Cell Biology, Chemistry, Cellular Reproduction, Genetics & Heredity, Scientific Reasoning

Cell Biology

The cell is the fundamental unit of life. There are two types of cells:
- Prokaryotes (single cell bacteria)
  A. Simple in structure, don't have nuclei
  B. Don't have organelles the way that eukaryotic cells do
  C. DNA floats in cytoplasm, cells is encased in a cell wall.
  D. They often have Flagella, little hair-like structures that they use for transportation. And they have pili, they are like stubby hairs that stick out all over the cell to help with interaction with nearby cells, transfer of DNA between cells

- Eukarotes (multicellular, animal/plant cells)
    - Have a nucleus and many organelles
  - Nucleus = contains DNA
      - Nucleoli is within the nucleus, it makes ribosomes
  - Ribosomes = protein synthesis
  - Vacuole = stores water and cellular waste
  - Mitochondria = generates energy for the cell (ATP)
  - Endoplasmic reticulum:
      Rough Endoplasmic Reticulum
        a. Has ribosomes
        b. Processes proteins made by ribosomes
      Smooth Endoplasmic Reticulum
        a. No ribosomes
        b. Processes and makes lipids (fats) and steroid hormones
    - Lysosome = breakdown of many different substances, especially hydrolytic enzymes. (Garbage disposal)
    - Cell wall = support and structure for PLANT CELLS
    - Cell membrane aka plasma membrane = cell structure, balances what is allowed to enter/exit the cell based on selective permeability
    - Golgi apparatus = (Fedex center of the cell) Packages and processes proteins, receives vesicles sent by rough endoplasmic reticulum, processes/modifies with enzymes, and sends them to other parts of the cell
    - Vesicle = moves materials in a cell
    - Chloplast = the mitochondria equivalent for plant cells. Uses photosynthesis to produce ATP (energy)
    - Cytoskeleton = cell shape and structure. Made up of microfilaments, intermediate filaments, and microtubules. Aids in cell movement and transferring materials.

Cell Theory

1. All living organisms havw 1 or more cells
2. The cell is the basic unit of structure and organization
3. Cells are formed from pre-existing cells

Macromolecules

4 basic types of macromolecules (biomolecules):

1. Lipids (fats)
2. Carbohydrates (sugars)
3. Proteins
4. Nucleic Acid

Monomer = the most basic form of a macromolecule
Polymer = complex form of a macromolecule

Carbohydrate:
Monomer = monosaccharide (glucose, fructose, galactose)
Polymers = Disaccharide, polysaccharide (cellulose, Sucralose, etc

Lipid:
Monomer = fatty acid
Polymer = diglyceride, triglyceride

Protien:
Monomer = amino acid
Polymer = polypeptides

Nucleic Acid:
Monomer = nucleotide
Polymer = RNA, DNA

Cellular Respiration = How the cell makes energy

Animal Cell

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + 38\ ATP$
glucose oxygen carbon dioxide water energy

Step 1a = Glycolysis
glycolysis = breaking up glucose. It begins in the cytoplasm. Breaks down the carbon backbone of glucose. Glucose is converted into pyruvate. This process produces 2 NAD+ (oxidizes into NADH), 2 Net ATP (Generates 4 ATP but uses 2 ATP, so net output is 2 ATP).

oxidation = loss of electrons, reduction = gain of electrons

Step 1b = pyruvate oxidation
After glycolysis, pyruvate undergoes oxidation to become acetyl co-a. It also loses a carboxyl group (decarboxylation), produces 2 co2, 2 NADH, 2 Acetyl co-a (2 acetate, 2 co-enzyme a)

Step 2 = Krebs Cycle
Takes place in the mitochondria, requires oxygen to work. 2 oxaloacetate + 2 acetate = 2 citric acid. Citric Acid turns into 2ATP, 4Co2, 6 NADH, 2FADH2

Step 3 = electron transport chain
Oxygen is required for this to work
NADH carries electrons to be pulled through the mitochondrial membrane to create water and NADH+ (NADH loses its electron) Hydrogen ions in the membrane space creates a hydrogen ion gradient. Hydrogen ions leave the membrane through ATP synthase, which generates 34 ATP.

Plant Cell (photosynthesis)

light dependent reaction (phase 1)
Photosystem 2
- Chlorophil absorbs sunlight
- Sunlight energizes electrons
- Electrons pass through electron transport chain
- hydrogen ions move from stroma to thylakoid space, creating hydrogen ion gradient
- water splits into hydrogen ions and oxygen (photolysis)
- oxygen diffuses out into the environment
- hydrogen ions from photolysis contribute to hydrogen ion gradient, replacing electrons that were initially lost

Photosystem 1
- As light energizes electrons they are accepted by NADP+, reduced to become NADPH
- NADPH is sent to the stroma
- hydrogen ions in the gradient go through ATP synthase to generate ATP

Calvin cycle (does not need light aka “dark” reaction/ light independent reaction
- takes place in stroma

Carbon Fixation
- Robisco (enzyme) chemically combines carbon from CO2 to ribolose bisphosphate (RUBP)
- new compound splits to form 2 PGA (phosphoglyceric acid)

Reduction
- ATP and NADPH turns PGA into G3P (glyceraldehide 3 phosphate, 1/2 glucose molecule)
- Some G3P is converted into glucose, other G3P goes back into cycle (regeneration)

Regeneration
- Remaining G3P is converted back to RUBP to keep the cycle going
- the cycle will keep going until materials from the light reaction runs out

Cellular Reproduction

Cell life cycle has 4 stages:
G1: Cell is growing / G0: Cell is resting
S: DNA is replicating
G2: Cell is preparing for division
M: Cell is dividing

G1, S, and G2 = Interphase

M = Mitosis/Meiosis

Mitosis = asexual reproduction

Broken down into 5 steps: Prophase, Metaphase, Anaphase, Telophase, and Cytokenesis

Prophase = DNA condenses into chromosomes, centomeres appear and the nuclear envelope degrades

Metaphase = Chromosomes migrate to the middle of the cell (metaphase plate), microtubules attach to centromeres

Anaphase = Microtubules pull chromosomes apart to opposite ends of the cell via separin

Telophase = Nuclear envelope reforms, motor proteins eat microtubules, chromosomes de-condense.

Cytokinesis = Contractile ring splits cell into two daughter cells

Meiosis = sexual reproduction
gamete (diploid cell = haploid + haploid (egg+sperm)

happens in two stages: meiosis 1 and meiosis 2

Meiosis 1

Prophase 1: Nuclear envelope disappears, replicated chromosomes become visible and haploids intertwine, causing genetic crossover between tetrads.

Metaphase 1: Alignment of chromosomes along metaphase plate, tetrads align spindle apparatus

Anaphase 1: Homologous pairs split, migrates to opposite ends of the cell

Telophase 1: Nuclear envelope reforms, chromosomes become less visible

*There are now cells with genetic information from both of the original haploid cells, but the cells need to divide again to split the chromosomes into sister chromatids

Prophase 2: DNA condenses into chromosomes, nuclear envelope degrades

Metaphase 2: chromosomes migrate to the middle of the cell

Anaphase 2: single unpaired chromosomes are pulled apart of opposite poles of the cell via sparing

Telophase 2: division is complete

Oogenesis: 1 mature egg cell + 3 polar bodies
spermatogenesis: 4 sperm cells

DNA Replication- happens during active cell division (M Phase)

DNA Helicase unzips the double helix structure
Primase begins the copying sequence by using RNA nucleotides
DNA Polymerase 3 copies the leading strand in the 5' to 3' direction, starting after the sequence that primase created
DNA Ligase bonds and seals the okazoki fragments that copy the lagging strand in the 3' to 5' direction via phosphodiester bonds
DNA Polymerase 1 replaces the RNA nucleotides that primase started with DNA nucleotides

Protein Synthesis

Two steps: Transcription and Translation

Transcription = copying of DNA into single strand RNA
Translation = RNA is translated into protein

Transcription:
- DNA is copied without being damaged, enables DNA to serve as blueprint. Way for DNA to communicate with the cell. End result is single strand mRNA (messenger RNA) that is constructed in the nucleus and shipped to the cytoplasm for further processing.
- Begins with initiation
- RNA polymerase 2 binds to promotor on DNA, unwinds double helix and gives RNA nucleotides a template strand of DNA from 5' to 3'
- Ends when RNA polymerase 2 reaches a terminator sequence and detaches.

Translation:
- Happens in ribosomes
- Starts with codon recognition. Codon = set of 3 nucleotides of RNA strand
- 5' end of mRNA binds to ribosome
-tRNA (transfer RNA) carries anticodon, arrives at A and P sites
-tRNAs brings with amino acids with them,
- Translocation releases tRNA, which leaves behind anticodon and amino acid
- Two adjacent amino acids form peptide bonds.
- As tRNA moves down the stand, they bring anticodons and amino acids. A string of amino acids is formed (multipeptide chain aka protein)
- This continues until ribosome reaches a stop codon on the RNA strand

Genetics

Gregor Mendel = father of genetics
↳ heredity experiments

gene = allele (trait from parent 1) + allele (trait from parent 2)
genotype = set of genes someone carries
- homozygous = if both alleles are the same
- heterozygous = if alleles are different
phenotype = how the gene is physically expressed
- dominant phenotype = expressed
- recessive phenotype = not expressed

recessive trait is expressed when it is a homozygous recessive genotype

Chemistry

When looking at the periodic table, remember that groups (columns) have the same number of valence electrons.

Rows have the same energy levels (electron shells)

Atom = nucleus + electron cloud
- Nuclues hold neutrons and protons (overall positive charge)
- Electron cloud has electrons (overall negative charge)

Protons have positive charge, determines atomic number
Electrons have negative charge, determines reactivity
Neutrons have neutral charge, determines atomic mass (based on average isotope)

atomic number = # of protons
#of protons = # of electrons (when atom is not an ion)
# of neutrons = atomic mass - protons

Isostopes refers to atoms with the same atomic number but different masses (different number of neutrons)

Ionic bonding = transfering of electrons Metal/nonmetal
Cation = positive ion
Anion = negative ion

Covalent bonding = sharing of electrons, sometimes creates polar molecules (molecules that have partial positive or negative charges at opposite ends)
nonmetal/nonmetal

States of Matter

Solid --> Melting --> Liquid --> Boiling --> Gas
Energy is being released

Solid --> Gas = Deposition

Gas --> Condensating --> Liquid --> Freezing --> Solid
Energy is being absorbed

Gas --> Solid = Sublimation

Chemical Properties = Characteristics that require chemical change in composition, needs to be tested in experiment.
- burning
- rusting
- corrosion
- reactivity
- flammability

Physical properties = characteristics that can be observed without changing composition
- color
- mass
- volume
- size
- shape
- amount
-malleability
- boiling point
- conductivity
- specific heat capacity

Cohesion = how well something "sticks" to other things
Adhesion = how well something "sticks" to itself

Intensive properties = properties that do not rely on the amount of a substance (ex: color, density, melting point)

Extensive properties = properties that are dependent on the amount of a substance (ex: mass, size, volume)

Chemical Reactions

reactant = the "before" substance(s) of a reaction
product = the "after" substance(s) of a reaction

Synthesis = combining (A+B --> AB)
Decomposition = taking apart (AB --> A + B)
Single Replacement (AB + C --> AC + B)
Double Replacement (AB + CD --> AC + BD)
Combustion (Fuel + Oxygen —> Water + CO2 + light/heat)

Exothermic reaction = release energy

Endothermic reaction = absorb energy

Conditions that affect chemical reactions:
- pressure
-presence of catalysts (catalysts lower the activation energy needed for the reaction
- temperature
- concentration of reactants

Acids and Bases

Acids = Ionize hydrogen ions, turn litmus papers red, have sour taste, produce salt precipitates when reacting with bases (Acids accept protons/hyrdrogen ions)

Bases = alkaline substances, bitter taste, soapy texture, produce hydroxide ions in solution (OH-), turns litmus papers blue (bases donate their protons/hydrogen ions)

Highly reactive acids/bases are strong because all of their atoms ionize in solution.
Weak acids/bases onle have a few of their atoms ionize/disassociate in solution

pH scale goes from 0 - 14, measures how many hydrogen ions are in a solution, the more H+, the lower the pH
>7 = acidic
7 = neutral (water)
<7 = basic

Scientific Reasoning

Scientific Method = Formulating problem —> Forming hypothesis —> Conducting experiment —> Analyzing data —> Drawing conclusion

Control group = Normal state of the variable being manipulated
Independent variable = The factor in the experiment that is being changed
Dependent variable = the factor that is being measured/recorded
Constant = factors in an experiment that stay the same