LECTURE NOTES

Lecture 13 Inheritance of Variation

Clicker Question: Most genetic disorders are associated with recessive alleles. Why?

a.) In general recessive alleles tend to be rare
b.) By definition, recessive alleles reduce an individual's fitness
c.) Selection eventually weeds out all copies of a harmful dominant allele and a harmful recessive allele can hide within a population of heterozygotes

Answer: C

Clicker Question: Which of the following is a true characteristic of dominant alleles?

a.) They are the most evolutionary fit alleles
b.) They are the most common alleles in a population
c.) They inhibit the expression of recessive alleles
d.) They determine the phenotype of heterozygotes

Answer: D

- Dominance status of allele describes its effect on the phenotype of heterozygotes, NOT whether the allele is helpful, harmful or neutral
- Dominance affects evolution rate and outcome
  - If a harmful allele is dominant, it is eventually weeded out through selection
  - If a harmful allele is recessive, selection is not able to weed out EVERY recessive allele, ad it stays within the population
  - If a beneficial allele is dominant, it increases in frequency very quickly
  - If a beneficial allele is recessive, it increases in frequency but much slower

<u>Other constraint on selection</u>

- By genetic correlations among traits (Darwin's finches and their beaks depth, which correlate with body size, beak length and more), can't select on one trait without seeing the selection on other traits
- A particular trait may be associated with a physical advantage in some instances but disfavours in another (e.g. male peacocks have flashy tails which are more impressing to hens but also more conspicuous to predators
- Time —> in some cases, the environment may change more rapidly than evolution can actually occur. The population will evolve to apply for conditions that may have already changed (e.g. timing for migration, food sources etc.) (e.g. insects evolve earlier in the year such that fly-catching birds don't have enough to eat during their peak season)
- Available genetic variation (e.g. cheetahs inbreed so they are individual similar to each other, thus they can't evolve well in response to environmental change)

Why is genetic variation important?

- Total amount of genetic variation affects the evolutionary potential
- inbreeding decreases fitness in individuals because they are not genetically diverse
- it affects individual and population level fitness

- Quantifying genetic variation
  - Of an individual: proportion of heterozygous loci (higher is more diverse)and the inbreeding coefficient

- Of a population: proportion of polymorphic loci (the fraction of individuals in a population that are heterozygous)

Why is one allele dominant?

Skin and hair pigments are created in specialized cells called melanocytes; melanycotes can make two kinds of melanin: red-yellow or black. Melanin is shipped out of in melanosome organelles into skin cells and results in the pigmentation of the skin. MC1R is embedded in the melanocyte protein and when turned on it increases the level of cycle AMP in the cell producing ONLY BLACK MELANIN. ASP mc1R is turned off and deactivates cyclic AMP producing pheomelanosomes and red pigment. The reason why some alleles are more dominant than others: in this case the recessive allele makes some red and some black melanosomes, the allele gets turned on and off thus being able to produce the protein some of the time but not often enough. The black allele is ALWAYS ON and dominance arises from the expression of those alleles

Genes in Populations

Q: If we start with a dominant allele that is common, and a recessive allele that is rare, what will happen eventually?

a.) The allele frequencies will not change but much
b.) Each allele will reach frequency of 0.5
c.) The dominant allele will reach a frequency of 0,75, the recessive allele will be 0.25
d.) The dominant allele will reach a frequency of 1 and the recessive will disappear

Answer: A

Q: In a large population, with the absence of selection, what influences future allele frequencies?

a.) Dominance status of each allele
b.) Starting frequency of alleles
c.) Both A and B

Answer: B

Despite the fact that evolution of populations occur on a much broader scale than just a single cross between a single male and female, we can still use the rules of inheritance to make testable predictions about allele frequencies and how they may or may not change

e.g. Assume there is a 60% likelihood of inheriting a W allele from your mother and 40% of inheriting an R allele. This means 60% of male gametes bear the brown allele. So what is the egg distribution?

Answer: Likelihood is: WW: 6 x 6 = 36, WR: 6 x 4 = 24, RW: 4 x 6 = 24, RR: 4 x 4 = 16
Ratio of 36:24:24:16 —> this is representative of the HW Principle: $p^2 + 2pq + q^2 = 1$

Lecture 14 Selection & Fitness

Just because an allele is recessive to another allele does not mean it automatically decreases the occurrence of that allele, therefore it will not simply die out. Evolution is a change in allele frequencies from one generation to another

Hardy Weinberg Principle

Species conditions under which a population of diploid organisms achieves **genetic equilibrium,** that is the point at which neither allele frequency nor genotype frequency changes in succeeding generations. In a large, random mating population where mutations are rare enough to be ignored, in the absence of immigration and emigration and it there is NO selection, the allele frequencies can be used to calculate the genotype frequencies. It is important to remember that the HW Principle is a **null model**, a "bench mark" and example of what a non-evolving population looks like. Comparing observed and expected genotype frequencies may indicate that populations are changing/evolving thus resulting in the changing frequencies.

To summarize the HW Principle, genetic equilibrium is only possibly if ALL of the following conditions are satisfied:

- **No mutations are occurring**
- **Population is closed to migration from other populations**
- **Population is infinite in size**
- **All genotypes in the population survive and reproduce equally well**
- **Individuals in population mate randomly with respect to genotypes**

<u>Selection</u>

Not all genotypes have equal fitness. If there is a situation where there is a strong selection towards one allele, that allele will disappear from the population fairly quickly.

<u>Absolute Fitness vs. Relative Fitness</u>

Absolute Fitness (W) is defined as the number of offspring produced over an individual's lifetime, it's lifetime reproductive success.
Relative fitness is defined as the measure of biological fitness expressed as the ratio of the absolute fitness of an individual. It is the comparison of fitness levels of an individual or a particular genotype to the FITTEST genotype of that particular population. **In other words it is the number of living offspring that an individual produces compared with the number left by others in the** population.The relative fitness of the fittest genotype (the one with the highest number of surviving offspring) would equal 1. All the other genotypes would be:
$w = \mathbf{W/W_{max.}}$

The difference in w between the genotypes reflects the strength of selection

In diploid organisms, dominance relationships can constrain selection

If the r allele is recessive, it can hide in the genotype of heterozygous individuals. Since there is the presence of heterozygotes, there will always be copies of the recessive allele in the population hereford it will never completely disappear. Despite selection favouring the dominant beneficial allele, the frequency of this the beneficial dominant will never increase to 1 and the frequency of the harmful recessive allele will never weed down to 0.

If the recessive r allele is beneficial, in this case it will ultimately reach a frequency of 1 however it takes a longer time to spread since it's present in heterozygote individuals but eventually it will become common then increase at a very rapid rate afterwards.

Lecture 15 Selection & Other Evolutionary Mechanisms

Directional Selection

Refers to selection against low fitness at one extreme of a distribution and favouring individuals with the beneficial trait at the other extreme. Individuals at one end of the phenotypic spectrum have the highest relative fitness. This type of selection shifts a trait away from the existing mean and towards the favoured extreme and if directional selection occurs over a long period of time there will be a decrease in genetic variation because alleles with higher fitness would become very frequent.

Stabilizing Selection
Individuals that have the intermediate phenotypes of a trait will have the highest relative fitness while the extremes will be selected against. This type of selection increases the frequency of intermediate phenotypes, reducing genetic and phenotypic variation due to less scatter in the traits and is the most common mode of natural selection.

Disruptive Selection
The opposite of stabilizing selection where the extremes have a higher relative fitness and are favoured over individuals with the intermediate phenotypes. Alleles producing extreme phenotypes occur more common promoting polymorphism

—> **Polymorphism:** the existence of discrete variants of a character

Frequency - dependent selection
The fitness of a genotype/phenotype depends on how frequent it is in the population.

Negative Frequency Dependent Selection
Rare forms have a selective advantage and thus higher fitness. In many predator-prey systems, predators look for the most common phenotype in the prey and therefore the rare prey have lower odds of being eaten. The rare forms will eventually become more frequent resulting in the fitness of the rare form dropping and the new "rarer form" will be favoured

Positive Frequency Dependent Selection
Common forms are favoured. E.g. Brightly coloured poisonous frogs warn predators to stay away. Frogs that are brightly coloured fare better and are therefore favoured. This does not result in stabilization however as the rarer forms will be lost cause a decrease in genetic variation.

Overdominance AKA Heterozygote Advantage
Heterozygous individuals are favoured maintaining genetic variation as both alleles are still present within the population. This leads to a balanced polymorphism in which two or more phenotypes are maintained in fairly stable proportions over many generations

Clicker Question: Which of the following tends to remove genetic variation from a population?

a.) Long term directional selection
b.) Spatial variation in selection
c.) Overdominance
d.) Negative frequency dependent selection
e.) All of the above

Answer: A

Mutation
Mutations are heritable changes in DNA caused by random, spontaneous errors in DNA synthesis. They can have beneficial, harmful (deleterious mutations, lethal mutations) or neutral effects on fitness. Lethal mutations that cause death before reproductive age are eliminated form population, not favoured by selection. If an allele is advantageous, it may be preserved by natural selection but once it has been passed down to a new generation, other agents of microevolution determine its fate. Mutations are the ultimate source of new genetic/heritable variations as it provides new alleles.

Neutral Mutations - neither harmful nor helpful, they may change an organism's phenotype without influencing its survival and reproduction

Deleterious Mutations - alter an individual's structure, function or behaviour in harmful ways

Lethal Mutations - cause death of organisms carrying them. If lethal allele is dominant, both homozygous and heterozygous carriers suffer from effects. If recessive, only affects hoozygous recessive individuals. Lethal mutations that cause death **before** an individual reproduces is eliminated since no offspring will exist to carry the mutation
Advantageous Mutation - Confers some benefit on the carrier, this "new allele" may be favoured by natural selection and may be preserved

Migration AKA Gene Flow
Gene flow is the movement of alleles between populations. If the gene pools are different, gene flow increases genetic variation within a population by introducing new alleles and tends to equalize allele frequencies between populations. If the gene pools are already similar, even a lot of gene flow will have little effect. Therefore the evolutionary importance of gene flow depends on the degree of genetic difference between populations and the rate of gene flow between them.

Genetic Drift
Genetic drift is the opposite of migration and tends to reduce genetic variability within populations. Occurs when there is an unpredictable change in allele frequencies between generations caused by chance events. More common in smaller populations and leads to the loss of alleles and reduced genetic variability

Population Bottleneck - greatly reduces reduces genetic variation even if population numbers rebound. Caused by stressful factors such as disease, starvation, drought etc. Eliminates many alleles.
Founder Effect - occurs when a few individuals colonize a distant locality and start a new population, they carry only a small sample of the parent population's genetic variation, some alleles may be totally missing from the new population and "rarer" alleles in the original population have higher frequencies in the new population

Non Random Mating
Many organisms select mates with particular phenotypes and underlying genotypes.
Assortative Mating - individuals prefer mating with others with similar traits
Dissassortative Mating - Individuals prefer mating with others with different traits

Inbreeding - a special form of nonrandom mating in which individuals that are genetically related mate with each other. Generally increases frequency of homozygous genotypes and decreases the frequency of heterozygotes since they carry the same alleles. This may result in an increased frequency of individuals expressing a genetic disorder since a recessive allele is more likely to be expressed

Lecture 16 Why Sex?

Sex as a Means of Recombination
Recombination results in genetic diversity and sexual reproduction forms new combinations of alleles from crossing over, independent assortment etc. This results in offspring that are distinct from either parent and usually distinct from each other.

Sexual organisms can be:
Dioecious - male and female functions are housed in two different individuals. Every individual is either male or female and cannot have both

Monoecious - an organism that contains both male and female reproductive organs (ovaries and testes). Organisms of this type are called **hermaphrodites**

Sequential Monoecy (Sex Change) - occurs when an organism is born one sex and can change sex when it reaches a certain age or size. E.g. Common in coral reef fish: fish are born as female and should this female become the largest individual in the population, it's female reproductive organs become male reproductive organs. This process can also occur in the opposite direction where males become females.

Size Advantage Model of Sex Change
The conversion from different sexes makes sense with regards to each sex:
Being a larger female may allow for more eggs to be laid compared to that of a smaller female; as for males, becoming bigger allows them to produce more sperm
Protrandry - the conversion from male to female —> larger females have much greater reproductive success than large males. It would seem that females have more to gain by being large and males having less to gain by being large. It is possible to see the opposite of this such as in species where males compete for females and the females don't have to be as large but the males must be in order to attract their attention.
Protogyny - the conversion from female to male. Females change because males need to fight for females

Why Reproduce Sexually?
There are many downsides with sexual reproduction:

Cost of Mating	Cost of Meiosis	Cost of Males
- Requires a lot of energy - Dangerous and risky to go out and look for mates due to predators - Competition, susceptible to predation and no guarantee for success	- The genome of each contributor is diluted, so it would seem ineffective as a means of getting genes to next generation relative to asexual reproduction - Offspring only inherit half of an individual's alleles whereas cloning results in a complete inheritance	- Males are a reproductive dead end - If a female reproduces asexually, she will produces only females who can reproduce themselves - sexual reproduction results in both males and females where males cannot reproduce by themselves

Mutation Explanation for Sex
While asexual reproduction seems like a good idea, mutations will accumulate over time in asexual reproduction and ultimately cause extinction. Sexual reproduction on the other hand has more benefits for the species as a whole. Sexual recombination benefits the species by speeding up evolution and therefore speeding up the rate at which harmful mutations are removed and beneficial mutations are spread through the population. The result is a decrease in the likelihood of extinction.

Muller's Ratchet
Asexual reproduction is like a ratchet because it can only go in one direction. And because of this, the detrimental mutations that are accumulated are very difficult to remove from the genome of the population. As a result the population will continue accumulating mutations until it goes extinct. Sexual reproduction overcomes the ratchet effect by combining alleles from two individuals to produce offspring that may or may not suffer from the accumulated mutations since they are not clones.

Ruby in the Rubbish Hypothesis: States that sex shuffles the combinations of alleles so offspring can have more or less harmful mutations, increasing the variation in harmful mutations.

Ecological Explanations for Sexual Reproduction

Lottery Ticket Hypothesis
If the environment is constant and the species is well suited to the environment, reproduction should be asexual to produce offspring that are also wells untied to the environment. But in nature, almost never does an environment not change, it is NEVER constant. If the environment is unstable and changing, then reproducing sexually is more beneficial because increasing diversity in offspring will increase the odds that offspring will be better suited to the new environment

Red Queen Hypothesis
When the environment is continually evolving, sexual reproduction should be favoured so that a species can keep up with the changing environment. An example of this is with parasites. If the parasite is continually evolving to attack a species, then the species needs to be continually evolving its defences to the parasite in order to survive.

Long term advantages of sex is that it can purge harmful mutations while short term advantages are that it can help a species evolve to a quickly changing environment. Sexual reproduction explains sexually dimorphic traits (traits only expressed by one sex) and traits seemingly incompatible with natural selection.

Summary: Why Sexual Reproduction?
Disadvantages: costly in terms of finding a mate, meiosis (offspring only inherit half of individual's alleles) and males which are incapable of reproducing themselves therefore a reproductive dead end.
Advantages:
- **Long Term:** Removal of harmful mutations, combining helpful mutations
- **Short Term:** Aids species in evolving and adapting to a quickly changing environment

Lecture 17 Sexual Selection

Consequences of Sex: Sexual Selection
- sexual selection explains
  - sexual dimorphism – differences in appearance of males and females
  - traits that reduce survival or have no survivorship advantage
    - for example, frogs that call loudly to attract mates put themselves in danger to reproduce sexually because their loud call also attracts predators
    - traits like this persists because they are favoured by sexual selection

Intersexual & Intrasexual Selection
Intersexual Selection - selection based on the interactions between males and females. males produce useless structures due to females finding them attractive. Often called female choice since females are usually the ones that are "choosy" with their mates
Intrasexual Selection - selection based on interactions between members of the same sex. males using larger features/structures to intimidate, injure or kill rival males

Selective Forces on Males and Females
What determines the fitness of a male versus that of a female?

For males to maximize fitness, they must mate with as many females as possible and the number of mates that can be accessed is usually what limits male fitness. Females on the other hand are more limited in their potential fitness due to their higher investment. They benefit more from one mate as they are more concerned with offspring quality than with quantity of offspring therefore females typically make careful choices, they are very picky in the characteristics of their male counterparts. Because of this, males usually have higher potential fitness than females.

Which sex has the higher average fitness?
If there is a 50:50 sex ratio in the population, the fitness of males and females will almost be equal.

Sexual Dimorphism - one gender is more colourful than the other
May be a possible outcome of sexual selection but why?
Males are often larger than females and possess ornaments and weapons used to attract females, displaying these warns off other males and attracts the attention of females. Why should females favour males with exaggerated structures? Males with larger, brighter features indicate they are healthy, their appearance indicate that they can harvest resources efficiently or simply he has managed to survived to an advanced age.

This "active choice of mates" varies among species. In some species, males engage in violent combat with rivals, more and more males interrupt these attempts and only the powerful males are not interrupted. In other species females have a more active mate choice as they mate only after inspecting potential partners. Males preferred by females sustain their territorial defense and high display rate over long periods. Ultimately, the male holding the "best" position mates with the most females.

In regards to the handicap hypothesis, females select mates that are successful: the ones with ornate structures. This is because these structures may handicap the individual: prevent effective movement, attract the attention of predators etc. These individuals are selected as they have survived despite such a handicap as the alleles responsible for this success will be passed onto the offspring.

<u>Why are Females Often the "Choosy" Ones?</u>
This may be due to **anisogamy** which is the inequality of gamete size between males and females. Eggs are metabolically expensive to produce relative to the cost of producing sperm and thus females are the ones with higher parental investment in the offspring however this is not always true, the general trend is that sex differences in parental investment and potential fitness determine which sex chooses and which sex competes. The sex with higher parental investment is almost always the one that chooses their mates

Direct and Indirect Benefits
Direct Benefits - Males provide direct benefits to females such as gifts. those that are able to provide more to the females make better fathers as they are better able to support the family (i.e. forage for food etc.)
Indirect Benefits - Some species are more extravagantly ornamented because they are of greater genetic quality therefore there are heritable genetic benefits to be had by the offspring and this makes the individual attractive to females.

<u>Mates as Resources</u>

Monogamy - A male and a female form a pair bond for a mating season or for the individual's reproductive lives

Polygamy - when an individual has more than one pair bond with the opposite sex

Polygnyny - one male has active pair bonds with more than one female

Polyandry - one female has active pair bonds with more than one female. Females contribute nothing to reproduction but eggs

Promiscuity - occurs when males and females have no pair bonds beyond the time it takes to mate

In areas where males have high quality territories, females may be able to raise young on their own, in this case the males are likely **polygynous**, in other words mate with several females as their role is that of a sperm donor and protector of the space rather than an active parent to his young. **Polygyny** is prevalent in mammals as females make larger investment in young compared to males.

Promiscuous mating occurs when females are with males long enough to receive sperm, but afterwards there is no bond.

Parental Investment and Sex Role Reversal

In parental role reversal females compete for access to males because males have the higher parental investment in the offspring. If both sexes invest heavily in parental care, sexual selection operates in both sexes. In general males are less selective about short term partners compared to females but when it comes to long term mating partners, both sexes are similarly selective.

What is each sex looking for?

Facial Symmetry - facial and body symmetry are good indications of an individual's long term health because it shows that the individual has high development stability, that is they withstood the stresses of development (they didn't get sick often, they withstood periods of infectious disease)

Lecture 18 Cooperation and Conflict

Types of Social Interaction

	Actor Benefits	Actor is Harmed
Recipient Benefits	**Cooperation**	**Altruism**
Recipient is Harmed	**Selfishness**	**Spite**

- spite almost never happens
- altruism is "a special difficulty, which at first appeared to me insuperable and actually fatal to my whole theory" - *Charles Darwin*

Parental Care

Success of offspring may come at the cost of parent survival. This parental contribution is not actually altruism due to the resulting increase in the actor's fitness because they are helping their genes carry on via their offspring, thus this can actually be thought of as a selfish or cooperative behaviour

Altruism occurs when an individual risks their own fitness to protect others to whom they are not related. The individual compromises their own survival/ability to reproduce to enhance fitness survival/ reproduction of another individual. This is considered altruism since aiding the others does not increase the fitness of the individual that performs the action. (e.g. squirrel —> adult squirrel will risk being located by a predator in order to warn the young of the danger)

<u>Direct and Indirect Fitness</u>
An individual offspring may forego their own opportunity to reproduce in order to help their parents produce more offspring. But how can traits reducing fitness (offspring production) be selectively favoured? It is believed that there is more to fitness than simply producing direct descendants. Fitness is increased by <u>getting copies of an individual's genes into the next generation</u> and there is more than just one way of doing so.

<u>Personal Reproduction</u> results in a **direct** increase of fitness
Additional reproduction by close relatives due to an individual's altruism results in an **indirect increase** in fitness because the individual's alleles, also carried by close relatives will be copied to more offspring
Inclusive Fitness - the total number of offspring one produces as well as offspring produced by relatives as a result of an action performed by the individual

Kin Selection - individuals are more likely to help closely related relatives because closer relatives share more alleles and therefore their propagation is favoured

<u>Hamilton's Rule</u>
This rule determines whether altruistic (costly) traits are favoured by kin selection:
$rb > c$
Where:

- b - benefit received by donor's relatives
- r - weighted by degree of relationship
- c - donor's direct fitness

Does the product of b and r outweigh the donor's direct fitness (c)? If rb is greater than c, then the altruistic trait should be favoured by kin selection. The benefits to indirect fitness are high enough to outweigh the cost to persona fitness.

Cooperation between Non-Relatives
Why is altruistic behaviour directed to non-related individuals? Selection can favour altruism if it's expected that the altruism will be reciprocated. This is more likely when groups are small and stable, when individuals can recognize and remember the helpers from the cheaters. It has been proposed that human emotions including trust, resentment, guilt and gratitude) may have evolved for this very purpose, as adaptations for score keeping, distinguishing friends from foes.

Prisoner's Dilemma
A hypothetical situation where two players are put in the position where they can either cooperate (stay silent) or defect (implicate the other in the crime). The payoff depends on the partner's choice as well as your own. Regardless of what your partner does, the better outcome is always to defect as it is the **rational choice**. If both individuals behave rationally, mutual defection is **irrational.** Both players would be better off if they could trust the other but this rarely happens.

Solution? Repeated interactions between individuals, as mentioned before being able to distinguish friend from foe.

Parent Offspring Conflict
Altruistic behaviour can be explained by an individual trying to maximize their inclusive fitness which explains the conflicts that occur between close relatives and even parent-offspring relationships.
The longer a parent provides care to an individual offspring, the more benefits there are as fitness of both parent and offspring increase, however there are diminishing returns. There are **costs to the parent** such as the loss of opportunity to produce other offspring. The offspring wants to maximize benefits it receives, they are selected to demand more resources than their parents can provide.

To illustrate this conflict, the human fetus and the mother are a good example. The fetus demands more resources from mother, it monopolizes more nutrients because it is in the best interests of the fetus. However the mother and the fetus are in constant conflict about the optimal amount of resources it receives. The mother is equally related to current offspring as she is to future offspring. From the fetus' perspective, it is more closely related to itself than it is to its future siblings therefore it should receive more resources. In order to obtain more, fetal hormones manipulate maternal blood sugar and blood pressure which causes an imbalance in favour of the fetus as this maximizes the nutrients and vitamins it receives, but ultimately causes a risk for both parties.

Reading Notes
Relatedness:

Full Siblings	0.5
Half Siblings	0.25
Parent - Child	0.5
Nice/nephew to aunt/uncle	0.25
First uncles	0.125

To calculate the degree of relatedness between two species:
1.) Draw a family tree to show all genetic links
2.) Determine the relatedness of each link
3.) Multiply the links together in the path from one to another to determine relatedness

Eusocial - a form of social organization observed in some insect species where numerous related individuals - a large percentage of them sterile female workers - live and work together in a colony for the reproductive benefit of a single queen and her mates

Haploidiploidy ca can favour high levels of cooperation in social insects because the infertile worker males are about 75% related on average, which is a higher degree of relatedness than would have resulted if they had been fertile.

Lecture 19 Species & Speciation

If there were no speciation we could still have evolution but there would only be one species present on Earth today. **Speciation** marks the interface between **microevolution** (the change within a single lineage) and **macroevolution** (large scale evolutionary patterns).

<u>Morphological Species Concept</u>
Identifies a species based on whether they look similar to each other. Using the morphological species concept, the spiders would be classified as being of four different species and the birds would be classified as being of the same species



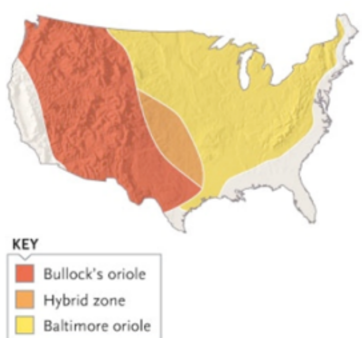
***Problems with this concept: It is difficult to apply the morphological species concept to species where there is sexual dimorphism because the males and females tend to look very different from each other and could therefore be incorrectly classified as belonging to separate species**

<u>Biological Species Concept</u>
A species is defined as an interbreeding (or potentially interbreeding) group of individuals that are reproductively isolated from other such groups. Referring back to the spiders, if this concept was used they would be the same species because they are not reproductively isolated while the birds would be considered different species because they are reproductively isolated and do not mate

***Limitations: I**t is difficult to see if the populations are of the same species when they are geographically isolated because their lack of contact doesn't allow them to mate naturally, if a species is extinct and fossil records are all that is known about them, then the morphological species concept is the only concept that can be applied to estimate whether they are of the same species, the biological species concept cannot be applied when organisms reproduce asexually because they are all reproductively isolated

One Species or Two?

Bullock's oriole



Baltimore oriole

- it depends greatly on the species concept that you are using

- using the morphological species concept, these two birds are from different species because they are different in appearance
- using the biological species concept, these two birds are of the same species because they are not reproductively isolated and will produce fertile offspring together
- whether the individuals are of the same species depends greatly on the concept used

Achieving Reproductive Isolation

Prezygotic Isolating Mechanisms - barriers which prevent species from interbreeding with each other. These mechanisms prevent the formation of the zygote and include:

Temporal Isolation - different species do not mate because their mating seasons differ

Habitat Isolation - two similar species may live in different reproductive habitats therefore they will not mate

Behavioural Isolation - also known as **courtship isolation** - mechanism where mating displays by some species are not attractive to another species, therefore mating will not occur

Mechanical Isolation - the sexual organs of one species are not compatible wit those of another species thus mating cannot occur

Postzygotic Isolating Mechanisms - barriers that ensure hybrid offspring are not selected for by natural selection

Hybrid Inviability - the hybrid dies prematurely

Hybrid sterility/infertility - should offspring be produced, the hybrids are usually infertile as they generally have a random mixed number of chromosome (difference even between hybrids)

Allopatry

Most speciation occurs in **allopatry - the occupation of isolated regions by the same species.** The two populations are isolated due to a geographic barrier (i.e. river, continental drift etc) and thus both populations will diverge due to selection and/or genetic drift; eventually the two populations will have diverged to the extent that they will not interbreed.

Other Types of Speciation

Peripatric Speciation - a special type of allopatric speciation where there is still geographic isolation but very few individuals survive in the isolated population. With such a small gene pool, rare genes are passed down more often causing genetic drift. The isolated individuals quickly become incompatible with their former species and have become a new species

Parapatric Speciation - The populations are not isolated by a physical barrier and are instead simply “beside” each other. Even though there is nothing stopping the individuals from mixing and mating, this does not happen for some reason and individuals within the population only mate with individuals in their immediate area.

Sympatric Speciation - The two populations are not separated and live in the same area. How would two populations diverge if they live in the same place? **Reproductive isolation** - individuals of the populations may come into their mating seasons at different times or preference of where to find a mate. Many species return to where they were born to mate and therefore would only be able to mate with others who were born in the same plce no matter where they move and live as adults.

Why are islands hotbeds of speciation?
Evolution occurs much faster on islands, predation on the island may be different from the mainland and therefore selection pressures may be different, genetic drift on the island is likely faster due to smaller populations and there is limited gene flow with the mainland.

Secondary Contact
If **secondary contact** occurs there are two scenarios:

1.) **It may reinforce reproductive isolation**
May have been caused by: differences in courtship that may have evolved over the time period, post zygotic isolation of the hybrids produced by interbreeding may have resulted in offspring that have low fitness relative to parent forms, direct selection favouring prezygotic isolating mechanisms

2.) **Reestablish gene flow between the two populations**
Little divergence has occurred and the populations will resume interbreeding (hybrid swarm) and eventually the two populations will once again become one

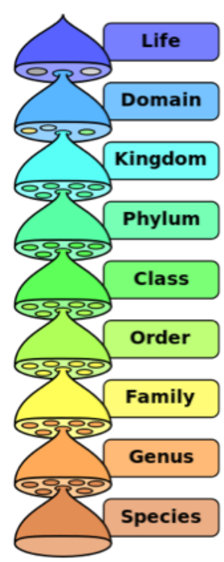
Speciation Without Allopatry
Although most speciation occurs allopatrically, speciation can also occur symmetrically (i.e. without any geographic barrier). One way this is possible is through mutations such as **polyploidy** resulting in instant sympatric speciation. Many species of plants appear to have evolved as a result of sympatric speciation. Another way this is possible is through adaptation to a new food type.

E.g. Hawthorn Maggot being introduced to North America: this subset of maggots began feeding and mating ONLY on apples which caused the species to become reproductively isolated because they would only mate on apples whereas the others mated on the Hawthorn fruit

Lecture 20 Phylogeny

Convergent Evolution - the tendency among organisms living under the same conditions to develop similar body forms. It refers to phylogenetically more distantly related organisms while **parallel evolution** refers to more closely related ones.

Systematics has two major goals
1.) Reconstruct the **phylogeny** (evolutionary history) of a group of organisms. Phylogenies are presented as **phylogenetic trees** which are formal hypotheses identifying likely relationships among species
2.) **Taxonomy**: the identification and naming of species and their placement in a classification. A **classification** is an arrangement of organisms into hierarchical groups that reflect their relatedness



The Taxonomic Hierarchy
A **family** a group of genera that closely resemble one another. Similar families are grouped into **orders**, similar orders into **classes**, similar classes into **phyla**, similar phyla into **kingdoms**, and finally all life is classified into three **domains.** Organisms included within any category of the hierarchy make up a **taxon.**

<u>What is a phylogeny?</u>

A phylogeny portrays the genealogical relationships of species and groups of species in a tree-like diagram known as a **cladogram** or **phylogram** which shows how lineages are related to each other and which lineages share a common ancestor

Systematists look for characters that are independent markers of underlying genetic similarity and differentiation. They create hypotheses and classifications by analyzing genetic changes that caused speciation and differentiation.

These characters must be **genetically independent** which is important because different organismal characters can have the same genetic basis.

Homologous characters share the same embryological (developmental) history, these phenotypic similarities reflect underlying genetic similarities and are used as indicators of common ancestry and genetic relatedness
Analogous characters have the same function but are **homoplasious** meaning they are phenotypic similarities that evolved independently in different lineages

Mosaic evolution refers to the reality that in all evolutionary lineages, some characters evolve slowly while others are rapid. Every species displays a mixture of **ancestral characters (old forms of traits)** and **derived characters (new forms of traits)**. Derived characteristics are particularly useful as once this characteristic is established, it is usually present in ALL of that species' descendants.

Outgroup comparison is a technique where the group under study is compared with more distantly related species
Monophyletic taxa – those derived from a single ancestral species. Includes an ancestral species and ALL of its descendants
Polyphyletic taxa – includes species from different evolutionary lineages
Paraphyletic taxon – includes an ancestral species and some, but not all, of its descendants

- E.g. Reptilia taxon is paraphyletic because it includes the obvious "repitiles" but not other descendants (mammals and birds)

Parismonious phylogenetic hypotheses include the fewest possible evolutionary changes to account for the diversity within a lineage
Assumption of parisomy – the simplest explanation should be the most accurate
Traditional evolutionary systematics – groups together species that share ancestral and derived characters . Classifications produced using this method reflect evolutionary branching and morphological divergence
Cladistics – produces phylogenetic hypotheses and classifications that reflect branching pattern of evolution, species are grouped together based on shared derived chharacters

How does one determine whether groups are more closely related/distantly related?

-Morphological similarities
-Developmental similarities
-Genetic similarities

Similarities are informative, they given an indication on relatedness

Homology - similarities that reflect recent common ancestry, the more recent the ancestor, the more traits various species would share with each other

Despite this, not all similarities are reliable and not all explain relatedness.
Homoplasy - similarities that may not reflect relatedness, they are misleading similarities or misleading dissimilarities

E.g. Crocodiles and Hippos: due to similar selection pressures the location of their eyes are similar, BUT they are not close relatives. **Convergent evolution** explains the location of their eyes.

E.g. Darwin's finches and **divergent evolution**: these birds are closely related to each other however due to their beak morphology they may not seem like relatives. Different selection pressures have changed the phenotype of the various finches

Homologous traits support the true phylogeny while homoplasious traits are misleading. But without knowing the phylogeny in advance, how does one determine if a similarity reflects homology or convergence?

- Sometimes we can infer from structure or development, same genes activating the development of a specific structure
- **Cladistics:** school of classification where phylogenies are built to only focus on similarities that are **informative**
- **Synapomorphies** – shared traits derived from a common ancestor
- **Symplesiomorphy** – shared ancestral traits – trait was already present before groups diverged
- **Autamorphy -** unique to a single group, derived within the group

Lecture 21 Phylogeny II and Evolutionary Ecology

In order to correctly arrange the sequence of branching events on a phylogenetic tree, and understand the patterns of relatedness, we need to reconstruct or make conclusions about the characters states of the common ancestors from which modern-day species are descended.
This is difficult because common ancestors are long extinct.

Reading and Building Phylogenies Recap

- "Related to" is NOT synonymous to "descended from"
  - i.e. you are related to your cousins but you are NOT descended from them
- "More complex" (in tens of morphological or developmental complexity) is NOT synonymous with "more evolved" since all species today have been evolving for the same amount of time
- Relatedness is NOT equated with similarity
  - Not all similarities are homologies
    - Shared traits could be due to convergent evolution
  - Not all homologies are synapomorphies
    - According to cladistics, we only pay attention to synapomorphies (shared, derived traits)

Is this trait ancestral or derived?

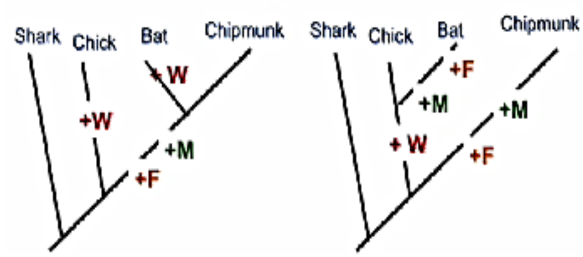
- Trait is **present** in outgroup and ALL of ingroup
  - Most likely ancestral (strong evidence)
  - The trait MAY have evolved multiple times over the course of evolutionary history (convergent evolution) but the probability is HIGHLY unlikely
- Present in outgroup and SOME of ingroup
  - Most likely ancestral
  - For some reason, the other ungroup lineages may have lost this trait over the course of evolutionary history
- **Absent** in outgroup but **present** in SOME of ingroup
  - Most likely derived
  - Most likely the trait was derived independently in each of the lineages that have the trait
- **Present** in the out group but NONE of the ingroup
  - We cannot tell in this case
  - There are essentially two equally likely possibilities:
    - The common ancestor did not have the trait (the trait is derived, it happened in the lineage leading to the out group)
    - The trait is ancestral but the trait(s) was/were lost in the evolutionary step leading to the ingroup
- **Absent** in outgroup but **present** in ALL of ingroup
  - We cannot tell, the trait MAY be ancestral and at some point the out group lost the trait OR perhaps the trait was derived in the lineage of the ingroup

The reasoning relies on parsimony

- **The simplest explanation is usually the best**
- Whichever tree requires the smallest number of evolutionary changes (gains or losses of a trait) is probably correct

How many potential phylogenetic trees are there?

- With increasing # of taxa (t), the number of candidate trees increases hugely (there is a formula, we do not need to know)
  - 2 taxa, 1 possible tree
  - 3 taxa, 2 possible trees
  - 4 taxa, 15 possible trees
  - 10 taxa, 34.5 million possible trees



Using parsimony to evaluate candidate trees

- Outgroup: Shark
- Ingroup: Chicken, Bat, Chipmunk
- **First identify which traits are synapomorphies**
  - Outgroup
    - Shark: No milk, no fur, no wings, no beak
  - Ingroup
    - Chicken: No milk, no fur, wings, beaks
    - Bat: Milk, fur, wings, no beak
    - Chipmunk: Milk, fur, no wings, no beak

Using phylogenies in classification

- In cladistics systematics, only **monophyletic groupings** are recognized
    - Monophyletic groups are groups that include all the descendants of the group's MRCA

On exam, you do not need to know polyphyletic and paraphyletic…

Many traditionally-recognized groups are not monophyletic

- Prokaryotes are not monophyletic
- Dicots (dicotyledons, flowering plants whose seed typically has two embryonic leaves or cotyledons)
    - Some dicots are more closely related to monocots than other dicots
- Many fish are more closely related to humans than they are to other fish
- Endotherm vertebrates (birds and mammals) are non-monophyletic because birds are more closely related to lizards (cold blooded) than mammals.

<u>**Evolutionary Ecology**</u>

- **Ecology:** Interactions between organisms and their environment
    - Abiotic (climate, temperature, nutrients) vs biotic (living organisms of same species – mates or competitors, other species – prey, predators, pathogens, parasites) components
    - These interactions affect evolution
        - Origin and demise of species (i.e. rates of speciation and extinction)

Evolutionary ecology and biodiversity

- Most species that have ever existed are now extinct… constant turnover and replacement
    - Species are outcompeted, or replaced by other species
- Biodiversity (number of species currently alive on planet) varies over time, reflecting between overall rates of speciation (new lineages being reproductively isolated) and rates of extinction (how fast lineages are becoming extinct, or dying off)
    - Angiosperms (flowering plants) have an increasing number of species, while gymnosperms are remaining more or less the same.

Adaptive radiation: Rapid speciation into many descendant lineages

- For a certain period of time, a single species will rapidly become isolated into many descendent lineages, called adaptive radiation
    - Occurred in Darwin's finches in Galapagos islands
    - **Ecological Opportunity**: Competitive release after colonizing new environment

Adaptive radiation on a larger scale

- Takes over a longer period time, and much more species arise
    - Example: Mammals
    - **Ecological Opportunity:** Competitive release after a mass extinction
        - The mass extinction of dinosaurs allowed for the burst of mammals (from 20 species to around 5000 species) since ecological niches were open the mammals.

Evolutionary innovations can induce adaptive radiation

- Seems to explain the huge radiation of angiosperms. There are 250 million types of angiosperms that arose in only 120 million years.
    - The key innovation for angiosperms is producing flowers that attract animals which can be used as a method of pollination

- Using animals as pollinators gives new opportunity to both bunching lineages of lowers as they both now have the opportunity to grow
- Flowers with different phenotype/temporal blooming will become reproductively isolated as they attract different pollinators or pollinators that operate at different types of environments
- Pollinator isolation —> prezygotic isolating mechanism

Benefit for plant: new combination of genes, able to reproduce, plants are immobile so this is the ideal situation for a plant
Benefit for the animal: receives food (nectar of flowering plant)

Lecture 22 Arms Race

Interaction of different species

Mutualism (Both Benefit)	Competition (Both Suffer)	Antagonism (One benefits, One suffers)

E.g. Plant and Flower, Domestication of animals and crops by humans	- Two or more species competing for limited resources
	- Coexisting species in an area will compete for resource
	- e.g. overlapping cheetah/lion range compete for food resources such as water
	- Each part is WORSE off due to presence of other species
	- Intensifies competition for resource (i.e. Plants compete for space, water, soil nutrients, sunlight —> become TALL to grow and obtain energy
		- One species exploits the other, natural enemies
		- Predator/Prey Relationship
		- E.g. Plants and Herbivores: plant suffers, may result in decreased growth rate, in extreme cases plant sustains too much damage and is unable to continue growing/ reproduce
		- Host-parasite relationships
		  - parasites and pathogens benefit at the expense of the host individual
		  - decrease fitness of host

Any of these types of relationships can give rise to an….

Evolutionary Arms Race

- Adaptation by one species improves its ability to interact with the other
- Can improve the ability to explore or benefit other species
- Selection pressure on the second species to evolve —> **counter adaptation -** a reaction to the adaptation of the first species

E.g. Evolution of a toxin: Rough skin newts —> only Garter snakes are able to eat this newt since it secretes a deadly toxin. Mutations that allowed for immunity against the toxins were favoured by selection pressures and over time the populations of Garter snakes developed the ability to consume the newts without suffering the consequences. The newt will subsequently evolve to produce more lethal toxins and the snakes will continue evolving to be able to break dan the toxin, this is known as an evolutionary arms race

Improved equipment ≠ Improved Success

- Evolution by arms race does not necessarily make an organism more evolutionary fit. Reciprocal selection occurs if predators evolve to possess characteristics that allow them to increase their fitness. The prey species would have to adapt as well resulting in a relationship that remains unchanged, where neither species fares better.

Who wins the Arms Race?

The arms race may continue and escalate until **costs outweigh benefits.** Both species are in **Red Queen Equilibrium** - not lose ground against natural opposing species. Generally, populations of a larger size are likely to fare better due to more genetic variation, species with short generation times may also fare better as they can evolve faster.

Life - Dinner Principle

The strength of selection on parties in an arms race is not necessarily equal. Selection is usually stronger on a prey species as this species has more to lose. Prey are running/fighting for survival while predators are simply looking for another meal and because of this, prey species are more likely to win the arms race.

Mutualistic Arms Race

Plants and pollinators:
Optimal outcome for pollinators: lots of pollen in a short amount of time
Optimal outcome for plant: very intimate and long transfer of pollen
From this relationship, the pollinating creatures evolve more efficient and effective extraction mechanisms to enable them to obtain the pollen/nectar from the plants as well as being able to better locate the plants while plants evolve longer pollen tubes/provide more dilute pollen.

Arms Race within a Species?

Competition between members: the competition for access to mates, mate choice: males and females impose selection pressures on sac other, females become more picky and "choosy" while males develop more elaborate structures.

Host-Parasite Interactions

Not all parasites are equally virulent (harmful). Parasites take resources to make copies of itself, exploiting the host, but the degree to which the host suffers is not the same for every parasite. Some diseases, viruses and parasites are quite lethal while others are merely harmless.

Prudent Parasite Hypothesis

A parasite that kills its host too soon before infecting a new host is doomed. The prudent parasite hypothesis suggests that a virus/parasite should have low virulence , to not kill the host too quickly, to do as little harm as possible to ensure the host continues living. How does this hypothesis apply to highly virulent parasites? This hypothesis suggests highly virulent parasites are very new, have recent evolutionary origins, they are parasites that have recently infected new hosts and haven't had enough time to adapt and become benign.

E.g. Simian Immunodeficiency Virus: AIDS in chimpanzees, unlike humans it seems this parasite has adapted to the host, suggesting the virus has been with chimpanzees for a longer period of time and therefore has learned to cause less damage to host cells.

Trade-off Hypothesis
Balancing the costs and benefits of virulence. How does high virulence harm the parasite? How does high virulence benefit the parasite? There is a positive correlation between virulence and host to host transmission. The more virions a virus creates, the faster it kills the host cell but from the virus' point of view, there is a benefit as it is able to spread to new hosts

Modes of Transmission
Optimal virulence is transmission-mode dependent, in other words it depends on how the parasite spreads. If a parasite requires direct contact between host individuals, it is said to have **low virulence** as it depends on the interactions of the host and should the host become too sick they will be unable to spread. Parasites that do not depend on direct contact but rather indirect contact have higher virulence and methods of indirect contact include: insect vectors, water contamination etc.

Examples

Q1: HIV-2 is less easily transmitted between hosts than HIV-!. What can you predict about its virulence relative to HIV-1?
A1: HIV-2 would be less virulent because it is less easily spread. It requires to host to live for a long period of time in order to spread.

Q2: A nematode parasite is transmitted mainly vertically (from parent to offspring), what would you predict about its virulence compared to horizontally-transmitted (infection of others through contact, air transmission (i.e. sneezing), environment) nematodes?
A2: Vertical translation —> low virulence as it requires the host to survive to reproduce, it relies on hosts making it to reproductive age before the parasite is able to spread.

Q3: How should host density affect optimal virulence of parasites?
A3: Dense environments where there are a large number of hosts in a small space favours an increase in virulence as there are many opportunities to transmit to new hosts and the parasites do not have to wait very long to find and jump to a new host individual

Q4: Condom use reduces the opportunity for sexually transmitted diseases to spread. How will this likely affect their optimal virulence?
A4: Reduces opportunity for sexual transmission

Lecture 23 Evolutionary Medicine

How does evolution affect human health?

- Pathogens evolve (resistance to vaccines, medicines)
- We can attempt to shape their evolution
  If we change change our ecology, shutting off opportunities for indirect contact (e.g. mosquito nets) then we can shape the direction in which pathogens/viruses evolve
- Traces of evolutionary history affect our health
- Trade-offs between competing demands
- Symptoms may be defences not defects

Diseases of Civilization

Metabolic Syndrome	Myopia	Autoimmune Disorders	Hygiene Hypothesis
- high calorie foods were a limited resource and ancestors were not adapted to such rich foods - obesity, diabetes, insulin resistance was not prevalent in ancestors - Reflects a "disease of civilization" since currently occupied environment is different than one which we are evolutionary adapted	Why were alleles associated with the inability to focus on distant objects not eliminated by selection? - Environmentally induced disease of population -E.g. Barrow Inuit Study: Children were taught to read, write, all close range activities while the older generation did not -The two different groups were exposed to different visual environments in early development. Alleles predisposing people to myopia did not cause myopia in ancestral visual environment	- On the rise as infectious diseases decline which reflects combat introduced by medicine - Our ability to combat them becomes more refined and is driven my medical advancements	- Suggests the decreasing incidence of infections in Western counties and recently developing countries is the origin of the increasing incidence of both autoimmune and allergic diseases - States that excessive cleanliness interrupts the normal development of the immune and this in turn leads to the susceptibility of diseases and an increase in allergies

Tradeoffs and Competing Demands

- Selection may maintain a harmful trait (i.e. sickle cell anemia)
- Natural selection promotes the maintenance of harmful alleles for the benefit of other benefits offered by the same allele (sickle cell anemia provides malaria resistance)
- Traits may be beneficial to early life but not for later survivorship (antagonistic pleoitropy) e.g. High levels of circulating sex steroids - may increase fertility when needed however it increases the risk of developing certain cancers

Q: **If a trait is very helpful during early life, but very harmful during later life, should the trait spread?**
One of the reasons we senesce (break down over time) is that traits associated with failure to repair the body later in life may be selectively favoured if they give a fitness effect early in life (e.g. High levels of sex steroids gives higher relative fitness even though predisposes organism to certain diseases (ex. Reproductive cancers) later in life). Selection acts more effectively on traits that are expressed early life history stages. Every individual can be young, but not all may make it to old age. Not worth it to invest in tissue repair if it is not guaranteed.

Antagonistic Pleoitropy and Senescence

Selection should favour alleles that increase reproduction early in life, even at the expense of reproduction or survival later in life. Anything that increases reproductive output/ early survivorship.

Antagonistic Pleoitropy: selection that maintains a harmful trait because it benefits fitness in another context.

- Male attractiveness, sickle cell anemia (harmful allele), Tay-Sachs disease (alle associated persists at a higher frequency, has been found that the high frequency has effects in preventing other diseases)

Age related antagonistic pleiotropy

- Benefits fitness when one is young, decreases fitness when one is old (e.g. Huntington's Disease)
- Fertility was higher with Huntington disease patients
    - Increased fertility
- Reproductive cancers
    - Mutations in specific androgen receptors
    - Don't' cause people to die until later stages of life

Same mutations in androgen receptor that increases susceptibility to these cancers have increased attractiveness/fertility during earlier life

Energy is channeled into reproduction, NOT repair

We have ways to repair tissues and all that it's just NOT worth it, or AS worth it

Why do we get sick?

- Improved equipment for survival vs. improved survival
    - Parasites keep evolving
    - Alter their ecology to direct their evolution
    - Have their own evolutionary agenda and upper hand over humans because of their large population size and rapid generation time
- Effects of history
    - Different selection pressures now than for most of our evolutionary history, we have not fully adapted to current environment
- The body is a bundle of compromises
    - Many genetic disorders are maintained because despite they have harmful effects in one context, they have beneficial effects in another context

Selection acts on lifetime reproductive success, not on health, happiness, or longevity

Lecture 24 Human Evolution

Are we still evolving and if SO, in which direction are we evolving?

- Survivorship is much higher, less struggle for existence, perhaps natural selection not necessary
- Historically we would have adapted to fit our environment, now we adapt our environment to suit ourselves
- We adapt ourselves? Gene therapy, certain medical techniques, artificial selection

- Yes but not in the same direction, as our environment is so different our directional selection is favouring very different traits than would have been historically favoured. Selection is NOT the only mechanism resulting in evolution
- Approaching Hardy-Weinberg equilibrium for some traits?
- Genetic drift is NOT as prevalent as it was in the past
- **Genetic structure is changing , exchanging of alleles is becoming a very common thing**

Dominant reasons for why we aren't evolving is because we have such control over environment (improvements in agriculture etc.) that natural selection no longer occurs, there is no struggle for existence. However this only applies to people living in wealthy countries, people in developing world don't have access to these resources. In these parts of the world, there is still a struggle for existence

Why Might We Stop?

- weaker natural selection due to medical advances
- babies born now have extremely good chance of survival, wasn't always true
- individuals with bad medical conditions can now not only survive but can successfully reproduce
- <u>Weaker sexual selection due to monogamy</u>

- Age at which males become fathers
  Mutation rate is likely to be lower now with regards to how many mutations are passed on to offspring. Historically, most powerful men had access to many mating partners. These men tended to be older while today, increased monogamy decreases the average age. On average societies have younger fathers which affects mutation rate. The older the male, the more opportunities for mutations to arise, passing on more mutations to offspring than younger males.

- Decrease randomness (genetic drift)
  Human populations are increasingly large and mobile. The larger the population, the weaker the effects of genetic drift. Currently, humans are more connected, individuals are interbreeding with others further and further away from where they're from while in the past, people weren't very mobile and had a limited social group.

<u>Evidence for Continuing Evolution</u>

SNPs and Sweeps

Selective sweep: when beneficial mutations increase in frequency and as a result, surrounding stretches of sequence do as well (temporarily). This causes the increase in frequency of the surrounding genetic information. By detecting sweeps, measuring the speed of adaptive evolution and analyzing sequence variation around SNPs, research has shown evidence of rapid recent evolution that has ben accelerating over the last 40 000 years. Lactase, CCR5, HbS (resistance to malaria) and many others were subject to faster acceleration.

Hallmark of Human Evolution: Increased Brain Size
Brain size has more than tripled in recent evolutionary history (over the last million years) But why hasn't everything evolved to greater intelligence? Big brains are very costly: energetically they are 2% of the body mass but requires 20% of the energy (requires large proportion of calorie intake, somewhere between 25-30%); it also puts individuals of populations at a great risk as there is a mismatch with the human pelvis due to bipedalism and increased head size causing conflicts during childbirth.

What were the benefits of having big brains?

- **Survivorship Advantage -** invention of tools, weapons
- Escape from predators, outwit prey
- Communicate and form groups, utilize language

Utility Hypothesis
Being able to use language, tools and the ability to plan meant survival. The larger brain was needed to communicate, plan, store food, think about how to escape from predators, the large brain was ultimately required for survival. Music, artistic expression, jokes are nothing but a correlated byproduct that arose.

Would a slightly smaller brain be more beneficial? Less risky?
The human vocabulary consists of 60 000 to 100 000 words but do we need such a big vocabulary to survive? We hardly use any of it. What kind of selection promotes the evolution of wastefully extravagant traits? **Sexual Selection.** Perhaps big brains were favoured not because of survival but having high intelligence may have increased reproductive success, the ability to find a mate

Mating Mind Hypothesis
Word play, humour, art may ultimately result in mating success. Having the high intelligence may have contributed to reproductive success. But men and women are both intelligent, aren't sexually selected traits sexually dimorphic? While this is true, humans are a monogamous species, males and females both choose ages putting selection pressures on BOTH sexes. The receiver doesn't have to have the trait to assess it, but intelligence is a unique trait where in order to assess it, one has to have some level of intelligence as well.