Chapter 1 Concepts

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Cell theory- living organisms are composed of cells. Cells are the fundamental building blocks of all living organisms

Common features of cells- have membranes, contain genetic material, have chemical reactions, generate energy

Exceptions to cell theory- some organisms or parts of organisms do not consist of typical cells- Robert Hooke examined cork cells in 1665

Light microscopes

$$\text{magnification} = \frac{\text{size of image}}{\text{size of specimen}}$$

Magnification = magnification = (size of image) / (actual size of specimen). Be careful for units!

Atypical examples of the cell theory
Striated muscle- has "stripes", changes the position of our bodies. These cells are larger than average and have multiple nuclei
Hyphae- long tube-like structures in some fungi
Acetabularia- algae that grows to a long length despite having just one nucleus

Unicellular organisms can still carry out functions of life

- Nutrition (obtaining food)
- Metabolism (chemical reactions inside the cell)
- Growth (irreversible increase in size
- Response (detect and react to changes in environment)
- Excretion (getting rid of waste products from metabolism)
- Homeostasis (keep conditions in organism within tolerable limits)
- Reproduction (sexually or asexually)

Limitations on cell size- surface area to volume ratio is important in the limitation of cell size

- The rate of reactions in a cell is proportional to the volume of the cell
- If surface area: volume is too low:
    - Less substances enter the cell and diffuse into the center
    - More heat cumulates as it is not dispersed

Paramecium- live in pond water. Heterotroph. Moves with cilia.
Chlamydomonas- unicellular alga living in soil and freshwater
Photosynthesis but no cell wall, so not a plant
Flagella

Multicellular organisms- have properties that emerge from the interaction of their cellular components

Emergent properties- arise from interaction of component parts of a complex structure

Cell differentiation in multicellular organisms

- Specialized tissues develop by cell differentiation in multicellular organisms
- Tissues carry out roles more efficiently

Gene expression and cell differentiation

- Differentiation involves the expression of some genes and not others in a cell's genome
- There are vastly different cells but they all come from the same genes :)

Stem cells

- Can divide over and over again to produce a lot of new cells. They can grow new tissues
- Not fully differentiated. Can differentiate to produce several cell types

- Used for embryos and also for therapeutic uses:
    - Can grow new tissues

Stargardt's disease

- Genetic disease developing in children around 6-12 that causes blindness
- Recessive mutation of ABCA4 gene
    - Stem cells could help grow back cells that can help restore site

Leukemia

- Cancer that produces abnormally large numbers of white blood cells
    - Stem cells can help treat leukemia by killing bad bone marrow cells before using stem cells to replace the bone marrow cells that were removed.

Ethics of Stem cells

- Look at notes.

Electron microscope- creates ultrastructures of cells. Created in 1930s

- Have much higher resolution
    - 200 times better than light microscopes at 1 nm
- Have a higher resolution because the wavelength of the electron wave is smaller than the wavelength for visual light.

Prokaryotes- simple cell structure without compartments

- Parts of the cell seem "lighter"- this is where the nucleoid region is (with the genetic material)

Prokaryotes divide by binary fission (asexual)

Eukaryotic cell structure

- Eukaryotes have compartmentalized cell structures
- Advantages
    - Enzymes/substrates for certain processes can be more concentrated
    - Harmful substances can be kept in a membrane of an organelle
    - pH can be maintained at an ideal level for a particular cell process
    - Organelles and their contents can be moved around the cell

Structures

1. Nucleus
    a. Nuclear membrane is double and has nuclear pores.
    b. Chromatin
        - Densely stained areas
2. Rough endoplasmic reticulum

    a. Contains flattened membrane sacs (cisternae)
    b. Outside cisternae are ribosomes (classified as 80s)
    c. Synthesizes protein for secretion from the cell
    d. Proteins go to the golgi body
3. Golgi body
    a. Has cisternae but they aren't as long
    b. Processes proteins before secreting them in vesicles
4. Lysosome
    a. Spherical with single membrane
    b. Formed in golgi vesicles
    c. Have high concentrations of protein and contain digestive enzymes
5. Mitochondrion
    a. Double membrane
    b. Inner membrane forms cristae
    c. Fluid inside the inner membrane is called the matrix
    d. Make atp (power for the cell)
6. Free ribosomes
    a. Look like dark granules in the cytoplasm
    b. Still classified as 80s
    c. Synthesize protein for the cytoplasm
7. Chloroplast
    a. Have stacks of thylakoids
    b. Make glucose with photosynthesis
    c. Have starch grains sometimes
8. Vacuoles and vesicles
    a. Single membrane with fluid inside
    b. Plant cells have large central vac**uoles**
    c. Transport vesicles are smaller
9. Microtubules and centrioles
    a. Move chromosomes around during cell division
    b. Microtubules for cilia and flagella
10. Cilia and flagella
    a. Whip like structures
    b. Used for locomotion

Endocrine gland cells of pancreas

- Endocrine- hormones
- Exocrine- digestive enzymes

Palisade mesophyll cells

- These produce the most photosynthesis in leaves
- Cylindrical shape

Phospholipid bilayers

- Hydrophilic- attracted to water
- Hydrophobic- not attracted to water
- Amphipathic- both hydrophobic and hydrophilic

Models of membrane

- Gorter and grendel (1920s)
    - Calculated that membrane contained a bilayer of phospholipids
    - Phospholipids in a monolayer had surface area twice as large as the surface area of plasma membrane
- Davson and Danielli (1930s) D&D
    - Proposed layers of protein adjacent to the phospholipid bilayer
    - Cell membranes are thin but are effective barrier to substances, so there must be layers of protein
- Singer and Nicolson (1966)
    - Proteins occupy positions in the membrane
    - Peripheral- attached to surface
        - Hydrophilic on their surfaces
    - Integral- embedded in the layer
        - These are often hydrophobic on one part of their surface
    - Fluid mosaic model

Problems with D&D
- Freeze-etched electron micrographs
    - There are transmembrane proteins
- Structure of membrane proteins
    - Proteins can be extracted from membranes
- Fluorescent antibody tagging

Membrane proteins
- Diverse
- Hormone binding sites
- Immobilized enzymes with the active site on the outside
- Cell adhesion to form tight junctions between groups of cells
- Cell to cell communication (receptors)
- Channels for passive transport to allow hydrophilic particles across
- Pumps for active transport

Some cells don't have a lot of proteins like myelin sheath cells
Others do, like mitochondria or chloroplasts

Cholesterol
- Type of lipid that belongs to lipids
- Has a hydrophilic hydroxyl group that can reduce membrane fluidity and permeability to some solutes

Endocytosis
- Fluidity of membranes allows for materials to be taken into cells by endocytosis
- Can take in food particles or nutrients

Vesicle movement in cells
- Just move materials around everywhere

Exocytosis
- Vesicles fuse with the membrane to expel stuff

particles move across membranes by simple diffusion, facilitated diffusion, osmosis, and active transport

- Simple diffusion- happens for membranes if a particle is permeable
    - Diffusion- spreading of particles in liquids and gasses. Move down the concentration gradient
- Facilitated diffusion- ions that cannot diffuse between phospholipids can pass into cells if there are channels
- Osmosis- movement of water through the membrane
    - Aquaporins speed it up a lot
- Active transport
    - Uses ATP to pump against concentration gradient
    - Attaching a phosphate to these proteins changes its shape.

Active transport of sodium and potassium in axons

- Axon- part of neuron. Convey messages from one part of the body to another in an electrical form called a verve impulse
    - Nerve impulses rely on sodium and potassium ions across the axon membrane
- Sodium potassium pump
    - "salty banana"
    - Pumps 3 sodium ions OUTSIDE of the cell with use of ATP; pumps 2 potassium ions INSIDE of the cell
- Typically, outside of axons are positive and the inside is negative (more positive ions outside than inside)
    - If this charge changes, potassium ion channels open, allowing the potassium to move inside the cell, before closing.

Osmolarity

- Isotonic
    - Osmolarity of outside and inside cell are the same, no net flow of water
- Hypertonic solution
    - Osmolarity of outside cell is higher, so water leaves the cell. This creates a "spiky" appearance
- Hypotonic solution
    - Osmolarity of outside cell is lower, so water enters the cell. This can puff up the cell and even blow the cell up.
- Normal saline
    - Term for solutions that are isotonic with cells

Cell division and the origin of cells

- Cells can be formed only from division of other cells

Spontaneous generation and the origin of cells

- Cells cannot suddenly "appear"
- For example, organisms will only grow on rotting meat if the meat is exposed to air

Spontaneous generation and Pasteur's experiments

- Organisms do not appear spontaneously

Origin of the first cells

- Arose from non-living material

Main stages

1. Production of carbon compounds such as sugars and amino acids
    a. Miller and Urey found that amino acids could be formed in early atmosphere
2. Assembly of carbon compounds into polymers
    a. Could have formed around deep-sea vents
3. Formation of membranes
    a. Phospholipids could have formed vesicles
4. Development of a mechanism for inheritance
    a. Needed genetic information…. Somehow

Endosymbiosis and eukaryotic cells

- Endosymbiotic theory
    - Mitochondria were once free living prokaryotic organisms that developed aerobic respiration
    - A large prokaryotic gobbled one up and kept it alive for energy production
- Proof
    - Have own genes (circular DNA like prokaryotes)
    - Have own ribosomes (classified as 70s)
    - Transcribe their own DNA
    - Only produced with the division of other mitochondria/chloroplasts

The role of Mitosis

- Mitosis allows cell to divide into 2 daughter cells, each genetically identical to each other.

Phases of Mitosis

1. Interphase
    a. Highly active phase
    b. DNA replication and protein synthesis
    c. Increase in number of mitochondria/chloroplasts
    d. Has 3 stages:
        i. G1 phase- growth
        ii. S phase- DNA replication
        iii. G2- more growth
        iv. G0- phase if cell isn't going to divide. Can be temporary/permanent
    e. Supercoiling of chromosomes
        i. DNA is naturally extremely long. For the cell to divide, they must be condensed
        ii. DNA wraps around histones in a process called supercoiling
    f. Visuals
        i. Chromosomes are visible in the nuclear membrane
2. Prophase
    a. Chromosomes coil
    b. Nucleolus breaks down
    c. Microtubules grow from Microtubule Organizing Centers (MTOC) to form the spindle
    d. Nuclear membrane breaks down
    e. Visuals-
        i. You should see the nuclei visible
3. Metaphase
    a. Microtubules grow and attach to centromeres on each chromosome (centers)
    b. Chromosomes are aligned at the metaphase plate
    c. Visuals
        i. Chromosomes are all aligned at the center and not inside the nuclear membrane

4. Anaphase
    a. Centromeres divide, allowing the sister chromatids to separate.
    b. Spindle microtubules pulls the chromatids to opposite poles in the cell
    c. Visuals
        i. 2 groups of V shaped chromatids pointing to the poles
5. Telophase
    a. Chromatids are pulled in a tight group and nuclear membrane reforms
    b. Chromosomes uncoil and nucleolus reforms
    c. Cells enter interphase again

Mitotic index
- Ratio between number of cells in mitosis in a tissue and the total number of observed cells
- Formula:
    - Mitotic index = (number of cells in mitosis)/(total number of cells)

Cytokinesis
- For animal cells
    - Plasma membrane is pulled towards center of the cell to form a cleavage furrow
        - Done with a ring of contractile protein (actin and myosin)
- For plant cells
    - Vesicles with cellulose move towards the center and form the **middle lamella**, with two players of membrane and a cell wall.

Cyclins and the control of the cell cycle
- Cyclins
    - A group of proteins that ensure the right things are done so the cell can divide
    - Cyclins bind to cyclin-dependent kinases
        - These kinases become active, attaching phosphate groups to other proteins
            - These proteins become activated, carrying out tasks important for the phases of the cell cycle
    - 4 main types
        - Cyclin D- G0 to G1 and G1 to S
        - Cyclin E- prepares DNA duplication in S phase
        - Cyclin A- activates DNA replication in S phase
        - Cyclin B- helps assemble mitotic spindle and other tasks for mitosis
    - "DEAB"

Tumor formation and cancer
- Tumors- abnormal groups of cells
    - Most of the time they are safe (benign)
    - Other times they can move around the body (malignant)
        - Metastasis
            - Budding off of cells from a malignant tumor