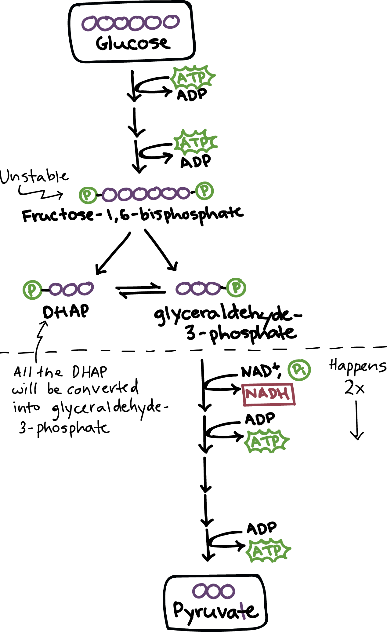
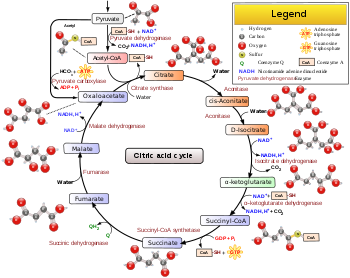
AP Biology Notes

1. Water
   1. Most important compound on Earth
   2. Hydrogen bonding because of its polarity
   3. Has a negative (oxygen) side and a positive (hydrogen) side
   4. If not polar, it would be gaseous (not good for us)
   5. Uses: homeostasis, waste removal, joint lubrication, body temperature, etc.
2. pH, Acids, Bases and Buffers
   1. pH = -log [H+] or -log [H3O+]
   2. Water 🡪 H+ + OH-
   3. Water + Water 🡪 H3O + OH
   4. Concentration of hydronium and hydroxide ions in normal room temperature water:
   5. [H3O] = 1.0 x 10-7 moles/L

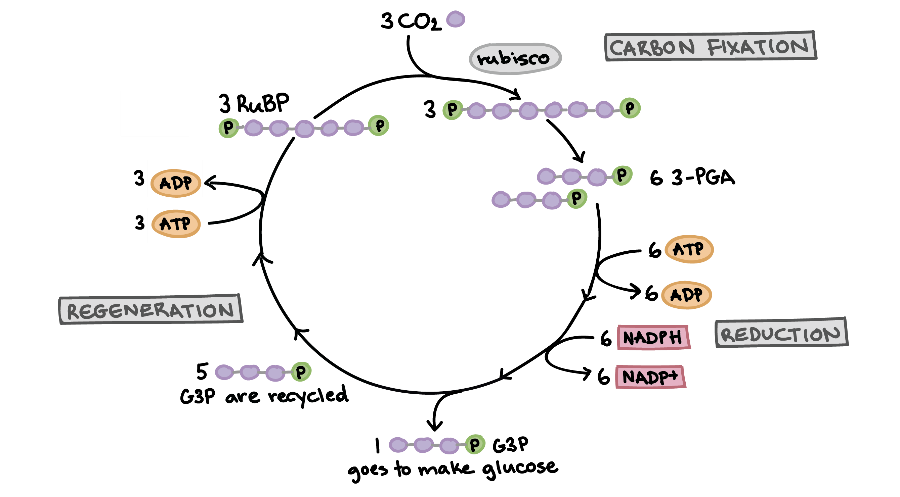
pH = -log [H3O+] = -log (1.0 x 10-7) = 7.00

* 1. As hydronium goes up, hydroxide goes down (more acidic)
  2. As hydroxide goes up, hydronium goes down (more basic)
  3. Acid: gives hydrogen, Basic: takes hydrogen, Salt: ionic compound
  4. Buffers resist changes in pH
  5. Hemoglobin and albumin regulate the amount of hydronium and hydroxide
  6. Carbonic acid (H2CO3) + water 🡨🡪 hydronium + bicarbonate ion (HCO3-)

1. Organic Molecules
   1. Carbon can form long chains, has four valence shell electrons
   2. Four macromolecules: carbohydrates, proteins, lipids, nucleic acids
   3. Carbohydrates: store and provide energy, building materials, cell identifying markers. Repeating simple sugars
   4. Proteins: building materials, enzymes to catalyze metabolic reactions. Repeating subunits of amino acids
   5. Lipids: long term energy storage, cell membrane structure, sometimes hormones. subunits of glycerol and fatty acids. Cholesterol is an example of a steroid, which are in the lipid category. They have four rings of carbon and are hydrophobic.
   6. Nucleic acids: genetic information, controls cell operations. Repeating subunits of nucleotides.
   7. Macromolecule construction: monomers linked together
   8. Dehydration synthesis: joins two monomers, produces H2O
   9. Hydrolysis: Breaks apart, requires H2O
2. Carbohydrates and Biological Polymers
   1. Carbs: three main functions: energy supply, structural molecules like exoskeletons, cellulose, plant walls, Identifying markers on cell membrane surfaces.
   2. Empirical formula: Cn (H2O) n
   3. Simple sugar: monosaccharide
   4. Hexose sugars: a glucose, b glucose, a mannose, b mannose.
   5. There are triose sugars, pentose sugars, heptose sugars.
   6. Deoxyribose (absence of OH) and ribose (includes OH)
   7. Disaccharide: two simple sugars connected via dehydration synthesis reaction (maltose, sucrose lactose made) If three connected, then it’s called trisaccharide.
   8. 2-10 simple sugars connected: oligosaccharide
   9. Multiple sugars include starch, glycogen, cellulose, lignin, chitin
   10. Galactose + glucose = lactose
   11. Glucose + glucose = maltose
   12. Polysaccharides: starch, cellulose, glycogen.
   13. Starch: long chains of glucose molecules, helices, may or may not be unbranched
   14. Cellulose: every other glucose is flipped over, long straight structure, tightly bound together by hydrogen bonds
   15. Glycogen: highly branched, animal equivalent of starch, long term glucose storage in liver and muscles.
3. Nucleic Acids
   1. Two types: DNA and RNA
   2. 5’ to 3’ (5 prime to 3 prime)
   3. Nucleotide structure: phosphate group connected to sugar connected to nitrogenous base
   4. Both are made from polymers of nucleotides
   5. Uracil does not hydrogen bond as strongly to adenine as thymine. This is why RNA could not form double helixes. May form hairpin loops sometimes.
   6. RNA is less stable. Th OH group makes the molecule more reactive compared to the single H on DNA.
4. Energy
   1. Hydrolysis and cellular respiration unlock energy from food.
   2. The energy in the universe is constant
   3. Every energy transfer increases the entropy (disorder) of the universe
   4. Carbohydrate hydrolysis – one molecule can be converted to thousands of carbon dioxide and water molecules
   5. Photosynthesis created carbohydrates and cellulose molecules from the chaotic forms of carbon dioxide and water.
   6. Photosynthesis comes at the expensive of the sun’s energy being released, which is constantly gaining entropy
   7. Gibbs free energy is available energy
   8. Enthalpy – total potential energy or heat content
   9. ∆G = ∆H – T ∆S (where G = Gibbs free energy, H = enthalpy, T = temperature and S = entropy)
   10. If G is positive, reaction is endergonic, so reaction is non-spontaneous. If G is negative, reaction is exergonic, so reaction is spontaneous
   11. If disorder greatly increases, a reaction is favoured to occur spontaneously
   12. If the reactants contain more energy than the products a spontaneous is also favoured.
5. Metabolic Pathways and Enzymes
   1. Very short-lived ATP supply (about 2 seconds)
   2. Cycles through two main forms – adenosine triphosphate and adenosine diphosphate
   3. Metabolic pathways – series of complex biochemical reactions to do a task
   4. For example, each product become will become the substrate for the next step in the reaction.
   5. In almost all metabolic reactions, and enzyme serves as catalyst.
   6. A coenzyme is something that aids enzymes to carry out catalysis. Not considered substrates. Non – protein organic molecules
   7. Cofactors are mostly metal ions or coenzymes
   8. Active site – region of enzyme where substrate molecules bind
   9. Inhibitors are molecules that bind to the active site of an enzyme to deactivate it.
   10. Activation energy – energy to start reaction, enzymes lower that activation energy
   11. Lock – enzyme and key/substrate
6. Hormones
   1. Nervous system – fast responses to new situations
   2. Endocrine system – slow but sustained communication. For example: insulin released in bloodstream after meal.
   3. Most hormones are produced in specific body parts and sent to specific locations
   4. Thyroxin is produced in the thyroid gland and sends signal to almost every cell in body
7. Enzymes: Vitamins and Coenzymes
   1. Vitamins are organic compounds required in small amounts in the diet. We cannot make vitamins.
   2. They boost immune system and support growth/development.
   3. Vitamins are smaller than enzymes. Vitamins are derivatives of coenzymes.
   4. Niacin (vitamin B3) is a component of NAD
   5. Fat-soluble
   6. Vitamin A (retinol): carrots, egg yolk, broccoli, dairy. Role: vision, immune system, reproduction. Deficiency: dry, brittle skin, epithelia of respiratory/urogenital tract, night blindness
   7. Vitamin E (tocopherol): wheat germ oil, sunflower seed, nuts, peanuts, hazelnuts, spinach. Role: antioxidant, red blood cell structure. Deficiency: anemia
   8. Water soluble
   9. Vitamin B1 (thiamine): whole grains, beans, peas, sunflower seeds, meat. Role: carbohydrate metabolism (part of coenzyme catalyst of pyruvic acid oxidation). Deficiency: Beriberi
   10. Vitamin C (ascorbic acid): citrus fruits, dark green vegetables, potatoes, tomatoes. Role: maintaining healthy connective tissue, blood vessels, gums, anti-oxidant. Deficiency: scurvy.
   11. Iodine – not a vitamin but a mineral. Deficiency: thyroid disorder
   12. Coenzymes help the enzyme catalyze a reaction
   13. They are organic non-proteins that bind to the active site of apoenzymes to form the holoenzyme. They bind using covalent bonds, can be reused.
8. Enzymes (continued)
   1. Most enzymes consist of a protein and a non-protein part.
   2. Non-protein = cofactor
   3. Catalytic activity of an enzyme is pH and temperature=sensitive (may cause shape changes of protein structure)
   4. Cofactors may be: organic groups permanently bound to enzyme, cations (activators) which temporarily bind to active site (gives positive charge), organic molecules (vitamins/coenzymes not permanently bound)
   5. Reactant 1 + enzyme 🡪 intermediate, intermediate + reactant 2 🡪 product + enzyme.
   6. Induced-fit hypothesis, molecules able to change shape to fit
   7. Above optimum temperature (usually 37.5 C) enzyme structure begins to denature.
   8. pH can also make/break intra/intermolecular bonds.
   9. Rate of reaction is proportional to the enzyme concentration, given that temperature and pH are kept constant and substrate concentration is high.
   10. Inhibitors – can be active site-directed (competitive) or non-active site-directed (non-competitive)
   11. Four principles of immobilization: covalent bonding to a solid support, adsorption onto an insoluble substance, entrapment within a gel, encapsulation behind a selectively permeable membrane.
   12. Amylase – starch to maltose. Includes salivary amylase and pancreatic amylase
   13. Maltase – maltose to glucose.
   14. Proteases – protein to peptides. Includes Pepsin and Trypsin
   15. Peptidases – peptides to amino acids
   16. Lipase – lipids to fatty acids and glycerol
   17. Nucleases – DNA/RNA to sugars and bases
   18. Most of the enzymes are made in the pancreas (including insulin and sodium bicarbonate) except maltase, peptidases and pepsin. Also, they all work inside the small intestine except for pepsin.
   19. Sodium bicarbonate neutralizes the acidity of fluid from stomach to pH 8.
   20. Thyroid (located at the bottom of the neck) produces thyroxin. A deficiency of this leads to lethargy, wait gain and metabolic problems.
   21. Bile emulsifies fat in the duodenum.
9. Taxonomy
   1. Monerans split into two separate kingdoms: eubacteria and archaebacteria
   2. Adoption of a three-domain system: bacteria, archaea, eukarya
   3. Abandonment of the kingdom level altogether
   4. 6-kingdom hierarchy
   5. Two prokaryotic kingdoms: eubacteria and archaebacteria, which are now domain bacteria and domain archaea
   6. Two of the four eukaryotic kingdoms (plants and animals)
   7. Prokaryotes: before a nucleus, first kind of cell to exist. Archaebacteria and eubacteria, including photosynthetic cyanobacteria
   8. Plentiful, diverse and inhabit all of Earth
   9. Prokaryotes are much smaller than eukaryotes, lack most organelles except ribosomes, vesicles and cell membranes, and do not have membrane-bound nucleus
10. Cell Structures
    1. Bacteria Cell:
    2. Flagella, pili or fimbriae
    3. Capsule – polysaccharide protects cell, often in pathogenic bacteria
    4. Cell envelope – gram-positive peptidoglycan or gram-negative lipopolysaccharide outside and peptidoglycan inside
    5. Gram-negative porin protein channel
    6. Membrane proteins
    7. Cytoplasm
    8. Ribosomes – protein synthesis; RNA is read and made into amino acids which assemble
    9. Storage granule – nutrients and reserves; glycogen, lipids, polyphosphate (maybe sulfur or nitrogen)
    10. Plasmid – circular DNA fragments, antibiotic resistance, can be transferred from different species,
    11. Nucleoid – no membrane, most of the DNA
    12. Genophore – bacterial chromosome, long DNA strand
    13. Animal Cell:
    14. Peroxisomes – protects cell from its own toxic hydrogen peroxide, break down to water and oxygen
    15. Centriole: nine groups of fused microtubules, three in each group
    16. Centrosome: microtubule production, in animal cells it is a pair of centrioles, replicates and forms spindles during cell division
    17. Golgi apparatus – membrane bound, packs vesicles and macromolecules
    18. Smooth ER: continuation of outer nuclear membrane, lipid and steroid hormone synthesis, breakdown of lipid-soluble toxins in liver, control of calcium release in muscle cell
    19. Rough ER – surrounded by ribosomes, protein made in ribosomes collect in the ER
    20. Cytoskeleton – transport, movement, structure. Microtubules, actin filaments, intermediate fibers
    21. Secretory vesicle: hormones, neurotransmitters, etc. are packaged and sent off.
    22. Nucleus – double membrane, nuclear pores
    23. Nucleolus – produces ribosomes
    24. Vacuole – membrane-bound sac, small in animals and used for intracellular digestion and waste release, large in plants and stores nutrients, water, waste, can act as lysosomes, regulates pressure
    25. Mitochondria – powerhouse of the cell, about size of bacteria, double membrane, folds of cristae, produces ATP
    26. Cytosol – mostly watery soup, proteins, that control cell metabolism including signal transduction pathways, glycolysis, intracellular receptors, transcription factors
    27. Cell membrane – phospholipid bilayer, proteins for receptors, sodium/potassium/calcium/chloride channels
    28. Ribosomes – packets of RNA, makes proteins, large and small subunits, mRNA moves along ribosome and tRNA adds amino acids to make protein chain
    29. Chloroplast – found in all higher plant cells, chlorophyll, double outer membrane, stacks of grana called thylakoids, absorbs sunlight for photosynthesis
11. Cell Membranes
    1. Provide compartments of certain regions to perform tasks
    2. Surfaces that enhance activity
    3. Transportation of substances
    4. Phospholipid bilayer
    5. Fluid Mosaic model
    6. The phospholipids and proteins are all moving
    7. Uncharged substances can move through a membrane, or really small
    8. Protein allows things into and out of cells
    9. Aquaporins allow water to go through
    10. Compartmentalization
    11. Having parts in the cell
    12. Increases surface area and specialization
    13. Rough and smooth ER, rough makes proteins, smooth makes lipids and steroids, regulates calcium concentration
12. Genetic Variation in Prokaryotes
    1. Three main ways: transformation, transduction and conjugation
    2. Transformation:
    3. Principle discovered in 1928 by Fred Griffith
    4. 1944 – Oswald Avery, Colin Avery, Maclyn McCarty experimented and found transformative agent was DNA
    5. Free segments of naked DNA pass through pores in bacteria cell membrane (adhesion zones)
    6. It is a rare event, but can be preserved by natural selection
    7. Transduction:
    8. Phages transport bacterial DNA from on to another
    9. The DNA gets pasted onto the gene of another bacterium
    10. Conjugation:
    11. “Bacterial Sex”
    12. One bacterium sends a pilus (singular pili) to another bacterium
    13. Cytoplasmic connection allows for DNA to be passed through
    14. Reproduction = new cells with combined genes from two cells
    15. Antibiotic resistance
    16. Genetic variations: DNA: codons of triplets which code for mRNA
13. Membranes
    1. Provide boundaries between cell and environment
    2. Provide boundaries between organelles
    3. Red blood cell – protein and phospholipid
    4. Phospholipid bilayer
    5. Proteins, which may contain hydrophilic and hydrophobic portions, may lie within the interior of the membrane
    6. Peripheral membrane protein
    7. Glycoprotein
    8. Cholesterol
    9. Protein channel
    10. Glycolipid
    11. Integral membrane protein
    12. Membranes are fluid
    13. When two cells joined together via Sendai virus, their membranes flow around each other
14. Surface Area to Volume Ratio
    1. Vesicles, waste, protein, etc. need to move around the cell. If volume is too large, it will have a difficult time doing so.
15. Osmosis
    1. Higher to lower concentration
    2. Does not work if both solute and solvent channels are open
    3. Measure changes in volume
16. Water Potential
    1. Always move from higher to lower concentration
    2. Expresses potential energy of water in an environment, compared to that of pure water at room temperature
    3. Normal atmospheric pressure: 1 bar
    4. Pure water: 0 bars
    5. Pressure potential
    6. Cell walls exert pressure on water inside, forcing it out
    7. ᴪ = ᴪs + ᴪp
    8. ᴪs = -iCRT
    9. I = ionization constant, (multiply by number of individual ions; for example: for NaCl, the I is 2)
    10. C = concentration in moles per liter
    11. R = pressure constant: 0.0831-liter bars / mol K
    12. T = temperature in Kelvin (273 + C)
17. Free Energy: Coupled Reactions
    1. Spontaneity depends on the change of free energy
    2. Reaction is spontaneous only if it is exergonic (G is negative)
    3. Many reactions are endergonic
    4. However, endergonic reactions use the energy of exergonic reactions to complete it
    5. Overall change in free energy will be negative
    6. Graph looks like an exergonic reaction followed by an endergonic reaction.
    7. ATP +H2O 🡪 ADP + Pi
18. Fermentation
    1. Two main types: alcohol fermentation and lactic acid fermentation
    2. Alcohol fermentation:
    3. Performed in cytoplasm of yeast
    4. Yeast-single cells fungi eukaryote
    5. Facultative anaerobes – with or without oxygen
    6. 1st step: 2ADP 🡪 2ATP
    7. 2nd step: 2 pyruvate 🡪 2CO2 + 2 acetaldehyde
    8. 3rd step: 2 ethanol
    9. During this process, NAD turns to NADH and vice versa
    10. Pyruvate → Acetaldehyde + CO2 → Ethanol
    11. Summary: Glucose + 2Pi + 2 ADP → 2 Ethanol + CO2 + 2 ATP
    12. Pyruvate – 3 carbon compound
    13. Acetaldehyde – 2 carbon
    14. Ethanol – 2 carbon
    15. Glycolysis occurs in cytoplasm
    16. Glucose enters cell by glucose transporter protein and goes through glycolysis pathway
    17. Addition of phosphate group by adding ATP to sixth carbon and first carbon
    18. The glucose turns into a fructose
    19. Glycolysis – splitting of glucose
    20. Glyceraldehyde – G3P
    21. Oxidation of NAD to NADH + H+
    22. Inorganic phosphate group is added to G3P, which is available
    23. Now 1-3 diphosphoglycerate (BPG)
    24. One phosphate group is harvested from BPG
    25. 2 ATP is produced
    26. G3P is re-arranged to 3PG and water is released
    27. Final phosphate is removed, and pyruvate created
    28. 2 ATPs are made by ADP
19. Lactic Acid Fermentation
    1. Also called lactate fermentation
    2. Regenerates NAD+ so that ATP production can continue
    3. Anaerobic, without oxygen
    4. Takes pyruvate into ethanol and lactate, produces CO2. Does this through yeast or muscles.
    5. Found in oxygen-depleted environments
    6. Muscles of people exercising
    7. Pyruvate to lactate reaction is a reversable equilibrium
    8. Summary: glucose + 2 Pi + 2 ADP 🡪 2 Lactate + 2 ATP
20. Cellular Respiration and Glycolysis
    1. Also called aerobic respiration
    2. Involves many coupled reactions
    3. Almost every step uses enzyme
    4. Four stages: Glycolysis, pyruvate 🡪 acetyl CoA, Krebs cycle, oxidative phosphorylation
    5. Glycolysis happens in the cytoplasm
    6. Glucose energy is released gradually to increase efficiency
    7. 36 ATP for every glucose
    8. Cellular respiration is oxidation-reduction reaction
    9. Oxygen gains electrons
    10. Glucose loses electrons
    11. Transfers energy in a stepwise fashion
    12. Nicotinamide adenine dinucleotide – NAD+ being reduce to NADH, typically through dehydrogenation reactions
    13. Flavin adenine dinucleotide (FAD) is a similar electron carrier which cycles to FADH2. Theses carriers are also coenzymes.
    14. Glycolysis:
    15. Ten step metabolic pathway
    16. Converts glucose to pyruvate
    17. Prelude to the citric acid cycle and electron transport chain in aerobic organisms
    18. Glucose + 2ADP + 2Pi + 2NAD+ 🡪 2 pyruvate + 2ATP + 2NADH + 2H+
    19. 2ATPs, NADHs and pyruvates are made
    20. Steps that need to be memorized:
    21. Glucose + ATP 🡪 Glucose 6-phosphate + ADP
    22. Rearranged to Fructose 6-phosphate
    23. Fructose 6-phosphate + ATP 🡪 Fructose 1, 6 diphosphate + ADP
    24. Makes dihydroxyacetone phosphate and Glyceraldehyde (three carbon)
    25. Glyceraldehyde (this is used instead of dihydro… phate) + NAD +P 🡪 1,3-Diphosphoglycerate + NADH + H+
    26. 1,3-Diphosphoglycerate + ADP 🡪 3-Phosphoglycerate + ATP
    27. 3-Phosphoglycerte 🡪 2-Phosphoglycerate (phosphate relocation)
    28. 2-Phosphoglycerate 🡪 phosphoenolpyruvate + H2O
    29. Phosphoenolpyruvate + ADP 🡪 Pyruvate + ATP
    30. Steps Y. to cc. is performed twice to obtain a net gain of 2 ATPs
21. Citric Acid Cycle
    1. Glycolytic pathway feeds into the citric acid cycle
    2. Begins with pyruvate, transfers from cytosol to mitochondria matrix
    3. Pyruvate turns into Acetyl CoA using Coenzyme A.
    4. Acetyl CoA turns into citrate, produces 1 NADH, 1 CO­2 (so in total, 2 NADH and 2 CO2)
    5. Citrate turns to isocitrate
    6. Isocitrate turns to a-ketoglutarate, produces 1 NADH, 1 CO­2
    7. Turns into succinyl-CoA, produces 1 NADH, 1 CO­2
    8. Turns into succinate, produces 1 ATP through CTP
    9. Turns into fumarate, produces 1 FADH2
    10. Turns into malate
    11. Turns into oxaloacetate, produces 1 NADH
    12. Two molecules of pyruvate 🡪 two cycles
    13. Total: 8 NADH, 2 FADH2, 2ATP, 6 CO­2
    14. Each NADH makes 3 ATP and each FADH2 makes 2, so a total of 28 ATP made in electron transport chain comes from the citric acid cycle



1. Electron Transport Chain
   1. Electron transport chain is the collection of molecules that line the inner mitochondrial membrane
   2. Mitochondria are organelles responsible for ATP production
   3. NADHand FADH2 pump electrons in channels, which force hydrogen protons to the intermembrane space. NAD turns into NAD + H, and FADH2 turns into FAD.
   4. Molecules are reduced and oxidized, including molecular oxygen. Water is produced from it
   5. Oxygen is split when it receives two electrons and two protons, creating water.
   6. Chemiosmosis:
   7. Hydrogen protons make an electrochemical gradient.
   8. Gradient makes ATP synthase rotate 360 revolutions/minute.
   9. FADH2 enters the chain at a slightly lower energy level, so it only produces two ATP
   10. Each NADH has enough energy to produce 3 ATP molecules
   11. Only 2 NADH comes from glycolysis:
   12. Outer mitochondrial membrane is impermeable to NADH, so NADH passes electrons to intermediate molecules that enter the mitochondria
   13. Electrons eventually passed to coenzyme Q
   14. This is how FADH2 comes in, so only two are made from cytosol NADH
   15. Poisons and pesticides can interfere electron transport chain
   16. Rotenone interferes with ubiquinone (coenzyme Q)
   17. Last step, electron transfer from cytochrome complex to oxygen, is blocked by cyanide and carbon monoxide
   18. DNP disrupts ATP synthase proton gradient
2. Intro to Photosynthesis
   1. Most important process in the world
   2. Fundamental energy supply for all organisms
   3. Is a redox reaction
   4. Electrons lost by water molecule, gained by glucose
   5. Light is not reactant nor enzyme, but energy source
3. Light Capture
   1. Surface layer of plants does not contain chlorophyll except for a pair that surround the stoma.
   2. Stoma allows gas exchange
   3. Parts that have chloroplasts: palisade cells, guard cells and spongy mesophyll
   4. May contain 1-150 chloroplasts
   5. Visible with light microscope
   6. Transmission electron microscopy – fine details
   7. Are bound by double membrane
   8. Interior filled with stroma, similar to matrix
   9. Pigments: chlorophylls and carotenoids are anchored to thylakoid single membrane
   10. Thylakoids make up stacks of grana
   11. Chlorophyll’s structure similar to hemoglobin
   12. Absorb red and blue wavelengths to make green
   13. Light energy shone on leaf, energy is collected by chlorophyll or by accessory pigment
   14. They are organized with enzymes into antennae complexes of 300 pigment molecules
   15. When a photon strikes one molecule, it excites an electron and raises energy state
   16. Excited electron returns to its normal energy level
   17. It emits electromagnetic radiation (photon) to neighboring molecule
   18. It goes along the line of molecules until it reaches a reaction center, excited electron goes to electron transfer chain
   19. Photosystem I – reaction center excited by light wavelength 700nm, p700, and photosystem II – excited by 680 nm, p680
4. Light-dependent Reactions
   1. Light dependent reactions first capture light photons to produce high-energy electrons for ATP production or NADPH
   2. Light independent – two pathways: non cyclic pathway and cyclic pathway, both make ATP but non-cyclic makes NADPH
   3. Plants use a combination of pathways, depending on light spectrum
   4. Non-cyclic and cyclic phosphorylation
   5. Non - cyclic:
   6. 1957 Robert Emerson
   7. Algal cells exposed to two different lights produced more O­2
   8. Synergism
   9. 1960s Robin Hill and Faye Bendall
   10. Two distinct photosystems that can work cooperatively
   11. PS I and PS II
   12. PS I - In the exterior or unstacked thylakoids (the stroma lamellae or frets)
   13. PS II – in interior stacked membrane of the grana
   14. Two photosystem work together when electron in chlorophyll A in PS II are raised to a high energy state
   15. Picked up by carrier molecules
   16. Plastoquinone moves protons across thylakoid membrane, concentrating them in lumen
   17. Plastocyanin diffuses through lumen and passes electron to PS I
   18. Osmotic gradient – ATP synthase produces ATP
   19. Water is split to replace electrons- - photolysis
   20. 2H­2O 🡪 4H + O2 + 4e
   21. PS I send excited electrons to through carriers with provides energy for synthesis of NADPH
5. Light-Independent Reactions
   1. Synthesis part of photosynthesis
   2. Make sugar and the essential ingredients such as 18ADP + 18Pi + 12NADPH + 6H
   3. ATP and NADPH are made to drive synthesis forward
   4. Research not available until radioactive isotopes were discovered after WWII
   5. 1945 Melvin Calvin at UC Berkeley
   6. Used 14CO2 to track location of carbon during fixation
   7. Through paper chromatography, they found the compound 3-phosphoglycerate
   8. They sought for a 2-carbon compound that could add to CO2
   9. 5 carbon compound could add to carbon dioxide and divide by two
   10. Calvin cycle is discovered
   11. For every six turns of the cycle, a glyceraldehyde-3-phosphate is skimmed off for glucose
   12. Rubisco – enzyme for carbon fixation in step 1 of the Calvin cycle.



1. Carbon Dioxide
   1. Rubisco – enzyme found in all aerobic photosynthetic organisms
   2. Most abundant protein on earth
   3. Catalyzes fixation reaction of Calvin cycle
   4. Photorespiration:
   5. Limitations – enzyme is also able to bin to oxygen with its active sites
   6. Oxygen competes with carbon dioxide
   7. Bad reaction – photorespiration
   8. Metabolic dead end, energy wasted
   9. Slowest enzymes on record
   10. 3-10 CO2 per second (typical: thousands)
   11. Evolution: rubisco cannot tell the difference because it was in carbon dioxide-rich environment before
   12. Rubisco might work at the perfect rate due to its bad discrimination
   13. Some say photorespiration does not decrease plant yield
   14. Photorespiration – reaction that happens that produces unneeded phosphoglycolate
   15. Plants can turn it into useful stuff, but ATP is needed
   16. It involves chloroplasts, peroxisomes and mitochondria
   17. CO2 primarily trapped in extracellular fluid around palisade cells and spongy mesophyll
   18. Higher [CO2] = lower photorespiration
   19. Stomata gas exchange
   20. Stoma with guard cell pair, which can close and open
   21. When there is light and water but no CO2, chemical signals activate proton pumps to establish a charge gradient across membrane
   22. K moves into cells, along with water
   23. Turgor pressure from water changes guard cell shape which opens stoma
   24. C4 photosynthesis – plants that has CO2 reservoir within plant leaf
   25. Hot dry climates
   26. All are angiosperms like corn, grasses, sugarcane, sorghum, millet, tumbleweed
   27. Carbon dioxide is picked up by PEP carboxylase enzyme and not Rubisco
   28. Reaction in mesophyll cells, and around mesophyll cells are chloroplast bundle sheath cells
   29. Bundle sheath cells get CO2 from 4-carbon organic acid like malate stored in mesophyll
   30. C4 pathway 10-60 times better than C3
   31. C4 – takes 30 ATPs to make one hexose sugar, higher than the 18 needed in Calvin cycle
   32. C3 pathway better in low light and temp.
   33. CAM plants – temporarily separates carbon capture from Calvin cycle
   34. Crassulacean acid metabolism, also found in succulents
   35. Effect similar to C4
   36. Stomata closed in day, open at night, carbon fixation to 4-carbon acid oxaloacetate
   37. Converted to malate, stored in vacuole
   38. Stored malate feeds CO2 to Calvin cycle
2. The Cell Cycle
   1. Cell theory – al living organisms are made out of cells which come from pre-existing cells
   2. Interphase is everything else (most of the cell’s life)
   3. DNA is a messy bunch unless it’s mitosis, when they form chromosomes
   4. Four stages of mitosis plus cytokinesis
   5. Interphase: first gap phase, DNA synthesis phase, second gap phase
   6. Haploid – single chromosomes, one copy, N
   7. Diploid – double chromosome pairs, 2N
   8. Chromosomes X shape after S phase
   9. Centromere in the middle of chromosome
   10. Centrosomes – organelles that create spindles
   11. IPMAT – interphase, prophase, prometaphase, metaphase, anaphase, telophase
   12. Telophase is where new nuclei is formed
   13. Cytokinesis – cytoplasm divides in half
   14. Cancer cells reproducing outside control
   15. G1 – first growth phase
   16. S phase – DNA replication
   17. Cell continues to prepare
   18. Identical copy – sister chromatid
   19. Epithelial cells divide twice a day while nerve cells do not divide at all
   20. Injury promotes cell division
   21. Chemical timing signals such as CDK enzyme (cyclin dependent kinase)
   22. CDK and cyclin combine with mitosis promoting factor (MPF)
   23. Discovered 1970 by Yoshio Masui and Clement Markert
   24. Concentration of cyclin fluctuates, but when it reaches peak level it influences CDK
   25. Cyclin is destroyed (negative feedback)
   26. Checkpoints in cell cycle
   27. G1, G2, Metaphase checkpoints
3. Mitosis
   1. Form of nuclear division: prophase, prometaphase, metaphase, anaphase, telophase
   2. Prophase:
   3. Chromosomes become visible
   4. Coiling of DNA and histones
   5. Chromosomes are two identical chromatids, connected by centromere
   6. Star-like array of microtubules extending outward in all directions
   7. Prometaphase:
   8. Disappearance of nucleolus and the dissolution of the nuclear envelope
   9. On the centromeres are kinetochore protein complexes
   10. The get attached to the mitotic spindles
   11. Metaphase:
   12. Chromosomes are all lined up at the equator of the cell
   13. Spindles pulling on opposite ends
   14. Anaphase:
   15. Centromeres split and are pulled by shortening microtubules
   16. Spindles are also elongated as the cell stretches, including the replication of organelles
   17. Telophase:
   18. Spindles disintegrates, nuclear envelopes and nucleoli reappear, chromosomes re-condense
   19. Cytokinesis:
   20. Two daughter cells separate
   21. Microfilaments cause the cell membrane to furrow, pinching the cell
   22. Plants cells: vesicles are sent from the Golgi to middle
4. Mitosis contrasted with Meiosis
   1. Homologous chromosomes pair up, cross over and exchange genes
   2. Another division occurs which results in four haploid cells
   3. Has half the chromosomes
   4. Fertilization is after meiosis
   5. Two haploid cells unite to form a diploid zygote
   6. Genes are shuffled
5. Meiosis
   1. Essential for sexual reproduction
   2. Fusion of two gametes
   3. Fusion of highly dimorphic gametes
6. Meiosis, Fertilization and Heredity
   1. Trait inheritance
   2. Crossing over
   3. Independent assortment
   4. Punnett square
   5. Dihybrid cross
   6. Sperm and ova
7. Eukaryotic chromosomes
   1. Majority of genetic information
   2. Chromosome, meaning colored body, is a misnomer
   3. Are not colorful nor are they in the familiar rod shape
   4. Many genes serve as switches to govern other genes
   5. There are about 21 000 genes in humans
   6. Mendelian genetics
   7. Heritable traits found within DNA of chromatin
   8. Chromatin has protein components
   9. Some called histones
   10. They contain alkaline amino acid chains that interact with negatively charged phosphate groups of DNA to form nucleosomes
   11. Helps packages DNA
   12. Errors in meiosis:
   13. Usually fatal during cell division
   14. Trisomy-21 is best known error in meiosis in humans
   15. Chromosome 21 is not accurately segregated to opposite poles during anaphase I or II
   16. Called nondisjunction
   17. They end up having 3 copies of the chromosome 21 and develop Down syndrome, because they have 47 chromosomes instead of 46.
   18. Nondisjunction can affect any chromosome
   19. Klinefelter syndrome – extra X chromosome, XXY instead of normal XY or XX in females
   20. Underdeveloped male sex organs and sterile
   21. Normal intelligence
   22. Turner syndrome – single X chromosome, XO
   23. Underdeveloped gonads, infertile, short stature, web neck, mentally impaired
   24. XYY – super male
   25. Was common among criminally insane but has then proven that XYY males have normal behavior.
   26. O, YO, YYO – lethal, no X chromosome
   27. XXX, XXXX, XXXXX females
   28. XXYY males have medical and behavioral difficulties
8. Mendelian Genetics
   1. Gregor Mendel (1822 – 1884) is considered to be the father of genetics
   2. First person to uncover basic rules
   3. Crossing true-breeding pea plants
   4. Reported many traits in peas
   5. Lectures published in Versuche uber Pflanzen-Hybriden
   6. First cross is P cross (parental, 1 purple 1 white)
   7. Then, F1 offspring (filial, purple)
   8. The idea of blending of traits
   9. But Mendel discovered F2s were 3:1 purple to white
   10. Purple is dominant, and white is recessive
   11. Found out using Punnett square
   12. Segregation of alleles
   13. Fifty percent chance of dominant and recessive if heterozygous
   14. Independent assortment
   15. Traits sort independently
   16. No influence on each other
   17. Some genes in physical traits found on same chromosome
   18. RA Fisher questioned Mendel’s work
   19. An assistant was aware Mendel’s expectations
   20. Alleles of parents would segregate independently
   21. Recombined through fertilization randomly
   22. Two forms and one is dominant
   23. Fisher thought the results were too perfect, everything was in 3:1 ratio!
   24. Avoided traits coded by multiple sets of genes or closely linked genes
9. Dihybrid Crosses
   1. Situations where two traits involving hybrids are considered at the same time
   2. Support for independent assortment
   3. Example: two parental genes PpYy
   4. Four possible combinations of gametes
   5. Each gamete contains one allele to code for each trait
   6. 4 x 4 Punnett square with four different combinations of gametes
   7. Dihybrid organisms is an organism that is heterozygous for two different genes at the same time.
   8. TtYy hybrid sex cells can be TY, Ty, tY, or ty.
10. Non-Mendelian Genetics
    1. Incomplete dominance:
    2. DNA makes mRNA which makes proteins
    3. Trillions of possible instances of which genes express themselves
    4. Mirabilis jalapa flower – pink, red and white varieties
    5. Pink variety crossed – 1:2:1 ratio of red: pink: white
    6. This does not fit Mendel’s theory
    7. Dominance is not always all or none
    8. Parent plants are Rr and the progeny are RR, Rr and rr
    9. Pink plants are heterozygous Rr, and a blend of both dominant and recessive phenotypes
    10. Codominance
    11. Heterozygous may have phenotypes associated with both parents
    12. Human blood groups: MN blood groups exist because of a specific glycoprotein
    13. Slight difference between amino acids between M and N, act as fingerprints
    14. Researchers found three types instead of two blood groups
    15. Alleles in this system are LMLM, LNLN, LMLN
    16. Individuals can have both LM and LN, expressing both phenotypes
    17. ABO blood types:
    18. Similar to the MN blood scenario
    19. Multiple alleles: more than two alleles at a single gene locus
    20. Inheritance of blood type: there are two dominant alleles, Ia, Ib and recessive i
    21. Type A: IAIA or IAi
    22. Type B: IBIB or IBi
    23. Type AB: IAIB
    24. Type O: ii
11. Quantitative Traits and Polygenic Inheritance
    1. One gene-one enzyme popularized in 1941
    2. Each of the pea genes Mendel inferred produced discrete variations
    3. A gene would make either one trait or another
    4. Multiples genes can govern a single traits, and one gene could govern multiple traits, or a single allele governing a trait
    5. Traits like height are called quantitative traits
    6. Several genes contribute, since the range is large
    7. Polygenic traits – height and skin color
    8. We could use a trihybrid cross
    9. AaBbCc x AaBbCc
    10. Different combinations: ABC, Abc, abC, aBC, Abc, aBc, abC, abc
    11. Only capital letters are dominant, so in each group of six (after multiplying on the Punnett square), count the number of capital letters.
    12. In reality, more than 90 genes are involved in skin color
    13. Melanin comes in a variety of forms
    14. Skin color may be due to selective pressures, perhaps due to vitamin D from the sun
    15. Races exposed to a lots of sun have better screening and more protected from skin cancer
    16. Races near poles are more vitamin-D deficient
    17. Childhood bone disease called rickets
    18. Light races better suited to make more vitamin-D
    19. Inuit are exception due to meat-heavy diet
    20. Epistasis – a gene that is unrelated to expression of a trait and overrides other genes
    21. Gene for albinism represses all of other skin-color genes
    22. Similar example of dwarfism: genetically tall person might be physically short
    23. Pleiotropy – single gene causes multiple effects
    24. Marfan syndrome – single gene: FBN1, which effects multiple body systems.
    25. Sex-linked inheritance
    26. Hemophilia – trait is recessive that I carried on the X-chromosome
    27. If a woman carrier it, other X chromosomes mask the disorder
    28. If a man carries it, there’s only one X chromosome and the Y chromosome he has is not homologous to the X.
12. Genes Interact with the Environment
    1. There are limits to genes
    2. Cannot fully account for traits, because it is in part regulated by the environment
    3. Combination of nature and nurture
    4. Hydrangeas color influenced by soil conditions, pH
13. The Nucleus
    1. Particular part of the cell and particular chemical responsible to carry genetic information
    2. Research done on eukaryotic organisms due to large size
    3. Portions of cut unicellular Stentor that contained nucleus were able to regenerate
    4. Acetabularia – genus of colonial unicellular green alga, gigantic in terms of cell size
    5. A. mediterranea and A. crenulata differ in cap structure
    6. Joachim Hammerling and Jean Brachet
    7. Experiment one: holdfast or stalk controls the shape of cap. A hybrid was made by fusing mediterranea and crenulata’s holdfasts, which produced an intermediate form
    8. Experiment two: stalks control the shape of the cap. A hybrid was made by switching mediterranea and crenulata’s stalks, which produced caps corresponding to the stalks
    9. After caps were cut off, the caps resembled holdfast caps
    10. Conclusion: nucleus controls genetic information. High concentration of protein and nucleic acids, so protein was thought to control genes
    11. Frederick Griffith – pneumococcus bacteria isolated to two different strains: virulent – smooth and harmless – rough
    12. Injected the different strains in mice: one rough 🡪 alive, one smooth 🡪 dead, one heat killed smooth 🡪 alive, one rough strain and heat-killed smooth strain 🡪 dead
    13. Fourth group – something transferred over from killed strain to rough strain
14. DNA Structure
    1. Nucleotide:
    2. Pentose sugar, deoxyribose
    3. Phosphate group
    4. Nitrogenous base
    5. Adenine, cytosine, guanine, thymine
    6. Two pyrimidine could not reach 2 nm diameter, two purines were too big, so pyrimidine and purine combination was perfect
    7. Double helix structure – Rosalind Franklin, photo 51
    8. Considering of a variety of organisms, the ratio of purines to pyrimidines was one to one
    9. Hydrogen bonds between bases
    10. CG has three hydrogen bonds and AT has two
    11. Each turn of DNA has 10 pairs, exactly 0.34 nm apart from each other
    12. Major and minor grooves, 3.4 nm apart
    13. Antiparallel – 3 prime to 5 prime one side, vice versa other side
15. Replication
    1. Three theories:
    2. Conservative replication – DNA generated intact, based on original strand, which also remains intact.
    3. Dispersive replication – DNA chopped into fragments, pieces replicated and put back
    4. Semi-conservative – half of DNA is used as a template to make a new half
    5. Meselson and Stahl Experiment:
    6. Grew E. coli bacteria with heavy isotope of nitrogen (a component of DNA)
    7. DNA was heavier than normal after generations
    8. Density gradient centrifugation with cesium chloride ions
    9. Heavier DNA was at the bottom of the test tube
    10. Later some E. coli was switched to regular nitrogen medium
    11. Then the DNA was half as heavy, then a quarter as heavy and then so on.
    12. This suggests that half the strand is old heavy, and the new strand is light.
16. Mechanism of Replication
    1. Enzymes are especially important in the replication of DNA
    2. Helicases unwind and stabilize the DNA at certain locations
    3. Replication occurs at different points along the DNA
    4. Helicases bind to DNA, unwind it, and break the hydrogen bonds between bases
    5. It slides along strand, keeping a Y-shaped fork
    6. Polymerase attaches nucleotides in a complementary fashion
    7. Nucleotides are always added in the 5’ 🡪 3’ direction
    8. Leading strand and lagging strand
    9. Primase puts a short strand of RNA in place
    10. Polymerase then goes backwards until it reaches RNA, and replaces RNA with DNA
    11. Ligase is used to seal breaks in the sugar-phosphate backbone of the lagging strand
17. Transcription and Translation
    1. Proteins have a wide variety of functions including catalysts, structural components, transport materials, cell reaction regulators, cell movement helpers, nutrient storage units and immune defense cells
    2. All proteins made of amino acids joined by dehydration synthesis
    3. Twenty common amino acids
    4. Amino acid has an amino group, a carboxyl group, a hydrogen atom, and a distinctive R group
    5. Amino group is the NH2
    6. Carboxyl group is COOH
    7. R group can be single hydrogen atom or a complex chain
    8. Primary, secondary, tertiary and quaternary structure of protein
    9. George Beadle and Edward Tatum 🡪 one gene one enzyme hypothesis
    10. First step is synthesis of RNA using DNA template
    11. mRNA leaves the nucleus, moves to ribosomes
    12. RNA synthesis proceeds in the 5’ to 3’ direction
    13. RNA polymerase copies from the template strand
    14. RNA has hydroxyl group attached to the second carbon of the pentose sugar
    15. 64 combinations of RNA triplets is sufficient with some redundancy
    16. To determine the code, synthetic mRNA made and put in in vitro system with ribosomes, amino acids linked to tRNAs and cofactors
    17. mRNA chain UUUU… produced polypeptide chain of phenylalanine
    18. Was reproduced using other amino acid chains
18. Gene Regulation in Prokaryotes
    1. Genes can be switched on or off
    2. Studies from bacteria can help us understand eukaryotic gene regulation
    3. Gene regulation in prokaryotes uses homeostasis and negative feedback
    4. For example: heart rate fluctuations and stabilization around set point
    5. Negative feedback a cycle of events – some product represses a cycle to maintain a steady state
    6. E. coli uses enzymes that feed on glucose, but it could also live on lactose which requires different enzymes
    7. Genes control activation and deactivation
    8. Negative control systems – inducible genes turn on a switch, repressible genes turn off a switch
    9. Positive control systems – activator proteins accelerate the transcription of genes
    10. Lac Operon system: coordinated unit of structural genes plus switches in lactose catabolism, is an inducible system
    11. Three enzymes are needed to run the metabolic pathway – galactosidase, lactose permease and transacetylase
    12. Structural genes that produce mRNA located consecutively in the E. coli genome
    13. Operator and promotor regions upstream the gene
    14. How easily RNA polymerase attaches to DNA determines the rate of transcription
    15. RNA polymerase binds to DNA at promotor region, but sometimes repressed by protein locked at a site known as operator
    16. Repressor can be removed by allolactose by binding to allosteric site
    17. Allolactose another form of lactose
    18. B-galactosidase changes any lactose into a structural isomer – allolactose
    19. If a cell is in lactose medium, then allolactose is also present
    20. If all the lactose runs out, then repressor re-attaches to the operator site – very efficient
    21. Positive control of the Lac Operon:
    22. Positive control mechanisms that accelerates the transcription of mRNA.
    23. 1) There is lactose available 2) there is little glucose available
    24. Glucose is overall better energy source
    25. E. coli makes regulatory protein catabolite activator protein (CAP), binds to promotor, physically flexes DNA, increases ability of RNA polymerase attachment
    26. Cyclic adenosine monophosphate is needed for CAP activation
    27. Enzyme that catalyzes camp is inhibited by glucose
    28. TRP Operon: governs synthesis of the amino acid tryptophan, is inactive unless co-repressor is present
    29. Structural genes downstream from the promotor and operator left on, amino acid is continuously supplied, but can be turned off if there is end product present (corepressor)
    30. Post-transcriptional gene regulation
    31. Most gene expression happens during transcription, regulation occurs after transcription, during translation or after translation
    32. Not common due to short mRNA half life
    33. May involve feedback inhibition of metabolic pathways
19. Gene Regulation in Eukaryotes
    1. Several kinds of controls: regulatory proteins, altering splicing of introns, controlling access or efficiency to channels of nuclear membrane, enzymes that degrade mRNA, speeding up or slowing down protein synthesis, availability of amino acids, phosphorylation.
    2. Only small part of eukaryotic genome is responsible for coding specific structures
    3. Only a part of the transcribed RNA is involved in translation
    4. Non-coding introns are excised
    5. Eukaryotes: have three RNA polymerase, TATA box promoter, basal transcription factors and regulatory transcription factors that for megaprotien complexes, extensive RNA processing, rare cases of operons.
    6. Bacteria: 1 class of RNA polymerase, -35 and -10 boxes, 35 and 10 nucleotides upstream from transcription initiation site, sigma protein bonds with RNA polymerase forming holoenzyme, no RNA processing, collection of several structural genes consecutively, regulatory sequences upstream from structural genes
    7. Gene expression may be regulated during transcription, translation and after translation, but many additional junctures
    8. Chromatin remodeling – undifferentiated cell receives a chemical signal from a neighboring cell.
    9. Chromosomes made of chromatin, a 30 nm fiber of DNA and histones, RNA inaccessible
    10. Two proteins govern unwinding and winding of chromatin, opening or closing the DNA
    11. Pattern, however, not controlled by genes
    12. Pancreatic cell divides, daughter cells may share complement of HATs and HDACs – epigenetic inheritance via protein interaction, not DNA.
    13. Some genes, when exposed to RNA polymerase, may be turned off due to DNA methylation, genes contain cytosines that have extra methyl groups attached.
    14. Not transcribed 🡪 not expressed
    15. Transcription – regulatory sequences may be upstream from the structural gene
    16. TATA box recognized and bound by TATA binding protein
    17. Regulatory elements may be located near the TATA box
    18. Regulatory sequences located far from genes
    19. Promotor proximal elements and enhancers or silencers
    20. Regulatory elements may be located anywhere in the DNA
    21. Remote enhancers and megaprotien complex binds and stabilizes the gene so promoter is accessible to RNA polymerase
    22. Gene – functional protein or RNA along with all of the regulatory sequences needed for expression
    23. RNA processing, introns removed, DNA spliced back.
    24. Introns play important role in regulatory functions, determines how exons are sequenced
    25. Alternative splicing increases eukaryotic genome
    26. Transcription end: enzymes add cap (7 – methyl guanylate and three phosphate groups to the %’ of RNA and a poly (A) tail with 100-250 repeating adenine nucleotides to the 3’
    27. Cap is signal to ribosomes to start translation, extends life of mRNA
    28. Protein complexes in nuclear pores regulate transcription within the nucleus, nuclear pores determine what gets in and out.
    29. Tethers the movements of chromatin remodeling, mature mRNA leaves nucleus.
    30. RNA eventually degraded
    31. Short pieces of RNA can regulate gene expression by messing with mRNA
    32. MicroRNA (miRNA), 22 nucleotides long, binds to protein RISC (RNA-induced silencing complex) in cytoplasm
    33. Enzyme in RISC chops up mRNA
    34. Imperfect fit 🡪 inhibition, not complete stoppage
    35. 20-30% of genes regulated this way
    36. Regulatory proteins and ribosomes to inhibit translation
    37. Protein may not be fully functional after translation, chemicals activate or suppress activity
20. Viral Structure and Replication Cycle
    1. Do not photosynthesize, no metabolic functions
    2. Can infect virtually any living organism
    3. Very small, can pass through bacteria fine filters
    4. Small piece of genetic material surrounded by capsid
    5. “Docking clamps” and “hypodermic injection” mechanism
    6. Phospholipid envelope, derived from host cell, viral and host protein markers to avoid detection
    7. Viruses can contain DNA or RNA
    8. Lytic and lysogenic cycle
    9. Lytic cycle: host cell lysed (split apart and destroyed)
    10. Enters or land on host cell, viral DNA controls cell, makes new viruses, host destroyed, viruses emerge
    11. Lysogenic cycle: host cell not lysed, but its genome
    12. DNA temporarily split apart, viral DNA inserted 🡪 prophage/provirus
    13. Viral DNA replicates with host DNA, but can also switch to lytic cycle
21. Defense Against Viruses
    1. Found in all environments and integrated into almost every living thing
    2. Almost all viruses are harmless to humans, necessary part of ecosystems
    3. Influenza, common cold, chicken pox, shingles, warts, herpes simplex, rubella, rabies, hepatitis, mumps, mononucleosis, polio, cancer, AIDs.
    4. Viruses attack only one type of cell, so we say it is specific
    5. Mump virus – salivary glands, tobacco mosaic virus – leaves and petals
    6. T4 can infect E. coli with special marker
    7. Polio virus – intestinal or nerve cells in humans
    8. Influenza is more broad
    9. Rabies – CNS of several mammals
    10. Contagious – the ability to spread
    11. Virulence – the ability to cause disease
    12. Different kinds of defenses, some can be nonspecific or innate immune
    13. Adaptive immunity takes time to develop
    14. Nonspecific skin defense
    15. Skin, epithelium, provides physical barrier, oils, sweat, acidic surface, mucus secretions, trachea with cilia, highly acidic stomach
    16. If inside body, bacteria or protozoan gobbled by leukocytes, peptides and proteins lyse viruses, bacteria, chemical signals producing heightened WBC response, interferon signals, natural killer cells: programmed cell death.
    17. Inflammation and fever, cell fragments cause reactions that excite WBC, release of histamine, vessel dilation and increased blood flow, capillary permeability, fever to increase body temp, destruction of host cells, phagocytosis speed.
    18. Specific immune defenses
    19. T lymphocytes (T cells)
    20. Produced in bone marrow, migrate to thymus gland, matures, responsible for cell-mediated immunity, accumulate at site of infection, recognize specific markers (antigens), large T cell variety, multiply via mitosis, memory T cells remain
    21. B lymphocytes (B cells)
    22. Made in bone marrow, migrate to lymph nodes (spleen), antibody-mediated immunity, make antibody proteins, antibodies tag viruses for destruction, memory B cells could be made
    23. Practices
    24. Good hygiene, avoid contact when sick, no risky sex, no sharing of bodily fluids, vaccinations
    25. Plant defenses
    26. Structural and chemical, cell walls, waxy cuticle with nasty chemicals
    27. Physical damage may occur however, viruses travel through cytoplasmic channels
    28. Plants can recognize foreign DNA and RNA, RNA silencing, plant enzymes digest foreign genetic strands into bits, plant keeps particles to use to recognize future attacks.
22. Recombinant DNA
    1. DNA that contains code from 2+ species
    2. Can insert human gene into bacteria
    3. Restriction endonucleases – enzymes that cleave DNA at sequences 4-6 nucleotides long.
    4. Two recognition sequences complimentary, so restriction endonuclease can bind to both
    5. Bond cleaved not positioned in the center of recognition sequence, DNA strand antiparallel, cut sites offset, thus leaving complementary fragment ends
    6. Single stranded ends can pair with each other, then ends can be glued with DNA ligase
    7. Any two fragments of DNA produced by the same endonuclease can be joined together
    8. Cloning a gene – first step: isolate the DNA from the organism, which is purified and fragmented with restriction enzyme, producing staggered cuts in specific sequences
    9. Fragments have single stranded sequences able to hybridize with like fragments
    10. Incorporated into plasmids, cloning plasmids have single restriction site, restriction enzyme cleaves it producing same cohesive ends
    11. DNA fragments line up and DNA ligase bonds them
    12. Plasmid put in bacteria via transformation
    13. Each bacteria has a different segment of DNA from original organism
    14. Cells plated on agar, desired cloned gene can be identified and isolated
23. The Earth’s Origin
    1. The universe exists 🡪 the universe has existed forever, or the universe had a beginning
    2. Beginning 🡪 created by God, or began from nothing
    3. Evolution can have many definitions: most common – the changes that have happened and continue to occur since the first living cell experienced changes to genetic mutation.
    4. Naturalism – nature is all there is (debatable)
    5. All living things: have an orderly structure with genetic code, can reproduce, grow and develop, adjust to changes, maintain homeostasis.
    6. Complexities of the cell are often underrated, even bacteria are trillions of times more complex than computers.
24. Chemical Evolution
    1. Abiogenesis
    2. Chemical evolution attempts to explain life form non-living materials
    3. Creation of self-replicating cell, with information-bearing molecules
    4. Creation of artificial RNA have been attempted by combining water and gases.
    5. How do we get beyond simple organic molecules to large molecules that contain information?
    6. Protocells may be an intermediate step to functioning living cells
    7. They have rudimentary similarities, phospholipid-protein membranes, but no organelles or genetic code
    8. Thus far, no experiment has been able to recreate the evolution from organic molecules to genetic code
25. Chemical Evolution Experiments
    1. Alexander Oparin proposed that geothermal energy, solar UV light or lightning could have provided energy to drive chemical reactions to form organic compounds
    2. Stanley Miller and Harold Urey simulated these conditions which produced amino acids and other compounds
    3. Amino acids formed in the experiments are a half/half blend of D and L amino acids. In living cells, L-form much more predominant. Meteorites could have triggered catalysis of L amino acids. Murchison meteorite contains a rich percentage of L amino acids
    4. Nothing more complex than molecules have emerged from the experiments, because to make RNA, a large amount of energy would be needed
    5. Oxygen, made from water vapor, prevents organic molecules from forming because it easily oxidizes with other molecules
    6. Currently there isn’t a single theory to evolution. Research now focuses on small cycles of self-replicating molecules, containment of reactions and solving handedness of amino acids.
26. Chemical Evolution Theories
    1. Ancient: Aristotle, spontaneous generation. Disproved by Louis Pasteur
    2. 1924: Alexander Oparin, primordial soup within coacervates (lipid bubbles). Not complex enough, requires special conditions, unstable.
    3. 1928: J.B.B. Haldane, hot dilute soup with more complexity. Heat destroys hot molecules
    4. 1953: Stanley Miller and Harold Urey, sparking gases to form organic molecules like amino acids, then separated, concentrated and isolated from destructive heat or sparks. Gas mixture unrealistic, lack of complexity and information in molecules, mixture of L and D molecules
    5. 1965: Sidney Fox, proteinoid microspheres that reproduce like cells. Would need pure amino acids and unrealistic conditions, replication is not complex at all.
    6. 1974: Carl Woese, simple RNA world, self-replicating RNA molecules gives rise to DNA. RNA very unstable.
    7. 1974: Leslie E. Orgel, self-replicating chemical cycles focusing on ribozyme, RNA self-copying. RNA very unstable on its own, need lots of proteins to be tethered to
    8. 1986: Walter Gilbert, RNA term is coined
    9. 1986-present: Stuart A. Kauffman, set of molecules able to catalyze the formation of other molecules, self-replicating set. Research continues.
27. The Early Earth
    1. Gradual accretion of space dust, planet formed by cooling magma 4.6 billion years ago.
    2. Infinity old earth was believed by Aristotle, but science proves otherwise.
    3. Georges Lemaitre said that the universe began at a finite point in time and has been expanding ever since.
    4. Age of the earth:
    5. Several ways the earth was dated
    6. Best known method is radiometric dating – traces of radioactive impurities were selectively incorporated when rocks were formed. Forty different methods of measuring these rocks exist but rely on same principle: radioactive element decays into a daughter element at a consistent rate. Multiple crystals are used when dating a rock and an average is taken to ensure accuracy
    7. Extinct radionuclides confirms earth’s age. Only naturally occurring radioactive isotopes are those with very long half-lives. Potassium-40, for example, with half life of 1.3 billion years., but not anything with a half life shorter than a billion years, because it would have run out of radioactivity due to earth’s very old age.
    8. Age of fossils:
    9. Radiometric dating would not work well on fossilized organisms, because radioactive materials are usually found in rocks that could not contain fossils
    10. Fossil dating relies on proximity to an igneous flow.
    11. Radioactive elements with very long half lives do not give an accurate dating of fossils.
    12. Radiometric dating is thus used alongside with relative dating of rock layers.
28. Allele Frequencies Concern Populations
    1. Individuals don’t evolve
    2. Only mutations in the gametes would allow evolution to occur
    3. Only mutations that help an organism are preserved
    4. Natural selection is not evolution
    5. Evolution is much greater than just natural selection, the preservation of particular alleles
    6. Changing allele frequencies:
    7. Natural selection, mutation, genetic drift (in small populations)
    8. Convergence, divergence and speciation
    9. Convergence, distantly related (virtually unrelated) species could share similarities
    10. Divergence, one species becomes two
    11. Analogous structures – no common ancestry but same function
    12. Homologous structures – structures that are similar in function and have common ancestry
    13. Speciation – low vs fully armored stickleback. Low armored sticklebacks grow faster, so they were preyed upon at a lower rate, so all the fully armored ones disappeared
    14. Adaptive radiation – once birds arrived on Galapagos, speciation occurred rapidly due to a new environment, all exploited different niches, mammals after the dinosaurs
    15. Extinction – 99.9% of all species that have ever existed are extinct.
    16. Mass extinction causes – Pangea, comets, volcanoes, carbon dioxide, gamma rays, sea level, climate change, methane hydrate, ocean anoxia, ocean circulation
29. Hardy Weinberg Equilibrium
    1. Things that may cause allele percentage change: migration, disease, mutation (not likely)
    2. Adults 🡪 mutation 🡪 gametes 🡪 random mating 🡪 zygotes 🡪 selection 🡪 juveniles 🡪 migration 🡪 adults
    3. If no change in allele percentage (phenotype percentage), then population is at equilibrium
    4. P2 + 2PQ + Q2 = 1
    5. (p + q) (p + q) = 1
    6. Punnett square – Bb times Bb.
    7. For example, if B brown is 55% and b is 45%, then final would be 80% brown eyes and 20% other color.
30. Advanced Mathematical Modeling
    1. Types of Natural Selection
    2. Evolution requires mutation, isolation and natural selection
    3. Stabilizing selection – natural selection where there is no change in the population and genetic variation is limited. In Britain, average baby weights were more likely to survive
    4. Direction selection – tends to reduce the genetic variability of a population. One extreme phenotype is selected against. Trees that can grow if climate changes
    5. Disruptive selection – opposite of stabilizing selection, favors extremes, average is less fit.
31. Evidence
    1. The principle of the uniformity of nature became the first axiom in all theology and Biblical criticism
    2. All miracle and all supernatural activity of God had to go under this royal principle.
    3. No direct evidence of evolution, but lots of people accept it
    4. Modern day examples of microevolution such as antibiotic-resistant bacteria strains and diverging stickleback fish population
    5. Evidence of a general theory of evolution:
    6. Biochemical comparisons, adaptations, embryological comparisons, morphological comparisons, breeding behaviors, geographic distribution, fossils
32. Sequencing Studies
    1. Dideoxy nucleotides are a way to sequence a chain of nucleotides by deleting a hydroxide group of one type of nucleotide.
    2. That nucleotide can no longer continue the sequence because other nucleotides cannot perform dehydration synthesis.
    3. In a sequence, different lengths of DNA can be formed because the ddNTP can be inserted into any one of the nucleotide positions.
    4. The smaller the length, the further it moves along a gel assay.
    5. Does sequencing reveal phylogeny?
    6. Evolution is based on only beneficial genes that are passed through generations
    7. Evolution thus depends on changes to DNA
    8. More distant relationship = more mutations = more differences in DNA
    9. Significant changes have been made to evolutionary trees
    10. Previous: morphology and embryology. Current: gene sequencing
    11. Example: flatworms are now higher up on the tree
    12. However, even with genetic sequences there can be many differences among different trees
    13. Another example is a phylogenic tree based on amino acid sequence cytochrome c.
    14. Graham Lawton says that DNA can be transferred horizontally