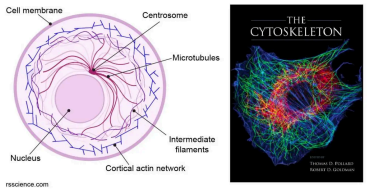
Biology

- **Characteristics of Life**
    - All living organisms share several key characteristics & functions
        - They are composed of one or more cells.
        - They have the ability to reproduce and pass on traits to their offspring (heredity)
        - They create and eliminate waste, as a result of carrying out life functions.
        - They grow and change over their lifetime.
        - They take in energy and transform it (metabolism - all of the biochemical reactions that occur in a cell)
        - They respond to and interact with their environment.
        - They can maintain a stable internal environment despite external change (homeostasis)
        - CRECIS (SEWICRC)
            - Cells
            - Reproduction
            - Energy Use (or Metabolism)
            - Response to environment (like light, temperature)
            - Stable internal conditions (or homeostasis)
            - Inheritance (or Growth & development)
            - Change over time

- **Cell Theory**
    - All living organisms are composed of one or more cells.
        - Unicellular vs multicellular
        - Prokaryotes vs. eukaryotic cells
    - The cell is the basic unit of structure in a function and organization in all living things.
        - Cells are made up of specialized structures called organelles.
        - An organelle is a structure that carries out a specific function and work together to perform the life functions of the cell.
    - All cells come from pre-existing cells
        - For centuries, people believed in the “spontaneous generation” of life from inanimate matter
        - By the mid-1800s, it was understood that new cells are created from a process of reproduction.
            - Genetic information is duplicated & passed down through a process called cell division (mitosis and cytokinesis).

- **Structure and function**

- Nucleus
  - Controls all cell activities
  - “Brain” of the cell
- Ribosome
  - Help to produce proteins, which make up much of a cell’s structure and are required for activities necessary for the cell’s survival; some ribosomes float in the cytoplasm, and others are attached to the ER.
  - “Protein factory workers” of the cell
- Mitochondria
  - Where energy is released from glucose to fuel cell activities through cellular respiration.
  - “Powerhouse” of the cell
- Cytoskeleton
  - Filaments (actin) and tubules (tubulin) that provide a framework for the cell, helping it maintain its structure and providing “tracks” along which vesicles and organelles can move.
  - “Scaffolding” or “Highway” of a cell
  - 

- Endoplasmic reticulum
  - A network of membrane-covered channels that transport materials made in the cell; is connected to the nucleus. Detoxification, lipidification.
  - Rough ER
    - Has ribosomes on its surface (looks "bumpy")
    - Makes proteins that are sent to the Golgi body, cell membrane, or outside the cell.
    - “Factory” (the workers would be ribosomes) of the cell
  - Smooth ER
    - No ribosomes (looks smooth)
    - Makes lipids (fats), detoxifies harmful chemicals, and stores calcium.
    - “Chemistry lab” of the cell
- Cytoplasm
  - Includes the organelles, and other life-supporting materials, such as sugar and water, all contained by the cell membrane.
  - “Land” of the cell
- Vacuoles
  - Contain water and other materials that are used to store or transport small molecules; plant cells tend to have one large vacuole, whereas animal cells have multiple small ones.
  - “Storage Container” of the cell

- Golgi Body
  - Receives products (like proteins and lipids) from the endoplasmic reticulum (ER) in small vesicles.
  - Modifies them — adds sugars or other molecules to make them ready for their final job.
  - Packages them into new vesicles (like small shipping boxes).
  - Sends them to:
    - The cell membrane (to be sent out of the cell)
    - Other parts of the cell (like lysosomes or storage vesicles)
  - "Post office" or "packaging center" of cell
  - 
- Cell membrane
  - Separates the inside of the cell from the external environment; controls the flow of materials into and out of the cell.
  - Outer layer of animal cells. For plant cells, it will be located just inside the cell wall.
  - "Security Gate" of the cell
- Vesicles
  - Membrane-covered sacs that transport/store materials inside the cell and sometimes help these materials cross the cell membrane to enter or exit the cell.
  - "Shipping boxes" of the cell
- DNA (Deoxyribonucleic Acid)
  - It's the molecule that carries genetic instructions for the growth, development, functioning, and reproduction of all living organisms.
  - Made of nucleotides, and each nucleotide has 3 parts (Sugar – called deoxyribose, Phosphate group – links sugars together, Nitrogen base (A = Adenine, T = Thymine, C = Cytosine, G = Guanine))
- Nuclear membrane
  - Controls movement of materials into and out of the nucleus. Protects DNA.
- Nucleolus
  - Produces ribosomes
  - Is a small, dense structure inside the nucleus
- Chromatin
  - Tangled Mass of DNA in nucleoplasm
  - Contains genetic information
- Lysosomes
  - In animals only
  - Sac of digestive enzymes. Breaks down food or harmful materials for reuse. Breaks down cell parts. "Suicide bags"

- Cell Wall (only in plant cells)
  - Thicker covering around the cell membrane. Helps protect and support plant cells.
- Chloroplasts (only in plant cells)
  - Small green chlorophyll sacs with double membrane. Transfer energy from sunlight into stored energy in carbohydrates during photosynthesis
- Centrioles
  - Two rod-shaped organelles. Involved with cell division.

- **Prokaryotes vs. Eukaryotic**
  - Prokaryotic
    - No nucleus – DNA floats freely in the cytoplasm
    - No membrane bound organelles (basically organelles that have their own membrane) – simpler structure
    - Smaller
    - Not included:
      - Nucleus
      - Mitochondria
      - ER
      - Golgi Apparatus
      - Lysosomes
      - Vacuoles
      - Chloroplast
  - Eukaryotic
    - True nucleus
    - Larger
    - Membrane-bound organelles
    - Cell wall only in plants/fungi
    - Reproduce by mitosis/meiosis

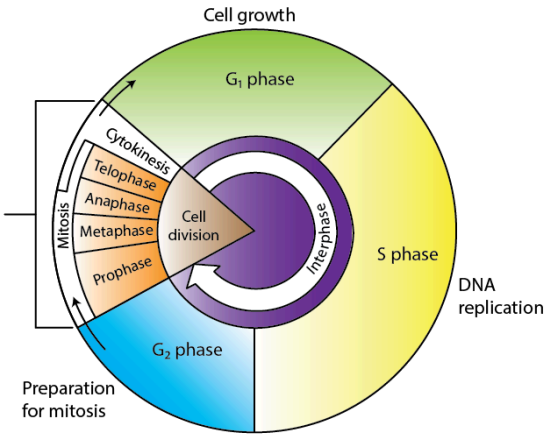
- **Plants vs Animals**
  - Animals
    - No cell wall – only a fixed cell membrane
    - No chloroplasts – cannot photosynthesize
    - Small vacuoles – more numerous not central
    - Round or irregular shape
    - Have centrioles for cell division
    - Get energy by consuming food (heterotrophic)
    - More types of lysosomes for digestion of waste
  - Plants
    - Cell wall: made of cellulose; gives shape and support (animal cells don't have this)
    - Chloroplasts: contain chlorophyll for photosynthesis

        - Large central vacuole: Stores water, nutrients, and waste; helps maintain turgor pressure
        - Rectangular, boxy shape
        - No centrioles. Instead they have Microtubule Organizing Centers (MTOCs), which essentially do the same thing of producing spindle fibres
        - Can make their own food (autotrophic)
    - Shared
        - Nucleus (controls the cell)
        - Cytoplasm (jelly-like fluid inside)
        - Cell membrane (controls what enters and leaves)
        - Mitochondria (produces energy/ATP)
            - ATP: Adenosine Triphosphate is the main energy currency of the cell.
        - Ribosomes (make proteins)
        - ER/Golgi (transport and package materials)
- **Mitosis**
    - Why are cells so small
        - Cells move materials by diffusion (dispose waste and take in nutrients)
        - As a cell grows, its volume increases faster than surface area. The higher the V:SA, the more inefficient the cell is.
            - It takes more resources and energy to get to the different organelles
        - If a cell grows beyond a certain surface area to volume ratio (SA:V), not enough materials will be able to cross the cell membrane quickly enough to sustain the life of the cell.
        - Solution: Build LARGE organisms out of many small cell units

    - Why do cells divide
        - Growth: Increase the number of cells in the body
        - Repair: To replace dead or damaged cells
        - Reproduction
            - Asexual
                - One parent, offsprings are 100% identical genetically = clones
                - e.g. bacteria, sea sponges, jellyfish
            - Sexual Reproduction
                - Two parents, offsprings are genetically different, ½ of the DNA comes from each parent.
    - What gets passed on to “daughter” cells
        - Exact copy of genetic material = identical DNA to parent cell!
            - Duplication/doubling of DNA occurs during interphase
            - Division occurs during mitosis.
        - Cytokinesis (organelles, cytoplasm, cell membrane, enzymes)

- Chromosome: A super condensed piece of DNA (containing many different genes) that is found in the nucleus of dividing cells.
  - Can be single stranded (unduplicated) or double stranded (duplicated)
- Chromatin: Uncoiled DNA found in the nucleus of non-dividing cells
- Chromatid: One half of a duplicated chromosome
- Chromatin coils up into chromosomes when it's ready to divide. It's made up of DNA and proteins
- Centromere = structure that holds together sister chromatids; spindle fibers will attach here during division.

- **Cell Cycle**
  - Interphase
    - Growth (G1 - damage to DNA and G2 - correct replication) & DNA replication (S - spindle fiber attachment)
  - Mitosis
    - Division of the DNA
    - 4 stages (PMAT):
      - Prophase, metaphase, anaphase, telophase.
  - Cytokinesis
    - Division of the cell.

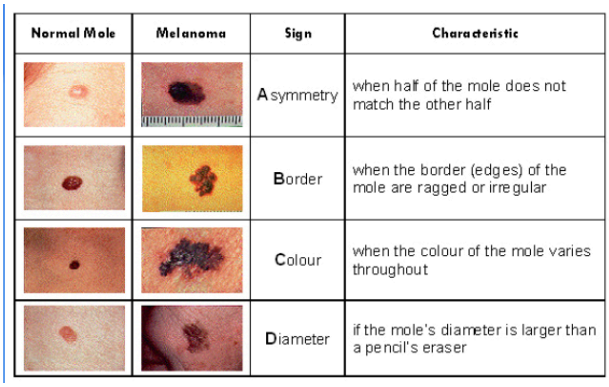


- **Interphase**
  - Longest phase of the cell cycle - 90%
  - Cell is doing its "everyday job" of growth and repair
  - When it receives the "signal" to prepare for division, DNA is replicated – Important!
    - 2 identical copies of DNA are created
  - Nucleus is well-defined (still intact) and DNA is loosely packed in dense chromatin fibres.
- **Prophase**
  - Chromatin condenses into visible chromosomes
    - Each consists of two sister chromatids (identical strands) connected at the centromere
  - Centrioles move to opposite poles of the cell

    - Spindle fibres begin to develop – these will eventually attach to centromeres and pull apart sister chromatids
    - Nuclear membrane breaks down.
- **Metaphase**
    - Nuclear membrane finished breaking down here
    - Chromosomes align along the equator (middle) of the cell; “meta” = “middle”
    - This helps to ensure that chromosomes will separate properly & that each daughter cell will receive one copy of each chromosome.
    - Spindle fibres attach to the chromosomes at the centromeres
- **Anaphase**
    - Centromere splits and sister chromatids are moved apart to opposite poles of the cell
        - Now called daughter chromosomes
- **Telophase**
    - Chromosomes arrive at the opposite poles.
    - Nuclear membrane reforms & daughter nuclei are created.
    - Spindle fibres dissolve/disappear.
    - Chromosomes disperse & uncoil back into chromatin.
- **Cytokinesis**
    - Cytoplasm & organelles split into two completely different daughter cells
    - Animal cells pinch off near the middle, forming a “cleavage furrow”
    - Plant cells form a cell plate to divide the new cells.

- **Checkpoints in the cell cycle**
    - Cells produce proteins that constantly monitor activities & surroundings.
    - Cells remain in interphase if
        - It receives signals from other cells not to divide
        - It doesn’t have enough nutrients
        - DNA has not replicated
        - DNA is damaged
    - G2 Checkpoint
        - Cell size
        - DNA replication
    - Metaphase
        - Chromosome spindle attachment
    - G1
        - Nutrients
        - Growth Factors
        - DNA Damage

- **Tumors**
    - Benign (not cancer) tumor cells grow only locally and cannot spread by invasion or metastasis

    - Malignant (cancer) cells invade neighboring tissues, enter blood vessels, and metastasize to different sites.
    - Metastasis
        - What makes some tumors so deadly is their ability to metastasize through blood and lymph
        - They break apart from other parts and go into other areas.
        - Secondary tumor sites can establish at other locations throughout the body
        - Secondary tumors are the same type of cancer as the primary tumor
- **Cancer causes**
    - Random changes in DNA
        - May result in the death of the cell
        - May occur in a gene that is involved in cell division
    - Spontaneous or can be inherited
    - Cancer tends to involve multiple mutations, unless it's in a tumor suppressor gene.
    - It doesn't allow the organs to follow a pattern, it's just random growth
    - Environmental Factors (Carcinogens)
        - Chemical or physical agent that has the ability to cause cancer
        - Mutagen: substance that induces DNA mutations (above the normal rate)
        - viral (HPV, hepatitis B)
        - radiation (ultraviolet radiation → skin cancer)
        - chemicals (tobacco → lung cancer)
- **Screening**
    - checking for cancer even if no symptoms
        - example: mammogram, prostate, Pap test
        - "ABCD of Moles"
        - 

- **IMAGING**
    - Endoscopy
    - X-ray
    - Ultrasound
    - CT Scan
    - MRI
    - Blood tests for cancer specific markers

        - PSA And prostate
    - Biopsy
        - Taking a piece of tissue and examining.
- **Treatment**
    - Surgery
        - If the tumor or cancerous tissue is easily accessed & well defined, it may be surgically removed
    - Chemotherapy
        - Drugs are used to slow/stop cancer cell division & metastasis and to kill the cells
        - Side effects may include hair loss, nausea and fatigue
        - Often the first stages of cancer treatment; used to shrink a tumour for surgical removal or for radiation treatment.
        - The bloodstream is used to transport the drugs throughout the body.
    - Radiation
        - Ionizing radiation disrupts cell division in rapidly dividing cancer cells
        - A focused beam is used to target the tumour or a radioactive source is implanted into the tumour
    - Oncolytic Viruses
    - Immunotherapy
        - Immunotherapy is a type of cancer treatment that helps your immune system fight cancer.
        - T-cell transfer therapy
            - a treatment that boosts the natural ability of your T cells to fight cancer
            - In this treatment, immune cells are taken from your tumor.
            - Those that are most active against your cancer are selected or changed in the lab to better attack your cancer cells, grown in large batches, and put back into your body through a needle in a vein.
        - Monoclonal antibodies
            - Immune system proteins created in the lab that are designed to bind to specific targets on cancer cells.
            - Some monoclonal antibodies mark cancer cells so that they will be better seen and destroyed by the immune system. Such monoclonal antibodies are a type of immunotherapy.

- **Benefits of being multicellular**
    - Larger size while maintaining efficiency
    - Longer life span
        - Survival of the organism does not depend on just one cell
    - Specialization
        - Cells with unique shapes/sizes/features can adapt to perform specific functions

        - This increases the complexity of the organism

- **Red Blood Cells**
    - Designed to carry oxygen
    - Found in blood
    - Structural
        - Large SA - Maximizes oxygen absorption
        - Hemoglobin - Iron-containing protein that binds oxygen
        - No nucleus - more space for haemoglobin = more room to carry
        - Round edges - travel through blood vessels more easily

- **Muscle Cells**
    - Designed to shorten or contract
    - Found in muscle tissue
    - Three main types: cardiac, smooth, and skeletal
    - Structural
        - Lots of mitochondria - high energy requirements for muscles to function.
        - Multi-nucleated - able to support the muscles as they grow.
        - Cylindrical and striated - able to support movement.

- **Ciliated Cells**
    - Designed to prevent airway/lung damage
    - Found in the lining of respiratory tract
    - Structure
        - Cilia
            - Coordinated sweep of mucus with trapped dust and bacteria back up the trachea to be swallowed/coughed out
        - High folded shape
            - Increased surface area
        - Lots of mitochondria
            - Powers the movement of cilia

- **Sperm Cells**
    - Designed to fertilize (ova)
    - Found in the testes
    - Structure
        - Pointed head - penetrate the egg more easily
        - Tail - provides movement so that it an swim and find an egg cell
        - Lots of mitochondria - provide power for sustained swimming.

- **Root hair cells**
    - Designed to absorb water & nutrients from soil
    - Found on the roots of plants
    - Structural features

        - Large surface area - speeds up absorption of water and nutrients via diffusion.
        - Semi-permeable membrane - permits water and minerals to enter the cell but not leave.

- **Cellular differentiation**
    - All body cells in an organism are produced by mitosis
    - These cells, that start out the same, develop into different cells with specific functions (specialized cells)
    - Cell differentiations refers to the process during which cells become specialized
    - Once specialized, a cell no longer undergoes mitosis.
    - **Why?**
        - 1. Contents of the cell
        - 2. Environmental conditions
        - 3. Influence of neighboring cells

- **Cell Specialization**
    - 50 – 75 Trillion cells in your body
    - 220 specialized cells
        - Heart
        - Nerve
        - Blood
        - Sperm
        - Etc.
    - Cells specialize by developing to produce different proteins, which perform specific functions
        - This can cause them to look different.
    - Even though all cells have the same genes (regions of DNA that encode proteins), not all genes are ‘turned on’, so not all proteins are produced.
    - In plants, undifferentiated cells that can become specialized cells are called meristematic cells
    - In animals, these cells are called stem cells
    - Both meristematic and stem cells produce more cells so that an organism can grow.
    - Stem cells undergo mitosis to make more stem cells or two specialized cells
    - Once specialized, a cell no longer undergoes mitosis.
    - In plants, undifferentiated cells that can become specialized cells are called meristematic cells.
    - In animals, these cells are called stem cells.
- **Stem cells**
    - Specialization starts with stem cells, which are undifferentiated (or partially differentiated) cells that have the potential to grow into many different cell types during development.

- Sources of human stem cells include:
  - Blood & bone marrow (can be donated)
  - Adipose (body fat) tissue
  - Umbilical cord blood (Can be banked)
  - Early-stage embryos
    - Ethical concerns as they are found in embryos, these can become anything, the others change based on their environment, but these, they can become anything. You can harvest small amounts from umbilical cord, but for large ones, you have to destroy the embryo.
- Adult
  - Mostly found in the bone marrow
  - Have undergone many levels of differentiation and specialization, leaving them with a limited ability to create a variety of cell types.
  - Most are involved in the replacement of damaged tissues (blood, skin, liver)
- Induced Pluripotent are just somatic that were genetically reprogrammed to behave like an embryonic cell.
- You can use stem cell therapy to prevent a disease or condition.
  - Bone marrow transplantation in leukemia.
  - Restoration of vision via transplantation of corneal stem cells.
  - Treatment of neurodegenerative conditions such as Parkinson's and Alzheimer's disease.
  - Regeneration of heart muscle cells following heart attacks.

- **Animal Tissues**
  - Tissue is defined as a group of cells that are similar in structure and function. The four main tissue types found in all animals are:
  - Epithelial tissue
    - Lines body surfaces and cavities (skin)
    - Functions as a protective, waterproof barrier.
    - Some epithelial cells form glands
    - Can be simple or stratified.
    - Different shapes: squamous, cuboidal, columnar.
  - Muscular Tissue
    - Specialized for contraction
    - Three types:
      - Skeletal: Attached to bones; generates body movement
      - Cardiac muscle: Found in heart; contracts in coordinated fashion
      - Smooth muscle: Lines hollow organs; propels materials through organs.
  - Nervous tissue
    - Specialized for communication
    - Two major cell types:

                - Neurons: Elongated cells with many projections (dendrites); communicate via electrical signals.
                - Glial: Support cells for neurons.
        - Connective Tissue
            - Varies widely in form and function
            - Includes everything that isn't epithelial, muscular or nervous.
            - Examples:
                - Bone: Structural support, protection, mineral storage
                - Cartilage: Flexible structural support, cushioning
                - Adipose (fat): Energy storage, insulation, cushioning
                - Blood: Fluid tissue containing blood cells (RBCs, WBCs, platelets)
- **Human Organ Systems**
    - Circulatory: Transports nutrients and oxygen to body tissues
    - Digestive: Breaks down food into nutrients
    - Respiratory: Exchanges oxygen and carbon dioxide with the environment
    - Excretory/Urinary: Filters wastes from the bloodstream
    - Lymphatic/Immune: Defends against disease
    - Muscular: Enables movement
    - Endocrine: Hormones. It tells our body what to do and when to do it.
    - Reproductive: Production of offspring and sex characteristics
    - Integumentary: Protective, waterproof barrier
    - Nervous: Senses changes in environment and coordinates responses
    - Skeletal: Provides structural support.
- **Digestive**
    - **Function**
        - Ingestion of food
            - Mouth
                - Teeth mechanically break down food.
                - Salivary glands produce saliva, which lubricates food & contains enzymes that break down starch (chemical digestion)
                - Pharynx
                    - Connects the mouth to esophagus
                - Esophagus
                    - Smooth muscle contracts in a wave to push food food down to the stomach
        - Digestion of food into nutrients
            - Mechanical and chemical
            - Stomach
                - Secretes gastric juice (hydrochloric acid + digestive enzymes + mucus)
                - Smooth muscle churns to further mechanically break down food.
            - Accessory Organs

            - Liver – produces bile (yellow liquid that breaks down fats)
        - Absorption of nutrients
            - Small intestine
                - Enzymes, bile & pancreas juices complete chemical digestion in the first segment of the small intestine.
                - Nutrients are absorbed into the bloodstream through the walls of the small intestine
                - Specialized structures called villi and microvilli increase the surface area for absorption.
        - Elimination of solid wastes
            - Large intestine (colon)
                - Absorbs water, vitamins and salt
                - Smooth muscle contractions move solid waste (feces) towards rectum.
            - Rectum
                - Solid waste accumulates & is excreted via the anal sphincter.
        - Major Organs
            - Mouth, Pharynx, esophagus, stomach, small & large intestine, rectum
        - Accessory organs
            - Liver – produces bile (yellow liquid that breaks down fats)
            - Gallbladder – stores bile & releases it into small intestine
            - Pancreas – releases digestive enzymes into the small intestine.
- **Circulatory**
    - Function
        - Transportation of nutrients, gases, and waste throughout the body.
    - 2 circuits
        - Pulmonary - deoxygenated blood travels from heart to the lungs to offload carbon dioxide and gain oxygen
        - Systemic - oxygenated blood travels from the heart to the body tissues to give oxygen and take away carbon dioxide
    - Major organs
        - Heart, blood vessels (arteries, veins, capillaries), blood
    - Blood
        - Plasma
            - Yellow, protein-rich liquid (mostly water) that carries blood cells; 55% of total blood volume
        - Red Blood Cells
            - Transport oxygen to body tissues.
        - White Blood cells (leukocytes)
            - Immune cells that recognize and destroy foreign molecules.
        - Platelets
            - Cell fragments involved in blood clotting

- Blood vessels
  - Arteries
    - Thick-walled, elastic blood vessels that carry oxygenated blood away from the heart
      - Pulmonary artery carries deoxygenated blood
      - Thick; able to withstand pressure
    - Veins
      - Thin-walled, wide blood vessels that carry deoxygenated blood back to the heart
        - One-way valves to prevent backflow
        - Pulmonary vein carries deoxygenated blood
      - Thin; blood has less pressure as its deoxygenated
    - Capillaries
      - Tiny, thin-walled vessels surrounding body tissues; allow exchange of gases & nutrients
      - Small and thin-walled to easily allow for this.
  - Heart
    - Pump muscles composed of cardiac muscle tissue that contracts as a single unit
    - Values located in the heart open when blood is pushed through them and close to prevent backflow
      - Unidirectional flow of blood through the heart
    - 4 chambers
      - 2 upper – left & right atrium
      - 2 lower – left and right ventricle
      - Right is deoxygenated, left is oxygenated

- **Respiratory**
  - Gas exchange (Oxygen is inhaled, carbon dioxide is exhaled)
  - Filtration and humidification of inhaled air
  - Close connection with circulatory system
  - Major organs
    - Nasal and oral cavities, larynx, trachea, bronchi & bronchioles (lungs), diaphragm, rib muscles
    - Passes to lungs via the pharynx, larynx and trachea
      - Trachea is lined with cilia and mucus to filter particles
    - Bronchi branch into smaller bronchioles which bring air deeper into the lungs
    - Lungs are packed with alveoli (site of gas exchange)
  - Gas exchange
    - Alveoli
      - Tiny, thin-walled air sacs surrounded by capillaries (connection with circulatory system)
      - Inhaled oxygen moves from alveolar sac to deoxygenated blood
        - Gets carried to body tissues

            - Carbon dioxide moves from deoxygenated blood to alveolar sac
                - Gets exhaled
        - Diffusion is when things move from a high area of concentration to a low area of concentration.
- **Interactions**
    - Oxygen diffuses from the air in the respiratory system to blood in the circulatory system; carbon dioxide diffuses from blood into air.
    - Nutrients diffuse from food in the digestive system into the circulatory system.
    - Oxygen and nutrients diffuse from circulatory system into body cells
    - Carbon dioxide and wastes diffuse from body cells into the circulatory system.
    - Wastes from metabolic processes pass from the circulatory system into the excretory system.
    - Nervous system (rapid response) and endocrine system (prolonged response) work together to regulate all systems & bodily functions.