BIOL1003 Notes DP - -Contains all the modules -Covers both lecture material as well as textbook

Biology 1: Evolution, Ecology and Genetics (Australian National University)

MODULE 1: EVOLUTION

- Peto's Paradox: Cancer rate in species is not related to the body size or number of cells. Its because of the presence of 20 copies of TP53 gene in elephants i.e. a tumour suppressor, P53 protein produced by this gene repairs the damage or kills off damaged cells.
- 20 MALES/ 20 FEMALES living together causes competition and chimps have bigger testes as compared to harems that live in 1 male/ 4 females group.
- **3 Questions: 1 Answer: Evolution by Natural Selection**
  - **UNITY**: Underlying similarity eg. Number of bones in vertebrae of vertebrates is the same, chemical processes, same protein does the same function in different animals and DNA similarity
  - **Design**: to fit the environment

    Eg- *Uroplatus pietschmanni* (rocky brown to camouflage), Mangroves (half in water),
    Uca mjobergi (crabs with 1 yellow and 1 red arm)- GAME THEORY: smaller less attractive males keep on waving to increase their chance to get a mate vs Larger males that get mates easily.

  - **Diversity**

- Why do we age?
  - Wear and tear
  - Slower metabolic rate
  - Hayflick limits: loss of parts of telomeres
  - Anatgonistic pleiotropy: when one gene controls for more than one trait where at least one of these traits is beneficial to the organism's fitness and at least one is detrimental to the organism's fitness.

Extrinsic and instrinsic mortality: Intrinsic is due to ageing factors and increases with age, and extrinsic is due to environmental factors that have the same likelihood at any time. Both contribute to increase risk of death.

BIOLOGICAL SPECIES CONCEPT: Species are potentially inbreeding nature populations that are reprofuctively iusolated from other such groups and produce a viable, fertile offspring but can't do so with members of other populations.
Eg: Horse and donkey reproduce but form a sterile mule.

Reproductive isolation occurs but **Hybrid Zones** exist: locations where the **hybrid**offspring of two divergent taxa (species, subspecies or genetic "forms") are prevalent and there is a

cline(the gradual change in certain characteristics exhibited bymembers of a series of adjacent populations of organisms o f the same species) in the genetic composition of populations from one taxon to the other.

Three Domains of Life:

Character	**Bacteria**	**Archae**	**Eukarya**
Circular chromosomes	Y	Y	N
Nucleus	N	N	Y
Organelles	N	N	Y
DNA is given priority while classifying (all information of evolutionary and ancestry present, more reliable information about relatedness)			
Peptidoglycan in cell wall	Y	N	N
Histones	N	Y	Y
Protein Synthesis	Formyl methionine	methionine	Methionine
Type of RNA	One	Several	Several

Phylogenetic trees based on morphology support DNA evidence except in following cases:

- Convergent Evolution:
- Shared derived character loss (evolutionary novelty unique to a clade)
- Shared ancestral traits persist (originated in ancestor of taxon)

Molecular Clock: Assumes constant rates of evolution in some genes to estimate the absolute time for evolutionary change. Nucleotide substitutions are proportional to the time since they last shared a common ancestor.

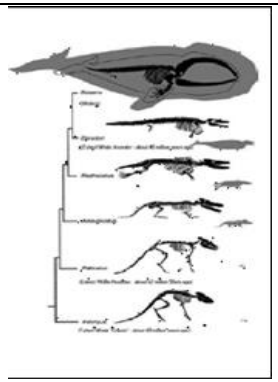
EVIDENCE FOR EVOLUTION:

1.) **Fossils:**

(a) **Extinct species:** sedimentary layers formed in Earth, upper layers are more recent organisms. 99 % organisms that existed millions of years ago are now extinct. New species are continuously being formed and replacing the older ones. (i)Radioisotope dating:
A method for determining the age of an object based on the concentration of a particular radioactive isotope contain edwithin it and the half-life of that isotope. It was found that according to these calculations 1 yr = 400 days which is because of the tides that slow down the rotation of Earth.
(ii) Coral Counting: Corals have daily growth rings There are annual cycles too Count rings in fossil corals.

(b) **Number:** of species is increasing with time.

(c) **Intermediates:** missing links exist. Eg: Tiktaalik roseae from land to water are both fish like (gills, scales, fins) and amphibian like (flattened head, neck, robust fin, ribs, sturdier and fewer limb bones) Eg: Archaeopatryx: birds and reptiles, scales evolved into feathers for flight
Eg: Whales evolved quite rapidly (Coyne, 2009) because adapting to life at sea did not require the evolution of any brand-new features - only modifications of old ones, evidence in fossils

1c. Fossils – intermediates	
Whales: No rear legs Paddle-like front limbs Flukelike tail Blowhole (nostril) Short neck Conical teeth Special ears Projections on	

vertebrae	

2.) **Vestiges and Atavisms**

(a) Wings: Kiwi, Ostrich, Penguins

Vestigial Eyes: burrowers, cave dwellers

Pelvis and legs: whales, snails, shortlimbs in dolphins

Humans: appendix, coccyx, goose bumps, ear wiggle

Bed Bugs: wing pads (multiple mating, forced insemination into female genetalia)

(b) Embryology: Ontogeny recapitulates Phylogeny mean that the development of an organism (**ontogeny**) expresses all the intermediate forms of its ancestors throughout evolution (**phylogeny**). Eg: dolphin limb buds

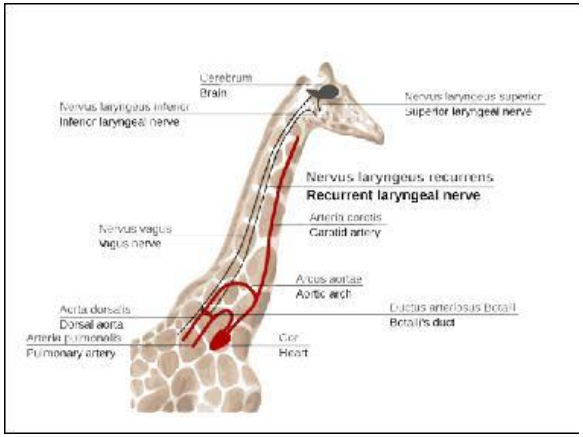
(c) Dead Genes and DNA Fossils: Nonfunctional Pseudogenes (part of chromosome that is an imperfect copy of a functional gene)

Example 1: GLO (L-gulono-ɣ-lactone oxidase) enzyme needed to make vitamin C Missing in primates, fruit bats, guinea pigs

Example 2: Olfactory Receptor (OR) genes- Mice: 1000 (duplicated variants), Humans: 400 expressed, 400 OR pseudogenes Dolphins: 80% inactive

(d) Constraints & Bad Design

(i) Giraffe: Laryngeal nerve due to elongation of neck, travels down the neck, loops around the dorsal aorta near the heart and travels back up the neck to control motor function of larynx muscles.



(ii) Panda**:** has five digits but also has an opposable thumb pad due to an underlying single bone. It is an evolved contraption and not an ideal design i.e. helpful for panda to hold bamboo properly while eating. This anatomy indicates that panda had a meat eating bear ancestry that evolved to eat bamboo.

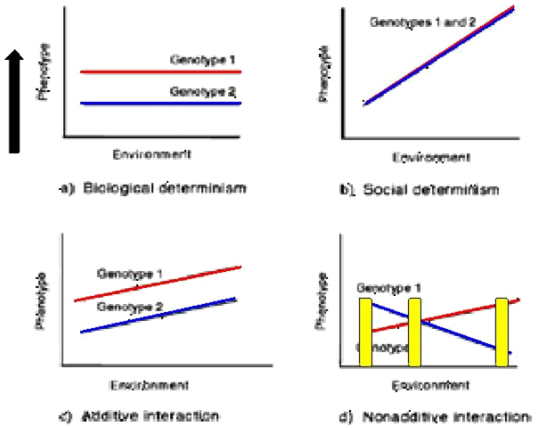
(iii) Flatfish Meme Flounder's Eye: Flatfish are born as normal-looking fish that swim vertically, with one eye placed on each side of a pancake-shaped body. But a month thereafter, a strange thing happens: one eye begins to move upwards. It migrates over the skull and joins the other eye to form a pair of eyes on one side of the body, either right or left, depending on the species. The skull also changes its shape to promote this movement, and there are changes in the fins and color. Evidently, they found it advantageous to tip onto their sides and lie on the sea floor, hiding themselves from both predators and prey. This, of course, created a problem: the bottom eye would be both useless and easily injured. Flatfish are the world's most asymmetrical vertebrates

3.) Biogeography:

(a) Convergent Evolution: Species are often most closely related to others species with which they co-occur, but morphologically similar to organisms from elsewhere due to similar habitats they adapt to similar habits and lifestyle.
Eg: Masupial Australian mole, European mole and African Golden mole
Cacti (America) and Euphorbia(Africa)
*Can be sometimes related due to continental drift: Pipidae Frogs (tongueless frogs)

(b) Oceanic Islands: Missing major taxa in Hawaii – no native fish, amphibians, reptiles and land mammals as they are unsuitable for oceanic islands(Coyne), since introducing such species on these islands destroys or endangers other native species, eg. Pigs and goats overran Hawaiin birds and took over the island.

But increasing endemism due to isolation of oceanic islands which were formed due to continental drift and sea phenomenons that broke it apart from continental mainland. Adaptive radiation is specie diversification due to ecological differentiation (sympatry) between populations of same species that inhabit a particular area like Hawaiin spiders. Crickets in the Hawaiian Islands have the highest documented rate of speciation known, which has been attributed to the role of courtship or sexual behavior in accelerating species divergence.
But this makes the species more vulnerable to extinction due to alien invasion perhaps because it is the most remote archipelago, alien species in Hawaii appear to have taken a much greater toll on the native biota.



(b) Continental Islands: species on some islands resemble mainland fossils.
Darwin studied and compared numerous animals (including his now-famous finches) on islands such as the Galapagos. He pointed out that, although animals and plants that live on islands are often somewhat different from those on the mainland, they still have a closer resemblance to their counterparts on the nearest mainland than to plants or animals on lands further away.

Lamarckism (or **Lamarckian** inheritance) is the idea that an organism can pass on characteristics that it has acquired during its lifetime to its offspring (Inheritance of acquired characters) eg: giraffes long necks to eat

leaves from taller plants.

Genotype(nature) + Environment(food-nurture) = Phenotype(height)

Conditions for Natural Selection:

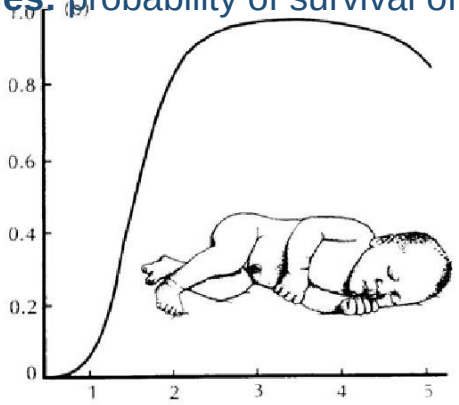
a. Variation in a trait among individuals (replicating units)

b. A consistent relationship between that trait and reproductive success (survival, mating, fecundity)

c. Heritability (parents resemble offspring at least partly unrelated to their common environment)

1. There are differences between individuals that are born and those that breed or reproduce successfully (**within-generation effects)-** selection occurs without evolution

(a)Birthweight of Babies: probability of survival of babies 3-4 kg is higher than both extremes.



(b)CCR5-delta32 mutation

If you inherit two copies of this gene you have almost complete protection from HIV/AIDS high frequency in N. Europe (more in older people as young people will die of the disease sooner).

DARC mutation
Resistance to malaria (parasite doesnot recognize the RBC and doesnot attack it) but susceptibility to HIV/AIDS (mainly found in people from sub-Saharan Africa) (more in younger people)

Hence, depends on the environment, like in Africa where Malaria is more widespread, the advantage of Malaria resistance outweighs the disadvantage of HIV susceptibility and the frequency of this gene increases in that population.

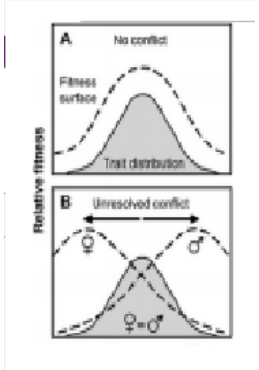
2. If the population is not at equilibrium, there are predictable differences between parents and offspring (**between-generation effects**), fitness (reproductive success) differences are measured by inference from a repeated relationship between trait and possible source of selection.
   (a) Eg 1: Lactase breaks down lactose in milk, lactase enzyme production occurs until lactation period in babies only, in adulthood bacteria in the Large Intestine ferment lactose producing gas and unpleasant feeling in gut.

In Sudan, 80% **Beja people** have lactase persistence (the continued activity of the enzyme **lactase** in adulthood), milk consumption is an important part of their diet hence the frequency of the 'lactase producing' gene increased in this pop. Due to significant selective advantage of lactose absorption whereas 30% **Nilotic people** show absence of lactase persistence alleles, breed cattle, but animals are kept not so much for the production of meat and milk, but rather as symbols of wealth and social standing. both ethnic and socio-economic aspects playing an important role in the distribution of genetic variants.

(b) **Galapagos cactus finch**: endemic species of Galapagos have larger beaks than their relatives, the ground finches. Long, pointed beaks made some of them more fit for picking seeds out of cactus fruits. Shorter, stouter beaks served best for eating seeds found on the ground.

(c) Myoxoma virus: In European rabbits, myxoma virus causes the fulminant disease, myxomatosis, highly lethal killing 99% infected rabbits. Best documented examples of host-virus Co-evolution. Development of resistance was encouraged by the emergence of attenuated (less virulent) virus strains which allowed the survival of moderately resistant rabbits. Resistant rabbits are less effective transmitters of the virus and this may encourage the emergence of more virulent virus strains.

Genetic variations and mutations due to DNA replications and recombination is what natural selection acts upon, not all variations produce a perfect individual, hence no one is in charge!



Sexual conflict or **sexual antagonism** occurs when the two sexes have conflicting optimal fitness strategies concerning reproduction leading to an evolutionary arms race (**evolutionary** struggle between competing sets of co-evolving genes) between males and females.
Some traits are different in males and females, sex conflict results in bias in **sex-specific offspring fitness**, there is a conflicting selection on genes controlling these traits. For instance, males may benefit from multiple matings, while multiple matings may harm or endanger females.

This kind of conflict represents a tug of war between natural selection on both sexes and sexual selection on one sex.

Artificial selection is intentional breeding of plants or animals with desirable traits to produce an offspring with those desired characters. It is goal oriented and always caused by humans.
Eg: *Brassica oleracea (*Apical buds/leaves/inflorescence/stem)

Natural Selection is not goal defined and can sometimes be caused by humans (Biston Betularia: industrial revolution and lichen (pollution indicators) - human induced natural selection)

Co-evolution: the influence of closely associated species on each other in their evolution. Eg- natural selection due to choice of leaf cutter ants that rear fungus.

Types:

1.) **Sexual Selection**
2.) **Balancing Selection – Heterozygote advantage/ Frequency dependent**

3.) **Stabilizing Selection**
4.) **Directional Selection**
5.) **Disruptive selection (ecological niche related):** Favours the extremes and leads to divergent evolution.

Eg- Black bellied seedcracker : small beak for tiny seeds and large beak for big seeds- Birds with large and small bills specialize on different seeds but intermediate sizes die)

Spadefoot toads: Two types- Carnivore and Omnivore. Carnivores have notched beaks and large jaw muscles, which should enable them to prey on fairy shrimp more effectively while Omnivores, by contrast, have longer intestines than either intermediates or carnivores which should enable them to process detritus more effectively. Intermediates struggle and compete for resources with two extreme phenotypes.

Two extreme types can persist due to:

- **Negative density-dependence**: When the density of a population is high (many individuals in a given area), resources are more limited for each individual. Because of this, more individuals will die, fewer individuals will be born, and the population size will decrease and become less dense.

- **Trade-off** : a trade-off exists when **one trait cannot increase without a decrease in another. Eg-** trade-off between the size and number of eggs, time wasted foraging w.r.t. finding a mate, gene of resistance to one disease causes susceptibility to another.

- **Fluctuating selection** (time & space; density): Fluctuating selection is a mode of natural selection characterized by the fluctuation of the direction of selection on a given phenotype over a relatively brief period of evolutionary time. For example, a species of plant may come in two varieties: one which prefers wetter soil and one which prefers dryer soil. During a period of wet years, the wet variety will be more fit and produce more offspring, and thereby increase the frequency of wet-preferring plants. If this wet period is followed by drought, the dry variety will be selected for and its numbers will increase. As periods of dryness and wetness fluctuate, so too does selection on dry-preferring and wet-preferring plants.

Adaptive Radiation
The evolutionary diversification of species or a single ancestral lineage into various forms that each are adaptively specialized to a specific environmental niche.
Eg: Ring species- divergence through time and cut offs

Isolating Mechanisms
Factors that prevent interbreeding between individual– leading to two distinct gene pools (i.e species). Pre and post zygotic barriers: temporal, habitat, pollinators, behavioural, gametic interactions.(refer textbook)

Gene flow: Transfer/ movements of genes between two populations that tends to makes pop. Similar, if too small: they fuse to one population.

Geographic isolation:

(a) Allopatric: geographic separation that prevents genetic interchange (usually sister species)

(b) Sympatric: Evolution of new species from a single ancestral species while inhabiting the same geographic region by substantial reproductive isolation (response to disruptive selection/ sexual selection) forming sister taxa. eg: Howes palms, cichlid fish, plant eating beetles- change in food/mating site

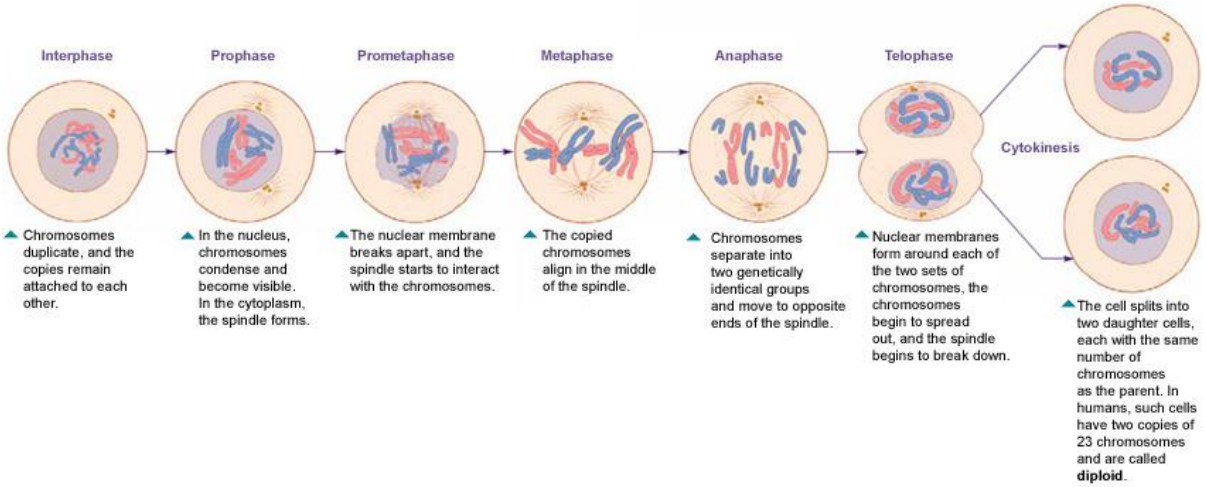
(c) Parapatric: no extrinsic barrier to gene flow present but population does not mate randomly, mate with geographic neighbors than individuals in different part of population range.

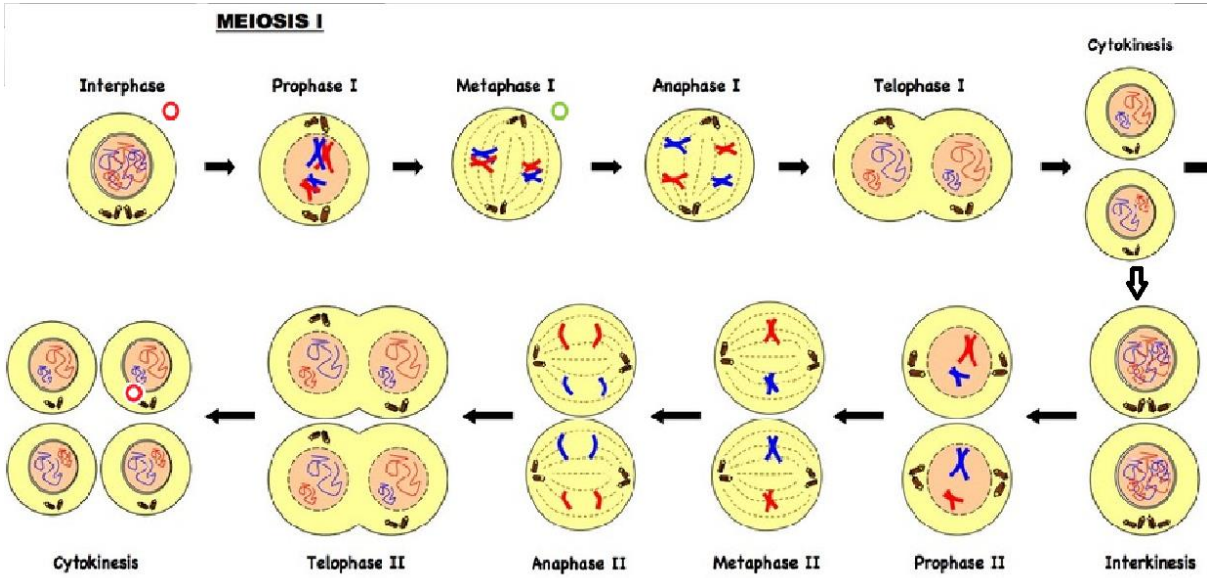
MODULE 2: GENETICS

MITOSIS	MEIOSIS
Equational division	Reductional division
Somatic cells and germ cells	Germ cells only
One division completes the process	2 divisions: meiosis I and II required to complete the process
2 daughter cells formed	4 daughter cells

Diploid no. of chromosomes	Haploid no. of chromosomes
No crossing over and synapsis	Crossing over & synapsis occurs in Prophase I
Daughter cells have the same genetic information as parent cell.	Daughter cells are genetically different than parent cell.
Prophase involves relatively few changes	Prophase I is divided into 5 sub stages
Chromosomes arrange on equator to form a metaphase plate.	Chromosomes arrange equally on either side of equator in Metaphase I.
Sister chromatids separate and centromere divides in Anaphase	Sister chromatids separate and centromere divides in Anaphase II only not in I.
Necessary for normal growth and repair of body	Necessary for sexual reproduction

MITOSIS





MEIOSIS II

Blending Inheritance (DARWIN):

Theory that **inheritance** of traits from two parents produces offspring with characteristics that are intermediate between those of the parents. Eg: Tall + Dwarf = Intermediate ht.

If blending inheritance were true, in this example, all members of a species would eventually converge upon a single value for height for all members. Variation will disappear, every generation should be more uniform than the previous one. By now, all individuals should be as indistinguishable as clones.

Confused with Incomplete Dominance:

Blending inheritance is similar to the modern legitimate idea of incomplete dominance and the terms are rarely, but incorrectly, used interchangeably by some. However, incomplete dominance results in blending only of the phenotype, keeping the alleles within the heterozygote distinct (and, thus still inheritable in successive generations), whereas the theory of blending inheritance referred to an actual blending of the genetic material (i.e. in modern terms, alleles would blend together to form a completely new allele).

Mendel's Laws of Inheritance:

(i) **Law of Segregation:** two alleles for a heritable character segregate during gamete formation and end up in different gametes.

(ii) **Law of Independent Assortment:** each pair of alleles segregate independently of each other during gamete formation. Only applies to genes located on homologous (different) chromosomes.

Complete dominance: in a heterozygote with two different alleles, only one allele is expressed phenotypically.

Incomplete Dominance & Co-dominance: depends on level at which phenotype is analysed.

Tay Sachs is a recessive autosomal disease, hence heterozygotes are not affected but have intermediate phenotype in the activity level of lipid metabolizing enzyme. At *biochemical level,* seems like incomplete dominance of either allele, since half the normal enzyme activity is sufficient to prevent lipid accumulation in the brain. At *molecular level*, both functional and dysfunctional enzymes are produced indicating co-dominance.

Epistasis:

Phenotypic expression of a gene at one locus alters the gene at second locus. Eg: gene for coat colour is dependent of gene for pigment deposition, gives different ratios than expected mendelian ratios.

Chromosomal Theory of Inheritance (Sutton & Boveri):

Mendelian genes have a specific loci along chromososmes and it is the chromosomes that undergo segregation and independent assortment.

Barr body: inactived X chromosome (active XIST gene causes methylation of N-bases) in females during embryonic dev. And reactivated during gamete formation, otherwise females may make twice as many proteins encoded by X-linked gene.

Genetic drift:

Random change in allele frequencies over time, caused by chance alone. Minor effect in large population but significant effect in small population size.

Small Population (25 stoneflies)	**Large population** (500 stoneflies)
Size of population kept constant to 25 for 50 generations.	Size of population kept constant to 500 for 50 generations.
Alleles become fixed or lost even in absence of selection.	Alleles neither become fixed nor are lost. Magnitude of drift is much less in each generation
Faster decline in heterozygosity due to increase in frequency of one of the alleles, but chance dictates which allele becomes fixed or lost. Low-frequency alleles face a higher probability of disappearing from a population than alleles that occur at a higher frequency.	

Genetic Disorders

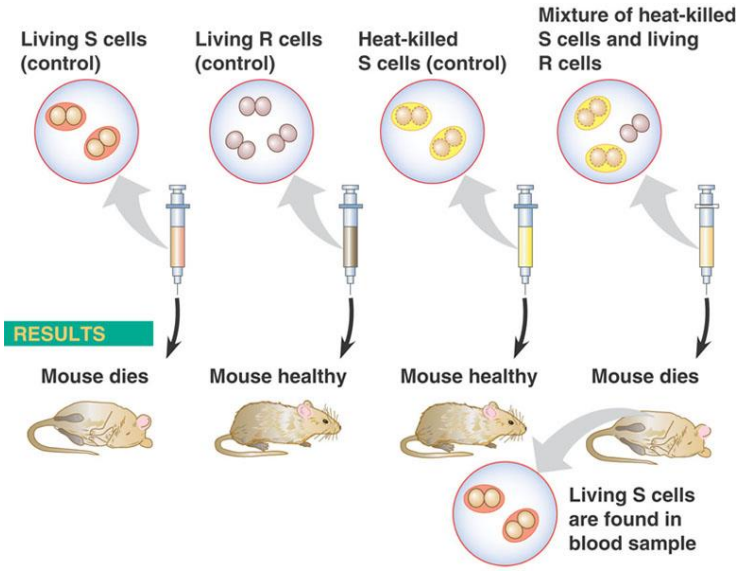
Autosomal Recessive	Sex-linked Disorders	Autosomal Dominant
*Cystic Fibrosis: Pleiotropy- single gene responsible for many char. of org.	Haemophilia: Absence of proteins reqd. for blood clotting	Achondroplastic dwarfism
Phenylketonuria: Phenylalanine hydroxylase not produces to metabolize phenylalanine converted to phenyl pyruvic acid and its accumulation.	Colour blindness:	Huntington's disease: Late onset after 45 years Deteoration of nervous system leads to motor disturbances Psychological disturbances
Albinism: Block in the phenylketonuria pathway due to which pigment melanin is not produced.	Muscular dystrophy: Progressive weakening of muscles (absence of key muscle protein dystrophin)	
Beta thalassemia: Reduced production of beta chain of haemoglobin caused due to mutations at 8	Fragile X-syndrome	

different positions on same gene as sickled mutation.		
Sickle cell anaemia: Some cells are sickle shaped, Oxygen molecules cannot bind to that cell as biconcave shape is missing. They accumulate clogging arteries leading to serious conditions.		
Tay Sachs disease: Brain cannot metabolize certain lipids because a crucial enzyme does not work. Lipids accumulate in brain cells, child suffers seizures, blindness, and degeneration of mental and motor performance causing death within a few years.		*Cl- ions are not transported from extracellular fluid in to cells due to gene defect, accumulation causes thick sticky coating of mucus around certain cells of pancreas, lungs, GIT- poor absorption, chronic bronchitis, bacterial infections.

Inheritance Pattern of genetic disorders

Autosomal Recessive	Sex-linked Disorders	Autosomal Dominant
Generations are skipped	Generations are skipped	Generations never skipped
Males & females affected equally	Occur entirely and primarily in males	Males & females affected equally

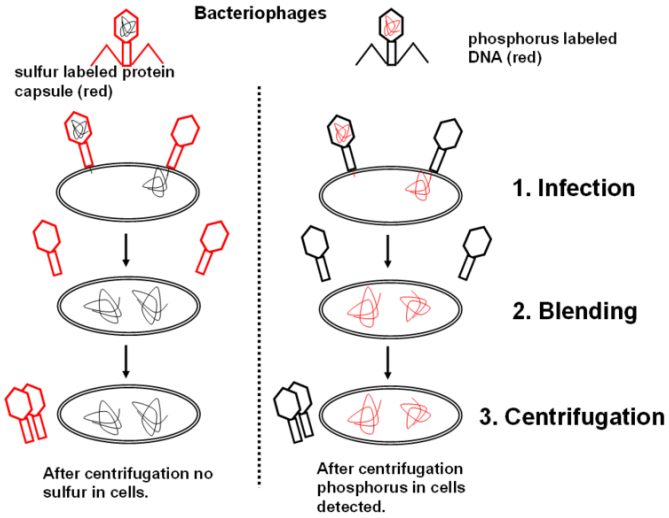
Consanguineous marriages expose harmful recessive alleles.	Passed from mother to son	



Griffith's Experiment

Transformation: Genetic alteration of a cell resulting from direct uptake and incorporation of exogenous genetic material from surrounding or a dead relative through cell membrane.

Avery, McLeod & McCarty showed that only digestion of DNA by nuclease does not cause transformation, hence it is the transforming principle.



Hershey-Chase Experiment: established that DNA is the transforming principle. Button material radioactive that causes infection in bacteria by T2 bacteriophage.

Chargaff's rules:

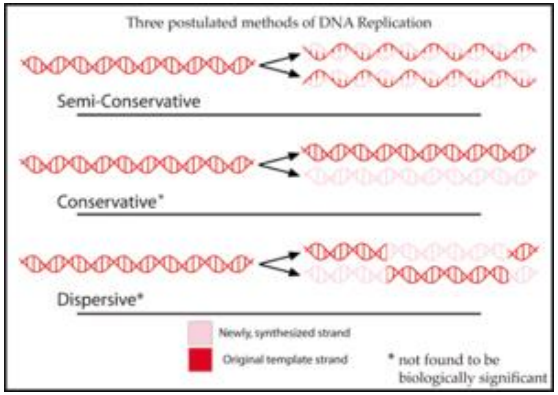
(i) The base composition varies between species
(ii) Within a species, the number of A and T is equal to the number of C and G

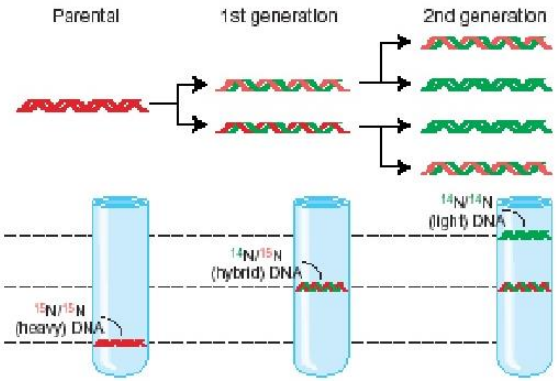
Franklin's X-Ray diffraction DNA data indicated:

(i) a sugar phosphate (negatively charged) backbone joined by phosphodiester bonds and hydrophobic N-bases towards the interior of molecule.
(ii) Helix makes 1 full turn every 3.4 nm along its length i.e. bases are stacked 3.4 A apart.
(iii) A=T and C=_G bonds gives stability to the molecule.

Watson & Crick with the help of X-ray diffraction data of DNA by Franklin and Wilkins discovered the double helix model with 2 antiparallel strands. Purine-purine pair is too wide and pyrimidine- pyrimidine pair is too narrow for 2 nm diameter of double helix, hence A-T, C-G for uniform diameter.

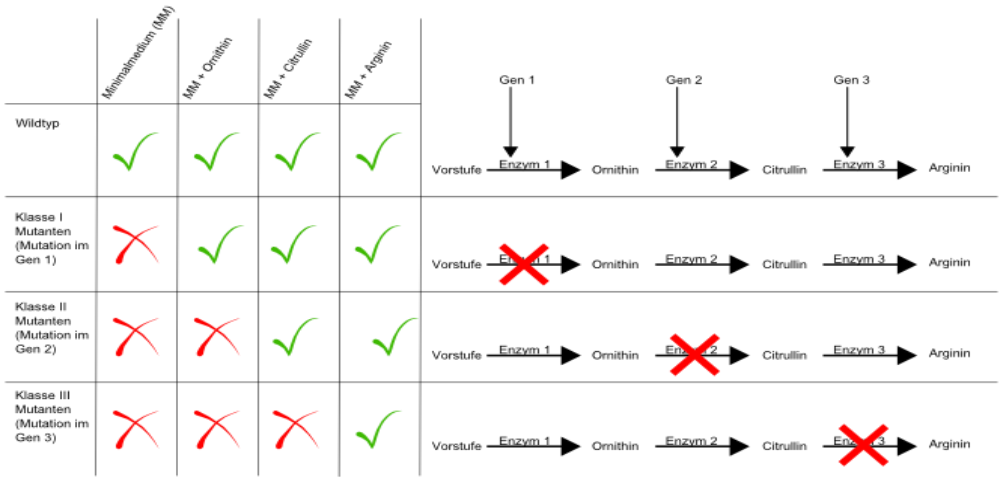
Meselson-Stahl Experiment: Semiconservative nature of DNA





DNA cultured on heavy N^{15} isotope and then transferred to lighter N^{14} isotope medium.

Beadle & Tatum Experiment:



1.) Bread mould fungus *Neurospora* bombarded with X-rays to form mutants that differed in their nutritional requirements.
2.) Wild-type can survive on Minimal medium (sugars and inorganic ions) as it is prototrophic and can synthesize all required organic molecules for growth. Mutants could not survive as they could not synthesize essential molecules from minimal ingredients.
3.) All mutants could grow and survive on Complete growth medium (MM + 20 AA + nutrients).

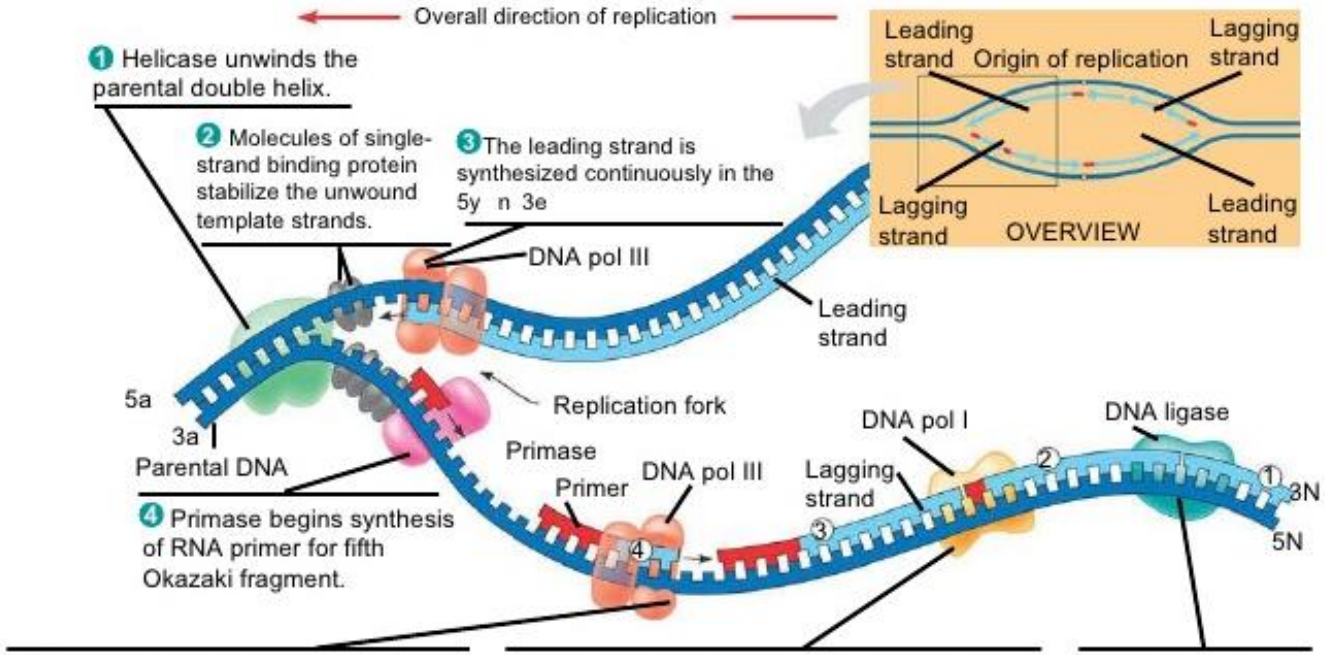
4.) All those defective in arginine biochemical pathway were collected. Mutants were allowed to grow on medium with MM + one additional nutrient of arginine pathway.

This defect included mutation in 3 different genes that block the pathway at different steps due to lack of enzyme at that particular step. **One gene, One Enzyme** hypothesis.

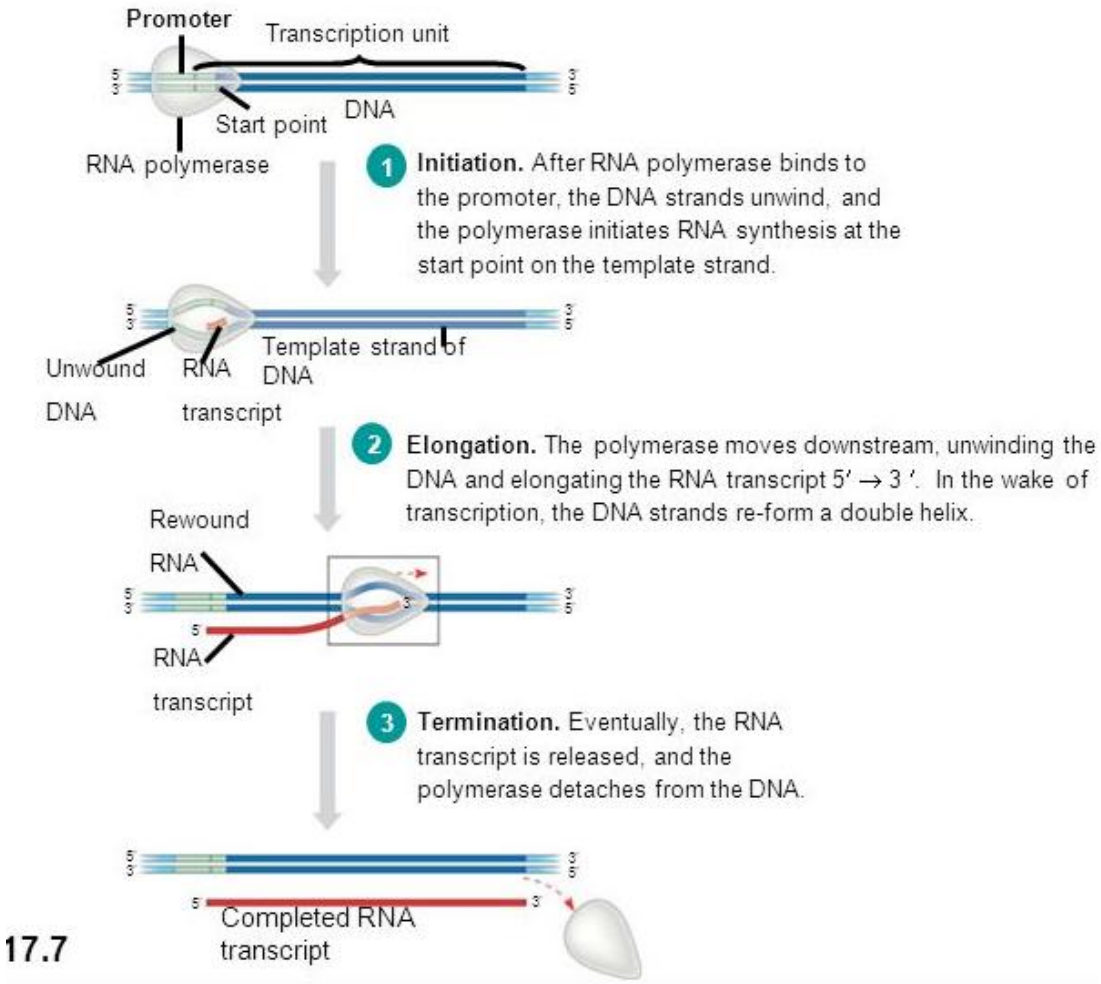
RNA	**DNA**
Single stranded	Double stranded
Ribose sugar	Deoxyribose sugar
Adenine, guanine, cytosine, uracil	Adenine, guanine, cytosine, thymine
Purine is not = to pyrimidine	Purine = pyrimidine
Hair pin and lollipops like structure	Complementary base pairing throughout the length of double helix
Genetic material of some viruses.	Genetic material of all living organisms.
3 types: mRNA, tRNA, rRNA	Occurs in one form only

DNA Replication (Nucleus)

- # A summary of DNA replication



RNA Transcription (Nucleus)



Initiation: Collection of protein- transcription factors bind to promoter and facilitate the binding of RNA polymerase

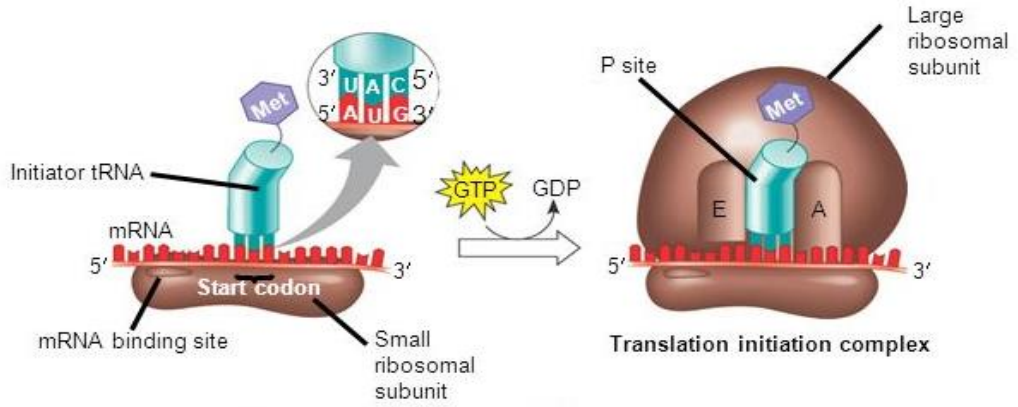
Elongation: unwinding exposes DNA nucleotides to add RNA nucleotides by complementary base pairing and form mRNA molecule which keeps on peeling out from its DNA template.

Termination: Terminator sequence in bacteria causes mRNA transcript to detach at terminator region and fall off.

Splicing: Non-coding introns are separated and degrade rapidly, coding regions exons eventually expressed are joined together by spliceosomes.

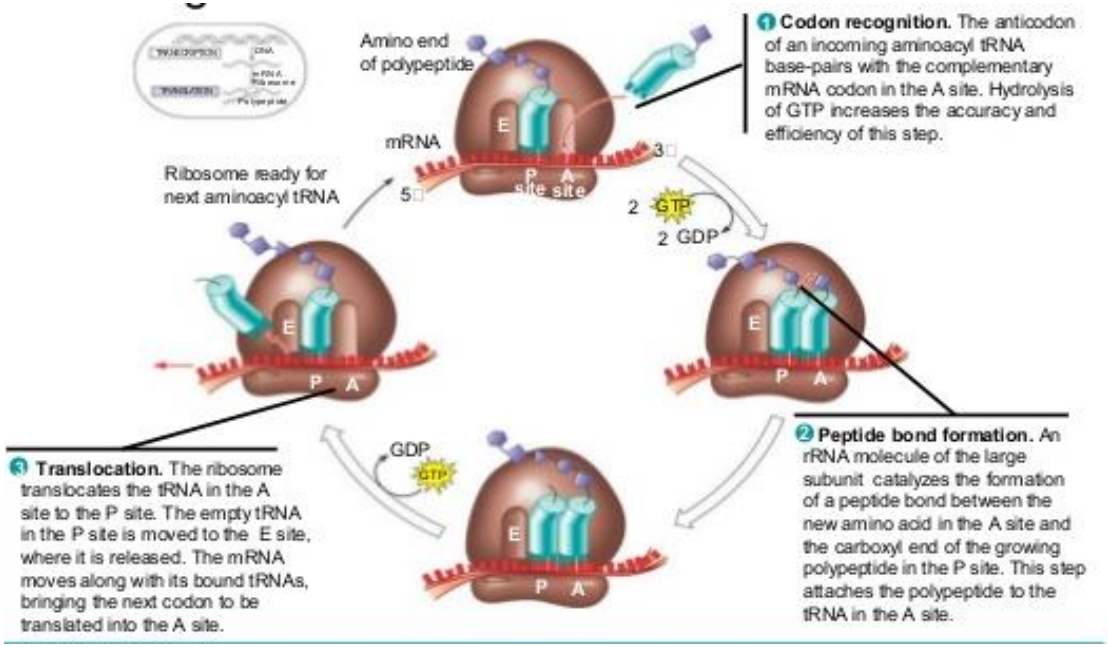
PROTEIN Translation:

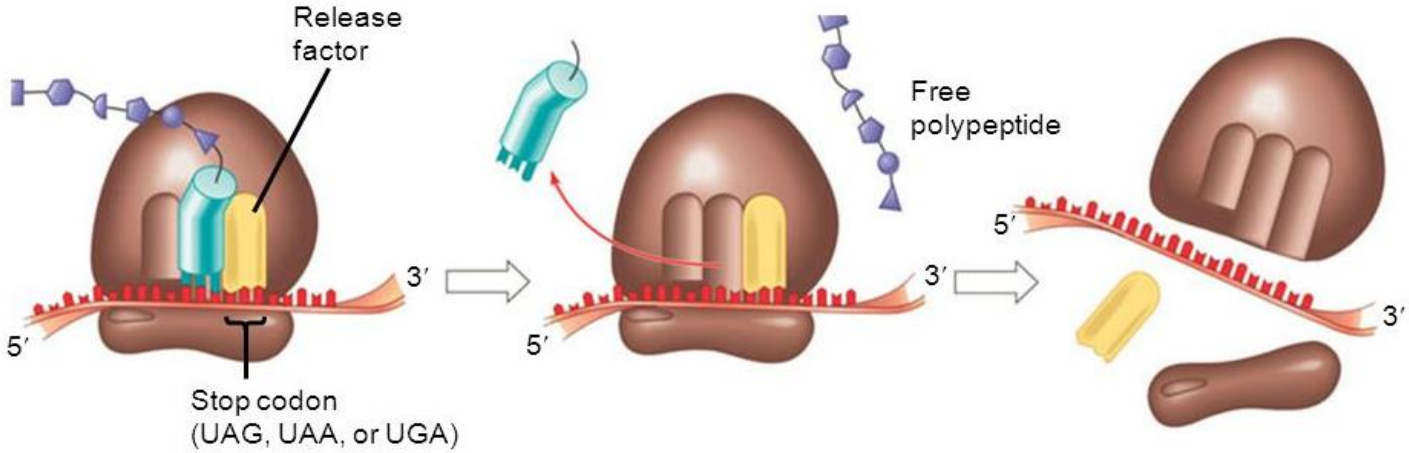
1.) Amino acetylation of t-RNA: AA + t-RNA + ATP = AA-tRNA + AMP + Pi



1. A small ribosomal subunit binds to a molecule of mRNA. In a prokaryotic cell, the mRNA binding site on this subunit recognizes a specific nucleotide sequence on the mRNA just upstream of the start codon. An initiator tRNA, with the anticodon UAC, base-pairs with the start codon, AUG. This tRNA carries the amino acid methionine (Met).

2. The arrival of a large ribosomal subunit completes the initiation complex. Proteins called initiation factors (not shown) are required to bring all the translation components together. GTP provides the energy for the assembly. The initiator tRNA is in the P site; the A site is available to the tRNA bearing the next amino acid.





1. When a ribosome reaches a stop codon on mRNA, the A site of the ribosome accepts a protein called a release factor instead of tRNA.
2. The release factor hydrolyzes the bond between the tRNA in the P site and the last amino acid of the polypeptide chain. The polypeptide is thus freed from the ribosome.
3. The two ribosomal subunits and the other components of the assembly dissociate.

MODULE 3: ECOLOGY

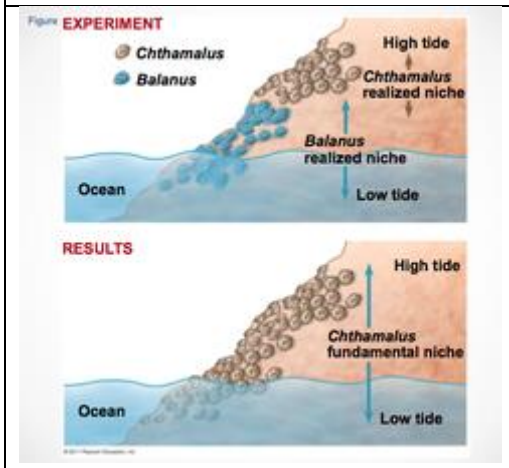
ECOLOGY

Biogeography: geographical distribution of plants and animals through space and time.

Biome: a large naturally occurring community of flora and fauna occupying a major habitat, e.g. forest or tundra.

Habitat: the natural home or environment of an organism.

Niche: An ecological niche is the role and position a species has in its environment; how it meets its needs for food and shelter, how it survives, and how it reproduces. A species' niche includes all of its interactions with the biotic and abiotic factors of its environment.

Fundamental Niche	Realised Niche
Possible distribution of an organism determined by its **evolutionary history.**	Actual distribution of the organism limited by interactions with other organisms (predation, competitive exclusion).
OR Entire set of conditions under which an organism can survive and reproduce itself.	
	Interspecific competition for the same resource between two species of barnacles: Balanus was a more successful competitor in the lower intertidal zone but could not survive in the upper zone that experienced so much dessication. It eliminated Chthamalus which shifted it's population from it's fundamental niche to the high tide area that became it's realised niche.

Population Dynamics: Study of **size** and **age** composition of a pop. And the biological and environmental processes driving them (birth, death, immigration rates).

Mala was once widespread throughout the arid and semi arid parts of central and western Australia but became nearly extinct during 1930s and 1950s due to hunting (he Mala is a key mythological symbol of Aboriginal peoples and was a favoured food) and environmental changes. Now it is limited to a few captive colonies and reintroduced populations.

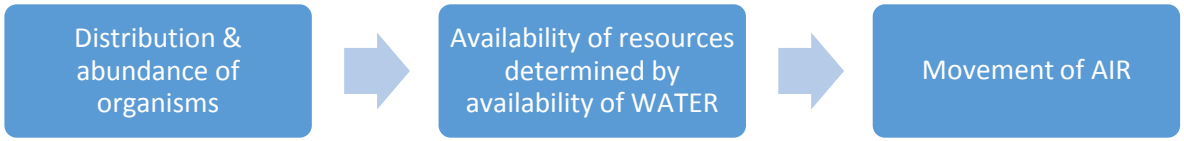
Cane toad was only found in Central and South America, introduced as a predator against cane beetles in Queensland (bio-control). Population explosion- around 1.2 million sq. km because they have no natural enemies in Australia, their toxin can kill most native animals that feed on frogs (poison glands behind eye sockets). This species puts both flora and fauna of Australia in danger.

Antarctic Krill – abundant distribution in Antarctic ocean as they feed on highly abundant phytoplanktons.

H5N1 is a highly pathogenic type of influenza virus that causes a highly infectious, severe respiratory disease in birds called ***avian influenza*** (occurs in conjunction with HDV- hepatitis D) which lead to a rapid decrease in poultry popultaions, hence they were vaccinated.

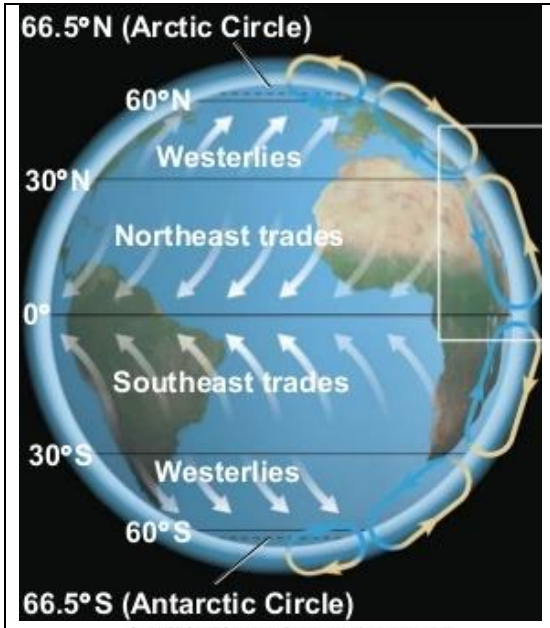
Suraj	Savanna	Dar	Desert	Ta(4)	Tropical forest, Temperate grasslands, Temperate broadleaf forest, Tundra
Caa	Coniferous forest	Haath (2)	Healthlands, High mountains	P	Polar ice

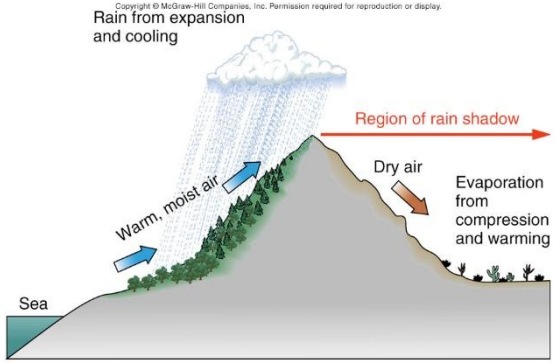
CLIMATE: Temperature, Sunlight, wind and precipitation, physical properties of air, water, rotation of earth and incidence of sunlight.



Principles of AIR:

- **Hot air carries more water than cold air** eg: when it is breathed out from body (37 C) to lower outside temp. it precipitates into water.
- **Hot air moves up and cold air moves down**
- **Hopkins' bioclimatic Law:** Air cools as it rises (1 C cooling is same as about traveling 100 km towards the nearest pole but achieved by 180m elevation increase instead, eg. climbing Telstra tower is like moving towards South pole)
- **Coriolis effect:** Longitudinal movement (air) on a rotating object (earth) results in apparent latitudinal drift (air).



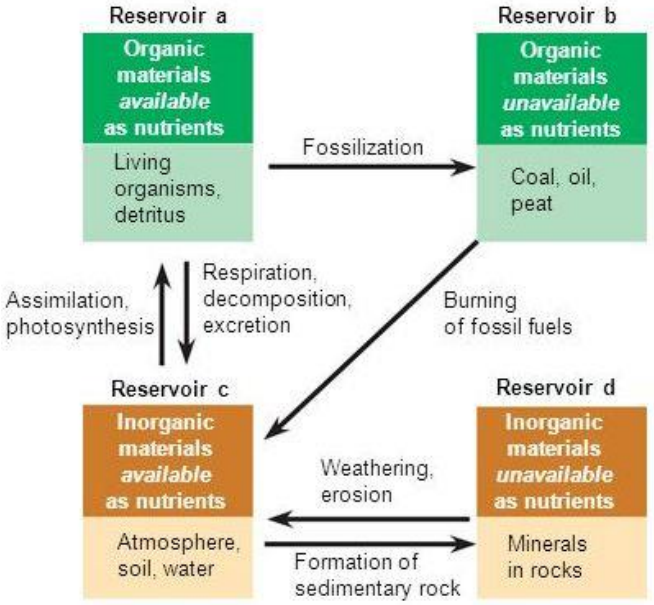


Earth's curvature causes **latitudinal variation in the intensity of sunlight**. More heat/ light per unit surface area is delivered in the tropics and at oblique angles on higher latitudes. **Global air circulation and precipitation patterns** are set up. Higher temperature in the tropics evaporate water from earth's surface causing warm wet air masses to rise which then releases much of its water content – abundant vegetation (green landmasses). The high latitude dry air masses descend and absorb all the moisture from land creating arid climate (deserts) at 30 N & S. Some of this wet air mass moves towards the poles and release abundant precipitation (< tropics) at 60 N & S. Some of this cold dry air flows to the poles and then descends back to the equator absorbing moisture and creating rainless and bitterly cold climates in polar regions.

As Earth rotates on it's axis at about 40,000km/day and almost 0 at poles, wind movement is fastest at equator (2πr greatest- highest velocity) deflecting winds from vertical paths and creating Easterly and Westerly winds.

Rain Shadow: When warm moist air approaches the mountain, air rises and cools releasing moisture on windward side. On leeward

	side, cool dry air descends absorbs moisture away producing a rain shadow (determines where deserts are found- eg. Gobi desert Asia).



Energy Transfer:

PHOTOSYNTHESIS-

$H_2O + CO_2 + light > glucose + O_2$

CELLULAR REPIRATION-

$Glucose + O_2 > H_2O + CO_2 + ATP\ energy$

ATP production depends on air and water availability.

Limits to Primary production:

LAND: water and temperature

SEA: light and CO_2

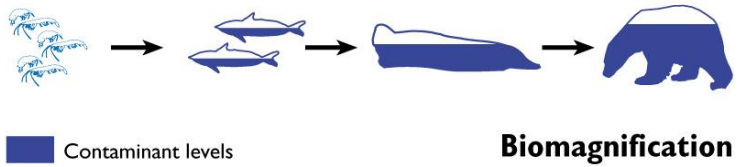
Net Prodn. = Gross Prodn. – Respiration

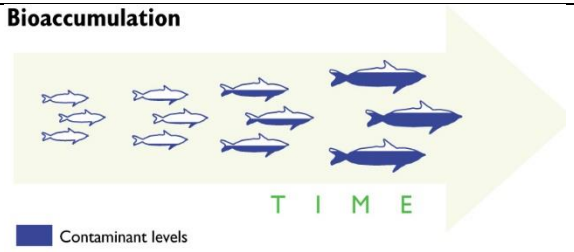
<u>Ecological Efficacy</u> determines **ABUNDANCE.**

	• Growth- energy assimilated as biomass • Waste production- highest in herbivores as indigestible energy • Cellular respiration- heat energy (wasted highly in homeotherms eg. humming bird).

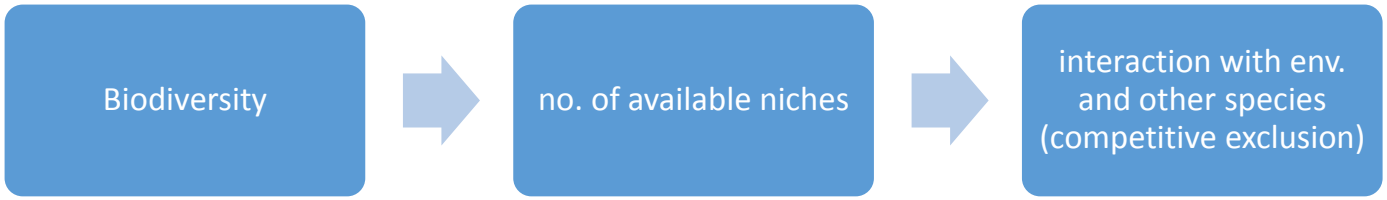
10 % law: During the transfer of energy from organic food from one trophic level to the next, only about ten percent of the energy from organic matter is stored as flesh. Rest of the energy is dissipated as heat, waste products, during growth and repair of body.

BIOMAGNIFICATION	BIOACCUMULATION
the increase in concentration of a toxic chemical as one goes higher up through the trophic levels of the food chain	Accumulation of a toxic chemical in the tissue of a particular organism
Organisms on multiple trophic levels involved	Organisms on a single trophic level
Many small fishes > few large fishes > Whale	A fish population feeding on the same plant species containing toxic substance which accumulates over time.



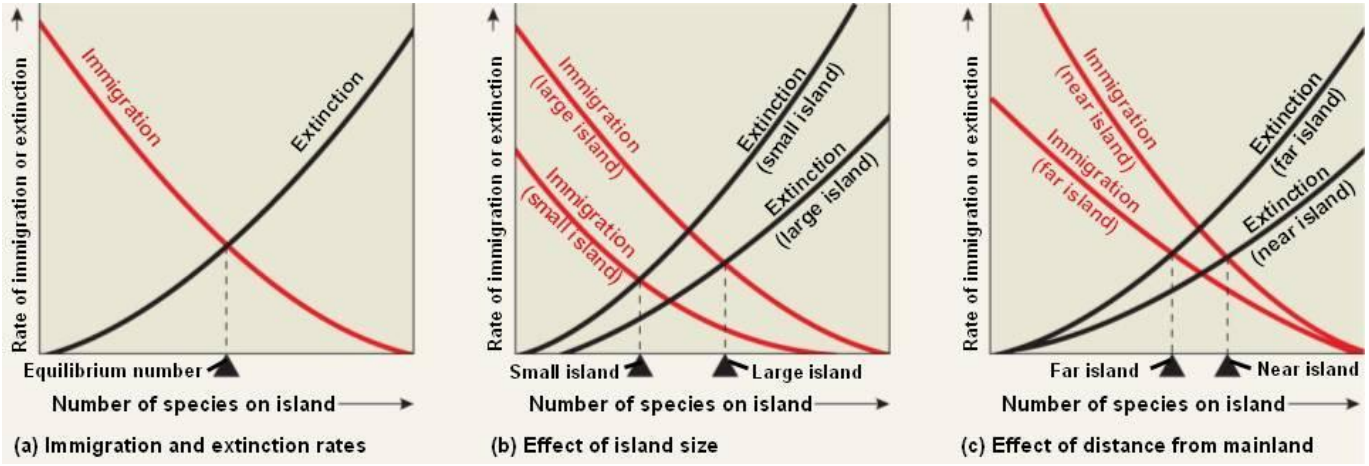


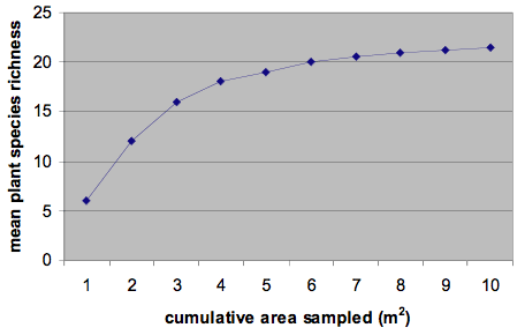
Toxic substances are accumulate bacause: (a) body can't eliminate them, (b) actively retained (mistaken as some other substance)



Wallace Line: line that separates the ecozones of Asia and Wallacea, a transitional zone between Asia and Australia. West of the line are found organisms related to Asiatic species (primate dominated); to the east, a mixture of species of Asian and Australian origin is present (marsupial dominated).

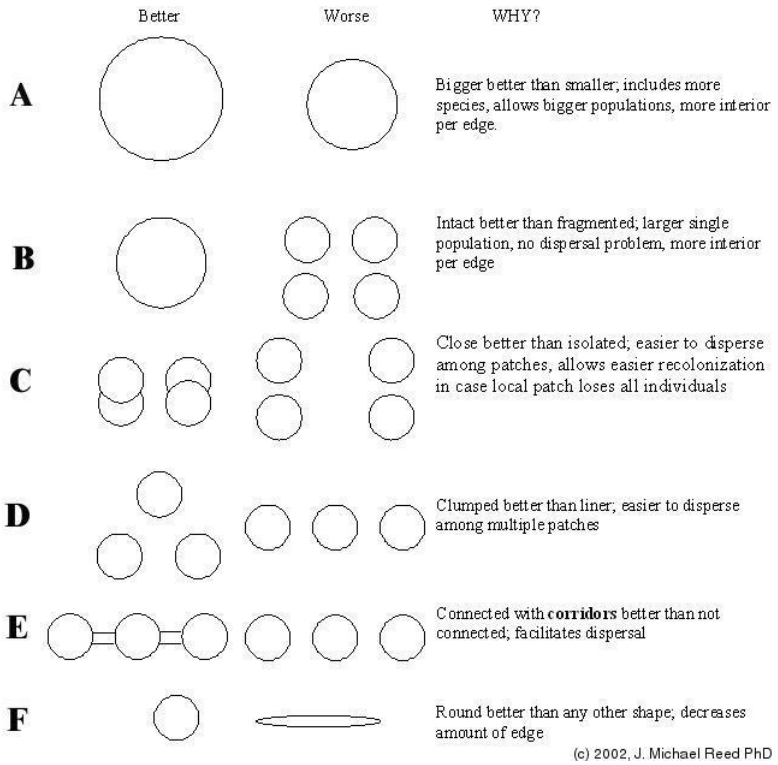
Island Equilibrium Theory: Specie diversity on islands will represent a dynamic balance between the probability of successful colonisation by new immigrant species and extinction of existing resident species.





Species-area curve (Von Humbolt) is a relationship between the **area** of a habitat and the number of **species** found within that **area**. Larger **areas** tend to contain larger numbers of **species.**

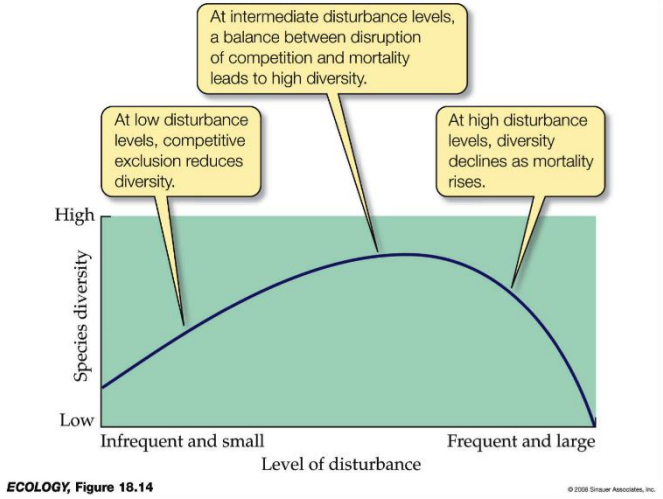
SLOSS Debate- Design of conservation Reserves



GENERALISTS	SPECIALISTS
A **generalist species** is able to thrive in a wide variety of environmental conditions and can make use of a variety of different resources.	A **specialist species** can only thrive in a narrow range of environmental conditions or has a limited diet.
	Ecologically more efficient at the cost of having a more restricted fundamental niche.

	Outcompete generalists when resources r ample.
Sanderlings	Avocets, Curlews, Spoonbills, Wrybills

Intermediate Disturbance Hypothesis:

	Local species diversity is maximized when ecological disturbance is neither too rare nor too frequent. OR Diversity will be highest when interference prevents competitive exclusion but is of low enough intensity/ frequency to allow species to prosper. **Disturbances:** • Predation: the preying of one animal on others • Competition for resources

Keystone species: are the species having the largest no. of significant interactions and are considered as maintaining the diversity of ecosystems. They can have disproportionate effects on other organisms.

High amount of algal bloom consumed oxygen depleting its availability under the sea for aquatic organisms. Menhaden was introduced that fed upon phytoplanktons and became a keystone species. To control their population, they were hunted commercially for Omega 3 production.

Prairie dogs are the keystone species in America. They were hunted and removed due to over population growth, they competed for the same food source as cattle (grasses, sedges, (flowering plants, roots and seeds) causing depletion of food sources. Even after removal, food sources kept on depleting hence they were reintroduced after their importance was realised. They are "keystone spp." as they create islans of habitats that benefit around 150 other species:

- help aerate and fertilize the soil, allowing a greater diversity of plants to thrive, hence more productivity of food source.
- Food sources for other species (coyotes, eagles, badgers and critically endangered black-footed ferrets)
- Many species, like black-footed ferrets and tiger salamanders, use their burrows as homes.

Interactions drive Diversity: Diverse communities are better as they have more niches available and tend to be more resilient to changes over evolutionary time (less likely to loose species in long term)

COMPETITIVE EXCLUSION: the inevitable elimination from a habitat of one of two different species with identical needs for resources.

RESOURCE PARTITIONING: occurs when species divide a niche to avoid competition for resources

CHARACTER DISPLACEMENT: Character displacement is an evolutionary divergence that occurs when two similar species inhabit the same environment. In this instance, natural selection favours those organisms that develop modifications (either behavioural, morphological, or physiological) that reduce their competitive pressures for resources, thus increasing their chance for survival.

Dispersion: Range/ distribution of an organism in an area

Dispersal: immigration of individuals or seeds from one site to a breeding or growing site.

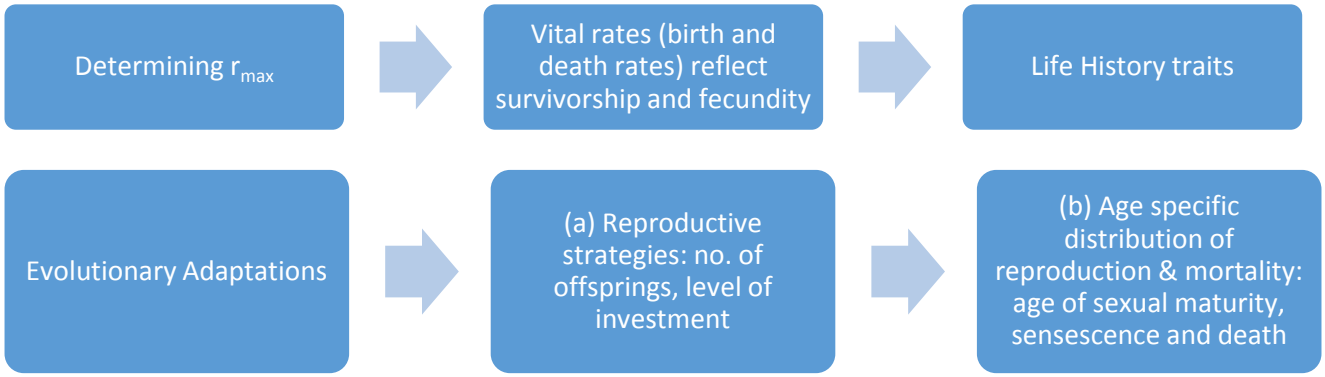
CLUMPED	REGULAR/ UNIFORM	RANDOM
Individuals live in areas of high local abundance, separated by areas of low abundance	Individuals uniformly spaced through the environment	Equal probability of an individual to occur anywhere in an area
Attraction b/w individuals, or towards a common resource	Antagonistic interactions b/w individuals , local depletion of resources	Neutral interactions between individuals and with environment
		
starfishes	King penguins	dandelions

Factors that affect Population growth:

- Growth rates: birth/ immigration and death/ emigration
- Exponential (phytoplanktons) and Logistic growth (paramecium)
- Carrying capacity (K) determined by interactions.

Intrinsic growth rate (no extrinsic limiting factors) for exponential growth: $dN/dT = r_{max}N$

$$\frac{dN}{dt} = rN\left(\frac{K-N}{K}\right)$$ When extrinsic factors (competition, predation) are considered.



Types of Survivorship

TYPE I	TYPE II	TYPE III
Mortality accelerates with age i.e. low death rates during early and middle life, increases steeply in old age	Constant death rate throughout the life span	High death rate for young ones but curve flattens out i.e. detah rates decline for those few individuals that survive
Large mammals that produce few offsprings- Humans	Belding's ground squirrels, some rodents and lizards	Marine invertebrates and fishes that produce large no. of offsprings but provide little or no care

Iteroparity	Semelparity
A species is considered **iteroparous** if it is characterized by multiple reproductive cycles over the course of its lifetime.	A species is considered **semelparous** if it is characterized by a single reproductive episode before death.
Primates	Antechinus (males die after mating)

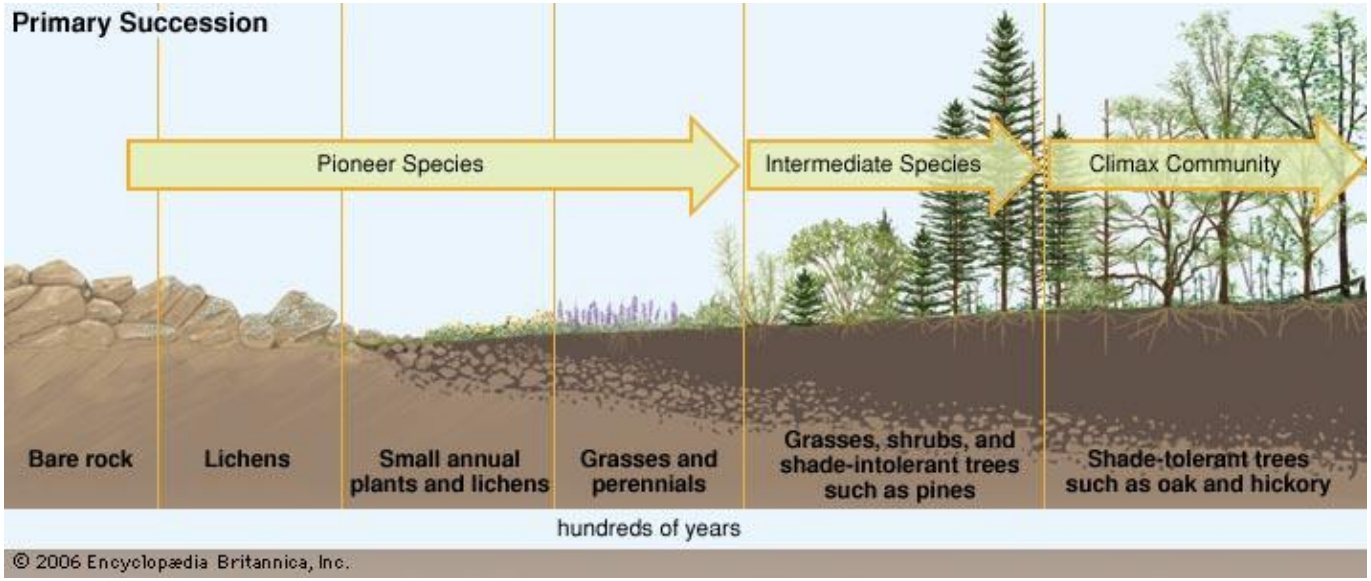
1080 poison used in NZ to control possum populations to protect native species. The use of 1080, a pesticide using sodium fluoroacetate, is a contentious issue in New Zealand, with the majority of the debate occurring between conservationists and hunters. Gastrolobium celsianum is an active ingredient in the pest control ***toxin.***

Optimising Reproduction

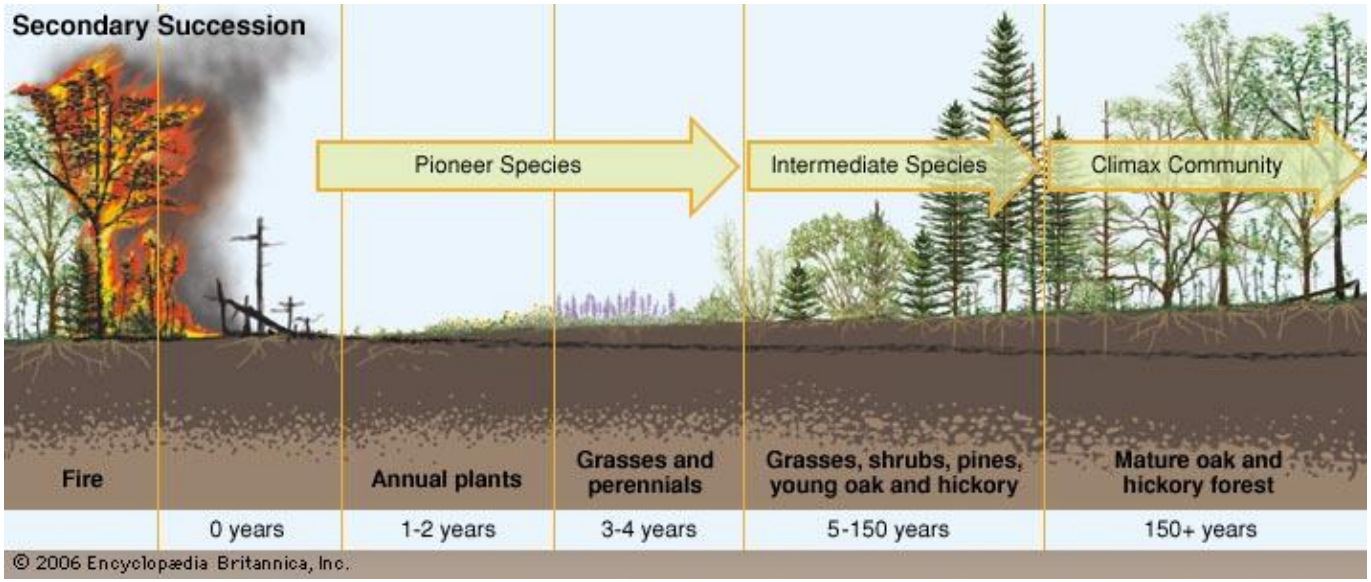
1. When resources are limited, an increase in reproductive effort leads to somatic costs eg: Tequila plant propagate without flowering, phylodes 2m long, fruits produced by plants to attract pollinators, major crop plants breed to produce large number of seeds and then die.
2. These somatic costs reduce future fecundity.
    - chosen when growing big is risky i.e. risk of predators,
    - when there is no going back, eg: salmons experience a lot of physiological changes in transition from marine (grow up all their life) to fresh water (to mate) and eels that go from freshwater to marine water.
3. There is a trade-off between current reproduction and residual reproductive value.
4. This trade-off is optimised by Natural selection

Ecological succession is the observed process of change in the species structure of an **ecological** community over time.

Primary Succession occurs in an environment lacking soil, devoid of vegetation and other organisms such as a lava flow or area left from retreated glacier. The organisms that engage in primary succession are known as pioneer species. Typical pioneer species include simple **lichens**, **algae**, and fungi. These simple organisms begin breaking down the resources in the environment and make it suitable for the later introduction of more complex species, such as vascular **plants**.



Secondary succession is the series of community changes which take place on a previously colonized, but disturbed or damaged habitat. Examples include areas which have been cleared of existing vegetation and destructive events such as fires.



MODULE 4: BEHAVIOURAL ECOLOGY

INHERITANCE OF BEHAVIOUR

Species	Observation	Aim	Method	Results	Conclusion
Snowshoe hares	Snowshoe hares change their fur colour from brown (Summer) to white (winter).	Observing the change in hair colour from Summer to Winter coats in Snowshoe hare populations	Observe survival rates of snowshoe hares that are placed in a winter environment after being kept in a warm environment to maintain brown hair colour, and compare this to normal winter hair colour (white) survival rates	White haired individuals survive whilst brown don't as they are predated by lynx's	Proves that animals can change due to temperature/time/day length to increase survival.
Blackcap birds	In winters, blackcaps migrate from their breeding grounds (Europe) to Africa. The pop.s nearer to the equator partially migrate while those residing in Europe fully migrate. The direction of migration of blackcaps is influenced so as to avoid the Alps,	To study the heritability of migration behaviour by (a) looking at the correlation between parents and offspring, (b) cross-breeding	Young ones from German (Western Europe) and Austrian (Eastern Europe) Blackcap populations were isolated and raised in isolation (captivity) without parental influence and tested for migratory behaviour	Off-spring showed the inheritance of migratory behaviour and followed the same pattern as the original population even after isolation: (a)Urge to migrate (b)Direction (c) Distance	Migratory behaviour is heritable.

	Mediterranean sea and the Sahara desert in Africa. <u>Early direction of migration (Oct):</u> German pop.s heads SW Austrian pop.s head SE <u>Late direction of migration (Nov):</u> German pop.s continue SW Austrian pop.s head South		in a cage with funnel walls. (a) Footprints observed to record the direction of migration. (b) no. days of restlessness to measure the duration of migratory behaviour. <u>Cross breeding</u> between Austrian and German populations to produce intermediate offspring and studied for direction of migratory behaviour	This behaviour follows polygenic inheritance hence hybrids of both populations are intermediates that head Southwards early (Oct). They end up in Sahara desert hence have low survival rates, Natural selection acts against the hybrids.	
Honey bees	Honey bees make vertical honeycombs of wax with hexagonal cells and lay eggs there. The cells are covered with wax caps after eggs are layed. The larva grows and pupates to mature into a healthy adult.	To study the hygienic behaviour of unaffected honeybee populations.	Molecular genetics studied.	Have two components of hygienic behaviour at two loci. (a)U (dominant allele) does not uncap the wax of dead infected larvae, u (recessive allele) uncaps; (b)R (dominant allele) do not remove the	Hygienic behaviour is heritable.

	If the growing larvae is infected with a bacteria that causes foulbreed disease, it dies and spreads an epidemic to infect other larvae as well. But certain honeybee populations are not adversely affected due to their hygienic behaviour.			dead infected larvae, r (recessive allele) remove. Unaffected populations have recessive alleles for this behaviour- selected for by Natural selection.	
Crickets	Two kinds of crickets: (a) Singers – sing to attract female mates (b) Satellite crickets (silent or sing very little) hang around singers to get hold of female mates	To study the inheritance of singing behaviour	<u>Artificial selection</u> Singing crickets and satellite crickets were separately selected artificially and allowed to breed to produce many generations.	Gradual divergence of two groups with successive generations based on singing behaviour under selective pressure which means that the trait is heritable.	Singing behaviour is heritable.
Voles	Prairie Voles: -pair bond with females even after mating (social) -males provide paternal care Meadow voles:	To study the inheritance of social paternal behaviour	<u>Molecular genetics</u> studied: Vasopressin (neurotransmitter) receptor gene: Active in prairie voles	Transgenic meadow voles became social and pair bonded with females even after mating to provide parental care.	Social paternal behaviour is inheritable.

	-solitary, do not pair bond with females after mating -males don't provide parental care		Less active in meadow voles	Though social behaviour is polygenic.	
Balloon Empidid flies	Male swarms gather to catch mosquitoes and carry them around as food to attract female mates. While they mate, female eats the food (necessary as producing eggs is a costly investment)	To study the evolutionary history? Amongst other things. Evolution of the original to be less expensive to the organism	Test the number of males that survive if the only finite number of mosquitos are in an environment with breeding populations	Sexual Selection; more food - more time to copulate, less risk of being eaten by mate Insects take a long time to mate	Observe the evolutionary history of providing a mae with something

MAKING DECISIONS

Species and Dilemma	Hypothesis	Experimental method	Results	Conclusion
Siberian Jays: Have well hidden nests but visiting the nest with food for young ones can give their location to the predators so they should visit their nests less when predators are around. Dilemma: Jays face the dilemma that reducing predation risk can increase starvation risk. High feeding rate will help offspring grow big well increasing the risk of being spotted by predator, Low feeding rate decreases predation risk but leads to starvation.	Jays feed their nestlings early in the morning to avoid predators.	Eggers: 1.Observation: Compared the rate of feeding (no. of nest visits per hour) in areas with and without predators. 2. Experiment in areas with no predators: Two conditions compared: (a)Raven (predator) playbacks to mimic predator activity (b) no playbacks.	Observation: Areas with predators Greatest rate of feeding very early morning (3-6am before the predators became active) No predators: No difference in the rate of feeding throughout the day. Experiment: Playbacks Greatest rate of feeding very early morning. No playbacks No difference in the rate of feeding throughout the day.	Jays make decisions about when to feed the nestlings to reduce the predation risk. Reducing predation risk (low feeding rate) can increase starvation risk and vice versa. Hence, an intermediate rate of feeding would be the best. 1 plot and happy medium plot
Crabs: Dilemma: Small mussels required less energy and time investment to break open (high chances of success) but had little energy	Crabs select the optimum size of mussels to prey upon.	Optimality Calculation Observation of crabs selecting mussel size and calculation of the profitability of mussels selected.	Great variation in the no. of individuals that either choose many small or few large mussels. Majority choose an intermediate	Crabs make decision while choosing mussel size and majority of individuals select intermediate optimum

content. Many small mussels should be collected to satisfy energy demand increasing predation risk. Larger mussels required more energy and time investment to break open (low chances of success) increasing predation risk but had good amount of energy content. Few large mussel is enough to satisfy energy demand.		Profitability = Energy content/ Time taken to break the mussel open to eat	optimum mussel size for maximum profitability.	mussel size for maximum profitability.
Species and Dilemma	**Hypothesis**	**Experimental method**	**Results**	**Conclusion**
Dungfly Dilemma: 1.Mating with many females and spend less time with each: few eggs fertilized per female 2. Mating with few females and spend more time with each: all eggs fertilized	Dung fly males make decision on how much time to spend copulation with each female.	Optimality calculation Observation of dung flies; Calculate fertilization rate = Total eggs fertilized Time spent guarding on dung pat + searching mate + copulating	Low fertilization rates when many females are mated briefly with (10 min) and few females are mated for a very long time (100 min.) % eggs fertilized vs copulation time (min) plot gives 41 min. as the predicted optimum time for maximum fertilization rate. plot Majority of the males spend an optimum	Dung fly males make decision to spend an optimum amount of time copulating with each female i.e. an intermediate value to maximize fertilization rate.

			amount of time (observed value = 36 min.) copulating with each female to maximize the proportion of fertilized eggs per female.	
Toads: Bigger males have deeper croaks (low pitch) Small males have high pitch croaks.	A male toad will attack another male toad already mating with a female only if it is smaller than its size.	<u>Experiment:</u> Recording the number of attempts to attack on the pair (male and female mating) by playing playbacks of high and low pitch croaks.	More number of attacks when high pitch sounds were played.	Frogs make a decision on whether to attack the male already mating with a female by estimating the size of the toad by the pitch of it's croak.

LIVING IN GROUPS

Species	Predator	Observation/ Aim	Experiment & Result	Conclusion
Cliff swallows	Blood sucking bugs	Cliff swallows live in colonies of 1 to 100s of pairs. Blood sucking bugs stunt the growth of nestlings. This is adversely affects their reproductive success.	Observation Number of bugs per nestling is higher for larger colonies.	Increased parasitism is a repercussion of living in groups.
Red-winged blackbirds	No predator, competition with other males	Males defend marshes or territories within marshes to determine paternity of individuals within nests of these territories. In these nests paternity varies based on position in the environment.	No real expected outcome, dependent on individual males and females.	Costly to be in groups like red-winged blackbirds in reproductive terms.
Pigeons	Goshawks	In larger groups each individual has to spend less being vigilant (keeping a watch over the predator), hence has more time for feeding.	Observation Success rate of Goshawk attack is lower for larger flocks of pigeons. Reaction distance is greater for larger flock size.	Vigilance effect: Larger groups spot the predator sooner when it is at a greater reaction distance, this gives the birds more time to flee away.
Water striders	Fish	Water striders generally found on the surface of water are predated upon from underneath the water by predators.	Observation Number of attacks per head per 5 minutes is lower for larger groups.	Dilution effect: In larger groups, each individual has a smaller chance of being predated.

Seals	Great White Sharks	To test the Selfish herd theory (WD Hamilton) Which states that individuals within a population attempt to reduce predation risk by putting other conspecifics between themselves and predators. This results in social behaviour. Principle: In aggregation, predation risk is greatest on the periphery and decreases towards the centre.	Experiment: Artificial seal models arranged in different geometries/patterns were thrown into the sea. Domain of danger around each seal was measured and the number of shark attacks were recorded. Risk of predation increases with domain of danger.	The seals show social behaviour and swim in groups to the feeding grounds for a selfish interest to reduce predation risk from sharks.
Fish	Ospreys	Ospreys watch other ospreys that carry schooling fishes and then head in the direction from where the previous ones came. Observing others gives the information that more fishes would be present to prey upon in that area and they have to spend less time.	Observation: (a)Schooling fish search naive- spent more time Informed –less time (b) Solitary fish search Almost similar amount of time spent whether informed or naïve.	Ospreys stay solitary and watch their neighbours to reduce competition of food resource.

ALTRUISM

Kin selection is the evolutionary strategy that favours the reproductive success of an organism's relatives, even at a cost to the organism's own survival and reproduction.

Hamilton's Rule: Altruism is favoured if

r (relatedness) X B (benefit to recipient) > C (Cost of donor)

Species	Observation	Experiment	Results	Conclusion
Belding's ground squirrels	Males mate and disperse while females produce young ones and live in colonies in the same area.	Replace females into other populations and test whether these females still signal the alarm.Similarly observe the normal complex to compare. Alarm call index was measured: (a)between males and females (b) females living in colonies with- (i) off-spring only	Females give more alarm calls than males. Alarm call index : Sisters> Offspring> no relatives	Females live in 'related' colonies and hence give more alarm calls. In the species, females stay in the colony throughout life,males move between colonies thus females call more as they are more closely related to each other than any males. Altruistic behaviour (measured by alarm call index) is greatest for sisters (most

		(ii) sisters only (iii) no relatives		related) then for offspring of sisters and least for non-relatives.
Vampire bats	Some of the bats go out to feed themselves with blood while some have to stay behind to look after the young ones. After returning, bats share and feed each other by regurgitating blood. An individual dies if they do not find blood two nights in a row (70 hours). Hence, though this costs the donor, the benefit to the recipient is greater. Individuals who have behaved altruistically in the past are helped by others in the future. A previously non-altruistic bat is refused help when it requires it. Hence, it is an example of kin selection.			

SEXUAL SELECTION

Species	Aim/ Hypothesis	Experiment	Results	Conclusion
House finches	To test the sexual selection of brighter males by females. Females will have stronger preference for attractive males	4 males with colour variations from dull to bright placed in four chambers around the female and observed. To avoid any other bias, males were randomly coloured with hair dyes.	The female spends most of its time near the male with the brightest plumage colour and least near the most dull male. Feeding rate was higher for brighter males.	Females selected brighter males because of their foraging abilities. They were better parents at finding food resources and feeding nestlings. 2 plots

	with brighter plumage colour.	Feeding rate was measured along plumage brightness.		
Satin bowerbirds	Males with more decorated bowers attract more female mates.	11 Control groups: Male decorate bowers to attract females and observed for the number of successful copulations. 11 Experimental groups: Decorative objects removed manually and observed for number of copulations.	Number of copulations were higher for control group (12) and lower for experimental group (3) with less decorative bowers and were less visited by females.	Females tend to get attracted towards bowers decorated with blue objects as ornaments. Hence, females choose to copulate with males with better decorative skills as (a)They consider this as a good gene. Males with genes of extravagant displays indicate good genetic quality, because an enormous amount of energy and effort is put into collecting blue objects, along with protecting self from predators while searching for such ornaments. Hence, such a male who has the potential to invest that amount of energy and effort has good genes for better survival. (b) These attractive genes are chosen by females so that they have attractive sons who will be capable of attracting more no. of females to copulate. Therefore the female's genes will be passed on to more number of grand-offspring.
Damselflies	Males have sperm removal organs and females have sperm storage organs.			

	During mating, males grab the female's neck and the female reaches the male's abdomen to receive sperms. The male first removes the sperms of the previous male stored in her organs to ensure that his sperms fertilize the egg and the female does not deceive the male. After mating, the female leaves the male but the male guards her against other males by carrying her around grabbed by the neck until the female lays the eggs.

COMMUNICATION

Species	How do they communicate?	What do they communicate?
Psyllids	Transmit signal through stem of plant to form duets between male and female. Each species has a different song, some short and sharp, others long and winded.	Unknown, most likely used to find a mate.
Black birds	Alarm calls	Warning of predators attacking such as hawks
Vervet monkeys	Three different calls depending on predator type, snake, eagle, and leopard. They respond differently to each of these alarm calls. For eagles, disperse, look up and run for cover. For snakes, look down, group, bare teeth and show full body size and for leopards look up and down and run. The direction they look is most likely as a result of the relative likelihood of that predator being in that position. Eagle's only dangerous/fast when airborne, snake is slow but deadly on ground, leopards could be in trees or on the ground so look everywhere.	Each alarm call corresponds to a type of predator and how to respond.
Honey bees	Dance to indicate food direction, quality, distance and type. They measure distance through optic flow, direction by angle of incidence from the sun (can see polarised light) and give quality by repeating dance more and type by regurgitating a sample. In the dance, repeats = quality, angle of the straight part of the dance indicates direction (waggle tail towards food) and angle of incidence of light (line angle can determine whether it is away or towards the sun). Bees can compensate for a change in angle of the sun in their head using beethagoras theorem :P. The dance gets lazy at 12 approx when sun is directly up, it confuses angle of incidence. Can	Indicate food direction, quality, distance and type

	deceive bees sense of distance by making them go through a heavily textured and narrow tunnel which generates a lot of optic flow so they think that what was actually 72 metres was 12 and thus confuse other female/worker bees in the hive into looking for ghost flowers.	
Creepy firefly	Fakes being a female from another species by mimicking reproductive signals	Signal they are “ready to mate” so that males from the other species come down, only to be eaten.