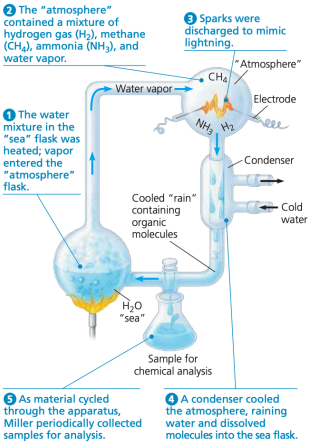
Unit 1. The Chemistry of Life

1. **Experimentation** (independent vs. dependent, hypotheses)
2. **Basic chem** (atoms, bond types, structure = function)
3. **Properties of water**
    a. Polar covalent bonds, cohesion/adhesion, high specific heat, evaporative cooling, ice floats, versatile solvent (forms hydration shell)
    b. Hydrophobicity vs. Hydrophilicity
    c. Basic solute math (moles, molarity)
    d. pH
4. **Carbon**
    a. Miller-Urey experiment – abiotic synthesis of organic compounds
    b. Carbon forms diverse structures
    c. Types of isomers (esp enantiomers)
    d. 6 functional groups (hydroxyl, carbonyl, carboxyl, amino, sulfhydryl, phosphate, methyl)



5. **Macromolecules**
    a. Monomers vs. polymers, dehydration/condensation reaction vs. hydrolysis
    b. Sugars – mono-, oligo-, poly-saccharides, aldose vs. ketose, types of glycosidic linkages (1-4 vs. 1-6, alpha vs. beta), glucose vs. cellulose, types of starch + glycogen, chitin
    c. Lipids – fats/triglycerides, phospholipids, steroids, hydrophobic, saturated vs. unsaturated properties, ester linkages,
    d. Proteins – basic amino acid structure, AMINO ACID PROPERTIES, proline/glycine break helices, cysteine has disulfide bridges, levels of protein structure, hydrophobic interactions, chaperonins aid folding
        i. Hydrophobic: **GLAMP FVIW**
        ii. Hydrophilic: **S**anta **N**ever **Q**uits **C**hr**Y**s**T**mas
        iii. Acidic: **DE**ath is negative
        iv. Basic: **His Lys Arg** basic
        v. Essential: **VH MILK**? **WTF**?!
        vi. Phosphorylated: **STY**
        vii. Aromatic (absorb UV): **W**hi**F**f**Y**
    e. Nucleic acids – DNA/RNA function/structure, purines (**pur**e **A**s **2 G**old rings) vs. pyrimidines (purines are A and G and have 2 rings)

Unit 2: The Cell

1. Basic microscopy
    a. Light (able to study live cells but usually requires fixation + staining that kills the tissue, diff techniques like phase-contrast, use of fluorescence, etc. make it better) <<< Scanning electron microscopy (SEM) – looks 3D and shows topography, uses electron beam < Transmission electron microscopy (TEM) – sample coated in heavy metals to enhance electron density of certain parts, electron beam passed through
2. Cell fractionation/differential centrifugation
3. Larger surface area: volume ratio is better for exchange
4. Eukaryotic vs prokaryotic cell
    a. Both have outer membrane, cytosol, and ribosomes
    b. Nucleus vs. nucleoid
    c. Eukaryotic has membrane-bound organelles

    d. Prokaryotic has peptidoglycan in cell walls
    e. Eukaryotic larger
5. Organelles
    a. Nucleus – double membrane, has pores
    b. Nucleolus – can be multiple, synthesizes rRNA, combines with proteins to make ribosomes
    c. Ribosomes – not technically an organelle because it's not membrane-bound; free (in cytoplasm) vs. bound (on rough ER) ribosomes
    d. Vesicles (more ab them in other organelle areas) – fusion
        i. V-SNARE proteins on vesicle, T-SNARE proteins on plasma membrane, fuse to become Cis-SNARE
    e. Endoplasmic reticulum (ER) – tubules and cisternae, continuous with nuclear membrane, smooth ER (lipid synthesis, metabolism, detoxification, Ca2+ storage) vs. rough ER (produces secreted proteins, makes membrane)
    f. Golgi apparatus – modifies/stores ER products, cisternae, directionality (cis face receives from ER/trans face sends vesicles elsewhere)
        i. Cisternal maturation model – cisternae move
        ii. Vesicular transport model – cisternae stable, COPI vesicles move to ER, COPII vesicles move to Golgi, clathrin (triskelion shape) vesicles move to plasma membrane
    g. Lysosomes – sac of hydrolytic enzymes only found in animals, helps with phagocytosis (merges with food vacuole) and autophagy, Tay-Sachs disease is a result of missing an enzyme that digests lipids
    h. Vacuoles – large vesicles, contractile vacuoles maintain water balance in unicellular protists, vacuoles help with hydrolysis in plants and fungi, small vacuoles in plants may hold substances, big central vacuole is an energy-efficient way to grow plant by accumulating cell sap
    i. Endosymbiotic organelles – proto-eukaryotic cell engulfed aerobic prokaryotic cell, which became an endosymbiont with proof 1) double membrane 2) have own ribosomes and circular DNA 3) autonomous within cell
        i. Mitochondria – the powerhouse of the cell :) more in cell resp
        ii. Chloroplast – type of plastid (amyloplasts, a type of leucoplast, store starch, chromoplasts store carotenoids)
        iii. Peroxisomes – not clear where these come from, single membrane, has enzymes that remove hydrogens from stuff and add it to oxygen to make hydrogen peroxide, which other enzymes neutralize
            1. Glyoxysomes found in seeds
6. Cytoskeleton
    a. Microtubules
        i. Made from tubulin dimers, has plus and minus ends
        ii. Centrioles (only in animals) – 9 + 0 triplets
        iii. Cilia + flagella – 9 + 2 doublets
            1. Primary cilia – 9 + 0 doublets
        iv. Basal bodies – 9 + 0
        v. Motor proteins
            1. Bent by dyneins (-)
            2. Kinesins (+) walk; typically go towards membrane (anterograde)
    b. Intermediate filaments – only in some animals, bear tension, made of proteins like keratins, uber tough, form nuclear lamina
    c. Microfilaments – 2 chains of actin, muscular contraction/amoeboid motion/cytoplasmic streaming with myosin, cortical microfilaments underneath plasma membrane create cortex and helps bear tension, cores of microvilli in intestinal cells
7. Cell walls in plants – cellulose synthase makes cellulose microfibrils, embedded in

ground substance (polysaccharides and proteins); middle lamella between cells contains pectins (give jams/jellies their characteristic texture)

8. Extracellular Matrix
    a. Collagen
    b. Proteoglycans (protein core, carbohydrate attachments)
    c. Fibronectin and other glycoproteins attach cells to ECM
    d. Integrins transmit signals and connect ECM to microfilaments in cytoplasm
9. Cellular junctions
    a. Plasmodesmata
    b. Gap junctions
    c. Tight junctions
    d. Desmosomes
10. Membranes
    a. Nature of phospholipids is amphipathic
    b. Effects of temperature/degree of saturation/cholesterol on fluidity
11. Cellular transport
    a. Simple diffusion for small/nonpolar molecules and gasses
    b. Osmosis – like diffusion for water
        i. Hypotonic vs isotonic vs hypertonic, turgor pressure and plasmolysis in plant cells
    c. Facilitated diffusion – channel proteins and carrier proteins
    d. Active transport (requires ATP)
        i. Primary active transport
        ii. Cotransport/symport – combines one molecule going up and one molecule going down its respective concentration gradient
        iii. Countertransport/antiport – exchange where molecules move in opposite directions
12. Endocytosis (in bulk)
    a. Receptor-mediated
    b. Pinocytosis (fluids)
    c. Phagocytosis (big chunks)
13. Cellular communication (reception, transduction, cellular response)
    a. G-protein coupled receptors (GPCRs)
    b. Receptor tyrosine kinases (RTKs)
    c. Voltage/ligand gated ion channels
    d. Kinases, phosphatases, and scaffolding proteins
    e. Second messengers
        i. cAMP and adenylyl cyclase
        ii. PIP2 → DAG and IP3 (opens Ca2+, another second messenger's, channels)
    f. Apoptosis
14. Cell resp/fermentation (look at slides)
15. Photosynthesis (look at slides)
16. Cell cycle
    a. Chromosome structure
    b. Interphase (G1/G0, S, G2) and M phase
    c. Mitosis
        i. Spindle/asters grow from centrosome
        ii. Kinetochore microtubules vs nonkinetochore microtubules
        iii. Separase cleaves cohesins in anaphase
        iv. Cytokinesis – cleavage furrow in animals, cell plate in plants
    d. Differences with binary fission
    e. Dinoflagellates have intact nuclear envelope
    f. Diatoms and some yeasts have division within nucleus
    g. Controlled by cyclin/Cdk/MPF system; MPF peaks in anaphase

h. Checkpoints – G1 most important, S checks DNA, M checks attachment of kinetochores to spindle microtubules before anaphase
i. Cancer – evades apoptosis, no density-dependent inhibition or anchorage dependence

Unit 3. Genetics

1. Meiosis (look at slides)
2. Mendelian genetics (look at slides)
3. Chromosomal/molecular basis of inheritance/DNA replication (look at slides)
4. Central dogma (look at slides)
    a. Beadle and Tatum's experiments on Neurospora crassa
    b. Transcription
        i. Parts of transcription
            1. RNA polymerase (doesn't need primer)
                a. Only one type in bacteria
                b. At least 3 in euk, RNA poly II transcribes into mRNA
            2. Promoter – where RNA poly attaches and starts
            3. Terminator – ending sequence in bacteria
            4. Transcription unit – part of DNA downstream from promoter that is transcribed into RNA
        ii. Initiation – starts at start point
            1. Eukaryotes have TATA box in promoter and require transcription factors for RNA poly II to bind properly (RNA poly + all the transcription factors = transcription initiation complex)
            2. Prokaryotes have Pribnow box in promoter
        iii. Elongation – gene can have multiple RNA polys transcribing simultaneously
        iv. Termination
            1. Bacteria use termination sequence
            2. Rho-independent vs rho-dependent
            3. Polyadenylation sequence
        v. Important codons (AUG = start/methionine, UGA, UAG, UAA = STOP)
    c. RNA processing/post-transcriptional modifications
        i. 5' cap and poly-A tail
        ii. Splicing
            1. Alternative splicing
            2. Spliceosome – snRNAs
            3. Ribozymes
            4. Exon shuffling
    d. Translation
        i. tRNAs have anticodons to match codons and are recharged by aminoacyl-tRNA synthetases
        ii. Wobble pairing because of inosine
        iii. Know structure of ribosome (EPA sites) – bacterial (30 50 70) vs euk (40 60 80)
        iv. mRNA, initiator tRNA, and ribosome form translation initiation complex, brought together by initiation factors and using energy from GTP
        v. Protein synthesized N-terminus → C-terminus
        vi. Elongation – codon recognition requires 1 GTP, translocation requires 1 GTP
        vii. Termination – release factor adds water molecule instead of amino acid, requires 2 GTP
        viii. Polyribosomes/polysomes formed when multiple ribosomes are translating at the same time

e. Post-translational modifications
f. Proteins made in rough ER contain signal peptide recognized by signal-recognition particle (SRP) and is brought to ER membrane
g. Mutations
    i. Point mutations – one nucleotide changed
        1. Substitutions
            a. Silent
            b. Missense
            c. Nonsense
        2. Insertion/deletion
            a. Frameshift can cause missense or nonsense
            b. Multiples of 3 delete or insert entire amino acids
h. CRISPR - Cas9
    i. CRISPR is a gene that codes for a guide RNA
    ii. Cas9 is an endonuclease that uses the guide RNA to cut a certain point in the genome
    iii. Target gene is repaired
        1. Knock out–allow the cell's systems to repair DNA by adding random nucleotides; usually makes the gene product nonfunctional
        2. Introduce other DNA that can be incorporated at cut site

5. Gene regulation
    a. Repressible operons (Trp)
        i. Trp is the corepressor to the repressor
            1. Repressor encoded by regulatory gene trpR
    b. Inducible operons (lac)
        i. Allolactose is the inducer, which inactivates the repressor
        ii. cAMP binds to CRP/CAP, the activator, which allows more lac mRNA to be synthesized
    c. Histone acetylation vs DNA methylation
    d. Epigenetics
    e. Transcription factors
    f. Other RNAs (ncRNAs)
        i. miRNAs
        ii. siRNAs – RNAi
        iii. lncRNAs – X-inactivation
        iv. piRNAs – induce formation of heterochromatin to block expression of transposons
    g. Development
        i. Cell differentiation – cells become specialized
            1. Formation of mRNAs for tissue-specific proteins is first sign
                a. Albumin in liver
                b. Crystallin in lens
            2. myoD, a master regulatory gene, creates myoblasts
        ii. Pattern formation – tissues and organs find their places
            1. Body axes are established by positional information provided by cytoplasmic determinants and inductive signals
                a. Anterior-posterior = head-tail
                b. Dorsal-ventral = back to belly
                c. Right-left
            2. Drosophila example
                a. Homeotic genes
                b. Embryonic lethals – mutations that cause death before birth
                c. Maternal effect/egg-polarity gene – create cytoplasmic

determinants that override offspring's genotype
                i. Bicoid gene
                    1. Bicoid protein concentrated in anterior and diffuses toward posterior to create a gradient in the early embryo
                ii. Morphogen gradient hypothesis – morphogens establish body axis and other features
            iii. Morphogenesis – development of form
            iv. Unfertilized eggs have uneven distribution of cytoplasmic determinants
            v. Induction (signals sent between cells) induces differentiation
            vi. Determination – embryonic cell irreversibly committed to a fate
        h. Cancer
            i. Proto-oncogenes stimulate normal cell growth and division but can become oncogenes as a result of
                1. Epigenetic changes – loosening of region with proto-oncogene leads to heightened expression
                2. Translocations – proto-oncogene ends up near active promoter/control element, which increases transcription
                3. Gene amplification – too many copies of proto-oncogene made
                4. Point mutations – could make proto-oncogene product more active or more resistant to degradation
                5. Ras gene is an example
                    a. G-protein that relays signal from growth factor that stimulates cell cycle
                    b. Mutations can make it hyperactive
            ii. Tumor-suppressor genes prevent uncontrolled cell growth
                1. Repair DNA damage, control adhesion of cells to each other or extracellular matrix, inhibit cell cycle
                2. Ex. p53 – promotes synthesis of cell-cycle-inhibiting proteins when DNA damage is detected
                    a. "Guardian angel of the genome"

Unit 4: Evolution

1. Darwin
    a. Evolution = descent with modification
    b. Studied fossils
        i. Strata
        ii. Paleontology – Georges Cuvier
        iii. Hutton and Lyell – geologic processes gradually change Earth
    c. Aristotle believed in the scala naturae and fixed species
    d. Carolus Linnaeus developed a classification system
    e. Lamarck's Hypothesis of Evolution
        i. Use and disuse shape body
        ii. Inheritance of acquired characteristics
        iii. Organisms have innate drive to become more complex
    f. Darwin voyaged on the HMS Beagle and observed organisms
        i. Adaptations enhance survival/reproduction
        ii. Natural selection
        iii. Artificial selection – humans breed organisms for desirable traits
2. Homology – similarity in structures due to common ancestry
    a. Homologous structures – arms, forelegs, flippers, wings of mammals
    b. Vestigial structures
    c. Analyzed with evolutionary tree
    d. Convergent evolution creates analogous structures

3. Fossil record
    a. History of cetaceans
        i. Odd toed ungulates = ROTH (rhinos, tapirs, horses)
        ii. Cetaceans came from even-toed ungulates
4. Biogeography (Pangaea)
5. Genetic variation makes evolution possible
    a. There is also nonheritable variation
        i. Nemoria moth caterpillars look diff depending on diet
    b. Sources of variation
        i. New alleles caused by mutation
            1. Heterozygote protection – maintains diversity
            2. Could result in neutral variation (doesn't help or hurt)
            3. Redundancy in codons beneficial against mutations
        ii. Altering gene number or position
            1. Duplication due to meiosis errors (unequal crossing over)
            2. Slippage during DNA replication
            3. Transposable elements
        iii. Rapid reproduction
        iv. Sexual reproduction
6. Hardy-Weinberg
    a. Conditions: PS 3M (large Population, no Selection, random Mating, no Mutations, no Movement)
7. Things that can alter allele frequencies
    a. Natural selection
        i. Adaptive evolution
    b. Genetic drift – frequencies fluctuate by chance, esp in small populations
        i. Founder effect
        ii. Bottleneck effect
    c. Gene flow
8. Natural selection
    a. Relative fitness – contributions made to gene pool relative to others' contributions
    b. Directional vs disruptive vs stabilizing selection
9. Sexual selection
    a. Sexual dimorphism – differences
    b. Intrasexual vs. intersexual selection
10. Balancing selection
    a. Frequency-dependent selection (scale-eating fish)
    b. Heterozygote advantage
11. Speciation – connects microevolution and macroevolution
    a. Biological species concept (generally accpeted) vs morphological species concept and ecological species concept
    b. Reproductive isolation
        i. Prezygotic – impede mating, hinder fertilization
            1. Habitat
            2. Temporal
            3. Behavioral
            4. Mechanical
            5. Gametic
        ii. Postzygotic – prevent zygote from becoming viable, fertile adult
            1. Reduced hybrid viability – frail offspring
            2. Reduced hybrid fertility – mules and hinnies are sterile
            3. Hybrid breakdown
    c. Allopatric speciation – populations separated
    d. Sympatric speciation – populations in same area

i. Polyploidy
    1. Autopolyploid – all chromosomes from same species
    2. Allopolyploid – hybrids
ii. Sexual selection
iii. Habitat differentiation

12. Hybrid zones
    a. Reinforcement – strengthen reproductive barriers
    b. Fusion – weaken reproductive barriers
    c. Stability – continued production of hybrids
13. Punctuated equilibrium vs gradual model

Unit 5 skipped (refer to usabo guide)

Unit 6 skipped (refer to usabo guide)

Unit 9: Ecology

1. Intro to ecology
    a. Types – Organismal, population, community, ecosystem, landscape, global
    b. Global climate patterns
        i. Determined by input of solar energy and Earth's movement
        ii. Seasonality
            1. Belts of wet/dry air move up and down as sun's again changes to create wet and dry seasons near equator
            2. Wind patterns create upwelling
        iii. Bodies of water
            1. Coastal regions wetter
            2. High specific heat moderates nearby climate
        iv. Mountains
            1. Rain shadows
        v. Effects of vegetation
            1. Forests absorb more heat (warming) but also transpire more, so they reduce surface temperature and increase rain
        vi. Microclimate
            1. Affected by shade, altering evaporation from soil, changing wind patterns
            2. Low lying ground in forests usually wetter
            3. Cleared areas have more climate extremes
            4. Abiotic and biotic factors influence
        vii. Climate change
            1. American beech range will move up or shrink
2. Terrestrial biomes
    a. Tropical rainforest – constant rainfall, lots of competition for light, highest animal diversity
    b. Desert – low and highly variable rain, hot or cold, lots of bare ground, nocturnal and water-conserving animals
    c. Savanna – warm, more rain than desert, in equatorial/subequatorial regions, large animals and lots of insects, scattered trees and lots of grass for grazing
    d. Chaparral – seasonal rain (rainy winters), shrubs and small trees, lots of plant diversity, evergreen leaves to reduce water loss, seeds of plants may only germinate after fire, browsers + amphibians + reptiles + birds + insects
    e. Temperate grassland (prairie) – cold winters and hot summers, wet summers, large grazers and burrowing mammals, grasses and forbs, quick fire recovery, deep, fertile soils
    f. Northern coniferous forest