



BIO1007 Notes

From Molecules to Ecosystems (University of Sydney)



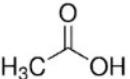
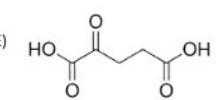
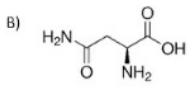
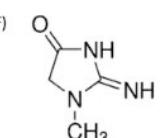
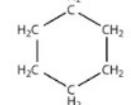
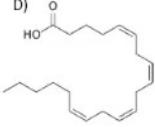
Scan to open on Studocu

BIO1007 Notes

Information Transfer

The Chemistry of Life

| | |
|---|--|
| Appreciate the common origin and makeup of the molecules of life | <ul style="list-style-type: none"> - Genetic material is shared through generations - Encodes the molecules of life - All species share common genes and cellular functionalities |
| Explore the properties of living organisms - key characteristics of life | <ul style="list-style-type: none"> - What is life? <ul style="list-style-type: none"> - Cell based - Can reproduce (single cell, organisms) - Are complex and organised - Use energy for growth and reproduction (plant growth) - Tend towards homeostasis - Change over time - Adapt to environment (physiological processes, behavioural adaptations) - Sensitivity or response to stimuli |
| Classifying living things | <ul style="list-style-type: none"> • 6 kingdoms • 3 domains |
| Appreciate that life is made up of a small number of elements of which carbon is particularly important | <ul style="list-style-type: none"> - Life is carbon based - Can bond with itself and other elements in lots of different ways - All major biopolymers have a substantially carbon backbone - “Sweet spot” of stability (stable but not too stable) for forming covalent bonds - Common elements: <ul style="list-style-type: none"> - Carbon - Hydrogen - nonpolar - Nitrogen - Oxygen - Smaller amounts <ul style="list-style-type: none"> - Phosphorus - Sulphur - polar |
| What properties of carbon make it | <ul style="list-style-type: none"> - Can bond with itself and other elements - Sweet spot of stability |

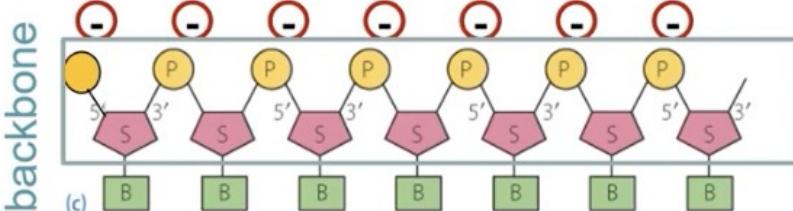
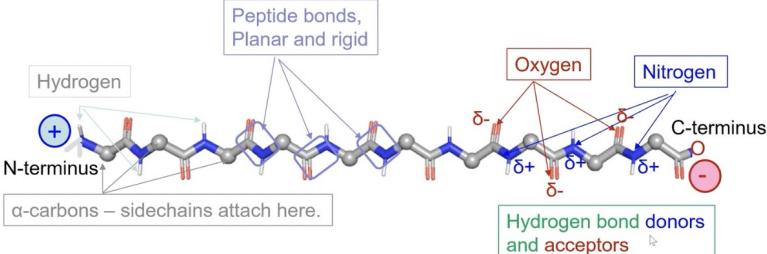
| central to life as we know it? | <ul style="list-style-type: none"> - 4 valence electrons and 4 bonds: can make a variety of structures - Carbon bonds often under kinetic control (good for enzymatic regulation) | | | | | | | | | | | | | | | | | | | | | |
|--|---|--|--------------------------------|--------------------|----------|--|--|----------|------------------------------|--|----------|--|-----------------------------------|----------|-----------------|------------------------------------|----------|------------|--|----------|------------------------------|--|
| Define the terms polar/hydrophilic and non-polar/hydrophobic | <ul style="list-style-type: none"> - Polar/hydrophilic: water liking, soluble in water - Non-polar/hydrophobic: water hating, insoluble in water - Carbon is inherently neutral (uncharged/non-polar) and non-polar/hydrophobic - Oxygen, Nitrogen and Phosphorus tend to make compounds polar/hydrophilic, partly (dipoles) or fully charged - Hydrogen is heavily influenced by what its near (C/H neutral, O/N polar) | | | | | | | | | | | | | | | | | | | | | |
| Which of the following molecules are mostly hydrophobic or polar? | <p>A)  E) </p> <p>B)  F) </p> <p>C) </p> <p>D) </p> <table border="1" data-bbox="514 1108 1460 1721"> <thead> <tr> <th></th> <th>Polar (lots of N and O)</th> <th>Hydrophobic</th> </tr> </thead> <tbody> <tr> <td>A</td> <td>More Polar - Most of the bonds are formed around O bonds, causing an unequal distribution of electrons</td> <td>Methyl group CH_3 is a little hydrophobic</td> </tr> <tr> <td>B</td> <td>More Polar - lots of O and N</td> <td></td> </tr> <tr> <td>C</td> <td></td> <td>More hydrophobic - mostly carbons</td> </tr> <tr> <td>D</td> <td>One polar group</td> <td>More hydrophobic - long chain of C</td> </tr> <tr> <td>E</td> <td>More polar</td> <td></td> </tr> <tr> <td>F</td> <td>More polar - lots of O and N</td> <td></td> </tr> </tbody> </table> | | Polar (lots of N and O) | Hydrophobic | A | More Polar - Most of the bonds are formed around O bonds, causing an unequal distribution of electrons | Methyl group CH_3 is a little hydrophobic | B | More Polar - lots of O and N | | C | | More hydrophobic - mostly carbons | D | One polar group | More hydrophobic - long chain of C | E | More polar | | F | More polar - lots of O and N | |
| | Polar (lots of N and O) | Hydrophobic | | | | | | | | | | | | | | | | | | | | |
| A | More Polar - Most of the bonds are formed around O bonds, causing an unequal distribution of electrons | Methyl group CH_3 is a little hydrophobic | | | | | | | | | | | | | | | | | | | | |
| B | More Polar - lots of O and N | | | | | | | | | | | | | | | | | | | | | |
| C | | More hydrophobic - mostly carbons | | | | | | | | | | | | | | | | | | | | |
| D | One polar group | More hydrophobic - long chain of C | | | | | | | | | | | | | | | | | | | | |
| E | More polar | | | | | | | | | | | | | | | | | | | | | |
| F | More polar - lots of O and N | | | | | | | | | | | | | | | | | | | | | |
| Describe the building blocks of life: water, carbohydrates, lipids, amino acids | Water <ul style="list-style-type: none"> - Very important molecule – humans are 62% water - A polar compound with extensive hydrogen bonding - Responsible for special physical and chemical properties that support life - Water stabilises temperature - Helps maintain heat (high specific heat) | | | | | | | | | | | | | | | | | | | | | |

| | |
|---|---|
| <p>and nucleic acids</p> <p>Main types of molecules used in biology</p> | <ul style="list-style-type: none"> - Good evaporative cooling - Freezing water releases energy and melting water absorbs it - Ice floats: layer of ice can insulate water underneath/floating platforms - High water tension → capillary reactions (water hangs together due to hydrogen bonding) - Good solvent of polar molecules - Poor solvent of hydrophobic molecules (hydrophobic effect – e.g. oils and fats, important for maintaining cell boundaries) <p>Carbohydrates</p> <ul style="list-style-type: none"> - Composed of C, H, O with the general formula $C_n(H_2O)_n$ (lots of O means very polar) - Monosaccharides usually form ring <ul style="list-style-type: none"> - Glucose (6 atom ring) → energy source - Ribose (5 atom ring) → building block - Disaccharides (two monosaccharides joined together) <ul style="list-style-type: none"> - Lots of different connection - Sugar polymers (long chains of monosaccharides) <ul style="list-style-type: none"> - Starch → important for storage - glucose storage (glucose molecules joined in a particular way) - Chitin → protection layer - Cellulose → provides structure - Bacterial cell walls/surrounding coats (complex polymers) <p>Lipids</p> <ul style="list-style-type: none"> - Diverse set of molecules including: fats, oil, waxes, steroids/sterols - Poorly soluble in water - Soluble in organic (hydrophobic) solvents - High proportion of C/H making it very hydrophobic - Saturated: all single bonds - Unsaturated: one or more double bonds - Function: energy stores (triglycerols), signalling molecules (steroids), protection and waterproofing (waxes), structures and barriers (phospholipids) - Phospholipids form cell membranes <ul style="list-style-type: none"> - Mostly hydrophobic but with a polar end (headgroup) - The polar parts interact with the aqueous environment, the hydrophobic parts cluster together - Lipid bilayers separate different aqueous environments (eg. inside and outside of cell) <p>α-Amino acids</p> <ul style="list-style-type: none"> - Building blocks of proteins - The 20 commonly occurring amino acids found in proteins and coded by our genes have the same basic alpha structure - In aqueous solution the amino and acid groups are charged (normal state for amino acids in nature) - Different functions based on their sizes and chemical properties <p>Nucleic acid building blocks</p> <ul style="list-style-type: none"> - Nucleotides |
|---|---|

| | |
|--|--|
| | <ul style="list-style-type: none"> - A phosphate group (negatively charged) - A sugar (ribose or deoxyribose) - A nucleobase (A, G, C, T, U) - Phosphate joins to sugar, sugar joins to base <ul style="list-style-type: none"> - Bases <ul style="list-style-type: none"> - Purins: adenine, guanine - Pyrimidines: cytosine, thymine, uracil - Mono/di/tri-nucleotides: difference is 1, 2 or 3 phosphates joined together |
| What are the differences between amino acids and nucleotides? | <ul style="list-style-type: none"> - Amino acids are building blocks of protein whilst nucleotides are building blocks of nucleic acid - 4 (or 5) nucleotides vs 20 amino acids - Amino acids consist of an amino (NH_2) and an acid (COH_2) an alpha carbon and a side chain - Nucleotide consists of a phosphate, sugar and a base |
| Describe some chemical properties of amino acids (solubility, polarity, charge), given their chemical structure | <ul style="list-style-type: none"> - 20 different R groups or side chains - Different properties and shapes according to how they are made up <ul style="list-style-type: none"> - Charge, polarity, hydrophobicity, aromatic, redox sensitivity, capacity for hydrogen bonds |

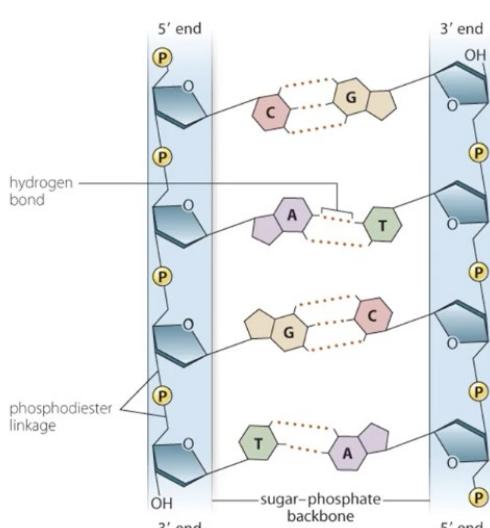
Biopolymers

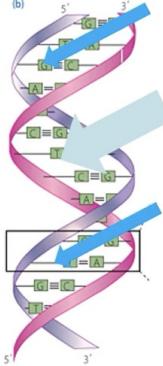
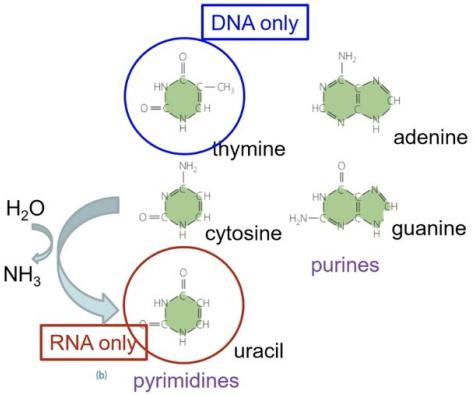
| | |
|---|--|
| Information containing biopolymers | <ul style="list-style-type: none"> - DNA: deoxyribonucleic acid - RNA: ribonucleic acid - Proteins - Can be very long polymers - The sequence of subunits/monomers within the polymer is important for function and differ for each type of protein or DNA/RNA |
| Identify the conventions of direction/end of protein and nucleic acids | <ul style="list-style-type: none"> - Information-containing biopolymers have a defined beginning and end - Biopolymers are synthesised in one direction only increasing the backbone - By convention we write them in the same direction (from left-to-right) - Residues: some of the monomer is lost in polymerisation, leaving a “residue” incorporated in the growing chain (for these molecules the residue is usually the biggest part <ul style="list-style-type: none"> - Biopolymer synthesis relies on dehydration reactions and are anabolic (require energy) <p>Nucleic acids: 5' to 3' (five prime to three prime) 5' -ATGACCTGCGGATCAGGATTGGTGGG-3'</p> <p>Proteins: N-terminus (or amino terminus) to C-terminus (or carboxy terminus) (N) -MTCGSGFGGRAFSCISACGPRPGRCIT- (C)</p> |
| Describe the | Nucleic acid polymers: DNA/RNA |

| | |
|---|---|
| <p>repeating units (backbones and side chains or bases) in proteins and nucleic acids</p> | <ul style="list-style-type: none"> - Nucleotide building blocks: phosphate, such base/nucleobase - Common sugar phosphate backbone: <ul style="list-style-type: none"> - Negative charge on phosphates - Hydrophilic (sugars and phosphates) - 5' and 3' ends - “Acid” because of the phosphate groups  <p>Proteins</p> <ul style="list-style-type: none"> - N-terminus: comes from the amino group - C-terminus: comes from carboxylic acid group  |
| <p>Identify the main chemical compound of nucleic acid</p> | <ul style="list-style-type: none"> - Nucleotides - Each nucleotide consists of a nitrogen-containing aromatic base attached to a pentose (five-carbon) sugar, which is in turn attached to a phosphate group |
| <p>Describe how the physical and chemical properties of proteins and nucleic acids can be exploited in experiment situations</p> | <p>Properties of Sugar Phosphate Backbone</p> <ul style="list-style-type: none"> - Common properties no matter what base is attached - Negative charge due to phosphates - Hydrophilic due to sugars and phosphates - Applications: <ul style="list-style-type: none"> - Electrophoresis <ul style="list-style-type: none"> - Electrophoresis separates RNA or DNA molecules from one another - Nucleic acids migrate in an electric field because they are charged → the distance they might depends on size - Ethanol precipitation <ul style="list-style-type: none"> - Nucleic acids become insoluble when mixed with salt (to neutralise charge) and ethanol <p>Properties of Proteins</p> <ul style="list-style-type: none"> - Amino acid building blocks - Common peptide backbone - Sidechains (R) of the different amino acids differ |

- Peptides if short ($<\sim 50$ amino acids)
 - Proteins if long ($>\sim 50$ residues)
 - Peptide bond formation:
 - Two amino acids combine by a condensation mechanism to form a dipeptide
 - Very energetically unfavourable (does not happen spontaneously)
 - Peptide bonds have double and single bonds that can exist in different forms (resonance structures)
 - Partial double bond makes the peptide bond flat and rigid
 - Encourages partial charges for hydrogen bonding (important for protein structure and function)
 - Can still rotate around other bonds
 - **Varied properties of amino acid side chains:**
 - Size/shape
 - Charge
 - Polarity
 - H-bonding potential
 - Hydrophobic
 - Aromatic
 - Redox sensitivity
 - Flexibility
 - Provide shape/structure and function
- Aromatic protein side chains and nucleobases**
- Have a characteristic absorbance ~ 280 nm (proteins) or ~ 260 nm bases
 - Use absorbance values at particular wavelengths to estimate concentrations of DNA or proteins
 - Helps monitor the purity by checking ratios of absorbance values for likely contaminating molecules
 - A₂₆₀:A₂₈₀ (proteins)
 - A₂₆₀:A₂₃₀ (carbohydrates/phenol)
 - Aromatic rings are flat/planar

DNA vs. RNA

| | |
|--|---|
| Appreciate that DNA is the source of genetic information | <ul style="list-style-type: none"> - DNA is the source of genetic information - Genetic inheritance was understood before it was known what genes were made up of (via pedigrees etc.) - Nucleic acids seemed too simple, and hard to really purify from proteins so lots of controversy about which carried genetic information |
| Describe the base pairing between nucleobases and appreciate that C/G pairing is strong than A/T(U) base pairing in nucleic acids | <ul style="list-style-type: none"> - There is species variation of DNA composition but for any species: <ul style="list-style-type: none"> - A = T - C = G - And A + G = C + T = 50% (purines) (pyrimidines) - A purine must bond with a pyrimidine <p>Bonding</p> <ul style="list-style-type: none"> - Nucleobases have hydrogen bonding potential: <ul style="list-style-type: none"> - Donor: oxygen that has H attached - Acceptor: no H attached - C and G compliment each other → 3 hydrogen bonds so stronger binding - A and T/U complement each other → 2 hydrogen bonds so a bit weaker  |

| | |
|--|--|
| Describe the double-helical structure of DNA | <ul style="list-style-type: none"> - B-DNA (DNA double helix) - Strands of DNA run in opposite directions - Flat bases stack on top of each other (reduced A260 intensity) in middle of the structure → affects electronic structure - Negative phosphates repel each other <ul style="list-style-type: none"> - This, combined with stacking bases, cause minor (small arrow) and major (big arrow) grooves - Right handed double helix  |
| Distinguish DNA from RNA, in terms of structure and stability | <ul style="list-style-type: none"> - Different sugars for DNA and RNA <ul style="list-style-type: none"> - Both have ribose derivative - RNA: truly ribose (OH group) - DNA: no OH group - RNA does not form B-type structure <ul style="list-style-type: none"> - Extra OH group on the sugar stops it forming B-DNA-type helices - RNA can base-pair (C-G and A-U) - Extra OH group makes RNA susceptible to degradation/breakdown - Bases are generally stable except spontaneous deamination (losing amine) of C to U <ul style="list-style-type: none"> - ~100 time per day - In DNA, uracil is recognised as wrong and repaired (mistakes corrected) - Uracil is tolerated by RNA and hence is not repaired so more prone to mistakes  |

What properties of RNA means that it is less suitable as genetic material than the DNA?

- The OH bond in the ribose of RNA makes the molecules more reactive → not stable
- Bases can undergo spontaneous deamination (losing the N) to convert C to U. This makes RNA more prone to errors and therefore, not the most suitable source of genetic material
- Less proofreading
- No DS structure

| | |
|-------------------------------|--|
| Sketch of double-helix | |
|-------------------------------|--|

Molecular Biology

| | |
|---|---|
| Outline the central dogma of molecular biology and describe the information flow between DNA, RNA and Proteins | <p>Central Dogma of Molecular Biology</p> <ul style="list-style-type: none"> - Describes the flow of information - Cannot go from proteins to RNA or from DNA to proteins and vice versa <pre> graph LR DNA[DNA] -- Transcription --> RNA[RNA] RNA -- Translation --> Protein[Protein] DNA -- Replication --> DNA RNA -- "Reverse Transcription" --> DNA style RT fill:red,stroke:red,color:white </pre> |
| Define the genome, transcriptome and proteome and how they differ from cell to cell | <ul style="list-style-type: none"> - Genome (the DNA): complete genetic composition of a cell or species; storage of DNA <ul style="list-style-type: none"> - Same DNA in all of your cells (eg. muscle and skin cells) - Each cell uses a subset of expressed genes to achieve its structure and function (through transcriptome and proteome) - Transcriptome (the RNA): the set of all RNA molecules in one cell or a population of cells <ul style="list-style-type: none"> - Different between cells due to different properties - Proteome (the protein): the complete set of proteins expressed by an organism, cell or tissue type <ul style="list-style-type: none"> - Different between cells |
| DNA as genetic store | <ul style="list-style-type: none"> - Double stranded: provides two copies and a template for repair <ul style="list-style-type: none"> - Obvious mechanisms for replication/transcription via base pairing - Stable: not prone to degradation; cells can repair cytosine deamination - Epigenetic regulation: the expression of <i>some</i> genes is altered by chemical |

| | |
|--|---|
| | <p>modification of DNA and proteins but NOT to the DNA itself - epigenetics</p> <ul style="list-style-type: none"> - Can be passed through generations of cells and individuals |
| RNA as the messenger | <ul style="list-style-type: none"> - mRNA is the message from making proteins - mRNA encodes proteins - Multiple copies of mRNA are made, designed to be used then degraded <ul style="list-style-type: none"> - Less stable than DNA so it can be degraded - Can tolerate cytosine deamination to uracil - Degradation via the ribose |
| Proteins | <ul style="list-style-type: none"> - The amino acid sequences determines the structure which determines the function - Proteins make up over 50% of the cell by dry weight - Proteins give the cell its shape, the form receptors, enzymes, hormones and growth factors, toxins, transports and antibodies |
| Appreciate the difference in size and construction between bacterial and eukaryotic genomes | <p>Bacterial Genomes:</p> <ul style="list-style-type: none"> - Most prokaryotes (bacteria and archaea) have circular chromosomes - Tend to be relatively small (12 kb - 15 Mb) - Mycoplasma genitalia; Circular dsDNA; 580,000bp; ~470 predicted coding regions <p>Eukaryotic Genomes:</p> <ul style="list-style-type: none"> - Linear chromosomes - Tend to be big (~10 Mb - 150Gb) - Condensed into chromatin - Wrapped around histone proteins - <i>Paris japonica</i> 149 billion base pairs (8 copies of 40 chromosomes) <p>The Human Genome</p> <ul style="list-style-type: none"> - Eukaryotic - Linear - 6 billion bp - 22 pairs of chromosomes (plus sex chromosomes) - Encode ~20,000 proteins - Often only one pair of copies of each gene (one on each chromosome pair: alleles) |

The Genetic Code

| | |
|--|---|
| Define the universal genetic code (triplet/ non-overlapping/common) | <p>Types of Code</p> <ul style="list-style-type: none"> - Singlet: 4 different bases and use only one position the you have 4 possible combinations: A, G, C or U - Doublet: 16 possible pairs - Triplet: 64 possible sets of three (code humans have) <ul style="list-style-type: none"> - There will be redundancy in the code → some amino acids have more than one code |
|--|---|

| Singlet Code: 4 | Doublet Code: 16 | Triplet Code: 64 |
|-----------------|------------------|------------------|
| 5' U 3' | 5' UU 3' | 5' UCU 3' |
| 5' C 3' | 5' UC 3' | 5' UUC 3' |
| 5' A 3' | 5' UA 3' | 5' UUA 3' |
| 5' G 3' | 5' UG 3' | 5' UUG 3' |
| | 5' CU 3' | 5' CUU 3' |
| | 5' CC 3' | 5' CUC 3' |
| | 5' CA 3' | 5' CUA 3' |
| | 5' CG 3' | 5' CUG 3' |
| | 5' AU 3' | 5' AUU 3' |
| | 5' AC 3' | 5' AUC 3' |
| | 5' AA 3' | 5' AUA 3' |
| | 5' AG 3' | 5' AUG 3' |
| | 5' GU 3' | 5' GUU 3' |
| | 5' GC 3' | 5' GUC 3' |
| | 5' GA 3' | 5' GUA 3' |
| | 5' GG 3' | 5' GUG 3' |
| | | 5' UAU 3' |
| | | 5' UAC 3' |
| | | 5' UAA 3' |
| | | 5' UAG 3' |
| | | 5' UAU 3' |
| | | 5' CAU 3' |
| | | 5' CCC 3' |
| | | 5' CCA 3' |
| | | 5' CCG 3' |
| | | 5' ACU 3' |
| | | 5' ACC 3' |
| | | 5' ACA 3' |
| | | 5' ACG 3' |
| | | 5' GCU 3' |
| | | 5' GCC 3' |
| | | 5' GCA 3' |
| | | 5' GCG 3' |
| | | 5' UGG 3' |
| | | 5' UGC 3' |
| | | 5' UGA 3' |
| | | 5' CGU 3' |
| | | 5' CGC 3' |
| | | 5' CGA 3' |
| | | 5' CGG 3' |
| | | 5' AGU 3' |
| | | 5' AGC 3' |
| | | 5' AGA 3' |
| | | 5' AGG 3' |
| | | 5' GGU 3' |
| | | 5' GGC 3' |
| | | 5' GGA 3' |
| | | 5' GGG 3' |

Understand the concept of reading frames for translating a nucleic acid sequence into a protein sequence

- The combination of 3 bases which codes for an amino acid is called a codon
- The codon sequence is quote 5' to 3' from the mRNA

Nucleic acid: 5' **AUGGGAUCCAAG** 3'
 Codon1 Codon2 Codon3 Codon4

Reading frame

- Only one reading frame gives the correct protein sequences
- Cell needs to look for where mRNA starts and finishes
 - Start: AUG
 - Finishes: STOP codon
- Start codon determines the reading frame
- Region between the start and stop codon of a gene that encodes the protein/peptide is referred to as an open reading frame (ORF)

2nd base

| U | | C | A | G | | 3rd base |
|---|--|--|--|--|------------------|----------|
| U | U | U | A | G | G | |
| U | UUU Phenylalanine UUC Phenylalanine UUA Leucine UUG Leucine | UCU Serine UCC Serine UCA Serine UCG Serine | UAU Tyrosine UAC Tyrosine UAA Stop UAG Stop | UGU Cysteine UGC Cysteine UGA Stop UGG Tryptophan | U C A G | |
| C | CUU Leucine CUC Leucine CUA Leucine CUG Leucine | CCU Proline CCC Proline CCA Proline CCG Proline | CAU Histidine CAC Histidine CAA Glutamine CAG Glutamine | CGU Arginine CGC Arginine CGA Arginine CGG Arginine | U C A G | |
| A | AUU Isoleucine AUC Isoleucine AUA Isoleucine AUG Methionine (Start) | ACU Threonine ACC Threonine ACA Threonine ACG Threonine | AAU Asparagine AAC Asparagine AAA Lysine AAG Lysine | AGU Serine AGC Serine AGA Arginine AGG Arginine | U C A G | |
| G | GUU Valine GUC Valine GUA Valine GUG Valine | GCU Alanine GCC Alanine GCA Alanine GCG Alanine | GAU Aspartic Acid GAC Aspartic Acid GAA Glutamic Acid GAG Glutamic Acid | GGU Glycine GGC Glycine GGA Glycine GGG Glycine | U C A G | |

Understand how to read a genetic code table and translate nucleic acid sequence into

- Genetic code table: a way to interpret the codons to determine which amino acid is encoded by any particular codon
- Read by first position, then second position, then third position
- STOP = 'stop codons' → do not encode amino acids

| protein sequence using such a table | <ul style="list-style-type: none"> - Terminates protein synthesis - Some amino acids have multiple codons - Some amino acids have one codon only - AUG encodes Met = start codon <ul style="list-style-type: none"> - AUG also encodes Met in the middle of a protein sequence | | | | | | | | | | | | | | | | |
|--|--|----------|-------------|----------|---|--------|--|----------|---|-----------|---|----------|---|------------|--|-------------|---|
| The genetic code | <ul style="list-style-type: none"> - The genetic code is degenerate or redundant - Is universal: used by all life forms (with a few minor exceptions) <ul style="list-style-type: none"> - Can take genes from one organism and express them in another | | | | | | | | | | | | | | | | |
| Mutations of DNA and RNA | <ul style="list-style-type: none"> - Can have combinations of mutations <table border="1"> <thead> <tr> <th>Mutation</th><th>Description</th></tr> </thead> <tbody> <tr> <td>Missense</td><td>Mistake in the DNA code, one of the DNA base pairs is changed</td></tr> <tr> <td>Silent</td><td>A mutation of the protein coding region that has no effect on the protein sequence</td></tr> <tr> <td>Nonsense</td><td>Single change in DNA code produces stop codon, prematurely terminates protein synthesis</td></tr> <tr> <td>Insertion</td><td>Addition of one (or more) nucleotide base pairs into the DNA sequence</td></tr> <tr> <td>Deletion</td><td>A piece of DNA is removed from the sequence</td></tr> <tr> <td>Frameshift</td><td>Insertion or deletion mutation results in a change to a gene's reading frame</td></tr> <tr> <td>Duplication</td><td>Incorrect copying leads to repeated sequences</td></tr> </tbody> </table> | Mutation | Description | Missense | Mistake in the DNA code, one of the DNA base pairs is changed | Silent | A mutation of the protein coding region that has no effect on the protein sequence | Nonsense | Single change in DNA code produces stop codon, prematurely terminates protein synthesis | Insertion | Addition of one (or more) nucleotide base pairs into the DNA sequence | Deletion | A piece of DNA is removed from the sequence | Frameshift | Insertion or deletion mutation results in a change to a gene's reading frame | Duplication | Incorrect copying leads to repeated sequences |
| Mutation | Description | | | | | | | | | | | | | | | | |
| Missense | Mistake in the DNA code, one of the DNA base pairs is changed | | | | | | | | | | | | | | | | |
| Silent | A mutation of the protein coding region that has no effect on the protein sequence | | | | | | | | | | | | | | | | |
| Nonsense | Single change in DNA code produces stop codon, prematurely terminates protein synthesis | | | | | | | | | | | | | | | | |
| Insertion | Addition of one (or more) nucleotide base pairs into the DNA sequence | | | | | | | | | | | | | | | | |
| Deletion | A piece of DNA is removed from the sequence | | | | | | | | | | | | | | | | |
| Frameshift | Insertion or deletion mutation results in a change to a gene's reading frame | | | | | | | | | | | | | | | | |
| Duplication | Incorrect copying leads to repeated sequences | | | | | | | | | | | | | | | | |

Effect of mutations on expressed polypeptide (below):

◀ CUGAAGC | **AUG** | CUA | UUU | CUC | CCC | UAA | CGCGG ▶
 Met | Leu | Phe | Leu | Pro | STOP

Missing 1) CUGAAGC | **AUG** | CUA | **UUC** | CUC | CCC | UAA | CGCGG -
 base/
 deletion → 2) CUGAAGC | **AU**U**** | CUA | UUU | CUC | CCC | UAA | CGCGG -
 3) CUGAAGC | **AUG** | C**AU** | UUC | CCU | AAC | GCG | G -
 4) CUGAAGC | **AUG** | CUA | **UUG** | CUC | CCC | UAA | CGC | GG -
 5) CUGAAGC | **AUG** | CUA | **UAG** | CUC | CCC | UAA | CGC | GG - 123

- 1) Met-Leu-Phe-Leu-Pro – no change (silent mutation)
- 2) No start codon – no protein
- 3) Met-His-Phe-Ser-Pro-Asn... – frameshift mutation (wrong protein sequence) (deletion)
- 4) Met-Leu-Leu-Pro – change in protein sequence (point mutation)
- 5) Met-Leu-STOP – premature stop codon (nonsense mutation) (stops full length protein from being made)

Copying DNA: DNA Replication

| | |
|--|--|
| Outline the general mechanism for copying DNA to DNA before cell division - replication | <ul style="list-style-type: none">- Require a template (transfer of information) for base pairing- Always copy the new strand from 5' to 3'- Use nucleotide triphosphates as substrate- Add the nucleotide monophosphate to the 3'OH end of the growing chain- Form a high energy phosphodiester bond- Release pyrophosphate (PPi)- Uses a DNA polymerase (enzyme)- Need a primer (short piece of DNA/RNA) to start |
| | Bacterial DNA Replication <ul style="list-style-type: none">- Start with the parental strand, unwind DNA to copy it, when we copy it we make two different complimentary copies, each with one old and one new strand- Both strands being copied at the same time in both direction<ul style="list-style-type: none">- 2 replication forks, 2 strands being copied at each for = 4 strands being copied |
| | ORI (Origin) Sites and Initiation <ul style="list-style-type: none">- AT-rich (easier to pull standard apart because less stable)- Multiple sites bound by DNA binding proteins- DNA helicase unwinds part of the DNA- DNA topoisomerase/gyrase stops supercoiling- Forms replication forks- Single-stranded binding proteins coat single stranded DNA (ssDNA) to keep strands apart/stop small segments of base pairing/protect DNA |

Leading strand replication

- Primase makes an RNA primer to begin
- DNA polymerase III makes a DNA copy of the strand in the 5'→3' direction
- Continuous copying

Lagging strand replication

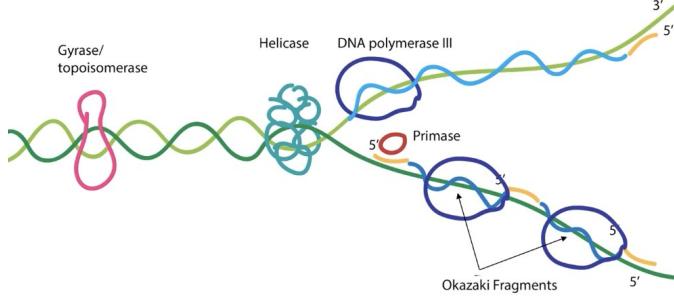
- Made in small pieces that get joined together
- Primase makes multiple RNA primers
- DNA polymerase III synthesises in 5' → 3' direction until it runs into the next primer making Okazaki fragments
- DNA polymerase I replaces the RNA primer with DNA
- DNA ligase joins the pieces of DNA

Biopolymer synthesis

- Initiation
- Chain elongation
- Termination

List the unique

- **Unwinding DNA:** Helical DNA needs to be unwound

| | |
|---|---|
| <p>problems associated with replication and describe the strategies used by the cell to overcome these. Include unwinding DNA, and leading versus lagging strand replication</p> | <ul style="list-style-type: none"> - Pulling long helical strands apart causes supercoiling - Solution: Topoisomerase enzymes cut strands, allow to unwind and stick back together (religate) - In cells only unwind small sections of DNA at a time <p>- Leading versus lagging strand replication:</p> <ul style="list-style-type: none"> - To avoid leaving things out, the DNA Primase in the leading strand every so often puts down a new RNA primer  <ul style="list-style-type: none"> - Keeping the strands separated <ul style="list-style-type: none"> - ssDNA binding protein - Initiation <ul style="list-style-type: none"> - Primer allows DNA polymerase to start (primase) |
| <p>Describe the general functions of proteins that are required for DNA-replication</p> | <ul style="list-style-type: none"> - DNA polymerase and DNA primase: catalyse nucleoside triphosphate polymerisation - DNA helicases and single-strand DNA binding (SSB) proteins: help open the DNA helix so that it can be copied - DNA ligase: seal together the discontinuous synthesis lagging-strand DNA fragments - DNA topoisomerases: help to relieve helical winding and DNA tangling problems |

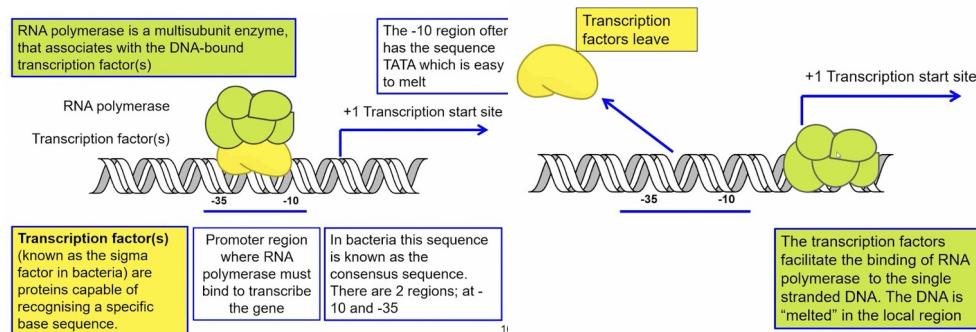
Copying DNA: RNA Transcription

Outline the general mechanisms for copying DNA to RNA - transcription

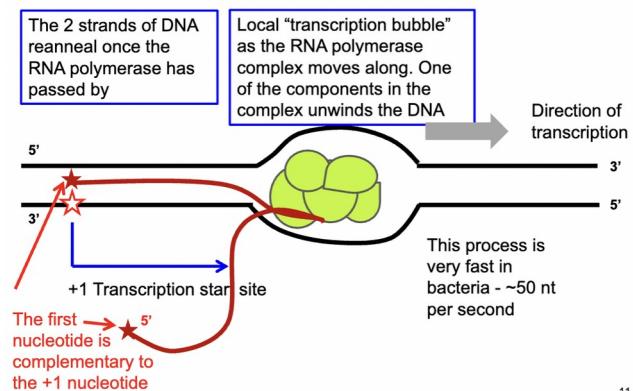
Starting and stopping

- RNA polymerase binds to a region of DNA known as the promoter, which sits just past the 5' end and starts transcribing downstream from that region
- Transcription stops at the terminator
- Requires:
 - Promoter region for initiation
 - A/T rich area
 - A sigma factor
 - Binding to RNA polymerase
- **Direction of transcription**
 - Only one strand of DNA is transcribed for each gene but which strand being copied can vary, even in the same region of the chromosomes

Transcription Initiation



Transcription Elongation



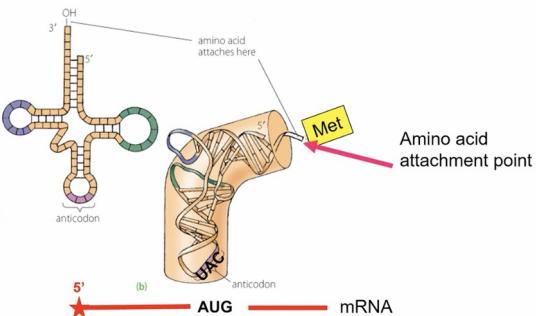
Transcription Termination

- Transcription uses a signal encoded in the transcribed RNA to stop
 - A G/C rich sequence, often followed by an A/T rich sequence
- G/C rich region can form:
 - Double stranded hairpin structures → pulls RNA strand away from RNA polymerase
 - OR a Rho protein binds, and uses helicase activity to travel up to and dissociate the DNA/RNA hybrid complex (physically pull or force apart)

| | | | | |
|--|---|-----|------|-----|
| | <p>the protein nucleic acid complex?</p> <ul style="list-style-type: none"> - Requires: <ul style="list-style-type: none"> - Terminator region - GC-rich region - Rho protein | | | |
| Gene expression regulation | <ul style="list-style-type: none"> - Genes can be expressed at different frequencies by: <ul style="list-style-type: none"> - Promoter strength <ul style="list-style-type: none"> - DNA sequence optimised for strong or weak sigma factor/RNA pol binding - Strong binding = more RNA copies made - Weak binding = fewer RNA copies made - Repressors <ul style="list-style-type: none"> - A protein repressor blocks the binding of the sigma factor complex - No RNA polymerase binding → no transcription → no gene expression - Accelerators <ul style="list-style-type: none"> - Weak promoter may not bind sigma factors well - A Transcriptional Activator binds to specific DNA sequence and alters the structure of the promoter so the transcription factor can now bind more easily | | | |
| List the unique problems associated with transcription (including unravelling DNA and making multiple copies of small sections of the genome at different frequencies) and describe the strategies used by the cell to overcome these | <p>Problems:</p> <ul style="list-style-type: none"> - Only small sections of the genome need to be transcribed. These sections often have to be copied thousands of times. Some sections are rarely copied in one cell but copied many times in another cell. <p>Solution: gene regulation</p> <ul style="list-style-type: none"> - Genes can be expressed at different frequencies (including at different times/conditions) by: - Promoter strength: DNA sequence optimised for strong or weak sigma factor/RNA pol binding | | | |
| Describe the general functions of proteins that are required for RNA transcription | <ul style="list-style-type: none"> - RNA Polymerase: make an RNA copy from a DNA template <ul style="list-style-type: none"> - Does not need a primer a start - Use of ribonucleotide triphosphates as substrate - Limited proofreading, no 3' to 5' exonuclease activity (make more mistakes) - Transcription factor: protein that binds DNA and regulates transcription | | | |
| Compare and contrast the | <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="padding: 5px; text-align: center;">DNA</td> <td style="padding: 5px; text-align: center;">SAME</td> <td style="padding: 5px; text-align: center;">RNA</td> </tr> </table> | DNA | SAME | RNA |
| DNA | SAME | RNA | | |

| | | | |
|---|-----------------------------|---|--|
| differences between making DNA and RNA | Whole genome copied once | Rely on base-pairing for correct sequences in new chains | Short segments copied at different frequencies |
| | Leading and lagging strands | Use polymerases and dNTPs or NTPs to add nucleotides; hydrolysis of PPi to provide energy | Stop signals encoded in the RNA sequence |
| | | Need to separate out/unwind dsDNA | Different types of regulation |
| | | Specific recognition of start sites by proteins | |
| | | | |

Making Proteins: Protein Synthesis (Translation)

| | |
|--|--|
| Protein synthesis/ translation | <ul style="list-style-type: none"> - Converts a nucleotide sequence to a protein sequence - Uses three types of RNA: <ul style="list-style-type: none"> - Messenger RNA (mRNA): contains template for protein synthesis about which amino acids to add in which order - Transfer RNA (tRNA): matches the correct amino acids to the template - Ribosomal RNA (rRNA): combines with proteins to form the machinery for protein synthesis and catalyses peptide bond formation |
| Explain the unique problems associated with converting the information as a nucleic acid sequence to an amino acid sequence | <ul style="list-style-type: none"> - The need to convert a sequence of nucleotides to a sequence of amino acids - The need to have the correct order of amino acids - How does the cell know to put Methionine in the protein when it encounters an AUG in the mRNA? <ul style="list-style-type: none"> - The Adapter (tRNA) is required to match right amino acid to start codon - Other end of tRNA is where the amino acid is attached - Different tRNAs for each amino acid/codon combination  <p>The diagram illustrates the process of protein synthesis. A ribosome is shown bound to a mRNA strand. The mRNA has an AUG start site indicated by a red arrow. A tRNA molecule is shown with its 3' end (labeled 'OH') and 5' end. The 3' end is labeled 'amino acid attaches here'. The 5' end is labeled 'anticodon'. The tRNA is shown binding to the mRNA at the AUG site. An amino acid labeled 'Met' is shown attached to the tRNA at its 3' end. A pink arrow points to this attachment point with the label 'Amino acid attachment point'. The tRNA is also labeled with 'anticodon' at its 5' end.</p> <ul style="list-style-type: none"> - How does the cell know to put Methionine on this tRNA? <ul style="list-style-type: none"> - Aa-tRNA-synthetases: recognise specific tRNAs <ul style="list-style-type: none"> - Catalyses the activation of amino acids - Use ATP hydrolysis to get the energy to make a high energy |

| | |
|--|---|
| | <p>bond</p> <ul style="list-style-type: none"> - Attach the correct amino acid to its matched tRNA - Recognise the anticodon and other parts of the tRNA - Note: only enzymes (Aa-tRNA-synthetases) have ability to recognise nucleotide sequences of tRNA and structure of amino acid → then catalyse the formation of covalent bond between the 2 |
| Outline the unique problems associated with protein synthesis, with particular reference to the unfavourable thermodynamics of peptide bond formation and the requirement for order. Describe the strategies used by cells to overcome these problems | <ul style="list-style-type: none"> - Peptide bond formation is very thermodynamically favourable due to the large amounts of water around <ul style="list-style-type: none"> - Hydrolysis is always favoured over condensation in an aqueous environment - Aa-tRNA-synthetases helps this process |
| Describe the general functions of proteins and RNA molecules that are required for protein synthesis | <ul style="list-style-type: none"> - Ribosome: lots of pieces of rRNA which interact to form the ribosome <ul style="list-style-type: none"> - Three important binding sites <ul style="list-style-type: none"> - mRNA binding site - P site: for growing protein chains - A site: accepts incoming tRNA-aa - Travels across mRNA, reads off the codon sequence and slowly add the amino acids to make the growing polypeptide chain <ul style="list-style-type: none"> - Making protein N-terminal to C-terminal <ol style="list-style-type: none"> 1. Small subunit of the ribosome binds mRNA and Met-tRNA 2. Large subunit of the ribosome binds - Special Met-tRNA: binds at the start codon |
| Elongation | <ol style="list-style-type: none"> 1. AA-tRNA comes in guided by anticodon/codon matching; Activated amino acids are positioned next to each other 2. Peptidyl transferase in ribosome catalyses peptide bond formation using energy stored in the aa-tRNA bond; first Met bound to second amino acid 3. First tRNA released, ribosome moves along to next codon on mRNA etc - No extra energy required to make peptide bonds |

| | |
|--|---|
| | |
| Termination | <ol style="list-style-type: none"> When stop codon is reached, no tRNA matches Protein release factor binds Peptidyl transferase adds water instead of an amino acid releasing the polypeptide The machinery disassembles and the parts can be reused |
| How can different genes be transcribed into RNA at different rates? | <ul style="list-style-type: none"> Promoter strength: effects how often RNA polymerase/Sigma factor are bound Repressor and accelerator/activator: <ul style="list-style-type: none"> accelerators make promoters faster repressors slow things down Additional metabolites: can regular binding of repressors and accelerators |
| tRNA and aa-tRNA Synthetases | <ul style="list-style-type: none"> Aa-tRNA synthetases: aa-tRNA-synthetases charges tRNA with the correct, activated amino acid tRNA: attach correct amino acid to matching tRNA by anticodon |

Making Proteins: Protein Structure

| | |
|---|---|
| Describe the differences between primary, secondary, tertiary and quaternary structure of proteins | <ul style="list-style-type: none"> Primary: amino acids sequence Secondary: local structures, alpha helix and beta sheet Tertiary: Overall 3D arrangement of a polypeptide chain Quaternary: Organisation of subunits (many but not all proteins have multiple subunits) <p>Features of secondary structure</p> <ul style="list-style-type: none"> Local features allow formation of a structure Backbone-backbone hydrogen bonding interactions are very important Sidechain interactions help hold the structure together and form the tertiary structure Alpha helices: always have same basic shape, right-handed helix Beta sheets: Arrow points direction of protein chains <ul style="list-style-type: none"> Can be parallel or antiparallel <p>Tertiary structure</p> <ul style="list-style-type: none"> Held together by lots of: hydrogen bonds, polar interactions, hydrophobic interactions <ul style="list-style-type: none"> Hydrophobic effect is a driving force for protein folding |
|---|---|

| | <ul style="list-style-type: none"> - pH, solvents and temperature are really important to maintain structure | | | | | | | | | | | | | | |
|--|--|-----------------|-------------------|---------------|------------------------------|--------------------------|---------|--------------------------|--|---|--|---|------------------------|-----------------|--|
| Appreciate that the protein sequence defines the protein fold and function, and that protein molecules are held together by the combination of many bonds | <p>Protein Folding</p> <ul style="list-style-type: none"> - Information encoded in amino acid sequence - Burial of hydrophobic surfaces/side chains in aqueous solvent - Collapse of protein chain/formation of secondary structure - Firming up tertiary structure by interactions between different part of the protein - Proteins and another structured biomolecules are not rigid by “breathe” as atoms move around, bonds twist and length and shorten within limits <table border="1"> <thead> <tr> <th>Bond/force type</th><th>Type of structure</th></tr> </thead> <tbody> <tr> <td>Hydrogen bond</td><td>Secondary, but also tertiary</td></tr> <tr> <td>Peptide bonds (covalent)</td><td>Primary</td></tr> <tr> <td>Hydrophobic interactions</td><td>Tertiary - located on the inside of the protein to be protected from water</td></tr> <tr> <td>Dipole dipole (london dispersion forces - temporary vs permanent)</td><td>Tertiary - London dispersion forces Tertiary/secondary if permanent</td></tr> <tr> <td>Ionic and polar interactions → hold entire structure together</td><td>Tertiary Quaternary</td></tr> <tr> <td>Sulphide bridge</td><td>Tertiary Quaternary <ul style="list-style-type: none"> - Join different chains together or different parts of the same chain to increase stability </td></tr> </tbody> </table> | Bond/force type | Type of structure | Hydrogen bond | Secondary, but also tertiary | Peptide bonds (covalent) | Primary | Hydrophobic interactions | Tertiary - located on the inside of the protein to be protected from water | Dipole dipole (london dispersion forces - temporary vs permanent) | Tertiary - London dispersion forces Tertiary/secondary if permanent | Ionic and polar interactions → hold entire structure together | Tertiary Quaternary | Sulphide bridge | Tertiary Quaternary <ul style="list-style-type: none"> - Join different chains together or different parts of the same chain to increase stability |
| Bond/force type | Type of structure | | | | | | | | | | | | | | |
| Hydrogen bond | Secondary, but also tertiary | | | | | | | | | | | | | | |
| Peptide bonds (covalent) | Primary | | | | | | | | | | | | | | |
| Hydrophobic interactions | Tertiary - located on the inside of the protein to be protected from water | | | | | | | | | | | | | | |
| Dipole dipole (london dispersion forces - temporary vs permanent) | Tertiary - London dispersion forces Tertiary/secondary if permanent | | | | | | | | | | | | | | |
| Ionic and polar interactions → hold entire structure together | Tertiary Quaternary | | | | | | | | | | | | | | |
| Sulphide bridge | Tertiary Quaternary <ul style="list-style-type: none"> - Join different chains together or different parts of the same chain to increase stability | | | | | | | | | | | | | | |
| Demonstrate how 3D protein structure is related to function using the example of the alpha helix in DNA binding proteins | <ul style="list-style-type: none"> - Local features allow formation of structure: Backbone-backbone hydrogen bonding interactions + Sidechain interactions help hold the structure together and form the tertiary structure - Sidechains can make interactions with other parts of the protein - Alpha-helix: Always have the same basic shape, right handed helix. Sidechains point outwards. - Perfect size to fit into the major groove of DNA. Sidechains must point the right way to recognize either the backbone for general/non-sequence specific binding, or the bases for sequence specific binding - Beta-helix: Can be parallel (strands point in the same directions) or antiparallel (strands point in opposite directions), Arrow points direct of protein chains (N>C), Sidechains point above and below | | | | | | | | | | | | | | |

Enzymes and Thermodynamics: Equilibrium and Thermodynamics vs. Kinetics

| | |
|---------------------------|---|
| Energy and Entropy | <ul style="list-style-type: none"> - Energy is the capacity to do work - Bioenergetics is the transfer of potential kinetic energy and back in living systems |
|---------------------------|---|

| | |
|---|--|
| | <ul style="list-style-type: none"> - Entropy is a measure of disorder |
| Understand the difference between potential and kinetic energy | <ul style="list-style-type: none"> - Potential energy: stored in chemical bonds/interaction - Kinetic energy: energy expressed as movement such as heat/radiant energy |
| Explain the concept of equilibrium and how it relates to energy | <ul style="list-style-type: none"> - Reversible reactions - Substrate (S) \leftrightarrow Product (P) will either be: <ul style="list-style-type: none"> - Favourable: give out energy/exergonic - Unfavourable: need energy input/endergonic - Decides what the equilibrium state will be → at the end of the reaction how much S vs how much P - Have a standard state → defined concentrations and conditions of substrate and product |
| Explain the differences between the thermodynamic and kinetic properties of a reaction | <p>Kinetics</p> <ul style="list-style-type: none"> - Kinetics: how quickly will the reaction happen <ul style="list-style-type: none"> - Must go over an activation barrier → add energy to get to the activation state - Energy is then released going from activation barrier to the product - Low Activation Barrier: a large fraction of molecules have enough energy to get over the barrier → reaction is fast - High Activation Barrier: very small fraction of molecules have enough energy to get over the barrier → reaction is slow - Barrier from need to break bonds <p>Thermodynamic</p> <ul style="list-style-type: none"> - No activation barrier → straight from substrate to product |

Enzymes and Thermodynamics: Enzymes

| | |
|--|--|
| Explain how enzymes act as catalysts, including what effect they have on reaction | <ul style="list-style-type: none"> - Enzymes are catalysts which lower the energy barrier/Activation barrier → speed up the rate of reaction <ul style="list-style-type: none"> - Does not change energy release - Occurs by stabilising 'transition' states <ul style="list-style-type: none"> - Goes through states where substrate is partially a substrate and partially |
|--|--|

| | |
|---|---|
| rates and final concentrations of substrates and products of a reaction | <p>the product</p> <ul style="list-style-type: none"> - Enzyme catalyses a hydrolysis reaction that cleaves the substrate into products which are quickly released - Enzymes (and other catalysts) act by reducing the activation energy, thereby increasing the rate of reaction. The increased rate is the same in both the forward and reverse directions, since both must pass through the same transition state. <p>Enzyme binding</p> <ul style="list-style-type: none"> - Enzymes are specific to the substrate: <ul style="list-style-type: none"> - Relatively big, highly functionalized binding pockets - Highly specific for the substrate - Lock and key model: substrate molecule fits directly into the active site - Induced-fit model: the substrate induces a shape change for optimal substrate binding and activity - Selection model: the enzyme exists in multiple forms in equilibrium, only one of which (A) binds substrate. Binding to A shifts equilibrium (B > A) to enable more binding |
| Enzyme naming and types | <ul style="list-style-type: none"> - Usually end in “ase” - Naming system based on the activity |
| Appreciate how enzymes can be used experimentally | <ul style="list-style-type: none"> - Used to speed up the rate of reaction - Biological catalysts - Individual enzymes have evolved to work best at specific temperatures and pH - May require an additional chemical component (cofactor) for optimal activity - Can be inhibited - Used to measure the rate of reaction → amount of product released over a certain amount of time - Under same experimental conditions and high substrate doubling the enzyme will double the rate |
| Understand that enzymes combine to form enzymatic pathways that are important for living organisms | <ul style="list-style-type: none"> - Enzymes form pathways for metabolism, synthesis of cellular materials, communication etc. - Mutations that reduce activity/changes specificity/increase activity/alter regulation cause disease |

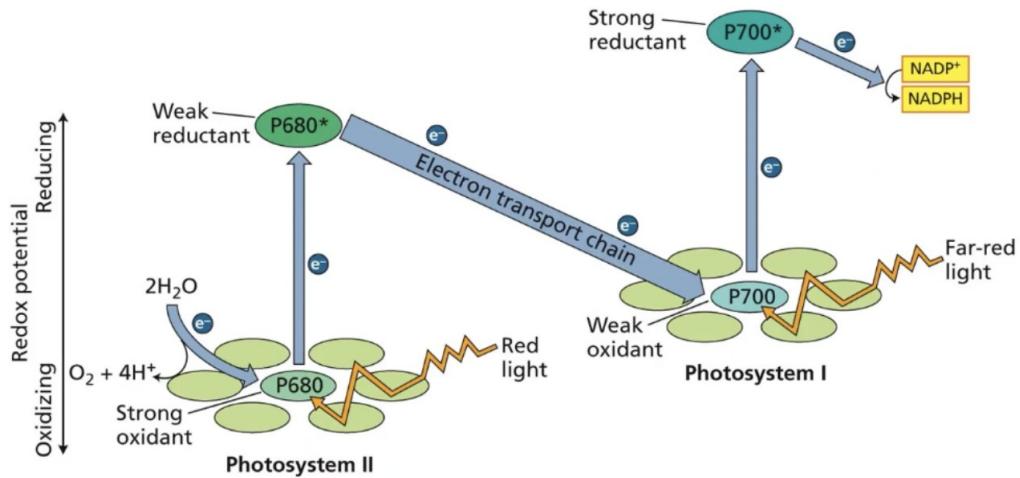
| | |
|---|--|
| <p>Describe how a secondary reaction can drive equilibrium and provide energy for an unfavourable reaction</p> | <ul style="list-style-type: none"> - Unfavourable interactions need energy input - Biopolymer formation is intrinsically unfavourable <ul style="list-style-type: none"> - Eg. nucleic acids need to make high energy phosphodiester bonds between successive nucleotides/amino acid activation releases PPi - Original polynucleotide, add in next nucleotide → end up with nucleotide being attached and diphosphate being released (unfavourable) <ul style="list-style-type: none"> - Step 1: use energy - Step 2: pyrophosphate is broken down which releases energy - Drives reaction in a certain direction, so it cannot go backwards → driving unfavourable reaction |
|---|--|

Energy Systems and Cells

Photosynthesis: Metabolism and Energy Currency, Capture of Solar Energy

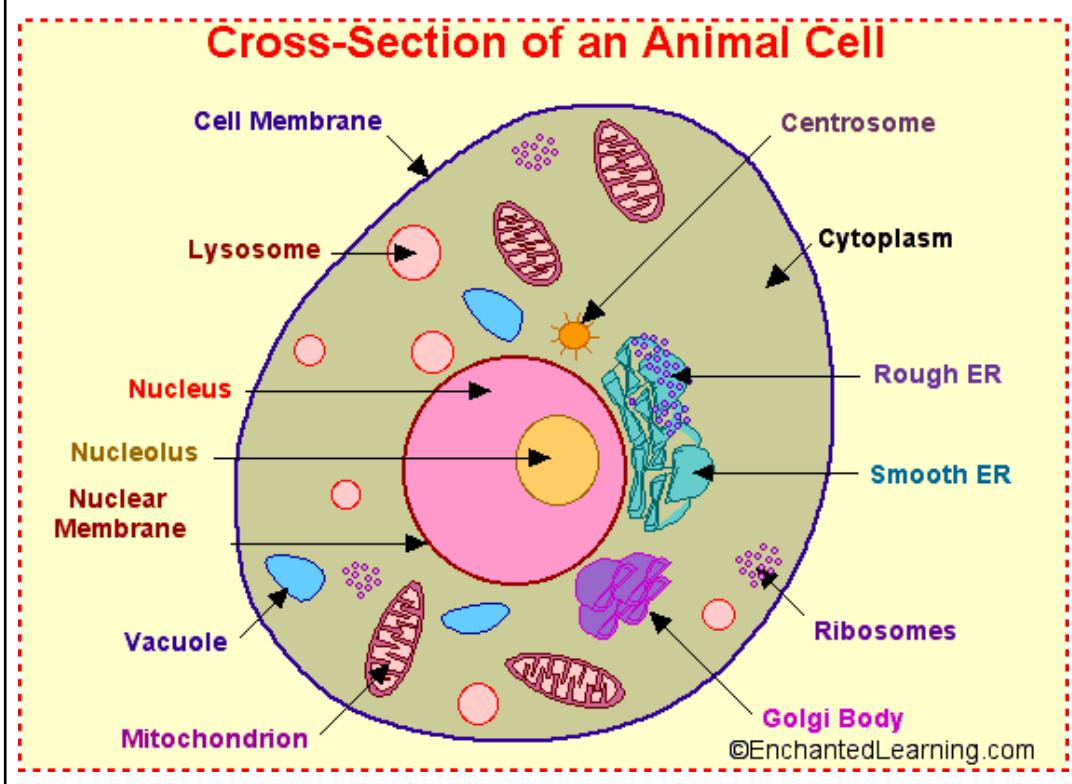
| | |
|--|--|
| Differentiate between anabolism and catabolism, and oxidation and reduction | <ul style="list-style-type: none"> - Anabolism: small molecules assemble into large ones → energy is required - Catabolism: large molecules break down into small ones → net release of energy - Redox reactions <ul style="list-style-type: none"> - Oxidation: removing an electron from a compound - Reduction: adding an electron to a compound - Electron carriers such as NAD⁺ can accept electrons from an organic molecule |
| Explain how ATP can power cellular processes | <ul style="list-style-type: none"> - ATP: adenosine triphosphate - ADP: adenosine diphosphate - Phosphate bonds a “high energy” bonds - Cellular energy carrier - Energy stored in ATP and is then released when needed by breaking bonds between phosphate groups |
| Describe the major evolutionary events to maximise light capture by plants | <ul style="list-style-type: none"> - Two main ways organisms can acquire energy: <ul style="list-style-type: none"> - Heterotrophy - Autotrophy (eg. photosynthetic organisms such as plants) <p>Evolution of Metabolic Pathways</p> |
| Describe, in overview, the conversion of radiant energy into chemical energy | <ul style="list-style-type: none"> - Goal of light reactions: trap sunlight and convert to chemical energy (ATP, NADPH) for later use - Chlorophyll resides between the thylakoids membranes of the chloroplast capture light - Chlorophyll form an antenna complex which transfer light energy into the |

| | |
|---|---|
| | <p>reaction centre</p> <p>Cyclic Phosphorylation</p> <ul style="list-style-type: none"> Begins with chlorophyll in the ground state (not excited) which receives energy from sunlight → raises an electron to a higher orbital Energy in high energy electron (from chlorophyll) is then used to pump protons from the chloroplast stroma into the lumen → causes a proton gradient between stroma and lumen → proton gradient drives ATP synthesis |
| Explain the overall organisation of the light reactions in photosystems I and II | <p>Non-cyclic Phosphorylation (Photosystem I and II)</p> <ul style="list-style-type: none"> Photosystem II: Begins with chlorophyll in the ground state (not excited) which receives energy from sunlight → raises an electron to a higher orbital Energy in high energy electron (from chlorophyll) is then used to pump protons from the chloroplast stroma into the lumen → causes a proton gradient between stroma and lumen → proton gradient drives ATP synthesis Photosystem I: Electrons then flow into another chlorophyll, which receives more light energy → raises electrons to an excited state <ul style="list-style-type: none"> In this excited state, the chlorophyll electron has a high redox potential, which can be used to reduce NADP⁺ to NADPH Used to convert CO₂ to glucose Note: there is not a lack of electron, water is split and this electron is then held by the chloroplast → oxygen released from water split is the oxygen we breathe |



| | |
|---|---|
| | <p>1st stage “Light reactions”</p> $2 \text{ H}_2\text{O} + 2 \text{ NADP}^+ + 3 \text{ ADP} + 3 \text{ P}_i + \text{light} \rightarrow 2 \text{ NADPH} + 2 \text{ H}^+ + 3 \text{ ATP} + \text{O}_2$ |
| Membranes in the Chloroplast | <p>The diagram illustrates the multi-compartment structure of a chloroplast. It shows the outer envelope, inner envelope, and the stroma containing stroma lamellae. Within the stroma are grana lamellae, which are stacks of thylakoids. A single thylakoid is shown with its lumen. An arrow points from the text "Outer envelope" to the outer boundary of the chloroplast.</p> <ul style="list-style-type: none"> - Multi-compartment structure is necessary for photosynthesis as it allows for different reaction to be kept separate → leads to development of proton gradient |
| Describe ATP synthesis during photosynthesis | <ul style="list-style-type: none"> - Proton pumping and oxidation leads to a high concentration of protons in the lumen and low concentration in the stroma - Only way for protons to diffuse from lumen to stroma is through the protein ATP synthase - As protons diffuse back through ATP synthase, phosphorylation is catalysed, leading to the production of ATP |

Labelled cell diagram



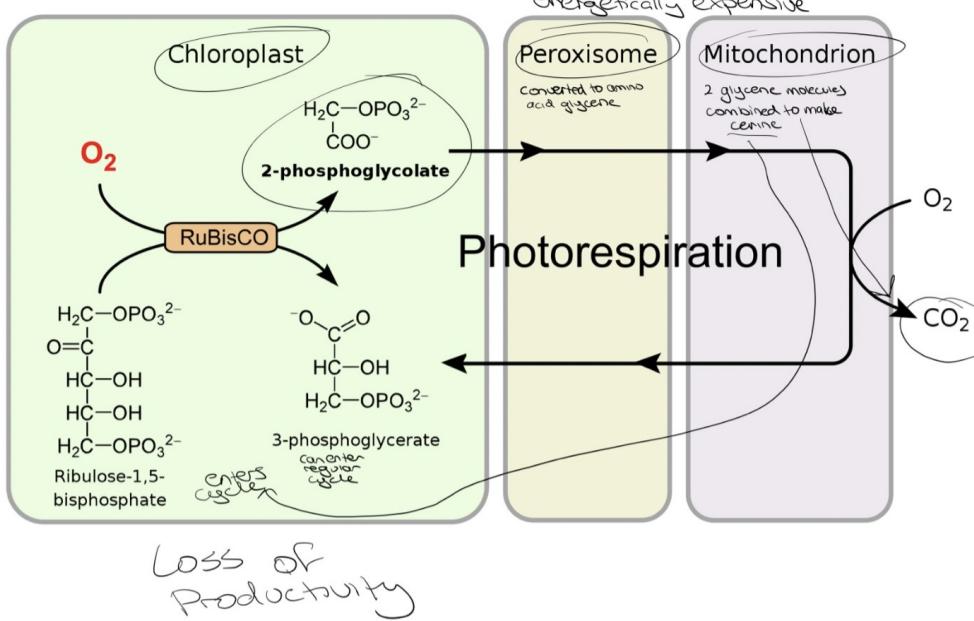
Photosynthesis: The Calvin cycle and CO₂ fixation, C₄ and CAM Photosynthesis

| | |
|---|---|
| Introduction | <p>2nd stage “Calvin cycle” or “light-independent”</p> $3 \text{ CO}_2 + 9 \text{ ATP} + 6 \text{ NADPH} + 6 \text{ H}^+ \rightarrow \text{C}_3\text{H}_6\text{O}_3\text{-phosphate} + 9 \text{ ADP} + 8 \text{ P}_i + 6 \text{ NADP}^+ + 3 \text{ H}_2\text{O}$ <p style="text-align: center;"><i>glucose</i></p> |
| Explain fixation of carbon dioxide in the Calvin Cycle | <ul style="list-style-type: none"> - Carbon dioxide is reduced to form a triose phosphate sugar ($\text{C}_3\text{H}_6\text{O}_3\text{-phosphate}$) that will eventually form glucose <ul style="list-style-type: none"> - Reduced by hydrogen and electron in NADPH → becomes NADP^+ <p>Calvin Cycle</p> <ul style="list-style-type: none"> - Occurs in the stroma - Carboxylation: CO_2 enters the cycle → catalysed by rubisco <ul style="list-style-type: none"> - Carbon dioxide is fixed into 2x 3 carbon compounds (3-Phosphoglycerate) - Reduction: ATP + NADPH (from light reaction) get added in via reduction to create Glyceraldehyde-3-phosphate - Regeneration: energy from ATP regenerates Ribulose-1,5-bisphosphate (5 carbon) - 1 carbon is added each cycle → to make glucose (a 6 carbon compound) the cycle must turn 6 times <p>Calvin cycle - CO₂ fixation 3 stages - occurs in chloroplast stroma:</p> |

| | |
|---|--|
| | <ol style="list-style-type: none"> 1. Rubisco catalyses attachment of CO₂ to RuBP (a 5C compound). → create an unstable 6C intermediate → break down to 2 molecules of 3PG (3C compounds). As a 3C compound is the 1st stable product, this cycle is called C3 photosynthesis 2. Next phase involves adding electrons and energy. NADPH and ATP supply energy + electrons. 3. 3PG is converted to G3P. 4. Some G3P is used up to make glucose and other molecules but most continues in cycle to be regenerated 5. The 3C 1P compound G3P is converted back to the 5c 2p RuBP using ATP from the light reaction 6. Compartmentalization is important to generating proton gradient (i.e. the lumen is surrounded by the phospholipid bilayer of thylakoid membrane) <ul style="list-style-type: none"> - The cycle has to turn 6 times to create 1 glucose (glucose has 6C) as only 1C is added each turn - Only 1 out of every 6 G3P molecules leaves the calvin cycle and is sent to the cytoplasm to contribute to the formation of other compounds needed by the plant (like glucose, sugars, etc.). - Because the G3P exported from the chloroplast has 3C, it takes 3 turns of the calvin cycle to fix enough carbon to export 1 G3P. - But each turn makes 2 G3Ps thus 3 turns make 6 G3Ps. - One is exported while the remaining 5 G3P molecules remain in the cycle and are used to regenerate RuBP, which enables system to prepare for more CO₂ to be fixed |
| Compare carboxylation and oxygenation by Rubisco | <ul style="list-style-type: none"> - Rubisco → occurs in chloroplast stroma <ul style="list-style-type: none"> - Single most abundant protein on Earth - Can fix both carbon (carboxylation) and oxygen (oxygenation) <ul style="list-style-type: none"> - Mistakenly fixes oxygen <p>Oxygenation (Photorespiration)</p> <ul style="list-style-type: none"> - Enzyme Rubisco fixes oxygen <ul style="list-style-type: none"> - Products: <ul style="list-style-type: none"> - 3-phosphoglycerate not a problem, can go into Calvin cycle - 2-phosphoglycolate: must be detoxified, requires 3 organelles working together collaborative and expends ATP, releases CO₂ - Accounts for 25% of the reactions via Rubisco → very common, wasteful |

Photorespiration

(AKA C2 cycle or oxidative photosynthetic carbon cycle)

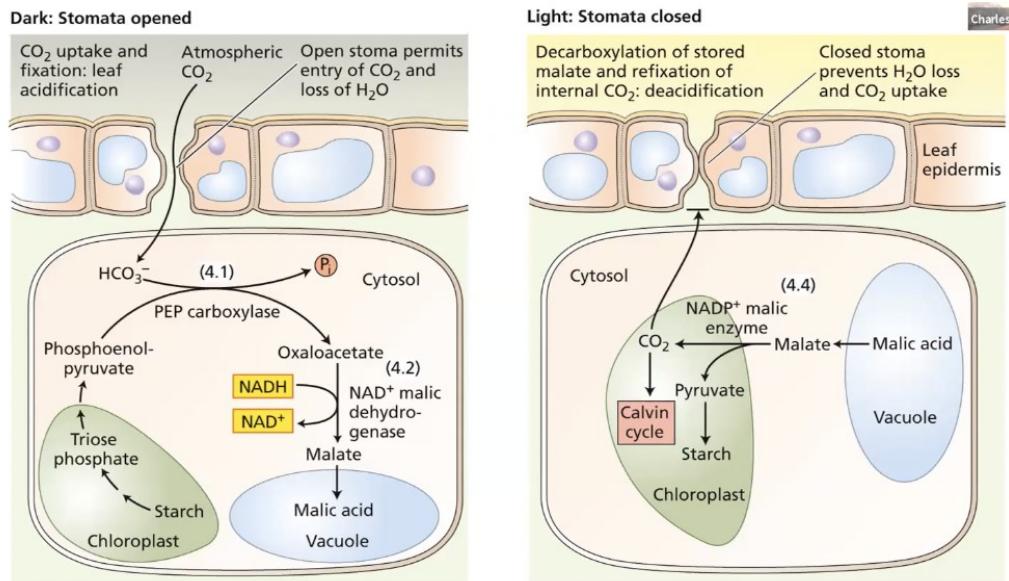


Describe the coevolution of photosynthesis (C₄) and the earth's atmosphere over time

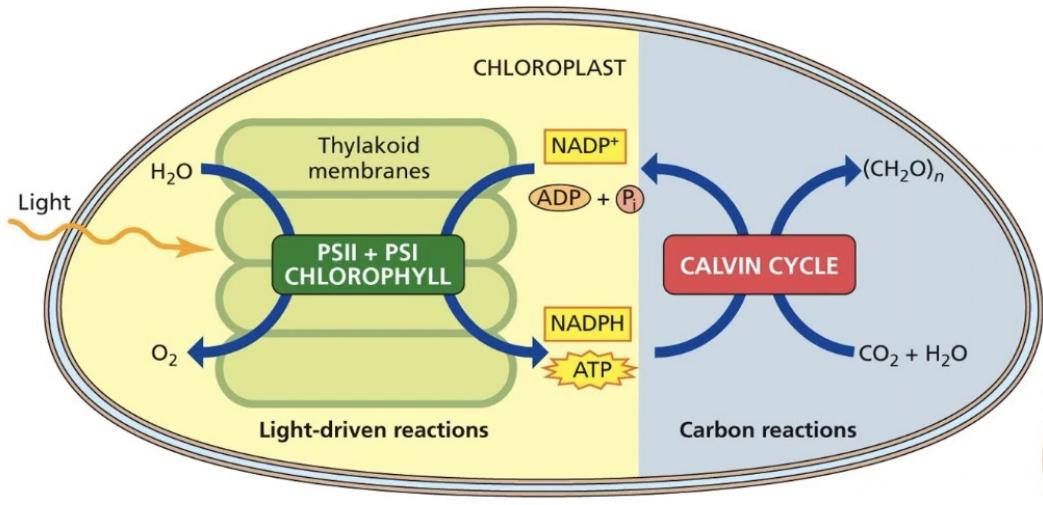
- C₄ photosynthesis occurred around the same time CO₂ concentration decreased
 - CO₂ concentration was high and then decreased → as CO₂ decreased, photorespiration occurred to a larger extent as it competes with CO₂ fixation
 - More CO₂ concentration in atmosphere = more CO₂ fixation
 - Less CO₂ concentration in atmosphere = more oxygen fixation (photorespiration, waste)
- C₄ photosynthesis: structural and metabolic adjustments
 - In all photosynthetic organisms, only Rubisco catalyses the net fixation of CO₂ into organic molecules
 - C₄ is a series of metabolic and structural adjustments exploiting phosphoenolpyruvate carboxylase (PEP carboxylase, or PEPCase or PEPC) to concentrate CO₂ around Rubisco
 - There are several version of C₄
 1. Mesophyll cell:
 - CO₂ diffuses into the cell and becomes bicarbonate (HCO₃⁻)
 - Bicarbonate is fixed by PEPC to become Malate (C₄) (PEPC only fixes CO₂)
 2. Bundle sheath cell
 - Maleic acid diffuses into bundle sheath cell where it is decarboxylated (lose CO₂)
 - Lost CO₂ is released around the outside of the chloroplast
 - Extremely high concentration of CO₂ around the outside of the chloroplast saturates the Rubisco, such that no oxygenation reaction occurs in the Calvin cycle
 - Pyruvate (by product of the NAD-malic enzyme) moves back into the mesophyll cell and returns to the cycle.

| | |
|---|---|
| | <p>Generally:</p> <ul style="list-style-type: none"> - Spatial separation between mesophyll cell and bundle sheath cell - CO₂ diffuses into the mesophyll cell and turns into bicarbonate (HCO₃⁻) which is fixed by the enzyme PEP carboxylase (no oxygenase activity – will only fix CO₂) - Converted into malate which diffuses into the bundle sheath cell and is broken down by the NAD-malic enzyme and CO₂ is released and moves into a chloroplast and therefore the Calvin cycle - The CO₂ saturates rubisco in the chloroplast (huge concentration) and stops photorespiration - Pyruvate (by product of the NAD-malic enzyme) moves back into the mesophyll cell and returns to the cycle. <p>The diagram illustrates the C4 photosynthesis pathway. It shows two cells: a Mesophyll cell at the top and a Bundle sheath cell below it. - In the Mesophyll cell, CO₂ enters from the External atmosphere and is fixed by the PEPcase enzyme into HCO₃⁻. This is then converted into Malate (C₄). - Malate (C₄) moves through a Diffusion barrier to the Bundle sheath cell. - In the Bundle sheath cell, Malate (C₄) is broken down by the NAD-malic enzyme. This releases CO₂, which then enters a Chloroplast where it enters the Calvin cycle. - The NAD-malic enzyme also produces Pyruvate (C₃). - Pyruvate (C₃) moves back through the Diffusion barrier into the Mesophyll cell. - In the Mesophyll cell, Pyruvate (C₃) is converted back into Pyruvate phosphate dikinase, which then releases HCO₃⁻ to regenerate CO₂ and complete the cycle.</p> |
| <p>Describe the photosynthesis-transpiration compromise and how CAM photosynthesis breaks the nexus between photosynthesis and transpiration</p> | <ul style="list-style-type: none"> - Crassulacean acid metabolism (CAM) photosynthesis <ul style="list-style-type: none"> - Solves photorespiration and saves water (relative to C₃ or C₄) - Solves photorespiration problem by using PEP carboxylase - Leads to higher water-use efficiency (than C₃ or C₄) <ul style="list-style-type: none"> - Controlled by stomata - CAM photosynthesis employs a temporal separation of biochemistry - At night, the stomata are open so CO₂ can diffuse in. The humidity is higher and temperature is lower at this time, meaning less water will leave the cell when the stomata are open. CO₂ moves in and changes to bicarbonate (HCO₃) where PEP carboxylase fixes it into malate/malic acid which is stored in the vacuole - During the day, the stomata are closed to prevent water loss and CO₂ uptake. The malic acid stored in the vacuole moves into the chloroplast and is decarboxylated by NADP+ malic enzyme, releasing the CO₂ into the chloroplast, causing an increase in the CO₂ concentration which saturates rubisco, causing no photorespiration to occur. |

- Typically in plants in dry temperatures (e.g. pineapple, cactus)



Photosynthesis Diagram Summary



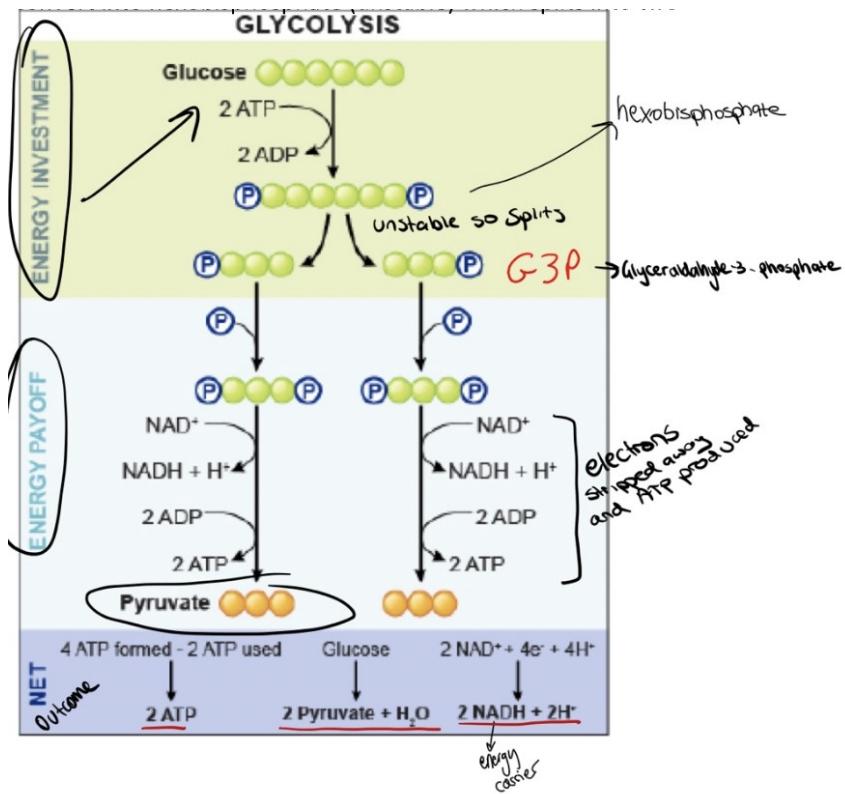
Respiration in Plants

Describe, in overview, the TCA cycle and glycolysis

- Cellular respiration: Combination of the Krebs cycle, glycolysis and electron transfer chain → occurs in inner membrane of the mitochondria

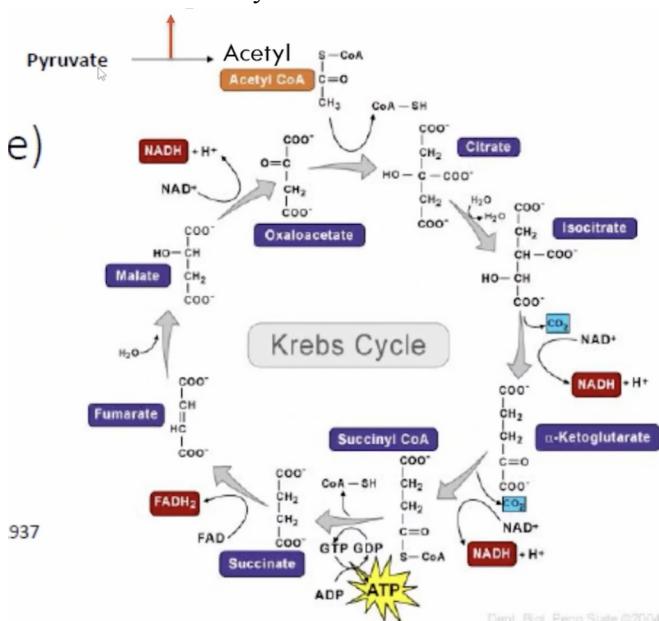
Glycolysis

- Glycolysis = sugar breakdown
- $\text{Glucose} + 2\text{NAD}^+ + 2\text{ADP} + 2\text{P} \rightarrow 2\text{pyruvate} + 2\text{NADH} + 2\text{H}^+ + 2\text{ATP} + 2\text{HH}_2\text{O}$
- Energy investment (2ATP) allows glucose to convert into hexobisphosphate (unstable) which splits into two glyceradahyde-3-phosphate molecules
- Converted to pyruvate (3 carbon compound)
- Electrons are stripped off and moved away via NADH and ADP is produced



Krebs Cycle (Citric Acid Cycle)

- Purpose = to remove electrons and put them into NADH/FADH₂ which can be used to generate ATP in the electron transport chain
- Starts with pyruvate (end product of glycolysis) which loses a carbon and is converted into an Acetyl group which is carried into the cycle with a CoA enzyme which immediately leaves the cycle
- The acetyl group brings another 2 Cs into the cycle, creating citric acid
- Throughout the process, CO₂ molecules are lost and electrons are harvested and carried out by NADH and FADH into the electron transfer chain



| Describe the electron transport chain and oxidative phosphorylation in mitochondria | <ul style="list-style-type: none"> - Strips electrons from acetyl group - Products from glycolysis and Kreb's cycle are used to generate ATP - Occurs on the inner membrane of the mitochondria - The electrons carried by NADH and FADH₂ are used to pump protons from the matrix to the intermembrane space - This results in a high concentration of protons in the intermembrane space - The protons move through ATP synthase which generates ATP - Terminal electron acceptor is oxygen - Oxidative phosphorylation | | | | | | |
|---|--|--------------|-------------|---|---|--|--|
| Summary | <p style="text-align: center;">Cellular respiration</p> <pre> graph TD glucose[glucose] --> glycolysis[glycolysis] glycolysis --> pyruvate[Pyruvate] pyruvate --> Acetyl["Acetyl / COA"] pyruvate --> CO21[CO2] Acetyl --> Krebs[Kreb's cycle] Krebs --> CO22[CO2] Krebs --> NADH[NADH] Krebs --> FADH2[FADH2] NADH --> ETC[ETC] FADH2 --> ETC ETC --> O2["O2 terminal electron acceptor"] ETC --> H2O[H2O] ETC --> ATP[ATP] glycolysis --> ATP_glycolysis[ATP] </pre> | | | | | | |
| Compare photosynthetic electron transport and the electron transport chain in mitochondria | <table border="1" data-bbox="412 1273 1473 1590"> <thead> <tr> <th>Mitochondria</th> <th>Chloroplast</th> </tr> </thead> <tbody> <tr> <td> <ul style="list-style-type: none"> - Surface area is increased by folding of inner membrane into cristae </td><td> <ul style="list-style-type: none"> - Thylakoids stacked on top of each other </td></tr> <tr> <td> <ul style="list-style-type: none"> - Space enclosed by inner membrane is matrix </td><td> <ul style="list-style-type: none"> - Space enclosed by inner membrane is stroma </td></tr> </tbody> </table> <ul style="list-style-type: none"> - Both synthesise proteins from instructions supplied by their own DNA - Both have electron transport chains that occur via a chemiosmosis mechanism <ul style="list-style-type: none"> - Chloroplast (photosynthetic): energy comes from light - Mitochondria (electron transport chain): energy comes from high energy electrons which are carried by FADH₂ and NADH (sourced from glucose) - Both have inner and outer membranes; the electron transport chain occurs on the inner membrane <ul style="list-style-type: none"> - In chloroplasts, the electron transport chain occurs on the thylakoid | Mitochondria | Chloroplast | <ul style="list-style-type: none"> - Surface area is increased by folding of inner membrane into cristae | <ul style="list-style-type: none"> - Thylakoids stacked on top of each other | <ul style="list-style-type: none"> - Space enclosed by inner membrane is matrix | <ul style="list-style-type: none"> - Space enclosed by inner membrane is stroma |
| Mitochondria | Chloroplast | | | | | | |
| <ul style="list-style-type: none"> - Surface area is increased by folding of inner membrane into cristae | <ul style="list-style-type: none"> - Thylakoids stacked on top of each other | | | | | | |
| <ul style="list-style-type: none"> - Space enclosed by inner membrane is matrix | <ul style="list-style-type: none"> - Space enclosed by inner membrane is stroma | | | | | | |

| | |
|---|--|
| | <p>membrane</p> <ul style="list-style-type: none"> - In the mitochondria, it occurs on the inner membrane - Special adaptations in both to increase the surface area of the inner membranes <ul style="list-style-type: none"> - In chloroplasts, the inner membranes are stacked in granum - In mitochondria membranes are folded (crista) - Both have a somewhat independent independence within their own cells <ul style="list-style-type: none"> - Synthesise many of their proteins from their own DNA - Electron chains are coupled with ATP synthesis <ul style="list-style-type: none"> - End result is ATP - Similar carriers in transport chain (e.g. synthase) |
| Describe variations on the basic model of cellular respiration | <ul style="list-style-type: none"> - Alternative Oxidase (AOX) can function as a by-pass as electrons flow through electron transport chain - Uncoupling protein: provides a pathway for hydrogen ions to diffuse back through the membrane <p>Respiration in Plant Cells</p> <ul style="list-style-type: none"> - Glucose often cited as substrate for respiration, but in plant cells substrate can be sucrose, triose phosphates, lipids, organic acids - In animal cells a variety of substrates are also used for respiration - Reactions and enzymes of the plant citric acid cycle <ul style="list-style-type: none"> - Strong expression of the NAD malic enzyme another way for compounds to enter the Krebs cycle - Malic enzyme takes malate (organic acid) and converts it into pyruvate. This can enter the citric acid cycle. Therefore, no need for glycolysis (more flexibility and allows the use of organic acids – malate as a respiratory substrate) - Sometimes, metabolites do not undergo the whole cycle → think of it as a roundabout <ul style="list-style-type: none"> - Metabolites can enter at some stages and exit at some stages - Switches between a full or incomplete cycle based on the metabolic requirements of the organism and cell <ul style="list-style-type: none"> - When a cell has enough NADH and FADH₂, the cycle won't run as a complete cycle. - The steps that are skipped are those that produce NADH and FADH₂ - It can be run in reverse - Added layer of flexibility in the electron transport chain <ul style="list-style-type: none"> - Alternative oxidase (AOX) is a safety valve - Causes electrons to be moved through where oxygen serves as the terminal acceptor <ul style="list-style-type: none"> - Meaning they are bypassing other complexes which reduces the scale of the proton gradient, resulting in the synthesis of less ATP - Uncoupling protein (UCP) allows protons to passively diffuse back through the bilayer without going through the ATP synthase = less ATP synthesised - Wasted energy is dissipated as heat |

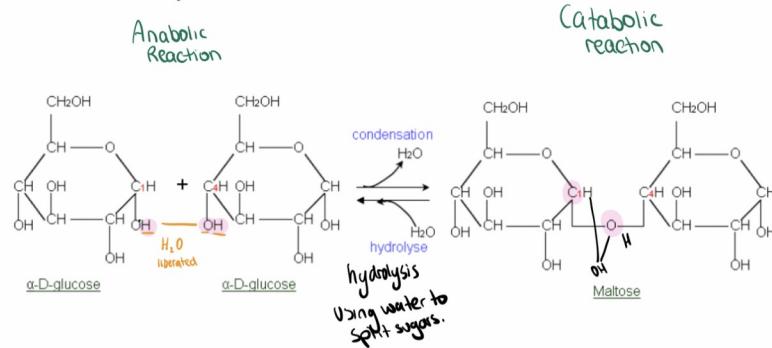
| | |
|--|--|
| | <ul style="list-style-type: none"> - Prevents the electron transport chain from becoming backed up with electrons and protons can be damaging - Alternative oxidase and thermogenesis <ul style="list-style-type: none"> - Plants use the heat formed from wasted energy to heat up tissues - At low temperatures, the lotus flower is respiring a huge amount, because it is respiring and using wasted energy via alternative oxidase pathways to heat itself up - As the temperature rises, the rate of respiration decreases, because it doesn't need to heat up the flower |
|--|--|

Metabolism

| | |
|--|---|
| Distinguish between macronutrients and micronutrients | <ul style="list-style-type: none"> - Macronutrients: nutrients the body need in large amounts <ul style="list-style-type: none"> - Larger than micronutrients - Carbohydrates, lipids (fats), proteins - Micronutrients: nutrients the body need in smaller amounts <ul style="list-style-type: none"> - Building blocks of tissue - Vitamins: cofactors to enzymes e.g. vitamin C does this in connective tissue - Minerals: cofactors to enzymes and used in tissue (integral part), e.g. calcium is an integral part of bone tissue |
| Characterise the terms anabolism and catabolism | <ul style="list-style-type: none"> - Anabolism: small molecules are assembled into large ones <ul style="list-style-type: none"> - Energy is required - Catabolism: large molecules are broken down into small ones <ul style="list-style-type: none"> - Energy is released |
| | <p>The diagram illustrates the relationship between energy sources and metabolic pathways. On the left, 'Catabolism' is shown as 'energy-yielding metabolism' where 'utilizable energy' from 'energy sources' is used to produce 'heat' and 'metabolic products'. On the right, 'Anabolism' is shown as 'biosynthetic metabolism' where 'utilizable energy' is used to produce 'ATP' (from ADP) and various biosynthetic intermediates and precursors from 'external nutrients'.</p> |
| Describe the composition of fats, carbohydrates and proteins | Carbohydrates/glucogen <ul style="list-style-type: none"> - Glycogen is stored in many cells, especially in the liver and skeletal muscle <ul style="list-style-type: none"> - When the liver breaks down glycogen it is released directly into the bloodstream |

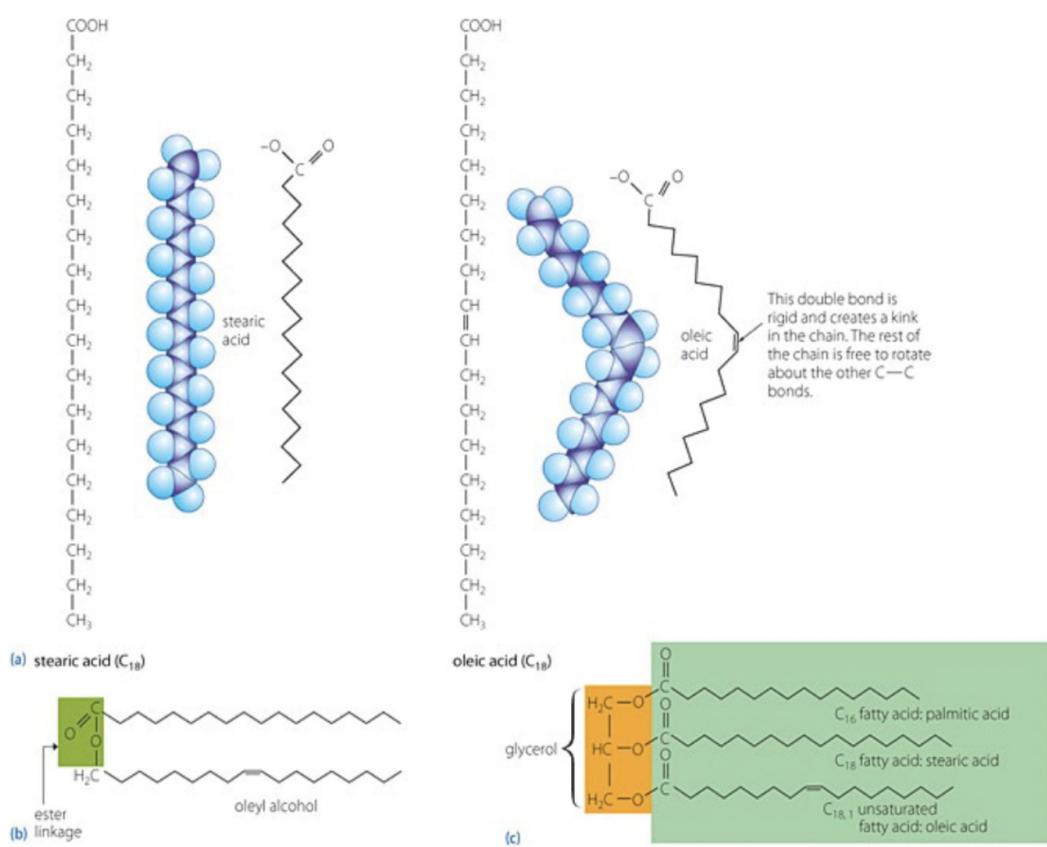
- Muscle does not have the enzymes that prepare glucose for export out of the cell, so the glucose that is produced when glycogen is broken down, it is kept in the muscle cells and used for energy in these cells
- Glucagon (from pancreas) is the hormone that catalyses the breakdown of glycogen antagonistic hormone to insulin (causes sugar from the blood to go into the liver and join into glycogen)
- Glucagon causes catabolism
- Insulin causes anabolism

Glycosidic bond formation



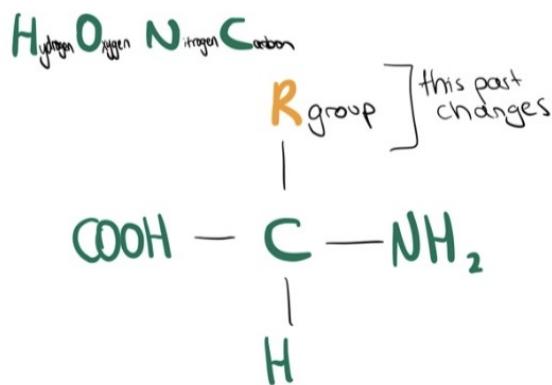
Fats

- CH₂
- The body stores fat as triglycerides in adipose tissue
- Fat is a concentrated form of energy storage
- Fat releases over twice as much energy than carbohydrates and protein when it is broken down
- Triglyceride



Proteins/amino acids

- In the stomach, proteins are broken down into amino acids that are absorbed into the bloodstream
- Non-essential: amino acids that can be synthesised by the cell
- Essential: cannot be synthesised, need to be obtained through diet
- All essential amino acid components of protein are made by plants

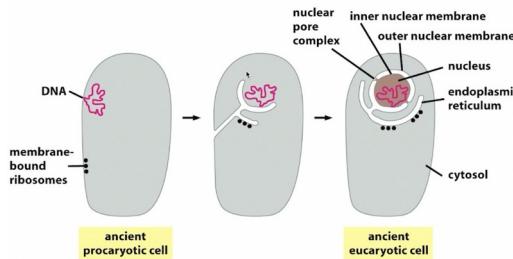
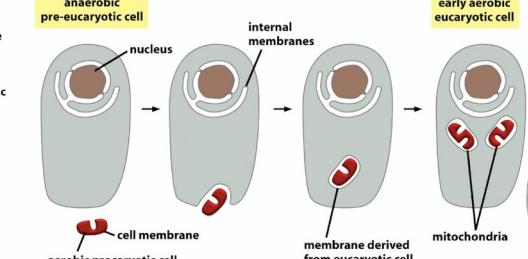


| | |
|---|--|
| Phosphate | Phosphate <ul style="list-style-type: none"> - Hydrophilic - Mineral micronutrient |
| Explain how ATP can power cellular | <ul style="list-style-type: none"> - ATP loses a phosphate to generate energy - Ribose sugar |

| <p>processes</p> | <ul style="list-style-type: none"> To put energy into a metabolic process, the gamma phosphate is removed and (often) attached to a protein and brings its negative charge The differing charges on the R groups in the amino acids in the protein gives the protein structure The negative charge on the phosphate group that joins the protein causes movement in the protein which can allow it to do work | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|--|--|-------------------------------------|-----------------------|-------------------------------------|------------|-----|-----|-----------|-------|-------|------------|-------|-------|---------|-------|-------|--------|-------|-------|------------|-----|-----|---------------|-----|-------|--------|-------|-------|-----------|-----|-----|--|-------------------|-------------|----|-----------|-----|-------------------|---|------------------|----|---------------|----|----------|-----|
| <p>Compare and contrast different nutritional sources of protein</p> | <table border="1"> <thead> <tr> <th></th> <th>Ground lean beef 100g</th> <th>Soy beans, dry roasted 86g, 1/2 cup</th> </tr> </thead> <tbody> <tr> <td>tryptophan</td> <td>277</td> <td>495</td> </tr> <tr> <td>threonine</td> <td>1,080</td> <td>1,478</td> </tr> <tr> <td>isoleucine</td> <td>1,111</td> <td>1,651</td> </tr> <tr> <td>leucine</td> <td>1,954</td> <td>2,772</td> </tr> <tr> <td>lysine</td> <td>2,057</td> <td>2,265</td> </tr> <tr> <td>methionine</td> <td>633</td> <td>459</td> </tr> <tr> <td>phenylalanine</td> <td>965</td> <td>1,777</td> </tr> <tr> <td>valine</td> <td>1,202</td> <td>1,699</td> </tr> <tr> <td>histidine</td> <td>846</td> <td>918</td> </tr> </tbody> </table> <p>*A 100g Beyond Burger contains 20g protein, 25g fat, 5g carbohydrates, 0g cholesterol, 22g total fat, 29g saturated fat, 23g trans fat, and 207 calories.</p> <p>VS</p> <table border="1"> <thead> <tr> <th></th> <th>ANIMAL-BASED BEEF</th> </tr> </thead> <tbody> <tr> <td>PROTEIN (G)</td> <td>19</td> </tr> <tr> <td>IRON (IV)</td> <td>12%</td> </tr> <tr> <td>SATURATED FAT (G)</td> <td>9</td> </tr> <tr> <td>CHOLESTEROL (MG)</td> <td>80</td> </tr> <tr> <td>TOTAL FAT (G)</td> <td>23</td> </tr> <tr> <td>CALORIES</td> <td>207</td> </tr> </tbody> </table> <p>PLANT-BASED ANIMAL-BASED ANTIBIOTIC-FREE ? HORMONE-FREE ? GMO-FREE ? SOY-FREE ✓ GLUTEN-FREE ✓</p> <p>DATA NATIONAL NUTRIENT BASED</p> | | Ground lean beef 100g | Soy beans, dry roasted 86g, 1/2 cup | tryptophan | 277 | 495 | threonine | 1,080 | 1,478 | isoleucine | 1,111 | 1,651 | leucine | 1,954 | 2,772 | lysine | 2,057 | 2,265 | methionine | 633 | 459 | phenylalanine | 965 | 1,777 | valine | 1,202 | 1,699 | histidine | 846 | 918 | | ANIMAL-BASED BEEF | PROTEIN (G) | 19 | IRON (IV) | 12% | SATURATED FAT (G) | 9 | CHOLESTEROL (MG) | 80 | TOTAL FAT (G) | 23 | CALORIES | 207 |
| | Ground lean beef 100g | Soy beans, dry roasted 86g, 1/2 cup | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| tryptophan | 277 | 495 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| threonine | 1,080 | 1,478 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| isoleucine | 1,111 | 1,651 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| leucine | 1,954 | 2,772 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| lysine | 2,057 | 2,265 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| methionine | 633 | 459 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| phenylalanine | 965 | 1,777 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| valine | 1,202 | 1,699 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| histidine | 846 | 918 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | ANIMAL-BASED BEEF | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| PROTEIN (G) | 19 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| IRON (IV) | 12% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| SATURATED FAT (G) | 9 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| CHOLESTEROL (MG) | 80 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL FAT (G) | 23 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| CALORIES | 207 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| <p>Understand the basics of how fats, carbohydrates and proteins can be interconverted via metabolism</p> | <p>Fats, proteins and carbohydrates are interconvertible</p> <p>Acetyl-CoA is readily converted into fatty acids, but acetyl-CoA cannot undergo net conversion to carbohydrate.</p> <p>Reproduced from Modern Nutritional Diseases with permission from Alice and Fred Ottolenghi.</p> <p>http://ketopia.com</p> | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| <p>Role of ribosome in protein synthesis initiation, elongation and termination</p> | <ul style="list-style-type: none"> Initiation: subunits combine with the mRNA inside; ribosome binds mRNA and Met-tRNA Elongation: peptidyl transferase in ribosome catalyses peptide bond formation using energy stored in the aa-tRNA bonds <ul style="list-style-type: none"> Accepts incoming tRNAs with correct anticodon | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

| | |
|--|---|
| | <ul style="list-style-type: none"> - Termination: stop codon does not match any tRNA, release factor protein binds into the A site when there is a stop codon <ul style="list-style-type: none"> - Water comes in and terminates the chain |
|--|---|

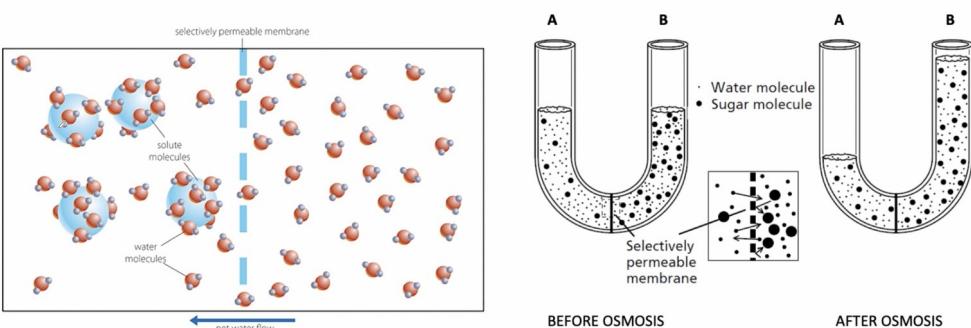
Cell Diversity

| Describe the theories on cell evolution | <ul style="list-style-type: none"> - Ancient prokaryotic cells had DNA and ribosomes stuck onto the plasma membrane - DNA moved from the edge of the cell into the middle, and brought some of the plasma membrane with it, as well as ribosomes - The membrane encircled the DNA, forming a nucleus - Excess membrane in the middle of the cell remained connected to the now membrane bound nucleus, with some holding ribosomes resulting in rough and smooth endoplasmic reticulum - These re-eukaryotic cells then engulfed an aerobic prokaryotic cell which became membrane bound mitochondria eventually evolved into multiple - The ER is connected to the nucleus. The nucleus has pores. - mRNA moves through the pores, through a ribosome on the ER and into the cytoplasm. <p style="text-align: center;">Evolution of the nucleus</p>  <p style="text-align: center;">Evolution of the mitochondria</p>  | | | | |
|---|--|-------------|------------|---|--|
| Distinguish between prokaryotic and eukaryotic cells | <table border="1" data-bbox="409 1284 1465 1959"> <thead> <tr> <th data-bbox="409 1284 931 1347">Prokaryotic</th><th data-bbox="931 1284 1480 1347">Eukaryotic</th></tr> </thead> <tbody> <tr> <td data-bbox="409 1347 931 1959"> <ul style="list-style-type: none"> - No membrane bound organelles - No nucleus - Evolved before eukaryotes - Have plasmids (extra DNA beyond chromosomes) <ul style="list-style-type: none"> - Antibacterial resistance - Can be exchanged – genetic advantage - Pilus – helps prokaryotes join together (conjugal pili) - and to other surface - Kingdoms: <ul style="list-style-type: none"> - Bacteria: peptidoglycan is a major constituent of cell walls </td><td data-bbox="931 1347 1480 1959"> <ul style="list-style-type: none"> - Well defined nucleus - Membrane bound organelles - Types: <ul style="list-style-type: none"> - Protists – single cell eukaryotes - Fungi - Plants (including algae) - Animals </td></tr> </tbody> </table> | Prokaryotic | Eukaryotic | <ul style="list-style-type: none"> - No membrane bound organelles - No nucleus - Evolved before eukaryotes - Have plasmids (extra DNA beyond chromosomes) <ul style="list-style-type: none"> - Antibacterial resistance - Can be exchanged – genetic advantage - Pilus – helps prokaryotes join together (conjugal pili) - and to other surface - Kingdoms: <ul style="list-style-type: none"> - Bacteria: peptidoglycan is a major constituent of cell walls | <ul style="list-style-type: none"> - Well defined nucleus - Membrane bound organelles - Types: <ul style="list-style-type: none"> - Protists – single cell eukaryotes - Fungi - Plants (including algae) - Animals |
| Prokaryotic | Eukaryotic | | | | |
| <ul style="list-style-type: none"> - No membrane bound organelles - No nucleus - Evolved before eukaryotes - Have plasmids (extra DNA beyond chromosomes) <ul style="list-style-type: none"> - Antibacterial resistance - Can be exchanged – genetic advantage - Pilus – helps prokaryotes join together (conjugal pili) - and to other surface - Kingdoms: <ul style="list-style-type: none"> - Bacteria: peptidoglycan is a major constituent of cell walls | <ul style="list-style-type: none"> - Well defined nucleus - Membrane bound organelles - Types: <ul style="list-style-type: none"> - Protists – single cell eukaryotes - Fungi - Plants (including algae) - Animals | | | | |

| | | |
|---|---|--|
| | <ul style="list-style-type: none"> - Archaea: do not have peptidoglycan in cell wall, often live in extreme conditions | |
| Describe the composition of lipid bilayer cell membranes | <p>Structure of a phospholipid</p> <ul style="list-style-type: none"> - Consists of a polar head (hydrophilic) composed of a glycerol and a phosphate molecule - Consists of two nonpolar tails (hydrophobic) composed of fatty acid (hydrocarbon) chains - Because phospholipids contain both hydrophilic (water loving) and lipophilic (fat loving) regions, they are classed as amphiphatic <p>Arrangement in Membranes</p> <ul style="list-style-type: none"> - Phospholipids spontaneously arrange into a bilayer - The hydrophobic tail regions face inwards and are shielded from the surrounding polar fluids, while the two hydrophilic head regions associate with the cytosolic and extracellular fluids respectively <p>Properties of the Phospholipid Bilayer</p> <ul style="list-style-type: none"> - The bilayer is held together by weak hydrophobic interactions between the tails - Hydrophilic/hydrophobic layers restrict the passage of many substances - Individual phospholipids can move within the bilayer, allowing for membrane fluidity and flexibility - This fluidity allows for the spontaneous breaking and reforming of membranes (endocytosis/exocytosis) - Cholesterol modulates the properties of lipid bilayers - Cholesterol stabilise and stiffen the region within the tail of the phospholipid - Stiffen structure caused by rings and it is packaged between phospholipids | |
| Explain the roles of compartmentalisation in cellular function | <ul style="list-style-type: none"> - Plasma membrane encloses the cell - Internal membrane allows the cell to perform specialised function <ul style="list-style-type: none"> - Allows enzymes/molecules on the inside of the cell to not - The Phospholipid Bilayer can form Barriers <ul style="list-style-type: none"> - Receiving information through membranes via the endocrine system (e.g. hormones) which affect the physiology of the cell - The membrane allows the cell to decide what molecules can move in and out of the cell through specialised carrier proteins | |

| | |
|------------------------------|---|
| | |
| Plant vs. Animal Cell | <p>An animal cell</p> <p>A plant cell</p> |

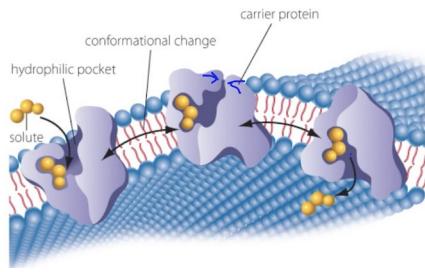
Compartmentalisation of Cells

| | |
|--|--|
| <p>Explain the major functions of the plasma membrane</p> | <ul style="list-style-type: none"> - Physical barrier: the plasma membrane surrounds the cell and separates the cytoplasm, from the extracellular fluid outside the cell. Thus protecting the components of the cell from the outside environment. - Selective permeability: plasma membranes are selectively permeable. Meaning that only certain molecules can pass through them. Like water, oxygen, carbon dioxide. - Endocytosis and exocytosis: Endocytosis is when a cell ingests relatively larger contents than the single ions or molecules that pass through channels. Through endocytosis, a cell can take in large quantities of molecules. Exocytosis is when the cell releases these materials. The cell membrane plays an important role in both of these processes. The shape of the membrane itself changes to allow molecules to enter or exit the cell. - Cell signalling: another important function of plasma membrane is communication and signalling it does so by the use of various proteins and carbohydrates. |
| <p>Describe passive (diffusion and osmosis) and active processes which allow the flow of substances across a semi-permeable cell membrane</p> | <ul style="list-style-type: none"> - Equilibrium: when there are more molecules of a substance on one side of the membrane than the other, they will move down the concentration gradient to reach equilibrium equal distribution <p>Passive Movement</p> <ul style="list-style-type: none"> - Passive movements occur due to concentration gradients - Osmosis: power of salt to attract water and visa versa (where salt goes, water follows) <ul style="list-style-type: none"> - Type of diffusion; the passage of water from a region of high water concentration through a semipermeable membrane to a region of low water concentration - Water is a polar molecule (oxygen has a partial negative charge and hydrogen has a partial positive charge) - Water moves towards solutes due to their charge (e.g. Cl^- (salt) ion will attract water because the positive H ions are attracted to it) - Solutes/salts with charges will attract water through a membrane equilibrium <p>Osmosis</p>  <ul style="list-style-type: none"> - Diffusion <ul style="list-style-type: none"> - Net movement of molecules from an area of greater concentration to an area of lesser concentration |

Active Movement

- Controlled channels: channels which are sometimes closed but open up
 - Eg. Voltage dependent channels will open up and let sodium ions rush into the nerve cell, depolarisation goes down the nerve
- Powered transport: pushing molecules across a membrane across a gradient
 - Used energy from ATP to power transport
 - High concentration of solute molecule on the inside of the cell → cell wants more of those molecules on the inside so they are pumped through
 - This occurs by allowing the solute to combine with the inside of the molecule which is open to the outside of the cell
 - These molecules then use a phosphorylation event using ATP (gamma phosphate is removed), which will change the configuration of the protein, and the top of the protein will close and the bottom will open up

Powered transport



Define diffusion and osmosis and tonicity including hypo, iso and hypertonic solutions

- **Diffusion:** the net passive movement of molecules or particles from regions of higher to regions of lower concentration
- **Osmosis:** the spontaneous passage or diffusion of water or other solvents through a semipermeable membrane (power of salts to attract water and vice versa)
- **Tonicity:** a measure of the effective osmotic pressure gradient
 - Hypotonic: lower concentration of fluid, sugars and salt than blood
 - In hypotonic solutions, there is a net movement of water from the solution into the body
 - A cell placed into a hypotonic solution will swell and expand until it eventually burst
 - Isotonic: similar concentration of fluid, sugars and salt to blood
 - No net movement of water
 - Hypertonic: higher concentration of fluid, sugars and salt than blood
 - In a hypertonic solution, the net movement of water will be out of the body and into the solution → soft and floppy carrot

| | |
|---|--|
| | <p>Hypertonic very concentrated solution $[Solute]_{in} < [Solute]_{out}$</p> <p>Isotonic $[Solute]_{in} = [Solute]_{out}$</p> <p>Hypotonic very dilute solution $[Solute]_{in} > [Solute]_{out}$</p> |
| <p>Describe how proteins are exported and imported out and into the cell via vesicular transport</p> | <p>Exocytosis</p> <ul style="list-style-type: none"> - Proteins are made on ribosomes and packages into vesicles <ul style="list-style-type: none"> - Vesicles carry protein cargo (bubbles of membrane that have the protein inside) - Proteins produced on the endoplasmic reticulum are transported to the Golgi apparatus (series of flattened discs of membrane called cisternae) - Vesicles will travel into the cis-face (inner face of golgi apparatus) where proteins will be released and where they may be modified (sugar/carbohydrates added to them) before they are released from the Golgi apparatus - On the trans face of the golgi apparatus, the protein is packed into a secretory vesicle which travel along microtubules by an adaptor protein which walks along the microtubule, carrying the secretory vesicle with it until it gets to the plasma membrane - The vesicle fuses and opens up into the extracellular space <p>Endocytosis</p> <ul style="list-style-type: none"> - Proteins bind to the surface/receptors of the plasma membrane - Piece of membrane then folds into the cell (called an endosome) - Can then feed proteins back into the golgi apparatus or to the lysosome <ul style="list-style-type: none"> - In the lysosome, the protein is torn down to its building blocks to be used again in the cell <ul style="list-style-type: none"> - Phagocytosis: Plasma membrane opens up and engulfs the bacterial cell which forms a vesicle which pulls the bacteria into an internal portion of the cell <ul style="list-style-type: none"> - The bacteria cell is digested - Pinocytosis: salts and small molecules <ul style="list-style-type: none"> - Brings in water and the solute |

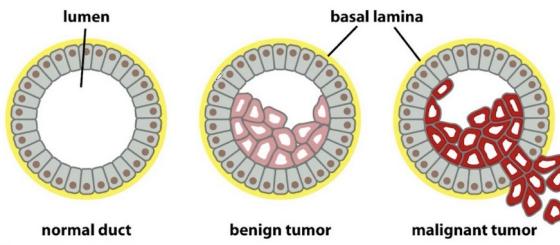
| | |
|--|--|
| | <ul style="list-style-type: none"> - Endocytosis: bigger molecules (proteins) <ul style="list-style-type: none"> - Usually need to bind to a receptor first - The receptor for that particular molecule will bring it into the cell with some membrane in a vesicle |
| Compare and contrast between the three components of the cytoskeleton | <ul style="list-style-type: none"> - Mitochondria are often attached to microtubules of the cytoskeleton <p>Components of the cytoskeleton</p> <ul style="list-style-type: none"> - Microfilaments – made of actin <ul style="list-style-type: none"> - Located around the cell in the cortex - just underneath the membrane - Double helix made out of actin - Microtubules – made of tubulin <ul style="list-style-type: none"> - Long-tube shape: made out of alpha and beta tubulin - Attached to organisational centres and radiate out towards the outside - The spindle in meiosis and mitosis is made out of microtubules - Can grow and shrink depending on the needs of the cell - Intermediate filaments – made of various proteins, often keratin <ul style="list-style-type: none"> - No distinct location – located everywhere - Very strong and tough – hold cells together and preserve the integrity of the cell membrane - Look like fibres running in a lattice structure that goes all through the cell |
| Name 3 major biological functions of mitochondria | <ul style="list-style-type: none"> - ATP synthesis - Steroid synthesis - Apoptosis: a signal to the cell to destroy itself → removes cells out of tissues |

Cells, tissues and communication

| | |
|---|---|
| Explore the ways that cells aggregate with each other to | <ul style="list-style-type: none"> - Most multicellular animals are made out of just 4 major tissue types <ul style="list-style-type: none"> - Epithelium, connective, nervous, muscle |
|---|---|

| | |
|---|---|
| form tissues | |
| Compare and contrast the four types of animal tissue | <p>Epithelium</p> <ul style="list-style-type: none"> - Number of layers: one layer = simple, multiple layers = stratified <ul style="list-style-type: none"> - Pseudostratified: nuclei are in different areas and it looks like multiple layers - Shapes: squamous, Cuboidal, columnar <p>Classify the epithelial sheets</p> <ul style="list-style-type: none"> - Epithelia is anchored to the basal lamina and sits on connective tissue - Active transport of glucose through apical membrane, passive transport through basal membrane - Desmosome: a cell structure specialised for cell-to-cell adhesion <ul style="list-style-type: none"> - Hemidesmosome: one plaque on inside portion of the cell that anchors directly into the basal laminar - The basal laminar holds cancerous epithelial cells for a long period of time (can hold back metastasis for a while → spread of tumours) <ul style="list-style-type: none"> - Cancer mainly originates in epithelial tissue |

Cancer



Nervous tissue

- Allows the multicellular animal coordinated movement and behaviour

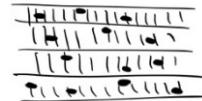
Connective tissue

- Components of connective tissue:
 - Cells
 - Fibres
 - Ground substance
- Fibres and ground substance are called extracellular matrix

Muscle tissue

- **Skeletal**
 - Straight fibres and unbranched
 - Striated (stripes) provide structure
 - Develops from myoblasts (stem cells) which join together to form myofibrils and the nuclei remains
 - Voluntary movement (to a certain extent)
 - Contracts in one dimension
- **Smooth**
 - Lines all organs except heart
 - Spindle shaped (eye shape)
 - Actin filaments forms criss cross pattern (cytoskeleton) allows it to contract in three dimensions
 - Not striated
 - Involuntary
 - Lines all hollow organs other than the heart
- **Cardiac**
 - Intercalated disc makes a strong bond between cells
 - Branched fibres
 - Striated
 - Proteins join the fibres together
 - Involuntary

1. Skeletal



2. Smooth



3. Cardiac



| | |
|--|---|
| | <ul style="list-style-type: none"> - Intercalated discs |
| Explore the functions of cells in their social context | <ul style="list-style-type: none"> - A cell can respond to signals (eg. in times of stress, things that challenge homeostasis) - Hormones signal cells to change their physiology in response to stress <ul style="list-style-type: none"> - Protein hormones: interact with receptors outside of the cell (as they are hydrophilic) and then receptor changes shape → interacts with relay proteins which relay signal to part of cells which can alter cell physiology/trigger response - Steroid hormones: go straight through membrane and alter cellular response - Change in behaviour of cell depends on the cellular signals <ul style="list-style-type: none"> - Survive - Grow and divide (eg. if limb is growing) - Differentiation (eg. changing anatomy to become a different portion of an animal like a finger) - Die (eg. removing tissue webbing between fingers) - Signals can affect the cytoplasm and the nucleus (alter behaviour of the cell) |
| Explain how cells communicate and regulate cell growth in a health state (eg. differentiation of stem cells) and what can go wrong to result in a pathophysiological state (eg. cancer) | <ul style="list-style-type: none"> - Steroid hormones <ul style="list-style-type: none"> - Go straight through cellular membrane - Interact with receptor in either the cytoplasm and then enter the nucleus or enter the nucleus and interact with a receptor there - All then combine with DNA, open it up to allow for transcription and translation and produce a protein as the end point of stimulation - Neurotransmitters <ul style="list-style-type: none"> - Bind to receptors coupled to a channel (eg. nerve tissue) - This opens up the channel, allowing sodium to come into the cell, thereby triggering the voltage dependent channels that transmit the signals - The stress response: allows body to react to increased physiological demand to increase metabolic processes <ul style="list-style-type: none"> - Hypothalamus secretes corticotropin releasing hormone (CRH) - CRH travels down the pituitary stalk until it gets to the pituitary and |

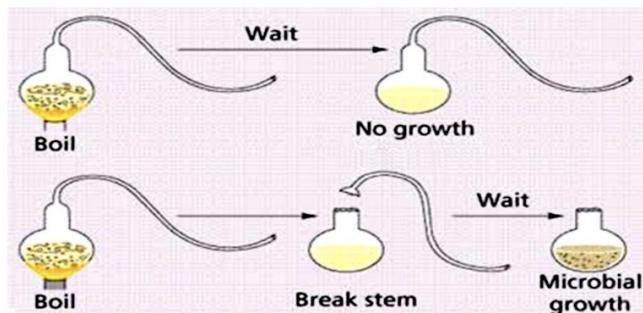
| | |
|--|---|
| | <p>stimulates the release of adrenocorticotropic hormone</p> <ul style="list-style-type: none">- Moves through the bloodstream into the adrenals and stimulates the adrenal cortex to produce the production of cortisol- Cortisol is a steroid that stimulates the breakdown of fat and protein to provide energy to deal with stress<ul style="list-style-type: none">- Increases fat and protein breakdown- Increases blood glucose levels- Has anti-inflammatory effects |
|--|---|

Global Health

Microbiology and the ‘One Health’ Concept

| | |
|---|---|
| Diversity of Microorganisms | <p>Viruses</p> <ul style="list-style-type: none">- The smallest and simplest biological entities- Depend on host cell for replication and metabolism- Viruses are small in size and genome content but have large effects on other organisms and ecosystem <p>Bacteria</p> <ul style="list-style-type: none">- Unicellular structure → smallest free-living organisms- Have own metabolism and replication- Simple morphologies of bacteria conceal complex biochemistry and interactions <p>Fungi</p> <ul style="list-style-type: none">- Large complex cells (Eukaryotes); nucleus, mitochondria- Can be unicellular (eg. yeast) or multicellular (eg. moulds)- Some fungi can have both macroscopic and microscopic parts (eg. fruiting body vs. spores of mushrooms)- Can be used for food or can cause disease <p>Protists</p> <ul style="list-style-type: none">- Large complex cells (Eukaryotes); nucleus, mitochondria- Protozoa: protists that are animal-like (predatory)- Protists are extremely diverse in morphology, lifestyles and evolutionary histories <p>Algae</p> <ul style="list-style-type: none">- Large complex cells (Eukaryotes); nucleus, mitochondria- Unicellular- Algae: plant-like protists – photosynthetic- Some protists cannot easily be classified as ‘algae’ or ‘protozoa’<ul style="list-style-type: none">- Exceptions to rules are very common in biology |
| Brief history of important ideas, discoveries and scientists in microbiology | <p>Hooke: the idea of ‘cells’</p> <ul style="list-style-type: none">- 1664: Robert Hooke describes microscopic structure of blue moulds, using a 30x magnification microscope- First to use the word ‘cell’. His book “Micrographia” (1665) was very influential, due to the excellent artwork <p>Van Leeuwenhoek: discovers bacteria and protists</p> <ul style="list-style-type: none">- 1684: Antonie van Leeuwenhoek develops powerful microscopes (300x mag.) discovers “wee animalcules”<ul style="list-style-type: none">- First evidence of bacteria and protists- He is considered the ‘father of microbiology’ <p>Paster: life does not arise from non-life</p> |

- Louis Pasteur made many crucial contributions to microbiology:
 - Vaccination
 - Fermentation
 - Pasteurisation
- 1861: Pasteur disproved the theory of spontaneous generation
→ the idea that non-living objects can give rise to living organisms
- Controversy from earlier work (1700's):
 - John Needham: a "life force" in all matter causes spontaneous generation → microbes reappearing after they had been killed
 - Lazzaro Spallanzani: repeated experiment but sealed the flask... the microbes did not reappear
 - Pasteur settled the debate with an experiment using 'swan-necked' flasks; allow entry of air but not microbes



Koch: germ theory of disease, Koch's postulates

- Robert Koch pioneered:
 - Staining methods for microscopy
 - Use of solid growth media (agar) to cultivate organisms
- Used these methods to identify bacteria causing:
 - Tuberculosis
 - Cholera
 - Anthrax
- 1876: Koch's most important contribution → definitive proof that microbes cause disease (ie. germ theory)
- Along with Pasteur's work, germ theory was important in disproving the idea of 'spontaneous generation'
- Koch's postulates – An organism that causes a disease must:
 - Be found in all cases of the disease
 - Be isolated from the diseased host in pure culture
 - Produce same disease in experimentally-infected host
 - Be re-isolated from the experimentally-infected host

Fleming, Florey, Chain: Penicillin

- 1928: Alexander Fleming (UK) found mould growing on a petri dish killed the bacteria around it
- 'Mould juice' killed many bacteria, including causative agents of scarlet fever,

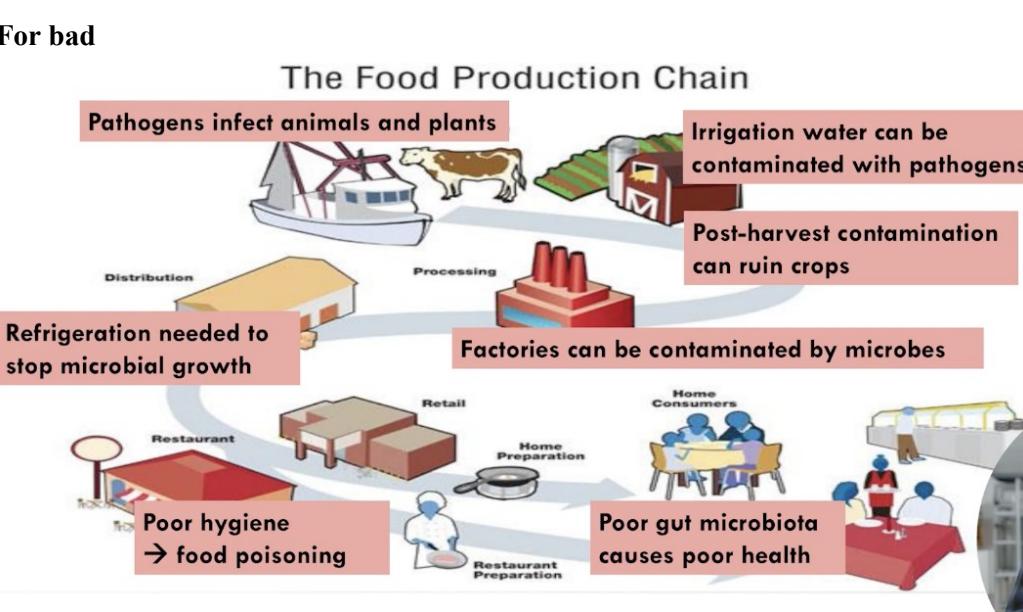
| | |
|--|---|
| | <p>pneumonia, meningitis and diphtheria</p> <ul style="list-style-type: none"> - 1935-1945: Howard Florey and Ernst Chain purify penicillin and developed mass production methods - Penicillin was the first really effective antibiotic – this discovery helped the Allies to win WWII |
| Important concepts in microbiology: normal flora, pathogens, ‘one health’ | <p>Normal flora</p> <ul style="list-style-type: none"> - Microbes that live in us and on us - Your body: approx. 30 trillion human cells but 40 trillion microbial cells - Normal flora <ul style="list-style-type: none"> - Found at specific sites - Specialised for that site - Mostly bacteria - Acquired at birth, from diet, and from the environment - Concept of normal flora is flexible - Differs between individuals, locations, times - Positive effects: <ul style="list-style-type: none"> - ‘Prime’ the immune system - Provide nutritional benefits <ul style="list-style-type: none"> - Breakdown complex molecules, synthesise vitamins - Compete with pathogens - Negative effects: <ul style="list-style-type: none"> - Can cause disease if moved to wrong location <ul style="list-style-type: none"> - Eg. <i>Staphylococcus</i> → wound infection - Can cause disease even in normal habitat if conditions change <ul style="list-style-type: none"> - Eg. <i>Streptococcus</i> → tooth decay <p>Pathogens, infection, disease</p> <ul style="list-style-type: none"> - Pathogens: a disease-causing microorganism - Some pathogens are always harmful – we call these ‘obligate pathogens’ <ul style="list-style-type: none"> - Eg. viral infection usually destroyed the host cell - Pathogens can be infect bacteria - Opportunistic pathogens: Pathogens which do not make us sick and can be normal flora (can cause disease in specific conditions) <ul style="list-style-type: none"> - Numbers: abnormally high cell density - Location: get into the wrong place - Host health: immune system compromised - Virulence factors (eg. gain antibiotic resistance) - Efforts to make things clean can make things worse <ul style="list-style-type: none"> - Difficult to keep coming up with new antibiotics - Overuse of antimicrobials contribute to the disease problem <p>One Health Concept</p> <ul style="list-style-type: none"> - A unifying principle for microbiology - Need to consider animals, plants and the environment when we are trying to manage human diseases <ul style="list-style-type: none"> - Many human diseases originate in either the environment or in animals |

- Use of antimicrobials in agriculture impacts on human pathogens
- Disease emergence and spread are influenced by urbanisation, globalisation, climate change, pollution
- Major infectious disease problems today
 - Emerging infections due to new pathogens
 - Human: COVID19, HIV, Zika, Ebola
 - Animal: Chytrid fungus (frogs), Varroa mites (bees)
 - New problems with old pathogens
 - Humans: malaria, tuberculosis
 - Animal: Koala Chlamydia
 - Plant: Panama disease (banana)

Example of a major microbial pathogens: *Mycobacterium tuberculosis*

- Caused by a bacterium: mycobacterium tuberculosis
- Spreads person-to-person by airborne droplets (coughing)
- **Infects lungs → cough, chest pain, weight loss, death**
- Disease can be ‘latent’ for many years (no symptoms)
- **Symptoms are nonspecific → difficult to diagnose**
- Estimated that one-third of world’s population is infected
- New strains of TB are resistant to antibiotic treatment
 - ‘MDR-TB’: multidrug resistant TB
 - ‘XDR-TB’: extremely drug-resistant TB

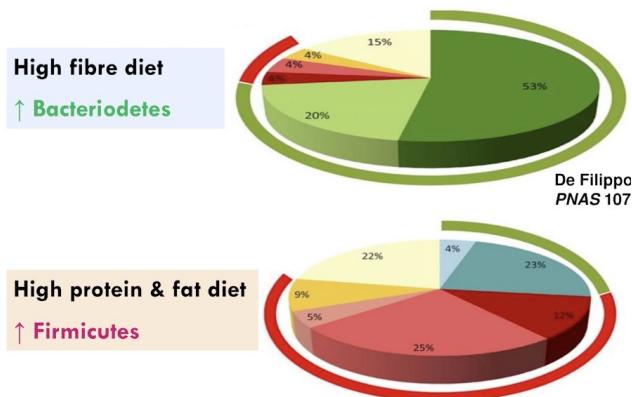
Microbes, food and nutrition

| | |
|---|--|
| <p>Microbes in food production</p> | <p>For good</p>  <p>The diagram illustrates the food production chain across four main stages: Production, Distribution, Processing, and Consumption. Key points highlighted by red boxes include:</p> <ul style="list-style-type: none"> Pathogens infect animals and plants (Production) Irrigation water can be contaminated with pathogens (Production) Post-harvest contamination can ruin crops (Production) Refrigeration needed to stop microbial growth (Distribution) Factories can be contaminated by microbes (Processing) Poor hygiene → food poisoning (Retail) Poor gut microbiota causes poor health (Consumption) |
| <p>Enhancing food production: microbes in soil</p> | <ul style="list-style-type: none"> - Microbes maintain soil health by: <ul style="list-style-type: none"> - Fixing nitrogen ($N_2 \rightarrow NH_4^+$) - Breaking down organic wastes into inorganic nutrients - Suppressing animal + plant pathogens - Breaking down toxins (eg. pesticides) - Microbes enable animals to digest cellulose: <ul style="list-style-type: none"> - Cellulose: a sugar polymer, abundant in plants, carbon-rich, but difficult to digest - Rumen microbes break down cellulose → sugars → organic acids, CO_2, CH_4 - Organic acids and microbial cells are then digested by animals as nutrient |

| | |
|-------------------------|--|
| | <ul style="list-style-type: none"> - Microbes promote plant growth via mutualism: <ul style="list-style-type: none"> - Mutualism: ecological interaction where both partners benefit - Mycorrhizal fungi (in most plants) enhance water and inorganic nutrient uptake by increasing surface area of roots, receive sugars from plant - Rhizobium bacteria (in legume roots) fix nitrogen, receive sugars in return |
| Plant pathogens | <ul style="list-style-type: none"> - Just like humans and animals, plants are subject to diseases caused by microbial pathogens - Fungi and viruses are the main problems - Crop pathogens cause global losses of ~30% of total yield - Example: tobacco mosaic virus <ul style="list-style-type: none"> - Only 3 genes but can infect many crops - Can survive in the environment for a very long time - Emerging diseases: sigatoka fungus <ul style="list-style-type: none"> - Threatens the survival of bananas globally - Modern Cavendish bananas are all grown from cuttings, not seed → genetically identical → all are equally susceptible to disease - Need to apply fungicides 50x per year, and fungus is rapidly evolving resistance |
| Animal pathogens | <ul style="list-style-type: none"> - Pathogens infecting animals inflict suffering, death and massive economic losses (~20% of total production) - Pathogens can be viruses, bacteria, fungi or protist - Modern agricultural practices can aggravate the microbial problems - Example: Foot-and-Mouth-Disease (FMD) <ul style="list-style-type: none"> - Infects cows, pigs, sheep, goats but not humans - Huge economic losses - Cause of UK outbreak: pigs fed waste products including meat illegally imported from infected animals - Poses many ethical and environmental issues in addition to economic problems - Zoonosis: human infection arising from animals <ul style="list-style-type: none"> - Microbe may be pathogenic to both animal and human hosts (eg. rabies virus) - Human pathogen may be normal flora for the animal (eg. <i>Salmonella</i> bacteria in chicken) - Animal is a 'vector' for disease (eg. animal ticks can carry <i>Borrelia</i> bacteria → Lyme disease) - The COVID pandemic most likely had a zoonotic origin |

| | |
|--|---|
| | <ul style="list-style-type: none"> The covid pandemic most likely had a zoonotic origin <p>The diagram shows the transmission pathway of SARS-CoV2. It starts with the 'Original host: Bat' (represented by bats hanging upside down). Step 1 shows the virus being transmitted to a pangolin. Step 2 shows the virus being transmitted from the pangolin to another bat. Step 3 shows the virus replicating in the second bat. Step 4 shows the virus being transmitted from the second bat to a human. Step 5 shows the virus replicating in the human. Step 6 shows the virus being transmitted from the human to other intermediates. Step 7 shows the virus replicating in these intermediates. Step 8 shows the virus being transmitted from the intermediates to a pangolin. Step 9 shows the virus replicating in the pangolin. The diagram also includes a legend: (A) Adaptive evolution, (B) Convergent evolution, (C) Adaptive evolution OR Convergent evolution, and (D) Convergent evolution.</p> |
| Enhancing food processing | <h3>Fermentation</h3> <ul style="list-style-type: none"> “Fermentation” has multiple meanings: <ul style="list-style-type: none"> Microbial transformation of food by fungi or bacteria Anaerobic metabolism of sugars → alcohols, acids, CO₂ Examples: beer, wine, bread, kimchi, yoghurt, cheese, pickles Fermented foods – beer production <ul style="list-style-type: none"> Barley: source of sugars to support fermentation Hops: natural preservative, provide bitterness Yeast: ferments sugars to alcohol and CO₂ Saccharomyces (brewer’s yeast): makes wine, cider and other alcoholic beverages, also makes bread |
| Microbial food spoilage | <ul style="list-style-type: none"> Spoilage is due to the growth of fungi or bacteria and/or due to enzymes that these microbes make and secrete Big economic problem: approx. 20% of all food is lost to microbial spoilage Spoilage prevention: refrigeration, preservatives, fermentation Food spoilage vs. food ‘poisoning’ <ul style="list-style-type: none"> Food poisoning can occur from spoiled food or fresh food. Different sets of microbes are responsible for spoilage vs. poisoning Food ‘poisoning’ is more like an infection or intoxication <ul style="list-style-type: none"> Food-borne infection: microbes grow in gut Food-borne intoxication: microbes make toxins in food Food poisoning risk factors: <ul style="list-style-type: none"> Origins of food: determines types and number of microbes Storage and preparation: refrigeration, raw/cooked Human factors: hygiene |
| One Health concept in food production | <ul style="list-style-type: none"> Maintaining a safe food supply depends on managing microbes at every stage in the production chain <ul style="list-style-type: none"> Soil Plants Animals People Factory Kitchen |
| The Human Gut Microbiome | <ul style="list-style-type: none"> Gut microbes are the most important element of our normal flora → these are primarily bacteria |

- Approx. 40 trillion bacteria in gut microbiome; now considered a separate body “organ”
- Gut microbiome depends on diet

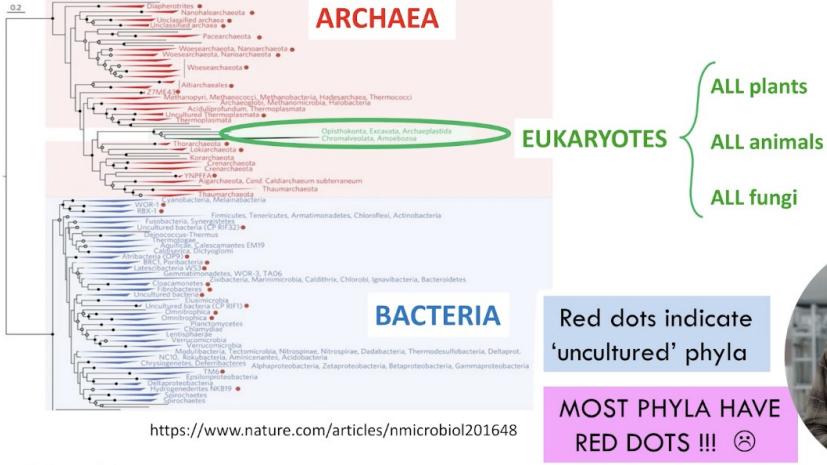
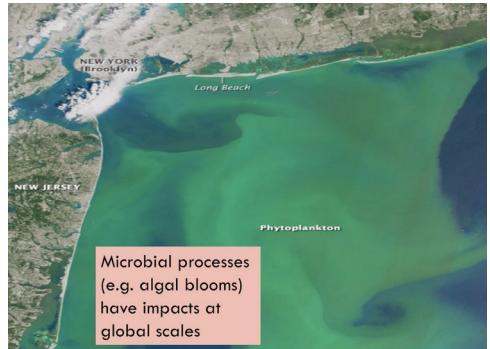


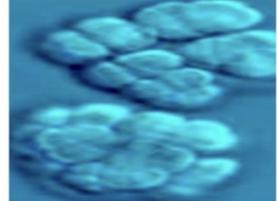
- Microbiome in child comes from the mother
 - DNA sequence of PCR-amplified ribosomal genes “Culture-independent analysis”
- Functions of gut microbiome:
 - Healthy microbiomes important for:
 - Proper food digestion
 - Resistance to pathogens
 - Immune functioning
 - Mental Health
 - “Bad” microbiome linked to:
 - Allergies
 - Type 2 diabetes
 - Cancer
 - Obesity
- Antibiotics/probiotics/prebiotics impact the human microbiome

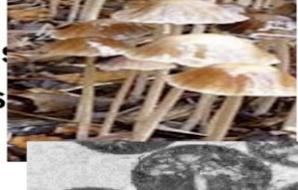
Gut microbiome and obesity

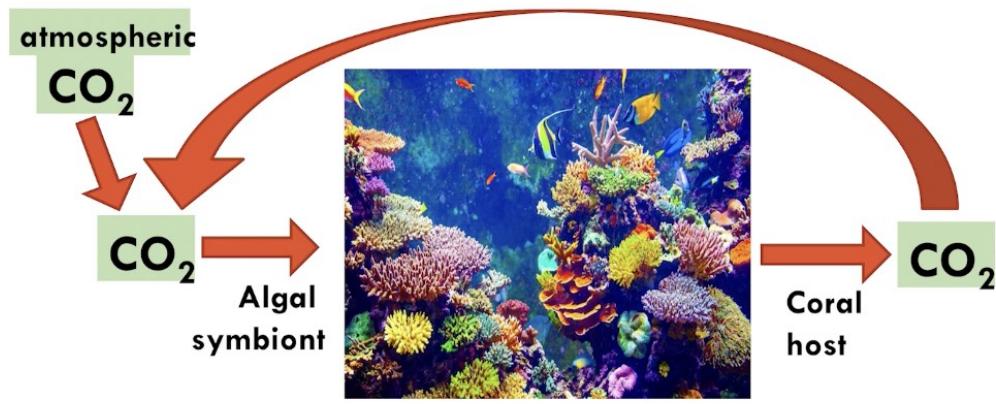
- Animal studies show:
 - Obese mice have a distinct gut microbiome
 - Transplanting ‘obesity-associated’ microbes makes germ-free mouse obese

Microbes and Ecosystems

| | |
|---------------------------------------|---|
| Planetary Health | <ul style="list-style-type: none"> - 16 of the 17 warmest years on record have occurred since 2001 |
| Microbes | <ul style="list-style-type: none"> - Microbes are the true rulers of the Earth <ul style="list-style-type: none"> - Appeared before larger living organisms - Many lineages can not be grown  <p>https://www.nature.com/articles/nmicrobiol201648</p> |
| Scope of biodiversity | <ul style="list-style-type: none"> - The majority or all biodiversity is microbes <ul style="list-style-type: none"> - Taxonomic diversity: diversity at level of DNA sequences - Metabolic diversity: - Niche diversity: microbes and archaea can occupy niches that are inhospitable to other organisms - Most microbes cannot be isolated or cultured |
| Biogeochemistry | <ul style="list-style-type: none"> - Biogeochemistry: biological processes that impact chemistry at a global scale <ul style="list-style-type: none"> - Most of these reactions are done by microbes |
| The four laws of ecology | <ul style="list-style-type: none"> - Everything is connected - Everything must go somewhere - Nature knows best - There's no such thing as a free lunch |
| Autotrophs in the Carbon Cycle | <p>Algae</p> <ul style="list-style-type: none"> - Autotroph: "self feeder" - uses CO₂ as carbon source - May use light as energy source (photoautotrophs) or may use chemical energy sources (chemoautotrophs) - Autotrophs convert inorganic C to organic C, act as "SINKS" for CO₂ → act to limit climate change - Algal blooms can also cause problems  |

| | |
|--|---|
| | <p>Methanogens</p> <ul style="list-style-type: none"> - Methoagons: Consume CO₂ and H₂, produce methane (CH₄) <ul style="list-style-type: none"> - Can colonise where no light is available - Very anaerobic organisms → oxygen can kill them - Methanogens instead breathe CO₂ and exhale CH₄ - This limits methanogens to oxygen-free habitats (deep sediments, solid micro-niches, animal guts) - Are chemoautotrophs: CO₂ is C source, H₂ is energy source - Impact on climate change: act as sinks for CO₂ (good), but can act as sources of CH₄ (very bad) → overall bad - Methanogens are an example of archaea <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;">  <p>Algae (free-living)</p> </div> <div style="text-align: center;">  <p>Methanogens</p> </div> <div style="text-align: center;">  <p>Algae (symbiotic in coral)</p> </div> <div style="text-align: center;">  <p>Algae (symbiotic in lichen)</p> </div> </div> |
| <p>Heterotrophs in the Carbon cycle</p> | <p>Methanotrophs</p> <ul style="list-style-type: none"> - Methanotrophs: Consume methane, produce CO₂ - Are heterotrophs: methan (the simplest organic compound) acts as both their carbon source and energy source - Impact on climate change: acts as sinks for CH₄ but act as sources of CO₂ → overall good - Methanotrophs are traditional bacteria - Methanotrophs are useful for removing methane as they have the enzyme methane monooxygenase (MMO) <ul style="list-style-type: none"> - They also attack other more toxic pollutants (eg. trichloroethylene - TCE) <p>Decomposers</p> <ul style="list-style-type: none"> - Take dead cells and recycle them back into useful nutrients other cells can use - Needs to eat other organisms or other organic carbon sources; these also supply energy - Heterotrophs are sources of CO₂ → bad for climate change - Decomposers: a key group of heterotrophs; recycle dead cells back to CO₂ <p>Predators</p> |

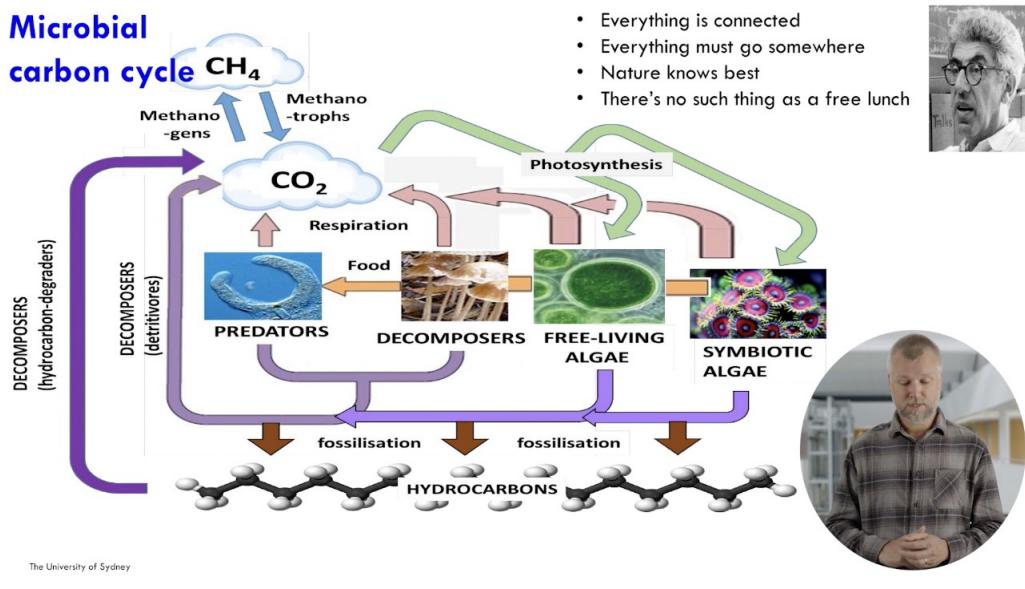
| | |
|---------------------------------------|---|
| | <ul style="list-style-type: none"> - Protists (protozoa type) are often predators of other microbes; these predators include ciliates (lots of tiny hairs on surface to swim), flagellates (large filaments to swim) and amoebae (blobs that use false feet to drag them along the surface) - Not all protists are predators, some are ‘detritivores’ (scavengers) and some are photosynthetic <p>Pollutant degraders</p> <ul style="list-style-type: none"> - Methanotrophs are just one example of bacteria that grow on hydrocarbons as their carbon and energy source - Hydrocarbon-degrading bacteria (including methanotrophs) are very useful for “bioremediation” <ul style="list-style-type: none"> - Bioremediation: the cleanup of pollution by microbes - Hydrocarbon-degrading bacteria are heterotrophs that specialise in eating ancient fossilised organic carbon - These are similar to other decomposers, except that they contain special enzymes which can attack hydrocarbons <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> <p>Decomposers (Detritivores)</p>  </div> <div style="text-align: center;"> <p>Predators: protozoa</p>  </div> </div> <div style="display: flex; justify-content: space-around; margin-top: 20px;"> <div style="text-align: center;"> <p>Methanotroph</p>  </div> <div style="text-align: center;"> <p>Hydrocarbon -degraders</p>  </div> </div> <div style="display: flex; justify-content: space-around; margin-top: 20px;"> <div style="text-align: center;"> <p>Coral (host animal)</p>  </div> <div style="text-align: center;"> <p>Lichen (host fungus)</p>  </div> </div> |
| Auto/Hetero-troph interactions | <p>Coral symbiosis</p> <ul style="list-style-type: none"> - Corals are primitive animals (Phylum Cnidaria) which depend on symbiotic microscopic algae to supply them with food <ul style="list-style-type: none"> - Algae: photoautotrophs, convert $\text{CO}_2 + \text{light} \rightarrow \text{sugars}$ - Coral: heterotrophs, convert sugars $\rightarrow \text{CO}_2$ - The coral symbiosis is like a minute ecosystem: |



Lichen symbiosis

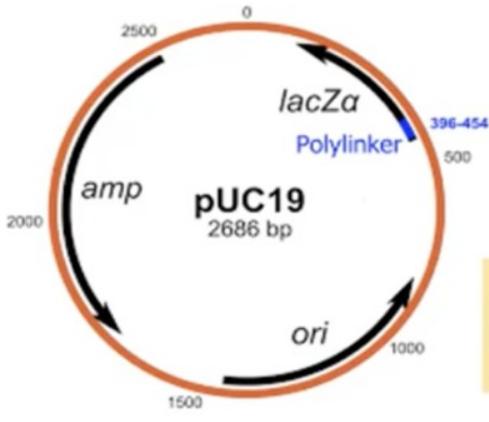
- Lichens are primary producers in some terrestrial habitats, especially in dry environments
 - Photosynthetic but they are not plants
 - Actually a symbiosis between two microbes: a heterotrophic fungus and an autotrophic algae
 - Fungus: provides host for system, also helps give algae with inorganic nutrients and moisture to grow
 - Algae: lives inside the fungus to perform photosynthesis

Microbial carbon cycle



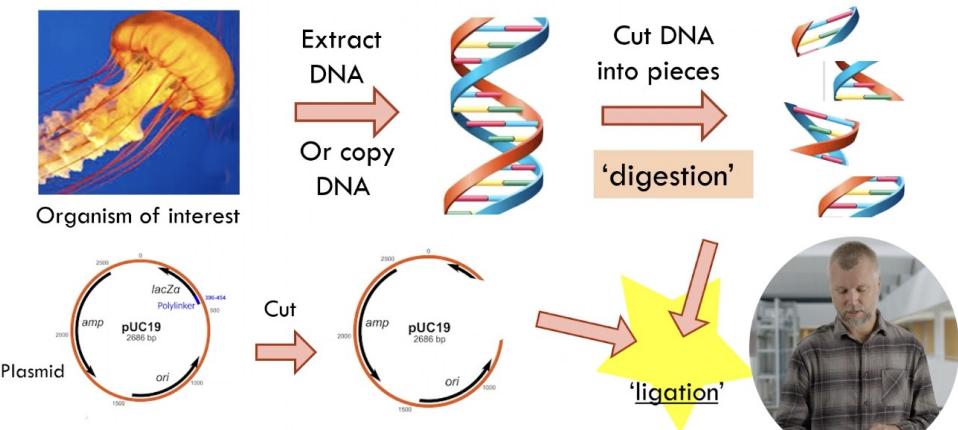
Cell Factories and Biotechnology

| | |
|---|--|
| Traditional biotechnology | - |
| Explain why microbes are useful for biotechnology, using examples of specific fungi (<i>S.cerevisiae</i>) and bacteria (<i>E.coli</i>) | <p>Traditional Biotechnology</p> <p>Fermentation</p> <ul style="list-style-type: none">- “Biotechnology” has been done by humans for more than 9 000 years<ul style="list-style-type: none">- Fermentation to preserve foods or make alcohol- Early fermentations used mixed culture of naturally-occurring bacteria and fungi- Earliest firm evidence for alcoholic fermentation also comes from around 7000 BC<ul style="list-style-type: none">- Analysis of jars from Henan province, China, revealed traces of alcohol and the plants used in fermentation- Fermentation could be defined as ‘cellular biotechnology’<ul style="list-style-type: none">- Need some biology skills (especially microbiology)- Don’t need understanding of DNA, RNA proteins <p>Diverse microbes are useful for biotechnology</p> <ul style="list-style-type: none">- Viruses<ul style="list-style-type: none">- Vectors to carry genes into new host → packing DNA and injecting it into a host- Source of enzymes (eg. T4 ligase comes from a virus which infects <i>E.coli</i>)- Archaea<ul style="list-style-type: none">- Source of thermostable polymerase enzymes for copying DNA sequences- Bacteria<ul style="list-style-type: none">- Excellent hosts for cloning DNA and expressing proteins- <i>E.coli</i>:<ul style="list-style-type: none">- Fastest growth- Very easy to extract or add plasmid DNA- Algae<ul style="list-style-type: none">- Conversion of CO₂ + light into biofuels (ethanol, H₂)- Fungi<ul style="list-style-type: none">- Yeasts: excellent cloning and expression hosts- <i>Saccharomyces/S.cerevisiae</i><ul style="list-style-type: none">- Better for expressing eukaryotic genes- Generally recognised as safe- Moulds: antibiotic synthesis- The host cell contains machinery for biosynthesis of high-value products from simple raw materials<ul style="list-style-type: none">- The host cell factory needs instructions or a blueprint to tell it which products to make |
| Explain what a plasmid is, and | <ul style="list-style-type: none">- Plasmid: circular DNA elements found in microbes; replicate independently of the chromosome(s) |

| | |
|---|---|
| define the roles of different kinds of plasmids in nature and in biotechnology | <ul style="list-style-type: none"> - Plasmids are the most commonly used vector for delivery of foreign DNA into a target host cell - Viruses can also be used as vectors - pUC19: example of a plasmid that is developed to take up DNA; very simple tame plasmid (extensively developed and refined) <ul style="list-style-type: none"> - Ori genes (origin of replication): ensuring the plasmid can replicate itself in its host - Selectable marker (amp gene in example): often an antibiotic resistance marker, enables us to force cells to take up plasmid (placing the cells on an agar plate with antibiotics will kill all of the cells that have not taken up the antibiotic resistance gene – allows selection) - Cloning site (polylinker site): foreign DNA is added here  <p>Example of a ‘tame’ lab plasmid: pUC19</p> <ul style="list-style-type: none"> - ‘wild’ plasmids found in nature allow microbes to swap useful genes - Plasmid-borne genes are not essential; but are useful under some specific conditions (e.g. antibiotic resistant genes) |
| Define the terms “DNA cloning”, “recombinant DNA”, “GMO” | <ul style="list-style-type: none"> - DNA Cloning: to make copies of a biological entity <ul style="list-style-type: none"> - Either creating identical organisms or making copies of a piece of DNA by adding it into a plasmid, then replicating the plasmid - Tools needed for DNA cloning – Enzymes <ul style="list-style-type: none"> - Copying DNA: thermostable polymerase - Cutting DNA: restriction enzyme - Joining DNA: T4 ligase - Recombinant DNA: contain bits of foreign DNA - GMO: genetically-modified organism |
| Explain how recombinant DNA and GMOs are | DNA Cloning Part 1: Digestion and ligation <ul style="list-style-type: none"> - Ligation mixture: |

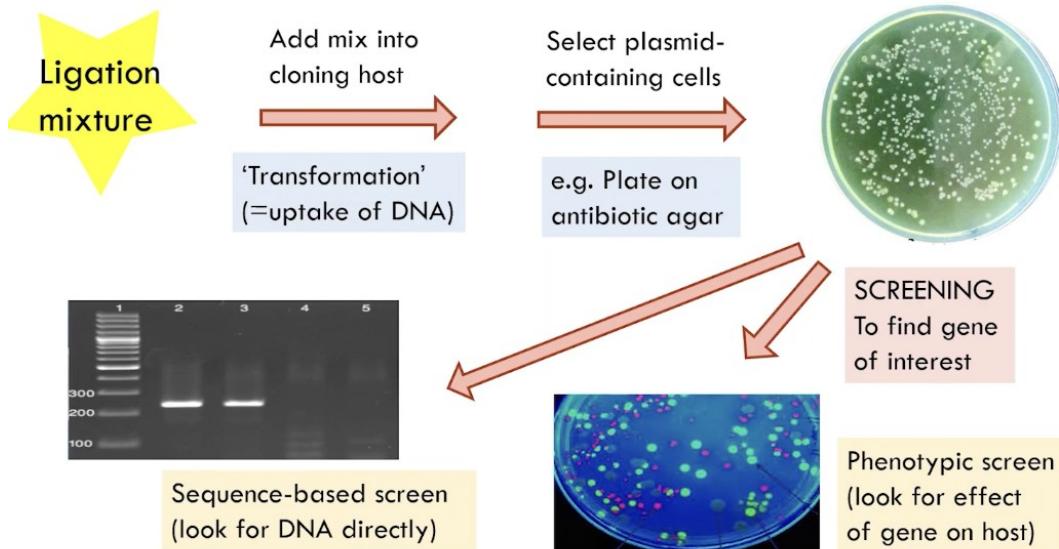
made, and especially which enzymes do which jobs in this process

- Some plasmids that are recombinant (contain bits of foreign DNA)
- The starting plasmid (non-recombinant)
- Non-ligated bits of foreign DNA



Part 2: Transformation and Screening

- Transformation is the uptake of DNA into a cell

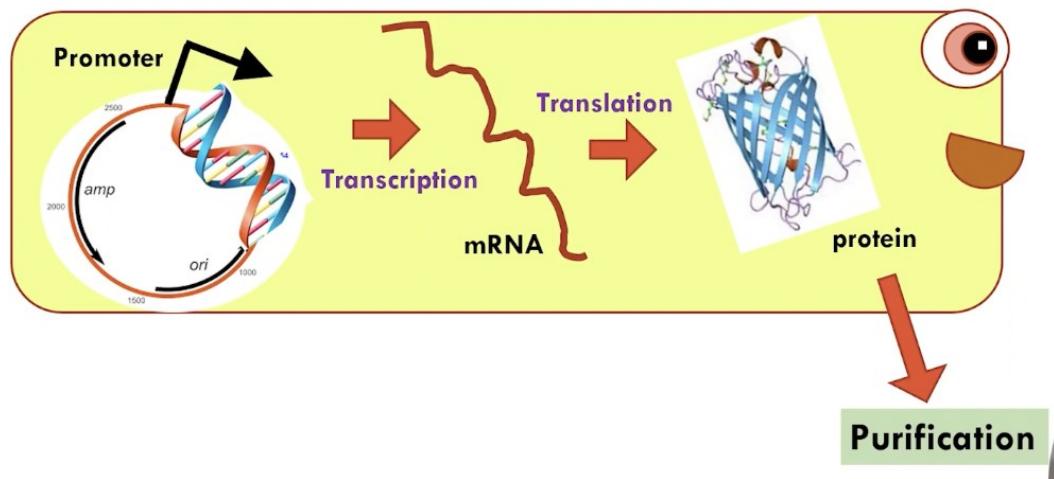


Part 3: GMO

- Recombinant microbe carrying gene of interest
- This is now a GMO
- What risks arise from GMO's?
 - Depends on what foreign genes were added
 - Antibiotic resistance gene transfer into pathogens
 - Commercial risks: legal constraints, public perceptions

Part 4: Expression of genes

- The foreign protein may itself be the end-product (eg. HepB vaccine) or it could make the end-product (eg. metabolic enzymes)

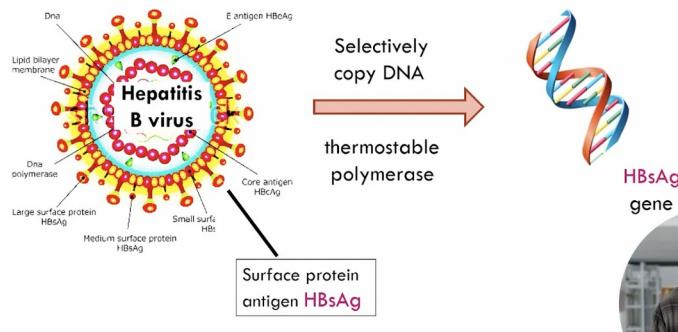


Discuss why vaccines are important, and how recombinant DNA methods can be used to make them

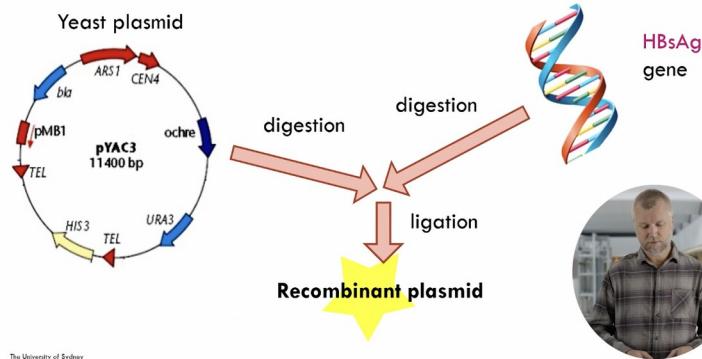
- Vaccines: a primary defence against infectious disease; save approx 3 million lives every year
- Protect against: smallpox, polio, rabies, diphtheria, pertussis, tetanus, hepatitis, measles, mumps, rubella, influenza, pneumonia, rotavirus, meningitis, papillomavirus (and more)
- Some diseases have no cure so prevention is the only problem
- Vaccines lead to 'herd immunity'
- Vaccines work by 'training' the immune system to recognise antigens associated with an invader. They may consist of
 - Live attenuated microbes: where you give a live organism as the vaccine but it is a strain that no longer causes serious disease but still stimulates immune system
 - Killed microbes: killed cells can still be quite antigenic and stimulate immune system
 - Antigens (proteins) produced in a GMO host
 - mRNA coding for antigens

Example: Hepatitis B vaccine

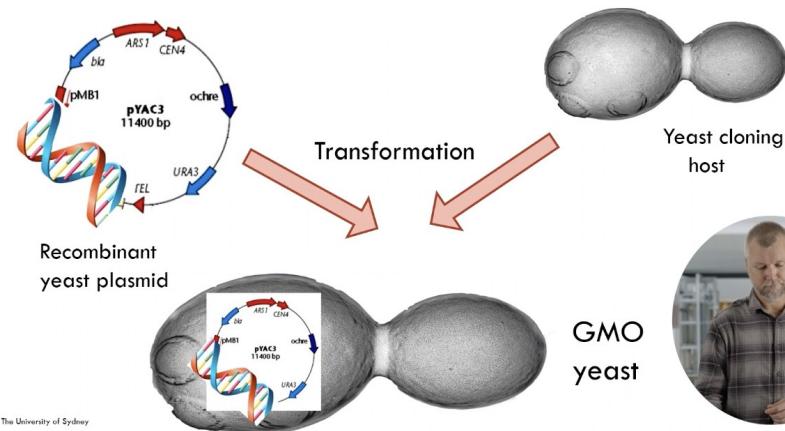
1. Isolate gene coding for antigen
- Surface protein antigen HBsAg
- Selectively copy DNA using PCR



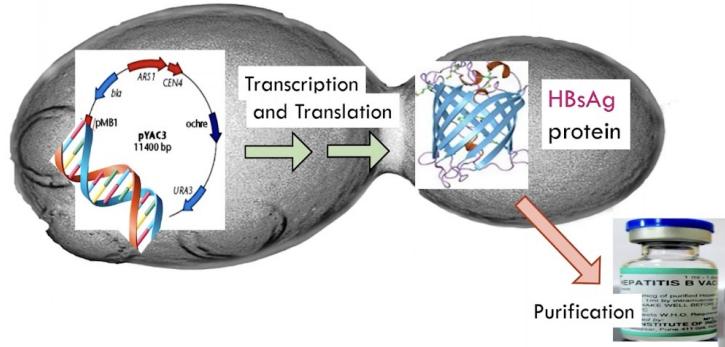
2. Cloning antigen gene



3. Transformation into yeast



4. Gene expression, protein purification

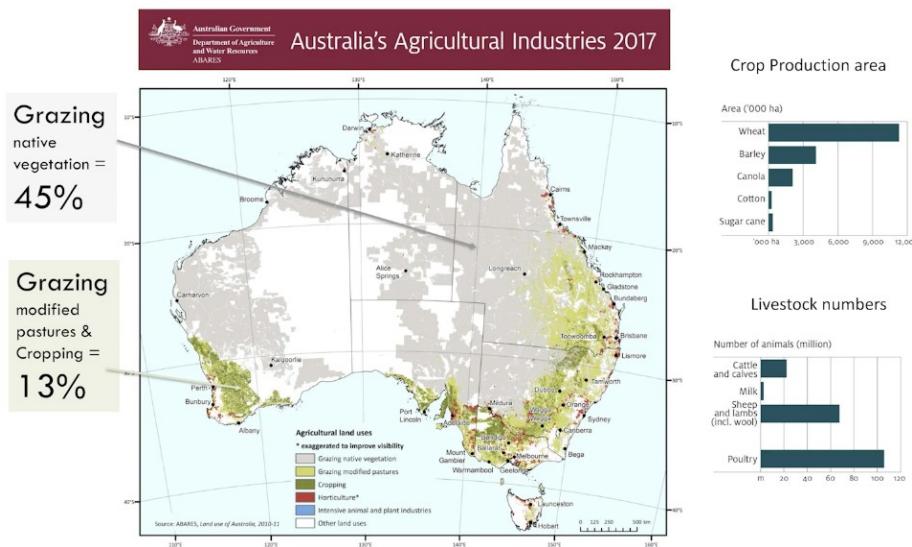


Ecosystems

Healthy Planet = Healthy People

Role of Biodiversity

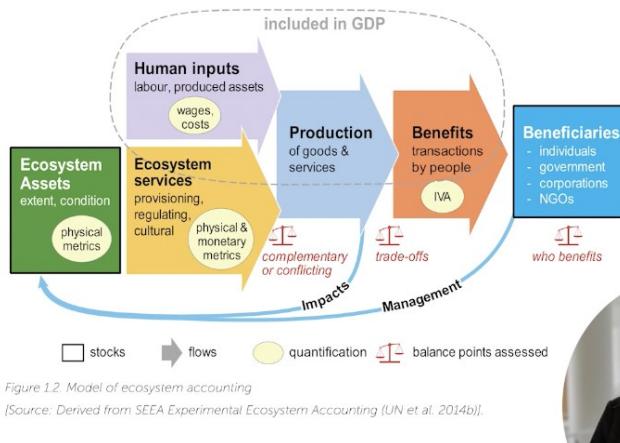
- Nature provides us with all the water we drink and the air we breathe and intact ecosystems absorb about one-half of our global CO₂ emissions
- Of the land used for agriculture, most (46% of the continent) is used for livestock grazing on native vegetation in arid and semi-arid areas

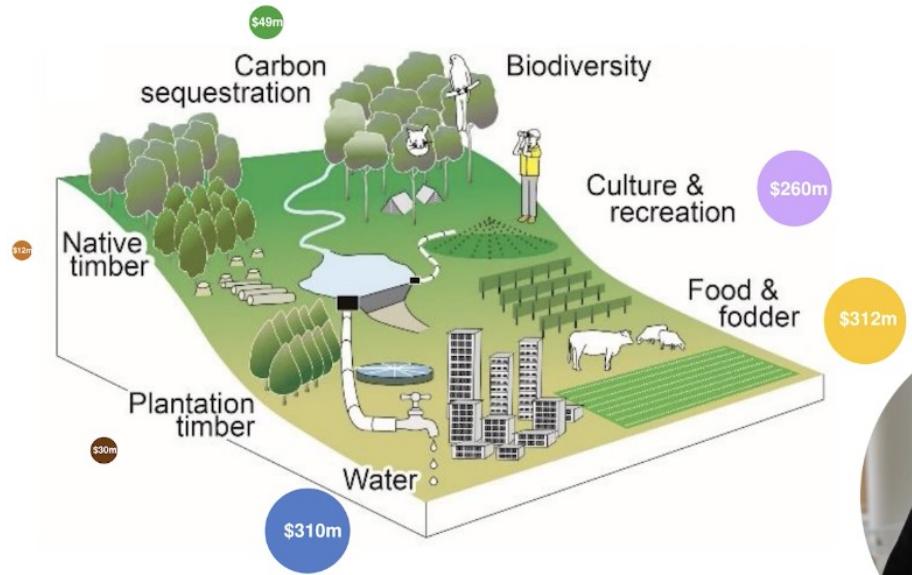


- Ecosystems are interconnected
 - Ecological communities and ecosystems have species interactions, dynamics and flows
- Ecosystems are the basis for life
 - They provide habitat, promote food chains and webs and control ecological cycles and processes

System of Environmental Economic Accounts – Case Study

- A tool for integrating complex biophysical data, tracking changes in the condition and extent of ecosystems, and linking these changes to economic and other human activity and the benefits they provide to society

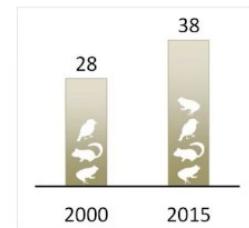




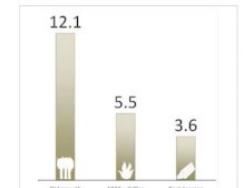
Key Findings



Economic contribution (Industry Value Added) of key regional industries substantially outweighs that of native timber harvesting in Victorian Central Highlands study area. Note: carbon sequestration is estimated as a potential value, as Federal Government regulation currently excludes native forests from the carbon market.



Number of listed threatened species (in Commonwealth EPBC Act) native to the Central Highlands of Victoria has increased by more than a third since 2000.

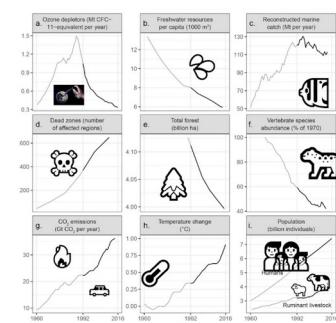


Number of hollow-bearing trees per hectare (HBTs) is more than three times higher in old growth forest, than in regrowth forest post-logging.

A functional biosphere is needed for a strong economy

Scientists Warning to Humanity

- Running out of fresh water
- Increasing dead zones in oceans
- Loss of total forest
- Decrease in vertebrate species abundance
- CO₂ emissions increasing
- Temperature increasing
- Population increase



Prevention is the most cost-effective strategy for public health

Ecosystem Collapse

| | |
|----------------------------|---|
| | <ul style="list-style-type: none"> - Changing an ecosystem to a non-functional state - Pulse: short-term event (storm) - Press: long-term/ongoing event - Sea level rise - Dust storms - Case study: Georgina Gidgee Woodlands <ul style="list-style-type: none"> - Vulnerable status - Landscape context is key to managing fire: long unburnt spinifex within Gidgee Woodlands is ecologically important but scarce in landscape |
| Planetary Health | <ul style="list-style-type: none"> - Having a functional Biosphere is fundamental to all sustainable development goals - Ecologists are the doctor for the earth <ul style="list-style-type: none"> - Record vital signs → primary observation in changes in diversity - Diagnose problems, manage risks, monitor change - Prescribe treatments for remediation and restoration - Advocate for ecosystem health |
| Changing the future | <ul style="list-style-type: none"> - Monitoring <ul style="list-style-type: none"> - Trusted, readily available data - Long-term - Understanding the ecosystem |
| Ecosystem service | <ul style="list-style-type: none"> - An ecosystem service is any positive benefit that wildlife or ecosystems provide to people. |

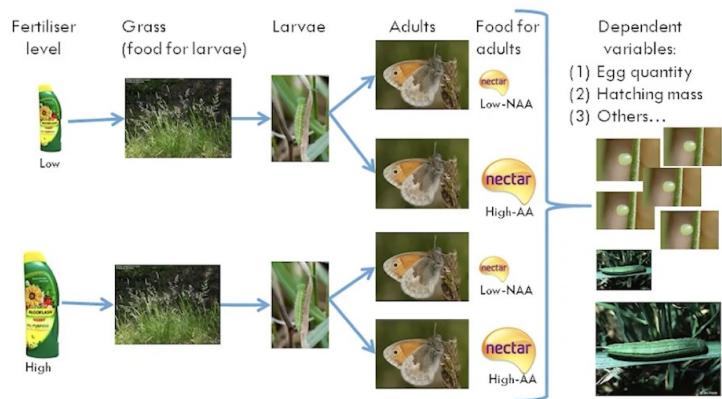
Individuals, Behaviour and Environment

| | |
|--|--|
| Understand links between morphology, physiology and behaviour | <ul style="list-style-type: none"> - Coping mechanism = morphology + physiology + behaviour <ul style="list-style-type: none"> - Behaviour: part of how organisms respond to the biotic and abiotic environment - Eg. carnivores versus herbivores differ: <ul style="list-style-type: none"> - In skill morphology, guts, gut flora, liver enzymes, metabolism - In behavioursL foraging strategies, social behaviour, communication |
|--|--|

Appreciate ecological and evolutionary significance of behaviour

Behaviour is:

- Ecological significance because it
 - Is a link between individuals and their environment
 - Affects demographics (population levels outcomes)
 - Affects interactions among species (community-level outcomes)
- Evolutionarily significant because it
 - Has some genetic basis (nature vs. nurture)
 - Affects fitness
 - Can be selected (benefits > costs)
- How do we know?
 - Observations: inter- and intra-specific comparisons
 - Manipulative experiments that test hypotheses
- Behaviour affects fitness
 - Fitness: an individual's relative contribution to the next generation's gene pool
- Example using plant-insect interactions:
 - Insect herbivores consume vegetative parts of plants (eg. leaves)
 - Insects pollinate around $\frac{1}{3}$ of all plants; often with food rewards (eg. nectar)
- Evidence: effect of feeding on high quality field
 - Larvae fed grass that had been grown with low or high fertiliser
 - Female butterflies were then fed with high or low amino acids
 - Low qualities diet = fewer eggs laid
 - High qualities diet = more eggs laid



| | <p style="text-align: center;"><i>Evidence: feeding on high quality food ↑ reproductive output (a surrogate measure of fitness)</i></p> <table border="1"> <thead> <tr> <th>Larval diet quality</th> <th>Adult food quality: AA - High</th> <th>Adult food quality: NAA - Low</th> </tr> </thead> <tbody> <tr> <td>Low</td> <td>~95 (ab)</td> <td>~85 (a)</td> </tr> <tr> <td>High</td> <td>~120 (bc)</td> <td>~130 (c)</td> </tr> </tbody> </table> <p>Adult food quality: ■ AA - High □ NAA - Low</p> <p>Adult nectar quality $P = 0.98$</p> <p>Larval diet quality $P < 0.001$ Interaction $P = 0.042$</p> | Larval diet quality | Adult food quality: AA - High | Adult food quality: NAA - Low | Low | ~95 (ab) | ~85 (a) | High | ~120 (bc) | ~130 (c) |
|--|---|-------------------------------|-------------------------------|-------------------------------|-----|----------|---------|------|-----------|----------|
| Larval diet quality | Adult food quality: AA - High | Adult food quality: NAA - Low | | | | | | | | |
| Low | ~95 (ab) | ~85 (a) | | | | | | | | |
| High | ~120 (bc) | ~130 (c) | | | | | | | | |
| Understand various behavioural strategies to obtain food and avoid being food | <p>Abiotic Environment</p> <ul style="list-style-type: none"> - Lizard cooling feet on hot Namib desert sand <p>Obtaining food</p> <ul style="list-style-type: none"> - Foraging strategies are linked with morphology and physiology <ul style="list-style-type: none"> - Ambush predators: camouflage → increases probability of prey encounter - Active predators: agile, fast → increases probability of prey encounter - Huge variety of foraging strategies defined by: <ul style="list-style-type: none"> - What they eat: frugivore, herbivore, nectarivore, granivore, insectivore, carnivore, omnivore - How they get it: ambush vs. active - Diet breadth: specialist → generalist - Optimal foraging theory: <ul style="list-style-type: none"> - Modelled which food items to eat in a non-depleting environment (always food supply) - Predicts foragers should maximise net rate of food (energy) intake - Marginal value theorem <ul style="list-style-type: none"> - Modelled when to leave a food patch in a depleting environment - Predicts that foragers should leave food patches when capture/harvest rate at patch < average capture/harvest rate - Constraints: <ul style="list-style-type: none"> - Optimal foraging theory focuses on efficiency of energy gain - But most foragers are also prey - Should expect: foraging strategies to be linked to predator avoidance strategies and a trade off between food and fear <p>Avoid becoming food</p> <ul style="list-style-type: none"> - Run away - Group: <ul style="list-style-type: none"> - Costs: more likely to be spotted, competition for food, social aggression - Benefits: less risk of being eaten - Hide | | | | | | | | | |

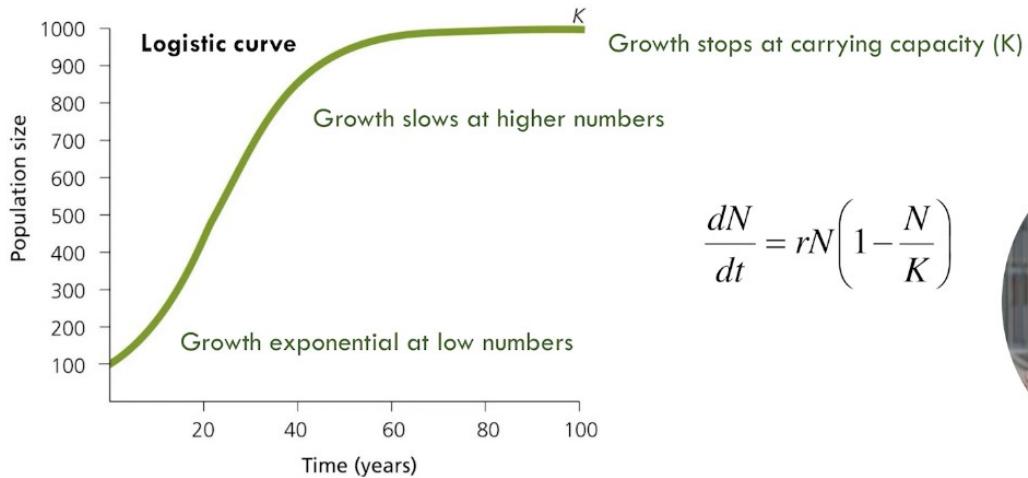
| | <ul style="list-style-type: none"> - Act costly: act dangerous, mimic unpalatable or toxic organisms - Be costly: sequester toxic compounds, have spines - Feed in safe places or time: vegetation cover, new moon - Eg. red-bellied pademelons more likely to feed close to shelter <ul style="list-style-type: none"> - Fewer scats the further away from vegetation you are | | | | | | | | | | | | | | | | | | | | |
|--|--|---|--|---|--|--------------|---------------------------|----------------------------|------------------------------------|-------------|----------------------------|----------------------------|-----------------------------|------------|-----|-----|-----|---------------|-----|-----|----|
| Understand strategies used in reproductive behaviour | <ul style="list-style-type: none"> - Courtship and mating behaviour: non-random <ul style="list-style-type: none"> - Relevant to sexual reproduction - Involved: competition between males and the choice females make - Results in non-random mating and nonrandom offspring - Important related concept: sexual selection - Example: peacock tail <ul style="list-style-type: none"> - High costs of such a tail → energy in production and maintenance; risk of predation - Benefits: access to mates → females choose mates based on tail size - Sexual selection <ul style="list-style-type: none"> - Intrasexual selection: competition between males <ul style="list-style-type: none"> - Sexual dimorphism (hefty vs. slight) - Intersexual selection: mate choice by female <ul style="list-style-type: none"> - Sexual dimorphism (flashy vs. plain) - Parental care <ul style="list-style-type: none"> - Variety of types and amount - For parental care to evolve the benefits must outweigh the costs - Benefits: increased survival and growth of offspring (fitness) - Costs: missed opportunities to reproduce again - Example: parental care and cooperative breeding (in superb fairy wren) <ul style="list-style-type: none"> - In some species, offspring stay and help parents rear more offspring - Increase number of independent young with more helpers - Trade-off costs versus benefits | | | | | | | | | | | | | | | | | | | | |
| Understand whether behaviour is something only animals do | <p style="text-align: center;">e.g. foraging behaviour?</p> <table> <thead> <tr> <th>Forager</th> <th>Brushtail possum (<i>Trichosurus vulpecula</i>)</th> <th>Thick-tailed bushbaby (<i>Otolemur crassicaudatus</i>)</th> <th>Slime mold (<i>Physarum polycephalum</i>)</th> </tr> </thead> <tbody> <tr> <td>Food quality</td> <td>Variable (leaves, fruits)</td> <td>Variable (fruits, inverts)</td> <td>Variable (bacteria, yeasts, fungi)</td> </tr> <tr> <td>Environment</td> <td>Variably risky (predators)</td> <td>Variably risky (predators)</td> <td>Variably risky (dry, light)</td> </tr> <tr> <td>They move?</td> <td>Yes</td> <td>Yes</td> <td>Yes</td> </tr> <tr> <td>Have a brain?</td> <td>Yes</td> <td>Yes</td> <td>No</td> </tr> </tbody> </table> <p>    </p> <ul style="list-style-type: none"> - Plants <ul style="list-style-type: none"> - Leaves and stems: grow towards light, respond to their environment by | Forager | Brushtail possum (<i>Trichosurus vulpecula</i>) | Thick-tailed bushbaby (<i>Otolemur crassicaudatus</i>) | Slime mold (<i>Physarum polycephalum</i>) | Food quality | Variable (leaves, fruits) | Variable (fruits, inverts) | Variable (bacteria, yeasts, fungi) | Environment | Variably risky (predators) | Variably risky (predators) | Variably risky (dry, light) | They move? | Yes | Yes | Yes | Have a brain? | Yes | Yes | No |
| Forager | Brushtail possum (<i>Trichosurus vulpecula</i>) | Thick-tailed bushbaby (<i>Otolemur crassicaudatus</i>) | Slime mold (<i>Physarum polycephalum</i>) | | | | | | | | | | | | | | | | | | |
| Food quality | Variable (leaves, fruits) | Variable (fruits, inverts) | Variable (bacteria, yeasts, fungi) | | | | | | | | | | | | | | | | | | |
| Environment | Variably risky (predators) | Variably risky (predators) | Variably risky (dry, light) | | | | | | | | | | | | | | | | | | |
| They move? | Yes | Yes | Yes | | | | | | | | | | | | | | | | | | |
| Have a brain? | Yes | Yes | No | | | | | | | | | | | | | | | | | | |

| | |
|---|---|
| | <ul style="list-style-type: none"> - moving - Roots: grow along chemical gradient towards nutrients, respond to their environment by moving - All living organisms respond to their environment - Behaviour: <ul style="list-style-type: none"> - Interaction with environment (abiotic and biotic) - Involves stimulus and response |
| Appreciate the science behind our knowledge and understanding of behaviour | |

Groups and Populations

| | |
|---|---|
| Background | <ul style="list-style-type: none"> - Groups: multiple organisms of same or different species occupying a common space <ul style="list-style-type: none"> - Can be ephemeral or consistent - Can be social (positive grouping), indirect (sharing common resources) or accidental (random chance) - Populations: a number of organisms of the same species in a defined geographical area <ul style="list-style-type: none"> - Properties of a population include: <ul style="list-style-type: none"> - Number of individuals or population size - Area they occupy - Age structure - Sex ratio - Play a central role in our understanding of the factors that shape and drive the diversity of life - Composition and structure are influenced by life history, mobility and habitat - Populations are essential for: <ul style="list-style-type: none"> - Ecology: <ul style="list-style-type: none"> - Distribution and abundance of individuals - Density - Evolution <ul style="list-style-type: none"> - Populations of organisms evolve, not individuals - Gene flow - Conservation and management <ul style="list-style-type: none"> - Invasive species - Defining threat status of taxa - Translocations and restoration |
| Importance of Population Biology | <ul style="list-style-type: none"> - Understand temporal dynamics of population <ul style="list-style-type: none"> - Rhythmic structure to explosion and decline in snowshoe hare and mynx (predator) |

| | |
|---|--|
| | <ul style="list-style-type: none"> - Understanding spatial distribution of populations - Natural selection occurs within populations |
| Describe and understand exponential and logistic models of population growth | <ul style="list-style-type: none"> - Populations change in numbers over time <ul style="list-style-type: none"> - Chance can be positive or negative - Rate (r) = change/unit time |
| Define instantaneous growth rates in discrete and continuous exponential growth models | <ul style="list-style-type: none"> - Exponential is geometric: a population's per capita growth remains the same irrespective of population size; thus populations grow faster as they get bigger - Dynamics over time depend on life history of organism <ul style="list-style-type: none"> - Discrete: reproduction occurs periodically (may be seasonal) - Continuous: reproduction occurs year-round - r = instantaneous growth rate - N = population size <p style="text-align: right;">$\frac{dN}{dt} = rN$</p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> <p>Discrete</p> <p>Population size (N)</p> <p>Time (t)</p> <p>$r = 1.2$</p> </div> <div style="text-align: center;"> <p>Continuous</p> <p>Population size (N)</p> <p>Time (t)</p> <p>$r > 0$: growth $r < 0$: decline</p> <p>$r = 0.02$ $r = 0.01$ $r = 0.00$ $r = -0.003034$</p> </div> </div> <p>Gotelli (1995) figures 1.1a & 1.2</p> <ul style="list-style-type: none"> - Resource limited growth <ul style="list-style-type: none"> - Population growth is often resource limited (eg. food, space, water, nesting sites...) - Numbers cannot increase without a bound |



- Estimating birth rates
 - Histology of reproductive organs
 - Capture/counting of fertilised gametes
 - Counting of newly born individuals
- Estimating death rates
 - Tagging
 - Follow individuals (for sessile organisms)
 - Probability based (for more motile organisms)

Become familiar with demographic rates and how they are measured

- Variables that drive changes in population size
 - Birth, death, emigration, immigration, growth, age at maturity, sex ratio
- Birth and death rates
 - Fundamental to population growth
 - Balance between additions (births) and losses (deaths) determines growth rates
 - Inherent to all types of population growth models
- Emigration (leaving population) and Immigration (entering population)
 - $N_{t+1} = N_t + \text{Births} - \text{deaths} + \text{immigrants} - \text{emigrants}$
 - Measured using tagging and recapture
 - Physical
 - GPS
 - Radio telemetry
 - Acoustic
 - Genetics

Estimating population size

Mark-release-recapture (MRR)

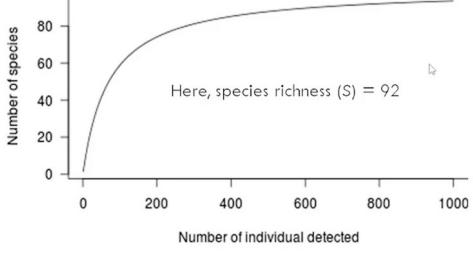
- The MRR method estimates the total population size from a sample proportion of a mobile species
- Uses the proportion of recaptures to estimate the whole population size
- Assumptions often are hard to satisfy
 - Closed population (ie. no immigration, no emigration)
 - All individuals equally likely to be marked
 - Marked individuals do not lose their mark
- Techniques have been used successfully on many animals

| | |
|--|--|
| | <p style="text-align: center;">Petersen MRR estimate</p> <div style="border: 1px solid black; padding: 10px; width: fit-content; margin: auto;"> $\frac{M}{N} = \frac{R}{n}$ <p style="text-align: right;"> N = pop. size M = marked 1st time R = recaps (marked) n = sampled second time </p> </div> |
| Understand what a stage/age structure model is | <ul style="list-style-type: none"> - Age and size of an individual affects: <ul style="list-style-type: none"> - Fecundity (probability of giving birth) - Survival - Do not treat all members of a population as identical → unrepresentative of natural population structure - Imbalanced initial age structure → age and number cycles - Life tables: show survivorship probability at each age - Long-term studies: key to understanding population dynamics - Age structure pyramids <p>Australia's human population dynamics</p> <ul style="list-style-type: none"> - Changes in human population size: mostly due to behavioural changes - Economists need to know the future age structure to plan → nursing homes, schools - Effects of COVID 19: negligible except for reduction in migration - Ageing population - Growth rate of many western countries <ul style="list-style-type: none"> - Below replacement rate → population numbers will level out then fall |
| Understand what a spatially structured population is | <ul style="list-style-type: none"> - Spatially scattered across a landscape - Can be called Metapopulations - Local populations, but individuals move - Demographic rates vary spatially - Large-scale dynamics dependent on local demographics and connectivity <ul style="list-style-type: none"> - Eg. Glanville Fritillary butterfly <ul style="list-style-type: none"> - Periodic local extinctions - Recolonisation from nearby populations - Metapopulations level extinction prevented |
| Understand the principles and implementation of population viability and analysis (PVA) | <ul style="list-style-type: none"> - Population viability analysis (PVA) is a tool to model population dynamics over time - Uses basic population data - Includes environmental variation in these values - Can change values to reflect human impact <p>Key information needed</p> <ul style="list-style-type: none"> - Population Size/Carrying Capacity (K) |

| | <ul style="list-style-type: none"> - Fecundity - Mortality: adults and juveniles - Inter-annual variation in parameters <p>Example: Long-nosed bandicoots</p> <ul style="list-style-type: none"> - Listed as an endangered population - Remnant population, cut off by urban development - At risk from cars, habitat loss and isolation - Monitored for ~20 years <ul style="list-style-type: none"> - Population size - Mortality - Fecundity - Use PVA to understand the effects of: <ul style="list-style-type: none"> - Habitat loss - Increased mortality rates - Non-native predators such as foxes - Multiple impacts <p>Carrying Capacity = 100</p> <p>Annual variability = 25%</p> <p>Maximum age = 2 years</p> <p>Adult mortality = 10%</p> <p>Juvenile mortality = 80%</p> <p>Mean litter size = 2-3</p> <p>30% chance of fox arrival</p> <p>Resulting in 20% adults killed</p> <table border="1"> <thead> <tr> <th>Year</th> <th>Probability of persistence (Basic)</th> </tr> </thead> <tbody> <tr> <td>2000</td> <td>1.0</td> </tr> <tr> <td>2010</td> <td>~0.95</td> </tr> <tr> <td>2020</td> <td>~0.90</td> </tr> <tr> <td>2030</td> <td>~0.80</td> </tr> <tr> <td>2040</td> <td>~0.70</td> </tr> <tr> <td>2050</td> <td>~0.58</td> </tr> </tbody> </table> | Year | Probability of persistence (Basic) | 2000 | 1.0 | 2010 | ~0.95 | 2020 | ~0.90 | 2030 | ~0.80 | 2040 | ~0.70 | 2050 | ~0.58 |
|-------------------|--|------|------------------------------------|------|-----|------|-------|------|-------|------|-------|------|-------|------|-------|
| Year | Probability of persistence (Basic) | | | | | | | | | | | | | | |
| 2000 | 1.0 | | | | | | | | | | | | | | |
| 2010 | ~0.95 | | | | | | | | | | | | | | |
| 2020 | ~0.90 | | | | | | | | | | | | | | |
| 2030 | ~0.80 | | | | | | | | | | | | | | |
| 2040 | ~0.70 | | | | | | | | | | | | | | |
| 2050 | ~0.58 | | | | | | | | | | | | | | |
| Extinction | <ul style="list-style-type: none"> - Genetic stochasticity (small population) - Demographic stochasticity (random nature of births and deaths) - Environment stochasticity (variability) - Catastrophes (cyclones, fires) - Human impacts <ul style="list-style-type: none"> - Habitat loss - Fragmentation - Over-exploitation - Hunting - Pollution - Pest species introduction | | | | | | | | | | | | | | |

Do Species Matter?

| Understand the biological species concept and others | <ul style="list-style-type: none"> - Biological species concept: “Groups of actually or potentially interbreeding natural populations, which are reproductively isolated from other such groups” (Ernst Mayr) - Other concepts: <ul style="list-style-type: none"> - Genetic species (differ in genetic/DNA profiles) - Ecological species (differ in ecology) - Phenetic species (defined on overall similarity) - Biological species concept prevails in general usage, despite the ‘species problem’ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|--|----------|-------|---------------|-------|---------------|------|---|----|----|----|------|---|----|----|----|------|----|----|----|----|------|----|----|----|----|------|----|----|----|----|------|----|----|----|----|------|----|----|----|----|------|----|----|----|----|------|----|----|----|----|------|----|----|----|----|------|----|----|----|----|------|----|----|----|----|------|----|----|----|----|------|----|----|----|----|------|----|----|----|----|
| Is there a ‘species problem’ and do species matter? | <p>Species Problem</p> <ul style="list-style-type: none"> - Most commonly understood definition of what species are but: <ul style="list-style-type: none"> - Many species hybridise; some produce viable offspring - Concept is hard to apply to asexual organisms - Concept cannot be applied to fossil taxa - Sometimes hard to reconcile with the range in form of particular species (eg. dogs → is the dingo a dog) <p>Importance of Species:</p> <ul style="list-style-type: none"> - Are ‘real’ for most familiar organisms - Continue to stimulate our thinking about biological variation - Provide a convenient means of labelling different organisms - Have strong historical precedents - Underpin local, state, national and international conservation efforts - Are central to biodiversity conservation – species, genetic, community and landscape are the most commonly accepted types of biodiversity - May become less relevant as we improve ways to assess genetic variation, but species will matter for the foreseeable future | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| How do we count the number of species in practice? | <ul style="list-style-type: none"> - Define an area of where you will be counting - Sample: what kinds of organisms will be counted - Methods of counting will differ for different organisms: <ul style="list-style-type: none"> - Counts for large/conspicuous animal or plants - Traps for small/shy species - Camera/remote sensor for small vertebrates - Genetic methods (eg. eDNA) for cryptic species - Time of day/season/weather conditions are all important consideration - Example: How many vertebrate species occur in the Simpson Desert, central Australia? Pitfall traps used for small vertebrates, observations for birds <div style="text-align: right; margin-top: 10px;"> <p>Vertebrate diversity: Simpson Desert, Qld Bats, fish not included in these counts</p> <table border="1"> <caption>Data extracted from Vertebrate diversity: Simpson Desert, Qld graph</caption> <thead> <tr> <th>Year</th> <th>Frogs</th> <th>Reptiles</th> <th>Birds</th> <th>Small Mammals</th> </tr> </thead> <tbody> <tr><td>1990</td><td>0</td><td>20</td><td>35</td><td>40</td></tr> <tr><td>1991</td><td>5</td><td>30</td><td>45</td><td>50</td></tr> <tr><td>1992</td><td>10</td><td>35</td><td>55</td><td>60</td></tr> <tr><td>1993</td><td>15</td><td>40</td><td>65</td><td>70</td></tr> <tr><td>1994</td><td>20</td><td>45</td><td>75</td><td>78</td></tr> <tr><td>1995</td><td>25</td><td>48</td><td>80</td><td>82</td></tr> <tr><td>1996</td><td>30</td><td>50</td><td>85</td><td>85</td></tr> <tr><td>1997</td><td>35</td><td>48</td><td>90</td><td>90</td></tr> <tr><td>1998</td><td>40</td><td>45</td><td>95</td><td>95</td></tr> <tr><td>1999</td><td>45</td><td>45</td><td>98</td><td>98</td></tr> <tr><td>2000</td><td>45</td><td>45</td><td>98</td><td>98</td></tr> <tr><td>2001</td><td>45</td><td>45</td><td>98</td><td>98</td></tr> <tr><td>2002</td><td>45</td><td>45</td><td>98</td><td>98</td></tr> <tr><td>2003</td><td>45</td><td>45</td><td>98</td><td>98</td></tr> <tr><td>2004</td><td>45</td><td>45</td><td>98</td><td>98</td></tr> </tbody> </table> </div> | Year | Frogs | Reptiles | Birds | Small Mammals | 1990 | 0 | 20 | 35 | 40 | 1991 | 5 | 30 | 45 | 50 | 1992 | 10 | 35 | 55 | 60 | 1993 | 15 | 40 | 65 | 70 | 1994 | 20 | 45 | 75 | 78 | 1995 | 25 | 48 | 80 | 82 | 1996 | 30 | 50 | 85 | 85 | 1997 | 35 | 48 | 90 | 90 | 1998 | 40 | 45 | 95 | 95 | 1999 | 45 | 45 | 98 | 98 | 2000 | 45 | 45 | 98 | 98 | 2001 | 45 | 45 | 98 | 98 | 2002 | 45 | 45 | 98 | 98 | 2003 | 45 | 45 | 98 | 98 | 2004 | 45 | 45 | 98 | 98 |
| Year | Frogs | Reptiles | Birds | Small Mammals | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1990 | 0 | 20 | 35 | 40 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1991 | 5 | 30 | 45 | 50 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1992 | 10 | 35 | 55 | 60 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1993 | 15 | 40 | 65 | 70 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1994 | 20 | 45 | 75 | 78 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1995 | 25 | 48 | 80 | 82 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1996 | 30 | 50 | 85 | 85 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1997 | 35 | 48 | 90 | 90 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1998 | 40 | 45 | 95 | 95 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1999 | 45 | 45 | 98 | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2000 | 45 | 45 | 98 | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2001 | 45 | 45 | 98 | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2002 | 45 | 45 | 98 | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2003 | 45 | 45 | 98 | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2004 | 45 | 45 | 98 | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

| | |
|---|--|
| <p>Understand species richness, species diversity and how to estimate these quantities</p> | <ul style="list-style-type: none"> - Species richness: number of species in a sample (S) <ul style="list-style-type: none"> - But note the S can vary with sample size - At sample size of 200, $S = 71$ - At a sample size of 400, $S = 82$ - Large sample sizes are needed to detect all the rare species that are present - Most living systems have a few common species and lots of species that are more rare - Species diversity: a measure of the number of species and the numbers of individuals of these species brought together into a single index - Example <ul style="list-style-type: none"> - The sample from pond 1 has 100 insects comparison of 10 individuals from 10 species - The sample from pond 2 has 100 insects comparison 91 individuals of one species and a single individual from each of the remaining 9 species - Both ponds have the same species richness ($S = 10$) → pond 1 has more diversity (numbers are more even)  <p>Species diversity indexes</p> <ul style="list-style-type: none"> - Berger-Parker index (D): $1 - (N_{\max}/N)$, where N is the number of individuals in the sample and N_{\max} is the number of the most abundant species - Simpson's index - Counts of species and diversity indexes are useful but tell us little about relationships between samples - |
| <p>How many species are there and where do they occur</p> | <ul style="list-style-type: none"> - Types of diversity <ul style="list-style-type: none"> - Alpha: the number of species within a particular area or habitats (local diversity) - Beta: the difference in species between areas or habitats (turnover diversity) - Gamma: the number of species from all areas of habitats combined - Biodiversity surveys usually specify areas, times and taxa to address this question (eg. mammals) - Number of species <ul style="list-style-type: none"> - Mammals of NSW: ~ 110 native species - Mammals in Aust: 397 native species (with 34 recently extinct species) - Mammals: world total ~6,495, of which 96 are recently extinct - Number of species in the world <ul style="list-style-type: none"> - 1.5-1.82 million species have been described and have a name according |

| | |
|---|--|
| | <p>to current texts</p> <ul style="list-style-type: none"> - Many more species remain to be discovered and names - Many are insects and other invertebrates as well as cryptic organisms such as parasites - Calculating world species <ul style="list-style-type: none"> - Extrapolate from current rates of discovery; eg. 25,000 new species across all taxa were discovered in Australia from 2008-2017 - Extrapolate from diversity in well surveyed areas to poorly surveyed areas - Expert knowledge estimates |
| Appreciate the science behind our knowledge and understanding of species and their behaviour | <ul style="list-style-type: none"> - Until 2017, most authorities estimate 10-100 million species on Earth with most compirons animals mostly in tropical areas - This changed in 2017 with recognition of huge diversity of bacteria <ul style="list-style-type: none"> - Larsen et al. (2017) estimates ~2.238 billion species on Earth with 70-90% being bacteria <ul style="list-style-type: none"> - Used existing estimates of global number of arthropods (~6.8 million) and multiplied this by the estimated number of cryptic species (6) for each known arthropod = 40.8 million - Assumed that each arthropod has one associate mite species ($40.8 + 40.8 = 81.6$ million species) - Then if each of these species has on average one parasitic nematode worm species: $2 \times 81.6 = 163.2$ million animal species - If each animal species host ~10.7 bacteria species on and in their body, then 163.2×10.7 gives us 1.75 billion bacteria species |

Trophic Ecology

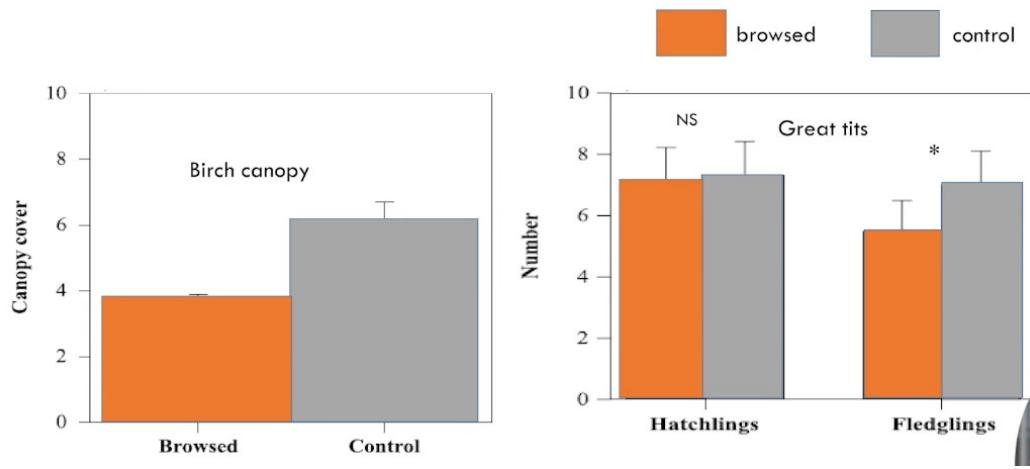
| | |
|---|--|
| Review how organisms get their energy | <ul style="list-style-type: none"> - Autotrophs <ul style="list-style-type: none"> - Producers - Make energy themselves (synthesis organic from inorganic compounds) - Green plants, phytoplankton, algae - Heterotrophs <ul style="list-style-type: none"> - Consumers, degraders, decomposers - Get energy from others - Animals |
| Describe the concept of trophic levels | <ul style="list-style-type: none"> - Trophic levels: the position of an organism in the food chain and ranges from a value of 1 for primary producers to 5 for marine mammals and humans. The method to determine the trophic level of a consumer is to add one level to the mean trophic level of its prey. |
| Explain how energy flows within ecosystems | <ul style="list-style-type: none"> - Hypothesis 1: the energy hypothesis <ul style="list-style-type: none"> - About 90% of energy is lost between trophic levels (Elton, 1927) - High productive ecosystems should have more chains - More species results in more trophic links in high energy tree hollows |

| | |
|--|---|
| | <p style="text-align: center;">(Jenkins, 1992)</p> <ul style="list-style-type: none"> - Hypothesis 2: the dynamic stability hypotheses <ul style="list-style-type: none"> - Longer food chains are less stable because fluctuations at low trophic levels magnify at high levels - Top predators more likely to go extinct |
| Describe food chains and food web | <ul style="list-style-type: none"> - Food chains: describe energy flow between organisms among trophic levels <ul style="list-style-type: none"> - In a natural system food chains are usually short - Food webs: describe more complex interactions of energy transfer |
| Describe the various types of ecological interactions among species | <ul style="list-style-type: none"> - Food webs involve ecological interactions <ul style="list-style-type: none"> - Mutualism: 2 organisms in close association, both benefit [+, +] <ul style="list-style-type: none"> - Obligate mutualism; symbiosis; partners can only survive together - Facultative mutualism: partners gain benefit from associated but can survive on either own - Competition: 2 organisms come off poorly than if they were on their own [-, -] - Predation: eg. herbivory, carnivory; parasitism [+, -] - Commensalism: one organism benefits and whilst there is no effect on the second [+ , 0] - Amensalism: association between two organisms causes a negative impact on one and no effect on the other [0, -] |

| | |
|--|---|
| | <ul style="list-style-type: none"> - No interaction: [0, 0] |
| Link ecological interactions to the flow of energy through trophic levels using herbivory as an example | <ul style="list-style-type: none"> - Herbivory: primary consumers are eating green plants - Plants are not great food for animals because of their low nutritional value (much of the energy and nutrient needed by animals is locked behind plant cell walls) - Herbivory is the biggest interaction on the planet - Important for individuals - Can affect populations and communities - Can affect ecosystem processes <p>Effects on populations → community level responses</p> <pre> graph TD P1[Plant] --> H[Herbivore] P2[Plant] --> H P3[Plant] --> H H --> P1 H --> P2 H --> P3 P1 -.-> P1 P2 -.-> P2 P3 -.-> P3 P1 -.-> P2 P1 -.-> P3 P2 -.-> P3 </pre> <ul style="list-style-type: none"> - Fundamentals of Herbivory <ul style="list-style-type: none"> - Tissue loss to herbivores: how much could plants have reproduced if not eaten - Herbivores selectively eat high quality plant tissue (so % impact is much greater than tissue loss suggests) - Plants have defences against herbivores (e.g. spiky thorns or tough, waxy epidermis) to reduce their tissue loss - The world is green because much plant tissue is not available to herbivores |
| Appreciate the science behind | Pedersen et al. (2007) |

ecological knowledge and understanding

Herbivory & community ecology



Assemblages and Ecosystems

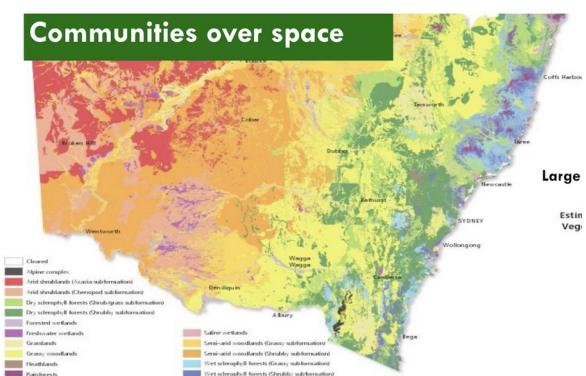
Communities as definable entities; comparison with assemblages

- **Communities:** two or (usually) more species that occur together in space and time
 - In addition to co-occurring, community members interact with each other as an ecological unit
 - Sometimes taken to be just vegetation, but should include all biota that occur together
- **Assemblages:** a group of species that live together with no assumptions made about how or whether they interact with each other
 - Less well defined

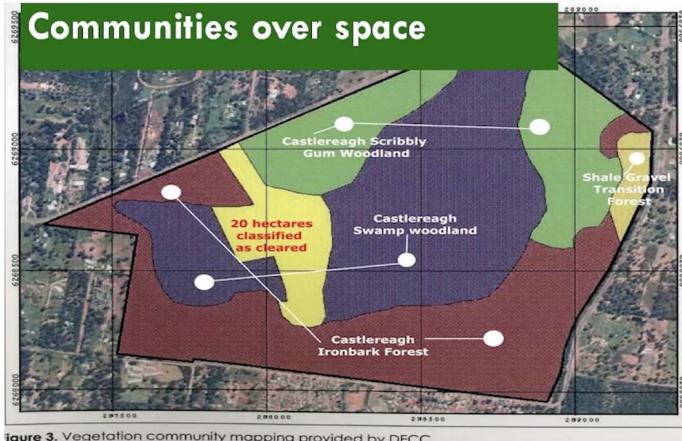
Understand spatial and temporal changes in communities

Spatial changes

- **Large scale: NSW as an example**
 - Coastal communities are light blue and purple → areas of rainforest, and high rainfall
 - Moving from east to west → drier communities dominated by shrubs
 - Further inland → arid environments



- Small scale: local vegetation-based communities



Temporal Changes

- Stable communities maintain consistent species richness and composition
- However, change in species composition is the norm in nature
- Change is driving by local colonisation and extinction of species
- Classic models are underpinned by succession of species
- Predictable patterns of change occur in response to disturbances
- New communities are being assembled by human activity
- New communities are often homogeneous in many parts of the world → 'biotic homogenisation'

Understand succession

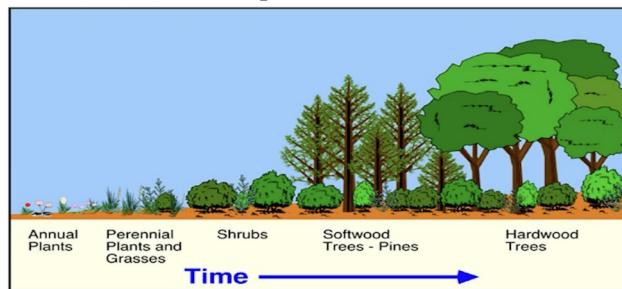
Succession

- Early ideas related to forests: tree falls down, creating gap for light (disturbance)
- Light unsuitable for certain species (esp. shade-tolerant), creates high quality environment for other species
- Changes in species composition and abundance, growth rates in lower canopy and ground level strata
- Dominant species in system change over time → various biogeochemical processes associated with the presence of certain species also change
- New dominant species move in
- Equivalent changes often seen with animals, fungi etc.
- Types of succession:
 - Primary succession: bare area without solid (eg. Sand-dune, bare rock)
 - Secondary succession: in a habitat modified by other species (eg. first gaps, abandoned agricultural fields)

Plant Species' role in succession

- Pioneer species
 - Grow in sun
 - Fix nitrogen
 - Good dispersal
 - Small seeds
 - Rapid growth

- Short generation time
- Poor competitors
- Climax species
 - Shade tolerant
 - Slow growth
 - Long-lived
 - Good competitors

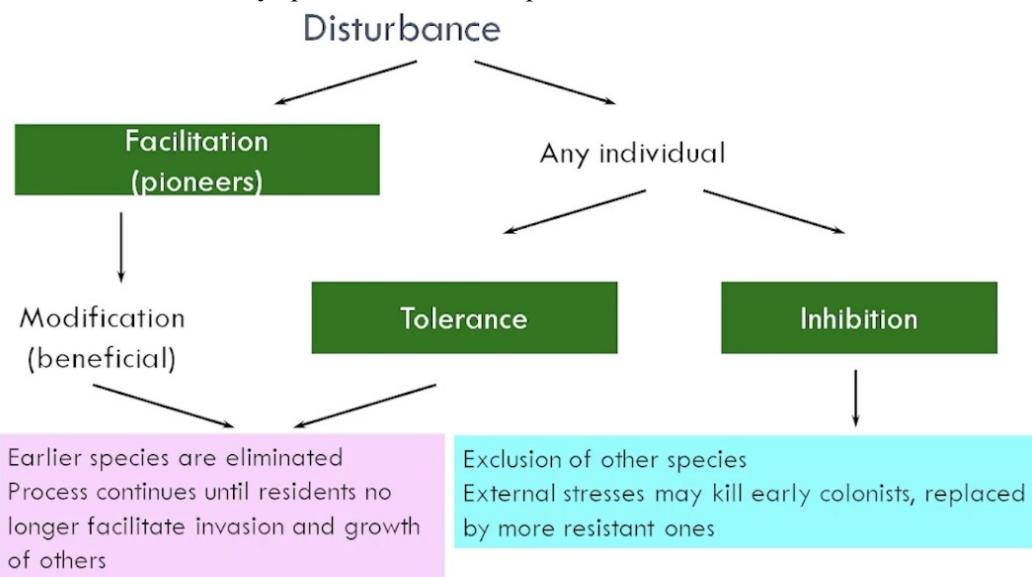


Succession of plant species on abandoned fields in North Carolina:

- **Pioneer species** consist of a variety of annual plants
- Followed by perennials and grasses, shrubs, softwood trees and shrubs, and finally hardwood trees and shrubs
- Succession takes about 120 years to go from pioneer stage to the **climax community**
- The concept of the climax community has been questioned recently: what happens when the old trees die?

Models of succession

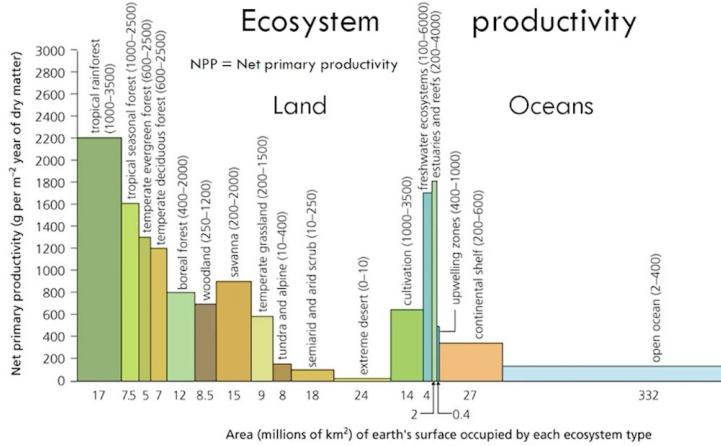
- Facilitation: early arriving species make environment more favourable for later species
 - Eg. fixing nitrogen, allowing water to be retained in soil
- Tolerance: Neither negative nor positive interactions between early and late species
 - No interaction
- Inhibition: early species inhibit later species



Understand resilience

- **Resilience:** how long before a community returns to an “equilibrium” after disturbance? Are there equilibria?
- What objective and non-arbitrary criteria for determining pre- and post-disturbance conditions do we have?
- Australia often uses the ‘before 1788’ criterion to define pre-disturbance

| | |
|--|--|
| | <p>conditions</p> <ul style="list-style-type: none"> - Area of debate as Indigenous people modified the land for their own purposes <p>et al. 1997, Science</p> |
| Role of disturbance in community structure | <ul style="list-style-type: none"> - Disturbance is a driver of species richness and community composition - Immediate disturbance <ul style="list-style-type: none"> - Observations of storms on tropical rainforests and coral reefs suggest that you need a little disturbance but not too much to increase diversity <ul style="list-style-type: none"> - Patchy mosaic of distanced creates highest diversity (intermediate disturbance hypothesis) - Disturbance stops one species from becoming particularly dominant - Too many disturbance can cause continual species resets <p>Source: Michael Keogh, University of Melbourne</p> |
| Ecosystems and productivity – global and local cycles | <ul style="list-style-type: none"> - Ecosystems: the community of living organisms considered in conjunction with the abiotic components of their environment, interacting as a system - Productivity is a key attributes of ecosystems <ul style="list-style-type: none"> - Productivity refers to the rate of generation of biomass in an ecosystem |



Biogeochemical cycles

- Energy flows through the biosphere
- Materials are recycled
- Ecosystem productivity is controlled by efficiency of recycling as well as by energy available
- Global cycles: materials transported in the atmosphere (water, carbon, nitrogen and sulphur)
- Local cycles: phosphorus, potassium, calcium and magnesium move through soil

The Water Cycle: a global cycle

- ~97% of water on earth is the oceans
- Processes of convection, precipitation, transpiration and respiration move water around the cycle
- ~3% of total water is relatively inaccessible, in icecaps, glaciers and as deep groundwater
- Within the scale of local ecosystems, water behaves more like energy because it effectively flows through and is not recycled locally

Nitrogen cycle: a global cycle

- Abundant in atmosphere, 78%
- Plants cannot absorb atmospheric nitrogen
- Absorbed as ammonium or nitrate after fixation of nitrogen by symbiotic bacteria or in soil solution
- Denitrifying bacteria convert nitrate back to gaseous nitrogen
- Electrical storms also fix nitrogen
- Nitrogen becomes limiting if microbial activity is inhibited

Phosphorus cycle: a local cycle

- Essential to all life in ATP
- Not common in earth's crust or in atmosphere
- Taken up by plants as phosphate from sparingly soluble soil storage
- Australian flora are well adapted to low P, and efficient at recycling phosphorus
- Symbiosis between plant roots and mycorrhizal fungi enhances the phosphorus supply

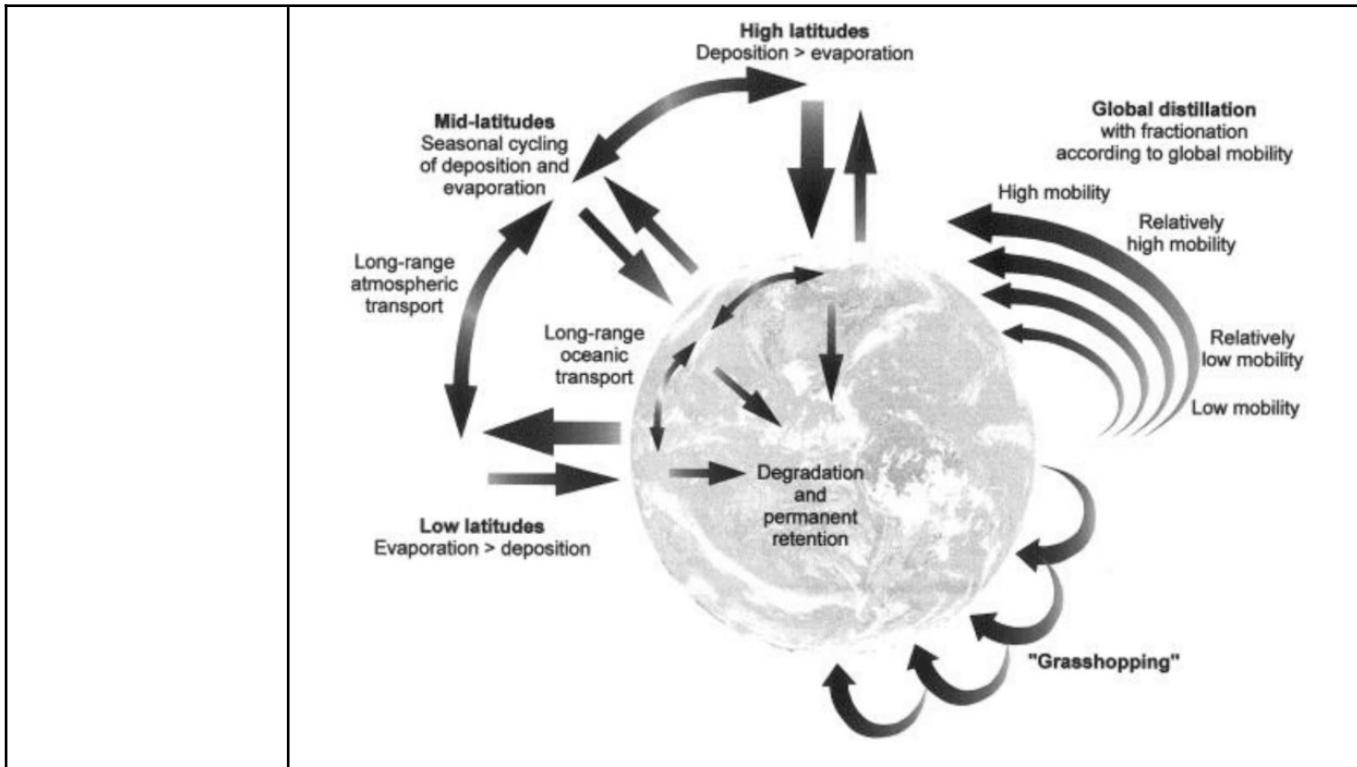
| | |
|---|---|
| <p>Case study - trophic cascades and carbon cycles</p> | <p>Carbon Cycle: a global cycle</p> <ul style="list-style-type: none"> - Most carbon is locked up in earth's rocks as carbonates (and fossil fuels) - The most active pool is carbon dioxide, 0.04 percent of the atmosphere (and increasing) - CO₂ is used in photosynthesis, released during respiration - Large amounts of CO₂ are dissolved in the ocean - Burning fossil fuels returns CO₂ to the atmosphere faster than it can be cycled → contributes to global warming <p>Trophic cascade: regulation of the carbon cycle by animals</p> <ul style="list-style-type: none"> - <i>The carbon cycle: can trophic cascades affect the storage and flux of atmospheric carbon? An analysis of sea otters and kelp forests</i> - Can sea otters eat enough urchins to reduce urchin herbivory on kelp? <ul style="list-style-type: none"> - Kelp forests store carbon and provide a habitat for a wide range of species - Data from past 40 years – North America <ul style="list-style-type: none"> - Kelp density and biomass measured with and without sea otters - Estimated the indirect effects of sea otters on ecosystems carbon © production and storage - In the presence of sea otters, there is more carbon being sequestered in kelp forests as sea otters are eating the sea urchins which eat the kelp <ul style="list-style-type: none"> - Sea otters drive very significant carbon storage; est. = 4.4-8.7 x 10⁻⁹ kg C <p>(a) Atmospheric carbon pool 1530 g C m⁻²</p> <p>(b) Atmospheric carbon pool 1530 g C m⁻²</p> <p>+ sea otters:</p> <ul style="list-style-type: none"> Kelp NPP: 313–900 g C m⁻² yr⁻¹ Kelp carbon pool: 101–180 g C m⁻² Respiration*: 156–89 g C m⁻² yr⁻¹ Deep ocean transport*: 3–450 g C m⁻² yr⁻¹ <p>- sea otters:</p> <ul style="list-style-type: none"> Kelp NPP: 25–70 g C m⁻² yr⁻¹ Kelp carbon pool: 8–14 g C m⁻² Respiration*: 12.5–89.75 g C m⁻² yr⁻¹ Deep ocean transport*: 0.25–35 g C m⁻² yr⁻¹ |
| <p>The science behind this ecological</p> | |

| | |
|------------------------------------|--|
| knowledge and understanding | |
|------------------------------------|--|

The Human Footprint

| | |
|--|---|
| Review how human activities affect the ecology of natural systems | <ul style="list-style-type: none"> - The Anthropocene: period of time during which human activities have impacted the environment enough to constitute a distinct geological change - Toxic inputs <ul style="list-style-type: none"> - Pesticides - Manufacturing - Industrial accidents - Chemical spills - Atmospheric pollution - Plastics - Nanoparticles - Anthropogenic noise <ul style="list-style-type: none"> - Deep sea noises on marine animals - Alan (artificial light at night) <ul style="list-style-type: none"> - Migration of turtles |
| Understand the impacts of pollution and how it affects the ecology of natural systems | <ul style="list-style-type: none"> - Bioaccumulation: occurs when an organism absorbs a toxic substance at a rate greater than that at which the substance is lost <ul style="list-style-type: none"> - Persistent and mobile - Accumulation occurs in body tissues - Particularly in higher predators at the top of food chains and webs - American bald eagle: early victims of eggshell thinning due to toxic chemicals <ul style="list-style-type: none"> - When the bird sat on them, their eggs broke <p>Problems with Lead – California condor</p> <ul style="list-style-type: none"> - Intensive captive breeding and medical intervention → requires perceptual, intensive support - Condors ingest lead after feeding on carcasses of animals that hunters have shot, leading to chronic lead poisoning - 2008 California ban on the use of lead shot where the birds were being reintroduced <ul style="list-style-type: none"> - But feather and blood samples from trapped birds found no discernible difference in lead levels before and after the ban - Lead poisoning severely damages birds' nervous systems and impairs liver and kidney function <p>Oil spill</p> <ul style="list-style-type: none"> - Exxon Valdez, Alaska → released around 40 million litres of oil - Deepwater Horizon → ~795 million litres of oil in the Gulf of Mexico - Oil impacts on coastal communities <ul style="list-style-type: none"> - Old perceptions: acute mortality through short-term toxic exposure to oil deposited on shore accounts for the only important losses of shoreline |

| | |
|--|---|
| | <p>plants and invertebrates</p> <ul style="list-style-type: none"> - New perceptions: cleanup attempts can be as damaging as the oil itself, with impacts recurring as long as clean-up (chemical and physical methods) continues <ul style="list-style-type: none"> - Strong pervasive biological interactions in rocky intertidal and kelp forest communities contribute to cascades of delayed, indirect impacts and expand the scope of damages well beyond the indirect losses and thereby also delay recoveries - Need for development of ecosystem-based toxicology; monitoring may be needed for more than 100 years |
| Impacts on human wellbeing | <ul style="list-style-type: none"> - PCBs found in breast milk of mother in southern Quebec in the mid 1980s - Inuit milk had 5 times the PCB levels (also toxaphene and chlordane) - Another study found that more than ½ of children had unacceptably high levels of PCBs - Older people had higher levels - Effects: <ul style="list-style-type: none"> - Children born to women who ate PCB-contaminated fish - 11-year olds exposed to PCBs in the womb had: <ul style="list-style-type: none"> - Lower IQ - Poor memory - Shortened attention span - Learning difficulties - How is it getting there? <ul style="list-style-type: none"> - No agriculture/manufacturing in Northern Canada - Inuit use almost every bit of the 100s of narwhal and beluga whales taken every year → preference for muktuk (skin and surface fat) - Also consume bits of ringed seals (livers), caribou (kidneys) and fish - These animals were at the top of their respective food chains → Toxins accumulate in certain body parts,, particularly fat - But who's using PCBs? <ul style="list-style-type: none"> - PCBs were banned in Canada in 1977 - “Global distillation” and “global fractionation” → processes whereby volatile chemicals are transported long distances - Heavy usage in tropics, where they evaporate from soils, carried on winds (fractionation) and then condensed out in the cold as toxic snow and rain (distillation) - Systematic transfer from warm to cold - Very slow breakdown in cold climates |
| Understand how pollutants move into natural systems | <ul style="list-style-type: none"> - “Global distillation” and “global fractionation” → processes whereby volatile chemicals are transported long distances |



| | |
|---|---|
| | |
| Understand the ecological impacts of habitat fragmentation | <ul style="list-style-type: none"> - Habitat loss is one of the major contributors to biodiversity loss - Fragment size and isolation are primary drivers of diversity - Edge effects are present - Shape matters - Connectivity and corridors enhance landscapes - Role of matrix <ul style="list-style-type: none"> - Matrix: areas of habitat in between native vegetation - Suitable matrices can lead to the dispersal of native flora and fauna - Tree Clearing in Queensland <ul style="list-style-type: none"> - Assuming ~120 mammals, birds and reptiles in total per hectare, tree clearing in Queensland has caused the deaths of more than 900 million native vertebrates in just 20 years |
| | <h4>Biomass collapse</h4> <ul style="list-style-type: none"> - Biomass collapse in Amazonian fragments (Laurance et al., 1997) <ul style="list-style-type: none"> - Experimentally fragmented landscape created between 1980-1986 - Patches of 1, 10 and 100 ha isolated by clearing/burning to create pasture - Biomass of plants in these areas was compared to biomass of plants in control plots - All trees with a diameter breast height of greater than or equal to 10cm were censured and converted to biomass estimates using an allometric model - Rate of biomass loss greater near forest edge (ie. small patches) - Decline in above ground biomass after fragmentation (from subset of |

| | <p>edge sites)</p> <ul style="list-style-type: none"> - High tree mortality - No recruitment of new trees <p>- Causes of biomass collapse:</p> <ul style="list-style-type: none"> - Microclimatic factors strongly affected on edges: <ul style="list-style-type: none"> - Wind - Hydrology - Increase in woody vines (lianas) near edges does not compensate for loss of trees - Applying results elsewhere, a general principle applicable in urban, forest and agricultural contexts <table border="1"> <thead> <tr> <th>Years after fragmentation</th> <th>Biomass loss (%)</th> </tr> </thead> <tbody> <tr><td>0-2</td><td>~10</td></tr> <tr><td>2-4</td><td>~7</td></tr> <tr><td>4-6</td><td>~8</td></tr> <tr><td>6-8</td><td>~11</td></tr> <tr><td>>8</td><td>~12</td></tr> </tbody> </table> | Years after fragmentation | Biomass loss (%) | 0-2 | ~10 | 2-4 | ~7 | 4-6 | ~8 | 6-8 | ~11 | >8 | ~12 |
|--|---|---------------------------|------------------|-----|-----|-----|----|-----|----|-----|-----|----|-----|
| Years after fragmentation | Biomass loss (%) | | | | | | | | | | | | |
| 0-2 | ~10 | | | | | | | | | | | | |
| 2-4 | ~7 | | | | | | | | | | | | |
| 4-6 | ~8 | | | | | | | | | | | | |
| 6-8 | ~11 | | | | | | | | | | | | |
| >8 | ~12 | | | | | | | | | | | | |
| Understand the ecological impacts of climate change | <ul style="list-style-type: none"> - Increase in carbon dioxide, temperature anomalies and extreme events - Various systems are being watched: <ul style="list-style-type: none"> - Polar bear behaviour - Timing of peak streamflow - Grape harvest - Spring flowering - Bird migration - Variation in freeze thaw pattern in tundra - Krill stocks - Glacier ‘wastage’ - Type of changes expected and now observed: <ul style="list-style-type: none"> - Animals and plants: <ul style="list-style-type: none"> - Range shifts (latitudinal or altitudinal) - Abundance changes - Change in growing season length - Earlier flowering, emergence of insects, migration and egg- | | | | | | | | | | | | |

| | |
|--|---|
| | <ul style="list-style-type: none"> - laying in birds - Morphology shifts (eg. body and egg sizes) - Hydrology and glaciers: <ul style="list-style-type: none"> - Glacier shrinkage - Permafrost thawing - Later freeze and earlier breakup of river and lake ice - Effects of loss of ice: <ul style="list-style-type: none"> - Species favouring ice-dominated systems with shallow benthic communities (eg. bottom-feeding sea ducks, such as spectacled eiders and marine mammals including walrus) will diminish, and be replaced by system dominated by pelagic fish |
| Appreciate the science behind this ecological knowledge and understanding | |

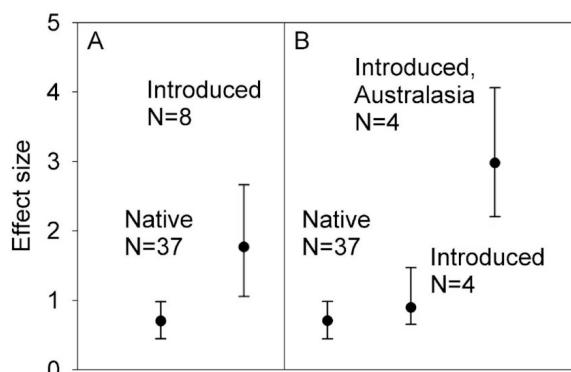
Conservation

| The Extinction Crisis - the effect of the human footprint | <ul style="list-style-type: none"> - More than 28 000 species are threatened by extinction - Scientists estimate that we are losing species at 1,000 to 10,000 times the natural background rate, with some suggesting we could lose up to half of all species by the end of this century - Mass extinction crisis: rate of extinction 10-100,000 times higher than background rates <ul style="list-style-type: none"> - Should be only 1 species every few years <p>Increasing extinction rates due to human activity since the year 1500* Highly conservative estimate</p> <table border="1"> <thead> <tr> <th>Period</th> <th>Mammals (%)</th> <th>Birds (%)</th> <th>Vertebrates (%)</th> <th>Other vertebrates (%)</th> <th>Estimated natural extinction rate (%)</th> </tr> </thead> <tbody> <tr> <td>1500-1600</td> <td>~0.35</td> <td>~0.15</td> <td>~0.10</td> <td>~0.05</td> <td>~0.02</td> </tr> <tr> <td>1600-1700</td> <td>~0.45</td> <td>~0.25</td> <td>~0.15</td> <td>~0.08</td> <td>~0.02</td> </tr> <tr> <td>1700-1800</td> <td>~0.65</td> <td>~0.45</td> <td>~0.25</td> <td>~0.15</td> <td>~0.02</td> </tr> <tr> <td>1800-1900</td> <td>~0.95</td> <td>~0.75</td> <td>~0.45</td> <td>~0.25</td> <td>~0.02</td> </tr> <tr> <td>1900-2014</td> <td>~1.45</td> <td>~1.15</td> <td>~0.85</td> <td>~0.45</td> <td>~0.02</td> </tr> </tbody> </table> <p>*Expressed as a percentage of species evaluated by the International Union for Conservation of Nature.</p> <p>Australia's recent mammal extinctions</p> <ul style="list-style-type: none"> - Australia has lost ~34 species in the last 200 years - Non-flying mammals in the “critical Weight Range” (CWR) <ul style="list-style-type: none"> - CWR = 35g to 5.5 kg → arid zone species most loss - Overall: more than 30% of nation’s mammals are extinct or threatened - Most had disappeared by the 1930s - Western NSW: case study of mammal loss <ul style="list-style-type: none"> - 1788: 72 species native mammals | Period | Mammals (%) | Birds (%) | Vertebrates (%) | Other vertebrates (%) | Estimated natural extinction rate (%) | 1500-1600 | ~0.35 | ~0.15 | ~0.10 | ~0.05 | ~0.02 | 1600-1700 | ~0.45 | ~0.25 | ~0.15 | ~0.08 | ~0.02 | 1700-1800 | ~0.65 | ~0.45 | ~0.25 | ~0.15 | ~0.02 | 1800-1900 | ~0.95 | ~0.75 | ~0.45 | ~0.25 | ~0.02 | 1900-2014 | ~1.45 | ~1.15 | ~0.85 | ~0.45 | ~0.02 |
|--|---|-----------|-----------------|-----------------------|---------------------------------------|-----------------------|---------------------------------------|-----------|-------|-------|-------|-------|-------|-----------|-------|-------|-------|-------|-------|-----------|-------|-------|-------|-------|-------|-----------|-------|-------|-------|-------|-------|-----------|-------|-------|-------|-------|-------|
| Period | Mammals (%) | Birds (%) | Vertebrates (%) | Other vertebrates (%) | Estimated natural extinction rate (%) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1500-1600 | ~0.35 | ~0.15 | ~0.10 | ~0.05 | ~0.02 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1600-1700 | ~0.45 | ~0.25 | ~0.15 | ~0.08 | ~0.02 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1700-1800 | ~0.65 | ~0.45 | ~0.25 | ~0.15 | ~0.02 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1800-1900 | ~0.95 | ~0.75 | ~0.45 | ~0.25 | ~0.02 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1900-2014 | ~1.45 | ~1.15 | ~0.85 | ~0.45 | ~0.02 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

| | |
|---|--|
| | <ul style="list-style-type: none"> - 1993: 45 species remain, 33 of which are secure - Faunal losses: 41% of marsupials, 65% of rodents |
| Paradigms for conservation biology | <ul style="list-style-type: none"> - Conservation biology as a response → multidisciplinary field of research <ul style="list-style-type: none"> - Miuchael Soulé founding ‘pioneer’ of conservation biology - Aims of Conservation Biology <ul style="list-style-type: none"> - To describe problems and understand processes - To predict impacts of threats - To develop solutions: undo the ‘human footprint’ - Ultimately: stop more species, communities and ecological processes going extinct |
| The ‘Evil Quartet’ and ‘HIPPO’ | <p>Jared Diamond’s “Evil Quartet” of extinction forces</p> <p>Alien Species</p> <ul style="list-style-type: none"> - Australia has 56 introduced species of vertebrates - Annual economic and biodiversity cost estimated at: <ul style="list-style-type: none"> - ~\$800 million - \$1 billion managing vertebrate pest animals - \$4 billion managing weeds - New Zealand has more alien plant species than native ones - New invaders brought new megafauna <ul style="list-style-type: none"> - Catte, sheep, goats, pigs, buffalo, donkeys, deer, horses, camels now all feral → pests - New “microfauna” <ul style="list-style-type: none"> - Cats, rats, mice arrive with early explorers - Rabbits, hare, foxes, cane toads - Invasion <ul style="list-style-type: none"> - Deliberate introductions <ul style="list-style-type: none"> - Acclimatisation societies - Ornamentals - Agriculture - Domestics - Biological control - Human traffic <ul style="list-style-type: none"> - Trade routes - Ease of global travel - Poor quarantine - “Tens rule” <ul style="list-style-type: none"> - 1 in 10 of the plant and animal species brought into a region will escape to appear in the wild - 1 in 10 of those escaped species will become naturalised - 1 in 10 of these will become invasive - Invasive species tend to have characteristics that: <ul style="list-style-type: none"> - Maximise or enable high reproduction - Enable great ecological dispersal - Enable species to be greatly ecologically flexible <p>Overhunting</p> |

| | |
|---|---|
| | <ul style="list-style-type: none"> - Humans over-exploiting wildlife - As potential competitors: <ul style="list-style-type: none"> - >500,000 bounties paid on brush-tailed rock-wallabies in NSW where the species is now endangered - >27 million kangaroos, wallabies, bandicoots killed in QLD 1877-1930 by government decree: the Marsupial Destruction Act - As food/resources: <ul style="list-style-type: none"> - Fisheries management - Overseas as bushmeat, wild meat - Overexploitation risks higher in data-deficient systems <p>Habitat loss</p> <ul style="list-style-type: none"> - Island biogeographic theory suggests that: <ul style="list-style-type: none"> - Reducing habitat area by 10% will eventually cause about 50% of species dependent on natural habitat to disappear - Extinction debt reflects the future ecological cost of current habitat destruction <ul style="list-style-type: none"> - Extinctions occur generations after fragmentation - Moderate habitat destruction is predicted to cause time-delayed but inevitable, deterministic extinctions <p>Co-extinction</p> <ul style="list-style-type: none"> - Critical ecosystem functions lost when species are lost - Loss of ‘engineer’ digging species from Australia’s rangelands - Examples: <ul style="list-style-type: none"> - Haast’s eagle in New Zealand went extinct after its main prey, moa, were hunted to extinction - Cassowaries are only vector of large rainforest fruits → their decline puts these fruits at risk <p>Edward O. Wilson’s “HIPPO” of extinction forces</p> <p>Habitat destruction</p> <p>Invasive Species</p> <p>Pollution</p> <p>Human overpopulation</p> <p>Over-harvesting</p> |
| Predicting the future better - impacts and extinction risk | <p>Experiments</p> <ul style="list-style-type: none"> - Experiments are key to identifying processes driving extinction and allowing management and future predictions to be made - Examples: <ul style="list-style-type: none"> - Predation experiments (removal/supplementation) - Meta-analyses → towards a general pattern across experiments and studies (Salo et al., 2007) <ul style="list-style-type: none"> - Alien predators have twice the impact of native ones |

- Huge impacts in the Australasian region due to naivety of local species to fox and cat predation



- Kinnear et al. (1988): Fox control and native mammal conservation
 - Endangered black-footed rock-wallaby in WA wheatbelt
 - Operation Western Shield:
 - 1080 poison used → native marsupials are immune but cats and foxes are not
 - Brush-tailed bettongs removed from endangered list, numbats, rock-wallabies, possums, bandicoots and chuditch also more common

Modelling

- Models of population dynamics are useful to predict impacts and to identify management options
- Population Viability Analysis
 - Most effective at comparing management options
 - Minimum viable population (MVP) size (MVPs must be large for long term persistence)
 - Data hungry process but very helpful and effective

Legislation

- Australia – federal listing
 - Environment Protection and Biodiversity Conservation Act 1999 (+2013 amendments)
- Listing in NSW
 - Biodiversity Conservation Act 2016, replaced Threatened Species Conservation Act 1995 + Native Vegetation Act + Nature Conservation Trust Act
- NSW Scientific Committee
 - List species, populations, communities → provides for recovery plans
 - Identify critical habitat
 - List threatening processes → Threat Abatement Plans

Other evidence-based approaches

- Smart ecological solutions
 - Evidence-based
 - Addressing causal factors rather than patterns
- Integrated Pest management

| | |
|--|--|
| | <ul style="list-style-type: none"> - Interrelationships between pests means we cannot just control one or others will benefit: need good ecological understanding - Restoration Ecology and Rewilding |
| What can we do? – Restoration Ecology | <ul style="list-style-type: none"> - “Ecological restoration is the process of repairing damage caused by humans to the diversity and dynamics of indigenous ecosystems” - Diverse goals: <ul style="list-style-type: none"> - Restoring ecosystems to some pre-impacts or reference state - Enhancing habitat quality - Restoring ecosystem functions via reintroductions <p>Bauxite mining</p> <ul style="list-style-type: none"> - Open cut mine s in which the clays are extracted from pods ranging in size from 1-100 ha - Restoration goals: <ul style="list-style-type: none"> - Establish self-sustaining jarrah forest ecosystem - Vegetation community which is floristically and structurally similar to the nearby undisturbed forest - Faunal assemblage recolonising over time <p>Cumberland Plain Woodland</p> <ul style="list-style-type: none"> - “Endangered ecological community” under NSW legislation <ul style="list-style-type: none"> - Recovery plan with explicit role for restoration - < 5% of its original extent <ul style="list-style-type: none"> - < 6000 ha remaining - Part of Sydney’s green belt - Numerous threats from: clearing for agriculture, urban development, pollution |
| What can you (BIO1XX7) do? | <ul style="list-style-type: none"> - Understand the problems facing life on Earth - Help to create solutions |