Biology notes for exam

Lecture 12

1. Strategy to distinguish between a phenotype that results from codominance relative to incomplete dominance
    - Incomplete dominance occurs when the effects of recessive alleles can be detected to some extent in heterozygotes
    - For example, in snapdragons, when a red flower and a white flower cross, they produce a pink flower
    - Two red colour alleles are needed to make enough pigment to produce entirely red colour. White alleles make no pigment whatsoever
    - Of course, when crossed, the pink flowers can produce both red and white flowers
    - In codominance, the effects of different alleles are equally detectable in heterozygotes
    - The alleles have approximately equal effects in individuals
    - Human blood types A and B are codominant
    - You would not be able to distinguish between codominance and incomplete dominance by looking at the inheritance patterns because they are the same
2. Characteristics that identify a pleiotropic allele
    - In pleiotropy, two or more characters are affected by a single gene
    - For example, sickle cell disease causes sickling of red blood cells, which also causes anaemia, fatigue, kidney failure, abdominal pain, etc.
    - These wide-ranging effects are caused by the single sickle cell gene
3. Conditions under which Hardy Weinberg Equilibrium is possible in a population.
    - The Hardy-Weinberg principle is a null model that describes how evolution does not occur. It specifies the conditions for genetic equilibrium

- Genetic equilibrium, in which allele frequencies and genotype frequencies do not change in succeeding generation, is possible only if these conditions are met:
  1. No mutations are occurring.
  2. The population is closed to migration from other populations.
  3. The population is infinite in size
  4. All genotypes in the population survive and reproduce equally well
  5. Individuals in the population mate randomly with respect to genotype
- Under these condition, microevolution does *not* occur
- This model is used as a reference point to access condition in which microevolution does occur, by identifying which conditions are not met

Lecture 12 lecture

1. General pathway of eukaryotic membrane protein production
   - DNA in the nucleus is transcribed and the transcripts leave the nucleus
   - Ribosomes take those transcripts to the ER and they are translated on the ER
   - These translated proteins are packaged into vesicles that go to the Golgi complex, then into new vesicles that send those proteins to the cell membrane
2. General physiology of skin/hair pigmentation
   - Pigment production is determined melanocytes which produce melanin packed into melanosomes which get exported into the skin/hair cells
   - There are two kinds of melanin: black and red, yellow melanin
   - Brown is produced by a mixture of red and black melanin
3. Characteristics of dominant alleles
   - The dominant alleles do not inhibit the recessive alleles. They simply mask the effects of the recessive alleles and determine the phenotype

- An allele isn't always dominant all the time (A dominant over O blood type but codominant with B blood type). It depends on the other allele present in the pair

4. Which allele in a heterozygote is dominant, given the biochemical mechanism of action of allele products?
   - Dominance happens because of the interaction of the gene products
   - Ex. If a R allele and a W allele are paired, the W allele will be dominant because the black melanin is sometimes produced and pigments the skin/hair
   - But if a W allele and a B allele pair, the B allele will be dominant because it produces black melanin all the time which determines the pigmentation
5. Factors that affect how allele frequencies change over time in a population
   - If there is no natural/sexual selection (equal fitness), allele frequencies do not change
   - Dominant alleles do not outcompete recessive alleles (or vice versa) in the absence of a difference in fitness
   - Dominance in an allele by itself does not make it more evolutionarily fit
   - In a large population, in the absence of selection, the starting allele frequencies influences future allele frequencies
   - Diploidy, dominance/recessive relationships, inheritance are not *in themselves* sufficient to drive changes in allele frequency
6. Allele frequencies (p and q), given genotypic frequencies.
   - Allele frequencies in a population can be anything, not just 50/50
   - If 60% of alleles in a population are p and 40% are q: pp = p^2 , qq = q^2 and pq = 2pq
7. Function of various MC1R alleles.
   - MC1R is a membrane receptor which produces black melanin if cyclic AMP levels are high. High cyclic AMP makes black melanin

- But under the influence of certain hormones, cyclic AMP levels can fall and the MC1R receptor produces red melanin instead
- An allele (W allele) codes for receptors that make brown and red melanin, depending on cyclic AMP levels
- Another allele (B allele) codes for receptors that are insensitive to hormonal stimulation and produce black melanin all the time
- In heterozygotes, B and W alleles are both present
- The B allele is on all the time, while the W allele is sensitive to hormonal stimulation. The B allele masks the effects of the W allele by coding for black melanin even though cyclic AMP levels are low, creating black skin/hair
- The R allele is off all the time and produces red melanin
- If either B alleles or W alleles pair with the R allele, it's effect will be masked by production of black melanin from the B or W membrane receptors

Lecture 13

1. Meaning of deme, population, allele frequency, genotype frequency
    - Deme: a local population of organisms of one species that interbreed with one another and share a distinct gene pool. Demes can be differentiated from one another on the basis of specific gene frequencies
    - Population: a group of potentially interbreeding organisms
    - Allele frequency: the proportion of different alleles within a population
    - Genotype frequency: the frequency of genetic constitutions within a population
2. Allele frequencies in a population, given the genotype frequencies
    - Two alleles, p and q. Three genotypes, pp, pq, and qq
    - Frequency of genotypes: $f(pp) = p^2$, $f(pq) = 2pq$, $f(qq) = q^2$

- Allele frequencies can be derived from these genotype frequencies by doing the reverse operation (square roots, division, etc.)

3. Genotype frequencies in the next generation, given the allele frequencies and assuming Hardy-Weinberg equilibrium
    - If the population is at genetic equilibrium of the locus p and q, the predicted frequency of genotype pp is the square of the allele frequency, p^2
    - For genotype pq, it is twice the product of the allele frequencies of p and q, 2pq
    - For genotype qq, it is the square of the allele frequency, q^2
4. Assumptions of Hardy-Weinberg equilibrium
    - In a population of randomly mating individuals, allele frequencies are conserved and in equilibrium unless external forces act upon them
    - Assumptions underlying this principle:
        1. Parents represent a random sample of gene frequencies in a population
        2. Genes segregate normally into gametes (heterozygotes for any gene pair produce their two kinds of gametes in equal frequencies)
        3. Parents are equally fertile
        4. The gametes are equally viable (have equal chance of becoming a zygote)
        5. The population is very large
        6. Mating between parents is random
        7. Gene frequencies are the same in both male and female parents
        8. All genotypes have equal reproductive ability
    - In summary: no evolutionary forces = allele frequency equilibrium
    - The ideal Hardy-Weinberg situation: genes on separate chromosomes, at least two alleles, a large effective population size, and no inbreeding

Lecture 13 lecture

1. Conditions necessary for Hardy-Weinberg equilibrium
    - In a large, random-mating population where mutations are rare enough to be ignored, in the absence of immigration and emigration and if there is no selection, allele frequencies will be conserved ($p^2 + 2pq + q^2 = 1$)
    - So large population, random mating, no gene flow, and no selection are the conditions necessary for Hardy-Weinberg equilibrium
2. Whether a population is in HWE, given observed genotype or phenotype frequencies
    - Use allele frequencies to calculate genotype frequencies:
    - Expected HWE frequencies: $f(A_1A_1) = p^2$ and $f(A_1A_2) = 2pq$ and $f(A_2A_2) = q^2$
    - Frequency of p = 2f(pp) + f(pq)/(total alleles)
    - Frequency of q = 2f(qq) + f(pg)/(total alleles)
    - Compare actual observed frequency of p and q compared to predicted HWE frequencies (ex. compare actual $f(A_1A_1)$ with predicted $f(A_1A_1) = p^2$)
    - If they are not equal, one or more assumptions violated. The population may be evolving
3. Effect of selection on changes in allele frequency
    - Selection against/selection for a genotype can cause the genotypic frequencies in a population to change as one genotype is weeded out by predators or lack of reproductive success, etc. This brings the population out of HWE
4. Relative vs. absolute fitness
    - Relative fitness (w) is the fitness of a genotype relative to other genotypes in a population (better than average, worse, etc). Lets one predict genotype changes
    - Absolute fitness (W) is the number of offspring/survival rates/lifespan/etc. produced by a certain genotype

5. How to calculate relative fitness
    - To calculate relative fitness, use $w = W/W_{max}$
    - The fittest genotype = 1, others between 0 and 1
6. How to quantify strength of selection
    - The greater the difference in w between other genotypes, the stronger the selection and the faster the evolution of the group
7. Relationship between dominance/recessiveness of alleles and response to selection.
    - When a dominant allele is selected against, it tends to disappear from the population quickly as it is weeded out
    - When it is selected for, it spreads quickly but may never reach a frequency of 1
    - When a recessive allele is selected against, it can remain at low frequencies in the population indefinitely as it is masked by the dominant allele in regards to phenotype
    - Carriers of the recessive allele have good fitness and live to pass on the allele
    - This explains why most human genetic disorders are caused by recessive alleles
    - When recessive alleles are selected for, it takes a while to spread, but given enough time, beneficial recessive alleles may completely outcompete their dominant partner
8. Effect of heterozygote advantage on genetic variation
    - Heterozygote advantage increases the number of heterozygotes in a population but it does not weed out all of the homozygous genotypes
    - This is because heterozygotes require equal proportions of homozygotes to maintain a high frequency. Both alleles will be maintained in equal frequency
    - This is a situation where there is selection (population out of HWE) but no evolution
9. Why the amount of genetic variation in a population is important
    - Genetic variation is the raw material for evolution to occur

- If the population lacks genetic variation, it cannot adapt to a changing environment
- Inbreeding depression: the offspring of close relatives tend to have low fitness because deleterious recessive alleles are more likely to combine in the offspring

10. Different types of selection (stabilizing, directional) and their effect on genetic variation
    - The vast majority of traits exhibit more continuous, quantitative variation
    - Stabilizing selection: individuals with extreme phenotypes (really big body size, really small body size, etc.) are selected against in a population, reducing the amount of variation of the trait (standard deviation from the mean).
    - Directional selection: an extreme phenotype (ex. long tail length, high running speed) is selected for, shifting the mean of the population in the direction of that extreme
    - Disruptive selection: extreme phenotypes on either side of the distribution are selected for with intermediates selected against (small beaks vs. big beaks, with intermediate beaks selected against), splitting the distribution into two.

Lecture 14

1. Difference between Batesian and Mullerian mimicry
    - Batesian mimicry is a mechanism based on frequency-dependent selection
    - In Batesian mimicry, palatable species that mimic distasteful models are protected against predators
    - In Mullerian mimicry, mimicry between different species benefits both because predators learn a single warning pattern that applies to all these potential but distasteful prey
2. How the population frequency of a mimic phenotype may affect its fitness
    - In general, in Batesian mimicry, the more frequent the mimic and the less frequent the model, the greater chance that predators will attack the mimic

- Conversely, the less frequent the mimic compared to the model, the greater the chance the mimic will be protected
- In Mullerian mimicry, when rare, conspicuous warning patterns on unpalatable individuals offers little protection because predators have few chances to learn their distastefulness
- Distinctive patterns offer greater protection when they are at higher densities

3. Why the same phenotype may be selected against in one environment but have a selective advantage in a different environment
    - A population sufficiently widespread enough may maintain a variety of genotypes, each of which is superior in a particular habitat
    - For example, there can exist both light coloured and dark coloured (melanic) moths. Each is more fit in one environment than another
    - Melanic moths are more fit in sooty areas which allow them to camouflage better. Light moths, on the other hand, have an advantage in areas without soot because the light coloured lichens on trees offer better camouflage for the light moths
    - Both phenotypes are selected against in one environment but are advantaged in another
    - Melanic forms exist in high frequencies in urban areas. Almost zero in rural areas
4. Meaning of genetic load and genetic death
    - Genetic load: the extent to which a population departs from an optimal genetic constitution
    - Genetic death: the loss of some individuals through any means that reduces reproductive ability
    - Most, if not all, populations carry genetic loads

- Environments change with time and the advantages of different genotypes vary accordingly. A population with a relatively high genetic load, may however, find an environment where the previously detrimental alleles may benefit survival

Lecture 14 lecture

1. Effect of various types of selection on amount of variation in a population
    - Stabilizing selection causes less variation about the mean of a population
    - Not all populations experience directional selection over the same time in the same way, so selection pressures can vary and maintain genetic variation
    - Selective environments may change and cause disruptive selection (ex. drought)
    - Negative frequency-dependent selection maintains both alleles as they switch from rare to common to rare and back again, balancing their average fitness
2. Examples of stabilizing, directional, disruptive
    - Stabilizing selection removes extremes from the population like low birth weight babies or very large sized birds (most widespread form of selection)
    - Directional selection favours one extreme phenotype, like extremely long tail lengths in widow birds or extremely fast running speed in cheetahs
    - Disruptive selection (least common) selects against intermediate phenotypes, increasing the frequency of phenotypes at both extremes (ex. selection favours big beaks or small beaks in finches and selects against intermediate size beaks due to availability of food during droughts)
3. Reasons why directional selection does not remove all genetic variation from a population
    - Natural selection can't forecast the future so variation isn't there in case the environment might change, but if it does change, selection forces also change
    - Selection pressure varies temporally (over time) and across habitats

- Adaptations (traits the increase bearer's relative fitness) are *environment-specific*
- Recessive alleles may "hide" in a gene pool, increasing the variation

4. Characteristics, and examples, of frequency dependent selection
   - Sometime the fitness of a particular phenotype will depend on its relative frequency in a population (how rare or how common)
   - Predators form search images of prey which creates a negative frequency-dependent selection (advantage of rarity). It is better to be the rarer form in a prey species because predators preferentially hunt the most common form
   - Of course, eventually, due to selective forces (higher fitness among rarer forms, lower fitness among common forms) the rarity of the forms switch and it is no longer adaptive to be of the previously rare form as it is now the most common
   - As well, there is rare male mating advantage. Ex. In drosophila, females will mate preferentially with males who are different
   - This is balancing selection and both alleles will be maintained in a population
   - Positive-frequency selection gives a selective advantage to the most common form in a population. Ex. warning colours teach a predator not to eat a certain colour of frog. But this only works if that colour is the most common in a population because otherwise predators don't learn to avoid that colour
   - Advantage to the most common form will quickly cause that allele to replace the other alleles in a population
5. Reasons why all living things are not perfectly adapted to their environment
   - The environment changes constantly (adaptation is at least one generation behind environmental change)
   - Selection doesn't always choose the most perfect allele because it may not exist

- Selection is constrained by available genetic variation
- Selection is not the only evolutionary force operating so alleles may randomly disappear or reappear
- Traits often represent a compromise between competing demands (trade-offs). Ex. the trait that protects against HIV makes one susceptible to West Nile virus
- Limited by dominance relationships (can't always weed the recessive alleles out)

6. Effect of genetic drift on allele frequencies within a population, particularly in the case of bottlenecks etc
    - Genetic drift occurs whenever population size is less than infinite
    - It is random, unpredictable changes in allele frequency due to sampling error. Allele frequencies change not to adapt, but just due to random luck
    - The smaller a population, the more heavily influenced by genetic drift
    - Bottlenecks cause a population to become small (ex. cheetahs) which reduces the amount of genetic variation. Cheetahs are virtually genetically identical to each other due to genetic drift (all other alleles are lost, one allele comes to fixation)
    - Founder events are when a population starts with only a few members (ex. polydactyly in Pennsylvania Amish). The Amish were founded by only a few hundred people and as luck would have it, a few of these individuals carried copies of alleles associated with polydactyly
7. Effect of genetic drift on variations between populations
    - Drift opposes selection and the outcome depends on the strength of the selection and the population size
    - Genetic drift reduces variation within a population and among population

- If 100 populations started with equal allele frequencies, in some of those populations one allele will go to fixation and in other the other will
- This is not due to selection, it is random and due to genetic drift
- So genetic drift reduces variation within a population but increases it among different populations

8. Mechanism that explain why mutation is NOT directed toward the needs of the organism.
    - Mutations are always occurring, not just because selective forces change
    - The reason a mutation increases in frequency is due to selection
    - Ex. an HIV virion doesn't cause the AZT resistance mutation, it occurs naturally then goes to fixation due to selection forces if present
9. General fitness effects of mutations
    - Most mutations have neutral or nearly neutral effects on fitness (because most DNA is non-coding)
    - Of those that affect fitness, most (but not all) are harmful
10. Why most mutations that affect fitness are harmful
    - Analogy: if you just randomly move switch things around in a car or a laptop, it is easier to break something than to make it work better
    - One switch in a base pair causes sickle-cell anemia
11. Effect of gene flow on allele frequencies
    - Gene flow can introduce new alleles to a population
    - Often opposes selection (selection-migration balance)
    - Phenotypes with high fitness in one environment may migrate to an environment where they have low fitness
    - Ex. dark coloured rock pocket mice vs. pale coloured rock pocket mice

- These mice do not stay in the environment where they are best adapted
- Prevents local population from becoming perfectly adapted to their environments

12. Characteristics of adaptive vs. non-adaptive mechanisms affecting allele frequency
    - Selection (several kinds) is the only form of adaptive evolution
    - Selection is the only thing that increases the fitness of a population by removing harmful alleles and increasing the number of beneficial alleles
    - Genetic drift, mutation, gene flow are non-adaptive mechanisms
    - They are random and often oppose selection but cause a population to go out of HWE and evolve (adaptively or non-adaptively)
13. How various evolutionary forces reinforce or oppose one another
    - Most mutations are harmful and so oppose selection, but they also provide the raw material for genetic variation and adaptive evolution
    - Genetic drift reduces variation within a population but increases it between populations. Gene flow may then balance the allele frequencies among these two populations

Lecture 15

1. How Darwin's theory of evolution differed from that proposed by Lamarck
    - Lamarck proposed a metaphysical perfecting principle caused organisms to become better suited to their environments
    - Two mechanisms fostered evolutionary change
    - The principle of use and disuse stated that body structures grow in proportion to how much they are used and unused structures get weaker and shrink
    - The inheritance of acquired characteristics stated that changes an animal aquired during its lifetime are inherited by offspring

- Darwin proposed instead that variations in hereditary traits enable some individuals to survive and reproduce while those that lacked favourable traits would die, leaving few, if any, offspring
- If the next generation was then subject to the same process, these traits would be even more common. He called this process natural selection
- Darwin provided purely physical rather than spiritual explanations about the origins of biological diversity
- He recognized that evolutionary changed occurred in groups rather than individuals

2. Meaning of catastrophism, gradualism, uniformitarianism
    - Catastrophism: a theory that reasons abrupt changes between geological strata marked dramatic shifts in ancient environments
    - One group of animals wiped out (by, say, a flood) and somewhat different species repopulated the area until the next catastrophe
    - Gradualism: the view that Earth changed slowly over its history under the influence of continuous processes acting over long periods of time
    - Uniformitarianism: the processes that shaped Earth's surface over long periods of time are the same as the processes observed today (ex. volcanic eruptions, earthquakes, erosion, and glacial movement)
3. Difference between relative vs. absolute ages of rock formations and the fossils they contain
    - Relative ages: sediments found in any one place form different strata which are arranged with the youngest layers on top. Because each stratum was formed at a specific time, the sequence of fossils from highest (oldest) to lowest (youngest) strata reveal their relative ages
    - Geologists use the sequence of strata to establish the geologic time scale

- Absolute ages: radiometric dating involves the use of isotopes and sometimes allows actual ages to be associated with different rock strata

4. Principle behind radiometric dating of rock strata
    - Radiometric dating exploits the fact that isotopes decay at steady rates so rock can be dated when the amounts of isotopes can be measured and the rates of decay are known
    - This approach is limited by the half-life of the isotope
    - Fossils that still contain organic matter can be dated by measuring the amount of the unstable isotope ^{14}C relative to ^{12}C
    - Living organisms maintain the levels of ^{14}C in their bodies but as soon as they die, no further replacement occurs and ^{14}C begins its steady radioactive decay
    - Scientists use the ration of ^{14}C to ^{12}C in a fossil to determine its age
5. Why most living things never form fossils
    - The soft remains of organisms are usually consumed by scavengers or decomposed by bacteria
    - Fossils rarely form in habitats where sediments do not accumulate or where soils are acidic
    - The absence of skeletons and hard parts makes some organisms (ex. jellyfish) less likely to be fossilized than others (ex. trilobites)
    - Many fossils are deformed by pressure from overlaying rock or from erosion

Lecture 15 lecture

1. Types of non-random mating
    - Inbreeding vs. inbreeding avoidance
    - Some species, like insect, will mate only with close relatives

- Some species, like humans, will almost never even consider mating with a close relative
- Assortative vs. disassortative mating
- Like mates with like. Ex. white snow geese mate preferentially with white snow geese and blue snow geese mate preferentially with blue snow geese
- Opposites attract. Ex. in white-throated sparrows, there are differences in plumage (white stripes vs. tan stripes) and individuals will only mate with other individuals who *do not* have the same plumage as they do
- Plumage is linked to behaviour (white striped is more aggressive, male or female)

2. Effect of non-random mating on HWE and on evolution
    - Random mating is a requirement for HWE
    - If a populations begins mating assortatively for a certain trait, but all genotypes have the same fitness (2 alleles, 3 genotypes, intermediate dominance, and each genotype mates assortatively) this perturbs HWE but doesn't cause evolution
    - Homozygotes will produce only homozygotes, but heterozygotes will produce some homozygotes and some heterozygotes
    - This reduces the amount of heterozygotes in a population
    - If a population is mating non-randomly assortatively, it changes the genotype frequencies but *not* the allele frequencies (allele frequencies stay the same)
3. Characteristics of a scientific theory
    - A coherent set of testable hypothesis that attempt to explain facts about the natural world
    - "Truth" is an assertion for which there is so much evidence, it would be perverse to deny it
    - Theories graduate to facthood after repeated testing fails to falsify them

- A theory must be able to be tested and to be proven false (falsifiability)

4. Components of the theory of evolution
    - Evolution happens: changes in allele frequencies in a population, between generations
    - Most evolution is gradual
    - Speciation happens
    - All life is related through common ancestry
    - Much of evolutionary change is caused by selection
    - Evolution occurs in populations, not within individuals
5. Evidence for "descent with modification"
    - Evidence for common descent in the form of homologies and intermediates in the fossil record
    - Lots of evidence for change within a species (ex. HIV)
6. Examples of homology and why they support the idea of evolution
    - Homologies can be structural, developmental, molecular…
    - Any similarity between two species, not explainable by shared function/environment, that reflects shared ancestry
    - Molecular homologies (ex. the genetic code)
    - Morphological homologies (same array of bones arranged in the same manner among invertebrate species that use their limbs for vastly different purposes)
    - Embryonic homologies show similarities in early embryonic development that make no sense unless there is shared ancestry behind it
    - Ex. humans form tails in early development which are then reabsorbed
7. Examples of vestigial traits and why they support the idea of evolution
    - Vestigial traits only make sense in the context of evolution

- Cave salamanders have rudimentary eye buds though they live completely in the dark. This trait only makes sense if it is a remainder of evolution from a common ancestor that did use its eyes
- A dandelion has anthers and pollen but it reproduces asexually. This must mean the dandelion has only recently evolved to be asexual from a different, sexually reproducing species of flower
- Vestigial genes also provide evidence for evolution. A functional gene codes for protein. But throughout the human genome, there are pseudo-genes that look very similar to functioning genes but do not code for anything
- Genes can be duplicated and take on a new function, but they can also be duplicated and lose its function or become disabled

8. Role of fossil record as evidence for evolution
    - Descent: transitional forms “link” related groups (from fossil record)
    - Modification: fossil evidence of change

Lecture 16

1. Relationship between sexual reproduction and genetic variation
    - Recombination or genetic exchange: sections of chromosomes can exchange genetic material (crossing over) thereby forming different arrays of nucleotides
    - Recombination can produce different combinations of genes along a chromosome
    - Millions of different kinds of gametes can be produced from recombination alone
    - The production of genetic variation is one of the hypothesis for the persistence of sexual reproduction
    - Sex in a population gets rid of deleterious alleles faster and makes it easier to combine beneficial alleles as they arise

- The advantages of genetic variation is that it allows a population to persist and adapt in a changing environment (ex. to resist parasites)

2. Different modes of genetic sex determination
   - Particular genes are located on those chromosomes associated with sex determination (sex chromosomes)
   - For many organisms, sex determination is associated with chromosomal differences between the two sexes (XX vs. XY in humans, XX:XO in nematodes, ZZ:ZW in snakes and birds)
   - Sex can also be affected by autosomal genes
   - In Drosophila, the sex of an individual is determined by the ratio of X chromosomes to sets of autosomes (A)
   - Males have an X/A ratio of 0.5 while females have a 1 ratio
   - In other species, the potential for becoming male of female exists at the time of fertilization, no matter what sex chromosomes are present
3. Different modes of environmental sex determination
   - Penis fencing in flatworms turns whichever worm is pierced with the other worm's penis into the female
   - Temperature dependent sex determination in alligator and other reptiles sets the sex of the organism by the temperature at which the eggs develop
   - Fish can change sex as adults, possibly due to hormones
   - Hormones can trigger a chicken to develop an ovary, a testis, or an "ovotestis"
4. Meaning of haplodiploidy
   - This is a mode of sex determination in which males develop from unfertilized, haploid eggs and females develop from fertilized, diploid eggs

5. Meaning of hermaphrodite. Whether hermaphroditism is generally rare or common in plants
    - Hermaphrodite: having both female and male function
    - Some 90% of seed plants produce both male and female gametes
    - Only a minority of the five percent of plant species with separate male and female plants have sex chromosomes

Lecture 16 lecture

1. Relationships among sexual reproduction, meiosis and genetic variability
    - Recombination in meiosis creates genetic diversity (new combinations of alleles)
    - Crossing over, independent assortment generates genetic diversity
    - Offspring are distinct from either parent and (usually) siblings
2. Mechanisms of asexual reproduction
    - Binary fission: the mother cell divides and gives rise to two genetically identical daughter cells
    - Plants can send out runners and create clones (vegetative propogation)
    - Pseudo-sex creates genetic recombination without reproduction
    - Bacteria exchange genetic information without binary fission
    - Facultatively sexual organisms can reproduce sexually or asexually
    - Obligately asexual animals (like the Amazon molly) reproduce entirely asexually but may not be able to reproduce without some courtship behaviou
    - The Amazon molly must expose her eggs to sperm so they develop properly, even though no actual fertilization takes place
3. Examples and predictions of size-advantage model of sex change
    - The relationship between body size and fitness is different between males and females in some species

- There may be some advantage to being large for females or for male
- If the fitness function is steeper for say, females than males, all organisms born will start out male and switch to female when they reach a threshold body size
- Or vice versa (female to male if bigger is better for males)
- Protandry: male to female sex change. Bigger females can produce more eggs
- Dominance can result in better fitness for bigger males
- This maximizes reproductive fitness

4. Distribution of sexual reproduction among all life forms, and particularly among animals
    - Sexually reproducing organisms may be dioecious or monoecious
    - In dioecious organisms, male and female functions are housed in different individuals (each individual is either male or female with separate gametes)
    - In monoecious organism, male and female functions can be found in the same individual (hermaphrodites). Most plants are monoecious
    - Sequential monoecy means an organism can switch from male to female
    - Most things, except plants and animals, reproduce mostly asexually
    - First life forms almost certainly reproduced asexually
    - But among animals, the vast majority of species reproduce sexually
    - Less than 1/10th of 1% of animals are obligately asexual
5. Costs of sexual reproduction
    - Cost of finding a mate, cost of courtship and mating (vulnerability to predators)
6. Cost of meiosis
    - If you reproduce sexually, you only pass on half your alleles to offspring
    - Genome is diluted
    - Cloning allows you to pass on all your genes, not just half

7. Cost of sons
    - Males are an “evolutionary dead end”
    - Males do not allow one to produce the maximum the population or the production of grandchildren
    - If one compares asexually reproducing organisms with sexually reproducing organisms, because it takes two individuals (male and female) to produce offspring instead of one female just cloning herself, the amount of potential grandchildren is halved (because a female produces half daughter and half sons)
8. "Muller's Ratchet" mutational load explanation for advantage of sexual reproduction
    - Muller’s ratchet: asexual lineages accumulate harmful mutations
    - There’s more ways of coming up with a harmful mutation than a helpful one so organisms that reproduce asexually accumulate harmful mutations over time
    - There’s no way for asexual lineages to get rid of harmful mutations
    - Sex breaks this ratchet by continually reforming genotypes
9. "Ruby in the Rubbish" hypothesis explanation for advantage of sexual reproduction
    - Sex continually creates genotypes with fewer (and more) harmful mutations than parental genotypes
    - It does not increase the average fitness but it increases the amount of variation in fitness among offspring. This allows selection to weed out harmful mutations and increase the spread of beneficial mutations
10. Combination of beneficial mutations for advantage of sexual reproduction
    - Some small minority of mutations are advantageous
    - Sex can speed up the rate at which beneficial mutations occur in the same individual.

- It's very unlikely that one individual will independently acquire three beneficial mutations at once, but sexual reproduction can combine these mutations
- If a large population is sexually reproducing, some individuals will have two out of three mutations and in the next, three out of three, and these individuals will have great fitness and spread quickly
- If in an asexually reproducing population three beneficial mutations arise, there's no way to combine them, the individuals with each mutation will be competing against one another
- The speed of evolution is faster in sexually reproducing organisms

11. Relationship between extinction rate and sexual reproduction
    - Sexual reproduction speeds up the rate of evolution by discarding harmful mutations and combining beneficial mutations, thus decreasing the likelihood of extinction
    - Almost all the obligately asexually reproducing animals are of recent evolutionary origins, This suggests that asexually reproducing species go extinct fairly quickly (or we would have ancient lines of asexually reproducing animals)
    - Sex reduces extinction rate
12. Does sex for the good of the species explain its persistence?
    - Traits almost never spread throughout a population at the expense of the individual
    - Things almost never spread simply because they benefit the species or there is some long-term benefit
    - This is because selection only works on the individual
    - The costs of sex means that, all thing being equal, an asexually reproducing organism should quickly outcompete all the sexually reproducing organisms

Lecture 17

1. Meaning of monogamy, polygamy, polygyny, polyandry, promiscuity, leks
    - Monogamy: the situation in which a male and a female form a pair bond for a mating season or for the individual's reproductive lives
    - Polygamy: males and females have more than one active pair bond
    - Polygyny: one male has active pair bonds with more than one female
    - Polyandry: one female has active pair bonds with more than one male
    - Promiscuity: when males and females have no pair bonds beyond the time it takes to mate
    - Leks: congregation of displaying males where females come only to mate
2. Conditions favouring the evolution of monogamous versus polygynous mating systems
    - If young require a great deal of care both parents can provide, monogamy prevails
    - In some birds, both males and females can bring food to the nest
    - Monogamy occurs in mammal species in which males indirectly feed the young by bringing food to the mother while she produces milk
    - If males have high-quality territories, the females living there may be able to raise young on their own
    - As such, males tend to be polygynous and serve more as sperm donor and protector than active parent to his young
    - Polygyny is prevalent among mammals because the females make a much larger investment in raising young than do males
3. Handicap explanation for why females prefer males with extravagant ornaments

- These features are signals of male quality (like health, efficiency in harvesting resources, age) and if they reflect the male's genetic makeup, he is likely to fertilize a female's eggs with sperm containing successful alleles
- As well, large, showy males may hold large territories. Females who choose these males can gain access to these territories
- The handicap hypothesis states that females select males who are more successful – the ones with ornate structures. These structures impede locomotion and may attract predators, so females mate with the ornate males who survived *despite* carrying such a handicap

4. Meaning of sexual dimorphism, intersexual selection, intrasexual selection
    - Sexual dimorphism: differences in size or appearance of males and female
    - Intersexual selection: selection based on the interaction between males and females. Males produce ornate structures because females find them attractive
    - Intrasexual selection: selection based on the interactions between member of the same sex. Males use their large body size, antlers, or tusks to intimidate, injure, or kill rival males.

Lecture 17 lecture

1. "Lottery ticket hypothesis" and "red queen hypothesis" to describe the relationship between environmental stability and benefits of sexual vs. asexual reproduction
    - Lottery ticket hypothesis: sex in unpredictable environments benefits the individual. Asexual reproduction is beneficial in extremely stable environments
    - If a female has survived to reproductive age, she is adapted very well to the current environment but she may not be well adapted to future environments

- If the environment is unpredictable, sexual reproduction produces diversity in offspring. You are maximizing the chance that at least some offspring will survive
- Red queen hypothesis: sex is favoured when your environment is continually evolving (natural enemies). If parasites are an important selective force, these species are continually evolving better ways to kill you
- Thus, it benefits the individual to produce a variety of offspring genotypes to better "arm" them against the parasites
- Ex. fresh water snails are facultatively sexual and when there is a greater number of parasites, the snail tend to reproduce sexually more than asexually

2. Long-term vs. short term advantages to sexual vs. asexual reproduction
    - The long-term advantage is that sexual reproduction speeds up evolution by weeding out harmful mutations and combining beneficial mutations
    - The short-term advantage of sexual reproduction is production of offspring that are genetically diverse. In a changing environment, this increases the chance that at least some offspring will survive and go on to reproduce
    - Reduced extinction risk may be just a consequence of sex, not an explanation
3. Why sex places different selective forces on males vs. females
    - Sexual dimorphism and traits that reduce survival are explained by sexual selection
    - Males must compete to gain access to females or vice versa.
    - Generations of choosy females have driven the evolution of sexual dimorphism in birds of paradise
4. Relationship between sexual selection and investment in offspring
    - The heavy-investing sex (usually female) is under selection pressure to choose the most fit individual to increase the fitness of her offspring

- The less investing sex (usually male) is under selection pressure to gain access to the most number of mates to create the largest amount of offspring

5. Role of parasites as an explanation for the persistence of sexual reproduction
    - Parasites are continually evolving better ways to parasitize their host
    - The host must them evolve faster to combat these parasites
    - Since sex speeds up evolution and allows the individual to produce genetically diverse offspring, sexual reproduction becomes advantageous when parasites are a major selective force in the environment
6. How sexual selection maintains traits seemingly incompatible with natural selection
    - Some traits that seem to reduce an individual's fitness (like loud mating calls that attract predators) are adaptations to maximize mating success
    - These adaptations allow the individual to produce more offspring, thus increasing fitness
7. Examples of traits favoured by intra vs. inter sexual selection
    - Intra-sexual selection (competition between member of the same sex) favours traits that can aid in combat with members of the same sex
    - Traits like horns, large body size, tusks, antlers etc.
    - Inter-sexual selection ("female choice") favours traits that are attractive to the opposite sex like bright colours, long tails, songs, etc.
    - The distinction can often be blurry (ex. male bowerbirds will decorate their bowers with blue to attract females but other male bowerbirds will drop red in other bird's bowers or destroy the bowers, etc.)
8. Why males are more usually competing for access to females (rather than vice versa)
    - Sperm is cheap and easy to produce, ova require more investment

- Males can produce millions of sperm at no cost, it is energetically costly for a female to produce an egg (anisogamy = unequal gamete size)
- Female mammals are also the ones who carry the offspring to term and nurse it, so they invest a lot resources in the care of the offspring
- Since females are limited by the number of offspring they can produce and the care they can provide, it is advantageous to be choosy when picking a mate
- Direct benefits are resources the male can provide the female (like food, or territory, care to offspring, or protection from predators)
- Indirect benefits are the genetic advantage provided to females
- The best mate provides the best alleles to the limited offspring a female can have
- Males, on the other hand, are not limited by the number of offspring they can produce, so it is advantageous to mate with a wide variety of partners to maximize the amount, not the fitness, of offspring produced

9. Relationship between parental investment and which sex is choosy vs. competing
    - Sex differences in parental investment and potential fitness determine which sex is choosy and which sex competes
    - The high investing sex becomes a limiting resource for the low investing sex
    - Ex. in evolutionary history, a female human who engaged in a short term mating opportunity wound up still investing heavily in the offspring
    - A male who did the same did not invest at all
    - This led to selection pressure favouring choosiness among the heavy-investing sex and selecting against choosiness in the less investing sex
10. What happens (in terms of sexual selection) when both sexes invest heavily in offspring
    - In some taxa (ex. humans and birds) offspring are very demanding

- This requires both sexes to invest heavily in the care of the offspring as it is virtually impossible for one person to successfully rear it alone
- This create selection pressure favouring monogamy with both sexes facing equal selection pressure and both sexes being picky in long term mating partnerships

11. Average vs. potential fitness of males vs. females
    - Average potential fitness of males and females is equal because all offspring have one female parent and one male parent. Equal numbers of males and female contributing to the next generation
    - Males have higher potential fitness though because they can produce offspring at a much greater rate than females
    - Females are limited by the number of offspring they can have. Female physiology puts an upper limit on the number of children they can have
12. Limiting factors on male vs. female fitness
    - The number of mates is the limiting factor in males fitness
    - Females are limited by the number of offspring they can produce
13. Traits valued in mate choice by human males vs. females
    - In humans, we must distinguish between short term mating partnerships and long term mating partnerships with both sexes being choosy when it comes to long term mating
    - Physical attractiveness (ex. facial and body symmetry) is important to both sexes
    - Someone who has developed very symmetrically has been able to withstand developmental stressors (high developmental stability)
    - Preference for symmetry is strong among populations who are subject to many parasitic diseases (like tropical populations)

- Females rank potential mates according to athletic ability, kindness to children, and resource holding potential (wealth)
- Males rank potential mates on cues that indicate fertility, youth, and health (like waist to hip ratios, circulating estrogen level)

Lecture 18

1. Identify the meanings of kin selection, altruism, reciprocal altruism, eusocial
    - Kin selection: individuals should be more likely to help close relatives because increasing a close relative's fitness means helping propagate some of one's own alleles
    - Altruism: doing something that enhances the situation of another individual
    - Reciprocal altruism: individuals helping non-relatives if they are likely to return the favour in the future (each member can potentially benefit from the relationship)
    - Reciprocal altruism is favoured by natural selection as long as individuals that do not reciprocate are denied future aid
    - Eusocial: thousands of genetically related individuals, most of them sterile workers, live and work together for the reproductive benefit of one individual (a queen and her mate)
    - Self-sacrificing behaviour directed to the benefit of kin
2. Calculate degree of relatedness between two individuals, given the type of relationship (parent-offspring, cousins, etc)
    - By calculating the degree of relatedness, we can quantify the average percentage of alleles shared by relatives
    - Half siblings share one parent so they share 0.25 of their alleles
    - Full siblings share 0.5 of their alleles (0.25 from mother, 0.25 from father)

- The degree of relatedness between a nephew or a niece and an aunt or uncle is 0.25 and between first cousins it is 0.125
- We can calculate the total relatedness between any two individuals by multiplying out the probabilities across all of the links between them

3. Identify why haplodiploidy can favour high levels of cooperation in social insects
    - In bees and other eusocial insects, sex is determined genetically through haplodiploidy (females are diploid, males are haploid)
    - All of the sperm carried by a haploid male will be genetically identical because he has only one set of chromosomes
    - When a queen mates with just one male, all of her worker offspring will inherit the exact same alleles from their male parent, ensuring at least a 50% degree of relatedness among them
    - They are also related through their female parent, so some share 100% of their alleles while others share only 50% of their alleles
    - This leads to a degree of relatedness of an average of 75%
    - This high degree of relatedness may explain the exception cooperation among bees and other eusocial insects
    - The workers devote their lives to caring for their siblings because a few of those siblings (carrying an average of 75% of the worker bee's alleles) may become future queens and produce enormous numbers of offspring themselves

Lecture 18 lecture

1. Examples of different types of social interaction
    - If the recipient is harmed and the actor benefits, that's selfishness (many, many examples in nature, not hard to explain evolutionarily)

- If the recipient benefits and the actor benefits, that's cooperation (many examples in nature, easy to explain because it increases the actor's fitness)
- If both are harmed, that's spite (almost never happens)
- If the recipient benefits but the actor is harmed, that's altruism (perplexing puzzle in evolutionary biology because the actor's fitness is reduced)
-

2. Behaviours that are, or are not, "altruistic"
   - Parental care is not altruistic because by providing care to their offspring, the parents ensure their genes are passed on to the next generation increasing their own fitness (cooperative behaviour)
   - Individuals who take risks for other organisms that are not related to them are behaving altruistically (in some cases)
3. How kin selection theory explains selection for altruistic traits
   - There is more to fitness than simply producing direct descendants
   - More than one way to get copies of your genes into the next generation
   - If you perform behaviours that somehow increase the ability of your close relatives to reproduce, they share alleles with you so any additional reproduction that they do contributes indirectly to your fitness
   - Kin selection favours traits that increase indirect fitness
   - This maximizes indirect/inclusive fitness
   - Hamilton's rule determines whether altruistic/costly traits favoured: $rb>c$
   - Benefit received by donor's relatives (b)
   - Weighted by degree of relationship (r)
   - Does this outweigh cost to donor's direct fitness (c)?

4. Direct vs. indirect vs. inclusive fitness
    - Direct fitness: personal reproduction/creation of own offspring
    - Indirect fitness: additional reproduction by relatives, due to your “altruism”
    - Inclusive fitness = direct + indirect fitness
5. Reasons why cooperation can evolve in face of prisoners' dilemma
    - Cooperation and altruism between non-relatives can be explained by reciprocity
    - In the prisoners’ dilemma, it’s always logical to defect IF this is a one time interaction. Selection can favour altruism if it is later reciprocated
    - The payoff for mutual defection is worse than for mutual cooperation
    - Reciprocal altruism most likely to happen when groups are small/stable and when individuals can recognize and remember helpers and cheater
6. Role of human emotions in support of reciprocal altruism
    - Human emotions like guilt, resentment, guilt, gratitude, etc. likely evolved as a way of “score keeping” to remember who helped and who cheated in the past
    - This facilitates reciprocal altruism
7. Conflicting interests of parents vs. offspring
    - Inclusive fitness explains conflicts between relatives (ex. how much and how long to invest in a particular offspring?)
    - The longer a parent provides care to an individual offspring, benefits to both through increases offspring fitness but diminishing returns
    - Parents lose opportunity to produce other offspring
    - P is equally related to all offspring so should cut offspring loose once $b<c$
    - Offspring is twice as related to itself as to its siblings so should demand care until $b<2c$. This is when conflict results

Lecture 19

1. Identify the differences between morphological, biological and evolutionary species concepts
    - Morphological species: a population of individuals that share more characteristics with one another than they do with any other organism
    - Biological species: a sexually interbreeding or potentially interbreeding group of individuals normally separated from other species by the absence of genetic exchange through reproductive and other barriers
    - Evolutionary species: a lineage evolving separately from others and with its own evolutionary role and tendencies
2. Identify strengths and limitations of each of the above three species concepts
    - The morphological species concept does not work for species that look very similar to one another but do not interbreed
    - As well, species that are sexually dimorphic (like birds of paradise) would be classified as different species by the morphological species concept even though they do interbreed
    - Applying the biological species concept has allowed distinctions to be made between similar-appearing populations that cannot be distinguished by morphology (sibling species)
    - Limitations to the biological species concept include: the inability to apply the concept to fossils and to asexually reproducing organisms, and the existence of organisms that are prevented from interbreeding only be geographic isolation
    - The evolutionary species concept incorporates change over time (evolution) and lays the groundwork for considering changes resulting from competition and interaction among species

- However, defining the stage when groups of organisms have reached complete speciation is subjective
- A species name indicates singularity but the individual members of a species display variation so no species concept will ever fit perfectly

Lecture 19 lecture

1. Why conflicts of interest can arise even between closely related individuals
    - Due to the asymmetry of the relatedness coefficient. Everyone is related to themselves with a coefficient of 1, but are only related to parents/siblings by a relatedness coefficient of 0.5
    - Ex. Fetus selected to "demand" more resources from mother than mother selected to give. Fetal tissue secretes hormones to manipulate blood pressure and blood sugar level so maternal sensitivity to these signals drop
    - This endangers both parties and can be explained by overlapping but not completely identical interests (asymmetry in relatedness)
2. Tragedy of the commons (why rational decisions by individuals can lead to the overexploitation of shared resources)
    - Unrelated individuals may have similar but not overlapping interests
    - Tragedy of the Commons: social dilemma (conflict) over use of shared resource
    - If several farmers have only one field to graze on, it is in an individual farmer's best interest to buy another cow to the detriment of the shared grazing field
    - As more cows added, cost of overgrazing shared by all farmers but the benefits of owning another cow are not shared

- It is rational for an individual farmer to buy another cow because the costs of overgrazing are discounted as they are shared among all the farmers
- Whenever an individual acts in their own interests (rationally), the shared resource is going to be exploited (the tragedy of the commons)

3. Morphological species concept
   - A species is a group of organisms that looks more like each other than any other group
   - Identifies species by whether or not they look similar to each other
4. Biological species concept
   - A species is a group of organisms that can interbreed
   - The species is reproductively isolated from other such groups
5. Applications of, and strengths and weaknesses of, biological vs. morphological species concepts
   - The morphological species concept is very easy to apply in the field but has several limitations
   - In the morphological species concept, sexual dimorphism (where males look vastly different from female of the same species) is not accounted for
   - Individuals of the same species can also have different markings or patterns (polymorphism). And some individuals look very similar to other individuals though the two cannot interbreed
   - The biological species concept is more precise but does not account for asexually reproducing organisms
   - As well, it can be impossible to test whether two groups can interbreed if they never meet in the wild and so have no chance to interbreed
   - There is likewise no way to know if extinct organisms would interbreed
   - And some animals hybridize (coyotes and wolves for example)

6. Phenotypic clusters
    -

7. Pre-zygotic vs. post-zygotic isolating mechanisms (achieving reproductive isolation)
    - Pre-zygotic isolation: populations are reproductively isolated because they never produce a zygote in the first place (different mating behaviours, different sexual organs, etc.)
    - Post-zygotic isolation: populations become reproductively isolated because the hybrid offspring do not develop properly (inviable or infertile)
8. Ecological (habitat) isolation, temporal isolation, behavioural (courtship) isolation, mechanical isolation
    - Ecological (habitat) isolation: two populations are reproductively isolated from each other by the habitat in which they prefer to live/breed
    - Ex. Some toads live/breed in dry, sandy habitats and do not interbreed from toads that breed in, say, colder darker forest habitats
    - Temporal isolation: different breeding seasons prevent two populations from interbreeding due to this differing mating behaviour
    - Ex. Some spotted skunks reproduce only in the spring and some only in the fall
    - Behavioural (courtship) isolation: different courtship behaviour (different song singing, different plumage, etc.) prevent interbreeding because the two species are simply not attracted/do not respond to the other's courtship display
    - Ex. Different birds of paradise have different courtship displays which do not facilitate interbreeding with females of other bird of paradise populations
    - Mechanical isolation: two populations have different sexual organs and so cannot interbreed

- Ex. Male damsel flies have a huge diversity of penis shape. Females are very picky as to the shape and will not breed with a fly who has a wrong shaped penis

9. Hybrid inviability, hybrid sterility
    - Hybrid inviability: the hybrid zygote can form and begin to develop, but at some point it becomes inviable (dies before it's born/becomes an adult)
    - Hybrid sterility: when the hybridized offspring of two species is not fertile. An "evolutionary dead end"
10. Allopatric, peripatric, parapatric, sympatric speciation
    - Allopatric speciation: geographic isolation causes a population to split and diverge (selection or genetic drift) to create new species
    - Peripatric speciation: a subset of allopatric speciation but in this case a small subset of a large source population splits off and selection and drift take the two populations in different directions
    - Parapatric speciation: the ranges of the two populations are neighbouring each other and there is some gene flow (a leaky barrier). Less likely to result in full blown speciation because there is some homogenizing gene flow (requires really strong selection pressure to outweigh the equalizing effect of migration)
    - Sympatric speciation: speciation without allopatry (no barrier)
11. Isolation, divergence, secondary contact, reinforcement
    - Isolation: A geographical change divides a population and prevents gene flow
    - Secondary contact: the isolating barrier is removed and the now two distinct populations are free to mingle again
    - Reinforcement: direct selection favouring pre-zygotic isolating mechanisms in the event of secondary contact (ex. due to unfit hybrids)

12. Which species concept is being used, given 'real world' examples
    - If you see a bird and say "Well, it has a long beak and a red body, therefore it is such and such species" you are using the morphological species concept
    - If you are a biologist and are looking at grey wolves, you can determine they are separate from red wolves because the two do not interbreed.
13. Which type of isolating mechanism is occurring, given 'real world' examples
    -
14. Why coming into secondary contact is not required for speciation to occur, but can promote prezygotic isolation
    - If little divergence occurred, the two populations resume interbreeding (hybrid swarm)
    - But populations may have become reproductively isolated (ex. differences in courtship, unfit hybrids)
    - If the hybrids are unfit, direct selection will favour pre-zygotic isolating mechanisms to prevent wasted resources in investing in an unfit offspring
    - Selection then favours the evolution of pre-zygotic isolating mechanisms
    - Uncertain whether post-zygotic or pre-zygotic isolation happens first
15. Role of islands in speciation
    - Islands are often hotbeds of speciation
    - Isolation across different islands restricts gene flow (reluctance to cross water)
    - Differences in selection pressure on islands vs. on mainland
    - Genetic drift can be a huge force on islands because the populations on islands tend to be smaller than on the mainland
16. Why most speciation occurs in allopatry (ie why parapatric and sympatric speciation are rare)

- The homogenization of gene flow makes it very difficult to establish speciation without allopatry
- Adaptation to a new food source can cause sympatric speciation (a subset of Hawthorn maggots diverged to feed on apples which began the process of speciation)
- Competition, disruptive selection, and assortative mating can cause sympatric speciation (limited resources can lead to adaptation to separate niches)
- Ex. Stickleback species are either big and bottom dwelling, or really small and plankton eating near the top of the lake. There are no niches for intermediate forms, leading to disruptive selection and assortative mating

17. How polyploidy can induce sympatric speciation
    - Polyploidy creates reproductive isolation between the polyploid individual and the original populations because the zygotes will not have the correct number of chromosomes for either species
    - Many plant species appear to have evolved through this sympatric, polyploid speciation mechanism (it can't interbreed with the parent population but it can self-fertilize and instantly create a new, reproductively isolated species)

Lecture 20

1. The meaning of systematics, phylogeny, phylogenetic tree, classification, taxon, taxonomic hierarchy
    - Systematics: the branch of biology that studies the diversity of life and its evolutionary relationships
    - Phylogeny: the evolutionary history of a group of organisms
    - Phylogenetic tree: a branching diagram depicting evolutionary relationships of groups. Formal hypothesis indentifying likely relationships among species

- Classification: an arrangement of organisms into hierarchical groups that reflect their relatedness
- Taxon: A name designating a group of organisms
- Taxonomic hierarchy: a system of classification based on arranging organisms into ever more inclusive categories

2. Why similarities in morphology or lifestyle do not necessarily reflect close relatedness.
    - North American cacti and African spurges have similar traits (like thick, water storing stems, CAM photosynthesis, and stomata that only open at night).
    - This is not due to direct relatedness but because convergent evolution led both groups to adapt in similar ways to desert environments
    - There is a tendency among organisms living under the same conditions to develop similar body forms
    - This can be called parallel or convergent evolution (depending on relatedness)
3. The two major goals of systematics
    - One is to reconstruct the phylogeny (evolutionary history) of a group of organisms
    - The second goal is taxonomy: the identification and naming of species and their placement in a classification
4. Principles underlying the Linnaean system of classification (species, family etc) and which groupings include which other groupings
    - A family is a group of genera that closely resemble each other
    - Similar families are grouped into orders, and orders are grouped into classes, classes into phyla, and similar phyla into kingdoms
    - Finally, all life on Earth is classified into three domains (Eukarya, archaea, bacteria)

- From most inclusive to least:
- Domain -> Kingdom -> Phylum -> Class -> Order -> Family -> Genus -> Species

Lecture 20 lecture

1. Correct interpretation of evolutionary trees, close and distant relatives, and where extinct taxa would be placed in a tree
    - Every living species is represented by the tips of the branches on the evolutionary tree and the farther down you move (towards the truck/roots), the further back in evolutionary time you're going
    - Common ancestors are found at the place where two branches converge (nodes)
    - For any two species currently alive on Earth, we can trace their pattern of descent to some common ancestor
    - Species are closely related when you don't have to go as far back to reach their common ancestor (their branch node)
    - Time passes from root to tips (relative order, b/c no scale bar)
    - Phylogenies give relative orders of time, but not absolute time spans
    - This means that if two branching events line up, it does not mean the two branching events occurred at the same time. We can only infer the time order of branching events within a single lineage
    - Rotating nodes changes nothing
    - Having an organism on top of the phylogeny does not mean the organism is "more highly evolved". You can rotate around the nodes and it's the same thing
    - No species has been evolving longer than any other species
    - Reading a phylogeny is like reading a family tree
    - Read the nodes, don't focus on the tips

2. Principles of phylogenetics
    - Similarity is the way in which we identify if two groups are closely related
    - The more traits two groups have in common, the more likely it is that they shared a recent common ancestor
3. Homology vs. misleading similarities due to convergence of unrelated taxa or misleading differences due to divergences among closely related taxa, and examples of each
    - Homology: similarity that reflects recent common ancestry (ex. bone structure among forelimbs in bats, humans, dolphins, pigs, basically all vertebrates)
    - Homoplasy: misleading similarity OR misleading dissimilarity
    - Convergent evolution happens when a trait is quite similar in two different groups that are not very related to each other
    - These are likely adaptations to a common environment (the two traits evolved independently of each other)
    - Ex. Hippos and crocodiles have similar eye placement though they do not share a recent common ancestor. This is due to convergent evolution as an adaptation to living in water
    - If things are close relatives of each other but have been subject to very different selection pressures, they can diverge, leading to misleading dissimilarities
    - Ex. Darwin's finches are very closely related to each other but due to vastly different selection pressure, they have greatly diverged to take advantage of different food sources and ecological niches
4. Synapomorphies, symplesiomorphies and autapomorphies on a phylogenetic tree
    - Synapomorphies: shared traits that are derived from a common ancestor

- Symplesiomorphies: a trait shared by two or more groups that was already present before the groups diverged (ancestral)
- Autapomorphies: a trait that is unique to a single group and derived within the group

5. The significance of outgroup analysis
   - Without knowing the phylogeny in advance, how do we know if a similarity reflects homology or convergence?
   - Sometimes we can infer from structure or development
   - Another solution is to use cladistics
   - Only some similarities are informative: those derived from a common ancestor
   - How can we know what traits the common ancestor of a group had?
   - The answer is to find an outgroup: a close relative known to have branched off earlier than any of the groups of interest

Lecture 21

1. What happened to the dinosaurs?
   - Most dinosaurs and other terrestrial and marine groups died out at the end of the Cretaceous Period (65 Mya)
   - This extinction event has been associated with the impact of an asteroid
   - Paleontologists suggest a combination of stressful environments, high volcanic activity, and collision with an asteroid as main causes of this extinction event
2. Relative severity of the end-Cretaceous mass extinction, compared to other mass extinction events
   - The extinction was of a large scale, eliminating most of the species on Earth
   - The late Cretaceous mass extinction was not the greatest extinction event to occur, this distinction goes to the Permian-Triassic extinction 251 Mya

3. Meaning of orthogenesis
    - Species and other classification categories follow a similar life history driven by internal factors. Species "grow old and die out"
    - But no evidence supports any biological mechanism other than the inability to cope with changing environments or competitive challenges as explaining extinction events
4. Factors that enabled mammals to diversify after the end-Cretaceous mass extinction
    - Extinction of non-avian dinosaurs allowed mammals to invade niches previously occupied by the dinosaurs
    - The breakup of Pangaea also served as a stimulus for mammalian radiation. This facilitated dispersion and isolation of major mammalian groups
    - Uplifting of mountains, submersions and regressions of shallow seas, delineation of shorelines, and diversification and radiation of ferns and flowering plants lead to new landscapes and had a major impact on mammalian adaptation, variation, and distribution
    - The survival or extinction of any group or lineage may be closely connected to the survival/extinction of other groups or lineages (coevolution/coextinction)
5. Evidence supporting the collision theory regarding the end-Cretaceous mass extinction
    - Iridium deposits of presumably extraterrestrial origins are found worldwide in the Cretaceous-Tertiary boundary
    - As well, high-impact particles like glasslike spherules and fractured quartz are found in the K-T boundary as well
    - This suggests an asteroid collided with Earth and threw up iridium and high-impact particles that dispersed worldwide

Lecture 21 lecture

1. Whether a particular trait is probably ancestral or derived, given a phylogeny and a suitable outgroup
   - Ex. The Caddis fly is an outgroup for the orange palm dart butterfly and the monarch butterfly. It has 6 legs. Therefore, the ancestral trait is having 6 legs. The derived state is 4 legs for the Monarch butterfly
   - The outgroup species is the species that is distantly related to the ingroup, but not extremely so. The species in the ingroup are more closely related to each other than to the outgroup species
2. Whether or not a particular trait is a synapomorphy, given its distribution among the outgroup and the ingroup
   - If a trait is present in the outgroup and in all of the ingroup, the trait is most likely to be ancestral
   - If a trait is present in the outgroup and some but not all of the ingroup, the trait is most likely to be ancestral
   - If a trait is absent in the outgroup but present in some of the ingroup, the trait is most likely to be derived
   - If a trait is present in the outgroup but none of the ingroup, you can't tell if the trait is ancestral or derived
   - Two equally likely scenarios: the common ancestor did not have the trait and it was derived in the outgroup OR the common ancestor did have the trait and it was lost in the lineage leading to the ingroup. Both involve just one evolutionary step
   - If a trait is absent in the outgroup but present in all of the ingroup, you also can't tell for the same reasons as above

2. Why similarity does not always imply relatedness

    - Not all similarities are homologies and not all homologies are synapomorphies
    - Ex. through convergent evolution
    - As well, according to cladistics, shared derived traits are the only similarities one must pay attention to
    - Ex. A shared genetic code is a homology but not a synapomorphy because every living thing has a DNA based genome (symplesiomorphy)

3. Meaning of parsimony, as it relates to phylogenetic trees

    - Parsimony is the principle that the simplest explanation is usually the best
    - Similar to Occam's razor
    - So whichever phylogenetic tree requires the least amount of evolutionary changes (gains or losses of a trait) is probably the best

4. Finding the most parsimonious phylogenetic tree among several options

    - Ex. Let's say the ingroup is chickens, bats, and chipmunks. The outgroup is sharks
    - Is the bat more closely related to the chicken or the chipmunk?
    - First, one must identify which traits are synapomorphies.
    - The shark has no milk, no fur, no wings, and no beak.
    - The chicken has no milk, no fur, wings, but it has a beak
    - The bat has milk, fur, wings, but no beak.
    - The chipmunk has milk, fur, no wings, and no beak
    - Having a beak is not a synapomorphy because it is not shared
    - Milk, fur, and wings are synapomorphies and likely derived
    - Therefore, it is more likely that the bat is more closely related to the chipmunk because the bat only has to derive wings independently

- If the bat had diverged from the lineage leading to chickens, it would have had to derive both fur and milk
- Therefore, a phylogeny that shows bats more closely related to chipmunks than to chickens is more parsimonious and thus more likely to be correct

5. The importance of monophyletic groups
   - In cladistic systematics, only monophyletic groupings are recognized
   - Monophyletic means groups that are related by a single common ancestor
   - The group includes all the descendants of the group's MRCA
6. Natural vs. unnatural groupings of taxa, given a phylogeny
   - Many traditionally-recognized groups are not monophyletic
   - Ex. Prokaryotes, fish, dicots, endotherms etc.
7. Why biodiversity changes over time
   - Interactions between organisms and their environment (ecology) affects evolution (origin and demise of species, rates of speciation and extinction)
   - There is a constant turnover and replacement of species
   - Most species that have ever existed are now extinct
   - Biodiversity reflects the balance between speciation/extinction and varies over time
8. Meaning of adaptive radiation
   - Adaptive radiation: rapid speciation into many descendant lineages
   - Ex. Darwin's finches (from single species of ancestral finch to 14 descendant lineages)
9. Factors that may trigger an adaptive radiation
   - Ecological opportunity: competitive release after colonizing new environment, competitive release after a mass extinction (opens up new ecological niches)
   - Evolutionary innovations can induce adaptive radiation

- Ex. Angiosperms use animals as pollinators by producing flowers. Different pollinators mean instant reproductive isolation (plants that attract hummingbirds will not reproduce with plants that only attract bees)
- Since there can be such a wide variety of pollinators and blooms, speciation of the angiosperms occurred rapidly and on a large scale

Lecture 22

1. Factors influencing why some pathogens (disease-causing organisms) evolve towards greater virulence (harmfulness)
   - If a pathogen relies on a healthy, mobile host for its spread, natural selection will favour the pathogens that do not harm their host as much
   - If a pathogen does not require a host to be healthy in order to spread, the pathogens that are the most exploitative for their own reproductive gains will be favoured
   - Mode of pathogen transmission is a factor influencing virulence
2. How reducing a pathogen's opportunity for water-borne and vector-borne transmission is predicted to affect its virulence
   - When a pathogen is transmitted through water, it evolves to be more virulent (because it does not require a healthy host)
   - If the opportunity for water-borne transmission is restricted, the pathogen will evolve to be more mild
   - Water-borne transmission favours more virulent pathogens but without access to water, natural selection favours more mild pathogens because they need a relatively healthy, mobile host to spread
   - Vector-borne diseases (like malaria) are more harmful than non-vector borne diseases

3. Predicted relationship between virulence and antibiotic resistance
    - Increased virulence coevolves with increased antibiotic resistance
    - A virulent organism causes a high proportion of people to be symptomatic and get antibiotics, which creates a high selection pressure favouring antibiotic resistance
    - Decreased virulence will favour decreased antibiotic resistance
    - Therefore, preventing water-borne transmission will not only decrease virulence, it will decrease antibiotic resistance in the same sweep

Lecture 22 lecture

1. Mutualistic, competitive and antagonistic relationships between species, given 'real world' examples
    - Mutualistic relationships: both parties get something out of the deal (ex. when birds pollinate flowers, they get to drink the nectar. The flower gets to have sex)
    - Competitive relationships: both parties may suffer. When species are competing for some mutual, limiting resource, each party is worse off than if the other wasn't there because they are forced to expend energy competing
    - Ex. cheetahs and lions may have overlapping territories so they are forced to compete with each other for prey.
    - Ex. plants compete for light. That's why in a forest, plants grow tall and straight
    - Antagonistic relationships: one party may benefit at the expense of the other (natural enemies)
    - Ex. predator/prey interaction or herbivore/plant relationships
    - As well, disease causing organisms benefit at the expense of their host
2. Examples of Red Queen equilibrium
    - When costs outweigh benefits, that's the Red Queen equilibrium

- Trees in a forest cannot keep growing taller and taller infinitely. Eventually there is a certain point where the trees are competing but unable to evolve to grow any taller

3. Factors that advantage one side or the other in an evolutionary arms race
    - If a species evolves some advantage (like toxins in the case of a newt) it puts the opposing species under selection pressure to develop a counter-advantage (metabolic enzymes that break down the toxin in the case of garter snakes)
    - This leads to directional selection with both sides selected to evolve more and more extreme measures and counter-measures in the evolutionary arms race
    - Sometimes, one side has the advantage through generation time, population size, or strength of selection. This means one side is evolving faster
    - Species which reproduce quickly can evolve faster, selection is more effective in large populations (more variation), and stronger selection means faster evolution
4. Meaning of 'life-dinner principle'
    - The idea that selection on one party in an evolutionary arms race is not necessarily going to be as strong as selection on the other party
    - Ex. Roadrunner has more to lose if coyote catches him (life) whereas coyote just doesn't get to eat that day (dinner)
    - Selection is stronger on prey species to avoid being captured
5. Difference between prudent-parasite hypothesis and trade-off hypothesis, in terms of the evolution of virulence
    - Prudent-parasite hypothesis: a parasite that kills its host too soon, before colonizing a new host, is doomed. The optimal virulence is low
    - High virulence suggests the host/parasite haven't been interacting long since the parasite hasn't had time to become benign

- Ex. HIV is more virulent in humans than in chimps because it has only recently begun infecting humans
- Trade-off hypothesis: balancing costs and benefits of virulence. The optimal degree of harm is going to depend on the ecology of the parasite and the host

6. Factors that influence the optimal virulence of a given host/parasite relationship
    - The optimal virulence for one disease is not going to be the same as the optimal virulence for another because it depends on the ecology of the host/parasite
    - Optimal virulence depends on how the parasite spreads
7. Costs and benefits of being highly virulent (from the point of view of the parasite)
    - Benefits: more chances to spread because more virions being replicated so a higher concentration in the secretions of the host.
    - Costs: too much harm to the host can limit the virus' ability to spread by incapacitating the host or killing the host too soon
    - High virulence/replication means a parasite can spread quickly from host to host
    - But a high replication rate might harm the host too much, restricting the parasite's ability to infect new hosts
8. Why improving equipment for survival does not always translate into 'winning' an evolutionary arms race
    - Modern day lions are much faster than lions in the past but they are not any better off because the prey species (wildebeest) has also become much faster
    - Both sides evolving so neither can win
9. Differences in virulence depending on mode of transmission
    - If transmission requires direct contact, that means the host must be healthy enough to move around and interact with other potential hosts

- Thus, the optimal virulence of diseases that require direct transmission would be low
- Diseases that spread indirectly (through water or vectors) have a higher virulence because they do not rely on a mobile host. It may even be better if the host is more ill (ex. too weak to brush away a mosquito)

10. Disease management practices that might reduce virulence of parasites
    - Reducing modes of indirect transmission will force parasites to rely on direct transmission, selecting for lower virulence
    - Condom use is one of the methods of reducing HIV transmission
    - If a population uses condoms a lot, it will take far more time for HIV to successfully transfer from one individual to another thus selecting for lower virulence.
11. Predicted effects of given factors on virulence of parasites, given "real world" examples
    - HIV-2 is less easily transmitted between hosts than HIV-1
    - This creates a selection pressure for HIV-2 to become less virulent to increase the time a host will be mobile and out spreading the disease
    - The nematode parasite is transmitted from parent to offspring
    - The parasite will be of very low virulence because it needs to keep a host alive until it has successfully reproduced, the more the better
    - The parasite may even become so benign, it is not considered a parasite
12. Arms races between mutualists
    - Organisms that have a mutualistic relationship often don't have identical interests. Ex. pollinators want to be very efficient at getting nectar and leaving quickly, while plants want pollinators to linger so they can get pollen on them
    - Over evolutionary time, pollinators have evolved longer and longer bills/tongues while plants have evolved longer nectar tubes or more dilute nectar

- As well, arms races between males and females of a species leads to sexual selection

Lecture 23

1. Examples of relevance of evolutionary principles to human health
    - The evolution of pathogens (like HIV evolving resistance to AZT)
    - Asymmetry in relatedness between mother and fetus causes reproductive problems (like gestational diabetes and preeclampsia)
    - Traces of our evolutionary history affect our health (modern day environment vastly different from environment to which we are historically adapted)
    - Evolutionary constraints (selection had to work with what it had, could not design the perfect structure for the human eye as an example)
    - The human eye is designed in such a way that we have a blind spot and can suffer from a detached retina
    - The appendix is functionless and can become inflamed easily but selection cannot get rid of it because to make it smaller and smaller would cause even more incidences of inflammation. Selection to avoid appendicitis selects for a relatively large appendix (evolutionary constraint)
    - Trade-offs between competing demands
    - Selection does not result in organisms being perfectly adapted to its environment because organisms subject to competing demands
    - Symptoms may be defenses, not defects (ex. fevers)
2. Trends in incidence of infectious vs. autoimmune disorders with respect GDP
    - Infectious diseases are declining while autoimmune disorders are rising in countries with a high GDP. In developing countries, infectious diseases are rampant but autoimmune disorders are rare

3. Evolutionary basis of diseases of civilization
    - Diseases of civilization: disorders that arise because there's a mismatch between our current environment and the ancestral environment to which we are adapted
    - Ex. the human body has only recently adopted its current environment filled with former rarities such as high-fat foods. This causes metabolic syndrome
    - Early humans would have faced death from starvation so the body adapted to hold on to every calorie and crave high-calorie foods
    - Myopia has a genetic basis but only arose because the visual environment humans occupy now results in eye strain (ex. reading by artificial light often)
    - In the past it would not have been a big problem. These alleles didn't cause myopia in the ancestral visual environment so selection didn't weed them out
4. Evolutionary basis of the "hygiene hypothesis"
    - In autoimmune disorders, the immune system basically starts attacking itself
    - It has been hypothesized that the evolutionary environment to which the body is adapted would have favoured an immune system that is highly active.
    - We've adapted to much dirtier environments (chronic infections)
    - Now, there are no infectious diseases for the immune system to fight but it remains tuned to a highly active state and so begins attacking itself or attacking non-pathogens (as in allergic reactions)
5. Reasons why harmful traits are maintained by trade-offs, antagonistic pleiotropy etc.
    - Selection does not weed out traits that do not affect fitness
    - If an allele is beneficial or even neutral in early life when most people are reproducing, the allele will be maintained even if it causes problems in later life
    - This is called antagonistic pleiotropy

- Ex. high levels of circulating sex hormones makes one attractive and fertile in early life but causes disease in later years
- As well, people in the past did not tend to live very long so these alleles were not even expressed since the person was likely dead before they were likely to, say, get cancer or heart disease
- Selection is stronger on early life history stages than late life history stages because everyone has a chance to be young but not everyone gets to be old
- Trade-offs between using energy for reproductive processes in early age vs. using it to repair the body for old age
- In Drosophila, Indy mutants outlive wild type Drosophila but produce fewer offspring so it is not favoured in natural populations
- Selection may maintain a harmful trait (sickle cell allele) because it benefits fitness in another context (helps prevent malaria). Heterozygote advantage
- Selection acts on lifetime reproductive success, not on health, happiness or longevity

Lecture 24

1. Arguments for and against the notion that humans are still evolving.
    - Weaker natural selection due to medical advances: all children born in developed countries have a very high chance of living to reproductive age
    - But this is not the case in developing countries
    - Weaker sexual selection due to increased monogamy
    - But monogamy is actually a strong selective force in humans. As well, sperm donation raises the chances of an individual contributing disproportionately to the next generation (ex. one sperm donor fathered 150 children)
    - Fewer mutations due to decreasing reproduction by old men

- Decreasing randomness (genetic drift) because human populations are now huge and super-connected (global village)
- Assortative mating now easier than ever due to online dating, global connectedness, and social media

2. Possible reasons for why evolution may be slowing down among humans.
    - Medical care reduces natural selection pressures, monogamy reduces sexual selection, fewer mutations because earlier age of reproduction among men, decreasing genetic drift, easier assortative mating
3. Evidence for recent evolution in humans.
    - Selective sweep: beneficial mutations (SNPs) rise quickly to high frequency and the surrounding sequence variation decreases (surrounding alleles dragged along)
    - Sweeps detected to measure speed of evolution. It was found that the rate of adaptive evolutionary change has increased during the past 8,000 years
    - Good evidence that evolution is speeding up, at least in our recent past
    - Evidence for ongoing human evolution can be found by measuring a large human population and looking at health related traits that correlate with the number of offspring produced
    - One study found that there were selection pressures on human females. Females that reached menopause later, hit puberty earlier, were shorter and fatter than average had more offspring on average
    - Higher reproductive success = traits favoured and allele frequency increases
4. Costs of large brains
    - Large brains require a huge amount of energy (2% mass but 20% energy use)
    - Big brains make childbirth difficult b/c female pelvis too narrow for such big heads

5. Possible advantages of large brains with regards to the "utility hypothesis" vs. "mating mind hypothesis"
    - Utility hypothesis: our ancestors needed big brains because big brains helped survivorship. Language, tool use, planning all aided human survival
    - Art, music, humour, creativity just a byproduct of needing brains for survivorship
    - But why are the brains quite so big? It's excessive
    - Mating mind hypothesis: sexual selection promotes the evolution of wastefully extravagant traits so big brains aid mating success
    - Word play, humour, art all aid human reproductive success much like big tails aid widow bird mating success
    - But why no sexual dimorphism? Both males and females intelligent
    - Male humans AND female humans are under sexual selection and both sexes compete for mates
    - As well, you need to be intelligent to access another person's intelligence