeded bone and osteoblasts lay bone where needed. Full weight-bearing exercise increases bone strength. Loosely organized woven bone gets replaced by highly organized Lamellar bone.</td>
</tr>
</tbody>
</table>

12. What lifestyle choices relate to the overall strength and protective properties of bone?

<table>
<thead>
<tr>
<th>Good Diet</th>
<th>Physical Activity</th>
<th>Healthy BMI</th>
<th>Not Smoking</th>
<th>No Alcohol</th>
<th>Avoid glococortiocoids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eat plenty of foods with calcium and vitamin D</td>
<td>Regular exercise strengthens bone</td>
<td>Healthy body weight (not too thin) reduces risk of osteoporosis</td>
<td>Smoking prevents the body from using calcium well &amp; brings menopause earlier</td>
<td>Alcohol raises risk of osteoporosis</td>
<td>Avoid medicines (such as these) that cause bone loss</td>
</tr>
</tbody>
</table>

**Lesson 5.3: Lymph and Blood Cells**

**Understandings**
- The lymphatic and immune system functions to drain and distribute fluid in the body as well as protect the human body against specific invaders.
- Antibodies are proteins found in the blood or lymph that seek out and bind to specific antigens.
- Only certain blood types are compatible with one another and can be safely transferred from person to person in a transfusion.
- Antibodies are produced in response to specific pathogens.

**Knowledge and Skills**

*It is expected that students will:*
- Describe the structure and function of the lymphatic and immune system.
- Recognize that a type of white blood cell called B lymphocyte is responsible for the production of antibodies and has the ability to remember invaders once they have entered the body.
- Recognize that blood type is determined by the antigens present on red blood cells.
- Describe the genetics of blood type.
- Describe the interaction between antigens and antibodies.
- Analyze simulated blood samples to determine blood type.
- Produce and analyze a family pedigree for blood type and determine potential donors for a transfusion.
- Graph and interpret antibody data collected after an infection and relate this data to the response of body cells.
- Diagram and create a flow chart of an immune response to a common cold.
- Apply knowledge of specific immunity to deduce how vaccines function.

1. **What body systems function to protect the human body?**

The immune system is the primary system that helps protect the body. The skeletal system supports the immune system by making immune cells within the bone marrow. The cardiovascular system supports the immune system by moving immune components through the body.
2. **How does the structure of the lymphatic system relate to its function?**

The lymphatic (“water”) system is part of the cardiovascular system. It’s made up of lymphatic vessels that carry **lymph** fluid (recycled blood plasma with WBCs) toward the heart. It overlaps with the immune system & contains organs like the lymph nodes & tonsils. It makes and circulates **lymphocytes** (WBCs that are the main cells of the system) & the spleen, thymus and bone marrow are considered parts of the system. There are rounded masses of **lymph tissue** called **lymph nodes** (“water knots”) that contain lots of **lymphocytes** and filter the **lymph** fluid. The **lymph** vessels empty into ducts that drain into veins.

3. **What is an antigen?**  **4. What is an antibody?**

<table>
<thead>
<tr>
<th>Antigen (“against formation”)</th>
<th>Antibody (“against a body”)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proteins found on the outside of <strong>pathogens</strong> (&quot;disease starters&quot;—viruses and disease-causing bacteria), unique to each <strong>pathogen</strong>. <strong>Lymphocytes</strong> recognize <strong>antigens</strong> as foreign and produce <strong>antibodies</strong> specific to each antigen.</td>
<td><strong>Y-shaped structures</strong> produced by <strong>lymphocytes</strong> to fight against <strong>pathogens</strong> by attaching to their <strong>antigens</strong>. <strong>Antibodies</strong> destroy the antigen (and therefore the <strong>pathogen</strong>) and it is then consumed by <strong>macrophages</strong> (&quot;big eaters&quot;). <strong>Memory cells</strong> remember past <strong>pathogens</strong> and can quickly make the right <strong>antibodies</strong> if attacked again, giving <strong>immunity</strong> in the future.</td>
</tr>
</tbody>
</table>

5. **How do circulating antibodies protect a person from receiving incompatible blood during a transfusion?**

**Antigens** are found on the surface of blood cells and platelets and if the **antigens** trigger an immune response (happens if blood types don’t match), producing **antibodies** to attack the antigens. This results in **agglutination**, which is a clumping of blood cells caused by the **antigen-antibody** interaction. **Agglutination** can be deadly, which is why it is critically important to know a person’s **blood type** before performing a transfusion. **Pedigrees**, which show genetic inheritance, can be used to help predict a person’s 2 **alleles for blood type**. Type O blood does not contain **antigens**, which is why people with type O blood are considered “universal donors”—it won’t trigger **agglutination** in others.

<table>
<thead>
<tr>
<th>Antigens present</th>
<th>Group A</th>
<th>Group B</th>
<th>Group AB</th>
<th>Group O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anti-A &amp; Anti-B</td>
<td>Anti-B</td>
<td>Anti-A</td>
<td>None</td>
<td>Anti-A &amp; Anti-B</td>
</tr>
<tr>
<td>Antibodies present</td>
<td>Anti-B</td>
<td>Anti-A</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Red blood cell type</td>
<td>A</td>
<td>B</td>
<td>AB</td>
<td>O</td>
</tr>
</tbody>
</table>

6. **What is specific immunity?**  **7. What role do lymphocytes play in specific immunity?**  **8. How does your body react the second time it is exposed to a particular antigen?**

Specific **immunity** is **immunity** against a particular **antigen** (or **pathogen**).

**T lymphocytes** (**T cells**) and **B lymphocytes** (**B cells**) are the two kinds of **lymphocytes**. All **lymphocytes** begin in the bone **marrow** and then mature into one of these types, with **T cells** maturing in the bone **marrow** and **B cells** maturing in the thymus gland. **B cells** are like military intelligence, seeking out pathogens and sending **T cells** to attack. **B cells** make the **antibodies** that match to each **antigen**. **T cells** are like solders, binging to **antigens** and then releasing a protein that punctures the pathogenic cells,
It is expected that students will:

- Describe how the body systems respond to extreme external environments.
- Explain how the systems work together to maintain homeostasis in the body and to complete basic functions such as movement and communication.
- Illustrate disease in the human body, from its initial symptoms to eventual diagnosis and treatment.
- Interpret knowledge of homeostasis in the body to design an innovative medical intervention or invention.
- Trace disease in human systems by generating a fictional case study and compiling a patient case file.