Lab manual: biolab1.uottawa.ca

Pre Darwinian Biology

Lecture Notes

- 1802: biology is given a definition by Treviranus

Predarwinian and natural sciences
- 400 BCE – late 1800s
  - 400 BCE – 450 CE: greek and roman ages
  - 450 – 1500s : midieval ages
  - 1500s – 1700s : renaissance and the scientific revolution

Darwin and evolutionary thought
- late 1800s – mid 1900s

Modern theory of evolution
- mid 1900s – present

Douglas Adams' four ages of sand/silica
- 1st : telescope 1608
- 2nd : microscope 1678
- 3rd : computer chip 1961
- 4th : fiber optics 1980s

Major events

- Hippocrates
  - 460-370 BCE
  - created the hippocratic corpus, a collection of knowledge of human biology, taken from many scientists

- Aristotle
  - scala natura
  - created an inventory of all living things and inanimate matter, ordered them in importance
  - man, mammals, aquatic mammals, egg laying things, cephalopods, shelled things

- Theophrastus
  - studied the medicinal, agricultural, and structural (wood and fibers) properties of plants
  - divided them by their reproductive structures and the way in which they form seeds
  - considered the father of taxonomy

- Classification: ordering things
- Taxonomy: organizing a classification
  - Artificial taxonomy: not necessarily how it works, written, organizing lists on appearance
  - Folk taxonomy: by word of mouth

- Medieval ages
  - scala naturae is only modified in the religious portion
  - essentialism: animals have an essence that they pass on each generation
  - Bishop Usher made first estimate of creation to be Oct 23 4004 BCE
  - Ages
    - 400-700 early middle ages (dark ages)
    - 1000-1300 high middle ages
    - 1300-1500 late middle ages (black plague)
      - about half the population was wiped out in 4 years
  - Byzantine and Islamic world did not suffer the plague
    - Al-Jahiz (781-869)
      - first theory of natural selection
    - al-Dinawari (826-896)
      - increased knowledge and database of plants
    - Alhazen (965-1040)
      - developed scientific method
    - Ibn al-Baitar (1197-1248)
      - pharmaceutical anthology of plants
      - still used in into the 16^{th} and 17^{th} century

    - Crusades put and end to Islamic golden age and stole copies the knowledge
      - contributes to renaissance

    - 16^{th} – 18^{th} century advances in the physical sciences, not natural sciences
      - Copernicus: earth is not the center of the universe
      - Kepler: planetary motion
      - Newton: laws of motion, gravity, and thermal conduction
      - Galileo: further proof of earth revolving around the sun
      - Boyle: behavior of gases
      - Pascal: origins of calculus
      - Descartes: geometry

      - Van Leeuwenhoek (1632-1723)
        - creates first microscope
      - Vesalius (1514-1564)
        - father of anatomy, did dissections

    - Harvey (1578-1657)
        - physiology
    - Linnaeus (1707-1778)
        - binomial nomenclature and hierarchical taxonomy
        - mechanical taxonomy
            - different from artificial because it has a distinct hierarchy (universal)
            - still physical appearance
        - autapomorphy: specific characteristics or an organism/group of organisms
        - Genus *species*
            - italics because its in a different language

- Physicalists: with the exception of humans all living things are machines (Descartes)
- Vitalists: physical and chemical laws apply but living things have a vital force (essence)
- Organicists (1930): vital force replaced by genetics program, whole is worth more than the sum of the parts (emergence)

- Physical science
    - inanimate objects
    - physical and chemical laws
    - universal
    - based on empirical observations
    - experimentation is the preferred method of gaining knowledge
    - single theory
    - single falsification enough to abandon a theory

- Natural science
    - animate objects
    - more than physical and chemical laws (genetics)
    - not universal
    - based on historical narratives
    - induction used to gain knowledge
    - multiple theories
    - single falsifications don't necessarily destroy a theory

- both types of theories have a pattern and a mechanism or process causing it

- Proximate Causes
    - phenotype, behaviour
    - mechanical

- Ultimate Causes
    - genotype
    - variable

Darwinian Thought

Georges-Louis Leclerc, Comte de Buffon

- noticed that there were cat like predators around the world, which had similar basic functions but different specifics
- believed that after creation in the garden of Eden, as they moved across the world, organisms' essences were changed by the nature around them

Erasmus Darwin

- translated Linnaeus' systema naturae into English
- creathed Zoonomia, the laws of organic life
  - created a poem based on this, which said life started in the oceans as micro organisms, and slowly grew onto land and acquired legs and wings

Georges Cuvier

- began collecting bones from quarries
- noticed that there are many similarities between the bones of the extinct species and those of some alive now
- catastrophic theory
  - one of the first people to use the term extinction
  - a student of his linked these extinctions to Noah's flood

Charles Lyell

- Uniformitarian theory
  - noticed that the strata in stratified rock had very specific characteristics
  - also noticed that certain fossils appeared in the same types of strata
  - stated that there's been no rapid changes in geology, only gradual changes
    - couldn't have happened in 6000 years
  - also realized there was a cycle (carbon cycle) replenishing the underwater ecosystem

Wegener

- noticed that Africa and South America fit together, and that they had similar species
- came up with the idea of Pangea, as well as continental drift
  - was laughed at because he had no mechanism to prove drift, because the earths plates were not known about yet

Jean-Baptiste Lamarck

- Tried to explain all the observations of the others
- he did say species change over time (transmutation)
  - infusarian: a very simple organism a long time ago, infusarians grow more complex over time
- Theory of Use and Disuse
- also thought traits that were used were augmented and passed on (giraffes)
  - didn't know that when an embryo is formed, germ cells are created which will create all of that organisms gametes (traits acquired in life do not get passed on)

Essentialist explanation of change

- transmutation of species
  - over a short time new species were created
- transformation
  - happened over a very long time

1800s: Modern Biology

- Wallace
  - worked in South America and Indonesia
  - stated that the fittest species pass on their traits
- Darwin was sitting on his findings not wanting to anger the church, but Wallace came along after 30 years with his findings, pushing Darwin to action
  - artificial selection: selective breeding due to humans
  - after his voyage on the Beagle, he had a collection of organisms comparable to a museum
  - between his families money and his wife's money, he never had to work, could study his collections
  - his theory allowed for organisms to branch off into multiple new ones, unlike Lamarck, who thought one species just became more complex
- Darwin's theory allows for Natural classification
  - 5 Theories
    - there is no constancy of species
      - fossils, extinction, transitional forms
      - seen in the evolution of horses
        - transitions from 5 toes to 1 toe (hoof) and thicker enamel to eat (moved to grasslands)
    - these changing species have common ancestors
      - comparative anatomy
      - divergent evolution (homologous): different uses, similar structure
      - convergent evolution (analogous): same use, different structure
      - vestigial structures: appendix, goosebumps, nictatating membrane (eye)
      - amino acid structure (DNA)
    - adaptation creates gradual changes in a population (no knowledge of genetics)
    - there is not a set number of species on the planet, they can multiply
    - natural selection, the fittest survive

- Pasteur
  - life from life, not from spontaneous generation
  - germ theory: comes from some sort of living plasma

- Schleiden and Schwann
  - cell theory
  - found a compartmentalized structure with a thing in the middle (nucleus)
  - also found organelles

- Mendel
  - same time as Darwin, no communication
  - law of segregation of characters
  - law of independent assortment

Modern Theory

- in the past, there was no clear definition of what a species was
  - they tried to use morphology

- Ernst Mayer
  - proposed the biological species
    - species are groups of actually or potentially interbreeding populations, which are reproductively isolated from other such groups
    - doesn't work for extinct species
  - does not work for bacteria
  - still no agreement on one specific definition

- Anagenesis
  - gradual change overtime of a species, slowly becomes the most prominent

- Cladogenesis
  - population is isolated, when they meet again, they don't mate

- Allopatric speciation
  - physically seperated
  - vicariance: geological change
  - dispersal: could be wind

- Sympatric speciation
  - same location, something about the environment seperates them
    - could be habitat differences

- Parapatric speciation
  - species in contact with each other in some areas, mate along the border of the locations they are found
  - create a zone of hybridization
  - why we use sub-species names
    - Canus lupus familliaris

- Hybridization outcomes
  - fusion of the populations
  - reinforcement of isolation
  - hybrid zone formation
  - extinction of one population
  - creation of a new species

- Henning
  - Cladistic taxonomy
    - base creating taxa solely on a change in genetics (trait or no trait)
    - cladogram: one starting branch, new groups go off one at a time
  - Apomorphies
    - derived characters within a group
  - Plesiomorphies
    - primitive characters within a group
  - Synapomorphies
    - derived characters shared between groups
  - Symplesiomorphies
    - shared primitive characters between groups
  - Outgroup
    - species that has 0 of the traits being looked at in a cladogram
- Occam's razor (parsimony)
  - simplest explanation is used in the even of multiple explanation
- Meiosis
  - genetic variability
    - recombination of homologous chromosomes
    - combinations of maternal and paternal chromosomes segregated during anaphase
    - specific gametes that meet in fertilization
- Huxley
  - synthetic theory of evolution: population genetics and natural selection based on Mendel's findings
- Microevolution
  - evolutionary changes that result from changes in allele frequencies in a population, or in chromosome structure or number due to mutation
- Punnet squares
  - 3:1
  - dihybrid cross 9:3:3:1
- Mendel
  - known as laws because they are mathematical proofs
    - they are based on independent chromosomes (no alleles on the same chromosome)

- Allele frequency
  - not based on homozygous/heterozygous, based entirely on the number of R to r

- Hardy-Weinberg Principle
  - $p^2+2pq+q^2=1$
  - Assumptions
    - no natural selection
    - random mating, no sexual selection
    - large population, no genetic drift
    - no mutation
    - no gene flow

- Genetic fixation
  - with heavy selective pressure, eliminate an allele in a population
  - the other allele becomes fixed, 100% frequency by the end
  - ex: bacterial immunity

- In normal circumstances, alleles don't disappear, they can just become much lower in frequency
  - this is important for maintaining genetic variation
  - generally plateau at 90%
- Heterozygote advantage
  - sickle cell anemia
    - reduces the number of parasites, does not cure it necessarily
  - quinine water: tonic water, provided protection to europeans from malaria, gin and tonic
- When there are multiple alleles affecting a trait, biologists look at a normal/bell curve
  - directional selection: shift in one direction
  - stabilizing selection: extremes are eliminated
    - goldenrod galls

- Natural Selection
  - directional selection
    - one side (size, amount) is less favorable, moves in one direction
  - stabilizing selection
    - deviation decreases on either side, very specific thing is most favorable
  - disruptive selection
    - against organisms in the middle of the distribution, extremes survive (beak length)
    - heads towards 2 new species (cladogenesis)

- Sexual Selection
  - inbreeding: heterozygotes removed, only homozygous remain
    - how Mendel looked at peas
    - artificial, non random
    - retains hardy-weinberg principal
  - sexual dimorphism
    - difference between males and females

        - males generally need to show off more than females (weaponry, colours)
    - combat (male competition)
    - sperm competition
        - sperm storage in the female can hold sperm from multiple males
        - damselflies holding on too each other, male is trying to stop the female from going to a different male who will remove the old stuff
            - females can empty it out themselves if they thought the male was shitty
    - infanticide
        - killing the offspring of rivals

- Genetic Drift
    - small populations can result in loss of an allele from random chance
        - genetic fixation
    - bottle neck effect
        - population decreased dramatically, survivors do not reflect genetic variability by chance
    - founder effect
        - small new population in a new location, others did not die
        - don't represent genetic variability of original populations

- Gene Flow
    - migration
    - immigration

- Mutations
    - a large amount of variation occurs solely because of random segregation of chromosomes in gametes

    - Chromosome mutations
        - deletion
            - segment deleted from a chromosomes
            - can be very severe if it contains important material
        - duplication
            - a section is put in twice
            - can range from harmful to beneficial, depending on the genes, though most are detrimental
        - translocation
            - a segment breaks off of one chromosome and attaches to another, nonhomologous chromosome
            - called reciprocal if both do it (pieces are called transposons)
            - usually negative side effects
        - inversion
            - chromosome segment breaks then reattaches, but backwards
            - beneficial or harmful
        - crossing over
            - chromosomal arms wrap around each other, arms break, and they get reconnected to

the wrong strand
    - doubles possible combinations for each event
- nondisjunction
    - homologous pairs do not separate in division
    - results in one n+1 gamete and one n- gamete
- aneuploidy
    - loss or gain of 1 chromosome
    - trisomy, monosomy diseases
- polyploidy
    - Autopolyploidy
        - gametes only underwent 1 division, cells are diploid
        - new individual will have double every pair of chromosomes
        - generally found in plants (cause its self fertilization, they can self polinate)
        - if viable, they are usually very different phenotypically
    - Allopolyploidy
        - autopolyploidy between 2 species, has double chromosomes
        - also generally seen in plants
        - the individual cannot mate with members of either of its parent species

- effect on protein production
    - point mutations (generally neutral in effect on body)
        - missense mutation
            - mutation alters codon to specify a different amino acid, therefore a different protein
            - may or may not alter polypeptide function
            - rarely involve the third nucleotide because it generally doesn't effect the protein
            - cause of sickle cell anemia
        - nonsense mutation
            - change from an amino acid coding codon to a termination codon
            - produces useless to partially functional polypeptides at best
        - silent mutation
            - change codes for the same amino acid as the original, having no effect
            - usually involves the third nucleotide
    - frameshift mutation
        - if a single codon is added or deleted, everything after it will be wrong
        - almost always non-functional

Hadeon Era

- Solar system
  - orbits were smaller, surrounded by a very large belt of asteroids/rocks
  - orbits grew larger, and the asteroid belt was either launched towards the sun or away from it
    - called The Nice Model
    - done largely by Jupiter and Saturn
    - 3.8-4.1 bya, caused the craters we see on the moon

  - Building phase
    - creation of planets, super heated, constantly bombarded by asteroids (building it)
  - Stabilizing phase
    - this stops, planet is left to cool

- Origins of Life
  - extraterrestrial origins (panspermia)
    - chemical evolution

- Chemical Evolution
  - Water is very unique
    - adhesion, cohesion, surface tension
      - at the surface, water can only bond to adjacent and bellow molecules, creates surface tension
      - cohesion is attracted to itself, useful in xylem with transpiration
    - solvent properties
      - polar means it can bond to cations and anions
    - ice formation
      - lowers density because hydrogen bonding causes largish hexagons
      - because ice is lighter, it stays on top of the water, insulating the water and allowing organisms to survive underneath
    - high specific heat capacity

  - Carbon
    - very diverse bonding opportunities
    - Miller-Urey experiment
      - creation of organic molecules through a spark discharge (lightning)
    - Hydrothermal vents
      - weak spots in the crust, magma coming out and hardening immediately
      - because of pressure, water could be 110 degrees without boiling
      - allowed for creation of organic molecules

- Macromolecules
  - reverse transcription viruses (HIV) showed us that DNA can be made from RNA
  - RNA can act as a catalyst to create proteins
    - speculated that RNA could replicate
  - Alternately speculated that proteins would replicate

  - nucleotides cannot be stitched together to be large enough to fold and be hydrophilic on the outside
    - this is why everything is still speculated

  - Clays
    - highly organized mineral molecules
    - interact with eachothers' charges
    - can also interact with amino acids/nucleotides
      - reaction could bond them together creating a chain that could dissolve

- Bubble hypothesis for cells
  - microsphere
    - very small spheres of lipids, created by mixing/shaking (oil in water)
  - Micelle (a protobiont: stepping stone to life)
    - a slightly larger lipid sphere that is hollow
    - if done with phospholipids, will spontaneously create a bilayer
    - replication: 2 water soluble molecules make the water insoluble material in the membrane, if enough is added it will just split off to 2 due to size
    - allows for molecules to stay in solution on the inside
      - reactions between molecules that cant leave the membrane resulting in in products that can leave the membrane

- Emergence
  - equal to more than the sum of its parts
  - hemoglobin vs myoglobin
  - life
    - organized
    - metabolizing
    - self regulating
    - reproducing
    - evolving
    - responding
    - grow (increase size over time)

Archean Era

- Bacteria
  - implicated by Pasteur, required invention of microscope
  - in the Kingdom Monera in Linnaean taxonomy
    - contained all prokaryotes

- mitochondria evolved before chloroplasts

- plants, animals, fungi
  - multicellular eukaryotic
  - autotrophs, ingestive heterotrophs, absorptive heterotrophs

- must look at bacteria DNA to classify them
  - this lead to the creation of Domain

- Prokaryotes
  - bacteria
    - eubacteria: means true bacteria as we know them now, not monera
    - no nuclear envolope, circular chromosomes, no histones on DNA
      - highly variable in genome
  - archea
    - no nuclear envolope, circular chromosomes, has histones on DNA
  - 1st amino acids in peptide chain are different, translation is different, cell walls too

- In bacteria, morphological diversity is very high and not very connected
- can be classified by difference in membrane proteins, flagellum proteins
  - hundred – thousands of variants

- Bacterial Cells
  - exist in a world based on perfect surface to volume ratio
    - volume required for reactions to occur
    - surface area required to absorb nutrients
      - can increase folding, bacteria do this
  - no compartments, ER, everything is floating around
  - peptidoglycan layer: gives rigidity
    - has 4 peptides
    - 2 modified sugars
    - covered by a glycocalyx, which when gelatinous is a capsule
  - flagellum for movement
  - nucleoid: bunch of DNA in an area

  - gram positive
    - one plasma membrane on the inside, peptidoglycan layer on the outside
    - will stain
  - gram negative

- second membrane on the outside of the peptidoglycan layer
- won't stain
- resistant to antibiotics (penicillin)
- almost all bacteria are gram negative

- flagellum
  - made of molecular motor with only 40 proteins
    - 23 are the same in all bacteria
  - has an anchor on each membrane/cell wall
    - called the hook
  - all energy comes from proton gradient
    - in flagellum, proton pump through the inner membrane
    - to return to the other side, they go through a motor protein, changing shape and nudging the shaft at the center of the anchor
    - attached to the hook and filament causing movement
    - 2000-1000 rpm
    - can stop immediately
      - direction changed by switch proteins

- Bacterial Reproduction
  - done through binary fission (cloning)

  - plasmid
    - extra piece of circular DNA that occurs in some bacteria
    - antibiotic resistance found on these
    - can be separate or contained in the normal DNA
  - endospores
    - additional layer of protection around the bacteria
  - pilli
    - provides cytoplasmic bridges between two bacterial cells
    - allows for transport of genetic material

  - conjugation
    - replication and transport of a plasmid to a cell that did not have one
    - if the plasmid is located on the normal DNA, it may bring some normal DNA with it when it moves to another cell

  - transformation
    - bacteria picks up DNA from the environment and incorporates it

  - transduction
    - virus injects its genome into a bacteria
      - destroys the bacterial DNA
      - controls transcription and replication genes, replicates its own genome
      - new viruses are made and released from the cell
    - sometimes bacterial DNA is not entirely destroyed, and a new virus will have

bacterial DNA
    - if this virus goes and injects its DNA into a new bacteria, this bacteria gains bacterial DNA

- Metabolic Diversity
  - autotroph
    - an organism that gets carbon from carbon dioxide
  - heterotroph
    - uses carbon from existing bonds

  - photo
    - uses light to create proton gradient
  - chemoorgano
    - uses existing carbon carbon bonds to create proton gradient
  - chemolitho
    - uses multivalent metals to create proton gradient

  - Nitrogen fixation
    - nitrogen gas (N_2) and hydrogen ions with ATP make ammonia and hydrogen
    - nitrogen is used in nucleotides and in proteins
      - bacteria do this in the soil, plants absorb nutrients (limiting factor for plant growth), animals eat plants
    - can also be done in small amounts by lightning

- Archaea
  - extremophile bacteria
  - we don't understand why they do not melt in high temperatures, freeze in cold temperatures, can live in salt saturated water

  - have histones, methionine as first amino acid, and complex rna polymerase, similar to eukaryotes

- Fossil bacteria
  - almost exactly the same as they are today
  - stromatolites
    - created by millions of years of biofilms of bacteria
    - cyanobacteria creating sugars from carbon dioxide and water

- Cyanobacteria
  - new oxygen oxidizes minerals in the sediment
    - kills off many of the organisms because oxygen is toxic to them
  - once high enough levels are reached, it diffuses into the air
  - spontaneous reactions cause the production of ozone
    - only then can organisms move to land

- Viruses
  - named/associated by the proteins on the surface of the protein case (H1N1)
    - done by getting rid of the genetic material, break up the shell
  - less dangerous strains be dangerous if two occur in an individual at the same time

  - morphology
    - genome (DNA or RNA) inside capsid protein case
    - not cells, no membranes, ribosomes, mitochondira

  - every single virus uses the same steps for replication
    - entry
    - transcription and viral protein production
    - replication of viral genome
    - assembly of virions (virus, typically inside the cell)
    - exit (if the host dies, called a bacteriophage)

  - lytic cycle
    - destroys all host DNA, kills cell
  - lysogenic cycle
    - incorporates the viral genome into the host genome

- prions
  - protein on the surface of cells
  - normal or abberant (bad) form
    - if normal form comes in contact with abberant form, the normal one changes
    - they stick to eachother, accumulating in groups
    - pushes apart neurons, destroying connections
  - no known way to destroy the aberrant form

- viroids
  - very small circles of RNA
  - can replicate itself and block translation
  - originally found only in plants

  - Hepatitis D is a viroid, no cure

Proterozoic Era

- Eukaryote Autoapomorphies
  - nuclear envelope
    - thought that folded membrane to increase SA became more extensive, until it created a new membrane around the nucleus
    - useful because nuclear material could be better controlled
      - optimized environment for message creation and gene control
  - endomembrane system (ER)
    - folding that made the nuclear envelope is also thought to have created the endoplasmic reticulum
    - why it is attached to the nucleus
    - useful because things don't need to be put in the cytoplasm to be moved, much more organized
  - mitochondria
    - occurred through endosymbiosis, also the root of chloroplasts
    - large bacteria swallows smaller bacteria, which can produce ATP from carbon 2 or 3 carbon compounds
    - extremely successful, almost all mitochondrial DNA is the exact same between all organisms
    - works because no meiosis, egg is the only gamete with mitochondria, no genetic mixing
  - multiple linear chromosomes and diploidy
    - provides a safety net for mutations
    - allows for random segregation, creating tons of variability
      - crossing over occurs, giving even more variability
  - centrosomes
    - made of tubulin
      - forms triplets of tubules, each around a single tubule in the center of the centrosome
    - direct the formation of microtubulin, which creates the cytoskeleton of the cell
      - microtubules act as railways for molecular motors (dyenin, kinesin, myosin)
      - burn ATP for shape change, moving it along
      - has a holding area on the top to carry
      - dyenin moves away from the centrosome, kinesin towards
      - could not transport enough stuff around solely with the cytoplasm
    - can replicate, but they don't have DNA (no clue whats up)

    - Origin of cellular motility\
      - centrosomes also thought to be the source of locomotion
      - pushes against the cell membrane
        - cell gliding or cell creeping
      - over time, centrioles created an optimal organization of microtubules, could coordinate
        - creation of the flagellum

      - can be used to divide single cell eukaryotes

        - unikont: 1 flagellum, in a groove
        - bikont: 2 flagella, 1 for moving laterally, and 1 vertically
            - could move into the photosynthetic zone
    - number of cell membranes of a plasmid determines when it was encorporated
        - if a mitochondria like bacteria was eaten, 3 membranes
        - if a cell that already ate a mitochondria is eaten again, 4 membranes

    - Flagellar and ciliary movement
        - Flagella
            - dyenin arms in 9+2 structure move on one side, then the other
                - this causes one side to lengthen, then the other, causing wagging
        - Cilia
            - works in the same way
            - much smaller, found in the thousands

        - movement
            - helicoid
                - moves up and down, wiggling
            - planar
                - moves all the way from one side to another
                - power stroke pushes, recovery stroke is bent so it doesn't push backwards as much
                    - in cilia, power strokes occur at right angles to recovery strokes, so they don't tangle with each other
                    - metachromal wave
                        - beats are out of synch, always the same amount of forward thrust
                        - the wave

        - myosin
            - moves along actin instead of cytoskeletal filaments
            - change the shape of the cell, contracting
            - amoeba
                - polymerized actin changes endoplasm to ectoplasm, making it more gel like

- Protist Anatomy
    - cilia can be used not only for locomotion, but also for eating (ciliates are very complicated)
        - pulls food and/or water into a gullet, where it goes to a vacuole for digestion
        - cytostome
            - cell mouth (for single cells)
        - cytoproct
            - cell ass (for single cells)
        - circular path of food into a vacuole causes circulation of fluids in the cell
        - generally only have one place that is a cytostome, and one place that is a cytoproct
        - have 2 nuclei, micronucleus and macronucleus

        - micronucleus is diploid, macronucleus is polyploid
        - polyploidy increases rate of transcription when required
        - micronucleus is only used in meiosis, not used day to day

    - living in fresh water
        - non animal like cells
            - cell wall prevents bursting
        - animal like cells
            - contractile vacuole
            - bag that fills with water, elasticity pushes water out, repeat

- Types of Life Cycles (seen in animal/plant/fungi like protists too)
    - diplontic (animals)
        - most of life is diploid, only gametes are haploid
    - haplontic (most fungi)
        - most of life is haploid, only zygotes are diploid
            - zygote immediately undergoes meiosis
            - 2 new cells become either another gamete, or a spore
            - when a spore lands, it grows into a multicellular structure (gametophyte)
        - meiosis not needed to create a gamete, normal cell just undergoes change
    - alternation of generations (plants, some fungi)
        - n gametophyte produces gametes
            - gametes make a zygote which produces a sporophyte
        - 2n sporophyte produces spores
            - spore creates gametophyte
    - parasitic
        - varies a lot between different species
        - Malaria
            - mosquito ingests gametocytes
            - gametes are formed in digestive system of mosquito, produces zygote
            - zygote undergoes myosis while imbedded in wall of mosquito stomach (oocyst), creating hundreds or thousands of sporozoites, which go to salivary glands (saliva needed as an anti coagulant)
            - sporozoites move into the blood of the host, go through the liver and lodge in a liver cell, creates schizont, which replicates frequently
            - merozoite finds a good red blood cell, becomes a trophozoite, cell eventually bursts, they move to the next
            - a few trophozoites become gametozytes
            - changes physiology of host (damage RBCs), sweating, heavy breathing, fever
                - this is a super strong signal for mosquitoes to come bite

Phanerozoic Era

Phanerozoic

- Paleozoic (550mya-245mya)
  - multicellular animals (oceans still largely unicellular)
    - wide array of soft bodied organisms
    - Cambrian (550-488)
      - land mass Laurentia was located near the equator
      - was on a continental shelf, which meant depth got gradually shallower until land
      - light, nutrients were more prevalent here, equator also helps
    - Ordovician (488-443)
      - extinction at the end
      - cnidaria, molluscs, worms, echinoderms, bryozoa, arthropods survived
  - multicellular plants arise at ocean edges, reproductive strategies change for move to land, start of movement to land (need a food source before animal come)
    - Silurian (443-416)
    - Devonian (416-359)
  - animals move to land, large amounts of carbon available from plants
    - Carboniferous (359-299)
    - Permian (299-245)
- Mesozoic (245mya-65mya)
- Cenozoic (65mya-present)

Choanocyte

- colonial
- each have a flagellum, creating a water current through the colony, supplying nutrients and food
  - microvili in the colony help with trapping
  - 5 chonocytes in a colony move more water than 5 by themselves
- thought to be the ancestor of all animals
  - identified by the cytoskeleton in the collar (where the food is trapped), the same in all animals

Animalia Autapomorphies

- ingestive heterotrophs
- cells with different funcitons
- collagen (sticks cells together)

Porifera (sponges)

- choanocytes still around today
- cells but not tissue, some are specialized to take in water (osculum), be a passage
- asymmetric
- totipotent cells

- pinacoderm
  - outer surface of sponges, not a true tissue cause no connections, they just stick to eachother
- porocyte
  - pore in the side of the sponge
- ameobocyte
  - most undifferentiated, creates what is needed
- spicules
  - rigid substance in the inside of the sponge, creates shape

- choanocytes are the only ones that can collect food, they give some nutrients too the other cells

- sponge sex
  - choanocytes become sperm
  - archeocytes (sponge stem cells) form the egg
    - can recognize members of its own species

New inovations
- gap junctions added, allows communication
- tissues develop, basement membranes required
  - diploblastic: ectoderm and endoderm

Gastrulation
- blastula: hollow ball of cells, early embryo
- outisde cells are ectoderm
- one portion grows towards the inside, creating two membranes with an opening

Skeleton
- gives form/structure
- lengthens a contracted muscle
  - ATP contracts, a skeleton stretches the muscle back to its original shape

Cnidaria (jellyfish)
- radial symmetry
- entire group is predatory
- cnidocytes
  - stinging cells, for the purpose of eating
  - launches out a harpoon like structure, has hooks, poison
    - moves in meters per second, super high force for its weight
    - developed because they need to kill early arthropods by penetrating their armour

- body wall (hydrostatic skeleton)
  - allows for movement with muscles
  - only group with muscles but no mesoderm, have muscle cells in the ectoderm and endoderm
  - uses the incompressability of water

- incomplete digestive system
  - mouth but no ass (poor bastard)

- polyp: ancestral form (hydra)
- medusa: newer form (jellyfish)
  - pretty much an upside down polyp

- mesoglea
  - gel like substance between epithelial layers
  - when a jellyfish contracts its bell, outside pushes down, moves up

- life cycle
  - planula larva to developing polyp
  - then creates a branching polyp which has tentacles to feed
  - this polyp creates a gonozooid branch, which creates a medusa

- planula are bilaterally symmetrical
  - we may have evolved from these

- coral reefs
  - built by polyps, which secrete a hard skeletal case for protection
  - coral bleaching is due to the death of an algae symbiont (from higher water temperatures)

Next Innovations
- triploblasts with a mesoderm
- bilateral symmetry

Embryology
- cleavage
  - spiral: cells on top sit in grooves of the ones on the bottom
  - radial: cells on top sit on the tops of the cells bellow

- complete gastrulation
  - blastopore goes all the way through, full digestive system

- ceolom formation
  - solid mass of mesodermal tissue between ectoderm and endoderm
    - schizocoel
  - can also form from endoderm cells, little pieces of tissue grow off and disconnect
    - called an enterocoel (cavity from gut tissue)

- protostome
  - first opening (blastopore) becomes the mouth

- deuterostomes
  - second opening becomes the mouth

Body Cavities

- acoelomate (developed after coelomates)
  - has a mesoderm, but no body cavity
  - solid block of tissue
- pseudocoelomate
  - have a cavity, but not completely lined with a mesoderm
  - mesoderm only touching ectoderm
- coelomate
  - completely lined with mesoderm, mesoderm touching the endoderm as well as ectoderm

Ecdysozoa

- all organisms that have an exoskeleton
- non living, excreted, why they must molt (ecdysis)

- Nematoda
  - have a collagenous cuticle
  - no circular muscles (only have longitudinal)
  - epitheliomuscular pharynx
    - both epithelial and muscle cell
    - 2 valves, allowing it to swallow
    - triradiate pharynx (valves have three points of squishing, most efficient)
      - has no circular muscles
  - triploblast, pseudocoelomate, protostome
  - muscles on one side contract, then the other, causing it to wiggle back and forth
  - found in soil (feed on bacteria, other single cell organisms)

  - very little known about them (thought to maybe outnumber the arthropods)
  - most are very small (dominate a microhabitat, evolve to be as small as possible)
    - no dendrites going to muscle cells, the muscle cells have cytoplasmic extensions to a nerve cord (probably for miniaturization)

- Onychophora (velvet worm)
  - Oral papilla
  - slimy cuticle, still needs to be changed
  - segmented
  - living fossil (haven't changed their appearance in millions of years)

- Arthropoda
  - protein matrix strengthened with chitin
    - acetyleglucosamine unit hanging off the side
  - food manipulated by limbs and jaws (increases surface area for digestion)
  - articulated exoskeleton of plates

- muscles arranged in bands
- compound eye

- tagma
  - appendages in each segment are not the same
  - ex lobsters: mouthparts (putting food in the mouth), large defensive claw, walking legs, swimming legs

- filter feeding
  - swimming moves water with particles up a groove to the head
  - first swimmers, feeding mechanism allowed them to feed on algae

Lophotrochozoa

- no clue they were related for the longest time (not until DNA sequencing)
- organisms had lophophores (feeding structure) or other groups are all trochophores (larvel stage)

- Lophophorates (Bryozoa)
  - sessile, have a U shaped gut so they have somewhere to crap out of
  - hard casing they live inside
  - lophophore: bunch of ciliated tentacles used to bring food towards the mouth
    - trap food and create a water current
    - current pushes waste away from mouth as well
  - colonial (very coral like)

- Trochozoans
  - trochopore larvae
    - ciliated band around the middle for movement and food collection

  - Mollusca
    - radular teeth
      - tongue covered in barbs
      - shoved into substrate, scrapes organic material off rocks
    - dorsal mantle
    - calcareous spicules or shells
      - leaves very good fossil record
    - ventral ciliated muscular foot
    - has a mantle cavity with a gill, can pull the shell down and continue to feed and breath

    - Gastropods (snails)
      - spiral shell allows them to fully retract inside
        - can go dormant
      - hemaphrodites
        - beneficial because each mating event results in 2 fertilized eggs
        - slow moving, rare to bump into anyone else
        - make a dart, try to stab each other, whoever gets stabbed is more the female

        - Cephalopods (squids and octopods)
            - muscular foot has been modified to tentacles
            - large fossil record (amonites)
                - shell disappeared for speed (they are predators)

        - Bivalves (clams)
            - no radula, extracts particulate matter straight from water in substrate

        - Annelida (worms)
            - metameres
                - longitudinal muscles that can contract, different segments can contract <>----<>
            - setae
                - when longitudinal muscles contract, satae stick out into surroundings, anchoring and allowing for movement

Platyzoa

- acoelomates or pseudocoelomates
    - strategies for miniaturization
    - loss of metanephridia and circulatory system

- Platyhelminthes
    - incomplete gut
        - branching digestive system
    - entirely hermaphrodites

    - body cavity
        - aceolomate
        - 2 forms of movement
            - cilia on the bottom of them
            - glands that secrete a sticky substance to hold them to a surface, inchworm forwards
        - flat, because it can adhere to the surface makes it hard to eat

    - bilaterally symmetric and cephalization, but mouth is on the middle of the body, on the bottom side
    - use stinging cells from cnidarians (coral), cnidocytes, as a defense mechanism and eats the cnidarians as well

    - life cycle (largely parasitic)
        - fluke: can be anywhere in the body
        - tapeworm: only digestive system
        - stick to a wall of where they are, completely flattened
            - don't want to obstruct anything

        - eggs are dispelled from the body, first forms have cillia

        - all flukes go find a gastropod (snail) as a host
        - next stage, sporocyst, creates many immature forms of flatworm inside it (redia)
        - next stage, cercaria, is free living
        - final metacercaria lies dormant in a fish (or something) until that fish is eaten, at which point the digestive system of the eater triggers it to wake up

        - evolved before chordata, likely just was a parasite to gastropods at first
            - species of host is usually very specific to one species of platyhelminthes

        - swimmers itch: cercaria of duck liver fluke trying to find a duck, biting cause they're hungry

Echinodermata

- radial (pentaramous) symmetry
- water vascular system (not the same as in sponges)
- mutable connective tissue (endoskeleton)
    - have control of the hardness of their exoskeleton

- larva have bilateral symmetry, adults are radial
    - reversal

- ancestors
    - stalk anchored to the ground
    - many arms on the top (inverted umbrella)
    - could change hardness of stalk and arms
    - could catch falling nutrients before it hit the bottom, where other organisms were

    - starfish is an upside down version of these ancestors

- water vascular system
    - each tube foot has a valve
    - feet have suction cups, when they attach muscles pull
        - coordinated by nervous system
    - composed of canals connecting tube feet
    - used for locomotion, transportation, movement

- secrete enzymes to eat

Cambrian Explosion Explanation (all of the previous stuff)

- snowball earth
    - no life on land, just rock
    - moved towards the equator, reflected heat and cooled the planet
    - large amounts of precipitation at equator, run off to ocean filled with minerals
        - minerals caused carbon to go into the water, reduced greenhouse effect

        - methane levels also reduced
    - poles froze, frozen ocean reflects more energy, poles got larger etc.
    - also called slushball earth by people who didn't think it was that cold
    - ended by volcanic heating, and gasses from the venting
    - explosion after millions of years of life lying dormant

- early fossils (say it wasn't quiet an explosion)
    - multicellular fossils found a bit before the Cambrian explosion
    - doushantuo fossils: had multiple cells, looked like embryos
    - ediacaran fossils: mistaken point (fractal bodies), multicellular organisms

- cambrian burrowers
    - can use organic materials that have built up bellow the surface
    - provides protection against predators
    - anchors to one spot

- shelled arms race
    - with arthropods doing well, organisms had to get bigger and bigger to eat themselves

- homeotic genes (hox genes)
    - genetic material is found on the side of the cell in which the proteins it produces are needed
    - creates an anterior and posterior end to the body
    - eventually, transcription factors are made on one side of the body, where they are needed
    - showed in experiment
        - moved leg genes on a fruit fly to the front, grew legs instead of feelers

    - universal to the animal world, genetics that control pattern (similar plant pattern genes as well)
        - otherwise, its just a mass of cells

All that last stuff was Cambrian and Ordovician, next is Silurian

Animal Innovations (invertibrate chordates, organism cephalochordata)

- pharyngeal gill slits
    - used for gas exchange, as well as nutrient collection
- dorsal hollow nerve chord
    - protostomes have a heart on the dorsal side
- notochord
    - cartilaginous rod that will not be compressed, but can bend, the start of a skeleton
    - segmentally arranged muscles allow controlled movement (tadpole movement)
    - creates post-anal segmentation (aka a tail)

- endostyle
  - set of cells at the bottom of the pharynx which create a mucous net, food (single celled) sticks to mucous and the mucous is swallowed

- Vertebrata (Craniata/brain case, don't know which developed first)

Agnatha (jawless fish)
- lamprey
  - ectoparasite, sit on the outside (don't eat their way in)
  - though it doesn't have a jaw, developed teeth as a clamp so it can hold onto fish
  - has a nostril so they can breath while eating

  - life cycle
    - males and females move up rivers into creeks
    - immature lamprey stay in the creeks until they mature
    - return to the exact creek in which they were born

Gnathostomata (jawed fish with paired fins)
- paired fins lessen the amount of undulation of the front of the body, while using the tail
- also has a dorsal fin

- evolution of jaw
  - bony gill arches hold gills open
    - one bone came from dorsal side, one from ventral side
  - muscles around the pharynx develop more, allowing to move the bony arches
    - closing the front two allows closing of the mouth
    - can trap food and water, propel it into digestive/respiratory system

Genome Duplication
- homeotic HOX genes (control pattern) were duplicated twice
- this allowed for “experimentation” with genes, while having a backup set

- ray finned fishes duplicated again, have 8X genome (zebra fish)
  - still seen diversifying today

Chondrichthyes (cartilaginous fish)
- pectoral and pelvic fin (as well as dorsal and caudal)
  - fins are not attached to axial skeleton, help in place by muscle
  - tail does all the work, fins for agility and turning

- heterocircular tail
  - larger on top than on the bottom
  - force created as well as fins makes the fish move upwards, counteracting gravity
    - also counteracted by cartilage (lighter than bone)
    - liver is larger, produces oil to make shark less dense

- placoid scales
  - laminar flow: smooth surface is attracted to water when moving past (also air)
  - placoid scales create bumpy surface, creates turbulence generating less friction
  - same composition of teeth (teeth are pretty much large scales on a shark, why they have so many)
    - not connected to bone, only epidermis, so they are easy to tear off

- life cycle
  - produces very few young, unlike other fish
  - create chitin case (mermaid purse), with fertilized egg inside

Actinopterygii (ray finned fishes)
- teeth embedded in jaw
- suction feeding
  - unusually hinged jaw that allows them to open their jaws very fast, and project it outwards
  - evolved a second jaw from another gill arch deeper in the mouth
- bony skeleton replaces cartilage
  - allows fins that can be used for movement (not tail)
    - tail associated with speed, fins with agility
  - can also hover in water, meaning they spend less energy
- swim bladder or lung formed from the gut
  - as you sink in the water column, air is compressed, changing the amount needed for neutral buoyancy
  - add and take oxygen from and to the blood depending on the depth
- opercular gill
  - opercular plate (bone) moves out and in
  - plate pushed against the body at the same time it opens its mouth
  - closes its mouth when it opens the plate, pushing water out and across the gills
    - can hover in one place and continue to pump water across its gills

Sarcopterygii (lobe finned fishes)
- has forefins and hindfins, these fish evolved onto land
- could breath air, mostly lived in freshwater

Plantae
- development of cellulose and alternation of generations occurred at different times
  - charophyta is all one cell type, but multicellular
- problem, some organisms other than plants have cellulose
  - cellulose synthetase, 6 cellulose synthases assemble to make a string of 6 cellulose molecules
  - 6 sets of 6 assemble to make a 36 cellulose fiber (called a rosette)
  - controlled by microtubules attached to rosettes under cell membrane
- phragmoplastic cell division
  - all microtubules making cell wall reform towards the center and move to make the spindles

across the length of the cell (no centriole, we don't know what controls them)
    - pick up vesicle filled with cell wall material (cellulose, pectin, proteins) and release them on the midline, getting larger and forming the cell plate
- plasmodesmata (transport, cell to cell communication)
    - apoplastic pathway: through cell wall
    - symplastic pathway: through cytoplasm
- alternation of generations
    - gametophyte
        - have gametangia producing gametes
        - antheridia: sperm
        - archegonia: egg
        - eggs and sperms nourished by placental cell next to them
    - sporophyte
        - have a sporangia producing spores, bursts and lets out all the spores when ready
    - 2n sporophyte undergoes meiosis, produces spores which make a n gametophyte
    - gametophyte alters a cell to make gametes which fertilize to make a sporphyte

Marchantiophyta (liverworts)

- one of the most simple plants
- thallus: large mass of plant cell tissue, no vasculature, has grooves for water to run along
- has an umbrella like structure that houses archegonia
    - antheridia not located in the same spot
    - splash fertilization: raindrop hits antheridia, splashes upwards and hopefully hits archegonia
    - why plants self fertilize so often
- Gemma cups
    - splash cup of tissue for propogation (cloning) just in case its really required
- created a waxy epidermis to protect from water loss
- has pores to gain carbon dioxide, but loses water through them
    - they are only found in very moist environments

Transition to Land

- guard cell allows for closing of stomata
- meristem (differentiate to anything, for growth)
    - determinate
        - grows into any of the normal plant tissues
    - indeterminate
        - can turn into anything, including more meristem
        - why you can create two plants by ripping a part off of one
        - tips of the plant, subject to a lot of UV radiation and mutation
        - essentially a new embryo

Mosses

- sporophyte grows out of the gametophyte
  - spore capsules higher off the plant, trying to get them into the air current

- life cycle
  - has both male and female gametophytes
  - still requires splash fertilization into an archegonia
  - creates zygote, which creates gametophyte, which creates sporophyte, which creates capsule
  - spores (haploid) starts dividing, creating protonema, which eventually forms a gendered gametophyte

Devonian

- many plants on land, still no seeds
- sphagnum moss put antibacterials into their cell walls to kill bacteria
  - eventually becomes very complicated in structure, now lignin
  - toxic to bacteria, indigestible, hydrophobic, structural integrity
  - strength allows plants to grow larger, can't be decomposed (current fossil fuels)
  - produces a secondary wall, because its hydrophobic becomes vasculature
    - tracheids (xylem)
      - align end to end along the length of the plant, and die when matured
      - creates the vasculature, becomes the xylem
    - sieve tube cell (phloem)
      - each has a companion cell to move glucose in and out of the sieve
      - higher solute concentration increases water, but can't swell cause solid walls
      - causes the water to move to another area, where glucose is required/stored (sink)
      - low glucose causes water to go back to xylem and go back up
- ended with an extinction
  - disappearance of most jawless fish
  - kills off most of the reefs

Carboniferous

- continents are beginning to come together
- plants very different from today, tree ferns and very large horsetails

Monilophytes (ferns)

- have leptosporangia
  - spores held inside, when water is taken out of the cells, it uncurls
  - catapults the spores out when it contracts (very quickly)
  - still splash fertilization, but less chance of self fertilization
- fronds are the sporophytes, gametophyte dies as sporophyte is created

Spores vs Seeds

- homosporous
  - bisexual gametophyte, genders aren't seperated
- heterosporous
  - microsporangia create male gametophyte, sperm
  - megasporangia create female gametophyte, eggs

Gymnosperms (conifers)

- different genders of cones
  - weird smaller, softer ones are male gametophytes
  - normal hard ones are female gametophytes
  - male cones located near the bottom of the tree to stop self fertilization

- life cycle
  - male cones make many microspores, released as pollen
    - pollen grain (4 types of cells)
      - wing cells for movement
      - prothalial cells for protection
      - generative cells follows tube cell to the egg
      - tube cells burrows into the female gametophyte to get to egg
  - female cones have megaspores in them, wait for microspore
  - once pollen grain falls in, area closes off and burrowing begins (can take over a year)
  - gymnosperm seed
    - embryo (sporophyte), nutritive tissue (last generation gemotophyte), protective coat (created by generation before that, tree)

  - problem: a lot of metabolic energy is being used making sperm and egg that are never used

Fungi

- have filaments that can absorb nutrients
  - septa, hypha, mycelia
- cell division
  - nucleus does not disappear, microtubules go into and out of the nucleus at each end (done by pole spindle bodies)
  - separates into 2 nuclei
    - done because there are multiple nuclei with no separation (same cytoplasm), wouldn't know what DNA was whose
  - in meiosis, creates a cell with one nuclei from each of the parents, which creates cells with 2 nuclei

  - plasmogamy: creates dikaryote cell
  - karyogamy: creates diploid cells

    - meiosis: creats haploid cell

- septal wall
    - separates areas of cell tissue
    - there was just one cytoplasm for the entire organism, this allows for larger organisms and better specialized ares

- life cycle
    - dikaryotic mycelia create bundles, water is pumped into it, creating a mushroom
    - hanging down from gills of a mushroom is dikaryotic cells (basidium)