EVANS

CHAPTER ONE – BIOLOGY AND THE TREE OF LIFE

CHAPTER ONE

- The cell theory and theory of evolution by natural election are unified by *ancestry* and *descent*.
- Evolutionary relationships can be represented by phylogenetic trees

Cell Theory

- *Cell* – highly organized compartment bounded by plasma membrane containing concentrated chemicals in an aqueous solution
- *Cell Theory* – all organisms are made of cells and all cells come from pre-existing cells
    - All cells are descended from a progenitor cell – the zygote
- *Hypothesis* – proposed explanation
- *Prediction* – something measurable and must be correct if the hypothesis is correct
- *Louis Pasteur* – designed an experiment to test if cells arose spontaneously or if they were the result of pre-existing cells
- Since all cells come from pre-existing cells, all organism are related by common ancestry, even multi-cellular organisms

Theory of Evolution

- Darwin (studied in the Galapagos) and Wallace (studied in South East Asia) proposed that all species are related by common ancestry; they also proposed that the characteristics of a species can be modified from generation to generation
- *Evolution* – postulates that:
    - Species are related to one another
    - Species can change through time
- *Natural Selection* – process that explains how evolution occurs -> over time, it is the transition of genetic material
- *Fitness* – the ability of an individual to produce offspring
- *Adaptation*
    - A trait that increases the fitness of an individual
    - The process of a species acquiring fitness improving traits over time
- For natural selection to occur these are required:
    - Variation in traits
    - Heritable traits (not environmental)
    - Traits that influence fitness
- If certain characteristics lead to increased success in producing offspring then these traits become more common in the population over time
- Natural selection acts on *individuals* but the evolutionary change affects the *population*
- Evolution occurs when heritable variation leads to differential successes in reproduction

Artificial Selection

- Individuals in a population are selected for mating based on particular traits
- Repeating this process over generations results in changes in the characteristics of a domesticated population over time
- Basically Chihuahuas didn't exist before, we bred them because people like small dogs

Inadvertent Artificial Selection

- Hunting the large horned animals meant that the population decreased and the population had smaller animals with smaller horns because it kept them safe from being hunted by humans

Speciation – is the diversification of an evolutionary lineage; lines represent different phenomena
There can be barriers to speciation – donkey + horse = mule, sterile

Tree of Life – diagram that depicts relationships among species

- Molecular variation in nucleotides (DNA, RNA) offers information for understanding the evolutionary relationships among all organisms
- Nucleotide sequences should be very similar in closely related organisms but less similar in organism that are less closely relationships
- *Phylogenetic tree* – diagram that depicts relationship among species
- You can compare the nucleotide sequences of the same gene across a bunch of different similar species – ie, there is an A where the other one has a G or there's a gap and someone else has a T
    - Allows us to compare similarities and differences between species on the genetic level
- Linnaeus' Taxonomic Levels
    - Kingdom, Phylum, Class, Order, Family, Genus, Species
- Linnaeus proposed just two kingdoms – plants and animals, however not all organisms fall into these; the five kingdom system was established in the 60's
- Now we have domains – domain bacteria (no nucleus), domain archaea (no nucleus), domain eukarya (nucleus) because plants, fungi, and animals are small branch tips on the tree of life
- A node on a phylogenetic tree represents the common ancestor of the two diverging lines
- The tree of life indicates three major groups of organisms – the eukaryotes (Eukarya) and the two groups of prokaryotes – Bacteria and Archaea
    - The new taxonomic level is the domain containing Eukarya, Bacteria, Archaea
- 5 branches on the tree

Behaviour Not Like A Tree

Hybridization – merging lines
Lateral Gene Transfer – in bacteria, useful information is being transferred, fused
Sexual Reproduction – fusion of genomes
Endosymbiosis – mitochondrial DNA use to be bacteria but now it is fused in a eukaryotic cell
Tasmanian Devils With Mouth Cancer – endangered species, they contracted mouth cancer from dogs and they transfer it to each other while fighting, they have Tasmanian devil DNA and dog genomes

Doing Biology – Why Do Giraffes Have Long Necks?

Hypothesis – giraffes have long necks to provide access to food resources
Prediction – giraffes eat food that is high on trees
Data – but most of the feeding is happening below the height of their head
Alternate Hypothesis – giraffes evolved long necks to be used in male-male combat, allowing them to win the fight and father more offspring

Chapter 24 – Evolution by Natural Selection

- Evidence of evolution (changes through time, extinction, vestigial traits, inter-relatedness)
- Evidence of natural selection (industrial melanism, antibiotic resistance, beak size in Galapagos finches)
- Animals do not do things for the good of the species (but might behave altruistically under particular conditions)
- Not all traits are adaptive
- Adaptations are constrained by trade-offs as well as genetic and historical factors

History

- Plato claimed that every organism was an example of a perfect essence or type created by God and that these types were unchanging
- Aristotle proposed that species were in a hierarchy based on strength and humans were at the top
- Jean-Baptists Lamarck proposed the first formal theory of evolution
    - characteristics that are not used are lost; characteristics that are used are passed on, including in a state acquired by the parent
    - ex – blacksmith acquires strong arms from working and will thus have sons with strong arms
    - experiment – people cut off tails of mice and then had them reproduce but all the offspring kept having tails
    - There is evidence that characteristics acquired during a parent's lifetime could be passed on to the offspring via mechanisms that do not involved changes in the nucleotide sequence of the DNA (ie – DNA methylation)
- Darwin described evolution as descent with modification
- Evolution - they change through time and they have common ancestry

Evidence for Change through Time

- Trilobite fossils that are 505 million years old (BC)
- Hominid footprint fossils that are 3.6 million years old (Tanzania)
- Many fossils provide evidence for extinct species
- Prehistoric turds and ancient DNA
- Artificial selection – speciation in today's time
- Speciation by hybridization
- Speciation of fruit flies by divergence of host plant usage
- Ring species
    - Five populations and the one on the left can populate with the one right beside it, that one can populate with the one right beside it, but the two species on the end of the linear relationship overlap but cannot reproduce with each other, only their adjacent populations
- Speciation by polyploidization
    - Genome duplication in African clawed frogs
    - 36 chromosomes which originated from 18 chromosome < the two 18 chromosome guys fused their genomes and created the 36 chromosome guy
- Transitional Forms
    - as the fossil record has become more complete, many *transitional forms* have been discovered with traits that are intermediate between earlier and later species
- Vestigial Traits

    - Goosebumps – we as humans lost our thick body hair (as opposed to gorillas and chimps) but we have goose bumps still
    - Coccyx – tail bone, new world monkeys and old world monkeys had tails, but apes/gorillas/humans etc don't have tails but we still have the tail bone
    - There are hind limbs in whales and pelvic spurs in pythons (from old legs)
- Extinct fossil species are typically succeeded in the same region by similar living species
    - Darwin and Wallace interpreted this as evidence that extinct forms and living forms are related, that they represent ancestors and descendents
- There are geographic relationships – where certain animals came from, similarities because of migration patterns
- In the Galapagos islands – four mockingbird species, they all are on different islands, the similarities between the birds show where/how the common ancestor migrated (ie, started in Eastern, then moved Southern, etc) based on similarities

Homology

- *Homology* – similarity that exists in species descended from a common ancestor
- *Genetic Homology* – similarity among species in DNA sequences, gene content, or other genetic attributes
- *Development Homology* – is a similarity among species in embryonic traits
    - By ancestry, not actuality, ie – bat wings are NOT homologous to chicken wings
- An identical or almost identical system is used by all known organisms to store the sequence of amino acids in proteins in nucleotides
- *Variatio*n – mitochondrial DNA substitution of single codons
- Chimps and humans differ by only ~1.5% of shared nucleotides but if you incorporate insertions and deletions it's ~6% difference
- Genetic - The gene that determines where the eye is located in fruit flies and humans is 90% identical
- Developmental – presence of gills in many things that don't have gills, like chick embryos, baby embryos, house cat embryos
    - The ancestral embryo always had gills, that's why the embryo develops it
- Structural – the bones in the appendages of turtles, humans, horses, birds, bats, seals are all homologous

- Studying natural selection:
    - Industrial melanism
    - Antibiotic resistance
    - Darwin's finches
- Genetic basis of selection – candidate gene approaches
- Limits of adaptation – evolutionary constraints

How Does Natural Selection Work?

- Individuals in a population vary in their traits – *Variation*
- Some of these traits are heritable – *Heritability*
- Not all individuals reproduce to the same amount/not all offspring survive – *Fitness effects and competition*
- Natural selection is one of the processes that determines whether individuals with certain traits produce more offspring than do individuals without those traits

- Heritable selected traits will increase in frequency in the population from one generation to the next, causing evolution – a change in the genetic characteristics of a population over time
- Evolution is a change in allele frequencies in a population over time

Industrial Melanism

- Black and white moths – influenced by one gene, colour varies because of differences in their genotype
    - A2A2 – black, A2A1 – black, A1A1 – white
    - Birds can spot the dark ones more frequently and eat them
    - At the start there are equal frequencies of A1 allele and A2 allele but there are more blacks (A2) because it is the dominant gene
    - But since the birds are able to see the black moth, an increased frequency of the white allele can be seen because they are able to survive and pass their genes on to their offspring

Antibiotic Resistance

- Bacterium that causes TB – sanitation, nutrition and antibiotics such as rifampin (known as rofact in Canada) greatly reduced deaths due to TB but then in the late 1950's TB began to rise again
- DNA from the rifampin-resistant bacteria was found to have a single point mutation in a gene called *rpoB* that encodes a component of the RNA polymerase which worked by interfering with the transcription
    - The mutation prevented the rifampin from binding
    - However under normal conditions, mutant forms of RNA polymerase do not work as well as the normal form (grew slower)
    - Since the ones that are susceptible to antibiotics die off, the ones that are immune although they are slow growing, can multiply because they are the only ones that survive, killing the patient

Darwin's Finches

- Beak form and body size are heritable in Galapagos finches
- A major drought led to 84% of the ground finches dying of starvation
- Natural selection resulting from this "natural experiment" led to an increase in the finch population's average beak depth
- After the drought – the depth size of the beak increased to find the water
- Another change in the population's characteristics occurred as a result of seven months of rain during which the small individuals with the small, pointed beaks had exceptionally high reproductive success
- Lower *Bmp4* expression – dark spots hybridize – the more dark area, the more the gene is expressed and the more the gene is expressed, the larger the beak
- They artificially manipulated the amount of *Bmp4* in chickens , normal expression of this gene causes a shallow beak, adding more of the expression caused a deeper beak
    - Did the researches demonstrate that *Bmp4* was not present in finches before the drought but present after the drought?
        - No – it was present before and after because it is a gene, but potentially the "expression" of this gene changed after the drought

    - Did the researches demonstrate that expression of *Bmp4* was lower in finches before the drought and higher in finches after the drought?
        - No – they did not
    - Did the researches demonstrate that there was a phylogenetic pattern to *Bmp4* expression that corresponded with beak morphology and that they could experimentally mimic this morphology in chickens?
        - Yes

What did the researches actually do?

- Get permits to kill finches, kill baby finches and perform in-situ hybridizations
- Make a transgenic chicken that ectopically expressed more *Bp4* than usual; kill transgenic chicks and normal chicks and compare in situ hybridizations
- Prior knowledge – "candidate gene approach"

Candidate Gene Approach Example

- Light colour substrate (soil) – light coloured mice, dark colour substrate (soil) - dark coloured mice
- *Agouti* gene knockouts results in dark coat colour, over expression of this gene causes light coat colour
- Sequencing of alleles in the wild populations found that a single amino acid deletion present at high frequency in the light coloured individuals from the sandy habitat but not the dark coloured individuals from the darker habitat
- Are light and dark mice examples of "incipient species"?
    - No
- Natural selection at work – favouring the light mice on the light soil and the dark mice on the dark soil
- Same as melanin – darker skin in areas with more exposure to light

<u>Unintended Artificial Selection</u>

- Undesirable evolutionary responses to predation by humans
- Which animals die in ecosystems without human predation?
    - The weak, the young, the old – animal on animal predation
- Which animals die in ecosystems with human predation
    - Everything that falls into the nets (for fishing)

- Evolution by natural selection is **not** goal directed, adaptations do not occur because organisms want or need them
- Evolution is also **not** progressive, meaning producing "better" or more complex organisms, there is no such thing as "higher" or "lower"
    - we're all related from the same ancestry
- Evolution doesn't increased complexity
- Individuals with "self-sacrificing" alleles die and do not produce offspring
- Individuals with "selfish" alleles survive and produce offspring
- As a result, selfish alleles increase in frequency while self-sacrificing alleles decrease
- Exception - *Kin Selection* – "I would lay down my life for two brothers or eight cousins"
- Adaptation is not a perfect process since not all traits are adaptive and the adaptations that organisms have are constrained in a variety of important ways

Genetic Constraints/Pleiotropy

- Selection is not able to optimize all aspects of a trait due to certain genetic constraints
- *Genetic Correlation* – occurs when selection favouring alleles for one trait causes a correlated but suboptimal change in an allele for another trait
- Selection also can only act on available variation, so the level of molecular variation is also a constraint for adaptation

Historical Constraints

- Present variation biases future possibilities

Formal Constraints

- Evolution needs to work within the laws of physics

Time Constraints

- Evolution occurs by mutation and it takes time for a series of useful mutations to occur

Fitness Trade-Offs

- A compromise between traits, in terms of how those traits are adapted for the environment – ie, change in the pelvis size, especially in women, to make way for the larger head of their offspring, as opposed to apes/chimpanzees
- Because selection acts on many traits at once, an adaptation may become a compromise

CHAPTER 25: Evolutionary Processes

- *The Hardy-Weinberg Principle* – a null hypothesis that projects what genotype frequencies should be given through known allele frequencies
- five assumptions/conditions are met with respect to the gene in question:
  1. *no natural selection* – it produces adaptations by causing increases or decreases in the frequency of certain alleles
  2. *no genetic drift* - it causes allele frequencies to change randomly
  3. *no gene flow (migration)* – it introduces new alleles and change frequencies between populations
  4. *no mutations* – it introduces new alleles
  5. *no biased mating* – inbreeding and sexual selection change frequencies
- HWE was devised as a mathematical model to analyze allele frequencies
- To do this they imagined that all of the gametes produced in each generation go into a single group called a gene pool and then combine
- Their calculations predict the genotypes of the offspring that the population would produce as well as the frequency of each genotype

HWE (Hardy-Weinberg Equilibrium) – Marbles Example

- Only two alleles – A1 and A2
- The frequency of A1 is represented by *p* and the frequency of A2 is represented by *q* because there are only two alleles – $p + q = 1$
- In this situation three genotypes are possible – A1A1, A1A2, A2A2
- A1 – $p = 0.7$ and A2 – $q = 0.3$
- A1A1 – homozygous A1
  - 0.7 x 0.7 = 0.49
  - $P \times P = p^2$
- A2A2 – homozygous A2

    - 0.3 x 0.3 = 0.09
    - *Q x Q = q^2*
- A1A2 (A2A1 also counts, but it produces the same genotype) - heterozygous
    - 0.7 x 0.3 = 0.21
    - *P x Q = PQ*
    - 0.3 x 0.7 = 0.21
    - *Q x P = QP*
    - 0.21 + 0.21 = 0.42
    - *PQ + QP = 2 PQ*
- ***P^2 + 2 PQ + Q^2 = 1***
- These are the genotype frequencies only if the population is in HWE

Population not in HWE

- A1A1 – 46.7%, A1A2 – 26.7%, A2A2 – 26.7%
- P = p^2 + pq = 0.467 + (0.5)*0.267 = 0.60
- Since the population is not in HWE you *cannot* assume that p = sqr root of (p^2)
- If the population is in HWE then you *can* assume that p = sqr root of (p^2)

HWE

- In a population at HWE, the frequency of A1A1 will be *P^2*, the frequency of A1A2 will be *2PQ* and the frequency of A2A2 will be *Q^2*
- The sum of the three frequencies must equal 1 (100% of the population) < regardless of if it is in HWE or not
- *P^2 + 2 PQ + Q^2 = 1* < ONLY for populations in HWE
- If the frequencies of A1 and A2 are *p* and *q* then the equation is valid generation to generation
- When alleles are transmitted according to the rules of Mendel inheritance the frequencies do not change
- ^ Two Statements of HWE

Examples

1) Are the MN Blood Types in Humans in HWE?

- Estimate genotype frequencies by observation, calculated allele frequencies from this observation, use the observation frequencies to calculated expected genotypes assuming HWE and compare those to the observed values
- It does follow HWE, those 5 things (selection, drift, migration, mutation, and biased mating) don't affect the genotype frequencies, YAY?!?

2) HLA (Human Leukocyte Antigen) Complex – on chromosome 6, they bind to antigens (foreign proteins) and provide a target for the immune system to attack said foreign particles

- Males wearing shirts for a few days, asked females to smell their t-shirts then rate them, compare the preferences to HLA genotypes
- Women on oral contraceptives preferred men with different genotypes (would cause heterozygous youngins)
- Women not on oral contraceptives preferred men with the same genotypes (would cause homogenous youngins)
- Couple with the same genotype – not able to get pregnant as fast
- Couple with different genotypes – able to get pregnant faster

- Experimenters researched genotypes of 125 Havasupai tribe members, do people with the same genotype produce with each other more often or different genotypes? Do the heterozygous youngins have a better chance of surviving?
- There are too many heterozygous/too few homozygous because this is the benefit – so natural selection or biased mating has been at work since being heterozygous is an advantage (higher fitness)

- *Heterozygote Advantage* – pattern of natural selection in which heterozygous individuals have higher fitness than homozygous individuals
    - Helps maintain genetic variation in populations and could explain the excess of heterozygotes observed at the HLA locus of humans
    - Alleles in a heterozygote must be "co-dominant" in that they have a phenotype that differs from either homozygote – ex – sickle cell anemia

- *Directional selection* – changes the average value of a trait
    - sometimes it is when an extreme phenotype is favoured by natural selection as in the following example
- Cold episode in population of swallows - in the original population the average body size was smaller than then surviving body size, directional selection caused the average body size to increase
    - Directional selection doesn't have to happen in one direction, smaller body sized swallows could be favoured again later down the line

- *Stabilizing selection* – reduces the amount of variation in a trait
- The low fitness areas are reduced – there is a reduction in variation, less phenotype variation, more individuals have the same average phenotype
- In humans this can be seen in the birth weight of human babies, the levels of mortality is much higher at the extremes (a very small or very large baby) but the babies born in the average weight survive the most

- *Disruptive selection* – increases the amount of variation in a trait
- The high fitness areas *are* the extremes, so they are increased and the average in the middle is actually the low fitness and decreases
- Example - only juvenile black-bellied seed crackers that had either very long or very short beaks survived long enough to breed, ones with middle beaks couldn't survive

Frequency Dependent Selection

- *Negative frequency dependent selection* – fitness is highest in rare phenotypes
    - The California kingsnakes – the rare colour patterns are the most fit because they cannot be spotted by predators, until they become more frequent, then they are hunted, but then another rare pattern is able to survive, making them the rare pattern and so on
- *Positive frequency dependent selection* – fitness is highest in common phenotypes
    - Poisonous frogs – they have really bright colours (bright blues, yellows) used as a warning signal to predators, if you're not the bright colour then you will be eaten because the predators haven't been alerted that you are poisonous and not to eat you, the common "bright colour" phenotype has the highest fitness

Allelic diversity can increase or decrease diversity, but it usually decreases diversity

Genetic Drift

- *Genetic drift* – is any change in allele frequencies in a population due to chance
- It causes allele frequencies to drift up and down randomly over time, *independent* of natural selection
- Is unbiased with respect to fitness because these changes in allele frequency are not adaptive
- It can lead to the random loss or fixation of alleles, decreasing genetic variation in a population
- If the frequency of the allele increases, the genetic variation decreases
- The effect is much stronger in small populations than large populations
    - Given enough time however genetic drift can be an important factor on large populations
- *Fixation* – all will have it
- *Extinction* – none will have it
- Example – bristle shape (normal vs forked) in fruit fly population
    - 29 had only forked, 26 had both, 41 had only forked after 16 generations
    - Genetic drift caused extinction of alleles within many populations – 70 of the 96 populations lost one of the alleles
    - Eventually all of the populations would have only one allele until mutation created a new one
    - In this study the flies were all kept separate – reproductively isolated because allowing them to mix would have slowed genetic drift
- Genetic drift is a great concern because the small populations found on nature reserves and in zoos are susceptible to it
- Example – Javan rhino (3 types) – the Indian rhino went extinct in the 20's, the Vietnamese rhino only had 12 but a poacher shot the last one in 2010, the Ujung Kulon NP rhinos are the only ones left and there is less than 40 remaining
- Genetic drift can be caused by any event or process that involves sampling error:
    - *Founder effects* – a continental population that has three alleles, but the island population only has two alleles, the colonizing population on the island didn't match the source population so you lose one of the alleles
    - *Bottleneck effects* – a "bottleneck" occurs to decrease the number of alleles, you start with 6 (3 different variations) but then the bottleneck decreased it to 3 and only 2 of the different variations survived and then when it increases back to 6 over time you will only have 2 of the 3 original variations remaining
        - Affected by the *severity* of the bottle neck (the amount of decrease) and the *duration* of the bottle neck (how long it lasts)

Gene Flow (Migration)

- The movement of alleles from one population to another, occurs whenever individuals leave one population, join another, and breed
- Gene flow tends to homogenize gene frequencies between the source and recipient populations
- Gene flow is random with respect to fitness, but movement of alleles between populations always tends to reduce the genetic differences between them
- Gene flow is going to mix up the alleles between two locations
    - Location one has red, white blue and location two has red, white, yellow

    - Both locations end up with red, white, blue, and yellow
    - This is dependent on the amount of movement, for example if there is very few migrants then the yellow might not move

Human Example

- Different parts of the genome have different modes of inheritance
    - Mitochondrial DNA – only passed on by females because it is carried in the ovum, the percentage of inheritance is 100% from the mother
    - Autosomal DNA – passed on by males and females, 50% inheritance from mom, 50% inheritance from dad
    - X chromosome DNA – 67% in females, 33% in males
    - Y chromosome DNA – 100% in males, 0% in females
- The nature of gene flow between Africa and American people is suggestive of biased mate pairing
- Slave trade brought men and women from Africa to the Americas, these people admixed with other races in the Americas – what was the nature of the mate pairing among these groups?
- Actual proportions suggest bias in mate pairing – most of the pairings occurred between the European white men and the African women

Biased Mating – inbreeding and sexual selection (violate HWE)

Inbreeding

- *Inbreeding* – increases the frequency of homozygotes which reduces the number of heterozygotes and leads to a decrease in fitness
- *Inbreeding* doesn't change allele frequencies, but changes the genotype frequencies
- *Inbreeding depression* does change allele frequencies because homozygous deleterious recessives are more common in inbred individuals and because the beneficial heterozygous genotypes are less common in the inbred individuals
- *Inbreeding depression* – decline in average fitness that occurs when the number of homozygous individuals increases and the number of heterozygous individuals decreases
    - This is caused by the fact that many deleterious mutations are recessive and the fact that at some loci there is an advantage to being heterozygous
- Flower Example – individuals produced between unrelated parents have high fitness whereas individuals produced by self-fertilization have low fitness
- Human Example – the mortality rate of children increases when the children are the result of first cousins as opposed to unrelated individuals

Sexual Selection

- *Sexual Selection* – occurs when individuals within a population differ in their ability to attract mates, favours individuals with heritable traits that enhance their ability to obtain mates
- *Fundamental Symmetry of Sex* – in most species females usually invest more into their offspring than the males and therefore the females should be choosy about their mates while the males compete with each other for mates

SS - Honest Advertising

- Example – beak colour in zebra finches is influenced by nutrition, scientists gave some birds better nutrition and then gave females the choice to pick a male; the females could pick out the

male birds in the experiment that had been given the better diet – females can sense which males will have better genetics/better fitness
- Human Example – all primates except the humans have a baculum (bone in penis), from an evolutionary perspective this could be to provide females an opportunity to detect if a male is a good mate or not – if a guy cannot get an erection (erectile dysfunction) he is not a good mate since erectile dysfunction is typically a sign of poor health, stress, and mental illness

SS – Resource Contribution/Nuptial Gift

- Sexual cannibalism - Female praying mantis eat the male after copulating, the male provides nutritional benefits to the female and her eggs
- Male-Male Competition – male elephant seals fight to establish territories, the women in those territories are for the males who own the territories
    - This becomes very intense because about 60% of females don't reproduce but the other 40 have 1-10 pups and over 80% of males don't reproduce but those that do have tons of pups (41-50 or 81-100)

SS – Sensory Exploitation/Sensory Bias

- Females have some kind of innate bias to a certain phenotype, even if that phenotype doesn't exist in their species
- Example – females in one species of spider prefer male spiders with furry legs even though their species of spider doesn't have males with furry legs

Consequences of SS

- Sexually selected traits often differ sharply between the sexes
- *Sexual Dimorphism* – refers to any trait that differs between males and females of the same species
- Violates the assumptions of the HWE by causing certain alleles to increase/decrease in frequency resulting in evolutionary change

CHAPTER 26 – SPECIATION

- *Speciation* – genetic divergence leads to this, the creation of a new species
- Occurs when populations of the same species become genetically isolated due to lack of gene flow, causing divergence
- *Divergence* – of populations/species is a consequence of natural selection/genetic drift/mutation/biased mating
- Populations can be recognized as *distinct species* if:
    - they are reproductively isolated from each other
    - they have distinct morphological characteristics
    - they form independent branches on a phylogenetic tree
- Populations can become genetically isolated from each other if:
    - They occupy different geographical areas
    - They use different habitats within the same area
    - One population is polyploid and cannot breed with the other
- Populations that have diverged can come back into contact, with several outcomes possible, such as:
    - Reinforcement through pre and post zygotic isolation
    - Development of hybrid zones

    - Speciation by hybridization
    - Fusion
    - One population goes extinct
- How are species defined and identified? Using the biological species concept (BSC), the morphospecies concept (MSC), or the phylogenetic species concept (PSC)

Biological Species Concept

- *BSC* – assigns individuals to the same species if they actually or potentially interbreed
- Considers populations to be evolutionarily independent if they are reproductively isolated from each other (don't interbreed) and therefore no gene flow occurs between them
- Problem – difficult to apply to natural systems, (who is really sleeping with who?)
- *Prezygotic Isolation* – occurs when individuals of different species are prevented from mating
    - Example – different shaped genitals prevent you from mating with other populations, only the ones that you are made to fit with
    - Causes of lack of interbreeding:
        - Temporal – they breed at different times
        - Habitat – they breed in different habitats
        - Behavioural – the courtship displays are different
        - Gametic Barrier – egg and sperm are incompatible
        - Mechanical – male and female genitalia are incompatible (example above)
- *Postzygotic Isolation* – occurs when individuals from different populations mate, but the hybrid offspring have low fitness, don't survive, or are sterile
    - Example – male lion + female tiger = male liger is sterile but female ligers aren't

Morphospecies Concept

- *MSC* – species are distinguished by differences in size, shape, or other morphological features, from the idea that distinguishing features are most likely to arise if evolutionary lineages do not have gene flow

- Non random mating – inbreeding and sexual selection
- Sexual selection – honest advertising (finches with better nutrition), resource contribution/nuptial gift (territory-seals, nutrition-preying mantis), or sensory exploitation/sensory bias (preference for a random characteristic unrelated to fitness)

Phylogenetic Species Concept

- *Monophyletic Group (Clade)* – a group that contains all of the descendents of the most recent common ancestor
    - Ex – Ling and Lisa isn't one, because it doesn't include Maggie, all of them have the common ancestor Jackie
- PSC defines a species as the smallest monophyletic group on a tree that compares populations, each clade is a phylogenetic species
- PSC is based on reconstructing evolutionary history of populations
- A drawback is the over diagnosing of species
- Example – six different sub-species/populations of sparrows, one of the types of sparrows started to go extinct so they crossed them with one of the other type. Afterwards, they determined that two of the subspecies formed two monophyletic groups when DNA sequences

were compared – nearly identical – and had they known this, they should've crossed them with the group they were nearly genetically identical to

Consequences with all of the concepts:
BSC – hard to demonstrate, some species are capable of producing hybrids, a-sexual organisms
MSC – subjective, how much morphological divergence represents species-level as opposed to population level differences
PCS – overdiagnosis, are all monophyletic groups really species

Allopatric Speciation

- Genetic isolation happens when populations become physically separated
- *Allotropy* – refers to populations or species that live in different places
- Physical isolation occurs by *dispersal* or *vicariance*
    - *Dispersal* – occurs when species moves to a different location, reproduces, and eventually speciates due to drift/selection/mutation/biased mating
    - *Vicariance* – occurs when a species is wide-spread and then some sort of barrier appears after the population is already wide-spread causing different species to be formed
- difference between dispersal and vicariance is the *age of the barrier* to gene flow compared to the *time of speciation*
    - age of barrier in dispersal is much older than species
    - age of barrier in vicariance is about the same age as the species
- Example – vicariance events during the last ice age, glaciers served as physical barriers, thought to be responsible for the origin of modern species
    - Gondwana was a super-continent and as it split all the different birds got separated, forming new species of birds from their common ancestor
- Example – rhinophrynidae (frog that burrows underground), pipidae (uterus on back – the babies pop out of the back of the female frog)
    - These two frogs live in different areas of the world, rhino – in texas, pip (has four variations) – in Brazil/Africa, they had a common ancestor but due to plate tectonics and the occurrence of the currents they got spread around

Sympatric Speciation

- Sympatric populations can undergo natural selections under certain circumstances by overcoming gene flow
- Soapberry bugs use their beaks to reach seed inside fruit, they began to feed on not-typical food, the bugs on the non-native plants had short beaks (for the non-native short plants) and the bugs on native plants had long beaks (for the native big plants)
    - In-breeding would be bad because it would cause middle sized beaks which would be inefficient

Polyploidization Speciation

- *Autopolyploids* – produced by spontaneous genome duplication with a species
- *Allopolyploids* – result from genome duplication in association with hybridization of two different species
- Example – maidenhair ferms include diploid (2n) and tetraploid (4n) populations – tetraploids are the offspring of a parent that produced diploid gametes and then self-fertilized; tetraploids can breed with other tetraploids but not diploids

    - Allopolyploidy may occur after two species hybridize, tetraploid species are generated and these can undergo polyploidization to generate "octoploid" species and so on
    - Two different species – has one big chromosome from each species and one little chromosome from each species (assuming each parent has two bigs and two littles)
        - This gamete is a diploid gamete, if two diploid individuals breed, they form a tetraploid gamete
        - Tetraploids tend to be genetically isolated because they produce diploid gametes
        - Triploids just form a bunch of messy gametes – mixtures of everything and usually inviable offspring because of all the assortments
- Example – African frogs – diverged into two separate 18 chromosome species, then fused back together, then went back and split into two separate 36 chromosomes (tetraploid), and then fused together to create an octoploid with 72 chromosomes
    - Searching for the ancestors of these polyploidy frogs by searching the common natural habitats for clues – rain forests in Africa areas
    - Dr. Evans is still searching for the lost ancestors, he keeps finding octoploid new species, not the ancestors ☹

Isolated Populations Coming into Contact

- When prezygotic isolation doesn't exist – populations may interbreed to produce hybrids
- Gene flow then occurs and may erase distinctions between the two populations
- Other possible outcomes are reinforcement development of hybrid zones, and speciation by hybridization

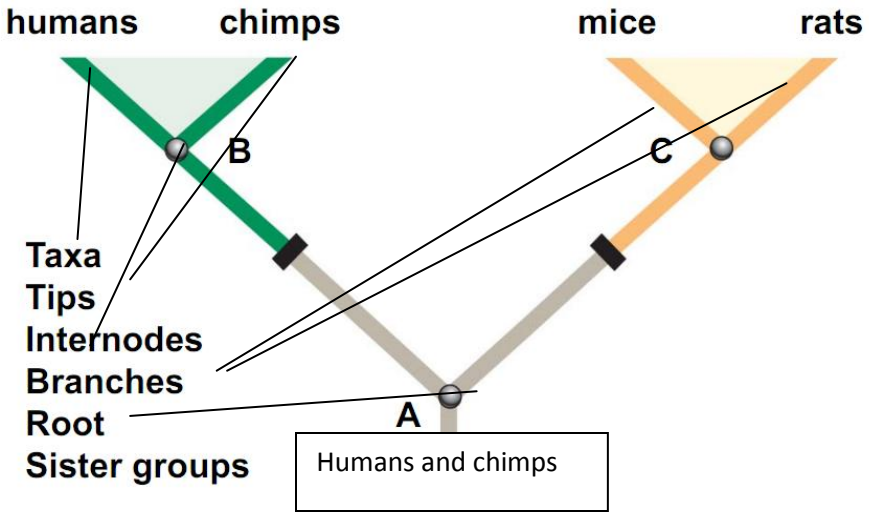
Reinforcement

- *Postzygotic Isolation* – two populations of related species diverge extensively and are genetically distinct, their hybrid offspring may have low fitness and will not develop/reproduce normally
    - When this occurs there is strong natural selection against interbreeding
- *Reinforcement* – selection for traits that isolate populations reproductively
- Sympatric species (living in same area) are seldom willing to mate with one another
    - Different mating calls to prevent hybridization
- Allopatric species (living in different areas) are often willing to mate with one another
    - Have the same mating call because they live in different areas so its okay
- Hybrid offspring sometimes can be healthy and be capable of breeding with each other and/or the parental species
- *Hybrid zone* – geographic area where interbreeding between two populations occur and hybrid offspring are common
- Hybrid zone size and shape depend on the extent over which parent species breed and hybrid fitness
- Shaping of hybrid zone depends on multiple factors – low gene flow vs high gene flow, they can move (geographically)
    - Geographic example – two types of warblers – there is an area of hybridization which is the area between the two types, at the top of the North its only the one type of DNA, in the middle there is mixtures – they look like one but have the DNA of the other (or vice versa), and at the bottom of the South its only the other type of DNA
        - The strange middle zone suggests that the hybrid zone used to be higher up and has now moved lower

- Hybrids themselves can speciate
    - Example – red wolves have the mitochondrial DNA (mtDNA) that is either derived from gray wolf or coyotes – red wolves could be either of hybrid origin or independent origin followed by extensive hybridization and mtDNA introgression
- Example – three species of sunflower, the anomalus one that lives in the desert hypothetically is a hybrid of the other two
    - So they crossed the other two to see what would happen and they found that yes, the two sunflowers seemed to prove that the anomalus was the hybrid and had selected the best part of the genomes of the original two for adapting to the harsh desert environment
- Consequences of hybridization:
    - Fusion of populations – freely interbreed
    - Reinforcement – hybrid offspring have low fitness
    - Hybrid zone formation – well-defined geographic area where hybridization occurs
    - Extinction of one population – one is a better competitor than the other, driving the other to extinction
    - Creation of new species – the combination of genes in the hybrid offspring allows for them to occupy distinct habitats/use novel resources and form a new species

Phylogenetic Trees

- *Phylogeny* – the evolutionary history of a group of organisms
- *Phylogenetic tree* – shows ancestor—descendant relationships among populations or species and may be interpreted as depicting the evolutionary history for the group
- *Monophyletic group* – set of individuals that contains all descendants of their most recent common ancestry
- *Adaptive radiations* – instances of rapid diversification associated with new ecological opportunities and/or new morphological innovations
- *Parts of Phylogenetic Tree*
    - Taxa – different units (what you're studying)
    - Tips – end of the trees, can be living or extinct
    - Nodes – dots that represent ancestral species or taxa that are forecasted that occurred previously in time
    - Branches – in between nodes (internal) or node to tip (external)
    - Root – indicates where the oldest part of the tree is
    - Sister groups – related tips (closest relative of taxa)
- Example – three types of mammals – monotremes (lay eggs), marsupials (like kangaroos), placentals (incubate babies) – loss of shelled eggs and nipples occurred on the branch after the monotremes broke off to form the marsupials, and the evolution of the placenta occurred on the branch after the marsupials broke off to form the placentals
- Researchers analyze characteristics of species (genetic, morphological, behavioural etc) to infer phylogenetic relationships among species
- There are four general strategies for using data to estimate trees:
    - Phonetic (distance), cladistic (maximum parsimony), maximum likelihood, Bayesian



- *Phenetic Approach* – based on computing a statistic that summarizes the overall similarity among taxa; a computer program then compares the statistics for different populations and builds a tree that clusters the most similar populations together
    - Data -> Distance Matrix -> Phylogeny

- *Maximum Parsimony* – attempts to minimize the number of changes on a tree that are needed to explain the observed data
    - Data -> consider trait evolution on many phylogenies -> select the phylogeny with the least amount of changes
    - Focuses on s*ynapormorphies* – the shared derived characters of the species under study; a trait that certain groups of organisms have that exists in no others (ex – nipples, lactation)
    - Ancestral sequence – AAA GCT ACT, splits into 1) AA**C** GCT ACT and 2) AAA G**G**T ACT
        - The presence of "C" in 1) is a synapormorphy – the clades that follow share this derived trait
        - The prescence of "G" in 2) is a synapormorphy – the clades that follow share this derived trait
- *Homology* – occurs when traits are similar due to shared ancestry
    - Example – forearm of human and forearm of bird came from a common ancestor
    - Example – "Hox" genes – even fruit flies and humans have a very similar Hox genes, they are useful for saying "where do your eyes go, where do your antennas go on the body (for the fetus), etc" – this suggests that a common ancestor had Hox genes so everyone inherited it
    - How do we know they're homologous? (as opposed to homoplasy)
        - Similar DNA sequence (homeobox domain)
        - Similar genomic organization
        - Similar expression patterns during development
        - Similar function
- *Homoplasy* - occurs when traits are similar for reasons other than common ancestry
    - Example – bird wing and bat wing came about differently
- *Convergent Evolution* - occurs when natural selection favours similar solutions to the other problems posed by similar ways of line
    - Example – dolphin and ichthyosaur – despite being similar (streamlined bodies, long jaws, fins, flippers) and in the water, ichthyosaur is actually more related to a lizard than dolphin, and dolphins are more related to rodents then ichthyosaur

        - Their ancestors didn't have these traits, they evolved these independently at the end of their trees
    - Example – the structures that support insect wings are not the same as bird wings or bat wings
    - Example – phylogeny of vertebrate animals, we evolved from a water ancestor, then we move back onto land, gained limbs, birds evolved, and then some went back into water (dolphins/whales) who would've lost the terrestrial advantages but re-gained the water ones
    - Ancestral sequence – AAA GCT ACT, splits into 1) AA**C** GCT ACT and 2) AAA G**G**T ACT
        - Mutations could occur that actually reverse these, of the two clades off of number 2), one created AAA GCT ACT (reversal mutation) this obscures the evolutionary history
- *Maximum Parsimony* – an assumption that the most likely explanation or pattern is the one that implies the least amount of change
    - For the DNA sequence above – two sequence changes occurred, however you could write another tree with four changes (C – G – C – G) instead of just (C and G) the one with four isn't as parsimonic

The Whale Evolution

- Whales were typically placed sister to all the other artiodactyls, but only sister because it lacked an astragalus (particular ankle bone)
    - Due to the stuff below though now they are in the astragalus group because of the DNA proof, except they are a branch off the "whippo" ancestor on the "loss of astragalus" branch
- Molecular data however suggests that whales are more related to hippos (the "whippo" ancestor)
- Short Interspersed Nuclear Elements (SINEs) showed that whales and hippos share several SINE genes that were absent in all other artiodactyls (even numbered toes)
- "Whippo" is further supported by the contention that homoplasy in SINEs is very rare compared to morphology and fossil evidence
- This phylogeny (with the new position of the whales) is less parsimonious than the previous one with respect to astragalus evolution, but when you consider all of the data in general it is more parsimonious

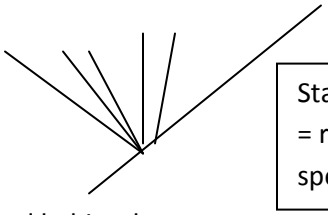
Cryptic Species

- Many species are not easily distinguished by morphology
- Animal and plant parts also are sometimes not easily identified
- Most diverse parts of the world are also the least known
- DNA Barcoding
    - Creating a database by looking at the same gene in all different species
    - Based on NA sequence of one gene in animals and an internal ribosomal RNA gene for plants
    - Useful for assessment of biodiversity, wildlife forensics, tracking food, importing and exporting, endangered species, species discovery, species identification, identification of cryptic species, disease outbreaks

- Criticisms – oversimplification of the science of taxonomy, many not distinguish recently diverged species, many not identify hybrid species, could draw funding away from traditional taxonomy
- Current dogma is that barcoding should contribute to enhance traditional taxonomy
- Goals – create an inventory of biodiversity and automate and expedite species identification

Adaptive Radiations

- *Adaptive radiations* – instances of rapid diversification of a lineage accompanies by ecological diversification
- Can be triggered by ecological opportunity and morphological innovation
- May include high diversity of species, spectacular divergence or specialization, or both
- *Adaptive radiation* – "the differentiation of a single ancestor into an array of species that inhabit a variety of environments that differ in traits use to exploit those environments"
- Criteria to detect adaptive radiation:
  - Common ancestry
  - Phenotype – environment correlation
  - Trait utility
  - Rapid speciation
- Single ancestor then disperses, changing with adaptations for the environment
- Example – single ancestor of finches then dispersed to island, and it diversified into different species because of the different environments they explored (different food resources – different beak sizes)
- Example – lots of branches come from one branch, rapid speciation
- Example – Hawaiian honeycreepers - specialized to eat insects, nectar, or seeds. Differ based on their beak sizes, about 20 species recently have gone extinct due to introduction of rodents and habitat lost



Star Phylogeny = rapid speciation

- Example - Hawaiian silverswords – specialized to different habitats such as rainforests and lava flows
- Example – cichlid fish – cichlids are a family of teleost fishes that include about 3000 species, about 10% of extant teleost diversity
  - Adaptations for feeding variation in social behaviour, size, and morphology
  - Cichlid dishes have a functionally decoupled set of jaws – oral and pharyngeal
  - Frees up jaws to independently to specialize in food collection and processing
  - Exploit new niches
- One of the most consistent triggers of adaptive radiations is ecological opportunity, meaning availability of new types of resrouces
- Example – biologists have documented adaptive radiations of the *anolis* lizards of the Caribbean islands – experiments of natural selection have resulted in similar phenotypical endpoints
  - Species of *anolis* vary in leg length and tail length, some species are ground dwelling whereas others live in distinct regions of shrubs or trees
  - the same adaptive radiation of *anolis* has occurred on different islands, starting from different types of colonists
  - Hispaniola – colonization of island by lizard living on trunks and crowns – however twig, crown, trunk/crown, and trunk/ground lizards all formed from this common ancestor

    - Jamaica – colonization of island by lizard living on twigs – however twig, crown, trunk/crown, and trunk/ground lizards all formed from this common ancestor
    - Both of these happened independently and repeatedly on the large islands of the Carribbean
- The larger an island is, the more species that will be on it (more diversity)

Example – Fanged Frogs

- Did they "adaptively radiate" on Sulawesi?
    - Because the Philippians is larger than Sulawesi, you'd expect more species diversity in the Philippians
        - True - Frog species diversity in the Philippines is higher than Sulawesi for most groups – for example *Platymantis* are found only on Philippines, however the exception is *Limnonectes* – there is equal diversity on Philippines and Sulawesi
- *Platymantis* – it doesn't reproduce in the traditional way, they don't require water, they mate, fertilize egg, the eggs are laid terrestrially, and the mother or father will guard the eggs, the eggs undergo tadpole development, then come out as baby froggies – direct development (adaptation for life on land)
- *Limnonectes* – in Sulawesi there is extraordinary variation of fanged frogs, suggestive of "ecotypes"
    - *Large ones* – very big, lots of webbing, in fast moving water
    - *Medium ones* – not as much webbing
    - *Small ones* – live away from the water – they have the same ecological adaption as *platymantis* – they lay eggs on land and one of the individuals guards the eggs so the tadpoles can undergo tadpole development
- Unrelated but cool - there is also another frog that does internal fertilization – fertilizing inside the female instead of the eggs coming out and being fertilized (again on Sulawesi)
- Different ecotypes are sympatric in different parts of Sulawesi
    - All three types are found everywhere except the south – only the small and large are found there
- There is very strong evidence that all of these evolved independently on the different parts of the island – the large are not related to the large, the large are related to the small/medium in the same area (they evolved)
- Comparison to Philippines – multiple sympatric species, variation in modes of reproduction and body size
- On Sulawesi – an ancestor of fanged frogs arrived there and then it diversified into different species (large, medium, small) and then there was an "opening" for a small frog that can reproduce on land (it was already taken by *platymantis* on Philippines) – these two frogs are unrelated but converged, they evolved similarly in the end

Morphological Innovation as a Trigger

- Ecological Opportunity – a niche arises for a species to evolve
- Morphological innovation can also be a trigger
- The evolution of key innovations allows descendents to live in new areas, exploit new food sources, or move in new ways – like insects, flowers, etc.

Extinction

- Mass extinctions are periods with extreme levels of biodiversity loss

- The "background rate" of extinction refers to the level of extinction during periods when mass extinctions are not occurring
- This can be determined by analyzing fossils
- "big five mass extinction events"
- *Background extinctions* – typically occur when normal environmental change, emerging diseases, or competition reduces certain populations to zero
- Mass extinctions – result from extraordinary, sudden, and temporary changes in the environment, they cause extinction randomly with respect to individual's fitness under normal circumstances
- DINOSAURS
    - The impact hypothesis proposes that a meteorite struck Earth 65 million years ago and caused the extinction of an estimated 60-80% of the multicellular species alive
    - Evidence:
        - Giant crater has been found off the coast of Mexico, strong peak of iridium, shocked quartz – all dating to about 65 million years ago
    - Some lineages were better able to withstand the environmental change brought on by the meteorite impact
        - For example, among vertebrates, the dinosaurs, pterosaurs (flying reptiles), and large marine reptiles perished, while the mammals, crocodilians, amphibians, and turtles survived.

6^{th} mass extinction (current extinction)

- Global diversity has undergone a progressive decline over the last 30 000 years
- Current rate of extinction is 100-1000 times faster that background rate
- Most human colonization is associated with environmental degradation
- As of Jan 2010, only 842 extinctions are documented by the IUCN – there are definitely may more than that
- Most extinctions go undocumented
- Ancient extinction – around the time humans reached Australia – giant marsupials died off
- Historical Extinction – dodo bird, hunted to extinction
- Mass Extinction – cichlid fish – extraordinary radiation adaptation, but extinct due to one cause
- Island Fauna Extinction – birds on Hawaii went extinct because of introduction of rodents, also the accidental introduction of a snake into Guam caused all the birds that couldn't fly to become extinct
- Extinction of once abundant fauna – passenger pigeons used to be extremely numerous – they got hunted to extinction and there were TONS, like trainloads
- Disease related Extinction – fungus in amphibians – associated with declining extinction of frogs, golden frog went extinct because of this fungus (it still existed in the 80s/90s)
- Extinction of Biological Phenomena – the great migrations of Buffalo in NA, and of wildebeest in Africa, Buffalo cannot do great migrations anymore because there are a lot less and highways are in the way

CHAPTER 27: PYLOGENIES AND THE HISTORY OF LIFE

Introduction of Nile Perch into Lake Victoria

- Nile perch was introduced from Lake Albert into the Uganda portion of Lake Victoria
- Explosive increase in Nile Perch population was observed in the 80s
- Reaches sexual maturity in 3 years – can produce 16 million eggs

- Voracious predator with a wide diet, can eat other fish (cannibalism)
- Can reach huge sizes – up to 230kg but usually between 3-6
- Introduction of Nile Perch caused the largest mass extinction of contemporary vertebrates
- Within a decade about 200 endemic species of cichlids went extinct in Lake Victoria
- Some species of cichlids ate algae – now algae is growing unchecked, because of this increased amount of algae more plant material settles at the bottom of the lake before decomposing
- Increased decomposition at the bottom of the lake decreases oxygen in the water forcing fish to live on the surface where oxygen is more plentiful, or they go extinct
- It also resulted in 5-fold increase in the amount of fish protein available to local communities and increased income and employment opportunities
- But, unlike indigenous fishes, perch must be dried over a fire, requiring large amounts of wood, deforestation occurred
- After all the cichlids died off, now the perch are smaller and overfished so many of the processing centres have been closed
- Species replacement – loss of cichlids led to expansion of other species with similar ecological roles – left an ecological niche for expansion of the native prawn (since the cichlids eating it were extinct too)
- Nile perch also feeds on the prawn but switched only after the cichlids went extinct

Fossil Record

- *Fossil* – the physical trace left by an organism that lived in the past
- *Fossil record* – the total collection of the fossils that have been found throughout the world; provides the only direct evidence about what organisms that lived in the past looked like, where they lived and when they exists
    - However they provide only a minimum age for groups – it's the least oldest fossil
- Several limitations to fossil record:
    - *Habitat bias* – organisms that live in dry, terrestrial areas are less likely to leave fossils vs swamps
    - *Taxonomic bias* – hard body parts (clams, fish) more likely to leave fossils vs soft bodies
    - *Temporal bias* – more likely to find things closer to the surface – stuff from the most recent eras is easier to find then way farther down
    - *Abundance bias* – something that was abundant at one time leaves more fossils then species with smaller populations
- Fossil record is incomplete and biased but still very informative

Life's Timeline

- Major events in the history of life can be summarized in a timeline broken into four segments – Precabrian Supereon (Hadean Eon, Archaeon Eon, Proterozoic Eon) and the Phanerozoic Eon (Paleozoic Era, Mesozoic Era [age of reptiles], Cenozoic Era [age of mammals])
- Precabrian Supereon:
    - Spans from formation of the Earth to the appearance of most animal groups about 542 million years ago – the first four billion years of the Earth
    - Almost all life was unicellular
    - Oxygen was virtually absent from the atmosphere for the first two billion years after the origin of life
    - Important things that happened – liquid water on Earth, origin of life, first eukaryotic fossils, first photosynthetic eukaryotes, first bilaterally symmetric animals

    - Fossils (such as stromatolites) from this eon are mostly highly metamorphosed and/or affected by erosion or still deeply buried
    - Fossils of bacteria older than 3 and ¾ billion years have been found in Western Australia
    - *Stromatolites*
        - some of the most ancient evident of life on our planet
        - form in shallow water when biofilms of microorganisms trap sediment
        - abundance of these decreased with the diversification of grazers that disrupted stromatolite formation
        - today they only occur in extreme environments
        - formed from microorganisms, especially cyanobacteria, which is also responsible for priming the Earth's atmosphere with oxygen
- Phanerozoic Eon:
    - Many animal groups – including fungi, land plants, and land animals appeared in the Paleozoic era which includes the Cambrian period
    - The paleozoic era ends with a mass extinction that wiped out almost all multicellular life
    - *Paleozoic Era*
        - Comb jellies, arthropods, vertebrates, first amphibians and reptiles
        - Lots of mass extinctions which marked the beginning/ends of periods in this era
    - *Mesozoic Era*
        - Age of reptiles
        - Rise and dominance of the dinosaurs – era ended with the extinction of the dinosaurs except birds
        - Plate tectonics played a huge role in the distribution of the continents and the ocean currents
    - *Cenazoic Era*
        - Age of mammals
        - First primates arose, first apes, and then homo sapiens

<u>The Cambrian Explosion</u>

- First animals – sponges, jellyfish, simple worms, appeared at the end of the Proterozoic Eon
- Until this point (3 billion years) almost all life was unicellular
- In about 50 million years animals had diversified into almost all of the major groups of today
- The lineages that emerged during this explosion had shells, exoskeletons, internal skeletons, legs, heads, muscles, eyes, jaws, brains, etc, etc, etc.
- There were no land plants and no land animals – everything went down in the water
- This is documented by three major fossil assemblages:
    - Doushantuo
        - China, prior to the explosion, showed the beginning of multicellular development
        - Sponges, cyanobacteria, multicellular algae, the first types of animals on earth
    - Ediacaran
        - Australia
        - Sponges, jellyfish, comb jellies, soft bodied animals – no shells, limbs, heads
    - Burgess Shale Faunas
        - BC
        - Virtually every major living animal group is represented in these fossils

        - This diversification filled many of the ecological niches still found in marine habitats today
        - Indicate extreme amount of diversification in a short amount of time
- Protosome – cell division forms pore that becomes mouth (molluscs and such)
- Deuterostome – cell division forms pore that becomes anus (humans and such)
- Asymmetry – no plane of symmetry
- Radial Symmetry – multiple plane of symmetry
- Bilateral Symmetry – single plane of symmetry
- Water Bears – capable of reversibly suspending metabolism, tolerate extremes in temperature, pressure, radiation, dehydration, found everywhere from the Himalayas to Cootes Paradise, these guys evolved in this explosion

Molecular Clocks

- Some nucleotide substitutions may occur at a relatively constant rate over long time periods
- If this is the case, DNA sequence comparisons may be used to estimate the timing of evolutionary divergence
- More closely related species diverge in less time from their common ancestor, so they should be more similar
- There is a correlation between molecular divergence and the actual divergence time of species
- The molecular clock alone can only provide info on the *relative* divergence times of two comparisons
- Example – divergence between humans and chimps is half as large as divergence between humans and orang-utans; this suggests that the first comparison has been diverging for half as long (but how many years is this?)
- To convert divergence in molecules to divergence in time, we need to calibrate the data with data from fossils or geology (one known example)
    - Example – if we know that humans and orang-utans diverged 13 million years ago, then humans chimps would be 6 and a half million years ago
- Problems – fossil record only provides a minimum age for a species and we do not know for sure if a fossil is a direct ancestor or a close relative of the species that branched off
- Geology can also be used to calibrate the molecular clock – plate tectonics, soil things, knowing paths of migration
- Ancient DNA can also be used to calibrate the molecular clock – the ancient DNAs age must be known
- How long ago did humans begin to diversify? – you'd want to survey lots of humans and the divergence between a known species (humans and orang-utans was 13 million years), the total divergence is 26 million years from their common ancestor
- We can also calculate the deepest molecular divergence between humans
- D**HO** / 26 = D**HH**/2x
- Estimated divergence time in extant humans is 125 000 – 161 0000 years ago
- We don't have a fossil of extant humans – but we can use people of today and molecular clocks to estimate this information

Evolutionary Development (Evo-Devo)

- *Modularity* – feature of development that facilitates variation; the adult form is realized via a series of biological events that are in some sense independent of one another

- Example – in a centipede, each segment in its body develops independently of each other, the same goes for ribs
- Demonstrated in the "Antennapedia" mutation
    - Mutation in a Hox gene called *antennapedia* that is normally only expressed in the thoracic segment where it governs leg development, the mutant version is found in cells that normally produce antennae but other aspects of development are comparatively unaffected – the mutated fly is basically normal except for the one mutation

Hox Genes

- *Hox genes* – fundamental regulators of animal development
    - Responsible for defining what each section of the body is and then other genes orchestrate what structures form in that part of the body
    - Example – development of spots on butterflies – the Hox gene doesn't cause the spots directly but triggers the genes that cause the spots
    - Example – a mutation in the Hox gene on flies causes the expression of additional wings instead of halters – the mutation tells the embryo that there are two thoracic segment 2s, instead of one 2 and one 3, causing a second set of wings to develop on the 3rd segment
        - However this isn't the same gene that causes two sets of wings on dragonflies – this is controlled by a different gene
- Occur in groups on one chromosome or a set of chromosome*s*
- Generally in the same order along a chromosome even in taxa that are very diverged
- There is a precise correlation between the order of these genes and the anterior-posterior location of the gene expression in the embryo
- Genes at the 3' end are expressed earlier than those at the 5' end
- Collectively these unique attributes are called temporal, special, and quantitative colinearity and are unique to Hox genes
- *Homeobox* – 180 base pair sequence that encodes a DNA binding domain in each Hox gene
- Hox genes encode proteins that bind to DNA to influence the expression of other genes, they are *transcription factors*
- Homologs are found in sponges/jellyfish/plants too but these species have a different organization and pattern of expression
- Some proteins act as switches whereas others set up gradients that trigger biological events in a continuous fashion; gene expression is also influenced by regions called promoters that also evolve (turning switches on and off)
    - Lightswitch 1 – can be on or off depending on the availability of genes
    - Lightswitch 2 – a gradient, depends on the concentration of the genes
    - Example – snakes don't have the *distal-less* gene which is essential for hind limb development in species with legs – so a species with legs would have it "on" but a snake have the gradient where it doesn't have the proper concentration and doesn't turn on
    - Example of gradient – axis development in fruit flies – different expressions/concentrations of the genes lead to the development of heads and tails as well as different variations (hunchback, nanos, bicoid, etc) – depends on the concentration of genes at the anterior vs posterior positions

Evo-Devo + Genes

- Humans have ~25 000 genes but flies have like ~14 000 genes and we are much more complex than flies so complexity doesn't necessarily relate to the number of genes, it relates to the expression of the genes which can occur in space/developmental time
    - Major differences exist between species because the same genes are expressed in different ways – "Genetic Toolkit"
    - Differences among species rise from how the tools in the toolkit are deployed to change the expression – leads to variation in body plans and parts
    - The basis for morphological appearances is laid down during development

The Embryonic Axes

- During development the vertebrate body plan develops from radial symmetric to almost bilateral symmetric
- Humans have 39 Hox genes organized into 4 clusters – these have major roles in development of CNS, axial skeleton, gastrointestinal, limbs etcetc
- Mutation of these cause developmental defects or lethality
- *"new genes, new bodies" hypothesis* – prediction that a strong association exists between the order in which animal lineages appeared during evolutionary history, the number of Hox genes in each lineage and each lineage's morphological complexity and body size
- Seems to be only in the bilateral section but the sponge/jellyfish have them, but only Hox homologs, the posterior Hox genes developed after the animals separated from the sponges/jellyfish
- The copy number of Hox genes changed through gene duplication and genome duplication

What happens when Genes Duplicate?

- *Nonfunctionalization* – over time the duplicated genes revert back to a single gene after one suffers non-functional protein mutation
- *Redundancy* – the duplicated gene is useless
- *Neofunctionalization* – the two genes become permanently preserved because one develops mutations that allow it to take on a new function
- *Subfunctionalization* – the two genes become permanently preserved because the two genes have lost their original functions through mutations

How does morphological diversification occur in animals?

1. Changes in Hox gene number
2. Broad changes of Hox gene expression
3. Subtle changes within Hox domains
4. Changes in regulation or function of downstream genes

Did Gene Duplication Trigger the Cambrian Explosion?

- The number of Hox cluster genes appears to have expanded in some groups (vertebrates) during the course of evolution but this is not the only cause for morphological diversification – insects are very diverse but have less Hox genes than vertebrates
- Both duplication of Hox genes and changes in expression and function of other genes have been important in the evolution of animal body parts

QUINN

Causation of Behaviour

- *Proximate* – the immediate sequence of physiological effects that lead to the behaviour
    - Ex. – walk to small pond, there are tadpoles in the pond, they start swimming away from the shore by proximately saying that they must have some ability to flip their tail due to sound waves
- *Ultimate* – the adaptive value or evolutionary origins of observed behaviour
    - Ex. – evolution favours those who take evasive action (adaptive value) – if the tadpole didn't swim it wouldn't survive

Basis of Behaviour – environment or genetic? Or both? (nature [genetics] vs nurture [learning environment]) → it is a continuum – we won't be studying epigenetics (studies have shown that females that lick/groom their young a lot, produce offspring that are calm and tend to be good parents as well, those who don't lick/groom their young a lot produce offspring that are tense/stressed and aren't good parents) – DNA is altered by behaviour (turning certain genes on and off)

Genetic Component

Evidence:

1. Deprivation experiments
    a. Prevent learning opportunities through isolation of subject
    b. If you don't give an animal a chance to learn there has to be a genetic component to it
    c. Squirrel burying – taking young squirrels immediately at birth, raising them in an isolation area (can't dig/don't see people digging) – put it into another chamber now with soil when it's older and it will automatically bury the nut
    d. Spiders web spinning – it has no opportunity to learn how to build a web from its parents (they float away immediately after birth) but they know how to build a web
    e. Kangaroo rat – when kangaroo rats are first exposed to rattlesnakes (natural predator) in the dark, they can sense them, and upon the first exposure they jump up and away immediately → you wouldn't want to have to learn to jump away because then you wouldn't survive

These are known as *Fixed Action Patterns*

- Patterns that appears, essentially complete, and is played out to completion once activated by a simple sensory cue
- Signal that the snake gives is the stimulus/cue
- First performed without training
- Stereotyped and predictable
- Sensory cue
    - Sign stimulus – external stimulus that triggers FAP
        - Graylag goose – if you move its egg away from the nest it will use its head to pull the egg back to the nest
    - Releaser – stimulus that signals from one individual to another (of the same species)
        - Red belly of fish, when it isn't breeding it doesn't have a red belly, when it is breeding it develops a bright red belly – it serves as a stimulus, if you present an odd shaped stone with a red belly stimulate anger in males (challenge the rock or flee) and females will be attracted

2. Selection Experiments
    a. Control the environment as much as possible (hold environment constant)
    b. Measure the phenotype of interest
    c. Breed individuals with extreme phenotypes together
    d. Measure phenotype in next generation
    e. Back to C

Rats:

- Made them run through a raze, mated smart (few error) rats with each other and mated not smart (lots of error) rats with each other
- You can cause two separate selection experiments – very bright on one side and very dull on the other side
- There must be genetic involvement
- The mean number of errors is different between the two populations

A change in mean behavioural phenotype in Tryton's selection experiment means that:

a) The hypothesis that there is a genetic component is falsified
b) The hypothesis that there is a learned component is falsified
c) The change is genetically based
d) The proficiency to learn a maze is partly genetic
e) C) and D) are both correct

3. Crossing of genetic strains
    a. Haplodiploidy – sex determined system

<u>Bee Example</u>

Queen bee mates with male, the sperm goes into her spermo-sac that she determines when open/close, if she opens her sac it is a diploid worker (female), if she shuts her sac it will be haploid and turn into a drone (male)

- Non-hygienic bees (UURR) and hygienic bees (uurr)
- Hygienic bees if they sense a dead larvae, they will cut the cell open, they will remove the dead pupa (this is good because if you leave the dead larva it will create a fungus and destroy the hive) → very sophisticated, lots of genes that explain this
- Non-hygienic bees are mutant bees, they won't cut the cell and even if the cell is cut they won't remove the dead pupa → couple changes in DNA that have messed up the behaviours, silly mutants
- Mate non-hygienic and hygienic = heterozygous female (UuRr) – big U and big R are dominant so it will behave like a nonhygienic bee
    - Its gametes are UR, Ur, uR, ur
    - Mate it with a uurr male
    - UuRr – non-hygienic bee
    - Uurr – non-hygienic will not cut the cap (the cell) but if you cut it for it, it will remove the dead larva
    - uuRr – non-hygienic will cut the cap (the cell) but will not remove the dead larva
    - uurr – hygienic
    - 1:1:1:1
    - Basis is genetic on two loci – two different behaviours

4. Molecular Genetics

Example – Mono Amine Oxidase (MOA) mutation

- Enzyme that breaks down neurotransmitters
- Neurotransmitter not broken down normally
- Hyper-aggressive disorder → often end up in jail because they cannot control themselves

Example – forager gene (Marla Sokalowski)

- Fruit flies chilling on yeast, some would go between two patches others would stay on the same patch of yeast
- If you put them on a plate of yeast:
    - Rover – moves around a lot
    - Sitter – chills in the same place
- If you put them on a plate of agar (no food):
    - Rover – moves around a lot
    - Sitter – moves around a lot
- There is a statistically significant difference in the foraging trail length
- "Forager gene" discovered on chromosome 2 (to behave as a rover or a sitter)
    - Known as PKG – increased PKG activity increases path length of larvae
- Homologous genes have been subsequently discovered honey bees (rovers tend to go get food, sitters tend to stay and take care of the hive) and roundworms
- Ant social behaviours – forager ant tends to collect and bring food to the nest (low levels of PKG), guard ants fight (high levels of PKG)
- Increase PKG increases guarding, less PKG increases more foraging

<u>Development of Behaviour</u>

Instinct – "a behaviour pattern that reliably develops in individuals that receive adequate nutrition and that is given in functional form on its first performance"

Learning – "a durable and usually adaptive change in an animal's behaviour traceable to experience by that individual"

Example – Pink Cockatoo

- large parrot-like bird, it nests in burrows, lives nearby this other bird called the Galah which are much smaller than Cockatoos but nest in burrows as well
- These birds will visit the hole, lay an egg, and miss each other for a while but then at some point they will meet and the Cockatoo will drive out the Galah
- However there may be a Galah egg in the Cockatoo eggs
- Great opportunity for nature/nurture

Three types of behaviour can be studied:

- *Begging calls* – begging for food from parents
- *Alarm calls* – given in presence of predator
- *Contact calls* – maintain associations with parent/flock

Example:

- Galah chick raised by pink cockatoos gives the galah begging call, galah alarm call – this makes sense because neither of these need to be learned because they are so important
- However the galah raised by pink cockatoos gives the contact call that is much more similar to the pink cockatoo call than the galah call – therefore it is learned

Types of Learning

- *Habituation* – repeated stimulate without appropriate feedback or unimportant stimulate
    - Young birds may initially respond to the movement of small birds/leaves by hiding but they eventually become habituated to these harmless stimuli and only respond by hiding to the large predator birds
- *Imprinting* – structured learning – critical periods, life–long learning – often involves mating
    - Scientist who incubated eggs/was there when they were hatched and since he was the first one that saw them when they hatched they followed him right away
        - Cannot be learned later in life, only occurs right after hatching
- *Associative Learning* – association of stimulate
    - *Classical conditioning* – Pavlov's dogs
    - *Operant conditioning* – trial and error < one time, ex – biting into poisonous insect
- *Insight Learning* – correct behaviour on first try (by reasoning, not instinct)
    - Many other animals can do that, not just humans
    - Chunk of meat tied to string, hanging from branch, a raven will come along, grab the string with its beak, hold it down with its foot and continue pulling until it reaches the meat < never taught this/no experience with this but it can reason
    - New Caledonia Crow – it will make and use a tool – cut a twig with a crook in it to stick into logs to collect larvae, can also do the same with leaves
- *Play* – physiological/social/cognitive practice – developing skills
    - Form of learning relating to social and physical development

Nature/Nurture is a Continuum

- Example – herring gull – when the parents come back to the nest, the chick pecks at the red part on the beak which is a stimulus for the adult to regurgitate food
    - Fixed action pattern < thought to be unchangeable, but not the case
- Example – relative pecking response of a chick to random stimuli
    - Chicks will predominately peck at a random red pen, a beak-lookalike with a red dot, a blob with a red dot
    - But after five days they will only peck at the beak-lookalike with the red dot, not the red pen or anything else
    - After three weeks they will only peck at their own parents
- Instinctive behaviour changes over time in some cases as these cases involve learning
- To what degree has evolution shaped learning abilities through genetically based neural substrates?

Predisposition for associative learning has been shaped by evolution (genetic constraints)

- Monkeys may have bigger brains than dogs/cats but have more trouble being toilet-trained than dogs/cats
- Rats will learn quickly not to drink sweetened water (they were then exposed to radiation) because it will make them sick
- If you ring a bell then shock a rat, they will quickly learn to jump away from the side that shocks
- But it will take them a long time to learn sweetened water with shock and same with ringing a bell then getting them sick

The nature of the cue and consequences of the response are determine whether the rat can learn quickly to modify behaviour

- Taste -> nausea = makes sense, small samples of new food (omnivorous diets)
- Sound -> pain == makes sense, warning of predators or other rats

Taste associations are easily learned in species that might encounter toxic foods > taste aversion
Most mammals tested learn taste aversion easily

Other Study – John Reynolds, Jeff Galef and colleagues asked if this was related to the risk of encountering toxins in their diets

- Three types of bats – frugivorous (will encounter toxic fruit sometimes), insectivorous (some insects have chemicals that make them toxic to predators), vampire bat (blood is not toxic, should have trouble then learning taste aversion)
- Hypothesis – a neural substrate for rapid learning of taste aversion is not maintained by stabilizing selection in vampire bats
- Prediction – therefore they should not be able to easily learn taste aversion
- Methods – each species was fed food with a novel flavour (cinnamon or citric acid) followed by A) experimental – an injection that made them sick OR B) control – an injection of saline that had no affect
- Later, after recovery of sickened bats, they were tested to see how much of the novel flavoured food they would eat
- Frugivore results – control groups ate everything, but the experimental groups (after being exposed to sickness) will not eat any of the food
- Insectivore – control groups ate everything, but the experimental groups (after being exposed to sickness) will not eat the food
- Vampire results – doesn't matter what you do to them, whether they get sick or not, they ate just as much as the ones who didn't get sick
    - Therefore – vampire bats do not learn taste aversion
    - A neural substrate for rapid learning of taste aversion *is not* maintained by stabilizing selection in vampire bats
    - Rapid learning of taste aversion occurs in other bats and mammals that may experience toxic foods
- Evolution shapes learning

Nobel Prize winners – the founders of ethnology
Niko Tinbergen – setting up landmarks to see if he could trick wasps into looking for their nest elsewhere
Konrad Lorenze – the baby ducks followed him
Karl von Frish – the waggle dance of the bees telling other bees where to find the food

Example – stotting springbok (antelope) – when it discovers a predator it leaps up into the air and straightens its limbs (energetically expensive) < originally was interpreted as altruistic – one who behaves in ways to benefit others at some cost to itself
< turns out it isn't an altruistic at all, it isn't warning the others, it is signally to the lion that the lion cannot touch them because they are in a group and can defend themselves

Example – VC Wynne Edwards – animals will try to assess their population size so that they don't overwhelm their environment – he said that if they found the population to be too big they shouldn't reproduce anymore
All the selfish birds will breed, producing more selfish breeders whereas the altruistic birds won't breed

Without controls or consequences, cheaters will do best.

Example of altruism

1) Birds
   - Sexually mature helper bird helps in various way to help raise the birds alongside the mated mother and mated father
   - They help feed the chicks, they defend the nest, and female helpers will make an alarm call
   - At the cost that they die sometimes
   - Turns out the helpers are a sibling from a previous hatching that stays behind
   - They get some evolutionary benefit from helping their siblings

2) Bees
   - Why does one queen get to do everything and the workers all serve her?
   - Selection acting on families, not individuals

3) Kin Selection
   - Haldane – sacrificing yourself only for more than you're actually worth
   - Behaviours that benefit those who are related to you, and therefore share genes, are helping those helping genes

Hamilton's Rule – an individual should help another when the following inequality is met:
rB > C
r – coefficient of relatedness
B – Darwinian fitness benefit to the recipient
C – Darwinian fitness cost to the donor

Example – what is the *r* between a queen and her daughter?
- Male – one chromosome (haploid), Queen – two chromosomes (diploid)
- If a rare allele is carried by the queen then the probability of rare allele transmission is 0.5
  - *r* between queen and daughter is 0.5
- What is the r between full haplodiploid sisters?
- If the male carries the rare allele, the chance that it came from dad is always 1 (they will all have it because he is haploid)
- But if you don't know who has the rare allele it's a 0.5 that it came from mom and a 0.5 that it came from dad
- Dad calculation – the chance of the rare allele being from the dad is 0.5 and therefore if it is from dad since he only has one gene the likelihood of the other sisters having it is 1
- Between two sisters – if the rare allele came from dad then it is 1, they both have it, if the rare allele came from mom then it is 0.5, they could or could not both have it
  - (0.5 x 0.5) + (0.5 x 1) = 0.75, therefore the sisters are more related than to their parents or their offspring, therefore it makes sense that a worker female would take care of the sisters
  - Kin selection is a possible explanation because that is why female workers will take care of the colony/larvae < aka their sisters

Example – termites, kin selection also works in diploid systems
- Worker termites don't have the same 0.75 relatedness among them
- Termites build large structures for reproducing, they cannot do it themselves
- Because siblings are all 0.5 – they are helping their siblings so it makes sense evolutionary for termites to help raise their siblings

Example – queen naked role mat

- Female helpers are sterile but they will guard the tunnels and sacrifice themselves to attacking snakes
- The queen lives in the central chamber with one or more 'kings' tended by non-ovulating workers
- Workers are related to breeders and many colonies are quite highly inbred and share many alleles in commons

Direct fitness (the fitness that you get when you have a child) + indirect fitness (through non-descendent young) = inclusive fitness < this is what evolution acts on!
Some critics claim that evolution does not explain human kindness

Kin selection, combined with natural selection and sexual selection can explain all typical cases of so-called altruism in humans except which of the following?

a) Caring for an ill sibling
b) Extremely risky "show-off" behaviour by young men
c) Blue collar crimes (ex-fraud)
d) Providing help for an unrelated friend
e) All of the above can be explained by these forms of selection

If the *fitness benefit* to the *recipient* is > then the *fitness cost* to the *donor* both participants will gain *if* the help is reciprocated at a later date.

- *Reciprocal Altruism* – cooperation with a time delay
- Benefit [recipient] > Cost [donor]
- Long-term association (opportunity for reciprocation)
- Individual recognition
- Detection and punishment of cheaters

Example – vampire bats

- Feed on blood, cannot survive more than three days without feeding
- Associate with kin and non-kin roost mates
- Regurgitate to kin that are in need
- Will regurgitate to kin and non-kin who regurgitate to them
- Only a small cost to the donor (from 55 hours til death to 50 hours til death)
- A huge benefit to recipient (from 5 hours til death to 35 hours til death)
- Vampire bats represents reciprocal altruism

- Don't actually calculate the 'relatedness coefficient'
- If you're a female ground squirrel and you see another female ground squirrel, it is just a known fact that you're probably related so engage in the beneficial behaviour (female ground squirrels live together)
- Those who act appropriately according to Hamilton's rule are favoured via natural selection

Example – reciprocal altruisim?

- Smooth-billed anis in Puerto Rico 2011
- "Referential alarm calling"

    - One call for terrestrial predators
    - Separate call for aerial predators
- Experiment – is this peculiar call observed over the years an actual warning call?
    - Call for terrestrial would mean the bird should fly up
    - Call for aerial would mean the bird should hide
- Peregrine falcons and red-tailed hawks are aerial predators to the anis
- Terrestrial-threat call – high pitched
    - When humans, cats, ground predators approach
- Aerial-threat call (chlurp) – more frantic, lower pitched
- Used white noise at the same frequency of the calls for control
- North East NS – exposed to the control, they look around but it doesn't mean much
- Rickety Gate – exposed to the terrestrial alarm, birds fly out of the ground and into trees
- South Farm Mid-Fence – exposed to the aerial (chlurp) call, they dive deep into the vegetation
- Therefore these birds have different calls and know what to do for each call
- Why should the birds be warning each other?
    - Reciprocal altruism or some other form of reciprocity?
    - Benefit for some individuals to be in large groups?
    - Why bother warning other people, why not just dive into the vegetation right away?
    - Ongoing work by Dr. Quinn

- Eco = house or abode
- Logy or ology = body of knowledge or collection
- Ecology is the study (collecton of knowledge) of the environment and how organisms interact with it
- The environment can be divided into:
    - *Abiotic* – that comprise on non-living attributes (substrate, humidity, temperature, wind etc)
    - *Biotic* – that comprise all the living attributes (organisms that make up habitat in which organism lives, competitors, predators, prey etc)
        - The biotic environment includes conspecifics

Canada's most biodiverse habitats

- Wetlands!
    - Bogs are stagnant and acidic; unproductive habitat, carnivorous plants; quaking bogs – wainfleet bog
    - Marches have non-woody plants; productive – no trees, Cootes Paradise Marsh
    - Swamps have trees and shrubs; productive – trees and shrubs, Beverly Swamp
- Marines are productive environments - estuaries

Terrestrial Biomes

Tropical Wet forests

- Extremely rich in species, biodiversity hotspots, very high biodiversity among the plants that are there
- High average temperature (25 degrees) and very low variation in temperature
- Annual precipitation is very high but the variation in precipitation is high as well

Subtropical Deserts

- Saguaro cacti are a prominent feature of the Sonoran Desert in the southwestern part of North America
- Average temperature is high but there is a moderate amount of variation
- Annual total of participation is very low with low variation

Temperate Grasslands

- Grasses are the most dominant life form in prairies and steppes
- Temperature average is moderate with moderate variation
- Annual precipitation is low but the variation is moderate
    - Not enough precipitation to support trees

Temperate Forest

- Dominated by broad-leaved deciduous trees
- Average temperature with moderate variation
- Moderate precipitation that is low in variation

Boreal Forest

- Dominated by needled-leaved evergreens, such as spruce and fir
- Low average temperature but the variation is very high
- Average precipitation is very low
- Variation is very low

Arctic Tundra

- Dominated by cold-tolerant shrubs, lichens, and herbaceous plants
- Permafrost underneath
- Very low average temperature with high variation
- Average participation is very low with low variation

How can organisms interact with their environment?

- *Evolutionary Adaptation* – long term solution
    - Genetically based changes due to natural selection favouring individuals carrying beneficial mutations (ex – evolution of crypsis)
        - Global climate change is acting too fast for evolutionary adaptation to take charge
        - Hibernation and camoflauge
- *Physiological Acclimatization* – medium term solution
    - Metabolic or physiological adjustment within the cells or tissues of an organism in response to environmental stimuli that improves the ability of the organism to cope with its environment (ex – adjustment of fish to rising temperature in a body of water > tolerance to high temperature increases over time)
        - Hibernation can also be this
- *Behavioural Response* – short term solution
    - Behaviours in response to the environment in broad terms (ex – retreat to burrow during intense heat; escape from predator)
        - Kangaroo rat jumps back at sound of snake
        - Lizards can behaviourally adjust their body temperature based on temperature – they will come outside and stand laterally on a rock to absorb sunlight

Major areas of ecological study

Organismal Ecology

- Salmon migrate from saltwater to freshwater environments to breed
- Some salmon come back as "bruisers", take two years to mature – territorial males have women lay eggs and then fertilize them
- Some salmon come back as "jacks", take only one year to mature – jacks will slip in quickly and steal fertilization from the large territorial males

Population Ecology

- Each female salmon produces thousands of eggs but only a few will survive into adulthood, on average only two will return to the stream of their birth to breed

Community Ecology

- Salmon are prey as well as predators
- Includes all the interactions with all the different species

Ecosystem Ecology

- Salmon die and then decompose, releasing nutrients that are used by bacteria, archaea, plants, protists, young salmon, and other organisms
- How do energy and nutrients cycle through the environment?

Consequences of human activities

- Mountain Pine Beetle Outbreak – climate change
    - Loss of timber
    - Loss of vast forests of pines and coniferous
    - Used to get rid of CO2, but now they die and release all their CO2 into the atmosphere, increasing CO2
    - We don't get enough cold winters
        - Only 10% should survive through the winters
        - Now 80% survive through the winters
    - If they start to jump into jack pine (moving east) they can cross the great lakes and hit all the eastern forests too

- Cheatgrass – Eurasian invasive in North America, transported by humans
    - "cheats" native plants of water in the spring before native plants become active
    - Seeds are fire resistant
    - Lead to huge fires killing off the native seeds
    - Adapted to thrive in fire dominated environments being an annual plant with seeds that sprout effectively in fire depleted soil
    - Native perennials are damaged by fire and do less well

- *Population* – a group of conspecifics living in the same place and time
- Spatial element varies as a function of motility of species
    - High likelihood of interaction with other members of group without having to migrate

Demography - study of factors and processes that affect the size and age structure of a population over time

Population size - count, or estimate by aerial counts of large organisms

- Especially in migration
- On breeding colonies
- In nesting colonies
- By active nest counts
- Point-quarter survey estimates (plants)
- Mark, recapture – the ratio that you get of those that you capture should be equal to the ratio of unmarked

Mark recapture population estimates

- Assumes non-migrating and mixing populations
- 1) capture and mark a number of individuals (ex – 100 butterflies marked with a subtle mark detectable on recapture)
- 2) release marked animals and allow them to mix
- 3) recapture a number of individuals and determine the fraction that were marked (ex – capture 300 of which 50 were marked)
- 4) estimate population size assuming fair sampling of population: m2/n2 = n1/N
- M2 – number that were marked in the second sampling effect, n2 – total number in second sampling that were caught, n1 – total number in first sampling that were caught (all marked), N – estimate of the total population size
    - In our example – 50/3000 = 100/N
    - N = 600

General Growth Equation

- Assuming no immigration or emigration
- dN/dt = (B-D) x N
- B = average birth rate/individual*year
- D = average death rate/individual*year
- N = # individuals at current time
- Ex – N = 5000, B = 20 births/1000 ind*year, D = 10 deaths/1000 indv*year
    - Dt = 1 year
    - dN/dt = [(20-10)/1000*1yr] x 5000
    - dN/dt = +50
- Year 2, N = 5050
- dN/dt = [(20-10)/1000*1yr] x 5000
    - = +50.5
- What if N = 6000, dN/dt = +60
- All else equal = dN/dt is proportional to N
- > B = > dN/dt
- < D = > dN/dt
- > D = < dN/dt
- B = D = dN/dt = 0 (zero population growth)
- D > B = < dN/dt (negative growth)

- Substitute r for B-D
- r = per capita growth rate
- dN/dt = rN
- under ideal conditions a population grows at the *intrinsic rate of increase* = rmax
- dN/dt = rmaxN = highest possible rate of growth
- each species has a characteristic rate of rmax
- this is the most extreme "j-shaped" exposnential growth curve however ideal conditions are rarely missed

Intrinsic rates of increase

- E. Coli rmax = 60/individual*day
- Homo sapiens rmax = 0.0003/individual*day (0.11/individual*year)

At a point in time under real conditions

- Populations grow at the per capita growth rate r (not rmax)
- If conditions remain constant (r does not change over time) the population experiences *Exponential Growth*
- High r – very exponential, becomes less exponential more straight y = 5 type line for low r

Theoretical examples of exponential growth

- 100 starfish -> 15 generations at rmax -> 10^79 starfish
- 2 houseflies -> April to August at rmax -> 10^20 house flies
    - Enough to cover the earth 10 ft deep in house flies

Real World Situations

- Actual growth often interrupted by catastrophic reductions in population sizes (not desity dependent)

Density dependent factors (examples):

- Food or shelter limited by competition
- Sunlight limited by shading of other plants
- Increased predation risk (predators tracking prey increase)

Density dependent factors reduce growth rates:

- Increased death rate
- Decreased birth rate

E. coli face limits to growth – grow at rapid exponential phase, enter log phase, enter stationary phase, then enter death phase – not enough food etc, density dependent factors

The point where the density-dependent birth rate = the density-independent death rate there is an equilibrium density

- Survival declines at high population density
- Fecundity (fertility) declines at high population density
- Early growth is rapid, growth beings to slow, later growth falls to zero (at carrying capacity)
- *Carrying capacity* – maximum population size that a particular environment can sustain

Logistic Growth Model

- We need a new term to describe logistic growth (dN/dt = rN doesn't work)
- It should cause < growth as density >
- Let K = carrying capacity
- (K – N) / K
- As N -> K, this term approaches 0
- As N -> 0, this term approaches 1
- $dN/dt = r_0N * [(K-N)/K]$
- r_0 is the rate of growth when a population is very small (close to 0)
- textbook uses $N/dt = r_{max}N* [(K-N)/K]$
- it is important not to use the generic "r" which can be measured at any stage in a population's growth

Applying population growth – a recovering species – whooping cranes

- Hunting and habitat loss reduced whooping cranes to 20 individuals in 40's
- Conservation efforts have brought them back to around 599 but they are far from carrying capacity
- Cranes breed once a year, hence have discrete growth (as opposed to continuous growth which is not tied to a particular annual season)
- In textbook – works through the following estimates of discrete and continuous growth rates using whooping cranes – **chapter 52, box 52.2**

Discrete Growth

- N_0 – population size at time zero (starting point)
- N_1 – population size one breeding interval later
- $N1/N0 = \lambda$ rearranges to $N_1 = N_0\lambda$
- λ = finite rate of increase
    - a vriable or constant term affecting the shape of the growth curve
- Generalized equation = $N_t = N_0*\lambda^t$
- Stable population structure (proportion femaes in each age class is the same...$\lambda = R_0/g$
    - Where g = generation time (the average time between an individual's birth and its first offspring's birth)
- Females limit the amount of offspring
    - $l_x = N_x/N_0$ – number alive
    - *Fecundity* – the number of young that can be produced each year by each age class
    - l_x – survivorship, M_x – fecundity, l_xM_x - average number of offspring produced per female born
- $R_0 = \sum_{i=0}^{x} lxmx$
    - R_0 – the net reproductive rate of the population (growth rate per generation)
    - $R_0 = 1$ means each female is replaced (zero population growth)
    - $R_0 = 2$ = growth rate per generation

Continuous Growth

- Many species show growth that is not tied to a particular annual season (ex – humans, yeast, bacteria)
- "r", the per-capita growth rate, measures growth at any particular instant

    - Also called instantaneous rate of increase
- r relates to λ according to:
- $\lambda = e^r$
    - where e is the base of the natural log (~2.72)
- Substituting in the discrete growth equation – $N_t = N_0\lambda_t$
    - Gives – $N_t = N_0e^{rt}$ – continuous growth equation

Making projections with Life Tables

- Determining how much of a population survives/how many are born, shows how much population results
- Read textbook

Life History

- Life History – how an organism allocates resources to growth, reproduction, and activities or structures related to survival
- High Fecundity – produce lots of offspring, but die right away (low survival rate)
- Low fecundity – produce not a lot of offspring, but survive a long time (high survival rate)
- Energy trade off – must find an equality between fecundity and survivorship
- Life history parameters reflect upon survivorship
- Type 1 – Convex, humans tend to survive very well until they get old and then it decreases dramatically
- Type 2 – Constant rate of death (linear constant decrease) – songbirds live long but can die at any time
- Type 3 – Concave, very high rate of dying at the beginning but once they get safely into the ocean and reach their adulthood then their survival rate is excellent, lives a very long time – sea turtles
- An organism's life (or time) pattern of growth, differentiation, storage, and reproduction
- Goal of life history is a greater number of successful descendants
- Life history involves trade-offs:
    - Growing fast and large vs. reproducing lots and early
    - These are incompatible – can't do both

Life History Components

- *Maturity* – age at first reproduction
- *Parity* – number of episodes of reproduction
- *Fecundity* – number of offspring produced per reproductive episode
- *Termination of life* – senescence and programmed death

Experiment

- Physella virgata experiment
- Hermaphroditic snail
- Has the ability to shift its energy depending on the environment
- Arbuckle Mountains in Oklahoma
    - Rapid early growth until it reaches 4mm in shell length then it starts to reproduce
- Downstream sites, contain predator to the snail
    - Rapid growth to 10mm shell length but reproduction begins later
- Set up two experiments – one had crayfish and snails, one had just snails

- Snails aren't very perceptive, they shouldn't be "looking" for crayfish, he assumed it was a chemical that triggered this change not sight of prey
- He set up water going to a watch glass, so one type of egg would get snail + crayfish water and one type of egg would get just snail water
- The egg with water from the just snail water grew to 4mm and started reproducing
- The egg with water from snail + crayfish water grew to 10mm and waited to reproduce
- There must be some chemical in the water to ignite this change
- If he put snails and crayfish together in the same tank BUT separated them so the crayfish couldn't eat the snails he got the same result as the snails only experiment, so it must be a chemical that releases once crayfish eat snails
- Large snails are less susceptible to predation by crayfish and snails at risk of predation grow fast and delay reproduction < natural selection
- Crayfish eating snails release chemicals that cause:
    - First reproduction at an older age and larger size
    - Death at an older age and larger size
- Changes in these life history traits are "plastic"
- Genetic predisposition to strategy A under one set of conditions and strategy B under another set of conditions
- Phenotypic plasticity < control investment of which they do, both snails are capable of doing both but it depends on their environment

Parity

Salmon – semelparity ("big bang") spend all your time preparing to reproduce all at once
Humans – iteroparity – producing enough young to survive to reproduce again

Cole 1954

- When should one produce only enough young to survive to reproduce again (iteroparity), and when should one produce more and die (semelparity)?
- Produce 0 "extra" offspring and survive to breed again (ex, humans)
- Produce >2 extra offspring and die (more than replace the DNA in a diploid individual ex, sockeye salmon)
- If you're going to die after reproducing you need to have yourself replaced
- Semelparity – 100% reproductive effort, passing on future reproductive efforts, just this one try

Big Bang (semelparous) male mammal

- Dusky antechinus – type of marsupial mouse
- Males compete for mates
- Fight, cruise, and copulate for up to 12 hours daily for up to a couple of weeks
- Then after ~2 weeks they die, exhausted
- Only remaining males are embryos
- Females live to breed again (interoparous)

R and K selection

- K selection individuals found in the carrying capacity area of the curve < should be a very competitive setting

    - If you give birth to an offspring into the carrying capacity area then your offspring needs to be high quality because they will not survive otherwise
- r selection individuals found in the beginning area of the curve < no competition
    - Can be lower quality offspring because they don't need to compete
- Clams have r selection, gorillas have k selection
- r-selected
    - Environment – unstable, density independent
    - Characteristics – usually small, high fecundity, low quality young, little parental investment, reproduce early, short life span, semelparous
- k-selected
    - Environment – stable, density dependent interactions (intra species competition)
    - Characteristics – usually large, low fecundity, high quality young, high parental investment, reproduce late, long life span, iteroparous
- Humans tend towards k-selected
    - We could hit carrying capacity?
    - But we don't have one single population of humans so curves can be misleading because they are the summation of all the populations in the world
    - Carrying capacities can change, they vary based on the available resources
    - Recent changes in human environment such as agriculture (allows more people to live in less areas), technology (we can get more done/out of the environment per person), petroleum products

Predicting with demographic and geographic data

- Leadbeater's possum – marsupial in Australia
- Population viability analysis – high vs low vs no migration
    - It is important to know this because their habitats are being cut down and so if there is no migration you're cutting them off and dramatically decreasing the population
    - But if there is high migration with some habitats within migration distance still available, the population will be okay with immigration/emigration
    - Helps conservation biologists to make decisions

Populations of different species influence each other

- Snowshoe hare and lynx – community ecology
- Hares increase dramatically then lynx increase dramatically which causes the hares to decrease extremely, then the lynx decrease as well and vice versa

Community Ecology

- *Community* – all of the species that interact with each other in a particular area
- Types of interactions:
- + and + = mutualism
- + and – = consumption parasitism
- + and 0 = commensalism
- – and – = competition
- Fire ants protect the tree (habitat), the tree produces leaves with lots of nutrients that feed the ants (mutualism)
- Caterpillar with egg sacks from parasitic wasps, the wasps eat the caterpillar, killing the caterpillar (consumption parasitism)

- Cattle egrets (birds) and when the water buffalo walk around just chilling, they shake the ground scaring up the caterpillar and the birds can eat the caterpillar, the water buffalo/birds aren't in competition or bother each other at all (commensalism)
- Hyenas try and get in and take food from the lion's kill, both competing for the same item, have negative effects on each other (competition)

Factors limiting populations and affecting the community

- Limiting resources
    - Food, water, shelter, nutrients, light, nesting sites, etc.
- Law of the minimum
    - Of all possible resources, one in particular will limit population
        - Deer – food
        - Bluebirds – nest cavities

Density Dependent Limiting Factors

- Intraspecific competition (logistic growth)
- Interspecific competition – between species competition
- *Niche* – the total ecological resource requirement of a species
    1. One niche dimension – single linear line, needs that range of light to survive
    2. Two niche dimension – like a square, needs certain range of light and water
    3. Three niche dimension – like a cube, needs certain range of light, water, and nitrogen
- *Principle of competitive exclusion* – in a stable environment, no two species can occupy the same niche indefinitely
- If two species share the same niche there are three possible outcomes
    1. One species will be extirpated (driven to extinction)
    2. Species divide resources to occupy separate niches
        - Strong and weak competitor, the weak competitor can shift from its fudamental niche (but it overlaps with its strong competitor) into its realized niche (away from the competitor)
        - Different warbler birds forage different parts of the coniferous trees to reduce competition

- Joseph Connell
    1. Studied type of barnacles, semibalanus in the lower intertidal zone and chtamalus in the upper tidal zone (area that dries out)
- When the tide is at its mean level the chtamalus is stuck out of the water but the semibalanus is under the water still
- Barnacles are crustaceans, they can close up and survive out of water but they can't do anything energy consuming
- They have very large penises, they can reach and find a woman far away because of the length

Why is the distribution of adult chtamalus restricted to the upper intertidal zone

- Hypothesis – adult chthamalus are competitively excluded from the lower intertidal zone
- Alternate hypothesis – adult chthamalus do not thrive in the lower intertidal physical conditions
- Transplant rocks containing young chtamalus to lower intertidal zone, let semibalanus colonize the rocks, remove the semibalanus from half of each rock and then monitor the survival of chthamalus on both sides

- So you have cthamalus on one side of the rock and both on the other side
- Cthamalus survives extremely better when it was by itself than when it was placed with the semibalanus
- Therefore semibalanus is competitively excluding the chthalamus

3. Species rapidly evolve to occupy different niches
- G. Fuliginosa, g. Fortis, G. Magnirostris – Galapagos islands
- If they're on an island where there is no competition, they have very similar sized beaks
- If all three are present, they all have different beak depths because they create different diches
- If two are present, they still have two different beak depths
- But if they're alone all of them (via different areas) have the same 10ish beak size
- Natural selection
- Tribulus seeds are common in drought years and they are tough
- In absence of G. Magnirostris, G. Fortis evolve larger beaks during the drought years
- Subsequent arrival of G. Magnirostris in this area caused little change because the G. Fortis just went back to eating their normal seeds until a drought year because G. Magnirostris ate all the tough seeds and only the smallest G. Fortis could survive because they could eat very tiny/little seeds whereas the rest had been evolving their larger beaks but they couldn't compete against G. Magnirostris because they all have larger beaks/are better at getting that seed

Predation Pressure
- Protective shelters from predators become limiting
- Predator/prey ratio may increase with increased prey density
- When prey become abundant, predators become abundant, causing a crash in the prey population followed by a crash in the predators, then prey becomes abundant again etc
- Predator performance may increase with practice (when prey density is high)
    - You might only be able to spot one type (ex of mushroom) at once, but as you get better at looking for them you'll be able to spot your prey easily

Disease and Parasitism
- Lungworm in rocky mountain bighorn sheep
    - Damage your lungs, problems breathing, death
    - Lungworm eggs are ingested while eating grass
    - Infects lungs, burrow through and lay eggs and cough eggs onto grass
    - At high density of sheep, re-infections are common as they eat grass with eggs on overused pasture
    - Sometimes fatal when sheep are at high density

Other interspecific interactions
- Anti-predator strategies
    - Group living – more eyes/dilution effect/mobbing
    - Crypsis – matching background (camouflage), pepper moths, galardia moth (hide on the galardia flower because they have the same colour as the petals), stick insect that looks like a stick, thorn bugs that just look like thorns so they all chill on a branch together looking like a thorny branch

    - Aposematic colouration – frog with bright yellow colours (warning because it is poisonous), bright striped moth larvae (warning again, toxic)
    - Mimicry
        - Batesian mimicry – a mimic that is not toxic that is mimicking one that is toxic, mimics the model because predators learn to avoid that certain colour pattern and they will avoid the mimics as well
        - Fake eyes/fake nostrils on a caterpillar that mimics a snake and jumps out at you
        - Mullerian Mimicry – two different species but both have the poisonous chemical but they evolved separately and then infringed on each other's territories and began evolving similarly/separately to look the same so they both are mimics and models, this is advantageous because they all look the same so predators will learn quicker not to eat either
            - Viceroy and Monarch are BOTH poisonous and BOTH look the same

Keystone Species

- Play a critical role in the community
- Productivity
    - Sockeye Salmon – increases productivity in the community when it dies because it degrades
    - Hippopotamus – create fertilizer for plants to grow, attracting other birds/insects/fish/other organisms, if it weren't for the hippopotamus fertilizing with their feces though it wouldn't be as productive
- Keystone Predators
    - Starfish feeds on blue muscles, as long as you have the predator the number of species present stays fairly high, but if you remove the starfish then the number of species present decreases dramatically until it is only blue muscles, so the starfish predator is needed

Individualistic vs. Interactive Hypothesis

- Interactive – community is made up of a whole bunch of interacting species, together for a reason
- Individualistic – it just so happens that all of these species have similar requirements/share a similar niche therefore that is why they're in the same place
- HA Gleason (individualistic) – the community is a change assemblage of species with similar habitat requirements
- FE Clements (interactive) – the community is an assemblage of species *missing*
- Calculated limits of tolerance for species tends to match actual range of species
- Look at a forest on a mountain – you can make predictions about how the species will change as you go down the mountain based on these two hypotheses
    - Each tree has a different niche, as you go down you're going to get a complicated pattern that doesn't make sense (individualistic)
    - There will be groups on the gradient that are very distinctive together (interactive)
    - Actual experiment there is strong support for individualistic

- As we go from beach to beech-maple forest, the beach recedes
    - Isostatic rebound

- Pioneer plants/pioneering species at the beach, lay down and die, break down into humus, more things can grow, reaches the climax stage when it gets to beech-maple forest
    - Increase in humus, increase in humidity
    - Increase in shade, decrease in light
    - Increase in shelter, decrease in wind

- *Pioneer stage* – not competitive, generally change the conditions, facilitating subsequent stages
- *Facilitation* – when one species alters the environment in a way that benefits other species, allowing them to enter the community
- *Inhibition* – one species is prohibited from becoming established by the presence of another species
- *Tolerance* – species equally capable of invading a habitat becoming established (outcome depends on establishment and competitive interactions and abilities of the two species)
- *Climax stage* – stable end community of succession (self-perpetuating under prevailing conditions)

Disturbance disrupts succession

- Tree fall gaps – important because sun can penetrate the canopy and then smaller plants can grow underneath to increase biodiversity
- Frequent fires in Florida caused by lightning are required to burn down the forest so that the fire-resistant plants can continue and then the Florida scrub jays can continue to live because when the forests are too big they can't
- Elephants like vacacia trees and get rid of them allowing other animals to enter where those trees were

Connell – Intermediate Disturbance Hypothesis

- The moderate frequency and severity of disturbance should promote higher species diversity
- Includes both colonising species and those that are better competitors in the same community
- Inner tidal zone
    - Small rock – have 1.7 species on it (gets moved around too much)
    - Medium rock – have 3.7 species on it (gets moved around moderately)
    - Large rocks – have 2.5 species on it (doesn't get moved around at all)
    - If he cemented the rocks down, they didn't get tossed around in the storms because they were cemented down so they all got 2.5 species on it

- *Secondary Succession* – gradual invasion of species from surrounding communities following a disturbance (including human habitat disturbance)

Some communities are mosaics of patches at different stages of succession

- Intermediate levels of disturbance lead to increased levels of biodiversity because of the different successional stages
- Successions vary in their degree of predictability and may have vastly different late stages

Island Biogepgraphy

- MacArthur and Wilson established island biogeography theory
- Suggested a balance of immigration and extinction leading to equilibrium levels of species richness (number of different species) on islands

Krakatau

- Island existing in the ocean, had a huge volcanic eruption, killed everything from the lava
- Plants and animals showered down as aerial plankton delivered by storms
- Next groups arrived – strong dispersers first
- Rate of arrival diminishes because strong dispersers established early on
- As island became crowded, extinction became more common as more and more species contend for space and resources
- Where the rate of immigration = rate of extinction = equilibrium number
- Larger island – immigration rate is higher, the extinction rate is lower (more space for different species)
- Smaller island – immigration rate is lower, the extinction rate is higher (less space for different species)
- Near shore island – immigration rate is higher, the extinction rate is lower (if they get wiped out by a storm, there are other individuals that keep coming in)
- Remote island – immigration is low, the extinction rate is higher (if they get wiped out, there aren't as many coming in)

Shannon Index (species diversity)

- Takes into account proportional representation of species
- Uses information theory
    - Evaluates the expected information content of continuing sampling
    - 100 individuals of 1 species with no other species has a very low information content (continued sampling will give the same answer)
    - 99 individuals of 1 species and 1 of another also has low information content
    - 20 individuals of each of 5 species has much higher information content for continued sampling
    - $H' = \sum_{i=1}^{s} p_i * ln * p_i$
    - Although 3 communities may have the same species richness (number of species) but they will have different species diversity because certain communities will have lots of one or two species but not enough of others = lower Shannon index vs lots of every type of species = higher Shannon index
- The closer we get to the equator, the higher the number of species in that area
- Terrestrial species richness increases towards the equator, generally

Ecosystems

- *Ecosystem* – community plus physical or abiotic environment
- Energy and foru components of the ecosystem – sun -> autotrophs (synthesize own food from sun typically), -> consumers (eat other living organisms) -> decomposers (feed on dead organisms) and abiotic environment is in the middle (soil, climate, atmosphere, matter, solutes, water)

<u>Ecosystems:</u>

- multiple cycles
- how do humans affect the cycle

Experiment (Brooks Hubbard): (in textbook)

- How does the presence of vegetation affect the rate of nutrient export in a temperate forest ecosystem?
- What extent is the vegetation holding onto the nutrients?
  Procedure:
  1) Two watersheds – one controlled; one that has been clearcut
  Hypothesis: Amount of dissolved substances in a stream, in devegetated watershed is higher than the stream in a vegetated watershed.

  Results:
- Presence of vegetation limits nutrient loss. Removing vegetation leads to a large increase of nutrients found in water system

Carbon Cycle:
- CO_2 enters atmosphere, plants remove it from atmosphere. Oceans also take up CO_2 (plankton etc). CO_2 could be washed up or forest fires could release CO_2

Upward climb of CO_2 levels is globally; causing global changes over time
Increase of CO_2 emission due to fossil fuel use

Human vs. Natural Impacts on Temperature (Global warming graph):
- not just based on computer models
- based on physics & history
- Human impact is larger than natural impacts in terms of climate change

Global Warming:
- documented increase in Earth's surface temperature, averaged over the globe
- current evidence shows that human activities are primary responsible for global warming – increase in greenhouse gases
- models currently being used suggest that average global temperature will undergo additional increases from approximately 1.1 C up to 6.4 C by the year 2100.

Humans are dumbasses:
- good at ignoring statistics
- if it doesn't involve you specifically, you ignore it

Scientific Consensus is Clear: humans are causing global warming and dangers are real!
- Scepticism in science is important: naturally legitimate alternatives need consideration, but in science must meet a higher standard to gain ground
- Denial is an ideology and is not science
- Deniers seek to muddy the waters and do not offer credible evidence

Cold-water copepods are declining in the North Atlantic:
- warm water copepods are moving up. More and more warm water species.
- Changes in the types of species in water

Flowering times for some species in Midwestern north America are earlier in the year:
- time of baptista flowers are growing earlier
- flower in dr. quinn's front yard grew a month early this year
- that is wack yo

Extinction risk due to global warming:

- due to human caused climate change
- Cold loving species with range restrictions;
  - we could only go so high, can't get colder
  - on mountains and at high latitudes (POLAR BEAR D:)
  - island dwellers without strong dispersal skills
- Coral reef species (especially temperature or acid sensitive ones)
- Species that cannot change their location

Productivity Changes:

- humans are inducing changes in biogeochemical cycles; alters NPP (net primary productivity)
- in general, these changes seem to be increasing NPP on land and decreasing it in the ocean
- increased productivity can be beneficial for certain ecosystems
- negative effects of increased productivity include a decline in species richness, anaerobic "dead zones" and harmful algal

Talking the Walk:

- People don't notice that you are good to the environment (taking public transit, biking)
- You must tell people!
- CUE DRAMATIC MOVIE ABOUT DR. QUINN?
- Hamilton350.com

Hubbard Brook Experimental Forest (New Hampshire):

- looked over broad areas of ecosystem
- 0.8% of energy captured by photosynthesis. 45% supports growth (11% enters consumer, 34% enter decomposer).
- The energy gets converted to fossil fuels.

Use of oils:

- developed countries consume the most
- we're caught up in the hype of consumerism

Petroleum & Natural Gas formation:

- creatures from the ocean that were powered from the sun through plants.
- Oil & Gas deposits are formed over million and millions of years
- Millions and millions of years from stored energy
- We should use solar, it'll always be here unless we fuck things up really bad

We're addicted to cheap & abundant oil

- great return getting/selling crude oil
- we're exhausting the supply, not going to run out, but it's going to be harder and harder to get the oil out
- should expect increase in gas prices

Peak oil:

- global peak in oil production (production rate peaks and starts a permanent decline)
- almost out of "cheap oil" and demand is rising

- energy and environmental costs and risks of extracting oil sands and deep water oil are high! Costs will continue to mount
- conservation and alternative energy sources are essential if we want to maintain lifestyle

Human impacts on biogeochemical cycles;
- water
- carbon
- nitrogen
- nutrient

Biodiversity: how many species??
- Known species:
  - different ways to estimate
  - insects are the megafauna
  - total is ever-growing as more are discovered
  - many species are currently undocumented therefore unknown to science

Estimating Arthropod Biodiversity:
- has these sheets to catch dead/dying arthropod
- Collects various, diverse arthropods to see which ones were specific to one tree or are new

Conserving Biodiveristy:
How many arthropods species in tropical rainforest?
- 900 beetles counted amongst arthropods on one tree
- most of these were previously un-described scientificially
- prior work indicated that about 160 of these live only on that species of tree
- beetles make up about 40% of arthropods worldwide
- therefore about 400 arthropod spp live in tree canopy and another 200 on its trunk and roots estimated)

Barcode of Life Database:
- sequence of mtDNA that is specific to each species
- won't work for plants
- works very well for animals

Phylogenetic Trees:
- red panda, Yangtze river dolphin -> conservation concern, expanded from one species (novel & unique species)

Devastation of deforestation:
- burn forests down to plant crops. Very few rotations because most of the nutrients were in the trees.
- Species curve are important for designing parks to protect species

Experiment – How does fragmentation affect the quality of tropical wet forest habitats?
Hypothesis: fragmentation reduces the quality of wet forest habitats
Procedure: Patches of forests found in land

Prediction: Species diversity and biomass will decline in forest fragments compared with those of the forest interior, particularly along edges of fragments

Conservation Biology/Global Ecology

Value of biodiversity

- Sources for agriculture, forestry, aquaculture, and animal husbandry
- Sources for medicine
    - rosy periwinkle (Madagascar) – source of vincristine (provides 95% remission for leukemia) and vinblastine (for Hodgkin's lymphoma)
    - Provide $100 million to North America pharmaceutical companies but nothing to Madagascar
- Commercial value
    - Ecotourism and money spent in natural ways (protecting reefs/safaris)
    - Natural resource harvesting (forests)
- Recreational, aesthetic, scientific value
    - Birding, camping, fishing, hunting, nature programs, scientific studies
- Self preservation (ecosystem services)
    - Air and water purification, moderation of floods/droughts, detoxification of wastes, moderations of weather extremes, protections from harmful UV
- Intrinsic value
    - Moral or basic right for all species to exist

Habitat Fragmentation

Neotropical migrants (near us) – Acadian Flycatcher, Red-eyed Vireo, Ovenbird, Wood thrush
These birds are dramatically decreasing – becoming rare
This is significant to people's living – biophilia (love of nature), human activities are causing loss of habitat

Amazon

Centinela Ridge (one of many islands in Andean foothills) – own assemblage of evolved speices (endemic)
90 new species of forest floor plants discovered – several had black leaves (mystery to physiology)
The ridge was cleared for agriculture – plants are now extinct
"Centinelian Extinctions" = human cause extinctions

30% of freshwater fish (Canada to Mexico) are near extinction or recently extinct

- Destruction of physical habitat – 73%
- Displacement by introduced species (68%)
- Alterations of habitat by chemical pollutants (38%)
- Hybridization with other species

Human-induced extinction causes

- Overexploitation
    - Depletion of fish all over the world
- Introduced new species that are killing our native species – zebra muscles
- Loss of mutualists

    - Species that require each other to survive, because a certain bee is going extinct, the flowers it pollinates is donezo
    - Dodo's are extinct
- Global warming and climate change
- Habitat destruction and alteration
    - Pollution and fragmentation
    - Forestry – clear cutting is not equivalent to fire
    - Agriculture and forestry replanting – lead to monocultures
    - Road building
- Photo of Hamilton – huge parkway – used to be corridor between escarpment and Lake Ontario, now it is a giant road/parkway because rich people who had land on the escarpment swayed politicians to build a road for them
- Forest loss in Costa Rica is huge – are now struggling to protect the remaining they have
- Basically the entire US eastern forest is gone
- Megafauna haven't gone extinct in Africa as much because humans evolved with the giant fauna
- But as humans moved elsewhere (North America, Australia, etc) we killed off all the giant faunta
- Easter Island – the statues looking inwards to the land – colonized about 680 AD, in 1722 there used to be TONS of huge trees but then when the settlers got there in 1722 they killed off all the giant trees to use them instead and complete erosion occurred – everything died
    - Agriculture became so poor, no more trees to build canoes so they couldn't catch fish, then the population crashed
    - The original priests tried to rebel, the military tried to change everything, they resorted to cannibalism
    - "the flesh of your mother sticks between my teeth" < Easter Island taunt

Amazon
Forest is being burnt and cut down and putting roads down
All the hunter/gatherer tribes are being killed off or left in big cities to become prostitutes and drug dealers because they have no 'modern day' skills

Biodiversity – Water and Air
- Common property of the earth and its inhabitants
- Buying bottled water – we are selling water, water is now something you can buy
- *The commons* – areas belonging equally or shared equally
- *The tragedy* – when the common is degraded for profit or gain that is not equally shared
- Common pasture land for people to put their sheep on – Farmer Bob marks his sheep with a circle, Farmer Joe marks his sheep with an X, Farmer Joe puts more sheep so he thinks he should use more and then over eating by the sheep causes the land to be destroyed – Joe gets a big yield though whereas Bob doesn't

Alaska Pollock Fishery
- Pollock stocks have decreased dramatically, causing sea lions and seal species to decrease dramatically
- Orca (deprived of their sea lion/seal species prey) are now eating sea otters
- Sea otter populations decreased so dramatically that their prey (sea urchins) took over all the area and the entire marine ecosystem collapsed

Silent Spring

- Book – pesticides were causing the extinction of songbirds
- This book initiated the environmental protection agency to do something

Chemical contaminants in the Hamilton water are causing mutant chicks.

Housed two sets of mice – one in Hamilton, one in control
The DNA of the babies from Hamilton = they had mutations (used electrophoresis to test this stuff)
Twice or 1.5 as many times mutations in the mice babies
Hamilton area = near the steel mill
The CEO of Fasco tried to disprove Dr. Quinn's experiment and they proved him an idiot
Then Dr. Quinn and his student tested to see that breathable particulat was causing the mutations
Again the mice had mutations but when they filtered the air, they found that the mutations went right back down to the controls

Externalities

- Profits go to company and shareholders
- Costs (in terms of wastes and environments) go to environment and those that breathe
- The benefits are held by companies
- Costs are felt by everyone
- *The commons* don't have to be treated like this
    - James Bay Cree/Whitefish fisher – they managed this fishery so well that if you took too much you were punished, the fish were shared so that future generations could continue

Reciprocity

- Doesn't scale so well on a global perspective unless you have political resolve
- Fair proportion of global carrying capacity (what the country actually needs) vs actual use of global carrying capacity
    - China and India aren't using half as much as they could be
    - US is using like 10x then what it actually needs
        - Same goes for most developed countries
- We actually need 3 earth's to make up for this

- Growing Economy
    - We think of it as a separate from environment, free of biophysical constraints
- Infinite Environment
    - We think of it as where we dump everything and use everything
- We cannot just take resources and them dump
- In actuality the economy is within our environment, not separate

Suggestions for improving life

- Pedal the planet don't peddle the planet
- We need to preserve the diversity of life

GUEST LECTURER #1

Mike Nickerson – secondary succession

- Babies learn faster than older people
- More fish, more money, cycle killed the east coast fishery business
- We will be tried in the court of natural selection for eating too much fish, burning too much fossil fuels, drinking too much water
- Forests are dying from acid rain but people rallied governments to make industries reduce their bad crap into the air, 50% reduction in acid rain occurred in 7 years
- Except even though everyone is giving less pollution for acid rain, we have even more industries now so kind of defeating the purpose
- Most of the money in the world gets created/actually comes into existence from borrowing it from someone
- We need to make society stabilized
- We are possibly in crisis
- A tree grew 160+ lbs in 2 ounces of soil from all of the carbon/nitrogen etc in the atmosphere
- We're all made of gases
- Our physical needs are minimal, need vs want
- In 7 years there is no trace of the things you were 7 years previously
- Human being without society is like a computer without an operating system
- A chipmunk on its own is better at surviving than a human without society
- We need to stop being bottomless pit caterpillars and realize we have enough and become butterflies

GUEST LECTURER #2

3 Degrees

Lee Norton

- Stronger storms due to increased energy (water vapour) in the atmosphere
- Heavier rainfalls due to increase moisture in the atmosphere
- Increased droughts due to changing rainfall patterns and more forest fires
- Melting of ice at the poles and mountains
- Decreased albedo (reflectivity of the earth) due to melting ice – increasing warming
- Rising sea levels
- Reduced agricultural productivity
- Increase the spread of diseases – E.coli, malaria, etc etc
- Warm records being broken
- Global observations at less than one degree of warming over pre-industrial times
- 350% increase in floods
- 330% increase in extreme temperatures, drought, forest fires
- 270% increase in storms
- 150% increase in earthquakes, tsunamis, volcanic eruptions
- What is causing the crazy flooding?
    - Warmer sea surface temperatures – more evaporation, therefore more water in the atmosphere, therefore more rainfall
- Cat 4 and 5 hurricanes have increased 75% - increased water vapour, warmer weather
- Glaciers are melting putting millions of people without drinking water
- Black carbon is causing global warming

- The reflectivity of our planet is decreasing because of the lack of ice so the earth is becoming warmer – positive feedback system
- Coral is becoming grey instead of colourful because carbon dioxide is making the oceans more acidic
- Rising sea levels are going to put the San Francisco airport under water in 40 years
    - Sea level rising could double on a 10 year basis
    - 5 metre rise at the end of the century
    - Antarctica ~80m, Greenland ~7m < all could melt and increase the sea level
    - West Antarctic sheet is melting much faster – we cannot predict the cracks or model when the ice is calving
    - A 1m rise would force 130 million people to relocate
    - Human impact = population x affluence x technology
- The world is dimming
    - Aerosol particles from burning of fossil fuels and biomass scatter and/or absorb incoming solar radiation
    - Global dimming has masked CO2 effect
    - If we got rid of these aerosols it would be 2.6 degree warming
- we can cool the earth by injecting SO2 high into the stratosphere – band-aid solution, doesn't get rid of the CO2
- *Climate* – 30 years of weather
- *Normal temperature* – average temperature of the last three decades

HOW HUMANS EVOLVED – CLASS NOTES

HHE – 10-13 (EVANS)

HOW HUMANS EVOLVED – Chapter 10

Primative – no organisms should be considered lower or higher, it is meant in the ancestral sense
Population – usually used in the sense of a community

Climatic Change

- Climate has changed substantially during the last 65 million years – first becoming warmer and less variable, then cooling, and finally fluctuating in temperature
- How do we actually know that the climate has changed?
    - Analyze the ratio of oxygen isotopes in dated strata from ocean cores
    - This means that snow and rain have a higher concentration of O-16 concentration than oceans
    - When there is extensive glacial coverage (cold climate) this causes the ratio of O-16:18-O to drop, because O-16 is trapped in the glaciers, so there is more O-18 in the oceans

Dating Fossils – Radiometric Methods

- *Potassium Argon Dating* – argon is absent from lava so any argon in a volcanic rock is derived from the decay of potassium
    - works for ages of 500 000+ years
- *C-14 Dating* – live animals have the same level of C-14 and C-12 as the atmosphere, after death the C-14 begins to decay into C-12 so the ratio of these two can be used to estimate age

    - Works for cells or tissues younger than ~40 000 years
- *Thermo-luminescence Dating* - high energy nuclear particles from cosmic rays and radioactive decay arte trapped by particles, these particles are released when heated, because burning "resets" the particle composition, the age of burned material can be quantified by measuring the particle composition
- *Electron-Spin Resonance Dating* – similar to previous but instead they measure trapped electrons in apatite crystals which are a component of tooth enamel

Dating Fossils – Relative Dating

- *Magnetic Reversals* – poles switch, we can see this by studying the shifts of the ocea bottom
- *Extinct and Distinct Species of Animals* – there are lots of fossils of pig species in Africa – this area must be as old as the fossils of these pigs found in it

Mammal Ancestor – Therapsids

- Thrinaxodon - long, warm blooded, covered with hair, layed eggs
- The ancestor of the mammals of today (the monotremes, marsupials, placentals)
- At the end of the Triassic period, these reptiles with ammalian traits, began to become extinct but one lineage of theraspids evolved and diversified, becoming mammals
- The diversification of mammals was couple in time with the diversification of angiosperm plants

Plants

- *Vascular Plants* – have a circulation system (xylem and phloem) for conducting water, minerals, and photosynthetic products
- This allows them to be much larger than non-vascular plants
- Ferms, gymnosperms, and angiosperms are all vascular plants
- What is the difference between plants with seeds and plants without seeds
    - Seeds are an innovation that evolved in the ancestor of gymnosperm and angiosperm plants
    - Before seeds evolved, all plants used spores (ferns use spores not seeds)
    - Spores, unlike seeds, have very little stored food resources
- *Gymnosperms* – produce ovules that lack a cover whereas angiosperms produce ovules that are covered by the ovary
- *Angiosperms* – vascular plants that form flowers
    - Seeds can also have a fruit coat around the seed coat
    - Most have endosperm within the seeds (flour is made from endosperm of wheat)
    - Most produce fruit that contain the seeds (apple)
    - Most diverse group of land plants
    - Experienced an explosive diversification during the Cretaceous
    - By the end of the cretaceous, angiosperms dominated habitat formerly occupied by ferns and cycads
    - By the end of the cretaceous era large canopy-forming angiosperms replaced conifers as the dominant trees
    - Not the first plants to establish mutualistic interactions with animals (some pines require animals to open the pine cones)
    - But these interactions did become more elaborate than conifers, ferns, and cycads
    - Pollination, defence, dispersal < relationships between angiosperms and animals

    - Example – ants that feed on a certain type of flower will come out and attack a giraffe that tries to eat the plant
    - Who was competing with the ancestor of primates for the angiosperm fruit?
        - Bats, birds, rodents

What is a primate?

- Adaptations for climbing and other forms of locomotion (leaping, wwalking on 2 or 4 limbs etc)
- Most have opposable thumbs and prehensile tails
- Increased reliance of stereoscopic vision
- 3-colour vision in some species
- Nails on toes and fingers
- Claws are typically curved, pointed and compressed sideways
- Primate hands generally have 5 digits, usually with nails
- Presence of nails may be correlated with small branch foraging
- *Ancestry*:
    - Most related species is colugo – gliding mammals that have flaps of skin between legs used for gliding
    - Studying the noses of primates gives you information about what type of primate
    - Tarsiers, loris, aye ayes, yakari (NWM), proboscis monkey (OWM(, bonobo
- Hominoidea – Apes
- There are a lot of different types of monkeys but they can be divided by their strange noses

Early Primate Evolution

- With Pangaea breaking up in the crestaces era, a revolution occurred in the plant lineage as flowers evolved
    - The evolution of flowering plants created new niches, primates were among the first animals that evolved to fill these niches
    - the ancestors to modern primates were small, nocturnal quadrupeds, similar to contemporary shrews
- Plesiadapiformes – taxon containing extinct animals, fossil specimens have been found on NA
    - They possess some primate-like traits but experts disagree as to whether or not they should be considered part of the primate order
    - Smaller brains, different jaw shape
- *Carpolestes simpsoni* – small creature that could be an ancestral primate, opposable toe with a nail instead of a claw, they had molars
- During primate evolution – what traits were favoured by natural selection?
    - Binocular vision, grasping hands and feet, nails on fingers and toes
        - These allowed for enhance ability to predate insects, improving locomotion and foraging for fruit and nectar
- During the early Eocene era, primates occurred in North America, Europe, Asia, and Africa, but not South America
- The primates that are currently in Central/Southern America migrated there later

Eocene primates

- Ancestor of all the wet/flat/downward nosed primates lived in Eocene
- There were two types of primates:
    - Aapides – small eye, lived during the day, similar-ish to lemurs

    - Omomyidae – large eye, nocturnal, similar-ish to galagos
- Uncertain which species more recent primates are more closely related too
- Primates similar to the modern ones radiated during the Oligocene, many features about these organisms are inferred by studying their teeth
    - Teeth are complex structures that reflect dietary specialization – insects vs plants vs animals
        - Example – front pointed teeth for tearing up insects, sharp side teeth for tearing leaves, large canine teeth for breaking through fruit and small molars for chewing soft food
    - They also grow through a well defined developmental sequence and generally preserve better than bones
- Diet influences the evolution of dentition
- New World Monkeys
    - Fossil record indicates that monkeys reached SA by late Oligocene
    - There are morphological links between NWM and African monkeys
    - These fossils showed up by the time SA and Africa were already separated ~3000km and there are no fossil records of these primates in NA
    - Maybe fossil record times is incorrect – they actually moved earlier in Oligocene when SA was closer to Africa

Miocene Primates

- In Miocene – climate was warmer with tropical forests in Eurasia, and then the climate became cooler due to changing climate/ocean currents
- Apes (hominoids) diversified during this time
- Formation of Himalayan mountains – India joined Middle-East, Africa joined Asi

Hominoids (Apes)

- Refers to clade that includes gibbons, orang-utans, gorillas, chimpanzees, and humans]apes differ from monkeys in dental/skeletal traits, brain size, and life history
- Suspensory locomotion – hanging on trees – first evidence for adaptations
- Some of these hominoids began to lack tails
- Fossils in Africa and Asia
- Types of Hominids:
    - Gibbons - ~17 species in southeast Asia
    - Orangutans - 2 species, in southeast Asia
    - Common Chimpanzee – north of the river – 4 subspecies
    - Bonobos – south of the river
    - Gorillas – western (lots of them) and eastern (very endangered) (2 species)
    - Diversification went Africa -> SA -> Africa -> humans

The Origin of Violence

- Gibbons – largely monogamous
- Orangutans – solitary, bi-maturation (males – in later adult life their face matures from juvenile face into large face despite already being able to reproduce, this maturation occurs depending on who is around them), occasional forced copulation
- Gorillas – harems, usually one silverback with many females with offspring; infanticide (male takes over new group and will kill the infants of other males)

- Chimpanzees – multi-male, multi-female groups, male dominated hierarchy, raids
- Bonobos – less hierarchical, strong female-female bonds

Morphological Adaptations

- The biggest adaptation was the change from walking on top of trees to hanging/suspending off the trees
- The arms and fingers became longer, the legs and trunk became shorter
- Opposable thumbs, hook like fingers
- Joints became more mobile
- Apes began to diversify in Miocene but eventually all but the ancestors of today's species went extinct
- Reasons – climate change? However in the late Miocene and early Pliocene, monkeys diversified extensively

CHAPTER 11 – FROM HOMINOID TO HOMININ

- Global cooling was associated with decreased rainfall and seasonality, including dry seasons
- Tropical rainforests shrank in size; dry woodland and grassland habitat expanded
- Ancestors of humans – the hominins – moved into the grassland habitat

What is a Human?

- Bipedalism, different dental anatomy
- Large brains, long period of juvenile development
- Dependence on material/symbolic culture
- Spoken language
- Ancestral hominins shared some of these human features and some chimpanzee features
- Hominin – lineage that led directly to homo sapiens after the diversification of the other species

Fossils

- Genetic data success that the most recent common ancestor (mrca) of chimps/humans lived about 5-7 mya
- 3 fossils have illuminated what this ancestor was like
- Ancestral features of these fossils include
    - Small molars, thin enamel, large canine teeth, large brow ridge
    - Small braincase relative to modern humans
- Derived features of these fossils:
    - Forward location of foramen magnum – allowing spine to straighten bipedalism
    - Smaller canine teeth and not sharpened
    - Changes in the femur, pelvis, knee, ankle
    - Flattening of the face
- Hominin lineage is the lineage leading to humans after divergence from chimps and bonobos
- This lineage diverseified and then there were 4-7 lineages for the next 2 million years
- Australopithecus
    - Small bipeds with small teeth
    - These species probably spent some time in trees too (long arms) despite bipedalism
    - Less pronounced dimorphins in canine teeth
    - Smaller molars

    - Change of pelvis shape for bipedalism – flattening from the front, and flared from the top
    - Alignment of femur and tibia – for bipedalism
    - Laetoli footprints - bipedal proof – footprints found from 3.5 mya
- Paranthropous
    - Small bipeds with big teeth, probably ate plants
- Kenyantrhopus
    - Small teeth and flat face

Hominins

- Different parts of Africa = different fossils at different times
- A. africanus
    - Flatter skull, less sexual dimorphism, large molars/jaws, developed rather rapidly
    - How can we tell they develop rapidly?
        - The same amount of enamel in humans takes much longer to develop as opposed to our ancestors
- A. Garhi
    - Similar to other A.'s but larger teeth
- Homo Habilis (could be part of A. Afarensis)
    - Some have large brains/large teeth, some have smaller brains/smaller teeth
- Many had large saggital crests used for large chewing
- Humans develop slower than our ancestors and close relatives

Phylogenies

- No "one" phylogeny for the origin of humans, continuously changing

Theories of Bipedalism

- Perhaps it is a more efficient way to move – for instance if food sources are far apart
    - But then why haven't all species evolved?
- Could be because moving on two legs kept them cooler, you're absorbing less solar radiation and there is more wind above the ground
    - Difficult to test if this is why it happened
- Could be a response to requirement to hold things and increased dependence of offspring
- Suspensory motion -> knuckle walking -> bipedalism
- Our ancestors had suspensory locomotion which is uncommon in other species
    - Possibly this ancestral feature pre-disposed the ape lineage to evolve bipedalism

Early Hominin Subsistence

- Hominins developed strategies for dealing with lack o food in dry season
- They hunted meat and had a broader diet
- Hunting of other primates has been visually documented in common chimp and one population of bonobos
- Baboons (OWM) are known to hunt monkeys, other small mammals, birds
- Gorillas have never been observed to eat meat – but they also live in very dense forest, hard to observe
    - DNA was extracted from gorilla and bonobo feces
    - It contained DNA from various vertebrates:

    - Maybe gorillas do eat meat? DNA of small antelopes were found
    - Maybe it was contamination from other animals since samples were not fresh
    - Bonobos DNA had domestic animals – highly suggests contamination
- Baboons hunt more in open habitats vs closed and in dry seasons vs wet seasons
    - Suggests that meat is used as a supplement in times when food is difficult
- If there is a small prey – chimp hunters will keep it, but if it is larger – it will be shared with group
- Chimps use tools
    - Using one stone as a pallet and another as a hammer to crack open nuts
    - Use sticks to poke into ground to get termites
    - Make sponges for drinking water from small cavities
    - Use sharpened sticks for hunting
- Gorillas use tools
    - Use sticks to test depth of water and for support in swampy areas
- Orangutans use tools
    - Use sticks to collect seeds from fruit and to measure water depth
    - Used leaves to modify the frequency of sounds they make – make a lower frequency kiss-squeak under distress because it makes it sound like a larger animal
- NWM, birds, elephants also have been observed using tools

- Food sharing may have been important to early hominins (especially mother-offspring, chimpanzees do this)
- Unlike orangutans, early hominins may have lived in multi-male, multi-female groups

Distribution of Food

- Generally not evenly distributed
- Variation in the density of food patches (fruit trees) and also there is a distance between food patches
- Distribution of food resources has the potential to influence social structures
- In theory, clumped food resources lead to competition and conflict
- Could lead to aggression, hierarchy, skewed energy gains, sexual selection
- Larger groups reduce feeding opportunities on an individual level
- Larger groups also might incur longer travel times between food patches
- If food is clumped it is conceivable that benefits of forming groups means you can defend the food resources which could outweigh the costs of intra-group competition
- Balance must be created – between resource cost of group size (intra-group "scramble" for food) and the benefits of large group size for defending a resource
- Food for chimps (which are often sympatric with gorillas) is more patchy than for bonobos, which often feed on widely available THV (terrestrial herbal vegetation)
    - Hierarchal social structure, more competition for reproduction
- If food is not limiting for bonobos, group size can be higher (less competition for food for these guys because south of the Congo there isn't any other people wanting their food)
- THV is plentiful and consumed more by bonobos (33% intake) vs chimps (7% intake)
- Bonobos also may have relaxed feeding competition because lower seasonality in their habitat
- During periods of food abundance, some researchers have found that chimps tend to split up whereas bonobos tend to stay in a group

- Another possibility is that group formation has little to do with the actual availability of food but instead related to predator avoidance
- But apes have large body sizes and relatively few predators (mostly felids, jaguars) so resource distribution may have a larger impact for ape social systems than predators

Group Size and Sexual Selection

- Large groups of females provides the opportunity for sexual selection
- Females in groups are easier to monopolize for mating vs widely dispersed females
- Cause intra-population competition
- This depends very much on the ability of males to 1) restrict reproductive access of males and/or 2) limit the movement of females
- Largest groups of non-human primates ever recorded are the mandrils
    - Groups are called "hordes" and typically have ~700 people
    - Wide diet, plentiful food resources
    - Very sexually dimorphic (colour and size)
    - Females are less than half the size of males (up to 50kg)
- Group formation also may be favoured if females need protection from males to avoid infanticide by other males
- Other factors – living in groups (group size and density) provides an effective vehicle for transmission of disease and pathogens
- This clearly played an important role in recent human evolution

CHAPTER 12 – OLDOWAN TOOLMAKERS AND THE ORIGIN OF HUMAN LIFE HISTORY

- First use of stone obviously preceded the first stone tools that were clearly modified by humans
- This could have included a transition stage where rocks were first shattered before use
- Earliest tools (~2.5 mya) in Ethiopia, Tanzania, Kenya, South Africa
- Oldowan/Mode 1 Technology:
    - Choppers
    - Hammer stones
    - Core and flakes
    - We don't know which hominin did this but it could be A. Garhi, H. Habilis, H. Eragester
    - The only stone tool technology (~2.5mya-1.7mya)
    - Overlapped in time with the next technology hypothetically because of variation among within species
    - Hammer stone – use to bang a 'core' stone to obtain flakes from the core
- Complex Foraging:
    - Collection (ripe fruit)
    - Extraction (termites, coconuts)
    - Hunting (baby monkeys ☹)
- Chimps and humans expend different degrees of effort on different types of foraging
    - Chimps – mostly do collection, a little bit of extraction/hunting
    - Humans – hunting the most, and extracting more than then collect
- Efficient extraction and hunting requires practice
- Hunting and extractive foraging lead to:
    - Food sharing
    - Division of labour, usually by sex

    - This leads to food flow among different ages and genders
    - Hunting also requires learning – peak ability for one hunter-gatherer society in Paraguay was age 35
    - Same is true of extraction of tubers by women in Venezuela
    - Men usually take primary responsibility for hunting
    - Women usually take primary responsibility for extraction/collection because its more compatible with child care
    - Self sufficient food production only achieved in adults
    - System only works if food is shared
    - Men contribute substantially to caloric intake in modern hunter-gatherer societies (maybe even more so in temperate regions)
- Complex foraging methods could have contributed to/benefited from the evolution of:
    - Larger brain sizes
    - Prolonged juvenile dependence (care supported by high nutrition content of meat and sharing; longer period for skill development)
    - Longer life spans (from better nutrition)
- Why share?
    - Success at hunting is unpredictable
    - Success at hunting often yields too much food for one individual
    - Nutritional benefits from a diverse diet
    - Food is relatively easy to transport back
    - Specialization on hunting or extraction increases efficiency
    - Food sharing has been observed in many other animals, not just humans, primates, bats, insects, birds, etc
    - Can occur among non-kin individuals, creating an interesting evolutionary situation
    - Vampires bats regurgitate food for other non-kin members of their group to avoid starvation; may involve recognition and reciprocity
    - Some species may exchange food for sex
    - In some cannibalistic insect species the male may provision food to the female before copulation
- Prisoner's dilemma: two prisoners being questioned in isolation
    - Both cooperate (don't rat out) – both go to prison for 1 month
    - B doesn't rat out but A rats out B (or vice versa) – A goes free, B goes to prison for 1 year (or vice versa)
    - Both rat each other out – both go to prison for 6 months
    - Optimal outcome is cooperation, but the individual choice will lead to suboptimal outcome (with respect to the prisoners) of no cooperation
- Iterated prisoner's dilemma – two prisoners being questioned in isolation repeatedly with memory
    - Are there circumstances where cooperation could result?
    - Last time your friend ratted you out, this time you'll rat him out as punishment
    - in order for cooperation to be achieved, behaviour is predicted to have the following characteristics
        - "nice" – prisoners are optimistic so they won't defect until the other does
        - "retaliation" – a prisoner will punish the other one if the other one defects
        - "forgiving" – a prisoner must stop retaliating if the other one stops defecting
        - "non-envious" – each prisoner is not trying to do better than the other
- The effects of food sharing and division of labour:

    - Less competition between males
    - Reduced sexual dimorphism
    - This is because males don't compete with one another as much for reproduction as in societies with little or no parental care

Archaeological Evidence of Food Procurement

- Research suggests that Oldowan tools could have been used for a variety of tasks including large game butchery
- Wear patterns on bone tools indicate that they were used to excavate termite mounts
- Meat eating
    - Oldowan tools have been found with animal bones in dense concentrations
    - High density of bones suggest transport of kills to a processing center
    - Also tools were transported between areas
- *Taphonomy* – study of processes that produce archaeological sites
    - Researchers evaluate, for example, whether concentrations of bones might be evidence of hominin activity or some other cause, such as hyenas
    - Marking on bone left by teeth vs marking on bone left by stone tool

Scavenging and Huting

- Risky; large mammalian carnivores practice hunting and scavenging
- Hominins might have stole kills from carnivores
- *Hunting* – tooth marks on top of cut marks
- *Scavenging* – cut marks on top of carnivore tooth marks
- Cut marks on bone remains correspond with the animal parts that have the most meat

Conclusions

- Oldowan toolmakers were probably complex foragers
- Probably used a wide range f approaches to collect, extract, and hunt for food
- Possibly hunted and/or scavenged
- This approach to collecting food probably influenced society and behaviour
- Probably lived in fairly large multi-male and multi-female groups
- Sharing of food was important
- Sexual dimorphism decreased, brain size increased, body size increased, juvenile period increased, longer leaning period

CHAPTER 13 – FROM HOMININ TO HOMO

Lumpers and Splitters

- Lumpers (put everything into one species – underdiagnose species) vs Splitters (split everyone into different populations – overdiagnose species)
- Anthropologists disagree strongly about how to classify Middle Pleistocene hominins:
    - Maybe hominins in Africa and Eurasia were one, single interbreeding population throughout the Pleistocene?
    - Or maybe hominins split into several new species as they migrated out of Africa during the Pleistocene?
- Differences exist in the interpretation of recent human evolution

- Lumper – homo sapiens have been around forever yo, and then it just went out and split into the rest of the world
    - This is the "multi-regional" hypothesis for human evolution
- Splitter
    - homo erectus, then homo heidelbergenis, etcetcetc
    - Homo ergaster then homo erectus then homo neander/sapiens etcetc
    - This is one version of the "complete-replacement" hypothesis
    - There's also homo ergaster to homo heidelbergeneis then homo erectus etcetc

Timing of Recent Hominin Fossils

- Ergaster – Africa
- Erectus – Asia
- Heidelbergensis – appeared in Europe afterwards guys

Glaciers, Environment, Etc.Etc

- We are currently in an interglacial period
- Some recent interglacial periods were warmer than today
- Radically different distribution of ecosystems during glacial periods
- Migration went down
- The Pleistocene epoch started 1.8mya and involved a cooling trend that started in the Miocene ~6mya
- Lower Pleistocene s from 1.8mya-900 000ya
- Middle Pleistocene is from 900 000-130 000ya
- Upper Pleistocene is from 130 000-12 000ya
- 12 000ya – present is an interglacial period called the holocene

Homo ergaster

- Lived from around 1.8-06mya in Africa and Eurasia
- May be the same species as H. Erectus which was first found in Indonesia
- Ancestral features include narrowing of braincase behind the eyes receding forehead
- Derived features include shorter jaws, large prognathic face, taller skull, smaller jaws/molars less sexual dimorphism, large brain
- Prime suspect for direct ancestry to homo sapiens
- Fully adapted for terrestrial life, lacking adaptations for aboreal life seen in earlier hominins
- No evidence that there was spoken language
- More rapid juvenile development than humans
- First species that left Africa
- Fossils of this species have been found in the Caucasus Mountains in the Republic of Georgia
    - Revealed fossils and stone tools
- Has a much larger brain than all the previous hominins
- This species was probably good at tearing and biting with canines and incisors and not as good at heavy chewing with molars
- The discovery of an almost complete skeleton from a 12-year-old boy reveals much about body dimensions
- Similar to modern humans that live in savannas today – long legs, narrow hips and shoulders, short arms and tall – like 6ft!

- Suggests ability to run long distances – humans can outrun most other species in a long race of more than a few km :O!
- Morphology of spinal column does not suggest this species had spoken language
- Less sexually dimorphic than predecessor hominins
- Relatively rapid development – faster than humans but slower than Australopithecus
- Infants matured slowly relative to hominin predecessors, much brain growth after brith
- Improved on Oldowan tools and added a new technology (Mode 2) – the Acheulean industry
- Axes could have been used to butcher animals, to dig up tubers or water, to strip bark from trees, as projectiles, or to generate flake tools
- One female fossil had a bone deformity consistent with vitamin A overdose – this can occur if you eat the liver of a carnivore
- Fossils of this species is also often found in association with hand axes and animal bones with cut marks from stone tools
- Additionally it survived in temperate regions where fruit yield is seasonal
- They could probably control fire
- Soil under campfire gets hotter than does soil under grassfires, this causes distinctive changes in the soil chemistry and magnetism
- Additionally – campfires burn bones in a way that is distinctive from grassfires, bones around these fossils show these traits

Homo Erectus

- Found in Java, Indonesia, dating between 1.8 and 1.6mya
- Persisted there until about 30 000ya
- Larger face, thicker cranial walls, lower, less domed, steeped cranium, pronounced occipital torus, pronounced browridges, saggittal keel (no saggittal crest)
- Less similar to modern humans than H. Ergaster
- Associated with mode 1 tools, lack of mode 2 tools could be related to different cognitive abilities between erectus and ergaster

- The actual divergence times for these hominin species probably pre-dates the oldest fossil
- The time of extinction probably post-dates the newest fossils

Homo heidelbergensis

- Larger brains
- Ancestral features – long, low skull, thick cranial bones
- Derived features – high foreheads and a more rounded occipital bone
- Aged between ~800 000-500 000ya
- Fossil evidence comes from areas as diverse as Spain and Zambia
- Mostly mode 2 Acheulean tools
- Solid evidence for hunting big game
- These individuals probably also eventually used the Levallois technique – Mode 3 technology
- *Levallois Technique* – flake the margin of the core, sharpen the edges (chip away the edges), then modify the surface and bottom of the core, remove the flakes by chipping the surface off and the flake has sharp edges
- Coexisted with Neanderthals

Tools!

- *Oldowan/Mode 1* – use a hammer to break flakes off of a core, use the chips
- *Achulean/Mode 2* – involves additional processing of flakes including working both sides of the flake
- *Levallois/Mode 3* – modification of shape of core culminating in a final flake cut from a modified core; some tools were hafted (had handles)
- For a long time mostly mode 1, 1 and 2, 2, then 1/2/3 but 3 only arrived in Africa-y Kenya-y areas most recently, then started to move into south Africa and up into Europe

Homo Neanderthalensis

- Present in western Eurasia from ~120 000 – 30 000ya but could go back as 400 000ya
- Lived in Europe, western Asia, and southern Siberia
- Anatomically modern humans were living in these areas at this time from ~80 000ya
- Faces that bulge in the middle
- Large browridges
- Rounded back of the skull
- Small back teeth, large front teeth (for nomming meat)
- Robust, heavily muscled
- Different shaped roots in their teeth
- More stocky than modern humans, shorter
- Neanderthal morphology my reflect adaptation to cold – tibia size/femur size, this ratio is shorter in cold climates and bigger in warm climates
- Mode 3 tool industry
- Mostly meat eaters but evidence of plant material has also been recovered on fossil molars
- Probably made shelters (book doubts this but other sources support it)
- Probably wore clothes – evidence of bone sewing needles and awls
- Controlled fire also made symbolic or ornamental objects
- Deliberate burial of dead and potentially marking of graves with flowers
- If they are the same species as us - TADAAAA
- But recent molecular data demonstrates that this was a substantially different lineage
- How did Neanderthals go extinct?
    - Maybe H. Sapiens could have been involved with violence conflict and replacement of Neanderthals
    - Maybe hybridization led to fusion of sapiens and Neanderthals
    - Maybe climate change or energetic requirements made Neanderthals unfit

Homo Florensis

- Flores island in Indonesia, near Bali
- Only about 3 feet tall
- Very small brains (sizes of chimps)
- Linked between 35 000 – 14 000ya
- Some researchers think these were descendants of homo erectus that became isolated and evolved different characteristics because of natural selection
- Alternatively these individuals made up a modern human population with a small stature and microcephaly (small brain, doesn't grow)

- Also possible that this is a lineage that preceded homo erectus into Asia (probably not true)
- Comparisons of skull size with modern humans suggested that florensis were not actually microcephalic
    - Front and temporal lobes of florensis was highly developed like normal humans, but smaller
- The species is shorter than the average height of the shortest populations of modern humans
- Cave where remains were found had evidence of usage of fire, hunting
- One possible reason of the small stature is the phenomenon of insular dwarfism
- On islands with less predation pressure, species sometimes evolve small stature as a way of existing with lower food intake
- Small size could also be advantages for reproduction if gestation and generation duration decrease too
- *Insular giganticism* – sometimes species get larger on islands, not smaller, this could also be related species becoming predators on islands because of the absence of other predators or because decreased predation pressure allows species to be large
- Attempts to extract DNA from florensis were usuccessful, probably due to environmental conditions being bad for long term DNA preservation and the fossils were damaged by an Indonesian scientist

Denisova Hominins – a new hominin from Asia

- March 2010 – new finger bone from a juvenile female of a previously unidentified hominin from a cave in Russia (~41 000ya) and toes
- Extracted DNA – did a complete mtDNA analysis
- Split off from modern humans/Neanderthals ancestors ~1 mya

Major Question in Human Evolution

- Recent out of Africa hypothesis (erectus/ergaster were same in Africa and then we evolved and left late) vs multiregional hypothesis (everyone spread out everywhere)
- Did gene flow occur between Afrian ancestors and anatomically modern humans (AMHs) and other hominins
- Was there population structure in the African ancestor of AMHs
- Did gene flow occur between humans and other lineages outside of Africa (erectus/Neanderthals etc)

Recent out of Africa hypothesis (erectus/ergaster were same in Africa and then we evolved and left late) vs multiregional hypothesis (everyone spread out everywhere)

- *Multiregional evolution* – Evolution of modern humans has been occurring since early humans (erectus) left Africa ~2mya – continuous exchange of genes among populations in different regions united this species as it evolved into modern humans < mainly disregarded in the scientific community
    - Supported by primitive characteristics in some modern races (shovel shaped incisors in Asians, prognathic face and large cheeks of Australian aborigines)
    - But these features could be convergently evolved or simply a polymorphic ancestral feature

- *Out of Africa* – modern humans dispersed out of Africa and replaced erectus and Neanderthals without interbreeding
- One version – Different lineages in different geographical locations and eventually one of them diverges to become the African population and the non-African population
- Another version – maybe there was gene flow before ^ this occurred
- Another version – no gene flow before the divergence, then gene flow occurred after the divergence

Genetic Evidence/mtDNA

- Genetic evidence exists for a single recent ancestry (~100 000ya) origin of some genes in Africa
- Deepest branches of mtDNA and yDNA are in Africa
- Mapped restriction enzyme sites in mtDNA from 147 people all over the world
- Earliest divergence occurred among Africans, non-African mtDNA is derived from an African ancestor
- More divergence in Africa in mtDNA than anyone else in the world
- Variation with African populations is as great as that between Africa and other populations or between other populations
- Greatest divergence between non-African haplotypes corresponds to times ~100 000ya – this implies that early Asian homo species did not contribute mtDNA that survives in modern humans
- Estimates the age of mtDNA haplotype is not the "birth date of the human species", it is the birth date of that particular mtDNA lineage

Did gene flow occur between Afrian ancestors and anatomically modern humans (AMHs) and other hominins

- One way that this could happen if there was population structure in Africa before AMH left Africa
- Another way that this could happen if there was gene flow with another diverged hominin

Challenges to sequencing the Neanderthal genome

- Ancient DNA is usually highly fragmented
- Usually contaminated with other DNA (bacteria etc)
- Usually modified by various chemical processes (so some DNA base pairs changed post-mortem)
- DNA was extracted from three different individual's bones
- From three different dates, three different areas
- The project also generated whole genome data from 5 human populations and also compared the Neanderthal genome to a previously available genome of chimpanzees
- mtDNA of Neanderthals is distinct from human mtDNA
- probably split from humans ~500 000ya
- comparisons with human DNA allows us to identify which parts of the genome are "uniquely human" in that they are present in humans but not Neanderthals or chimps
- 20 regions were identified that are distinctive in humans vs Neanderthals
- 5 of these don't contain protein-coding genes (chromosome structure?)
- 15 include protein coding genes that play roles in metabolism, cognitive and cranial development
- Another thing they culd do with the data from Neanderthals is to test whether there was evidence for gene flow between modern humans and Neanderthals

- They did this by quantifying how similar the Neanderthal genomes were to other mdern human genomes from Africa/Europe/Asia/New Guinea
- One possible expectation was that modern Europeans might be more similar to Neanderthals
- Not what they found – instead they found that all non-African modern humans shared ~1-4% of their genome with Neanderthals but modern humans from Africa do not
- This suggests gene flow with Neanderthals happened after humans left Africa but before they diversified into Europe/Asia
- No gene flow from homo erectus to Neanderthals
- No gene flow from Neanderthals to Europeans
- Maybe gene flow from Neanderthals to ancestor of Europeans and Asians
- Maybe population structure before homo sapiens left Africa

What does the genome sequence of the Denisova hominin say?

- Another diverged lineage that is distinct from Neanderthals (mtDNA)
- Autosomal DNa – turns out this species is actually more closely related to Neanderthals than Neanderthals are to AMH (which is opposite of what the mtDNA says)
- Evidence of gene flow between Denisova and modern humans?
    - Yes – parts of the genomes of populations from Melanesia (off the east coast of Australia) have a signature of gene flow
    - ~3% of the genome of these people is relate to denisova
    - After divergence, denisova hominins and Neanderthals did not have much gene flow with each other
    - But each lineage had periodic gene flow with AMH
    - AMH experienced genetic exchanges with multiple lineages and at multiple times during our evolution
    - ~7.4% of the Melanesian genomes are derived from the (Neanderthal + Denisova lineages)

What else can we learn from complete genome sequences from human populations?

- First hypothesis – single dispersal; says that Austalian Aboriginals (ABR) are closely related to mainland Asians (ASN)
- Second hypothesis – double dispersal; says that and early colonization of Australia and a second dispersal of an ancestor of Europeans (EU) and ASN
- Last year (2011) a complete genome sequence of an Aboriginal Australian who lived 90 years ago was reported
- The analysis suggested that there were two major dispersal events out of Africa into Asia
- The first led to colonization of Australia and Melanesia and gene flow with Denisova hominin; the second occurred more recently, involved gene flow with the “first wave” and seeded other populations in Asia and eventually the New World
-

When did hominins lose their body hair?

- The hominin lineage lost extensive body hair after divergence from chimps, but when?
- Parasitic sucking lice of chimps and human head lice diverged from each othera round 6mya – the same time that speciation occurred
- Crabs in humans is closely related to lice of gorillas and diverged ~1-3myam this may have been the time when there was a barrier to dispersal between the head and pubic region

When did humans start wearing clothes?

- Humans appear to have outcompeted other archaic hominins in various parts of the world
- Clothing is an important innovation that contributed to the successful expansion of humans into higher latitudes and colder climates
- Eyed needles appear in the fossil record ~40 000ya
- Body lice which is different from head/pubic lice is thought to have diverged from an ancestral hair lice when humans began wearing clothes
- The divergence time of the head lice and clothing lice is ~180 000ya
- Clothing probably was worn by our ancestors that diverged from Africa

How is genetic variation distributed among modern humans today?

- They found that 93-95% of variation was shared among populations and only 3-5% comprised differences between populations
- The average proportion of genetic differences between individuals from different human populations only slightly exceeds that between unrelated individuals from a single population
- There's as much variation within populations as there is between two different populations

Human demography and the biodiversity crisis

- *Human demography* – the study of the characteristics of human populations, such as size, growth, density, distribution and vital statistics
- "the pattern of human population growth" in the twentieth century is "more bacterial than primate"
- From 1959 – 1990 we had a two times increase in 40 years; 7 billion people yo
- Global population growth rate maximum occurred around 1970 – 2.1% per year
- Absolute annual increase in people peaked in 1990 – 86 million people per year

Striking demographic transitions

- *We are getting old* – before 2000, young people outnumbered old people; after 2000 old people outnumber young people
- *Urbanization* – before 2007, rural people outnumbered urban people; after 2007 urban outnumber rural
- *Growth of developing world* – in 1950 the lesser developed world had two times the number of people than the developed world; by 2050 there will be six times the number of people in the lesser developed world
- Typically the death rate of a population decreases before the birth rate decreases
- This causes population growth until the birth rate decreases to match the death rate

When will it stop?

- There will be 8 billion people on the planet in ~14 years
- India will have more people than China around the same time
- Most European countries, Japan, and China have birth rates below replacement
    - Immigration makes up for it
- Most population growth will be in poor areas
- The European part of the former USSR – is not really growing
- China will stop growing by about 2050
- By the end of this century, by 2100, we assume the world will stop growing

- Cumulative properties of reaching a proportion 60+ of one-third or more for the world and selected world regions by calendar year
    - Japan
- We have to take care of all the old people, there are too many old people and not enough money to take care of them
- Young people are going to be exploited

Where are we growing most?

- Most rapid growth was in Europe and North America prior to 1950
- Since 1950 most rapid growth has shifted to Asia, Africa, and Middle East
- Population growth is highest where biodiversity is highest

Biodiversity

- *Biodiversity* – the variety of life on Earth at all its levels *MISING*
    - Genetic variation, community diversity, ecosystem diversity, ecological processes, evolutionary processes; natural selection
- Biodiversity is not evenly distributed
- The 25 hotspots of biodiversity originally comprised ~12% of the Earth's surface but now after deforestation only ~1.4% of these spots remain
- The areas with the most biodiversity have the most population density
- 20% of the world's population is living in the biodiversity hotspots
    - Freakin India is ruining a biodiversity spot
- Growth rates in hotspots are higher than the global average, and higher than even the average for developing countries
    - Again, India, New Guinea, Congo etc
- In Canada most biodiversity is in the south
- Over 99% of the species that have ever existed have already gone extinct
    - The background extinction rate – approximately one species per million species per year
    - Actual rate of extinction varies over time from this average
    - We are currently causing the 6^{th} mass extinction
- *lists of lots of animals that have gone extinct due to increased human activity and habitat destruction*
- Why should we care?
    - Intrinsic values – all species have a right to exist and all species rely on other species and genetic variation is necessary for adaptation
    - Antropocentric value
        - Direct value – fuel, food, fiber, medicine
        - Passive value – services like oxygen and carbon cycling, pollination, nitrogen fixation, climate control, erosion control
        - Potential value – information (new understandings for future)
        - Psycho-spiritual/aesthetic/non-use value –
- Ecosystems provide goods and services that our entire lives depend on!
    - Study found that the things ecosystems provide are worth about $33 trillion

Reasons for Optimism

- Problems have already been identified and some legislation is in place
- Synergies – education (especially women, it reduces birth rates), sustainability

- Technology – we can create things to help, more efficient cars, better public transport, the resources are available, we are a resourceful enough species to fix some of these problems
- Urbanization
    - Bad – concentration of impact, strains capacity
    - Good – concentration of impact, economies of scale, abandonment of marginally productive lands
- Kuznet's Curve – fantasy or reality?
    - Environmental degradation will hit a turning point where it has gone so far that it starts to decrease
        - NY city
- Consumption disparity – a bigger issue than population growth?
    - Average consumption of oil and metals and production of wastes like plastics and greenhouse gases is about 32 times higher in North America, Western Europe, Japan, and Australia than in the developing world
    - We can radically reduce consumption and waste without sacrificing our standard of living
- Amazing biodiversity discoveries are still occurring!
- Conservation success is possible
    - By 1900 population of Atlantic Right Whales was about 100 individuals
    - Legislation was created to prohibit speeding/hunting
    - In 2008 not a single whale was killed
    - Population is about 400 now

HHE - 14-17 (QUINN)

Homo habilis, Homo erectus, Homo sapiens

- The size of the brain cage (cranial capacity) increases dramatically between habilis > erectus > sapiens

Things that may have influenced natural selection for large brain size:

- Complex foraging
- Cooperative breeding and complex social interactions (associated with social competition)
    - Socially intelligent people may gain an advantage
- Cooking with fire

Constraints on brain size increase:

- Temperature sensitivity of the brain
- High metabolic cost of the brain (20% of resting metabolic cost goes to your brain despite it only being 2.5% of your body weight)

First Brain Size Increase from habilis > erectus

- Complex foraging!
- Corresponds with increased meat consumption – higher quality food
- Emergence of erectus and ergaster from Australopithecus
- Small stomach (eating less vegetables/fibre so don't need tons of digestion anymore) and large brain
    - As brain size gets better, stomach size tends to decrease

- High metabolic cost
- Skillful hunting may benefit from enlarged brains
- Food sharing leads to increased sociality and other forms of reciprocity
- Specialization and risk reduction leads to pair bonding and shared parenting (rare in mammals) – monogamy or polygamy
    - Permanent pair bonds, not promiscuous

Second Brain Size Increase

- Cooperative breeding and complex social interactions (associated social competition)!
- Recall that homo sapiens has long development time and short inter-birth spacing
    - Having lots of kids and having to raise them for a long time < costly
- Recent studies argue that homo sapiens is a cooperative breeder
- Mothers and older siblings have the most positive effect on child survival followed by maternal grandmothers and then paternal grandmothers
    - Fathers, maternal grandfathers, paternal grandfathers are the least because of that extra "is that really my baby?"
- If there was not some important function for survival after reproduction, then there would be no survival
    - Ie – life after menopause, why should these women still be around for many years afterwards when they cannot reproduce? Natural selection favours them because they contribute largely to the raising of their grandchildren < increasing their inclusive fitness
- Cooperative breeding in humans explains how we can have long development time and reduced inter-birth intervals
- Enhanced social skills may benefit from big brains
    - Understanding care givers may allow smart kids to gain more care
    - Smart negotiators may gain fitness within social groups

One human activity that is not shared by any other species:
Cooking our food; controlling fire

- Theory - cooking decreases the digestion costs of human foods, allowing a reduction in the size and cost of the digestive system
- They argue that this may explain the last increase in brain size in homo sapiens
- Change in digestibility of some foods like potatoes and wheat from raw to cooked foods increases dramatically, easier to digest
- Don't have to worry about food borne illnesses from raw uncooked meat
- Annual number of illnesses from ingesting raw meat in some societies = 42.1
    - If you're a hunter/gatherer and you're getting sick 42 times this is really dramatic, you cannot hunt/gather/raise youngins
- Cooking benefits exceed other non-cooking food processing in terms of gelatinisation of starch, denaturation of proteins, and killing of food borne pathogens being the most significant gains
- These energetic improvements over eating raw foods may have led to decreased investment in the digestive system and increased energetic investment in our "growing" brain

Other study:

- Recent study of mammals in general suggests that increased brain size correlated with reduced fat levels and less so with reduced digestive systems
- Homo sapiens may have had a reduction in both fat and digestive system

    - Efficient bipedal locomotion
    - Steady and high quality food supply (partly due to cooking)
        - Less need for fat
- Increase in net energy input
    - Improved diet quality, energy subsidies (cooperative breeding), stabilized energy supply (avoidance of starvation)
- Change in energy allocation
    - Locomotion costs decreased, production decreases
- Therefore – Improved diet quality, allomaternal subsidies, cognitive buffering, reduced locomotion costs, and reduced allocation to production all operated simultaneously thus enabling the extraordinary brain size increase over time

Genetic Features

- Human and chimp genome projects
- 1.06% fixed difference in DNA sequence (ignoring repetitive DNA and indels)
- Over 13 000 homologous proteins shared with 29% having the same amino acid sequences and many others have small changes that may not affect the protein's function
- Many DNA changes may be neutral and under genetic drift
- Some changes may be favoured by natural selection
- How can we tell?
    - If you're looking at the DNA in particular -> we know the third position in the triplet position that codes for the amino acid is typically redundant
    - A change in the third position is not seen to be important via natural selection, seen to typically be redundant because it typically codes for the same amino acid
- Genetic drift acts on synonymous (produces the same amino acid, just third letter in codon) and non-synonymous substitutions (changing the first or second letter)
- Directional selection favours base changes that have a positive effect on protein function

1. The ratio of non synonymous to synonymous substitutions a gene
    a. Should be higher in genes that differ between species because of genetic drift
    b. Should be higher in genes that differ because of directional selection
    c. Doesn't matter because many amino acid changes are neutral
    d. Is the same whether due to directional selection or genetic drift
    e. Confuses me

- However if you're changing the first or second letter of the codon, this can significantly change the amino acid sequence < this is what natural selection acts on
- Genetic drift acts on both but natural selection acts ONLY on non-synonymous
- Genes with a high ratio of non-synonymous to synonymous changes indicates directional selection
- However, in some cases one or few mutations will change the protein appropriately, so the gene will not stand out in N-S/S ratios
    - Ex – FOXP2 gene – 2 substitutions led to large change in speech ability in humans
    - Mutation in FOXP2 gene gives rise to language impairment (Specific Language Impairment, SLI)
- Only a small fraction of protein coding genes show evidence of positive selection since the divergence of human from chimp lineages

- What about "non-coding" DNA sequence?
    - It can have an effect on whether a certain protein is to be transcribed or not – binding parts (where the mRNA/tRNA bind)
    - Involved in DNA regulation – to what extent are the genes coded into mRNA/proteins created
- Chimps and people differ dramatically in brain gene expression, less so for liver and blood genes
- Gene expression is controlled by regulatory regions of DNA

Katherine Pollard – evolution of humans studying non-coding DNA

- Find regions at least 100 bp long sharing >96% bases (strong stabilizing selection)
    - If you can find this between chimps/rats/mice, then that says this selection MUST have been preserved it MUST be important < maintained by stabilizing selection
    - If it is important all the way up to chimp...how about humans? If it exists all the way to chimps but contains tons of mutations in humans – this means it is unique to us! Must be something important in human evolution.
        - Suggests directional selection between chimps and humans
- They found 35 000 regions between chimps/rats/mice
- In 202 of the 35 000 regions, human sequence had a significantly faster rate of change compared to the other taxa (they included an additional 9 vertebrate species)
- These 202 **H**ighly **A**ccelerated **R**egions (HAR) were ranked and named HAR1 (fastest of the fast) to HAR202 (slowest of the fast)
- HAR1 (118bp region on human chromosome 20) showed only 2 bp changes between chicken and chimp (very different species but since such few changes shows very conserved region)
    - There were 18 changes between chimps and humans – an 80x increase in the rate of evolution
    - HAR1 codes for an RNA molecule that folds into a stable structure
        - RNA -> specific protein -> regulate gene expression
    - Expressed only in the brain, especially during the brain's development
    - Associates with "reelin" protein, which plays a role in developing layered structuring characteristic of human brains but not other species brain
    - Rapid changes in human HAR1 are likely related to the fast evolution of the larger and more complex human brain
- The study of such gene regulatory regions is in its infancy and will likely prove crucial to our understanding of the evolution of differences among species including our own

<u>Genetic Variation and natural selection in *homo sapiens* – various skin colours</u>

- Skin colour is partly genetic – natural selection should be acting on it
- The 8818G allele of the agouti signalling protein (AIP) gene is ancestral and is associated with darker skin colour in African Americans
- Genetic evidence for the convergent evolution of light skin in Europeans and East Asians
- Is human skin colour an adaptation?
    - Without considering tanning – consistent dark skin
    - Very little melanin – light skinned people
    - Larger non –aggregated melanosomes – much more melanin – dark skinned people
- Melanin protects against UV radiation with its ability to prevent direct (blocking) and indirect (scavenging reactive oxidative species) damage to DNA at wavelengths where it is most vulnerable

- Constitutively dark skinned folks have a sun protecting factor (SPF) of 10-15 while moderately pigmented people like those from the Mediterranean achieves an SPF of 2.5
- Lighter constitutive pigmentation is associated with a higher sunburn response, a lower tanning response, and a greater susceptibility to skin cancers

Vitamin D3

- Vitamin D is necessary for efficient use of dietary calcium
- Vitamin D3 is needed for proper growth of bones in vertebrates
- Shortage of vitamin D3 leads to weakened bones (rickets disease)
- Vitamin D3 synthesis/breakdown is facilitated by UVB light
- Vitamin D3 is made from 7-dehydrocholesterol
- 7-dehydrocholesterol is found in keratinocytes of the epidermis, absorbs photons from UVB
- Vitamin D3 production is facilitated by UVB exposure
- Vitamin D3 and a pre-vitamin D3 stage are broken down by UVB radiation – preventing D3 intoxication from excess vitamin
- Melanin absorbs and scatters the UVB wavelengths that catalyze vitamin D3 synthesis
- The photoconversion of 7-dehydrocholesterol to pre-vitamin D3 in the skin is also adversely affected by:
    - Increasing age
    - Clothing
    - The use of topical sunscreens (block UVB)
- D3 is important

Factors favouring dark skin in tropics:

- Human skin is almost hairless – cooling through sweating is more effective
- Melanin protects skin from UVA and UVB damage
- UVA breaks down folic acid (folate)
- Adequate folate status necessary for proper DNA synthesis, repair, and expression
- Folate deficiencies play a negative role in reproductive and developmental processes (neural tube defects, early pregnancy losses among others)
- UVA does damage to folic acid < causes it to breakdown
- Dark skinned people have sufficient melanin, UVA isn't able to travel as far – cannot damage the folic acid, because of their melanin they are less prone to cancer/these other things when they are in areas of high light but in low light they are at risk still

Predictors of skin colour:

- Average UVMED (average UV radiation induced minimum erythral dose) – minimum dose of UVR to cause slight reddening of lightly pigmented skin
- Average UVMED correlates with latitude and varies also according to precipitation levels and seasonal UVMED
    - If it rains a lot, less sun
- All of these factors were combined to predict optimal skin colour as a function of UVR exposure
- Light skinned people should be very north and very south
- Dark should be everywhere else
- Actual measures of skin colour of aboriginal populations match predictions well

Better skin colour info:

- Recent migration of Inuit to the far North from more Southern climes in Asia

- Jablonski – recent immigration (5000 years ago) and a diet that is very rich in vitamin D (fish and marine mammals) offsets the need for increased sunlight penetration (they can have darker skin to better protect folate while acquiring sufficient vitamin D)
- Other cases of mild miss-match seem to well explained by recent migration events

Beja Passtoralis are lactase persistent

- Milk provides almost all nourishment in this arid climate
- Natural selection would prefer those who can digest lactose because it leads to survival
- We are the only mammals who drink milk after weaning
- Lactase breaks down lactose
- Single locus with two alleles
- LTC*P/LTC*P – synthesize lactase and digest lactose as adults
- LTC*P/LTC*R – synthesize lactase and digest lactose as adults
- LTC*R/LTC*R – do not synthesize lactose and unable to digest
- We originally would've been homozygous R –once we were weaned no more milk, but a mutation caused P and that became favourable
- There seems to be a historical relationship between dairying and lactase persistence
- Lactase persistence areas are where the highest amount of genetic diversity for milk proteins in domesticated cattle is found
    - Suggests that is the original area (ancestrally) of cattle
    - Bigger herds (original herds) favours increased diversity
- Milk can be store for production of cheese or yogurt (low in lactose)
- Vitamin D facilitates gut uptake of calcium
- Light levels are low in winter in northern Europe = low levels vitamin D = risk of rickets and osteomalicea (bone disease)
- Calcium from milk may impair vitamin D breakdown in liver so calcium uptake can continue
- Milk proteins and lactose apparently facilitate absorption of calcium and milk contains high calcium levels
- Northern Europeans with lactase persistence are less prone to calcium shortage and bone disease

Directional Selective Sweeps

- Directional selection in populations with history of dairying
- "selective sweep" allows molecular evidence
    - Looking at DNA sequence around the mutation
- Beneficial mutations are favoured by natural selection
- Imagine this situation if there were no crossing over and recombination – then the whole chromosome would spread through the population and a genetic marker of this chromosome would detect presence of the mutation
- But because crossing over occurs, we cannot just use any genetic marker on the chromosome because some has moved to the other chromosome
- When a new favourable mutation initially spreads, it will be surrounded by a large chunk of with the same sequence
    - This sequence is linked with the mutation and is called a *haplotype*
- Because crossing over continues you might lose the genetic marker as the mutation sweeps through the entire population

- The haplotype will remain intact until recombination breaks the linkage, this takes about 10 000 years depending on the size of the haplotype
- Once the sweep is through the population there won't be any genes without the mutation so you cannot detect anymore
- With a small selective advantage the frequency f the allele can sweet to prominence within 7000 years (300-350 generations since dairying began)
- Selective sweep should be detectable even with a small 3% selectvie advantage haplotype still intact
- We *no longer* await further exploration of human sequences
- Lactose malabsorption – opposite of lactase persistence
- There are a number of populations where nearly all the people in the population has lactose malabsorption
    - A lot of populations in the world have a lot of people that cannot digest milk
- Most people close to the equator – where milk is not readily available, are likely to have an inability to break down lactose
    - Exception is just the Baja people
- Most people at higher latitudes are usually able to digest lactose
- The outlier (Greenland/Siberia) makes sense – so far north it is difficult to keep cattle
- The higher the mean temperature the higher your level of lactose malabsorption
- Those areas with high numbers of cattle diseases (not easy to do dairying) are highly correlated with high levels of lactose malabsorption
- Lactose digestion ability in mature people of dairying ancestry may exemplify culture as a selective force driving organic evolution

Contours in skin colour

- Generally smooth gradients away from the equator
- Lighter skin farther away as you move away from the equator
- Inuit exception
- High sunshine = you need to protect your folate to protect your DNA!

Contours of genetic similarity

- East/West gradient
- Based on 120 genes from 42 human populations
- Become less and less similar as we move E->W and W->E

The patterns of skin colour and genetic similarity don't match.

- Skin colour is probably determined by environmental conditions
- All the other genes have other reasons for being different
- Skin colour therefore says very, very little about our genetic differences

Evolutionary Psychology

- Application of evolutionary concepts to understand human behaviour
- Human cognitive abilities have been shaped in specific ways by natural selection through evolution
- Most of our evolutionary history was probably spent as small bands of cooperative hunters and gatherers
- Food sharing was probably essential, organised as a form of reciprocal altruism

- Food sharing likely favoured adaptations facilitating attention to fairness in social exchange and attention to breaking of social contracts

Environment of Evolutionary Adaptedness (EEA)

- Human behaviour was shaped during our long evolution as hunter gatherers
- Complex behaviours – shaped over long time frame
- *missing*
- Genetic constraints limit or shape learning
- Our brain may be designed to solve the kinds of problems that our ancestors faced when they lived in small foraging bands
    - Subsistence by hunting and gathering
    - Controlled fire
    - Had home bases
    - Shared food
    - Talked, shared cultural beliefs, ideas, and traditions
    - Exploited resources and then moved on
        - You could do that in the past because human population sizes were very small
- If our ancestors lived like this for many *missing*

Language

- Chimps and gorillas can be taught to communicate non-verbally
- "KE" family pedigree showing Specific Language Impairment (Dominant mutation in the FOXP2 gene)
- SLI causes difficulty learning to speak – small vocabulary and poor grammar as adults
- Pattern of inheritance suggests a single dominant gene
- As seen earlier, organic evolution and genetic traits influence behaviour and in this case – language and culture
- Evolutionary changes in genes such *missing*

Shared Human Characteristics

- Inbreeding avoidance
- Birds – typically females disperse farther than males or both sexes "shotgun disperse" after fledging
- Mammals – typically males disperse once reaching maturity (ex – deer mice)
- Breeding with kin increases homozygosity
- Loss of heterozygosity (reduced heterozygote advantage)
- Increased risk of homozygous deleterious recessives (ex – human recessive diseases, PKU, Tay-Sachs disease, cystic fibrosis)
- If you have one copy of sickle cell, you're immune to malaria, but if you have both, you get sickle cell disease
- Incest avoidance is a common trait in humans

Minor Marriages in Taiwan

- Arranged marriage
- Betrothed prospective bride adopted by groom's family during infancy
- If the girl is adopted at less than one year old, the fertility rate is very low
- The younger the girl is adopted into a family where her groom is a sibling, the lower her fertility

- If the girl is adopted at less than one year old, the rate of divorce is much higher

Why does the male peacock have the feathers?

- Why are the sexes so different?
    - They are actually not very different
    - Males have higher testosterone levels
    - Males provide tiny sperm
    - Females provide large eggs
    - Males are generally limited by mate acquisition

However B, C, and D are part of the answer

- Intra-sexual selection
    - Males of most species are generally indiscriminant
- Females get to check out and think about who she will mate with
    - Inter-sexual selection
- Males tend to be competitive and indiscriminant
- Females tend to be coy and choosy
- *Anisogamy* – morphologically dissimilar gametes
    - Female has giant egg, most of the resources for the zygote, sperm just has DNA
    - Females are limited by egg production
    - Males are limited by mate acquisition
    - Males will compete for excess to mates
- What limits reproduction when more than just the gametes are invested?
    - *Parental investment* – investment that increases offspring survival at a cost to the parent's ability to invest in other young
    - Usually the female parental investment is much greater than males
    - Female reproductive success is limited by ability to raise offspring
    - Male reproductive success is limited by access to fertilizable eggs
    - Sexual selection usually acts more strongly on males
        - More male-male competition and ornamentation (female choice)
- *Intra-sexual selection* – within sex *missing*
    - Male elephant seals competing to mate with females
- What happens when male parental investment is greater than female parental investment?
    - Females inject an egg into male's pouch and carries the young and then they are born out of the pouch < seahorses
    - Pipefish – females lay an egg into the male's pouch, male takes care of the eggs until they hatch
        - Male egg brooding takes twice as long than the time for females to produce a clutch of eggs
        - Sex role reversal in a pipefish – in this species males exercise mate choice, favouring large females and females with a larger ventral skinfold ornament
- What limits human reproductive success? Humans are sexually dimorphic
- Moulay Ismail (the bloodthirsty) – emperor of Morocco – fathered 888 children
- The largest amount of children by a female is 69 in 27 pregnancies
- Men tend to desire more "partners" than women do
    - This appears to be cross-cultural
- Female age specific fertility rate – most fertile at 25
- Male age specific fertility rate – around 30, need to be older

- Men generally favour traits that indicate youth (child bearing potential)
- Women generally favour traits that indicate resource acquisition capabilities (resources)
- When males are younger they want older women, but then it switches and they greatly prefer younger females
- Females tend to prefer same age or older males
- Men generally prefer females that are chaste but in China women are more concerned about a potential male's chastity
- Women are more interested in good financial prospects

Sexual Jealousy
Forced choice surveys indicate that:

- Males are most concerned about sexual infidelity
- Females are most concerned about emotional infidelity
- When asked "how much they focused on each type of infidelity" the sex differences disappeared in one study but gained support in others
- More current research supports the human sex differences in jealousy, but indicates individual differences among members of the same sex may be great

- Man is child's father, current mate is child's mother = parenting + mating effort
- Man is child's father, current mate is not child's mother = parenting effort
- Man is not child's father, current mate is child's mother = mating effort
- Man is not child's father, current mate is not child's mother = neither

Among the Hadza people, Grank Marlowe found that:

- When men's mating opportunities (abundance of eligible women) were low they invested more time caring for their genetic offspring
- When eligible women were abundant, less time spent caring for genetic offspring

Patterns of parental care and genetic relatedness

- Some evidence suggests that genetic relatedness is important in decisions about parental care

Child murder is more common by step parents than natural parents

- Study – parents were randomly given many more hours with their child during the first 48 hours as opposed to just a few hours during the first 48 hours after birth
- Statistically significant – those parents with many more hours with their child had less reports of child abuse

Culture is an adaptation that is shared with our common ancestors and seen in other primates.

- Different chimps have different ways of obtaining food by foraging
- Culture allows humans to exploit a wide range of environments
- Inuit people out-lasted the Norse living on Greenland because of their culture that developed in the same environment
    - Example – small kayaks for hunting aquatic organisms
    - Because of cultural differences the Inuit were better at surviving

Culture – information stored in brains that is acquired by imitation, teaching, or some other form of social learning that is capable of affecting behaviour or some other aspect of the individual's phenotype

Meme – a unit of cultural information (belief or value) transmitted by imitation or learning (R. Dawkins)

Culture spreads through the survival and persistence memes in a form of cultural evolution
Cultural evolution does not have to support evolution, some memes may not be adaptive (ie – rock climbing)