**BIOLOGY 1B EVOLUTION STUDY GUIDE**

Penicillin

* Discovered in 1929
* Mass-produced in 1943
* S. aureus became resistant to it in 1947
* Example of evolutionary medicine

Monoculture crops and GMO’s

* Went from high diversity to monoculture crops
* Because of genetic similarity, pests (weeds, insects, and pathogens) can wipe out entire crops
* Example is potato famine in Ireland where fungal disease killed all potatoes
* We can implant genes from one plant into other ones, but we don’t know the evolutionary implications of doing so

Humans as an Evolutionary Force (CCHOI)

* Invasive species
* Habitat loss
* Competition
* Climate Change
* Overharvesting

Important People to Know and Their Contributions

1. Aristotle
	1. *scala naturae* – simple organism developed into what humans are today
	2. there is a “chain of being” or a hierarchy that includes all organisms with humans at the pinnacle
2. Linnaeus developed current taxonomy system used to classify organisms
	1. King Phillip Comes Over For Good Soup: Kingdom Phylum Class Order Family Genus Species
3. Lamarck, Erasmus Darwin
	1. Evolution – organisms can change over time
4. Cuvier
	1. Extinction and the fossil record
5. Lyell, Hutton
	1. Gradual geological change and uniformitarianism
6. Humboldt, Hooker
	1. Biogeography, or the distribution of species across the globe
7. Malthus
	1. Population pressure – idea that populations will run out of resources before they stop overproducing offspring (J vs S curve)
8. Owen and Huxley
	1. Comparative anatomy and embryology
		1. Owen hated evolution
		2. Huxley defended evolution
9. Darwin and Wallace
	1. Theory of Evolution – descent with modification via natural selection
	2. Both thought inheritance worked by blending genetic factors

Darwin Biography

* Was hired as an eduated companion and naturalist for Captain Fitzroy of the *HMS Beagle* (roughly the size of 2050 VLSB)
* Recommended by his teacher, Henslow
* 5 year voyage that sailed around the world
* Saw finches of various colors and different beaks on various islands
	+ Finches had a single common ancestor that diversified into different forms (aka speciation)

Wallace

* Collected organisms for collectors as a living
* Kept very detailed notes about organisms’ features and geographical origins on his travels
* Wallace published his papers first, and when Darwin saw he felt compelled to publish his own work

Natural Selection

* The mechanism for descent with modification
* Is literally the differences among phenotypes with regards to survival and reproduction
* 3 conditions: variation in traits, inheritance, fitness/competition
	+ Variation in traits – individuals have different characteristics and traits
	+ Inheritance – traits inherited by offspring from parents are a blend/mixture of both parents’ traits
	+ Fitness/Competition – the more “fit” the individual, the more likely they will survive and reproduce
* Differences in phenotype inherited results in the difference of genes in the next generation
* Individuals don’t evolve because they are born a set way; populations and species evolve because the fitter individuals born will survive and pass on their genes to the next generation

Cladogenesis is the splitting of species while anogenesis is the continuous splitting of a branch

Evolution via Natural Selection

* Artificial selection – nature can “select” traits that allow organisms to survive and reproduce better
* Biogeography – nested geographic distributions, where species that occur on islands are often closely related to species on nearby mainland
* Fossil record – many fossilized species no longer exist and they are organized into time series, or strata
* Embryology – helps us see speciation and differences
* Population process/pressure – population growth requires resources (S and J curve)

Homology is trait variations that stem from a common ancestral condition

* Bird vs bat example
	+ Bones in the wings of both are homologous
		- They are the same bones/elements that are modified in similar ways
		- Difference in the bones stem from the same bone/condition
	+ Wings themselves are not homologous
		- Birds and bats’ common ancestor did not have wings
		- Thus, the wings were independently evolved and are called nonhomologous/analogous structures
* To figure out the real tree of life and all of the pieces, we must look at homologous structures and determine how things derived to what they are today from ancestral traits
* Embryological homologies – a developing baby looks similar to developing frogs and other animals

Molecular Homology (Invisible to Darwin)

* Genetic code is the same over all eukaryotes (AGTC)
* Amino acid sequences are all the same (same 26 amino acids for all of life)
* **HOX GENES???? COLINEAR SEGMENTATION?????**
	+ **The genes that govern development of specific structures are known, however the same gene sequence form different things in different organisms (spinal cord in mouse vs fly’s body)**

Phylogeny is the hypothesis about how different species are related to each other

* Such hypotheses about relationships must be testable experimentally
* From a single ancestor, there are multiple branches/lineages with diverging phenotypes, all a result of natural selection
* Phylogenetics is the use of shared derived homologous traits to relate two different species to a common ancestor
	+ Monophyletic – contains a common ancestor and all of its descendants
	+ Paraphyletic – contains a common ancestor and descendents, however is missing one or more descendents of said ancestor (like monophyletic except does not have all descendents included)
	+ Polyphyletic – two or more taxa that do not share a common ancestor
		- NOTE: Can something be both paraphyletic and polyphyletic? NO
		- What if a group is missing the common ancestor? 🡪 poly
		- Refer to notes at the end for definitions of all terms relating to cladistics

Molecular Phylogenetics (DNA Sequencing)

* Choose a specific gene to analyze, sequence it across a range of different taxa, and look for homologous nucleotide positions
	+ Done to determine whether similar phenotypes/character states arose from a common ancestor or were independently evolved
* Genetic changes accumulate over time
	+ If mutations arise/accumulate at a steady rate, then the rate can be used as a molecular clock to estimate the dates of divergence of other lineages
		- If we have rate/molecular clock and number of changes, multiply the two to find out how long it took for the species to diverge from the common ancestor
* Molecular analysis was used to reduce the five kingdoms down to 3 domains
	+ 3 Domains of Life: Bacteria (E. coli), Eukarya (plants, fungi, animals), Archaea (thermas aquaticus)
* Outgroup is typically used as a control against the various taxa
* 2 ways of analyzing above data
	+ Parsimony – finding the simplest explanation for a phylogenetic tree
		- Must map out all possibilities and then choose explanation with least amount of evolutionary changes
	+ Statistical models can be used to find out how variations occur
		- For example, mutations between A&G occur faster than between T&C
			* Molecular Clock: When taxa first branch, there are a few mutations between the two. As more time passes, more mutations occur and can be seen. If we know the rate at which mutations occur and the number of mutations, we can figure out how long ago the taxa diverged from the common ancestor.
		- Can also use percent divergence to determine time of divergence if given external calibration (typically rate of mutation of gene in group)
			* Can be done by DNA sequence between two taxa to find point/time of divergency, and use calibration points to find point of divergence between more taxa
			* These calibration point can be plot on a graph where the slope is the rate of divergence
				+ With enough data and genes, slope is approximately linear so common ancestor can easily be found by locating point of percent divergence (graph is percent divergence vs time)

People who Shaped Neo-Darwinian Synthesis

1. Mendel
	1. Determined the basic principles of inheritance with pea genetics
2. Fisher, Wright, Haldane (“math dudes”)
	1. Developed mathematical theory of genetics, combining particulate inheritance with evolutionary principles
3. Mayr, Dobzhansky, Huxley, Simpson (“experimental biologists”)
	1. Perform experiments to test hypothesis

Neo-Darwinian Synthesis

* Considered the foundation of modern evolutionary biology
* Led to the comparative studies to test the predictions of hypothesis about the natural world
* Evolution is no longer an experimental subject
* DNA (genetic material) was discovered by Watson and Crick in 1957
	+ This discovery led to modern evolutionary biology
	+ Ability to sequence DNA allows us to compare entire genomes across the tree of life
* Evolution draws upon many scientific fields and is both comparative and experimental

Mendel’s Principles and Terms

* Alleles are variations of particular genes and account for variation
* Offspring inherit two copies of genes, one from each parent, in most cases
	+ Such are known are diploid organisms
* Alleles can be either dominant, codominant, or recessive
	+ Dominant alleles mask the phenotypic expression of the recessive allele
	+ Codominant alleles blend/mix together in the phenotypic expression
	+ Recessive alleles are only phenotypically expressed in homozygous individuals
* Homozygous is when diploid genotype contains only one type of allele
* Heterozygous is when diploid genotype contains more than one type of allele

Population Genetics

* A population, in genetic terms, is a randomly breeding group of individuals that is largely isolated from others
* Key evolutionary processes that affect inheritance of genes
	+ Mutations – ultimate source of genetic variation
		- Occurs at random with respect to adaption
	+ Genetic Drift – sampling process (large vs small populations)
	+ Selection – fix of differential survival and reproduction
	+ Migration – movement of individuals from one population to another and subsequent gene flow that occurs
	+ Non-random mating
* Breeding occurs at random in a natural population
* Genotypes are the alleles possessed by an organism for a particular gene
* Phenotype is the characteristic/trait portrayed in the organism due to the genotype
* For alleles A1 and A2
	+ Genotypes: A1A1, A1A2, A2A2
		- If codominant, there are 3 phenotypes (where heterozygote looks like a blend of A1 and A2 alleles)
		- If A1 is dominant, there are 2 phenotypes (where heterozygote looks like the dominant A1A1 phenotype)
* In a random mating population, allele frequencies in the gametes determine genotype frequencies in the zygote which determines phenotype frequencies in the individual
	+ The phenotype frequencies depends on whether the mode of inheritance if dominant or codominant

Assumptions of Hardy-Weinberg Equilibrium

* Random mating for gene in question
* No mutation for population in question
* No selection for population in question
* No migration/gene flow
* Large population with no sampling error (aka genetic drift)

Hardy-Weinberg Equilibrium

* Is a null hypothesis because if a population does not conform to Hardy-Weinberg equilibrium, it means that evolution has occurred
* This equilibrium is achieved very quickly (within 1 generation)
	+ Allele/gene frequency: p+q = 1
	+ Phenotype frequency: p2 + 2pq + q2 = 1
	+ To find allele frequency of p from phenotype frequency: p2 + (2pq) = p2 + pq = p(p + q) = p(1) = p
	+ If we only know q, we know q because p = 1-q
	+ For rare alleles (q<0.1), it most often occurs in heterozygotes rather than homozygotes (2pq>>p2)
* Hardy-Weingberg proves that inheritance of genes alone does not cause the frequency allele changes of evolution
	+ If there are very few heterozygotes and many recessive and dominant allele homozygotes, it is safe to assume that the population is not in Hardy-Weinberg equilibrium and that one of the five assumptions is not being followed

Mutations

* Occur at random through replication error (with or without DNA damage from mutagens) or genomic rearrangement during meiosis or during the process of making gametes that go on to form the zygote
* Occurrences are rare and arises randomly with respect to adaptiation
	+ One in a hundred million chance for a mutation to occur per nucleotide per generation (10-8)
	+ There are 3 x 109 nucleotides in humans
	+ Every gamete has about 30 mutations, so every human is a mutant and has about 60 mutations
* Typical gene includes exons and introns
	+ Regulatory sequences are DNA sequences where transcription factors (polymerase, etc) bind to regulate the expression of gene
		- Such mutations do change the gene expression
	+ Coding sequences are sequences that, when translated, determine the sequence of amino acids and the proteins
	+ Neutral mutations are those that occur in the exon but do not affect the genotype
	+ Changes in the number of genes (or even whole chromosome segments) is a very common mutation and sometimes connected to phenotype
		- Examples include schizophrenia, Crone disease, extra amylase in humans vs chimpanzees
		- Another mutation example is Agouti in mice
			* Agouti blocks the mc1r receptor (which stimulates the production of melanin) and allows for the production of lighter colored mice
			* It also regulates/suppresses the mc1r gene in membrane from over-producing melanin
* Different types of mutation can give rise to the same phenotype
* Analogous phenotypes can arise from different mutations
* Because of the rarity of mutations occurring in a given gene, we are still able to predict the frequencies of phenotypes

Genetic Drift

* Genetic drift is the amplitude of allele frequency fluctuation from one generation to the next
	+ In small populations, genetic drift can result in a loss of variation across the entire genome over time and a loss of polymorphism (going from multiple alleles for a gene to few alleles for same gene)
		- Polymorphism is the presence of multiple alleles for a particular gene
	+ However, such fluctuations in allele frequency can also result in novel genetic combinations that is not possible through selection alone
* Genetic drift changes allele frequencies and thus phenotype frequencies
* Frequency of an allele in a small population varies across many generations and the variation of frequency is large (can be thought of by a coin toss example)
	+ Can decrease variation by wiping out an allele entirely and thus decrease genetic diversity
	+ Can create new allele combinations and thus increase genetic diversity
* Genetic drift can lead to an increase of alleles that are disadvantageous to the organism

Large Population Size

* In small populations, we have sampling errors because these small samples taken from a population is usually nonrepresentative
* When a few gametes come together to form even fewer zygotes, there is a high chance in fluctuation in allele frequencies
	+ This results in genetic drift because allele frequencies fluctuate a lot and loss of genetic variation becomes possible

Small Population Size

* Population Bottleneck – occurs when a population undergoes a severe decrease in size in one habitat, resulting in stronger genetic drift do to a smaller population
	+ Also results in a rapid change of allele frequencies and thus genetic diversity
	+ Population bottleneck does not involve migration
	+ Likely causes for population bottleneck are disease, habitat loss, overharvesting leading to insufficient resources
	+ The lack of genetic diversity means an increased possibility of extinction
* Founder Event – a small sample of organisms from a large one leaving to form their own population in a new habitat
	+ Results in reduced genetic diversity, rapid change in allele frequency, high potential for divergence and speciation, and increased selection
	+ Higher potential for divergence and speciation means more novel genetic combinations, and thus higher potential for enhancement of genetic diversity

Gene Flow/Migration

* Gene flow is the net movement from where one is born to where one reproduces
	+ Opposes genetic drift (has opposite effect) and spreads new mutations among populations
		- Likelihood of mutation survival is low, but if it does survive then genetic diversity increases due to the gene flow
	+ Basically gene flow prevents speciation/divergent selection
* Migration is mostly the movement of an individual throughout its lifetime
	+ Evens out genetic drift between two populations, increasing genetic variation within each population and decreasing the overall genetic variation between the population
		- This is because new/different genes are continuously introduced to the gene pool and the mixing of genes means the two populations are more similar
		- With isolated populations, no new genes are introduced so if an allele is wiped out, it is gone forever thus lower genetic diversity/variation within the said population
	+ Cline is a gradual transition in allele frequency from one place to another
		- Is possible due to the dispersal or migration of gametes and natural selection
		- Example is plants. Their pollen is dispersed by wind. Obviously the closer to the mother plant, the more likely the plant there is similar to the mother plant. As you get further away, the resemblance is less and less

Selection

* Is the adaptation in response to the environment with differential survival and reproduction
	+ Operates through phenotype and depends on genetic variation
* Natural selection acts through the phenotype of individuals and its effects are felt on the population as a whole
* Different components of fitness: fertility, mating success and fertilization ability, survival up to reproductive age
	+ Fitness can be considered the ability to transmit genes from one generation to the next relative to other genotypes and phenotypes
* Forms of Selection, where favored means has higher fitness
	+ Stabilizing selection – favors the intermediate phenotype over the extreme phenotypes
		- Heterozygotes are typically over-represented in this group
		- Can reduce genetic variation within the generation, however over time with random mating the distribution will revert back to normal
			* This is because the heterozygotes will produce the homozygotes when they reproduce
		- When this occurs, the phenotype distribution narrows as it focuses in on the heterozygotes
		- Over time the phenotypic distribution goes back to normal as the heterozygotes mate and form the homozygotes again
	+ Directional selection – favors one end of the phenotype distribution (the extreme phenotypes), but only one side
		- When this occurs, the phenotype distribution shifts to the side that is favored
		- Phenotypic distribution would only go back to normal if there was some sort of environmental factor pushing it back to normal
	+ Disruptive selection – intermediate types are unfavored; both ends of the phenotype distributions (the extreme phenotypes) are favored
		- When this occurs, the phenotype distribution looks like two humps
		- However, over time and with random mating the distribution goes back to normal
* Example is sickle-cell anemia. Typically there is directional selection (normal homozygous dominant). If you have the sickle-cell recessive homozygous, then you have anemia and are less fit. In Africa where there’s malaria, heterozygotes are more fit because the shape prevents malaria from spreading (stabilizing selection)
* With distinct resources, specialists do better than generalists because they can utilize resources more effectively
	+ More disruptive selection in this example as generalists are in the middle of the phenotypic distribution
* Darwin thought that evolution by natural selection was a very slow process
	+ In actuality, it is very fast, taking only a few generations
	+ If a recessive allele was more advantageous, however, it will slowly replace the dominant allele, however at a much slower pace than if the dominant allele was advantageous over the recessive allele
* Selection can be tested and proven through experimental evidence from experiments with organisms with a short life cycle (bacteria, yeast, flies)
	+ Example is the fish and their spots, an experiment performed by Endlew and Reznick
		- This experiment shows the balance between higher mating success and lower survival/lower mating success and higher survival
		- Tradeoff is where one component of fitness is sacrificed for another component that increase fitness, as shown in this example

Probability of Fixation

* A combination of mutation, selection, and genetic drift
* It is the survival of an adaptive mutation and its increase in frequency over another allele for the same gene
* Probability of fixation = Ns, where N is population size and s is selection advantage/coefficient that goes from 0 to 1
* Selective sweep is where an advantageous allele wipes out other alleles so that its frequency is 1 and the other allele’s frequency is 0
* Bigger population has a higher chance of survival because there’s more individuals with the gene

Sequencing of Genomes

* We can now sequence entire genomes and see the effect of the distribution of genetic variation along the genome
* When we compare across a large spectrum of different organisms, we can see individual variation in the nucleotide sequence
	+ Also known as single nucleotide polymorphism (SNP)
* SNP can be found via genetic sequencing and then use it as a place to start researching
* If there is little variation in the sequence, it means the gene we are examining is undergoing selection

Co-Evolution

* Typically occurs when a species develops a trait that influences evolution in another species, which influences more evolution in the first species and so on (reciprocal interactions)
* Two types of co-evolution: positive and negative interactions
	+ Positive/Mutualistic is to the mutual benefit of both species
		- Example is plants and pollinators
	+ Negative/Antagonistic is where the benefit for one species is detrimental to another species
		- Example is host-pathogen and prey-predator relationships
			* Pacific newt and gartner snakes: the newts are very poisonous however its coevolved predator, the snake, has the ability to detoxify the poison and prevent itself from being harmed by the poison. As the snakes become more resistant to the poison, newts develop new poison via evolution and the process continues
			* Can be thought as an “evolutionary arms race”
* Antagonistic co-evolution has a particular effect on evolution called frequency-dependent selection
	+ Rare-type Advantage is birds learning to eat a common phenotype. The less common phenotype has higher survival because the bird has yet to learn to eat said type. Rare types do better in antagonistic interaction, and the fitness of an allele then depends on frequency in a population
		- Over time, the rare type will become the common type, so the process continues in an oscillating manner
		- This type of evolution maintains polymorphism

Sexual Reproduction – Why Sex?

* Drawback of having different genders/sexes
	+ Risky/dangerous
		- Mating can last for several hours, meaning the organisms are exposed to predators/are unprotected
		- Flashy colors on males to attract females means increased visibility to predators
	+ Can break up good gene combinations during sexual recombination
	+ Is really inefficient in terms of demographics
* Alternatives of sexual reproduction is parthogenesis, or cloning to give birth to offspring genetically identical to the parents (asexual reproduction)
	+ Calculative parthogenesis is alternation of sexual reproduction
		- When the environment is good, reproduce asexually
		- When environment is bad, reproduce sexually

Advantages of Sexual Production

* Produces genetically diverse offspring through sexual recombination
* Decreases the accumulation, or the rate of, disadvantageous mutations
	+ This is because bad combinations are wiped out via strong selection
	+ Known as Mueller’s ratchet
* Can combine positively adaptive mutations and increase the rate of adaptation as a whole
* Most effective if genetic drift is very weak, so best in large populations
* Ability to more effectively evade pathogens and predators

Sexual Selection

* 3 mating systems
	+ Monogamy – one female and one male for a period of time
	+ Promiscuity
		- Polygyny is a single male mating with multiple females
		- Polyandry is a single female mating with multiple males
			* Results in offspring with higher survival rate due to increased genetic diversity
		- Polygynandry is free for all sex
	+ In polyandrous and polygynandrous systems, sperm competition develops because the female mates with multiple males
		- This sperm competition helps ensure that their sperm and thus genetic material make it to the egg first
		- Sperm from a single male often find each other and “clump together” while searching for an egg to fertilize
* Mating and fertilization success makes up one major part of sexual selection
* Darwin laid out the major concepts of sexual selection in Descent of Man
	+ Intrasexual selection is competition among males for access to females
		- Sometimes referred to as reproductive skew, leading to few males dominating reproduction
		- Leads to sexual dimorphism (i.e. males are larger than females, males have distinct traits to help them fight off other males such as antlers)
	+ Intersexual selection is interaction between the sexes
		- Usually female choice where females choose to mate with males that are attractive to them
		- Drives the evolutionary traits
* Tradeoff between mating success and survival
	+ Since both are components of fitness, the net effect controls how successful one is at passing on genes

Benefit of Female Choice

* Direct benefit – survival and fertility of female is enhanced through chosen male
	+ Example is a male in control of high-quality territory
* Indirect benefit – increased survival or mating success of offspring
	+ Known as the “good genes hypothesis” as males who have better mating success often has other good genes that increases survival
* Males have genetic traits that females prefer, and female preference is a genetic trait
	+ Female preference is due to neurological and hormonal mechanisms that is quite complex
* Can use phylogeny to map out the evolution of said traits to determine whether female preference or male genetic traits came first
	+ Sensory bias is when the female trait develops before the male traits and the males exploit said preference
	+ The preference decreases with excess, similar to how an asymptote looks

Altruism/Self-Sacrifice

* Inclusive fitness focuses on not how many offspring you produce but rather how well your genes are transmitted to the next generation
* Because it depends on how many of your genes are passed on, we must consider the degree of relatedness between organisms (Haldane)
	+ Full siblings share 50% of your genes (relatedness factor r=0.5)
	+ First cousins share 12.5% of your genes (relatedness factor r=0.125)
		- Thus, you will sacrifice yourself to save 2 or more full siblings and 8 or more cousins. Any less and the benefit does not outweigh the cost
* Hamilton further developed this idea with the Kin Selection Theory
	+ Relation (genes shared by descent) \* Benefit to recipients > Cost to donor
		- Altruism/self-sacrifice will be favored if rB – C > 0 (aka the rB > C, or the benefit must outweight the cost)
	+ Typically seen in eusocial insects and mammals
		- Example is the ground squirrels. The females live together their entire lives while males disperse. Thus, the females are all related as they came from the same mom or siblings of the mom. They are more willing to sacrifice themselves by giving alarm calls when predators are near because the benefit of having all of their siblings survive and having the survivors reproduce (and thus pass on their genes) outweighs the cost of them dying and not being able to reproduce and directly pass on their genes
		- Another example is turkeys forming male coalitions to mate. If the males are brothers, helping a brother mate means they indirectly pass on their genes
* Microevolution is the effect of natural selection, genetic drift, mutation, migration, and the interaction of all things to shape the evolution of phenotypes and genomes within populations within species
* Macroevolution is the dynamics of speciation and extinction in large scale biogeographic processes
* In short, genetic differences over time between closely related individuals is microevolution and leads to speciation while macroevolution consists of the differences between various clades

Defining a “Species”

* Before all of this evolution stuff, it was thought that species were fixed and you can’t change them over time (typological species concept)
* Morphological species concept – descent with modification, combined with extinction results in discontinuous phenotypes (Darwin’s view that focuses on physical similarities)
	+ Such have morphological distinctiveness and are generally monophyletic
* Phylogenetic species concept – evolutionary grouping where species are identified as groups of populations with common ancestry but are distinct due to one or more character differences (focus on traits)
* Biological species concept – species are groups of populations reproductively isolated from others (focus reproductive isolation)
* Combination of all three concepts results in the General Lineage Concept (GLC)

Reproductive Isolation

* Why can’t two sets of populations mate at random?
	+ Two species may live in separate habitats
	+ Timing of mating may be different, resulting in no opportunity for fertilization
	+ Behavior – females may just prefer to mate with males of their own species rather than males of another species
	+ Mechanical – the penis may just not fit in the vagina of a female from another species
* 2 types of reproductive isolation:
	+ Postzygotic – survival of offspring (viability) and fertility of offspring
	+ Prezygotic – anything that suppresses mating and fertilization
		- Examples can be above reasons about why two sets of populations don’t mate at random as well as gamete recognition (protein on sperm and receptor on egg that acknowledges it’s a sperm and to signal for egg to make the blocker that prevents other sperm from fertilizing it)
* No set sequence of reasons for reproductive isolation to occur and many things can be simultaneously occurring
* The longer things have been isolated, the easier it is to diagnose
	+ In such cases, all three concepts will generally yield the same result
* Recently separated lineages are often in a “gray zone” where different concepts give different results
* The difference in diagnosing shorter isolated lineages as compared to longer ones stems from the fact that there is no specific sequence/order of events that defines a species
* Reproductive isolation can be pre-zygotic (formation of gametes to formation of zygote and things that prevent mating/fertilization) or post-zygotic (after successfully forming zygote, does offspring live to adulthood? Is it sterile?)

Gray Zone

* Despite efforts to separate organisms into species, there will be instances where we hit a gray zone where it’s impossible to tell if two populations are the same species or not
* Long story short: we can’t tell if they’re species or not……
* Gray zone tells us a lot about the mechanisms that underlie the formation of new species

Evolution of Post-Zygotic Reproductive Isolation

* Evolution of stability and reduced hybrid viability
* Evolution via natural selection chooses traits to increase fitness over time
* However, reproductive isolation selects traits that decrease fitness because fertility is reduced

Dobzhansky-Muller model (DM model)

* Dobzhansky was an early experimental geneticist involved in forming neo-Darwinian synthesis
* Muller understood formation of mutations and inheritance of mutation in flies
* Model basically reinforces the idea that genetic variations and subsequent selection can lead to reduced viability of offspring, so much so that eventually the two sets of organisms (although very similar and came from a common ancestor) will no longer be able to mate and thus diverge into two separate species
* Epistasis is where the fitness of one gene depends on the other gene

What will favor evolution as a byproduct of reproductive isolation?

* Increase of reproductive isolation (typically post-zygotic) in combination with increased time yields increased divergent selection
* This results in a decrease of gene flow, and thus increased isolation
* Over even more time, there can be an increase in genetic drift

Geographic Modes of Speciation

* Almost occurs exclusively because of divergent selection where mutations accumulate so much so that the resulting organisms can no longer mate and thus have become their own species
* Allopatric (complete isolation with a geographic barrier)
	+ Dominant form of speciation where a population splits off from main population and over time diverges because of selection and/or drift. So much so that they become reproductively isolated
* Parapatric (adjacent habitats/population so adjacent orchards or the mine plant fields)
	+ Needs divergent/disruptive selection to function as a mechanism for speciation
* Sympatric (overlapping habitats)
	+ Nonrandom mating and divergent selection, with prezygotic isolation as a side effect
* Peripatric (an island type separation/Founder-like speciation event)
* There is increased opportunity for gene flow going from allopatric to parapatric to sympatric
* Allopatric is dominant mode of speciation
* Eventually gives rise to speciation if given enough time, especially when paired with divergent selection
* Allopatry e.g. sister species in adjacent isolates
* Assorted mating: mating between like individuals
* Nonrandom mating & divergent selection lead to speciation, particularly in allopatric and sympatric allocation
* Cline: divergent selection but gene flow is present
* Sympatric speciation: phytophagous insects
	+ These insects begin feeding and mating/breeding on different plants.
	+ This creates an opportunity in sympatric speciation
	+ Such example is fruit flies (Rhagoletis)
	+ Generally hard to pin down specific examples though
* Peripatric: continent with rare migration to an island (founder event) – small sample of large population
	+ Idea come from Earnsten Mayr
	+ This can lead in very rare/unique combination of genes that aren’t possible in the larger population
	+ Different from others by having a small population bud off and then become isolated whereas other examples are like half and half of population (very much like allopatric)
* Peripatric can be the outcome of a founder event and strong genetic drift and selection
* Adaptive Radiation: common ancestor splitting off very quickly into a large number of species
	+ Typically very profound differences in ecologically relevant traits among species (ecological diversification)
	+ Very common in remote island archipelagos where there is no ongoing gene flow through the source population
	+ Example is Hawaiian archipelagos
	+ Basically colonist comes to island where ecological niches are unoccupied and there is ecological opportunity so colonists diversify rapidly through divergent speciation/selection

QUESTIONS TO ASK:

Morphological deals with living and extinct species while phonological deals with living species and their differences? --- morpho is differences in traits while phylogenetics and relationships in ancestry

If people wipe out a gene because of fitness, do we become a new species because certain genes are missing?

HOX GENES/COLINEAR FRAGMENTATION

LECTURE 25

Processes of speciation

* With divergent selection, over time there are more mutations between each and they eventually form new species due to such differences that lead to reproductive isolation
	+ Increase in reproductive isolation over time (graph primarily for postzygotic)
	+ General relationship for prezygotic is much harder to see
* Runaway sexual selection – reinforcement of evolution of female and male traits where it’s the alternation of males having a trait that females prefer and females exhibit the preference so the males continue to develop and the preference continues to persist and so on
	+ Over time, this increases prezygotic isolation
* Secondary contact is when two species that have diverged (allopatric) come back together
	+ Can show us reproductive relationship between said species

Outcomes of Secondary Contacts

* Fusion – can exchange genes and eventually come back to become one species
	+ Can be thought of a failed speciation event
* Complete isolation can be so completely isolated that hybrids do not form or are sterile or infertile
	+ If diverged in ecological niches, then they can overlap with minimal competition
	+ Jordan’s Rule – most closely related species tend not to overlap geographically, thus this is really rare
* Localized hybridization over time results in stable hybrid zone, yet genetic exchange is limited
	+ Reduced fitness in the hybrid zone, so offspring there is not as fit as the original parent
	+ Demographic sink occurs in hybrid zone and would disappear altogether if organisms weren’t coming into the hybrid zone
	+ This results in a cline in the two geographic areas
		- Width of cline is proportional to migration rate and inversely proportional to selection strength
			* Stronger selection against hybrids, worst hybrids do and more of them die
* Reinforcement – there is selection for mating with one’s own type if there is strong postzygotic isolation
	+ Reinforcement of female selection giving postzygotic isolation
	+ Can’t select for postzygotic isolation, but it is an outcome of independent evolution and accumulation of genetic differences
	+ Hybridization will reduce over time with reinforcement
	+ This leads to complete isolation
* Reduced fitness can only be seen when diverging populations come back together and mate to produce hybrids
* Rainforests is a good place to study this
	+ During dry periods, rainforests separated. A few thousand years ago, forests come together again. This is called a sutrazone, or place where multiple independent pairs of lineages come back to meet and mate after prolonged periods of isolation
	+ Allows us to do comparative studies via the genetics of the hybrid zone
* Allopatric – reproductive isolation is most likely in this system
* Parapatric and sympatric – need to stop gene flow for incompatibility between organisms in terms of reproduction
* Allopolyploid – Evolution of a hybrid species to become its own species
	+ Needs to be viable and fertile
	+ For this to occur, the hybrid needs to be isolated from the parents
		- Most commonly occurs when hybrid becomes polyploidy
		- Must be even number ploidy. If odd number, then offspring is sterile
* Speciation and extinction links microevolution to macroevolution
	+ Microevolution is the evolution between similar populations of organisms
	+ Macroevolution is the evolution over time of everything

Fossil Record

* Darwin predicted that we can find intermediate forms of species in the fossil record
* There are layers of sedimentary rocks that we can date, which allows us to know when things lived/died
	+ Fossils are trapped between these layers
	+ To date, we look at the percentage of stable isotopes
* Low oxygen world and overtime we had a steep increase of oxygen, which is critical to most forms of life
* First eukaryotes at about 2bya, with algae at 1.2bya. around 600-550 thousand years ago, we see instantaneous presence of multicellular animals (metazoan)
	+ This is known as the Cambrian Explosion, or the sudden appearance of major phyla of multicellular animals (metazoa)
* Walcott – Burgess Shele is where a lot of fossils that shows Cambrian explosion is found

Extinction, Evolutionary Forms, and Human Evolution from an Ancestor

Extinction

* We need groups of organisms that readily form fossils in order to study this
* Extinction is normal – background rate of extinction with occasional giant spike
* 5 well recorded mass extinction events discovered in the marine invertebrate record
	+ End Ordovician (86% of organisms went extinct)
	+ End Permian (96% of organisms went extinct)
		- Syberian trap, which altered earth’s ancestors
	+ End Cretaceous (76%)
		- Also called K/T boundary
		- With increased analysis of the rock here, we found that there are high levels of iridium (present in meteors)
			* It is assumed that mass extinction occurred because of an asteroid impact, and is located in Yucatan peninsula in Caribbean
				+ This was decided by Alvarez
			* So much dust in air changed Calvin cycle in plants and led to mass extinction
		- Birds and reptiles are modern day reptiles
* Don’t know exact reasons why, but we assume it’s because of dramatic ecological change (typically with reduced oxygen in atmosphere)
* Very difficult to prove extinction because you have to prove the absence of something
* Pleistocene – when climate change and human impact causes mass extinction
* Elevated levels of extinction results in more currently endangered species
	+ Such species are getting closer to mass extinction but not quite yet

What Can We Learn/Obtain From Fossil Record

* Can document extinction dynamics
* Can approximately date ancestral taxa
* Can observe transitional forms
* Dynamics of diversity over time is often referred to as macroevolution
* Dynamics of speciation extinction in whole clades of organisms

Net Speciation rate = rate of speciation minus rate of extinction

* Balance between those will show us if a particular clade’s organisms if diversity is increasing or decreasing
* Species Selection – a clade where one fork has low diversity and the other fork has very high diversity and speciation (diversity differs between clades)
	+ Different and above the results of individual evolution between sister clades

Plants

* Can be self-incompatible or self-compatible (self fertilization)
	+ Self-fertilization leads to inbreeding and loss of genetic variation
		- More successful in clade
	+ More genetic variation if self-incompatible
		- Less successful at surviving because faces more extinction due to reliance on outside forces to reproduce

Transitional Forms

* Tetrapod vertebrates came from an aquatic life form that moved to terrestrial environment
	+ Can we find intermediate steps between people? This interested Neil Shubin, a paleontologist from the University of Chicago
		- Discovered Tiktaalilc, which was the transitional form he predicted
* Evolution of complex traits via intermediates
* Exaptation – modification of existing adaptation for a different purpose
	+ Example is evolution of feathers in birds for flight, which possible was originally used for thermal insulation or attraction for mating
		- Newly discovered fossils in China where they found preserved fossils of therapod dinosaurs with feathers, but such organisms didn’t fly
* Hominidae is the groups of all monkey-type organisms
	+ Chimpanzees and humans share a common ancestor about 7mya, and the lineage that split off from this and eventually evolved into humans is called Hominins
	+ Homo sapiens are the only extant species from this hominin branch
	+ Highest diversity that occurred in the hominin lineage was in Africa about 4-2mya

Hominins – Modern Humans and Now Extinct Ancestors

* Hominins and chimpanzee line split off from common ancestor about 7mya
* Increase in diversity of hominins about 4-2mya
	+ Upright stance and reduced canines

Homo Genus

* Traits used to differentiate homo as a group (about 2mya)
	+ Increased brain size
	+ Decreased jaw
	+ Decreased sexual dimorphism
* Neanderthals
	+ Originally from Africa
	+ Found fairly widespread in Europe about 200,000-240,000 years ago
* We found a hobbit that was dated back about 12,000 years ago on island of Flores
	+ Called Homo floriensis (dwarfism)
	+ More discoveries of bones hints that it is a separate species
	+ Organisms are usually smaller on islands
	+ Modern humans was also in area and must have interacted with this species
* Multiregional idea
	+ Single ancestor gave rise to 3 Homo erectus which all gave rise to Homo sapiens
* Out of Africa idea
	+ Same thing, except only one Homo erectus gave rise to Homo sapiens
	+ Oldest Homo sapien was about 160,000 years
	+ Went into Europe and Asia about 100-60/60 thousand years ago
	+ Entered North/South America by passing Bering Strait
* Gave rise to paleogenomics where we sequence entire genomes
	+ Born on Berkeley campus in 70s and 80s, and Paabo was a post-doc in one of these labs doing research on the subject
* Paabo spent his career trying to extract DNA from hominid fossils to trace similarity and determine when divergence occurred
	+ In a Siberian cave, Paabo and his students were sequencing every bit of gene they could find about Neanderthals
	+ Denisovan – only found finger and tooth; 5-6% found in Paupans
* 3-5% of our genes are derived from Neanderthals
* Migration patterns
	+ Africa to Europe (with some Neanderthal genes) to Asia across Bering Strait to North America
	+ Africa to South Asia (with some Denisovan genes) to Australia to Asia
		- 40,000-60,000 years ago

Are Homo sapiens still evolving? YES

* We are still faced with novel pathogens and there are many pressures that force us to continue to evolve in order to survive
* Lactose intolerance is an ancestral trait, however humans are evolving so that we now have an enzyme called lactase that changes lactose into glucose which we can metabolize
* Melanism (skin color)
	+ Adaptive trait that increases protection against UV rays
	+ Decreases production of vitamin D because UV rays have vitamin D in it (typically at high altitudes)
* Selection for increased oxygen transport in blood for those living in areas of high elevation versus those in lower levels of elevation (Tibetans vs others)
* Some alleles are more advantageous in the heterozygote state
	+ Cystic fibrosis is bad, but the heterozygote state is good for extreme water loss for things like cholera

How Does Evolution Shape the Way We Think About Medicine and Public Health

* Proximate causes (medicine)
	+ How did we get said illness? How can we treat it to enhance survival, quality of life, etc.
* Ultimate causes (public health): how were humans predisposed to condition
	+ Because of evolution of pathogen (AIDS, other viruses, etc)

Evolutionary Mismatches – how has evolutionary history shaped our current phenotype

* Through a variety of processes, there is a rapid increase in the age of first reproduction
	+ Change in cultural processes, increase in choice for women to control their reproduction, etc.
	+ Example: Canada – average age in first reproduction increased 5 years over the last few decades
* There is also an increase in longevity (post-reproductive, post child rearing)
	+ Average age of death was typically 40-50 years around a couple of hundred years ago, however over the last two hundred years it has increased to over 70 years old (all in about 8 human generations, which is amazingly fast evolution/shift in genotype)
	+ Our biological clock can’t keep up with this shift in age of reproduction and longevity because there hasn’t been selection for longevity beyond reproduction and child rearing

Thrifty Genes Hypothesis

* Selection for efficient use of nutritional compounds
* Populations that are adapted to limited nutrition are prone to diabetes and other diseases related to this as they are exposed to high-calorie foods
	+ This is because the body will store the calories as fat because body is conditioned to think it’s going to starve so it needs fat reserves to rely on

Hygiene Hypothesis

* Decline in transmissible diseases over time, however autoimmune diseases such as asthma is increasing
* By reducing exposure to transmissible diseases early on in life, we are predisposing ourselves to autoimmune diseases later on in life
* Autoimmune diseases are where our immune system attacks itself