

A Word on Biology Olympiads

The most prominent Biology Olympiad is the International Biology Olympiad, a competition that tests students' theoretical and practical understanding of the subject. It's a yearly competition where each country sends its 4 strongest high school biologists to compete. Winning a Gold Medal (top 10% of competitors) at the IBO means that you are one of the strongest life scientists your age in the world. Why would you do this? The canonical answer is because it's interesting or fun, but I also think that these competitions force you to develop a biological intuition about central topics like evolution and protein synthesis that make you a better problem solver more generally. I also found

that after a few months of intense preparation, I became very good at processing lots of information very quickly and accurately, which made school work, exams, and standardised tests

much easier. Also, if you get to the training camp or make the national team, it's a significant enough achievement that universities will value it non-trivially. This level of detail in your scientific understanding will also enable you to explain things in a much clearer, more holistic way during science interviews. Of the 5 major international science olympiads (IMO, IOI, IPhO, IChO, IBO), IBO is probably the easiest to "prepare" for, and requires the least "innate ability". I hope you find these notes that I hand wrote over the course of ~4 months useful!

Section 1: Obscure But Important A-Level Facts

This section is *not* a collation of the most important and central topics and concepts in the CIE A-Level syllabus. Instead, I recommend you use the summary sections of each chapter, the big diagrams in each chapter, and the End-Of-Chapter-Questions of each chapter, altogether, to ensure you have a sound understanding of major concepts in the syllabus.

Instead, this first section is a listing and short summary of all the small, hidden factoids that are present in the A-Level syllabus/textbook that Olympiads often like to test as a method to separate the "wheat from the chaff". These will largely seem like obscure facts—that's the point. They're the inconspicuous ideas that are in the textbook, but rarely tested on exam papers, but *are* sometimes tested in Biology Olympiads. Start learning these *only* after 1) knowing all the important concepts in the textbooks inside-out 2) having done *all* the past BBO papers you can get your hands on. In my experience, A-Level past papers are terrible preparation for Biology Olympiads. I've separated these chapter-by-chapter so that you can go to any section to learn the material for that chapter (as given in the CIE A-Level Biology textbook used in school at this time—2018)

Section 2: Olympiad Knowledge Facts

This section is a collation of facts that I had to learn while doing IBO past papers. A more structured way of learning them would be via reading Campbell's Biology (*the "bible" for Biology Olympiads*) but if you're feeling like you want to maximise efficiency of material you're learning, swallowing these facts could be helpful as *every single fact listed in this section has come up at least one on a past BBO or IBO paper*. In fact, I wrote these notes while doing every BBO/IBO past paper ever written. So there's nothing "redundant" in this section. Still, make sure you know and understand the school material very well before you try to digest this set of information. It may seem like disparate facts, but the process of understanding these new facts will build up and reinforce new concepts and ideas in your brain, which is also helpful.

Other Important Resources:

The staple text to read: *Campbell's Biology*

Corollary texts: *Albert's Molecular Biology, Raven's Plant Biology*

see <https://biolympiads.com/> for all the IBO resources you could ever want—membership on this site is well worth it if you're trying to make the British IBO team/medal at IBO.

SECTION 1: OBSCURE BUT IMPORTANT A-LEVEL FACTS FOR BBO ROUND 1/2

1. Cell Biology

Eukaryotes — up to 40 μm diameter.

Prokaryotes — up to 0.5-5 μm diameter.

Ribosomes are made of:

1. RNA
2. Protein

Ribosomes are roughly 25 nm in diameter.

Mitochondria are around 1 μm in diameter (1000nm).

SER makes lipids, such as steroids like cholesterol, as well as hormones (which are often lipids)

Cell membrane is about 7nm thick.

TEM has a resolution of about 0.5 nm, and SEM slightly less resolute (3-20 nm).

The number of nucleoli in a eukaryotic cell is variable!

Lysosomes contain multiple types of digestive enzymes.

Enzymes from lysosomes are sometimes secreted out of the cell, not always inside the cell like in phagocytosis. An example of this is when we're releasing enzymes outside of cells to digest cartilage with bone.

The heads of sperm contain Acrosome, a special type of lysosome that digests the cell wall of an ovum.

Lysosomes are around 100-500 nm in diameter (0.1-0.5 μm). As such, they can still be seen by light microscopes.

Mitochondrial outer membranes contain porin, so small, soluble molecules have easy access to the inter-membrane space.

Mitochondria can do other things, even synthesise lipids!

Mitochondria develop and divide by themselves (endosymbiont theory), and make their own proteins. They contain their own (prokaryotic, circular) DNA and even ribosomes (mitochondrial ribosomes are 70S, not 80S).

Mitochondrial DNA is inherited ONLY from your mother.

Mitochondria can no longer live independently.

MTOCs are where microtubules are assembled and taken apart. Two centrioles at right angles are called a centrosome, which plant cells do not have. Each centriole is 9 triplets of microtubules.

Chloroplasts are larger than mitochondria, at around 3-10 μm .

There are some small spheres inside chloroplasts, which are lipid droplets — these serve as reserves for the creation of membranes inside the chloroplasts.

The only organelle that prokaryotes have is the ribosome. No nuclei — just circular DNA.

Prokaryotes can also have membrane infolds (for photosynthesis or respiration or nitrogen fixation, eq to cristae), pili (hair for cellular attachment), plasmids, capsules or flagella, they also have murein walls (a type of peptidoglycan).

Virus: central self-replicating molecule of RNA/DNA. Outside that, a capsid membrane made of individual capsomere proteins. There may be a lipid coat with glycolipids on that outside everything.

Peroxisomes remove hydrogen from various reactions, and create hydrogen peroxide, which is then broken down as it is toxic.

2. Molecular Biology / Biochemistry

Sugars are called so because they are sweet and dissolve in water. Mono/disaccharides are simple sugars. Polysaccharides are polymers; not simple sugars. Polysaccharides are water insoluble.

Sugars end with 'ose'. The monosaccharides are glucose, fructose and galactose, disaccharide are lactose (glucose, galactose), sucrose (glucose, fructose) and maltose (glucose, glucose).

Glucose = Hexose

Ribose = Pentose, used in RNA & DNA

Benedict's reagent is Copper (II) Sulfate in alkaline solution. It tests for reducing sugars because those reduce the Copper 2+ ions into Copper 1+ ions, reducing it. Goes from blue to red-brown.

You only add Benedict's reagent to a glucose solution (then heat it in a water bath). The intermediate steps are blue -> green -> yellow -> orange -> red-brown.

Colorimeters are tools to measure reducing sugar concentrations more quantitatively.

After negative Benedict's test, heat solution w/ HCl (hydrolyzes any non-reducing dimers or polymers into monosaccharides, which are all reducing sugars) then do Benedict's test to determine if original solution had non-reducing sugars or no sugars at all.

If glucose ONLY was stored in cells, would affect osmotic properties and cell chemistry (glucose is reactive).

Starch is made of:

1. Amylose (1,4 glucosidic bonds only, linear chain that curves into a hexagonal shape due to slight curvature of 1,4 glycosidic bond)
2. Amylopectin (1,4 & 1,6 glycosidic bonds, branching occurs)

Starch grains CAN be seen w/ a light microscope (and so must be >200nm).

Glycogen granules clump together in liver and muscle (these two especially) to form an energy reserve.

Cellulose is THE most abundant organic molecule on the plant (present in all plant cell walls, difficult to break down). Made of beta-glucose ONLY. Microfibrils (many beta-glucose chains w/ 1,4 glycosidics) -> fibres (run across each other and hydrogen bond) inside a glue-like matrix.

Lipids = organic, insoluble in water. Common examples of triglycerides (a common type of lipid) are fats (animals) and oils (plants).

Lipids are characterised by ester bonds between fatty acids and alcohols.

More than one double bond = polyunsaturated.

Fat is mainly stored under the skin (subcutaneous) and around organs (visceral). Lipids are important as a metabolic source of water!

Most of the dry mass of most cells are protein, including enzymes, hormones, structural proteins, antibodies.

Proteins can be storage products, such as casein in milk and ovalbumin in egg white. These storage proteins can store of inorganic ions or various other things.

Hydrogen bonding between CO of one amino acid and a NH group of an amino acid four places ahead of it causes secondary structure.

Alpha helices are intra-molecular hydrogen bonds (one polypeptide), whereas beta pleated sheets are inter-molecular hydrogen bonds.

Disulphide bonds form specifically between cysteine molecules, and are strong covalent bonds (broken by reducing agents by giving each sulphur a hydrogen)

Ionic bonds are formed between ionised groups of various different amino acids, such as NH₃⁺ groups and COO⁻ groups of different amino acids. pH changes break these.

In sickle cell Anaemia, a glutamic acid group used in one beta chain of haemoglobin is changed to a valine, making the protein less soluble.

Collagen (NOT Cellulose) is the most common protein found in animals (Cellulose is the most common organic molecule overall!). Collagen is used in places like the walls of sea anemones to egg cases of dogfish.

In a Collagen molecule, the third amino acid of every strand is glycine, so it fits like a puzzle. Three polypeptide helices make a molecule. The three polypeptides (inside the molecule!) are held together by some hydrogen and some covalent bonds.

There are also intermolecular covalent bonds between different fibres (between different groups of 3 helices).

3. Enzymes

Enzymes (like so many globular proteins) put their hydrophilic R groups on the outside, so they are soluble.

Enzymes may catalyse reactions by having R groups (local environment) that encourage a certain reaction, by using induced fit to change the substrate shape to encourage reaction, or in other ways. R groups of enzyme amino acids hold substrates in place (induced fit)!

Catalase is the enzyme that converts H₂O₂ into Hydrogen and Oxygen.

Lysozyme is an enzyme that defends against bacterial infection by breaking down bacterial cell walls (peptidoglycans such as murein). It's an enzyme found in tears, saliva, etc.

Optimal reaction temperature for body enzymes is around 40 degrees. We maintain at 37 so we have some leeway so the enzymes don't all denature during a fever.

Initial rate of reaction varies linearly with enzyme concentration.

V_{max} is the quickest rate a given enzyme can work at (given excess substrate).

Ethanol acts as a competitive inhibitor for someone who has drunk antifreeze (ethylyne glycol) to prevent formation of oxalic acid, which damages the kidneys.

Competitive inhibition is always reversible by increasing substrate concentration — the competitive inhibitor can simply leave the active site.

Non-competitive (allosteric) inhibition may or may not be reversible.

Negative feedback inhibition of enzyme activity is known as end-product inhibition (when the end product regulates it's own formation by acting as an inhibitor for various enzymes).

Turnover rate is the rate at which an enzyme works, how fast it can churn out product. Carbonic anhydrase has one of the highest turnovers, around 600,000 molecules of CO₂ a second.

A double reciprocal (lineweaver-burke) plot helps us accurately read out V_{max} on a substrate/velocity graph.

The Michaelis-Menten constant, K_m is a measure of substrate concentration. At this substrate concentration, half of the enzyme active sites are full — it records enzyme affinity. A high K_m implies a low enzyme affinity (for that substrate), and vice versa.

K_m tells us how quick an enzyme-catalysed reaction will proceed to its maximum rate (though the value of K_m doesn't influence what that maximum rate is). It is therefore independent of V_{max} .

V_{max} indicates the maximum possible rate — but this may not necessarily be the enzyme with the highest rate under cellular conditions.

K_m can vary for an enzyme depending on pH, temperature, and other conditions.

These two metrics are important because:

1. They allow us to computationally model metabolic pathways — we have quantified exactly how an enzyme will behave under given conditions, so we can see what will happen if different reactions occur quantitatively.
2. We can easily compare enzymes and compare different substrates for an enzyme (especially in a commercial environment).
3. We can use K_m to calculate exactly how many active sites are filled at a given substrate concentration.

Lactase is immobilised using alginate beads. Immobilized enzymes don't contaminate products, don't lose the enzymes, and make the enzymes more hardy.

Lactase mixed w/ Sodium alginate, then the solution put into calcium chloride. CaCl₂ and Sodium Alginate react to make a jelly, holding lactase in place.

4. Cell Membranes and Transport

Liposomes are membrane bound vesicles we create, and use for drug delivery (and cellular modelling). We add specific antigens for targeting as appropriate.

In a cellular plasma membrane cross section, the P-face is closer to the inside and the E-face is closer to the outside.

Membrane fluidity is also affected by tail length — the longer the fatty acid tail, the less fluid the membrane.

Transmembrane proteins is a subset of intrinsic proteins, which are bound to the membrane.

Intrinsic proteins are actually embedded in the proteins, whereas extrinsic proteins merely float around the outside of the membrane due to chemical interactions.

The hydrophobic (fatty acid facing) parts of the transmembrane proteins often contain many α -helical chains.

Phospholipids can do more than form the basic structure of membranes — they can be chemically modified to act as messengers moving around laterally the cell membrane, or hydrolyzed into water soluble components that bind to receptors inside the cell.

For example, in pancreatic cells, the hydrolysis of phospholipid into the cell contents causes release of Calcium ions out of the ER, causing exocytosis of digestive enzymes.

Cholesterol is abundant in animal cells, less so in plant cells, and absent in prokaryotes.

Myelin sheath is made of many layers of cell membrane — which is why it's an insulator for ions.

The mixed molecules on the outside of membranes serve different uses:

1. Glycocalyx stabilises membrane structure by forming hydrogen bonds with the water on the outside. Glycoprotein glycocalyx in animals, Glycolipid glycocalyx in plants.
2. Receptors — signalling receptors (recognize neurotransmitters or hormones causing a reaction cascade), endocytosis receptors, cell adhesion (of cells to each other to form tissues).
3. Cell markers like antigens.

Proteins on cell membrane can be enzymes!

Transduction is the conversion of a message to a signal to be transmitted.

Receptors can be acted on by:

Oestrogen, a steroid hormone made in the ovaries, is hydrophobic, and so just enters target cells which have receptors inside of their nuclei, the complex controls gene expression.

Acting directly on the signal with a membrane bound enzyme such as insulin.

Open an ion channel having received the receptor, such as nicotine-accepting acetylcholine receptors.

Signalling cascade: signal, membrane protein receptor, G protein, enzyme that makes second messenger molecules, second messenger (amplification), other activate enzymes, desired response.

Cell to cell contact, eg during embryonic development lymphocytes detect foreign antigens on other cells and act appropriately.

Channel proteins aren't just holes — they are gated so they can open and close due to various stimuli.

Water potential is how much water wants to leave a solution. Pure water at atmospheric pressure is 0, so any solution (at atmospheric pressure) will have a negative water pressure.

Cell wall is very inelastic, so any protoplasmic pressure is reciprocated causing an equilibrium of water potential inside and outside the cell (cell wall applies pressure potential raising water potential inside the protoplast so no more water enters).

Plasmolysis is said to occur when the pressure potential of a plant cell hits 0 (protoplast leaves the cell wall).

In a Sodium-Potassium pump, three Sodium ions are forced out, while two Potassium ions are pumped in.

Plant cells use exocytosis to get cellulose molecules for the construction of the cell wall outside of the cell membrane.

Water Potential = Pressure Potential (positive) + Solute Potential (negative)

6. Nucleic Acids & Protein Synthesis

Purines (A,G) bond with pyrimidines (C,U,T) because one is bigger the other is smaller. It must, geometrically, be so.

During DNA replication (S Phase in Interphase), there are nucleotides in the nucleus with two extra phosphate groups added to them, 'activating' them so they are the ones used to create a new strand of DNA.

DNAp links up phosphodiester bonds, while as nitrogenous bases are added extra P_i groups are ejected.

A mistake in nitrogenous base matching during DNA replication only occurs around once in every 10⁸ base pairs.

Only about 3% of our genetic code encodes for protein.

All alleles of genes originally came about through mutation of the original gene (and then were selected to survive by selection pressures).

Only the sense strand is read during transcription.

RNAp stops transcribing when it reaches a terminator sequence such as ATT, ATC or ACT.

Only 2 codons fit inside the ribosomes at a given time.

The formation of the peptide bond between two amino acids in the ribosome is catalysed by peptide transferase, which is found in the small subunit.

Translation stops when a sequence of UAA, UAG or UGA is read.

tRNA is single stranded, and folds over on itself like a clover. The various tRNA anticodons are recognised by different enzymes, which load on correspondingly different amino acids onto the attachment site (always CCA).

7. Plant Transport

Gold is toxic to plant cells, so many plants that accidentally absorb it sort it in in crystals in the leave and bark so it doesn't harm them.

Plants have large, branching bodies instead of animal-esque compact ones because they need a large SA for light absorption.

Xylem has a relatively high water potential, it's mainly water, with some inorganic ions (only goes upwards).

The petiole is what joins a leaf to a branch.

In a dicot stem, vascular bundles are arranged in a circle, but in a monocot stem, they are arranged randomly.

Epidermis -> Cortex -> Endodermis -> Pericycle -> Vascular Bundles (central in root)

Epidermis is one cell thick. There are some stomata on the top of leaves, too. The epidermis is what has extensions in root cells, too.

The pith is the central region of a stem, cortex is everything between the endodermis and epidermis.

In roots, new roots grow from the pericycle. In stems, the pericycle is lignified (sclerenchyma).

Tracheids are derived from single cells but vessels come from a line of cells. Tracheids are much thinner than vessel elements, and are present in all vascular plants (only angiosperms have vessel elements). Tracheids are thought to be much more primitive than vessel elements.

Air inside the leaf is saturated with water vapour due to evaporation from mesophyll walls. When there's a diffusion gradient between the inside and outside, transpiration (loss of vapour) occurs.

In monocots, epidermal cells are long and narrow. In dicots, epidermal cells are rounder and irregularly distributed like in a jigsaw puzzle.

Xerophytes (grow in no water) -> Mesophytes (moderate environment) -> Hydrophytes (grow in water)

In Marram Grass, a xerophyte, special hinge cells cause a thick, waxy cuticle (fatty) to be exposed to the outside.

Flattened stems increase SA:V so less water is lost, more photosynthesis can occur. Swollen stems also work as a xerophytic adaptation as they store a lot of water.

Wood is made of xylem, so gets its strength from lignin (abundant organic polymer).

Pits are crossed by cellulose cell walls, are not completely open. These stop air locks from moving place to place, so mass flow can occur uninterrupted.

Roots actively secrete ions in at the bottom, which helps increase the water potential gradient that causes transpiration to occur — but this only plays a small part.

The Caspary Strip is in the endodermis, stopping all apoplastic flow, allowing a place to control what enters through passage cells. All of transpiration, from soil to atmosphere, is passive.

As endodermal cells age, more of them become completely suberized, eventually leaving only passage cells open to symplastic flow.

Root hairs are replaced every few days.

Mycorrhizas are in/part of some plant roots, helping to absorb water and nutrients (mostly phosphate), and the fungi get some nutrients in turn.

Sieve tube elements only have a mitochondria and Golgi in some (very little) cytoplasm. Rest of organelles are in companion cells. Sieve pores can be seen through a light microscope (so are >200nm)

Callose is the carbohydrate that helps clot things in plants (especially phloem transport). Castor Oil plants are the exception — they don't clot very fast.

Mass flow is much (10,000x) faster than diffusion.

Invertase hydrolyses sucrose into glucose and fructose.

8. Animal Transport

Heart disease is the leading cause of death, then cancer.

Mesenteric artery is source of blood supply for the intestines (hindgut). Celiac artery supplies blood to the liver, stomach and spleen (foregut). There are three iliac arteries, each supplying a part of the pelvic area. The femoral artery is the continuation of one of these parts, supplying the leg with blood supply.

Lumen -> Tunica Intima (Squamous Epithelium) -> Tunica Media (Elastic & Muscle) -> Tunica Externa (Collagen & Elastic)

Aorta has diameter = 2.5cm near heart, and wall thickness of about 2mm.

Arteries far from the heart have least elastic, and more muscle.

Capillaries are approx. 7 μm in diameter.

Blood samples are usually taken from veins, lower pressure.

Plasma proteins like albumin help maintain the osmotic properties of blood, and globulins transport molecules that help with immune function.

A build up of tissue fluid is oedema. Arterioles try and reduce blood pressure so less net movement of water out overall.

Valves in blind-ending lymphatics are large enough to allow protein into them, otherwise it would collect in the tissue fluid causing oedema.

Lymph vessels have smooth muscles in their walls. Lymph nodes cleanse lymph.

We have about 5 litres of blood in our body.

Lymphocytes are smaller than most phagocytes, and have a large nucleus.

Some (a small amount) of CO₂ bonds with the amine groups of a haemoglobin molecule, making Carbaminohaemoglobin.

Carboxyhemoglobin (HbCO) is very stable, so it stays bound that way for a long time. Smokers can't breathe optimally largely because of this.

Altitude sickness is the sudden movement to a high altitude, where your body doesn't have time to adapt. Over long periods of time, red blood cells make up a larger portion of the blood.

Papillary muscle connected to tendons then to the valve prevents the atrioventricular valve from flopping backwards under pressure during ventricular systole.

If the right ventricle imparted too high a pressure on blood going to the pulmonary circulation, tissue fluid would accumulate in the lungs, hampering gas exchange.

While the SAN is myogenic, its rate can be adjusted by nerves connected to it. Once the excitation from the AVN reaches the bottom of the ventricles, the whole ventricles contract bottom up.

When electrical activity in the heart goes wrong, you get fibrillation. It can be started by an electric shock or damage to the heart muscle.

9. Gas Exchange and Smoking

The larynx is the voice box, a tube above the trachea with the voice cords in it.

Bronchioles -> Terminal Bronchiole -> Respiratory Bronchiole -> Alveolar Duct -> Alveoli

Trachea and Bronchi have everything: smooth muscle, cartilage, cilia and goblet cells. Submucosal glands also produce mucus in addition to goblet cells.

Bronchioles don't have cartilage or goblet cells, just smooth muscle and cilia.

Alveolar Duct & Alveoli have nothing — no goblet cells no cilia no smooth muscle and no cartilage.

The moistening of air that enters is so that the airways don't desiccate (dry out). Particles larger than 5-10 µm are caught in the nose hair or airway mucus. Goblet cells are present in the ciliated epithelium.

Mucus = Mucin solution, mucin is a glycoprotein w/ many carbohydrate chains so it's sticky for foreign particles.

Some chemical pollutants can dissolve in mucus to irritate the lining of the airways.

Macrophages patrol the airways scavenging bacteria and small particles.

Small particles can settle in alveoli and these small particles may contain bacteria which can cause infections.

Signs are what you can see, and symptoms can only be ascertained by the patient.

Tar destroys the goblet cells —> more mucus (breeding ground for infection)—> dead cilia —> try to cough to remove it —> muscular damage to the airways —> constricted breathing.

Emphysema often follows bronchitis, as macrophages w/ elastase wanna get at the infected airways. As emphysema progresses, capillaries become more resistant to flow and the right side of the heart enlarges to pump harder to the lungs.

COPD is set to become the third biggest killer in the world soon.

Nicotine causes arterial constriction, and stimulates the adrenal glands to produce adrenaline. There is a decrease in blood supply to the extremities. Nicotine can also increase the risk of blood clotting. It's highly addictive due to causing a dopamine response.

Carbon monoxide can damage the walls of arteries. This could lead to an easier time getting coronary heart disease or a stroke.

Symptoms of lung cancer are coughing up blood and chest pain.

10. Infectious Diseases

Pathogens spread the way they do because of the conditions they survive best in. Cholera bacteria thrives in water/food which is why it spreads through water and feaces.

Smallpox is the major infectious disease that has been completely eradicated.

TB is caused by *M. Bovis* and *Myobacterium Tuberculosis*.

Measles is caused by a species of *Morbillivirus*.

Smallpox (eradicated) is caused by the *Variola* virus.

Incidence = number of new people diagnosed w/ the disease in some unit of time

Prevalence = number of people who have the disease at any one time

Epidemic = when there's a sudden increase in the number who have the disease, pandemic is an epidemic that is everywhere in the world.

Cholera:

- 3/4 of cholera people are symptomless carriers, and can pass out lots of bacteria in their faeces.
- Diagnosed by examining faeces under a microscope.
- Bacteria secrete cholera toxin (toxin) that disrupts intestinal epithelium, causing salts and water to leave the intestine.
- Giving cholera patients glucose is important, as it is absorbed into the blood and takes ions with it.

Malaria:

- Female *Anopheles* mosquitos (vector) feed on human blood to obtain the protein they need to develop their eggs, taking up plasmodium (4 different species) gametocytes in the process. When feeding, the mosquito injects an anticoagulant to take up more blood, and injects the protist with it.
- Can also pass from person to person during blood transfusion and from mother to child through placenta.
- Detected through microscopical examination or dip stick testing.
- Through continued exposure, malaria can be developed resistance to. The rainy season is the most agriculturally productive, but also when malaria is most ripe.
- Prophylactic drugs like Chloroquine (prevents parasite spreading by inhibiting protein synthesis), and Proguanil (inhibits sexual reproduction of Plasmodium).
- Malaria is easily misdiagnosed as influenza as the initial symptoms are similar.

HIV/AIDS:

- Destroys helper T cells
- Cannot survive outside of the human body
- Haemophiliacs are at a high risk because they get isolated clotting factors from many donors, some of whom might have HIV.
- Common opportunistic infections accompanied by AIDS include Kaposi's sarcoma, dementia, pneumonia and, of course, tuberculosis.
- A tiny minority of HIV+ can be symptomless carriers and have immunity.
- Combination drug therapy using drugs like Zidovudine are used, this one blocks the action of reverse transcriptase.

TB:

- Spread through airborne droplets and undercooked food.
- Primarily infects lungs, then spreads to whole body.
- Diagnosed by microscope examination of sputum for bacteria or via chest x-ray.

- A large number of people have an inactive form of TB, and don't spread it to others. This inactive form can later activate such as when the body is weakened by AIDS.
- Disease is most infectious from 2-4 weeks.
- Can be vaccinated against using the BCG vaccine.
- TB can come from animals, too.

Measles:

- Virus that multiplies in upper respiratory tract, spread via cough droplets in air.
- Clears up on its own, rarely any complications (but when there are, they are serious)
- Very contagious, kills a lot of children.
- Can be, and is, vaccinated for.

Penicillin prevents cross links between peptidoglycan molecules, so autolysins just poke holes in them and they burst.

Soil bacteria have many mechanisms similar to modern antibiotic resistance, and many bacteria may even have gotten their original antibiotic mechanisms this way.

Penicillin can be broken down by β -lactamase enzymes. This is one way bacteria can get resistance.

Not finishing your antibiotic prescription means bacteria survive and have an opportunity to mutate, and if so, spread their mutations horizontally (eg conjugation) and vertically. Resistance can randomly crop up in a non-pathogenic species, but then will spread to a pathogen.

Gonorrhoea is a bacterial infection we soon will not have a cure for due to antibiotic resistant bacteria.

11. Immunity

Polio is the second disease likely to be eradicated after smallpox.

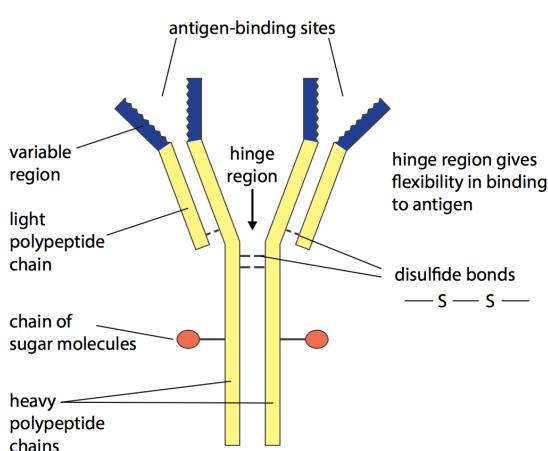
Macrophages (monocytes) are long-lived, neutrophils are short-lived.

Dead neutrophils collect to form pus.

Lymphocytes are smaller than phagocytes. Lymphocytes are produced before birth, in the bone marrow.

B Lymphocytes, like monocytes, go to organs like the lymph nodes, liver and spleen once mature.

T Lymphocytes mature in the Thymus, a gland in the chest (that is large in kids).



Plasma cells fight by antibody production and memory cells stay in blood so they can replicate to form both lymphocytes and phagocytes in future .

Antibodies are glycoproteins; one of the main types of plasma proteins (along with albumins) is immunoglobulins, which antibodies are.

Antibodies can: block toxins, make flagella immobile, clump bacteria, break cell walls, facilitate phagocytosis.

T Lymphocytes activate when they see antigens on a host molecule (antigen presentation).

Helper T cells secrete cytokines when activated encouraging the specific B cells to become plasma cells for an immune response.

Both helper and cytotoxic T lymphocytes do their functions as well as become memory cells. Killer T Lymphocytes ‘punch’ holes into the infected body cells’ membranes and inject toxins, killing the body cell as well as the pathogens.

Active Immunity = going through a full immune response yourself, natural or artificially induced
Passive Immunity = temporary introduction of protective molecules, naturally or artificially sourced

Colostrum is a thick yellow fluid produced by a mother’s breasts for the first few days after birth, and when ingested by the baby they line its gut to protect from bacterial/viral growth.

Vaccines that have a dead microorganism and fail to emulate a realistic live organism are less effective at providing immunity.

When vaccinated, you may excrete a live virus (that you’ve been vaccinated with) which could infect others, so everyone should be vaccinated at the same time — herd immunity.

Antigenic drift is a slight change in antigenic structure — immune response still works. During antigenic shift, however, there is a large change in antigenic composition.

Malaria has (sporozoite, merozoite, trophozoite) stages and is a protist — eukaryotic. Thousands of antigens that changes gradually while inside us, this is why there’s no cure. It also hides within red blood cells, and so is harder to get at.

Trypanosoma, the causative agent for sleeping sickness has thousands of antigens which vary every few days.

We can’t vaccinate against Cholera because the bacteria resides in the intestines, where vaccines can’t reach (digested).

Smallpox (Variola virus) involves pustules developing on skin, eyelids being glued together, and is transmitted by direct contact.

Smallpox could be eradicated and successfully vaccinated against because the virus didn’t change a lot (vaccines were constant and cheap to produce), live vaccine was used (effective), vaccine was easy to store, victims were easily identified and lots of people got involved.

Autoimmune diseases occur when T Lymphocytes with self antigens aren’t completely destroyed.

MG targets neuromuscular junctions because the B Lymphocytes make antibodies that destroy ACh receptors so action potentials can’t be transmitted.

Multiple Sclerosis (MS) affects CNS, causing paralysis due to loss of myelin sheaths.

Rheumatoid Arthritis affects joints, causing progressive destruction.

Type 1 Diabetes (also an autoimmune disease, but partly viral causing islets to be unrecognisable as self) so beta cells are destroyed (no insulin).

Lupus affects skin, kidneys and joints causing progressive deformity.

Monoclonal antibodies are produced through hybridoma, and can be used both for treatment and for diagnosis. When used for treatment (injected), they usually have to be genetically modified — humanised (genetically changing components of antibody molecule so it resembles that of a human).

P1 Practical Skills for AS

Rennin (chymosin) is an enzyme that clots milk, and is found in the stomachs of young mammals. Rennin acts on casein, something that's found in milk.

You can measure:

- Initial rate of reaction
- Time till identifiable end point (identifying it produces uncertainty)
- Time till substrates completely react — runs to completion

Sources of error include:

- Inherent inaccuracy in measuring instruments
- Difficulty in controlling standardised variables
- Difficulty/imprecision in measuring dependent variable (eg colour change)

13. Cellular Respiration

All respiration reactions are redox reactions. Redox doesn't necessarily have to have a complete transfer of electrons, but a change in electron density. So, even with covalent compounds, like hydrocarbons, when they're oxidised they lose electrons as the electrons move closer to the oxygen.

When electrons go from a neutral (eg C-H) atom to a polar (eg C=O) atom, they lose potential energy, 'going down the oxidising hill', and this energy is what's released in respiration and trapped in glucose by various coupling mechanisms.

Compounds with lots of hydrogen have lots of electrons equally shared ready to go down potential energy hills, and are therefore 'energy rich' in the biological sense.

Dehydrogenase enzymes are what take 2H (2 protons + 2 electrons) off the compound and put it on NAD⁺ to make it NADH, releasing one H⁺ into solution around it.

In the electron transport chain, each accepter is more oxidizing than the next, with oxygen at the end. This is the 'pull' down through the membrane (coupled to pump H⁺ out).

In prokaryotes, oxidative phosphorylation occurs in the plasma membrane. The contrast to oxidative phosphorylation is substrate level phosphorylation to produce ATP during various other stages.

Glycolysis has an energy investment phase (2ATP in) and an energy payoff phase (4ATP out). This is done in many steps with many enzymes making subtle changes to the chemical structure of glucose to finally create pyruvate.

Inside the mitochondria, the same multi-enzyme complex decarboxylates pyruvate, oxidizes the product (making NADH) and adds to CoA (attached by the sulphur on CoA), and then CoA is fed into the Krebs (citric acid) cycle.

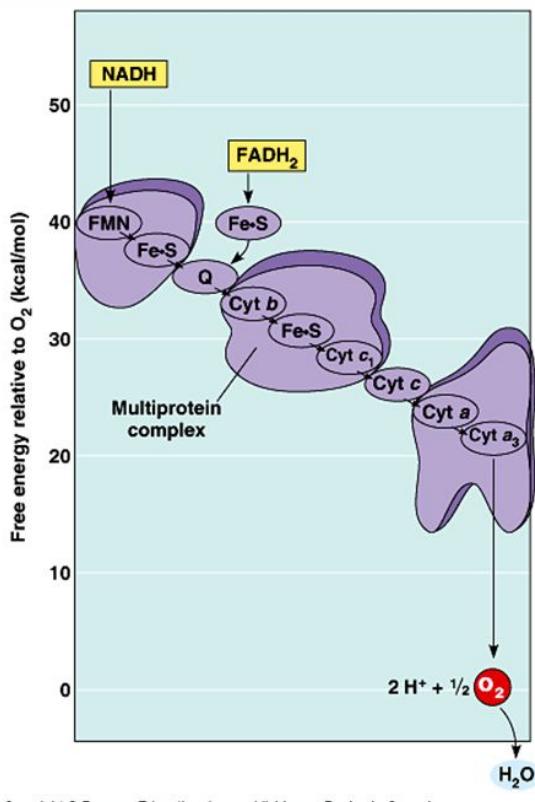
For each Acetyl group into the Krebs cycle:

- 2CO₂ (obviously, Acetyl group fed in has 2CO₂) released
- 3NADH
- FADH₂

- 1 ATP (w/ GTP intermediate)

The acetyl groups aren't the ones used up, they just replace the carbons that are used up (originally in oxaloacetate) in the citric acid cycle.

Figure 9.13 Free-energy change during electron transport



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All the cytochromes have a heme (iron) prosthetic group that helps accept and donate electrons.

The reasons that each glucose molecule, through the respiratory pathway generates 'about' 30-32 ATP molecules is that:

- There is no fixed amount of H⁺ that go through ATP Synthase to make ATP.
- The electron shuttles bringing the electrons in NADH to the electron transport chains have varying loads and efficiencies.
 - The H⁺ gradient (proton motive force) isn't just used to make ATP, but powers other things like the taking up of pyruvate from the cytosol of the cell to the matrix of mitochondria.

Anaerobic respiration means no O₂ as a final electron acceptor — not necessarily no ETC, as some deep water bacteria use chemicals like sulphur as their oxidising agent.

Fermentation, however, necessitates only glycolysis — but since there's no ETC where do the NADH go to avoid a buildup? They deposit their H⁺ with the pyruvate (made into ethanal) and the ethanal becomes ethanol, so the NAD⁺ are free to continue glycolysis.

In humans, pyruvate isn't decarboxylated into a 2C molecule (ethanal) but added H to it in order to make lactate.

There are:

- Obligate anaerobes: can only do fermentation or anaerobic respiration.
- Facultative anaerobes: can do EITHER fermentation or aerobic/anaerobic respiration.

Remember that macromolecules are broken down then fed in at various stages of the respiratory pathway so they, too, can be used to make energy. EG fatty acids are fed into CoA (after broken down by beta oxidation into 2C fragments), and amino acids can be fed in either w/ Pyruvate (before link reaction) or as ACoA.

Also, molecules are sifted to and from places in the most efficient anabolic/catabolic path. Molecules are removed in the middle of glycolysis if they can then be slightly modified for a different use, and molecules don't have to all be broken down and re-formed, our body takes stuff out and puts stuff in at various stages of all metabolic pathways.

Feedback mechanisms are used constantly in anabolism and catabolism so that things occur exactly in the amounts they are need to occur in, like in ATP inhibiting a glycolytic enzyme (phosphofructokinase), and AMP stimulating it. This enzyme can be thought of as the pacemaker of respiration.

13. Photosynthesis

A typical mesophyll cell will have about 30-40 chloroplasts, each a few micrometers across.

The CO₂ in photosynthesis doesn't split up; it's just hydrated from a hydrogen source, which can be water (in plants), or H₂S, like in some other organisms.

Photosynthesis is like reverse respiration, the electrons move from a polar atom (CO₂) to a higher energy state (C-H), in sugar. Instead of the fuel being oxidised as in respiration, CO₂ is reduced by the addition of H to make a sugar. The reaction is endergonic, and so requires energy input (sun).

Light dependent reactions take place on thylakoid membranes, but Calvin Cycle (dark reactions) take place in the stroma.

A photosystem is a multisubunit complex found in thylakoid membrane w/ primary and accessory proteins acting as photosynthetic pigments all taking in energy from different wavelengths of light.

Light is used to:

Phosphorylate ADP to make ATP (used in Calvin Cycle)

Photolysis of water to release electrons for non-cyclic photophosphorylation, prove the hydrogen, and to release hydrogen ions that will be used to reduce NADP+

RuBP + CO₂ → G3P → Triose Phosphate, which is used to (5/6) regenerate RuBP or (1/6) produce sugars (glucose in the photosynthetic equation) and other carbon compounds the plant needs.

CALVIN CYCLE

Calvin's apparatus. The "lollipop" apparatus used by Calvin and Benson to study photosynthesis. The algae cells are held in the flattened "lollipop" flask near the center of the picture. Provided you put in bicarbonate ions (with labelled carbon) you can track where the carbon goes and what it does. When he let methanol in after a minute, he killed the cells and took an extract of the suspension and centrifuged it, getting a complicated pattern.

Rubisco, Ribulose Bisphosphate Carboxylase, is the most common enzyme in the world and it catalyses RuBP + CO₂ → G3P.

The grana are complex and folded like the cristae of mitochondria, which is useful because they are the site for the light dependent reactions of photosynthesis, and so since electron transport is involved you need many membranes.

GALP = Triose Phosphate = Founder Molecule

The grana-like structure of all the thylakoids together means that they are more efficient at harvesting light.

C4 Plants

Malate is a 4C compound formed by the combination of multiple compounds.

In normal C3 fixation the enzyme RuBisco is oxygen sensitive.

The membranes of the grana hold ATP synthase so that ATP can be made during the light dependant reactions via the CHEMIOSMOTIC mechanism.

Maize, sorghum and other tropical grasses make 4-carbon molecules during their light independent reactions, as opposed to G3P, like in normal C3 plants.

The problem for C4 plants isn't with RuBP but it's with Rubisco enzyme, which combines with oxygen at high temperatures. To avoid Rubisco being exposed to air, we pack it, and RuBP into bundle sheath cells separate from the light dependent reactions of photosynthesis.

The ring of mesophyll cells around bundle sheath cells carry out the light reactions as usual, and the CO₂ is reacted w/ PEP to make oxaloacetate to make malate which then has its CO₂ removed so that it can be used with RuBP without exposure to air, so that no photorespiration occurs.

14. Osmoregulation & Excretion

You can be an osmoconformer (be isotonic to your environment) or an osmoregulator (not necessarily be isotonic to your environment). Osmoregulators have to use more energy to maintain their internal environment.

Stenohalines CANNOT tolerate major external changes in osmolarity but euryhalines CAN tolerate major osmolarity changes.

While osmoconformers are isosmotic to their environments, they don't necessarily have the same concentration of any given solute as their environment, so they still have to regulate their internal environment, like other organisms, which requires energy.

Some bony fish that are hypo osmotic to salt water:

- Drink sea water to replace lost water
- Actively move Cl⁻ out (and Na⁺ ions follow them out due to electrical attraction)
- Kidneys remove other ions without losing much water

Anhydrobiosis is surviving through dormant even in conditions of extreme dehydration, like tardigrades.

In most tissues, we have transport epithelia that move solutes in controlled amounts in specific directions. These can be arranged in complex networks in some species.

Marine birds' nasal glands remove salt through a countercurrent mechanisms, so they can drink sea water.

Nitrogenous wastes from protein/nucleic acid breakdown must be excreted and this is key to water level maintenance. You can excrete nitrogenous waste in varying ways — NH₃, urea, uric acid, but the latter stages require energy to be made, but are less toxic and so require less water to be used in their disposal.

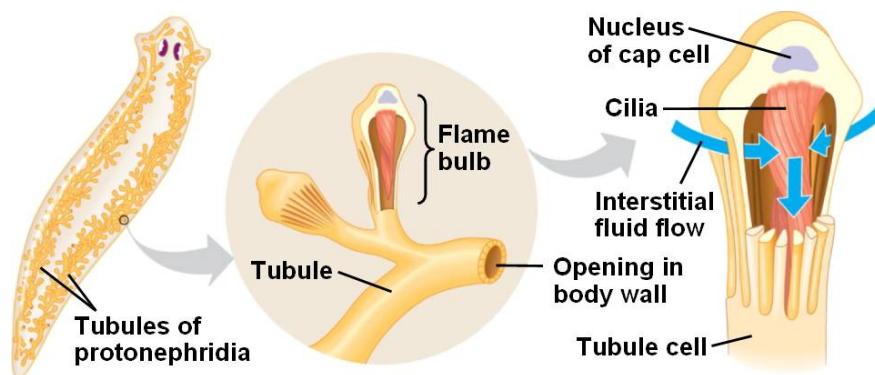
Most terrestrials excrete nitrogen as urea. This is much less toxic so it can be stored at higher concentrations. Less water is wasted on excretion, then.

Snails, insects and birds excrete using uric acid because this can be excreted as paste (thus not losing much water at all) but requires lots of energy to make.

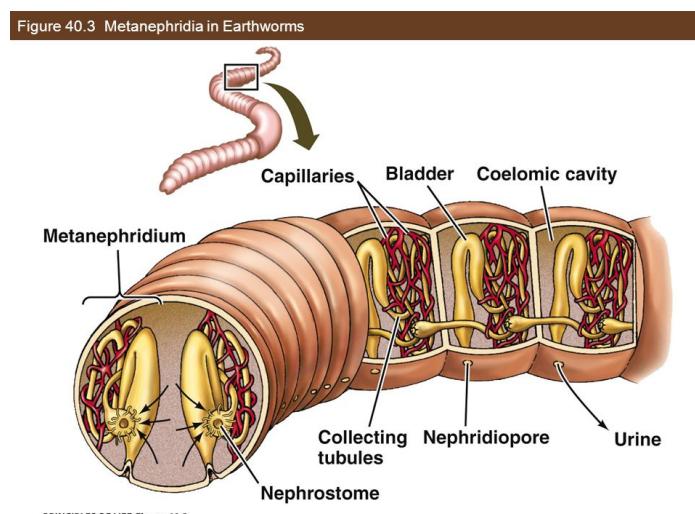
The method of an animal's reproduction impacts whether they extra using urea or uric acid because if one is soluble, it can diffuse through eggs and affect the offspring, whereas the other wouldn't be able to.

Urine is produced through similar mechanisms in all species, body fluid being filtered and then refined.

Flatworms have systems of protonephridia, a system of tubules that are dead ended and have opening capped w/ flame bulbs. These have cilia that draws water and solutes into the tubule system. Urine then leaves into the external environment. This protonephridic system is also present in molluscs, lancelets.



Most annelids have metanephridia, a similar system that draws in fluids from the coelomic cavity, through a coiled collecting tube, into a storage bladder.



PRINCIPLES OF LIFE, Figure 40.3
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Earthworms have a net uptake of water (since they live in damp soil) and so produce dilute urine.

Insects/terrestrial arthropods have Malpighian tubules, which are tubules poking out into Hemolymph. Transport epithelia secrete stuff into the lumen of these tubules and water follows. This all flows into the rectum, and depending on which solutes are pumped into the tubules again, insects can excrete things without losing water.

Vertebrate kidneys used to be segmented (as seen in hagfish, which are segmented chordates), but aren't now.

85% of nephrons are cortical and these are, obviously, mostly in the cortex.

15% of nephrons are juxtamedullary, and have long loops of Henle that go deep into the renal cortex.

Important macromolecules and 99% of water is reabsorbed in the filtration process.

The peritubular capillaries surround the proximal and distal tubules.

The vasa recta is the group of capillaries near the loop of Henle.

PROXIMAL TUBULE:

- Na^+ out, Cl^- follows
- Water follows
- Glucose, Amino Acids, other ions like K^+

all go into the peritubular capillaries.

The proximal tubule also helps maintain pH, if pH is too acidic then NH_4^+ is secreted, and most bicarbonate is absorbed.

Some things processed in the liver are fed into the peritubulars so they can be transported INTO the proximal tubule.

The descending loop of Henle is permeable to H_2O , and the thin ascending loop has salt diffuse out, and the thick ascending loop has salt actively transported out.

DISTAL TUBULE:

- Actively secretes K^+ in
- Reabsorb salt ions
- Help control pH in the same way as the proximal tubule

Kidney control of blood pH is more long term than blood buffers or respiratory responses, which are immediate response to sharp changes. The collecting duct is the final gatekeeper in this — it can secrete H^+ or bicarbonate ions in depending on whether the body is too acidic or alkaline.

Near the bottom of the medulla, tubule becomes permeable to urea, which diffuses out (everything is very conc. at this point in the renal medulla).

To dilute urine, collecting duct actively transport salts into the blood without letting water follow — this is the opposite effect of ADH.

The collecting duct's transport epithelium reacts to changes in blood pressure, volume and osmolarity via hormones and neurohormones from the brain.

The active transport out of the thick ascending limb creates the initial gradient that sets up the countercurrent multiplier. Due to all this secretion/active reabsorption, the kidney requires a lot of energy!

Birds have short loops of Henle, so how come they conserve water so well? Secretion of nitrogen as uric acid instead of urea.

Many territorial reptiles only have cortical nephrons, and so must reabsorb fluids in their cloaca (reptilian rectum) as well as use uric acid.

Amphibians mix up excretory tactics from using their skin to absorb salts to using an ADH/aquaporin mechanism.

Some marine fish have shorter nephrons to stop water loss. Also, kidneys excrete very little urine. Mostly excretes ions taken in by drinking sea water, and the gills secrete monovalent ions.

ADH = vasopressin, induces water reabsorption.

The hypothalamus detects changes in the blood and secretes ions/hormones accordingly.

Diabetes insipidus prevents ADH production so there's a lot of water loss and dehydration. This is NOT the same as diabetes mellitus.

In addition to ADH as a regulatory mechanism, we have the renin-angiotensin-aldosterone system (RAAS).

When blood pressure/volume decreases → JGA (juxtaglomerular apparatus, located near the afferent arteriole) releases renin → renin makes angiotensin II → blood pressure is raised by constricting arterioles, stimulating adrenal aldosterone release. Drugs that block angiotensin are used to treat high BP because angiotensin causes BP increase.

Aldosterone acts on distal tubules which absorb a lot of salt and water to increase volume and production, which, in turn, reduces renin production.

So:

ADH → tackles high osmolarity by bringing in water

RAAS → tackles low BP/Volume by bringing in Na⁺ AND water.

ANP (atrial natriuretic peptide made in atria) → opposes RAAS (so inhibits renin → inhibits aldosterone so lower BP/volume)

Note that despite absorption, osmolarity doesn't change through proximal tubule because while solutes are absorbed, the solvent is, too, and so concentration of things remains largely the same.

15. Coordination

Sensory neurones have cell bodies poking out in their middles, but motor neurones don't — they just start their connections with the dendrites on their cell bodies. The cell bodies of the motor neurones lie within the CNS.

Myelin is lipid with some proteins, made in, and by, Schwann cells.

Nodes of Ranvier are tiny, and occur every few millimetres.

Axons in organisms like squids and earthworms are very wide, we can insert electrodes to measure potentials inside them.

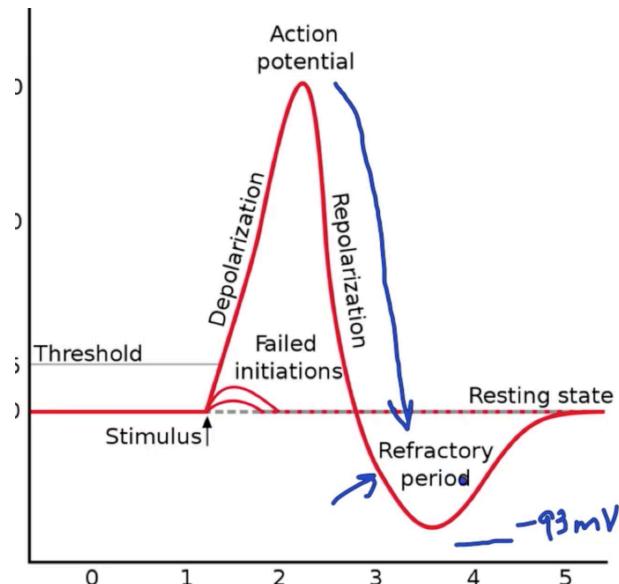
Cell bodies are concentrated in grey matter, and axons in white matter.

The dorsal root has the nuclei of the cell bodies of sensory neurones.

The membrane of the neurone has many more protein channels for potassium than for sodium, so it's much easier for potassium to diffuse out than sodium to diffuse in. There are negatively charged molecules inside the cell that hold potassium ions in.

Small current causes some voltage gated channels to be opened, causing further depolarisation as positive ions flow down the electrical gradient. If the voltage is under -50 to -60 mV then no action potential occurs (threshold potential).

1 ms after the action potential, the sodium gated voltage channels close and potassium channels open. This means sodium stays in and potassium leaves, and this is called repolarization. Then, Potassium is on the inside and Sodium on the outside. To go back to normal, we go through a refractory period where $\text{Na}^+ \text{K}^+$ pumps work to bring conditions back to normal.



The refractory period means:

- Action potentials are discrete — they don't overlap.
- There is a minimum time between action potentials (refractory period).
- The length of the refractory period determines the max. frequency of action potentials.

Action potentials' amplitudes don't vary — they only ever reach a peak value of +30mV, independent of the stimulus. It's their frequencies that vary.

We get ideas of the intensities of stimuli from:

1. The frequency of action potentials received
2. The number of neurones that carried those action potentials

and ideas about how to respond based on which nerves (where the stimuli originated) the stimulus came from.

Saltatory conduction is the jumping of action potentials between nodes of Ranvier, as opposed to all down the axon.

Thick axons transmit action potentials faster as they have less resistance to ion flow. Earthworms have thick axons (unmyelinated) so it can contract and escape predators very quickly.

In real life, we can't input small electric currents to start action potentials, but receptors transduce real stimuli into these currents for us to start action potentials.

Receptors include:

- Rods and Cones
- Taste Buds
- Olfactory cells in nose
- Pacinian corpuscles in skin (pressure)
- Meissner's corpuscles in skin (touch)
- Ruffini's endings in skin (temperature)
- Proprioceptors (muscle stretching)
- Hair cells in ear (balance and hearing)

Tongue -> Pappillae -> Taste Buds -> Receptor Cells

Each chemoreceptor has receptor proteins on it that start a chemical message when activated with some stimulus.

EG salt receptors are influenced by sodium ions. In this salt receptor, the entry of sodium ions causes channel proteins for calcium to open, these ions prompt the release of neurotransmitters by exocytosis.

EG sweet receptors, when activated by a sweet stimulus, start off a G protein which activates an enzyme to release cyclic AMP, amplifying the signalling cascade leading to closure of potassium ion channels which depolarises the membrane.

Receptors can be specialised cells that start action potentials, or just the beginnings of sensory neurones themselves.

Dopamine, Glutamic acid, GABA are all neurotransmitters that only occur in the brain.

It's always the influx of calcium ions at the end of a neurone that stimulates release of vesicles containing neurotransmitters. Each action potential causes a few packets of ACh to be released, so if the next neurone gets enough neurotransmitter to bind with it to open sodium ion channels to go over the threshold potential, it will.

Neurotransmitters, like ACh, are recycled.

The amino acids composing the channel proteins at the end of the synaptic cleft (start of the post-synaptic neurone) are negatively charged, as to attract sodium ions.

Synapses:

- Ensure one-way transmission (longer neurones risk being able to go backwards)
- Integrate impulses (each neurone has many before it fed into it, but it's only activated if its threshold potential is met).
 - Interconnection of nerve pathways — each neurone is attached to many others so all parts of body get all sorts of information.
 - Involved in memory and learning (new stimuli create new synapses that are reactivated when you see those stimuli again)

Striated Muscle:

- Multinucleate (syncytium)
- Parallel bundles of myofibrils
- Long, unbranched, cylindrical cells
- Attached to the skeleton
- Neurogenic

Cardiac Muscle:

- Uninucleate
- Parallel bundles of myofibrils
- Short, interconnected cells
- Heart
- Myogenic

Smooth Muscle:

- Uninucleate
- Long, unbranched cells
- Contractile proteins not organised into myofibrils
- Found in tubular structures to control their diameter
- Neurogenic

Each muscle is made of muscle fibres, the equivalent of cells — but they are multinucleate and composed of parallel myofibrils.

The infoldings of the sarcolemma (membrane) are called T-tubules, and they run near the sarcoplasmic reticulum. These are responsible for conducting the action potential down the muscle so that the depolarisation can cause calcium ion release inside the muscle to free up actin to bind to myosin.

Membrane of SR have proteins that transport calcium ions out so they can bind w/ troponin and tropomyosin to stop the inhibition of muscle contraction. This is done when they get the message from the T-tubules.

Striation is produced by the regular arrangement of many myofibrils in parallel.

Each myosin head is an ATPase, uses that energy to slide and connect, causing muscle contraction.

In a neuromuscular junction: Calcium Ions \rightarrow ACh \rightarrow Sodium Ions \rightarrow Calcium Ions (for troponin and tropomyosin to move out of myosin's way) \rightarrow sliding filament \rightarrow ATP to remove binding so it can happen again/relax

The antagonist muscle restores the sarcomeres of a muscle to its original length before contraction of the Z discs.

Muscles store creatine phosphate in their sarcoplasm to transfer the phosphate group to phosphorylate ADP for energy. After the energy intense period, the creatine molecules can be 'recharged' through addition with phosphates (an input of energy).

Uterine cycle has to match ovarian cycle (primary->secondary->ovarian/Graafian follicle->corpus luteum)

Anterior Pituitary Gland makes LH & FSH.

Follicle makes Oestrogen (ovaries).

Corpus Luteum makes Progesterone.

Menstruation \rightarrow Follicular Development \rightarrow Ovulation \rightarrow Lining Maintained \rightarrow Menstruation
LH + FSH \rightarrow Oestrogen \rightarrow LH \rightarrow Progesterone \rightarrow LH + FSH

The birth control pill contains Oestrogen and Progesterone, inhibiting production of LH and FSH, stopping follicular development/ovulation. Women stop the pill for a week every month, during which time women menstruate.

Plants also have action potentials, and some responses are coordinated by them. EG *Mimosa*, which responds to touch by folding up its leaves. They don't have neurones for this purpose, but their normal parenchymal cells transmit electrical activity in a similar way.

Plant action potentials are slower, and last longer, than in animals.

In the Venus fly trap, deflection of sensory hairs activate calcium ion channels at the base of the hairs. You need successive deflections to cause closure, which occurs (likely) by the release of elastic tension.

This plant is also adapted because it has small gaps in the leaves so that small animals can crawl out — they wouldn't be worth digesting.

Plants don't have glands — hormones are produced in a variety of tissues.

Auxin is made in the meristems of plants, where cells are dividing. They are then transported up and down the plant by active transport.

Embryo is surrounded by endosperm (polysaccharide rich) which is surrounded by aleurone layer (protein rich). Diffusion of water into a dormant seed causes amylase to be synthesized. This is done by gene regulation — it destroys the DELLA proteins that inhibit transcription of amylase.

HORMONES/ENDOCRINE SYSTEM

Endocrine means secreted into the extracellular matrix. These are ductless glands, they just secrete stuff that diffuses through the stuff round them — hormones move through blood.

Local regulators (NOT hormones) are chemical signals acting over very short distances (they're chemicals that just diffuse place to place, like cytokines. There are paracrine (act on cells near the secretor) and autocrine (acting on the secretor itself)

Neurotransmitters go from synapse to next nerve cell. Neurohormones go from the nerve cell ending into the bloodstream, almost like an intermediate between a neurotransmitter and hormone. ADH is a neurohormone example.

Hormones can be of three classes: Polypeptides, amines, and steroids. The first two are soluble in water and steroids are soluble in lipids. This has implications for how they move from place to place.

Water soluble hormones: secreted by exocytosis (can't diffuse through the lipid membrane), bind to cell surface receptors, and travel freely in the bloodstream.

Lipid soluble hormones: diffuse out of the cell, travel in blood bound to transport proteins, diffuse straight into cells to take action.

Many hormones bind to receptors causing a change in gene transcription via a protein triggered by the receptor causing a second messenger then enzyme cascade, or otherwise.

Epinephrine (adrenaline) is a water soluble hormone secreted by the adrenal glands during stress. It affects G-protein receptor cells, causes cAMP release, kinase release, and an enzyme cascade inactivating glycogen synthesis. Glucose for respiration is then released.

Estradiol is a form of estrogen. It's a lipid-soluble hormone. No signal transduction is needed because they bind to intracellular receptors by diffusing through the membrane.

One hormone can have many effects, having different receptors or different signal transduction pathways can mean the same hormone leads to different outcomes. By extension, the same hormone may have different effects in different species — thyroxine is a developmental regulator in tadpoles.

Nitric Oxide is both a neurotransmitter and local regulation, it binds to receptors to cause muscle relaxation and therefore vasodilation.

Prostaglandins are local regulators — modified fatty acids — released by mast cells into the extra cellular matrix. They help all cells communicate; they're involved in immunity, digestion, reproduction etc. They help inflammation and clotting and so are present in aspirin.

An example of negative feedback is the low pH of the stomach. Endocrine cells release secretin causing bicarbonate release, raising pH in the stomach. This is one type of its exocrine function.

Only 2% of the pancreatic mass is dedicated to an endocrine function (alpha, beta cells).

Diabetes Mellitus is what we commonly know as diabetes — high blood sugar but cells aren't able to take it up. They start metabolising fat since they can't take up glucose; this messes up homeostatic regulation and the internal environment.

Type I is auto-immune, it's when we destroy our own beta cells. No insulin is therefore made. It's something that's genetic, and present since childhood.

Type II is mostly developed in obese adults, where there is decreased response of insulin receptors to insulin. Most cases of diabetes are really this: Diabetes II.

In many invertebrates, nervous and hormonal systems are integrated. Nerve cells can secrete hormones and therefore regulate development.

Hypothalamus integrates neuronal and endocrine function. It communicates with and regulates the anterior and posterior pituitary gland.

The anterior pituitary gland is more separate — it's starts off in kids as a growth above the mouth, and then separates completely from the mouth. The posterior pituitary gland can be thought of as more of an extension of the hypothalamus.

Anterior pituitary (many of these are tropic hormones):

- LH/FSH
- GH
- MSH
- ACTH
- Prolactin
- TSH (hypothalamus makes TRH stimulating this, it causes thyroxine production)

Posterior pituitary (these are released by the pituitary but made in the hypothalamus):

- ADH
- Oxytocin (baby suckling creates a positive feedback loop of this neurohormone)

topic hormones are those that regulate the function of an endocrine gland, such as LH/FSH (gonadotropins) and ACTH.

Nontropic hormones like prolactin and MSH (melanocyte stimulating hormone) are made by the anterior pituitary.

Prolactin stimulates mammary gland growth and milk production, but also regulates other function in other organisms — so it must be an ancient hormone.

MSH (non-tropic) regulates neurones in the brain, regulating hunger in mammals, but regulates skin cells of fish, amphibians and reptiles.

Growth Hormone has both tropic and non-tropic effects. (tropic) it stimulates liver to release IGFs that cause bone & cartilage growth. It opposes insulin by raising blood sugar. Too much can cause gigantism or acromegaly (overgrowth of limbs) and too little causes dwarfism.

Anterior pituitary gland makes most major hormones (not ADH or Oxytocin).

Thyroid is two lobes on the ventral (front) side of the trachea. Thyroid hormones are T3 and T4 (iodine chains) and they control metabolism. Not enough iodine means not enough T3 and T4, thyroid glands enlarge due to large amounts of TSH being made in an attempt to overcome lacking thyroid hormones. This is a goiter.

The thyroid also makes calcitonin. It works with the parathyroid glands in regulating calcium levels in the body. Calcium must be strictly controlled to avoid calcium phosphate formation (too much) leading to organ damage, or skeleton muscle contraction (too little) leading to tetany.

Parathyroid glands release PTH, controlling Ca²⁺ levels (it causes reabsorption of Ca²⁺ as well as activates Vitamin D with reabsorbs Ca²⁺ in the intestines).

A neuroendocrine cell is: neurotransmitter → neuroendocrine cell → hormonal response

Adrenal cortex has endocrine cells (outer liver bit)

Secretory cells of adrenal medulla are neuroendocrine. This is what make epinephrine and norepinephrine, both of which are catecholamines. These are hormones, but also neurotransmitters.

Any stress prompts their secretion. They will move blood from non essential to essential organs. You get autonomous signals from the nervous system to release these.

Whereas adrenal medulla reacts to nervous signals, adrenal cortex reacts to signals from other hormones.

Aside from catecholamines, the stress hormone can be further prompted by the anterior pituitary gland, which releases ACTH, which creates corticosteroids.

Corticosteroids

Glucocorticoids => Cortisol. These make more glucose using all sorts of mechanisms, and also suppress the immune system by discouraging inflammation. NSAIDs are usually preferred to cortisol for an anti-inflammatory response.

Mineralocorticoids => Aldosterone. These act on salt and water, such as aldosterone, the last step in the RAAS pathway, which raises blood volume.

Adrenal glands also make some sex hormones, mostly androgens (male hormones like testosterone).

But sex hormones are mostly made in the gonads, where you get:

Androgens: male sex characteristics, when used as a steroid you get less actual natural androgens due to negative feedback, so small dick syndrome.

Estrogens: like estradiol.

Progesterins: like progesterone.

All of these are part of hormone control pathways. Secretion is controlled by gonadotropins, which are in turn controlled by gonadotropic releasing hormone.

The pineal gland (in the brain) is responsible for biorhythms. This makes melatonin (a modified amino acid). This is connected to the eyes and so light affects activity in this part of the brain — it modulates light/dark cycles, is secreted at night and is the link between biological clock and everyday activities. It's involved in things like the biological rhythms of reproduction.

16. Inherited Change

Meiosis & Sexual Life Cycles

The specific sequence of nucleotides in your body defines who you are.

Words of a language convey mental images / feelings in the same way that nucleotide sequences convey proteins and therefore biological traits.

Chromosomal number is characteristic of species, where each chromosome is just one long DNA molecule!

Every chromosome is identifiably different based on its size and staining pattern. Each cell has a James, Christian, Andy, Helen...

Chromosomes arranged in pairs in order of size constitute a Karyotype.

All sexual life cycles have meiosis and fertilisation but the timing of these characterise the type of life cycle.

1. MOST ANIMALS — Gametes are the only haploid (n) cells in the life cycle.
2. PLANTS/SOME ALGAE — Alternation of generations (sporophyte/gametophyte)
Sporophyte ($2n$) → Spores (n) — mitosis → Gametophytes (n) — mitosis → Gametes (n)
3. MOST FUNGI/ SOME PROTISTS —
Gametes (n) → Zygote (the only $2n$ stage here!) → Haploid Cells (n) → Haploid multicellular organisms (n) → Gametes (n)

Plants don't have centrioles (and so no centrosomes) but DO use spindles, which they therefore have to create a different way. Plant cells are less evolutionarily evolved, and what they do is have other mechanisms to govern spindle formation and regulation, including phragmoplasts (which don't replace centrosomes, so to speak, but govern an entirely different process in which even the cell wall is involved).

Both haploid and diploid cells undergo mitosis in various life cycles. However, only diploid cells can undergo meiosis.

Although the timing of meiosis and mitosis varies between life cycles, any meiosis adds genetic diversity & variation to the next generation.

Both mitosis and meiosis are preceded by replication of chromosomes during S phase of interphase because DNA (initially in meiosis) doubles in both processes.

Meiosis I separates HOMOLOGOUS CHROMOSOMES and Meiosis II separates SISTER CHROMATIDS.

During Meiosis I —

- Synapsis + Crossing Over: Parent ($2n$) cells homologous chromosomes become connected along the synaptonemal complex during synapsis. They then swap genetic information across non sister chromatids so you can have combinations of genes you didn't have before. In late Prophase I the protein complex is disassembled by the homologous chromosomes stay connected in some places via chiasmata.

- During Metaphase I, PAIRS OF CHROMOSOMES (AS OPPOSED TO SINGLE CHROMOSOMES) line up at the metaphase plate.
- During Anaphase I, each of the members of the homologous chromosome pair move away in different directions — the individual chromosomes stay intact!
- During Meiosis I, chromosomes are held together by cohesion proteins, whereas in mitosis enzymes remove these cohesive so that sister chromatids can move to opposite poles.
- In Meiosis, cohesions are cleaved during Anaphase I AND Anaphase II (cohesins in between chromosomes, within chromosomes, respectively)
- Shugoshin protein stops sister chromatid cohesin cleavage during Anaphase I.

Variation in Meiosis comes from:

- CROSSING OVER (P1): Proteins orchestrate the exchange of genetic materials on the same loci on homologs, this happens approx. 1 to 3 times per chromosome pair.
 - INDEPENDENT ASSORTMENT (M1): A given daughter cell has a 50/50 chance of getting maternal or paternal chromosomes from the homologous pair that signs up on top or bottom during Metaphase I. There are therefore 2^n combinations possible of gametes. This top/bottom duality also occurs in chromatid separation during Metaphase II.
- +RANDOM NATURE OF FERTILISATION ITSELF

MITOSIS:

$$46 \text{ 'chromatids'} \rightarrow 46 \text{ 'chromosomes'} \rightarrow 2 \times 46 \text{ 'chromatids'}$$

MEIOSIS:

$$46 \text{ 'chromatids'} \rightarrow 46 \text{ 'chromosomes'} \rightarrow 2 \times 23 \text{ 'chromosomes'} \rightarrow 4 \times 23 \text{ 'chromatids'}$$

REMEMBER:

- Presence of single chromosomes (chromatids) or double chromosomes (chromosomes) doesn't at all tell you about ploidy: somatic cells have 46 'chromatids' normally but are diploid, and cells in the middle of meiosis have 23 'chromosomes' but are haploid.
- Any chromosomes consisting of two sister chromatids have been created by replication of the first chromatid! The chromatids on either side of the centromere are identical!
- While in animals and humans meiosis makes gametes, other life cycles make gamete by mitosis (e.g. alternation of generations where gametes are made by mitosis of the gametophyte).

Basic Inheritance & Genetics:

- Mendel did so well to track binary (YES/NO or RED/GREEN) traits which is why his results were so unambiguous.
- Mendel had some principle ideas he concluded on from his work. Alleles are just different DNA sequences at the same chromosomal locus.
- Law of segregation is that alleles on different chromosomes (non-homologous) end up in different gametes; this variety of alleles leads to the variety of offspring.
- A test-cross/backcross is breeding an ambiguous dominant case with a recessive homozygous case and using the presence of any recessive homozygotes in the offspring to ascertain whether the dominant parent was or wasn't heterozygous for the recessive allele.
- The law of independent assortment means that $YyRr$ (F1) won't just make YR and yr gametes, but equally will make Yr and yR gametes, too.
- Incomplete dominance is when the phenotype is in the middle of the two — red and white alleles make pink. On the other hand, co-dominance is when both alleles are expressed, like antigens of a blood group.
- Dominant and recessive alleles don't 'interact', they're both doing their thing, but recessive alleles are usually just dysfunctional or don't code for a protein, and so their results aren't manifested in any way unless there's a lack of dominant alleles.

- Just because an allele is dominant on a macroscopic level, it isn't necessary on other scales. For example, If T codes for a functional version of an enzyme and t for a dysfunctional version, T is dominant on an organismal level, but they are biochemically incompletely dominant (you get half as much functional protein) and cellularly co-dominant (they are both coding for their respective chemicals).
- A dominant allele isn't necessarily more common than a recessive one. Polydactyly and Achondroplasia (dwarfism) both arise from dominant alleles.
- Most genes are actually pleiotropic — they affect many phenotypic traits (the gene causing sickle cell anaemia has a variety of phenotypic effects).
- Epistasis/polygenic inheritance means multiple alleles are involved in determining inheritance. For example the gene for pigment position is epistatic to the gene for pigment colour.
- The 'norm of reaction' specifies the range of phenotypes that an allele can code for.
- Consanguineous mating just increases risk of recessive disorders because both people share a common ancestor and so if one has a recessive allele, the other likely does too.
- Amniocentesis and CVS can be used to sequence embryo's genomes to check for genes.

In Katydids, the allele for a green body (normal phenotype) is actually recessive, surprisingly, to the dominant allele.

During development of gametes, it goes:

Diploid Cell/ Spermatogonia / Oogonia
Spermatocyte / Oocyte (n)
Spermatid/ Secondary Oocyte
Spermatozoan / Ovum

In girls, eggs are produced before birth, but mature once a month. During the development of female gametes, polar bodies are formed and then discarded.

Inside the anthers of a flower: pollen mother cells (2n) make haploid cells which double up their nuclei via mitosis (tube nucleus + generative nucleus), and these mature into pollen grains.

Inside the ovule (inside the ovary inside the carpel), a spore mother cell divides by meiosis to produce four haploid cells. All but one cell degenerates, and that one becomes the embryo sac, and the nuclei of the embryo sac divide by mitosis three times to get eight nuclei in the embryo sac, one of which is the egg cell.

We can predict with certainty and exactness what proportion of gametes will be produced, but not how those gametes will meet each other — this is why children's phenotypes aren't always as predicted.

Factor VIII is a protein needed for blood clotting, and is sex linked. The recessive allele causes hemophilia.

In dihybrid crosses, you're just considering the gametes that can be produced by two genes instead of one. They aren't linked or connected in any way, there's just more arrangements in how they can go together because of independent assortment.

Base substitutions are often silent mutations because they don't cause frame shifts that completely destroy the protein, unlike in base additions/deletions. Examples of diseases caused by these mutations are sickle cell anaemia, where the new amino acid is less soluble and hemoglobins now stick to each other, forming longer, crescent shaped red blood cells.

Albinism affects melanin production. Another form, one that affects the eyes but not skin, is sex

linked. Tyrosinase, the enzyme responsible for a step in the process that makes melanin, isn't produced (or is inactive) due to this mutation in albinism.

Tyrosinase (melanin enzyme) is an oxidase with two copper atoms in its active site which bind to an oxygen molecule. It's a transmembrane protein found in the membranes of melanosomes, organelles that are in cells called melanocytes. Tyrosinase is present in plant cells, too.

Huntington's is actually caused by a dominant allele. It's caused by genetic stutters in the CAG triplet.

Inducible enzymes are those that are produced when their substrate is present in their environment (such as in the lac operon). An operon is a unit of gene expression in a bacterium.

β -galactosidase is an inducible enzyme that hydrolyses lactose.

There are 3 structural genes (ones that code for protein) involved in the lac operon:

- lacZ: codes for β -galactosidase
- lacY: codes for permease, a protein that allows lactose to even enter the bacterium
- lacA, coding for transacetylase

The repressor involved in inhibiting the structural genes of the lac operon is an allosteric one. Lactose binds to the repressor, changing its shape so it can't bind to the lac operator.

Transcription factors:

- Activate genes in sequence, so the right one is on at the right time
- Different transcription factors are invoked during different environmental stimuli, such as switching on the correct gene to respond to high environmental temperatures.
- Transcription factors regulate the cell cycle, including apoptosis.
- Hormones have their effect through transcription factors.

EG Gibberellin, which causes breakdown of DELLA proteins that inhibit transcription of amylase.

17. Evolution & Natural Selection

The major types of natural selection are stabilising (natural grey background so any deviants in either direction are selected against by predators), directional (a new environmental condition or allele causes one allele to be more fit to the environment than others, causing all phenotypes to shift towards it) and disruptive (black and white background common in nature so any grey middle ground phenotypes are selected against).

Types of evolution include:

- Parallel: side by side without influence on each other's evolution
- Co-evolution: side by side *with* influence on each other's evolution
- Divergent
- Convergent

Examples of natural selection in action today:

- peppered moth (directional selection in favour of peppered moths in polluted, lichen-free areas that are dark to help camouflage)
- sickle cell anemia/malaria (carriers don't show symptoms of either whereas both selective pressures are individually harmful, stabilising selection keeping the HbS allele in the population in the form of carriers)
- antibiotic resistance (directional selection in favour of those with resistive genes)

Hardy Weinberg EQM is the set of two equations used to calculate gene frequencies in a population given a limited amount of information about two alleles of a gene. It makes a few key

assumptions that evolution is not occurring (as it predicts that allele frequencies stay the same over the course of generations):

- assume that population is large/infinite so sampling errors/founder effect due to genetic drift has a minimal effect on change in allele frequencies
- assume no evolution/selection pressure
- assume no migration/gene flow
- assume no mutation
- assume random mating/ no sexual selection

If we see that a population obeys HW EQM, it means there is no evolution at play. However, if we see that subsequent generations don't match in terms of allele frequencies, and we know there's no migration/mutation and it's a large population, we know that there is evolution taking place—which is what this is essentially a baseline test for.

Allopatric speciation is geographical isolation causing one population to be exposed to different selection pressures due to a different environment, so that its biochemistry, morphology and behaviour eventually deviate to a point where it can no longer successfully mate with its parent organisms.

Sympatric speciation comes in a few forms:

- Autotetraploids are $(2n) + (2n)$ gametes from the same parents, often sterile because meiosis becomes very messy with this arrangement. New species because it can no longer mate successfully with its parents (or itself, for that matter).
- Allotetraploids $(2n) + (2n)$ from two different species' gametes, meiosis actually works here as having those sets of chromosomes from two different parents makes the jigsaw puzzle a little bit more effective, but still a new species as it can't mate with its parents.
- Triploids are just $(2n) + (n)$, obviously sterile.

To compare evolutionary distance and create taxonomic relationships, we:

- compare cytochrome c as it's necessary in mitochondria for respiration and so is likely to be incredibly well conserved since it has such a clear and specific function, by looking at differences in its amino acid sequence we can derive evolutionary distances between organisms
- compare mtDNA as it is passed down in the ovum from one initial mitochondrial "eve" from whom we can compare distance from each other. Moreover, it's just contained in one plasmid inside the mitochondria, so it can only change due to mutation (which happens relatively fast) and so from mutation differences we can make conclusions about evolutionary distance.

18. Biodiversity and Classification

Species are given their scientific names using the binomial system, created by Linnaeus. The first word is its genus, then the second its species.

Epiphytes are plants that grow on other plants.

Biodiversity:

Variation in ecosystems

Variation in species

Species Richness (how many species there are)

measured by considering species density in random samples

Species Evenness (how they are distributed)

measured by considering species frequency in random samples

Variation within a specific species

The Congo basin, South-East Asia, the Caribbean, South America, South West Australia all have many endemic species — large biodiversity.

Species diversity accounts for both species richness (number of species) and species evenness (how they are distributed). This is important because ecosystems with high species diversity are more stable and likely to survive because of all the niches present.

Intraspecific diversity is important because it means that a species can be resistant to changes in biotic and abiotic living conditions.

A pooter is a piece of apparatus that is used to collect small animals, and is used through suction.

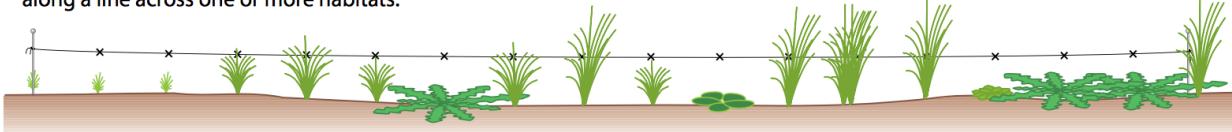
When you are sampling and can't count things (eg grass) you can use percentage cover in your species density calculations — or the more qualitative Braun-Blanquet cover scale.

Use random sampling when there is no pattern in an area, or when the area is regular and repeating. Use systematic sampling when you want to look at a pattern down a particular line or gradient.

In systematic sampling, you can use a line or belt transect — they serve different purposes.

Line transect – a line across one or more habitats

The organisms found at regular points along a line are noted. Transects are used to detect changes in community composition along a line across one or more habitats.



Interrupted belt transect

The abundance of organisms within quadrats placed at regular points along a line is noted.

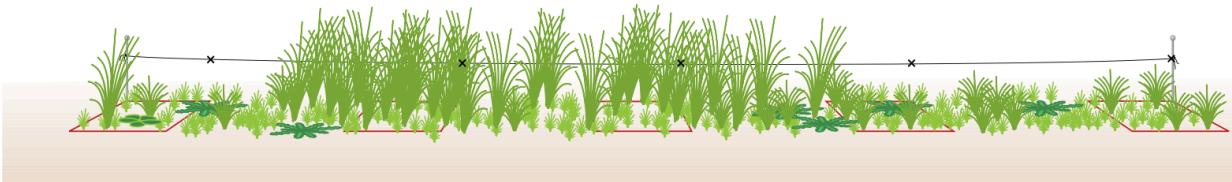


Figure 18.11 Systematic sampling using transects: **a** a line transect, and **b** an interrupted belt transect.

Archaea and Bacteria are different domains due to RNA differences between the two. Archaea are much more primitive, and live in extreme environments like hot springs.

Archaea are characteristically the same as Bacteria, but with cell walls not made of peptidoglycans. The transcription mechanisms of Archaea are more similar to eukaryotes than Bacteria.

Eukarya

Protocista (protozoa, algae) — sometimes animal-like cells, other times plant-like cells.

Fungi (heterotrophs, reproduce via spores, cell walls of chitin or else — NO cilia)

Plants (autotrophs, large permanent vacuoles, may have flagella — gametes in ferns)

Animalia (may different ways of heterotrophic nutrition, uniquely have *nervous* system — these and plants seem to be set apart by the fact that their cells can differentiate/specialise)

Viruses are acellular.

Major causes of loss of biodiversity:

- Habitat loss

- Climate Change
- Fertilisers and pollution
- Exploitation of resources

It is practical to maintain biodiversity because:

- income as ecotourism for some people
- source of new alleles for future breeding/domestication
- food for plants and animals
- source of medicines in future/important for scientific research

ANIMAL BEHAVIOUR/ETHOLOGY

All of animal physiology contributes to behaviour and behaviour influences all of physiology.

Behaviour is a big factor subject to natural selection, behavioural methods are largely genetic.

Always ask about Tinbergen's first and second two questions: what are the proximate causes and the ultimate causes? These are the questions that behavioural ecology attempts to answer.

A fixed action pattern is a sequence of unlearned acts directly linked to a simple stimulus. These are unchangeable and usually carried to completion. They are triggered by an external cue called the sign stimulus.

Birds, fish and other animals use environmental cues to guide migration (a regular, long-distance change in location). This can be a certain star in the sky, or magnetic receptors.

The internal clock is normally synchronised with the light and dark cycles of the environment (think pineal making melatonin), but the clock doesn't have to be ticking on the scale of a day, but circannual rhythms are internal clocks for the seasons and years.

Internal clocks can also be associated with things like the timing of the new moon and tide, due to natural selection for animals that associated their circadian rhythms with these.

A stimulus transmitted from one organism to another is called a signal. The transmission and reception of signals between animals constitutes communication, which plays a role in the proximate causes of behaviours.

There is such thing as a stimulus-response chain, where the response to each stimulus is itself the stimulus for the next behaviour. An example of this is in fruit fly courtship.

Most terrestrial mammals are nocturnal, so visual displays are relatively ineffective — so many species use olfactory and auditory signals, which work as well in the dark as in the light. In contrast, most birds are diurnal (mostly active during the day), which affects how they communicate.

Pheromones are chemical substances that are used in animal communication through odours or tastes. These are common communicative techniques in mammals and insects, and often relate to reproductive behaviour.

In a honeybee colony, pheromones produced by the queen and her daughters, the workers maintain the social order.

Pheromones can be effective even at crazy low concentrations.

Behaviour that is developmentally fixed and all individuals behave alike is called innate behaviour.

A cross-fostering study is one in which the young of one species are placed in the care of adults from another species. It's a useful tool in seeing which behaviours are nurture, and which nature.

Interestingly, the influence of experience on behaviour can be passed onto progeny, as parents will behave a certain way, encouraging their offspring to behave similarly. So, experience during development (like in a cross-foster) can be extended down generations.

In a twin study, you compare the behaviour of identical twins raised apart with the behaviour of twins raised in the same household.

In the young, there's a certain kind of learning called imprinting — the establishment of a long-lasting behavioural response to a particular individual or object. Imprinting can take place only during a specific time period in development, called the sensitive period.

Associative learning is associating one environmental stimulus with another like colour with smell etc.

Classical conditioning is making an arbitrary stimulus lead to a specific response.

Operant conditioning is trial and error, where an animal will learn to associate its behaviour with a reward or punishment, and thus learn what to do.

Cognition is the process of knowing — it involves awareness, reasoning and judgement.

Problem solving is a cognitive activity that involves devising a method to proceed from one state to another in the face of obstacles.

Many animals learn to solve problems by observing the behaviour of other individuals, this type of learning through observing others is called social learning.

Vervet monkeys have an initial, unlearned tendency to give calls upon seeing potentially threatening objects in the environment, but social learning fine tunes it to only happen with specific predators. It forms the root of culture, which is a system of information transfer through social learning or teaching that influences the behaviour of individuals in a population.

Foraging includes not only eating, but also any activities an animal uses to search for and capture food items. Studying this gives us many insights into animal behaviour.

One of the most significant costs to a forager is the risk of predation.

Another important factor to consider in looking at animal behaviour is sexual selection. Sexual dimorphism is the extent to which males and females differ in appearance. This will vary with the type of mating system — monogamy vs promiscuity etc.

The needs of the young are an important factor constraining the evolution of mating systems. For example, most hatched birds need a large, continuous food supply — so two parents are needed. Reproductive success is maximised in a monogamous relationship.

Another factor affecting mating systems is certainty of paternity. If you're the father, you'll want to take care of your kid to see that your genes really are passed on to the next generation. If you're not sure if you are... not so much.

Certainty of paternity is relatively low in most species with internal fertilisation because the acts of mating and birth are a long time (9 months in humans) apart, so it's not immediately clear who the father is.

REMEMBER: none of these factors influencing sexual acts are conscious by the animals — they don't actually care if they are or aren't the father, these behaviours exist because they provide a selection advantage for genetic propagation.

Sexual selection can be:

- Intersexual selection is when one sex chooses another based on their characteristics.
- Intrasexual selection is when one gender competes for mates.

Mate-choice copying is a behaviour in which individuals in a population copy the mate choice of others. This is evolutionarily viable because a male that successfully courted another female likely has characteristics you want your son to have.

Agonistic behaviour is often-ritualised contest that determines which competition gains access to a resource such as food or mates.

Game theory is a very useful tool to analyse and study behavioural systems with.

Frequency dependent selection is when mating success of an individual is influenced by the relative abundance of the other types of individuals in the population. By studying the links between this and rock paper scissors, we've learned more about how and why it comes about.

Fru is a master regulatory gene in flies that directs the expression/activity of many genes with narrower functions. These genes, together, bring about sex specific development in male fruit flies.

Slightly differently, behaviour can arise from variation in activity of a gene product. EG, in voles (mice-like), the amount of ADH in a system can affect pair-bonding abilities of males.

When behavioural variation between populations of a species correlates with variation, it may reflect natural selection.

When researchers offered banana slugs to snakes, coastal snakes readily ate them but inland snakes mostly refused.

How did a genetic preference come to so well match the presence of slugs in their environments? A hypothesis is that thousands of years ago snakes migrated from inland (no slugs) to coastal regions. Some had genes that let them smell the banana slugs, and others didn't. Those that did survived (natural selection) and became the generation we see today.

When an animal gives a call to warn others, it makes them more conspicuous and likely to be killed, giving away their location. This is a form of altruism.

Inclusive fitness is wanting your genetic information to be passed on, and so helping your close relatives is a selective advantage in this. Note that parents and offspring as well as siblings have a 0.5 coefficient of relatedness.

Hamilton's rule is that natural selection favours altruism when $rB > C$, where r is the co-efficient of relatedness, B is the benefit in overall offspring and C is the cost in overall offspring.

The fact that natural selection favours altruism in certain cases is called kin selection. This obviously weakens with hereditary distance as r decreases but other factors remain.

Some animals occasionally behave altruistically toward others who are not relatives. This exchange of aid is called reciprocal altruism — it's largely limited to species that have complex social groups like humans and other sophisticated primates. It's done in the hope that one day the favour might be returned. But surely it's an evolutionary advantage to 'cheat'? Game theory

suggests that 'cheating' is better for an individual but worse for a group — and natural selection acts on large populations, so 'cheating' is actually detrimental in terms of overall species fitness.

19. Genetic Technology

Genetic engineering is special because of its specificity — selective breeding allows us to select various genes for propagation, but genetic technology gives us the power to handpick individual genes.

Restriction enzymes cut specific portions (sequences) of the sugar-phosphate backbone of a DNA strand, and come from bacteria.

Many restriction sites are palindromic so they can be cut from either direction.

You get plasmids into bacteria by putting them concentrated calcium ion solution then giving them a heat shock, transforming a few bacteria to now be recombinant.

We used to identify which bacteria have taken up the new plasmids by putting them near various antibiotics to see which lived (still had resistance) and which didn't (lost resistance when lost plasmid).

Instead of the above method, we now label genes with GFP so when UV light is shone upon them they glow.

Promoter doesn't just allow RNAP to begin transcription, but also to ensure the RNAP has the right strand (template/sense strand).

Gel electrophoresis is like mass spectrometry — particles are moved due to their charge and size when exposed to an electric field.

Allozymes are variant forms of enzymes produced by different alleles of the same gene coding for the enzyme.

Variable Number Tandem Repeats vary from person to person, and so are normally the section of the genome used to compare people during DNA electrophoresis for forensics.

PCR = Heat to break two stands -> Primer -> RNAP (from extremophiles to withstand heat) to double strand -> heat....

Microarrays:

1. Collect tissue and isolate RNA through centrifuge.
2. Isolate mRNA because that tells us which genes were being transcribed.
3. Make mRNA -> cDNA (reverse transcriptase) and put the cDNA onto a microarray with millions of known DNA samples.
4. Each sample either pairs or doesn't with a known sample on the microarray, telling us which genes are active in that organism.

Know:

- Insulin pathway genetic engineering
- PCR
- Microarrays
- Electrophoresis (forensics, diagnoses—sickle cell)
- Genetic screening (pre & post implantation)
- Gene therapy for things like cystic fibrosis
- Modifying plants for herbicide & pesticide resistance

- Modifying animals (salmon growth)
- problems with genetic modification of plants & animals

SECTION 2: OLYMPIAD KNOWLEDGE FACTS

Acetyl CoA gets oxidised by oxaloacetate in the Krebs Cycle, returning to CoA. Removal of carbons in this case causes loss of electrons to the CoA overall, so it's oxidation.

Carbon skeletons created from the Krebs cycle are not all used to synthesise glucose — some are just pulled out at various points in respiration to be used conveniently for anabolic reactions.

Polyoids (autopolyploids + allopolyploids) are not widespread because the plants are less hardy (less climate resistant) and are often sterile (meiosis struggles to arrange chromosomes when there are so many.)

The surface tension of water is key to underwater life — small particles gather on the surface and don't all fall for a carpet overing underwater life.

Auxins are used for elongation, but can be used in various ways to be used as a rooting power, in fruit abscission, in the production of seedless fruit (parthenocarpy). Auxin can NOT be used as a weedkiller.

In animal ethology:

Polygyny — One male, many females.

Polyandry: One female, many males.

Promiscuity — animals mating randomly and with multiple mates , evolutionary weird since choosing a mate is favourable.

Polygyny + Polyandry + Random mating = Promiscuity

Polygynandry — Multiple males mate w/ multiple females, but in an exclusive way.

Beans are just edible seeds (dicots). Seeds contain:

- Radicle (root)
 - Plumule (Shoot)
 - Hypocotyl (Stem)
 - Endosperm+Aleurone — outer endosperm — monocots OR Cotyledons (Dicots)
- Pericarp is the area outside the seed but inside the fruit, like the cytoplasm of a cell.

Pancreas is both endocrine (insulin + glucagon in the islets of Langerhans) or exocrine (enzymes for digestion)

Gall bladder holds the bile made in the Liver

Liver: makes bile, creates and breaks down glucose (gluconeogenesis), makes clotting proteins has a lot of metabolic involvement, creates albumin (the hepatocytes do) and de-aminate proteins (converting the usable parts into other macromolecules).

The gut flora have a mutualistic association with us (subset of symbiosis)

They synthesise vitamins we can't and metabolise some things. We, in turn, give them a perfect environment. They are developed a year or two after birth.

We secrete products into our gut that help accommodate the bacteria. The intestinal mucosal layer helps with this, too.

Colchicine is a medication that treats you (sudden arthritis) but is not being used in plant breeding to stop chromosomes moving during anaphase, creating 4n cells. These can then make 2n gametes, inducing various polyploid phenomena. We use them when breeding plants.

A dental formula is just the number of each type of teeth in an animal. The upper teeth are written above the lower ones, and the order is ICPM. They help tell us what food an animal eats, and what the animal is.

Albumin is a globular protein (made by hepatocytes in the liver), it functions to regulate oncotic pressure (osmotic pressure caused by saluted like proteins) by binding various things together like a glue.

Proximal convoluted tubules reabsorbs most things, glucose, sodium ions, chloride ions, water.

Distal convoluted tubules absorbs salt ions, but also actively secretes potassium ions INTO the tubule.

Echinoderms (Starfish — Phyla)

Bivalves (Molluscs — Class)

Cephalopods (Squids — Class)

Gastropods (Snails — Class)

Chordata (Humans — Phyla)

Moulting is the shedding of the exoskeleton (all arthropods) but also in various ways with all animals.

Thyroxine increases heart rate (vagus nerve decreases it). Thyroxine controls much of metabolism.

Oestrogen:

- Stops FSH
- Builds endometrium
- Growth, thickening of Vagina, increasing in vaginal acidity
- Thick fallopian tube w/ contractions to move the ovum along tract
- Cervical mucus with secretions regulated
- Growth and flow of milk in boobs (along w/ prolactin)

In Mark-Release-Recapture, (Sample1xSample2)/Amount marked in 2nd sample

Tight Junctions = The needle sowing together two pieces of cloth.

Gap junctions = Tube that lets various small molecules through cell membranes.

Desmosomes = Pop rivet fastening cell membranes together (with intermediate filaments on either side)

Photosystems I (longer wavelengths) & II (shorter wavelengths) absorb slightly different wavelengths, and Chlorophyll A & B absorb slightly different wavelengths (but A & B are in each photosystem). PS I is involved in both cyclic and noncyclic photophosphorylation, whereas PS II is only involved in cyclic phosphorylation.

Plastids are a class of small organelles in the cytoplasm of plant cells.

Genetic terms:

Operator: Where a repressor or activator binds

Enhancer: Transcription factors that promote transcription rate bind here.

Promoter: Where RNAP actually binds first during transcription.

AUG sequence: First codon (start) in any gene sequence (mRNA since it's a codon)

TATA box: non coding sequence (TATAA) that always initiates transcription in eukaryotic gene sequences (it's a promoter)

Silencer: type of operator where only repressors can bind.

Temperature Co-efficient (Q10): Rate of change of a biological/chemical system when you increase Celsius temperature by 10 degrees. It's unit less — it shows how the rate varies and is susceptible to temperature changes. For most biological systems, the co-efficient is 2-3.

rRNA is 3/5 of the material that a Ribosome is made of (2/5 protein)

The Thymus is a gland in the chest. T-cells mature there, and it's exceptionally big in children (shrinks into adulthood).

The isoelectric point or isoelectric pH is the condition at which an amino acid/polypeptide has a neutral electrical charge.

85% of plant diseases are fungal based. Others can be caused by viruses/bacteria.

Late frosts are icy cold frosts that occur at unusual times, harming plants.

Asexual plant reproduction:

1. Micropropagation (lab): Take a plant part and put it into sterile agar w/ Growth Hormones, and take samples that become their own plants, identical to the parent. Especially good because it reduces the incidence of fungal attack as it takes place in a lab.

2. Vegetative adaptation (natural environment) = tubers, bulbs, runners

Insects want to conserve water, and so expel nitrogenous waste in faeces.

For gas exchange, gas moves in and out of insects. Spiracles → Tracheae → Tracheoles → Tissue, where O₂ diffuses in. They don't use blood for gas exchange — they don't even have 'blood'. They have an internal fluid called hemolymph, but it isn't blood.

Steroids are lipids, and so can easily diffuse into cells for the most part. Cholesterol enters cells via receptor-mediated endocytosis.

An 'adaptive' behaviour confers a survival/reproductive advantage in an organism.

You can induce genes into plants (genetic engineering) by:

- Agroinfection (viral infection of plants to introduce genes such as using a bacteriophage).
- Electroporation (electric field makes cell membrane permeable such as in production of insulin using bacteria).
- Microinjection (literally using a micro-pipette to poke genetic material in, as in an injection)

Lake stratification is the layering of water in lakes, as density varies with temperature in water. Water is densest at 4 degrees.

A thermocline is a SUDDEN, ABRUPT, temperature gradient in a water body.

Lake turnover is the seasonal movement of water from top to bottom as the top is colder during the autumn, so hotter deeper water rises up and the epilimnion (top) and hypolimnion (bottom) swap places.

The carrying capacity of an environment on a particular species is the maximum population that can be maintained indefinitely, this varies with environmental conditions and other things.

Alzheimers is a form of Dementia. It involves memory loss, cognitive dysfunction, and is more likely for those above 65. It's degenerative, and can be caused by aluminium ions.

Parkinsons is characterised by a lack of dopamine production, loss of motor control (due to failure of substantia nigra in the brain, and is often caused by iron ions.

The pituitary Gland makes (Posterior:

ACTH (stimulates cortisol production (which raises blood glucose during times of long term stress) and is produced in the adrenal glands)

GH

LH & FSH

Prolactin

TSH (metabolism control — thyroid makes hormones that affect nearly all bodily functions)

The hypothalamus makes:

ADH

Oxytocin (motherly hormone during baby delivery)

but these two are stored in the pituitary gland.

Parathyroid glands in the neck control Calcium ion levels in the body via PTH.

Territorial behaviour lets an animal live and hunt in peace, disperses a population and can be useful in marking a breeding ground. This can be conveyed through scent or through sounds.

Cyclins are proteins in cells that collect over time, like sand in an hour glass. Cyclin Dependent Kinases (CDKs) are inherently present in all cells. When Cyclins reach a level where it can bind to lots of CDKs, Mitosis Promoting Factors are produced, stimulating mitosis to begin.

Neurotransmitters:

Acetylcholine:

Neuromuscular junctions

Used in Parasympathetic nervous system.

Used inside the actual brain at many times for memory and motor control.

Dopamine (similar to Norepinephrine): used in various brain functions like:

motion, emotion, hormone regulation

Serotonin:

brain areas responsible for sleep, mood, pain suppression

Endorphins:

a family of neurotransmitters responsible for pain suppression and rewards

The plasmodium protist lives and grows in a mosquito. In the mosquito, it goes from a microgamete to a zygote to a sporozoite. The sporozoite is what's introduced in the human host.

The sporozoite becomes a merozoite in the liver, and is released in the blood. The trophozoite grows in blood cells, and becomes a gametocyte which is taken up by the mosquito.

Oviparous = eggs

viviparous = live young (animals), plantlets/seeds (plants)

ovoviparous = eggs but they hatch inside the parents body (snakes)

parthenogenetic = natural asexual reproducers

Microlecithals = an egg with a small amount of yolk, evenly distributed

Panting is a thermoregulatory mechanism as it increases evaporation from the inside of the mouth.

The oviducts (fallopian tubes) are lined with ciliated epithelium.

The chloride shift is also called the Hamburger shift and is the exchange of bicarbonate (HCO_3^-) and Cl^- ions across the RBC membrane. This is how bicarbonate ions get into the bloodstream to be transported (exchanger protein does this)

Microtubules = alpha & beta Tubulin (used in motility, cilia, flagella, cytoskeleton)

Intermediate Filaments = polypeptides like keratin etc. (used in mechanical support not motility)

Microfilaments = Actin (support in cytoskeleton, organelles and also in some motility)

centriole is 9+0, so basal body is 9+0, but cilia is 9+2

Dynein is the contractile protein that through ATP hydrolysis, leads to flagella/cilia bending.

Monocytes circulate in the blood then migrate into tissues. Organs like the tonsils, appendix, spleen and lymph nodes trap and destroy foreign bodies and bacteria.

In prokaryotes, transcription and translation are coupled; the mRNA is made and at the same place translated by ribosomes that bind to its Shine-Dalgarno sequence to make protein. Nucleotides of this sequence bind to some rRNA to put the ribosome into position in line with the start sequence.

Mammals are defined by mammary glands, lungs, four-chambered hearts, dorsal nerve cord, but NOT necessarily a placenta.

Inverted biomass pyramids are possible, but arise only when the bottom trophic level reproduces fast and is consumed fast, so the mass at any one given time isn't that high, but can still cause the mass at higher trophic levels to be high.

Molecular chaperones are proteins that help other proteins fold into their 3D shape.

Ethidium Bromide is a DNA-binding dye that fluoresces under UV light.

A geologic epoch is a measure of time, longer than an age but shorter than a period. We're in the Holocene Epoch of the Quaternary period now. (Eon-> Era-> Period -> Epoch -> Age).

Homo sapiens first appeared in the Pleistocene epoch (1.8 MYA).

Tubers, stolons, rhizomes, bulbs, runners, are all modified stems.

In angiosperms, there is double fusion fertilization. One sperm fertilises the egg, and the other sperm combines with the polar body (making a nucleus that becomes the endosperm). This is unique to angiosperms.

Parenchyma have a thin cell wall. Collenchyma support plants that are still growing, as sclerenchyma are inflexible upon maturity.

Duodenum is important in the digestion of chyme (stuff from the stomach), jejunum is important in absorption and so is ileum.

The colon (same as large intestine) is divided into:

- ascending colon (caecum + appendix) which absorbs fluids
- transverse colon (faeces are formed)
- descending colon + rectum (store faeces)

Inbreeding is the mating of consanguineous (related) individuals. This leads to:

decreased fitness (inbreeding depression) because it makes recessive homozygous more common, reducing variation and making genetic disease much more common.

Inbreeding is used in selective breeding to spread a desirable trait or to identify weak alleles that can be culled afterwards.

A saprotroph is an organism that derives nourishment from decaying organic matter. Detritivores (consume matter, worms) and decomposers (break down matter, bacteria and fungi)

Cerebellum calibrates how the form of a movement will be. It doesn't decide to move or how to move, just executes it. Also controls things like posture.

Eosinophils are white blood cells that combat parasites and infections. They are also involved in allergic reactions.

Basophils are the largest white blood cells, involved in inflammatory and allergic reactions alongside eosinophils.

Platelets and co-ag factors work to clot. Platelets have no nucleus; they are just fragments of cytoplasm from megakaryocytes. They are only found in mammals. They respond by:

- adhesion
- activation
- aggregation
- fibrin

Platelets also release chemical signals to reduce blood pressure.

A proteasome is a large protein complex that chops up unneeded proteins inside the cell. It knows what to chop up because unneeded proteins are tagged with ubiquitin.

Agonistic behaviour is any animal behaviour related to fighting.

During territorial behaviour, note that a territory is worth more to the owner than the intruder, as the owner is already familiar with it. The owner will escalate the battle usually. The owner usually defends against conspecifics.

Dormancy in buds is adaptive for plants in temperate climate zones because when they dry out they start to germinate. This way, they only germinate under good conditions. In other plants, dormancy can also be broken by other conditions, like light or temperature.

Short day plants form flowers only when day length is <12h, long day plants only form flowers when day length is >12h. Some plants are day neutral — they don't care. The timers in the plants for day/night length are interrupted by flashes of light — they need continuous light/dark.

Second messengers are small and water soluble, so they can diffuse easily. Examples of second messengers are Cyclic AMP, Calcium Ions, Inositol Triphosphate (IP3) and Diacyl Glycerol (DAG).

In population ecology, r is a measure of intrinsic rate of increase of a population and K is the carrying capacity of a population.

In reproduction, female mammals are 'K-selected', they have large parental investment into making sure their offspring survive because they have a lower reproductive potential. Male mammals are 'R-selected', they maximise number of offspring.

In plants: sporophytes (dominant in vascular plants) -> spores ($2n$, e.g. ovary and anther) -> gametophytes (n , ovule and pollen). In angiosperms, megagametophyte makes eggs and microgametophytes make pollen.

A moss antheridium is the male sexual structure that makes sperm cells.

In a lake, the zone well lit, off shore is called the limnetic zone. The zone near shore with some submerged plants is called the littoral zone. Benthic zone is at the bottom of the limnetic zone.

The fact that it was discovered that monocots weren't the first flowering plants to evolve shows that evolution doesn't always just go from simple to complex.

Salt is actively removed from the loop of Henle, so if the Kidneys fail, there will be a very high salt concentration in the blood.

A common observation is a decrease in species diversity as organic pollutants collect in an ecosystem. A few species take over because they have a higher tolerant for that pollutant than others.

While monocots can grow laterally (secondary growth), most exhibit only primary growth.

Ribozymes are RNA molecules that function as enzymes.

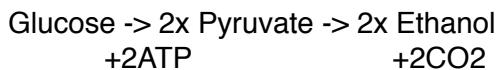
The adrenal gland near the kidneys respond to stress by producing cortisol. This is long term stress. ACTH (pituitary) stimulates production of cortisol. CRF is a hormone that stimulates production of ACTH. Cortisol is a glucocorticoid, a corticosteroid, a steroid.

Aldosterone controls blood levels of ions by controlling reabsorption in the kidney, and so controls water levels and blood pressure. It also helps maintain blood pH.

Lysosomes contain a variety of enzymes in each one, not just one enzyme. Hepatocytes are standard liver cells, basically the parenchyma of liver cells, mainly involved in protein synthesis (and therefore have well developed Golgi).

Phagocytosis takes in much bigger chunks (solid material) than pinocytosis(liquids). Receptor mediated endocytosis can be an entry point for virus (tricking the receptors).

During fermentation, 1 ethanol produced means 1 CO₂ released. 2 ATP are made per glucose molecule.



In DNA exons code for proteins, and introns do not (introns are found between exons). Introns are common in higher level vertebrates.

Primers are starting points for DNA replication but RNAP binds to promoters for protein synthesis.

Fructose diffuses across the intestinal membrane by passive diffusion.

In phylogenetics, primitive means something given, something taken for granted, something that developed very early on or was there from the beginning. Vertebrates are primitive to vertebrates.

Derived means advanced, that something was developed later, vertebrates are advanced to chordates since not all chordates developed them. Given Chordates, you can't assume vertebrates.

In addition to the sympathetic and parasympathetic divisions, the autonomous nervous system also has the enteric nervous system, which controls everything to do with the gut and intestines.

Types of reproductive isolation include:

Mechanical isolation: body parts physically cannot mate, eg sex parts don't fit together

Gametic isolation: gametes are inserted, but they don't interact to make a zygote

Ecological isolation: living in different habitats so you don't meet

Cooperative breeding: alloparental care from ‘helpers’.

Hybrid breakdown: reproductive failure (sterility) that appears after the F2 generation between incompatible organisms (eg different species) because gametes can’t work together anymore. For example, while a horse and donkey can mate to make a mule, the mule will be sterile.

Glyoxisomes (found in plants) are a special type of peroxisomes, and both have catalase (breaks down hydrogen peroxide), but glyoxisomes can also break down fatty acids in addition to this.

An assay is an analytic test to see the amount or presence of activity of a target (molecule/chemical/cell/gene etc.)

Kin selection is an evolutionary strategy where organisms favour the survival and reproduction of their relatives even at their own cost — this is altruistic behaviour.

Neoteny is the retention of juvenile features in an adult animal, like a sexually mature axolotl in a larval state.

Inclusive selection is selection of organisms not just based on their individual offspring, but on everyone they’ve rescued, reared, helped.

Heterochrony is a developmental change in the rate of events leading to changes in size and shape. Giraffes got their long necks by heterochrony — they extended the timing of the growth of their neck vertebrae which led to a longer neck — they didn’t add more bones.

Heterotopy is a change in positioning of something in an embryo, which can lead to stark morphological changes, too.

Pectin is a polysaccharide in cell walls (it composes middle lamellae, the jam like carbohydrate holding cells together)

Primary growth in plants is an increase in length (from the meristems) whereas secondary growth is an increase in lateral size (lateral meristems — cambium)

Vegetative (asexual) reproduction in plants:

- Tubers are fleshy underground storage structures that are enlarged parts of the stem, with buds on their surface that grow into new plants (eg potato)

- Runners: Slender horizontal stems that spread outward from the main plant, nodes on runners give rise to new plants (eg Strawberry)

- Bulbs: Spherical underground buds w/ fleshy leaves; they contain many other buds which grow into new plants (turnip, onion)

All modified versions of, or derived from, the stem.

Plant Ions/Mineral:

- Nitrates -> Nitrogen deficiency means that leaves from the bottom up start going yellow as chlorophyll can no longer be produced, also less protein production leads to stunted growth.

- Magnesium -> The main central ligand in the porphyrin ring of chlorophyll is magnesium, deficiency of which causes less chlorophyll production and therefore yellowed leaves. Mg²⁺ is also a cofactor—part of the ATPase structure (co-enzymes are subsets of co-factors, with the other subset being prosthetic groups like heme in hemoglobin).

- Phosphates > Essential for all types of phosphorylation (both ATP in respiration and things like photophosphorylation in photosynthesis, phosphate group is crucial part of DNA and therefore in replication). This last point causes phosphate deficient plants to have fewer and smaller leaves.

Phosphate deficiency also causes imbalance in carbohydrates because photophosphorylation (production pathway for carbohydrates is impaired)—or can even cause carbohydrate buildup and therefore darkening of leaves.

- Potassium -> Responsible for maintenance of osmotic balance and providing cytoplasmic ionic balance for reactions, require for opening/closing of guard cells and therefore controls gas exchange, co-factor for many enzymes responsible for protein synthesis, does similar for respiration. Deficiency can cause scorching and curling of leaf tips, typically in the older leaves first (like nitrogen since they're both mobile nutrients), with seed and fruit development being reduced.

Tropism is a direction movement of plants in response to stimuli.

Taxis is the directional movement of animals in response to stimuli.

Kinesis: Movement of organism in response to stimulus, non directional

Sign stimulus/Releaser (ethology): Stimulus that prompts a fixed action pattern.

Supernormal stimulus: An exaggerated version of a normal stimulus that already elicits a response, age candy being a supernormal stimulus for carbohydrates.

Pleiotropy: One gene influencing two or more unrelated traits, usually unrelated to each other.

Epistasis: Interactions of genes that aren't for the same phenotype, genes that aren't alleles. Normally refers to one gene suppressing another. For example, a gene for blue eyes suppressing another gene for long legs.

Lethal alleles often results in a 1:2 ratio in a 1-gene cross, (1:2:1 but the homozygous recessive is dead since it's a lethal allele).

Insects are a type of Arthropod, which is a type of animal.

Insects have a head, thorax and abdomen. They have 6 (3 pairs) of legs and 1 pair of Antennae. All insects have these, and those that don't (eg spider) are not insects.

Apoptosis is cell death — usually lysosomes that spew out contents into a cell killing it.

A cotyledon is the embryonic leaf in a seed-bearing plant, they are the first leaves to appear from a germinating seed.

Monocots:

Parallel Veins

Vascular Bundles are complex, irregular

Fibrous Roots

3x Petals

Dicots:

Netlike veins

Circular Vascularity

Taproot Systems

5x Petals

Vascular Plants (Tracheophytes) :

Ferns — megaphylls (leaves w/ many veins)

Lycophytes — microphylls (leaves w/ one vein)

Spermatophytes

Angiosperms

Gymnosperms (eg Conifer)

A mesosome is a folded part of a plasma membrane that serves to increase membrane SA, doesn't have a formal chemical function.

Nitrogen fixation is when N₂ is fixed into organic molecules with nitrogen in them — this is an endergonic process.

Auxins: Elongation by H⁺ ions pumped to weaken cellulose, water added to elongate cells so they grow.

Gibberellins: Meristem elongation (plant height) and in seed germination by starting production of amylose.

Abscisic acid: Stress hormone in plants that closes stomata by stopping H⁺ leaving the cell (K⁺ stops entering as no electrochemical gradient exists any longer) so water leaves the cell (and secretes Ca²⁺ into the cell).

Geotropism:

- Root: plant grows downward because auxin at bottom inhibits growth on top so root grows downward.
- Shoot: In shoot, auxin collection at bottom prompts bottom to grow, curving it upwards.

Phototropism/heliotropism: caused by movement of auxins to shaded side, inhibition of auxin synthesis on illuminated side.

Indole Acetic Acid is a type of Auxin.

Carotene: Orange photosynthesis pigment that transmits energy to chlorophyll and absorbs energy from reactive oxygen to protect the plant.

Xanthophylls: Accessory pigments that absorb what chlorophyll cannot and protect it against sunlight.

Phytochromes: Circadian rhythm of plants -> detecting day length and detecting colour of light that plant is exposed to.

Ferns are vascular plants that reproduce via spores. They don't have seeds and flowers. They predate the flowering plants, which are also vascular.

Alternation of generations is also called heterogenisis or metagenesis.

Sporophyte 2n (dominant in vascular plants) -> Spores n -> Gametocyte n -> Gametes n

Bryophytes (non-vascular land plants):

- Liverworts
- Hornworts
- Mosses (gametophyte stage is what we see as a green moss and the 2n sporophyte is a small attachment)

Amphoteric — one end acidic, the other basic.

The CNS is the Brain and Spine.

connected to:

Autonomous NS

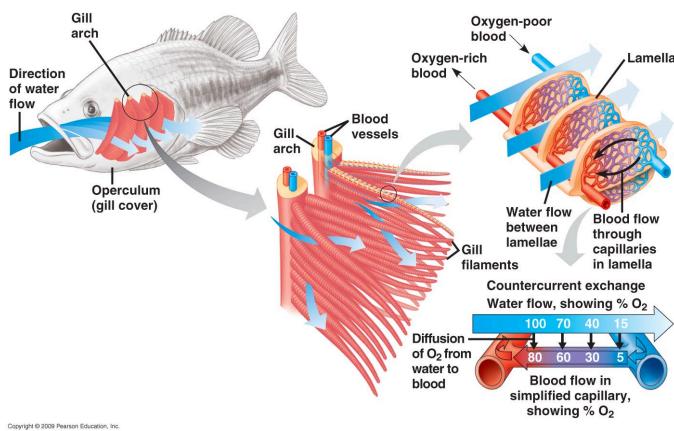
Parasympathetic NS: normal basic bodily functions (sacral and cranial nerves)

Sympathetic NS: basic functions during fight/flight response (thoracic/lumber/autonomic nerve)

Enteric/Intrinsic NS: nervous system concerning the gut

Somatic NS: actual conscious movements of the body: sensory & motor neurones (spinal & cranial nerves)

Vagus nerve (longest cranial nerve) and spinal ganglionic nerve decreases heart rate.



Fish gills work using countercurrent gas exchange, a type of homeostatic hug mechanism, such as heat loop in moose leg or loop in nephron. As fish open mouths, water moves through the gill filaments (lamella) so blood flows in the opposite direction to water. More water (and thus O₂) flows past per second.

Freshwater fish:

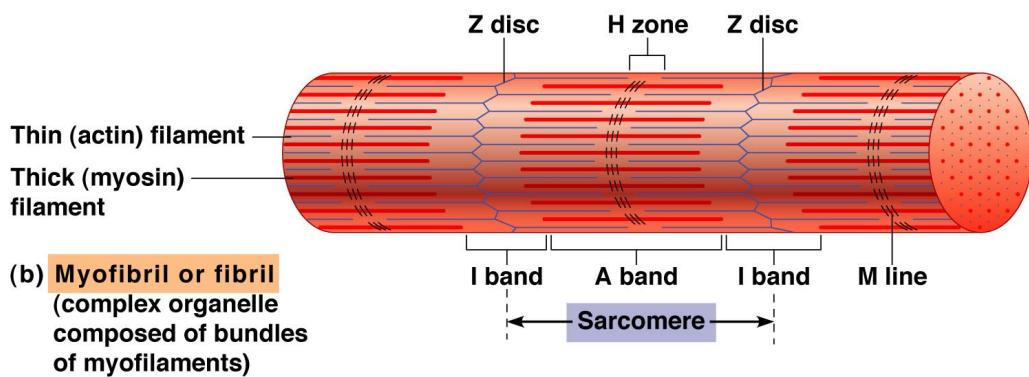
- Blood is hypertonic to water so water flows in and salts flow out
- They have cells to move salts from

water to blood so they don't lose too many salts.

Saltwater fish:

- Fish blood is hypotonic, water flows out, nor much urine, they excrete salts into the water lest the blood get too concentrated.

myofibril -> muscle fibre -> muscle.



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myosin (thick) and actin + troponin + tropomyosin (thin)

Tropomyosin and troponin move out of the way during contraction because the Ca²⁺ from the SR bind to troponin during contraction.

Cyanide ions inhibit the enzyme cytochrome C, a protein on the inner mitochondrial membrane used in the electron transport chain, lowering activities of ion pumps in general.

Aneuploides (incorrect chromosomal number) is due to failed cytokinesis, not failed mitosis/meiosis.

If a sperm fuses with an ovum that has no sex chromosomes, it results in a spontaneous abortion.

Analogous: Similar functions but different origins
Homologous: Similar origins but different functions

Wings of a butterfly and bat are analogous.

Human arms and seal flippers are homologous (both came from mammalian forelimb, but have different uses now)

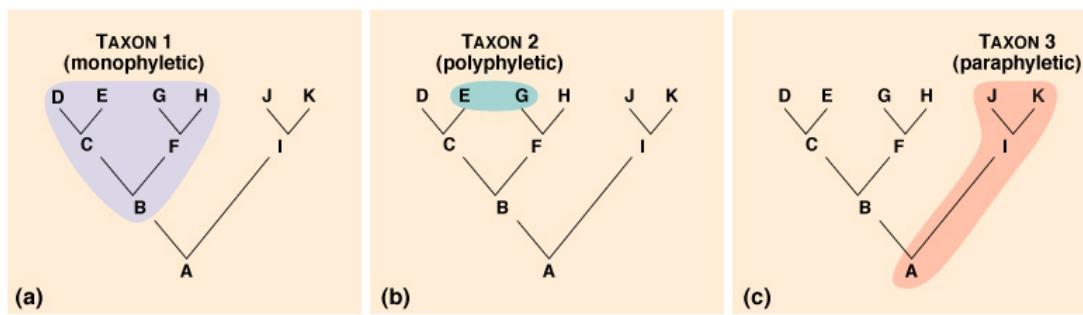
Divergent evolution is when there's a common ancestor but different environments/adaptations

Convergent is different ancestors/origins, but similar physiology like a flying squirrel and sugar glider (kangaroo-esque) didn't come from the same thing, but have similar physiological adaptations due to similarities in their environments.

Monophyletic grouping is a group of one thing and all its descendants.

Polyphyletic is the descendants that come from different (immediate) ancestors.

Paraphyletic is one ancestor and one line of its descendants.



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Hardy-Weinberg equilibrium: alleles and genotypes remain constant in a population given absence of other evolutionary forces (no selection pressures, no genetic drifting, no mutation)

Adaptive Radiation: One ancestral species diversifies quickly often due to an environmental change creating new selection pressures and niches, like the finches on Galapagos islands.

Humus is a type of compost that benefits plants and the soil because its decaying matter packed with nutrients. This promotes the co-existence of plants, animals and microbes.

Ecological succession is the change in an ecosystem/the changes in the species that constitute a community over time.

- Primary: new environment colonised by living things for the first time.
- Secondary: Previously occupied area disrupted then recolonized.

Livestock Grazing can be a force for good or for bad depending on its use.

- Pros: Nutrients are cycled, seeds are dispersed, soil is kept at a high quality.
- Cons: Can kill (and act as a selection pressure for) some plants, transmit disease and even displace species.

Calcifuge plants do not tolerate basic soil .

Calcicole plants love basic soil.

Insect exoskeletons and fungal walls are made of chitin.

Snail shells are made of calcium carbonate.

Symbiosis is a close, long term interaction between 2 species.

Mutualism is symbiosis where both animals win.

Commensalism is a relationship where one benefits and the other isn't harmed (neutral).

Starfish and sea urchins are found ONLY in the sea.

Jellyfish and sponges can be found on land.

Fungi can never fix N₂.

Animals have brains to process stimuli, and as you get closer to your spine, brain functions become more basic.

The animal plan is spinal cord (relaying info) -> hindbrain (motor skills and basic processes) -> midbrain (spatial awareness) -> forebrain (higher level thinking and reasoning)

Brains stem (midbrain, pons, medulla) controls:

- Breathing, heart rate, swallowing
- relaying information to the correct parts of the brain

Cerebellum controls the execution of all motor functions.

Thalamus:

- Sorts information to the correct places

Hypothalamus:

- Homeostasis + some hormone production

Pituitary gland:

- Hormones and regulation

Limbic System:

Amygdala: Emotion

Hippocampus: Memory

Cerebrum:

- Integrating and processing of all information (cortex)

Frontal lobe is for decision making and emotions.

The motor cortex is a part of this lobe that works with coming up with motions to do.

Parietal lobe is for sensation and stimuli.

Somatosensory cortex is a part of this lobe that works for senses

Temporal lobe is for language and memory.

Occipital lobe is for vision.

Corpus Callosum connects the two hemispheres of the brain.

Basal Ganglia are a set of nuclei under the corpus callosum important in motor control.

Producers -> Consumer -> Decomposers and Detritivores -> Producers

Only 1-3% of all of sunlight's energy is imbued into organic molecules during photosynthesis, rest is reflected or present in wavelengths that they can't absorb.

Ecosystems are hard to look at in isolation — they all bleed into and affect each other.

Net productivity = Gross productivity - Respiratory Losses

Ecological Pyramids can be of:

- Number: Less organisms at the top, but doesn't account for size so this doesn't always have to be the case (oak tree)
- Biomass: Takes full size of biological mass into account, but this is variant because of water mass, so dry mass has to be used. Thus, only dead things can be tabulated this way.
- Energy: Most accurate depiction, but data is hard to collect to compile this.

A pest is any organism that competes with a human for food or for space.

Pesticide: Should be specific, biodegradable, cost effective and shouldn't accumulate like DDT did.

Biological control: Acts more slowly than pesticide, doesn't completely eradicate pests but keeps them low.

Intensive Rearing of Livestock is minimising energy losses up food chains so that animals can be made to have the most biomass for the energy supplied.

- Optimal combination of macronutrients given so that no money is wasted — almost like atom economy.
- Warm environment (less energy spent on thermoregulation)
- Use of growth hormones
- Predation excluded
- Movement restricted (so energy can be used for biomass)

Integrated system is when residues and waste is usefully cycled as a fertiliser or as a nutrient for other species to make the ecosystem as efficient as possible.

Organisms grow 10x by number as you go up a pyramid of number (usually) because energy is 1/10th at each successive trophic level. However, chemicals like mercury and DDT don't get lost — they just become 10x more concentrated at each trophic level.

Inorganic Ions:

Ca^{2+}

- Rigidity in bones, teeth, cartilage and exoskeletons
- Ion used in muscle contraction and nerve impulses (to prompt release of neurotransmitters after reception of an action potential)
- Involved in permeability of cell walls (middle lamella) and in formation of cell membranes (calcium pectate adds rigidity to fruit and veg walls)

K^+

- Nervous transmission (action potentials involve movement of potassium and sodium ions in and out of neurones)
- Guard cells pump H^+ out so K^+ enter cells causing water to follow and the guard cells to become turgid and open stomata.

Na^+

- Involved in osmoregulation (eg vacuolar turgidity) and to maintain pH
- Transmission of nerve impulses

Mg^{2+}

- Chlorophyll
- Some ATPases have Mg^{2+} binding sites

NO_3^-

- Proteins
- DNA & RNA

PO_4^{2-}

- Nucleotides (phosphate group) and ATP

- Calcium Phosphate used in bones
- Cl-
- Ion ejected in the loop of Henle to control urine concentration
 - Cystic Fibrosis means CFTR protein can't move these out to make airways moist
 - Balances the +ve charge from cation

Not all hormones are steroids — hormones can be:

- Amino Acid Derived (eg melatonin — for sleep regulation)
- Eicosanoids (eg prostaglandins — fatty acid derived)
- Steroids (eg oestrogen — all cholesterol derived)

Instinct is behaviour present from the very beginning (genetically built in)

A fixed action pattern is an instinctive behavioural sequence that runs to completion, like raising eyebrows to acknowledge seeing someone you know. These are done reflexively — geese will nudge light bulbs and tennis balls back into their nests, along with their eggs.

Imprinting is learning that happens during a 'critical phase' age geese being imprinted to follow their mother around. Often learning in this phase is rapid and independent of consequences.

Associative learning is associating a stimuli with an affect, like Pavlov conditioning dogs to associate bell with food.

Trial and error is pioneered by BF Skinner, by teaching animals complex behaviour through letting them experiment with stimuli, like in a Skinner Box, or with Crows and vending machines.

Classical conditioning: signal causing a reflex, this involuntary. It was pioneered by Pavlov, there's a stimulus then a response. EG bell causing salivation.

Operant conditioning is reinforcing stimulus after there's been a behaviour, this is often voluntary and was pioneered by BF Skinner. It involves a response, then a stimulus. EG Insert a quarter into the vending machine and get food.

Observational learning is watching and mimicking behaviour using mirror neurones.

Insight is problem solving — learning from mistakes and making appropriate changes. Social animals most often have insight.

When studying behaviour, think about proximate causes (what stimulates this behaviour in animals) and ultimate causes — what was the evolutionary reason that this behaviour came about?

Foraging is the behaviour of finding food.

Sexual selection is the process of animals competing with those of their own sex to attract mates.

Altruism is doing something that benefits some other organisms — even to your own detriment, but still makes evolutionary sense, Hamilton showed this.

Natural selection acts on both physiological traits and how effectively animal behaviours allow these traits to be used.

Learned behaviour both spread and fade quicker than genetic behaviours, since you can teach something faster than you can reproduce, but you also then have no genetic safety net and it's a behaviour that will die with you.

When looking at animal behaviour you must consider:

- Stimulus? Response?

- Learned? Innate?
- Evolutionary reason for it to come about?

-Foraging and food:

- Contingency Theory is when animals care about the energy time they receive carbs give up a big meal if it would take too much time to crack the mussel.

Marginal value theory is the law of diminishing returns when should an animal leave a patch to search for a new one?

Game theory can be used to study animal decision making and its evolutionary origins.

Histamine is a nitrogenous compound stored mainly in granules in tissue mast cells, and in basophils. It's also involved in smooth muscle contraction, blood vessel dilation, lowering of blood pressure, stimulation of acid secretion in the stomach, and acceleration of heart rate. It can also be used as a neurotransmitter.

Infected tissue releases histamines to dilate nearby vessels so immune cells can more easily reach the injury/infection.

Prostaglandin is a lipid derived hormone-like substance. Uses depend on the type of receptor it binds to. Produced all throughout the body. They are vasodilators and inhibit platelet aggregation, and are heavily involved in inflammatory responses.

Anagenesis is the formation of species without branching of the evolutionary line of descent. Cladogenesis is the formation of new organisms by evolutionary divergence from an ancestor — the main cause of the diversity we see today.

Aves are birds.

Lepidosauria are reptiles.

Testudines are turtles.

Reptiles don't have loops of Henle, and so don't produce concentrated urine.

Adaxial surface of a leaf is the upper side.

Hypodermis is just under the epidermis (plants and animals), and is usually subcutaneous tissue.

Polygyny is more common in an environment where the territory varies a lot, and is patchy, and where males are not very territorial.

There are many types of epithelium:

- Simple + Stratified Squamous
- Simple + Stratified Cuboidal
- Simple + Stratified Columnar

Stratified columnar epithelium is used in the lining of the urethra.

G0 phase is a state of rest, dormancy — can either be an extension of G1 in the cell cycle or separate from the cell cycle entirely. Fully differentiated cells are often found in this phase.

Anadromous migration is when you move from one part of something to another — eg fish moving from one part of a water body (fresh water) to another part of a water body (salt water). In fish, this happens because of trophic adaptation, the search for food causing changes in behaviour.

Allergic reactions are caused by antigens of IgE.

Types of channel/carrier proteins:

- Uniporters just let one ion through.
- Symporter lets two ions through in the same direction.
- Antiporters let two ions through in opposite directions.

Transcytosis is what it says on the tin — endocytosis, moving through a cell, exocytosis. This is the mechanism by which macromolecules go from lumen to interstitial fluid.

Fats are absorbed from food into the lymph then eventually emptied into the blood (via subclavian vein), since fat can't dissolve in blood, it is transported by binding with lipoproteins (which are soluble) or serum albumin (a class of plasma proteins). Although only a small amount can bind with serum albumin, it has a rapid turnover so fats can efficiently be transported via this mechanism.

Abnormal levels of certain lipids on certain lipoproteins can hint at atherosclerosis.

Liver plays a key role in this: synthesises cholesterol and removes cholesterol from the body via conversion to bile salts into the bile then faeces. This is negative feedback control via HMG-CoA reductase, the pacemaker of cholesterol synthesis. Lipoproteins can be distinguished by looking at their density.

Cells take up cholesterol via receptor mediated endocytosis where cholesterol is carried by LDL (it's a lipid that can't move freely throughout the bloodstream).

Vision is vertically inverted (and then flipped back to see correctly by the brain) but fine horizontally.

Stereoscopic (stereo= solid, three dimensional and scopic= to see) vision is the ability to use both eyes to see slightly different things, and then to combine the images in the brain to achieve things like depth perception and to judge distance. The fact that the two eyes see slightly different things is called retinal disparity.

Hyperpolarization in nerve cells is a consequence of potassium channels opening and there being a lot of potassium inside the nerve so the nerve goes slightly too negative for a second. The refractory period follows, returning the internal environment to its previous conditions.

Cytochrome C/ Cytochrome oxidase is the last protein involved in the ETC.

The human loop of Henle is broken up into the thin descending limb, thin ascending limb and thick ascending limb.

Thick ascending limb actively transports solute out. This means interstitial fluid is more concentrated, and since thin descending limb is permeable, water moves out of it and solutes into it via osmosis.

The thin ascending loop is permeable to solutes, but not water. So, solutes move out (they were very concentrated at the bottom of the descending loop) of the thin ascending loop of Henle.

Insect hemolymph is open — it just flows throughout the body not in vessels. There are, however, vessels to keep this flow going.

Lactic acid formation involves breaking Glucose into Pyruvate (releases energy) and then the pyruvate is converted into lactic acid so that the NADH can be reused in glycolysis in the absence of oxygen.

Kin selection is behaviour that favours the success and survival of an organism's relatives, even at a cost to the organism itself.

Colder water holds more gas, so deeper waters are more oxygen rich because they're further from the hotter surface as well as have less life sucking oxygen out of the water.

Transamination is a chemical reaction that transfers an amine group to a keto acid ($\text{COOH} + \text{C=O}$) to create an amino acid. This is how deamination in the liver and kidneys takes place.

Auxins acidify the cellulose near them not to hydrolyse it but to weaken the hydrogen bonding within it so primary growth can more easily occur.

In a graph of growth of a population, the predator's growth will always slightly shadow the prey's growth because the predator eats the prey so any increase in prey will cause subsequently more food for the predator, and, therefore, that population to grow, too.

Far-red is the wavelength on the spectrum between red and infra-red. It is special because lights reflect far-red light, but absorb red light (and blue light due to absorbance spec of chlorophyll). This means under a canopy you have a higher ratio of far-red to red than usual. This wavelength of light is also used for vision by certain organisms like deep-sea fish.

We get the restriction enzyme EcoRI from E.coli. The reason it doesn't cleave the insides of these bacteria is because the sequence it targets has been slightly modified in these bacteria so they can't be targeted.

Plasmalemma=Protoplast. Only a change in the differential permeability of the protoplast is required for water to leave and plasmolysis to occur.

Fat produces more ATP per molecule of it as well as more ATP per oxygen used. It's just more energy dense in general than glucose & carbohydrates.

Nerve cells can be further excited by blocked potassium outflow (so positive feedback grows for maximum depolarization), increasing calcium influx (increases neurotransmitters sent), increasing sodium influx (actually increases the action potential), or by closing chloride channels.

DNAp goes from 5' to 3' because you need a free 3' OH group to start replication. NOTE that DNA is read (RNAp) in the opposite direction — from 3' to 5'.

In fresh/saltwater fish, you control the salt levels and therefore the water levels. For example, you actively transport salt out in saltwater fish NOT transport water in.

DNA replication and transcription/translation both require ATP.

Not only do prokaryotic and eukaryotic Ribosomes have different sizes, but their subunits have different sizes. They also have different rRNA making them up and so are often used as the differentiating factor for antibiotics to target bacteria specifically.

Gene interaction is when multiple random mutations occur on different genes causing resulting changes you wouldn't expect given the nature of the individual mutations.

The protoderm/dermatogen is the primary meristem in vascular plants, and it gives rise to epidermis.

Eukaryotic cells can in fact engulf other eukaryotic cells in a symbiotic relationship.

Peroxisomes are not made in the Golgi, like the lysosomes, they're formed by vesicular fusion of two vesicles from different places (in humans from mitochondria and ER).

An agonist is a chemical that binds to a receptor to cause a response. An antagonist blocks this, and an inverse agonist does the opposite of the agonist.

Mitochondrial DNA develops all throughout the cell cycle in preparation for mitosis, not just during the S phase like the DNA of the cell.

The kidneys (along with lungs + brain) play an important role in pH regulation by excreting H⁺ ions/ absorbing bicarbonate (HCO₃⁻) ions as needed to regulate pH.

C₄ photosynthesis has two advantages over traditional photosynthesis: avoids photorespiration (because CO₂ is taken in and fixed in different places) and water loss (they fix CO₂ more efficiently — can do it when CO₂ concentration is lower) and so can keep stomata closed for longer, losing less water. This is only an advantage in hot climates as opposed to cold, moist climates where C₃ plants are more efficient.

The lac operon isn't controlled only by lactose levels — lactose digestive enzymes are only produced when lactose is present AND glucose is absent. This is regulated by the lac repressor (lactose sensor) but ALSO by Catabolite Activator Protein (CAP — glucose sensor). CAP only activates transcription when glucose is low. CAP senses glucose through a cAMP mechanism (like in glucagon binding).

The Calvin cycle is broken up into fixation (CO₂+RuBP), reduction (3PGA—>G3P) and regeneration (of RuBP). 3CO₂ + 3RuBP —> 3 (6 carbon intermediates) —> 6 (3PGA)
—> 5 (3PGA) regen
—> 1 (3PGA) glucose

In fixation, 6 NADPH—> 6NADP+ (reduction) and overall, 9 ATP are used (6 in reduction to G3P and 3 in RuBP regeneration). Regulated by stromal enzymes which are in turn regulated by light conditions. CO₂ activates Rubisco, and also acts as its substrate during fixation.

Grey matter is cell bodies, white matter is myelin. Grey matter is 40% of the cerebrum, and white matter 60%. Grey matter consumers over 94% of the oxygen, though. Grey matter is what's used in actual processing, and white matter in relaying of impulses.

AT & AU pairs are bonded by 2 H bonds, whereas GC is bonded by 3 H bonds.

Cyanobacteria are the only prokaryotes that can produce oxygen; they can photosynthesize.

Secondary growth is growth laterally, the periderm (bark) is the secondary protective tissue (inside the epidermis but outside the endodermis/vascular tissue)

Sieve tubes are modified parenchyma cells (no nucleus — that's in companion cell).

A small hair or outgrowth from the epidermis of a plant is called a trichome. It's usually unicellular and can fulfil a variety of functions, such as being a root hair, a glad, or many other things. They can also be used for protection.

Primary cell wall is more flexible, develops while the cell is growing. The secondary cell wall is hard, and set in stone — there when the cell is developed.

The small opening in the surface of an ovule (inside the ovary inside the carpel of a flower) is called a micropyle, that's how the pollen tube enters.

In a dicot root we have: Epidermis -> Cortex -> Endodermis -> Pericycle -> Phloem -> Xylem

A spider building a web is innate behaviour; a young bird recognising the call of its mother is, however, learned.

Radial symmetry is symmetry in a circular shape, and bilateral is symmetry across a vertical line split into two halves.

Echinoderms (starfish) have endoskeletons, and radial symmetry.

Eutrophication is mainly caused by nitrates and phosphates.

Mitochondria are involved in oxidation (transfer of electrons between electron carriers), carboxylation (ACoA+oxalocetate) and dehydrogenation (pairs of H atoms are lost from substances in respiratory intermediates).

Innate immunity is a response that isn't specific to the antigen but will happen when any non self molecule enters the body — physical barriers becoming inflamed, phagocytotic activation.

Adaptive immunity is specific to the antigen entering the body — e.g. which clone of antibodies are selected for expansion. This also includes immune memory.

Humoral immunity is a response against free-floating antigens in the body's interstitial fluid, whereas the cell-mediated responses is a specific responses against invaders that have entered body cells.

In succession, the ecosystem changes, becoming more conducive to life over time, this involves change in domination of various species.

Zones of a root:

Zone of maturation: elongating cells complete their differentiation here. Recognised by the presence of root hair cells in this area.

Zone of cell elongation: Cells expand as their vacuoles group up and fill with water. This is where the force for roots penetrating the soil comes from.

Zone of cell division: acts as the meristem of the root, divided into the protoderm (makes epidermis of root), pro cambium (makes xylem/phloem), and ground meristem (makes the cortex and root parenchyma).

Root cap: protects root from abrasion, and meristem behind it replaces cells that wear off, its penetration into the soil is assisted by the epidermal production of mucigel.

The liver is involved in removal of toxins by making them water soluble and separating them from whatever they're attached to so that they can be excreted from the body.

Glucose and amino acids are absorbed via a co-transport mechanism through the microvilli of the small intestine. Cotransport is necessarily a form of active transport, where one molecule is moved down its energy gradient so the other can be moved up — this is where the energy comes from. You can have synporter or antiporter cotransport mechanisms.

A zymogen is an inactive chemical that is ready to be converted (activated) into an enzyme by another enzyme.

Magnesium ion deficiency can cause leaf discolouration as well as short internodes.

Nitrogen ion deficiency causes leaf discolouration as well red patches on the stem.

Ecological succession happens because each new species that enters an ecosystem exerts an impact on it that influences how other species can interact with the ecosystem.

Pioneering plants & animals -> climax ecosystem (steady state & self perpetuating)

The signal polypeptide on the leading end of the immature insulin protein is used for attachment to the RER membrane, and also dictates direction of translation (5'—> 3') as well as halts translation until the free ribosome it's being made in has bound to the RER (so it can, too).

Aldosterone is a hormone that is made by the adrenal glands, and acts on the kidneys to retain certain ions, water, and increase blood pressure. Low levels of this lead to excretion of lots of water.

DNA ligase is used in DNA replication, molecular cloning (genetic engineering), and doesn't require ATP.

Albinism, Cystic Fibrosis, Haemophilia, Sickle Cell Anaemia are all recessive genetic traits. Achondroplasia (Dwarfism) is a dominant genetic trait.

Chromosomal inversion is when nucleotide sequences aren't broken but instead reversed.

Chromosomal translocation is when there is swapping of nucleotide information between non-homologous chromosomes.

Chromosomal transposition is when nucleotides are moved from one place on a chromosome to another.

Once the primary transcript of DNA is made, it is processed in various ways before becoming mRNA. These include 5' cap, PolyA addition, and alternative splicing.

5' cap is a specially altered nucleotide sequence on the 5' end that's put on precursor mRNA to regulate translation and a host of other things. It's important in the creation of stable and mature mRNA that will be used in translation. Mitochondrial/Chloroplastic mRNA are not 5' capped.

Polyadenylation is the addition of a PolyA tail to a precursor mRNA molecule. These molecules need the PolyA tail before they can be translated. It is therefore involved in gene expression. It shortens over time and when it is short enough the mRNA is degraded. The PolyA tail binds to the 3' end.

Alternative/Differential splicing is a process that leads to one gene coding for multiple proteins. It just means that some exons are or aren't included in the creation of mRNA, and so the protein produced will vary accordingly. It allows eukaryotic genomes to create more proteins than expected by looking at the number of genes.

RNA splicing is the process whereby precursor RNA are made into mature mRNA, which may involve all the processes above, but also the removal of introns and the ligation of the remnant exons.

Transposons (TEs) are 'jumping genes' and can move around a genome, creating or reversing mutations. Class I 'retrotransposons' (R for RNA) use RNA as an intermediate to be transcribed from place to place in the genome. Class II 'DNA transposons' use enzymes to be cut and pasted from place to place. Transposons can alter the cell's function and it's genome size.

Allolactose and tryptophan are allosteric effectors that bind to the repressor molecule (eg in the lac operon) causing it to change shape and move away so the operator is free for transcription to occur.

The N-terminus of a protein/polypeptide is that with an amine (NH₂) group poking out.

Histone acetylation increases gene expression because it make the DNA on the histones more accessible by transcription factors, while de-acetylation of histones has the opposite effect.

Kinase enzymes are proteins characterised by the fact that they serve to phosphorylate other molecules, resulting in a functional change. (De)phosphorylation is a key regulation mechanism in

the body in that it causes enzymes to be turned on or off. It usually occurs on amino acid side chains we call 'residues'.

DNA methylation is a mechanism our bodies use to regulate gene expression, usually acting as an 'off' switch. When a promoter is methylated, gene transcriptional activity usually decreases. This is a regulatory mechanism key for normal development.

RF = (recombinant/total)*100 and 1% RF = 1 centiMorgan (cM) or Map Unit (mu). These RF relationships can be used to map genes to see where they are located relative to each other. RF > 50% because when RF = 50% it implies they are assortet independently as normal.

DNA can exist as a single strand (ssDNA). Bacteriophages have unusually high purine DNA compositions.

A bacteriophage can infect bacteria using one of two life cycles: the lytic cycle (inserts its DNA into that of the bacterium to make many copies of itself causing the host to burst/lyse and die) and the lysogenic cycle (infects a cell and integrates its DNA/RNA into that of the host bacterium but the genetic info is inactive; the bacterium continues its life cycle as usual until the genes integrated are activated, which is when it swaps into the lytic cycle — using the bacterium to make more phages).

A Northern (RNA) blot analysis is used to look at gene expression by detection of RNA/mRNA in a sample.

A Southern blot is like a microarray — you look for a specific DNA sequence by separating the DNA via electrophoresis and then adding DNA probes to see which bind. This is also used to detect transgenic organisms via the same mechanism.

A Western blot is an analytical technique where you detect for the presence of specific proteins by putting in specific antibodies which bind to those proteins.

SNPs or single nucleotide polymorphisms are just singular variation in nucleotides between people. SNPs are just point mutations that occur in a large proportion of the population.

A transition mutation is when a purine changes to another purine (A—>G) or pyrimidine to pyrimidine. These are common forms SNPs take. SNPs are also useful in genotyping.

A missense mutation is a point mutation in a codon that causes it to code for another amino acid. These mutations occur less frequently than transposon mutations.

Exonuclease enzymes that cleave nucleotides one at a time from the end of a polynucleotide chain, whereas endonuclease enzymes cleave nucleotides from the middle of chains.

DNA polymerases need somewhere to start (a primer) before they can add their nucleotides to the chain during DNA replication. Some, but not all, DNA polymerases can 'proofread' (correct errors) by using their 3'-5' exonuclease activity to remove any incorrectly placed nucleotides as well as add new ones.

As such, DNAP can function as an exonuclease in both directions, but only an endonuclease in the 5'-3' direction.

Transduction is the genetic process where foreign DNA is inserted into a cell, often by a virus or the like.

Palindromic DNA sequences are often target sites for restriction endonuclease enzymes because the restriction enzymes are usually homodimers and so rely on being able to cleave by attaching to

the site in either way. They can cut leaving sticky or blunt ends, though sticky ends are usually more successful in ligating.

The 'wild' allele refers to the normal, common allele, and the 'mutant' to, well, the abnormal, mutated type allele.

The major function of a peroxisome is breaking down long fatty acid chains, dealing with hydrogen peroxide the process.

Not all species are XY heterogametic. Some use ZW, others use three chromosomes to determine sex. Birds DO NOT use the XY chromosomal system, but ZW instead (some reptiles use this, too).

The coelum is defined to be the main body cavity in animals, surrounding and containing the digestive tract and several other organs.

The pH in blood (7.4) is maintained through the bicarbonate buffer system (and phosphate+plasma protein buffer systems, but the bicarbonate one is the only one linked to the respiratory system and so is most important).

Buffer systems work by having a weak acid (carbonic acid) and its conjugate base (HCO_3^-). This is the equation for the body:



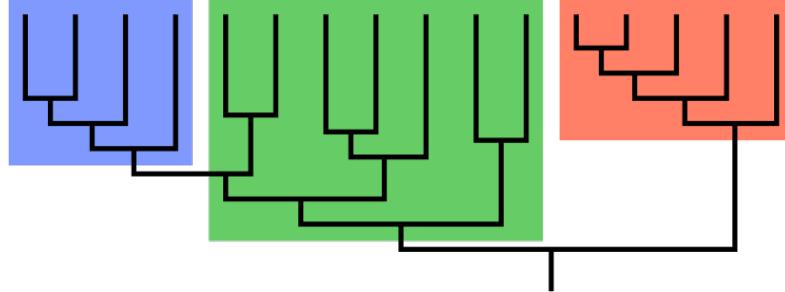
So any new H^+ / HCO_3^- ions that enter will react with the opposite species and be cancelled out. For example, if lots of acid is added to the blood, it will react to make carbonic acid, then CO_2 / H_2O , which reduces blood acidity. When you take away hydrogen ions, more carbonic acid will be made, dissociating into more H^+ ions to counteract that. This is Le Chateliers principle.

Breathing more removes CO_2 from the body, so the system becomes less acidic as less carbonic acid is formed. Kidneys can also respond by secreting/reabsorbing H^+ / HCO_3^- appropriately, too.

CoQ is also ubiquinone (ubiquitous in animals!), present in the ETC of mitochondria (using oxidation energy to move protons up a gradient before using that gradient to make ATP).

Platyhelminthes = Flatworms. Their flat nature is so that they can maximise their exposure to the surrounding medium.

A clade is:



During the development of an embryo, cleavage refers to the division of cells WITHOUT growth that occurs initially after fertilisation. The various tiny cells formed after this are referred to as blastomeres, and the final compact group of cells the morula. They eventually form the blastula, a hollow sphere similar to the previous structures.

The cleavage can be holoblastic (all the parts of the initial cell divide and multiply) or meroblastic (only some parts start to cleave and not others).

Determinate/Mosaic cleavage is when the two cleaved product cells cannot survive alone; if separated they will die.

Indeterminate cleavage is when the two cleaved product cells can be separated, and they will survive on their own

Protostomes (a clade of worm-like animals), cleave spirally (subset of holoblastic cleavage) and determinately (so they cannot survive by themselves if initially separated).

Their sisters, deuterostomes, such as sea cucumbers, just differ in development — the same hole develops into the anus of the deuterostome becomes while in protostomes it becomes the mouth. Cleavage for these specimens is radial (still holoblastic) and indeterminate (the two cleaved cells can actually survive if separated).

Immunoglobulins = Antibodies. Immunoglobulins come in various classes/isotypes EG IgA, IgG, etc. These differ in the constant regions they have NOT the variable regions. Therefore, class switching doesn't affect the antigenic receptors that the antigens have. The changing of the heavy chains mean that the different classes can be regulated and interact with different effector molecules. This is a normal part of the immune response.

Not all classes can switch to each other, though. Class switching is irreversible.

Insect exoskeletons are made mainly of protein and chitin (polysaccharide).

All B vitamins serve in aiding digestion of macronutrients, and in the metabolism of fats and proteins. Lack of B1, thiamine, leads to beri-beri. This disease affects the heart, breathing rate, and weakened muscle due to pyruvic acid build up.

Vitamin K is important in blood clotting.

In the development of a nervous system, neurones go as seen here: Plate->Fold->Crest->Tube

The urine, after it leaves the collecting duct, goes into a minor, then major calyx, and then the ureter.

Trehalose disaccharide helps anhydrobiotic animals like the tardigrade survive because it protects cell membranes in freezing temperatures and it replaces water otherwise associated with proteins and membranes.

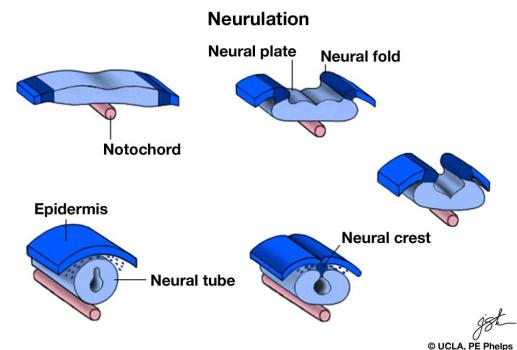
Goiter = Swelling

Miction = Urination

The zygomatic arch is a connective bone on the temporal side of your head, above and in front of your jaw. It is particularly large in herbivorous animals because they have to grind so much.

The foramen magnum is the big hole in the base of your skull through which your spinal cord passes to connect to your brain. It's thought to be linked to bipedalism — upright species have it pointing forwards whereas other species it is posterior facing.

Simple epithelium rests on the base membrane whereas stratified epithelium only has one layer in contact with it. Stratified epithelia have more layers, and so offer better protection, and so are useful when transporting or filtering toxins (think oesophagus, urethra). Columnar epithelium



(elongated single cells) are more effective at protection than their squamous counterpart, but not as much as stratified. Simple tissue are found where absorption/transport through the membrane is necessary.

The wings of any bat/bird are elongated forelimbs covered in feathers that help it fly. Similarly, the front flippers of dolphins and whales are also forelegs and the hind legs of these animals are tiny bones buried inside the body.

Sagittal plane is one that divides the body into left and right sections.

Coronal plane divides the body into front/back (ventral/dorsal, respectively)

Transverse plane divides the body into a cross section (top and bottom).

Oblique plane divides the body at some angle.

The complement system is a part of the immune system that enhances the ability of antibodies and phagocytic cells to clear microbes and damaged cells from an organism, promotes inflammation and attacks the pathogens cell membranes. It's part of the innate immune system — which is not adaptable, and doesn't change over the course of an individual's lifetime. It consists of proteins found in blood, but synthesised in the liver.

Celiac disease is an immune reaction to eating gluten in some individual, causing an immune response against your own villi. This causes absorption problems, nutrient deficiencies, and abdominal pain.

Jaundice is the yellowing of skin due to high bilirubin levels — a pigment found in blood.

Steatorrhea is the excretion of abnormal amounts of fat with faeces because of the intestines' inability to absorb said fat.

Dolphins are the only mammals known to employ countercurrent heat exchange.

There are three main categories of cell surface receptors:

- Ligand-gated ion channels (ionotropic/metabotropic): responsible for transmission of signals across synapses by allowing a flow of ions across the plasma membrane. They transduce a chemical signal in the form of neurotransmitters delivered.

- Enzyme-coupled receptors: various kinds, including some different kinase associated receptors, they act with enzymes inside the cell to transduce signals through cascade mechanisms.

- G-protein-coupled receptors: what it says on the tin. Cause a signalling cascade via G-proteins. Because these proteins are so versatile, drugs are usually made to target these receptors.

In neurones: Ionotropic receptors act quickly, and change shape when bound to by a ligand (a ligand is a molecule that binds to a central metal atom to form a coordination complex).

Metabotropic receptors take a little longer to react — they don't have channels (unlike ionotropic receptors) instead use a G-protein mechanism (but, somehow, not G-protein coupled receptors).

The enzymal stages of protein digestion are:

- Pepsin
- Chymotrypsin
- Carboxypeptidase
- Aminopeptidase

Trypsin is a type of protease, produced by the pancreas.

An atom/functional group can be charged, but not polar, and vice versa. Charged refers to its overall electric charge e.g. H+ has a formal charge of 1. However, H+ is not polar. Conversely, HCl isn't charged, but is polar. Phosphate functional groups are charged, but not polar.

The first encoded amino acid in every protein is methionine (encoded for by AUG). The polypeptide only starts to fold into a certain 3D shape after it terminates it's time in the ribosome.

Clathrin is a protein that plays a specific role in the formation of vesicles. It forms a triskelion shape composed of three heavy and three light chains to form a lattice around the vesicle. This coating is an important way that receptors recognise vesicles, as well as a way to specify the vesicles' final destinations.

SNARE proteins are mainly used to facilitate endocytosis of vesicles. There are vesicle (v) and target (t) snares. V snares are embedded in the vesicular membranes. When calcium ions rush into the end of a neurone, they attach to the v snares of vesicle membranes, which are consequently attracted to the t snare proteins on the presynaptic membrane, causing vesicular fusion and so release of neurotransmitters. In a similar way, v and t snare proteins control the directionality and specificity of a vesicle.

Osmosis can be used to measure the molecular weight, and reverse osmosis is a process whereby you apply pressure to force water through a membrane down a water concentration gradient.

pH can be calculated if you know the molarity of hydrogen (hydronium) ions using $\text{pH} = -\log(\text{mol})$

Fluorophore is a molecular component of GFP that is energised by a specific wavelength of light, and dissipates the energy by emitting light at a longer wavelength. The GFP is made of hundreds of amino acid residues (modified amino acids) that, when stimulated with blue/UV light, give off bright green light.

Genetic drift is evolution due to just the random change in the gene pool of an organism.

There are many sources of information input when developing a phylogenetic tree; molecular/genetic analysis, shared morphology, ancestry tracing, and more.

Cold water holds more oxygen than hot water, low salinity (saltiness) holds more oxygen than high salinity.

A chromophore is an atom or group of atoms that is responsible for the colour of a compound. When an auxochrome is attached, the auxochrome can alter which wavelengths and intensities of light are absorbed.

Rhodopsin is a pigment that is light sensitive and found in the retina — the 'rods' in 'rods and cones'. When exposed to light, it undergoes a chemical change. It's a G-protein coupled receptor that causes various chemical changes when exposed to light.

Vitamin A is the chromophore of rhodopsin (basically lack of Vitamin A leads to night blindness because then rhodopsin doesn't have the right colour to detect light/dark because VA is the chromophore).

Isoleucine is the most hydrophobic amino acid. Lysine is amphipathic (hydrophilic&phobic at different places).

Cell Adhesion Molecules (CAMs), Netrin 1, Slith are all molecules involved in directing growth of axons in the nervous system.

The hypothalamus is responsible for circadian rhythms. The limbic system is responsible for memory, amongst other things.

Process of degradation:

- Body composition = 64% water, 20% protein, 10% lipid, 5% mineral, 1% carbs
- Proteolysis is regulated by moisture, temperature & bacteria. Keratin is especially resistant to breakdown. Proteins are broken down into peptones (early stage breakdown products)
- > amino acids-> phenolic substances, often releasing ammonia via deamination.
- Carb degradation is from polymers to monomers to $\text{CO}_2 + \text{H}_2\text{O}$.
- Adipose tissues (loose lipid tissue) are broken down immediately into fatty acids, being torn from their glycerol backbone. These fatty acids can react with minerals to produce salts. In anaerobic conditions, fats are hydrogenated (made more saturated), and in aerobic conditions, they're oxidised to give aldehydes and ketones.

Water is important in driving protein folding. The hydrophobic effect is one of the biggest enthalpic driving forces in what might otherwise be an energetically unfavourable process. Therefore, when water evaporates over time, proteins lose their shape and decompose.

Absorption = being taken in and becoming part of internal structures

Adsorption = being put onto the surface/ external structure

Honey is prevented from the three devils of decomposer by 1) no bacteria because it's slightly acidic 2) no bacteria because there's no moisture. However, it's hydroscopic (can easily take in water) and so can spoil if exposed to water.

The number of amino acids we have is a delicate interplay between three factors: 1) cost of resources to manage increasingly large numbers of amino acids (chaperones for increasingly complex protein folding, etc.), 2) number of errors being caused due to increasing lack of degeneracy (each codon having its own amino acid would cause any tiny mutation to lead to completely different protein shape), 3) the need for diverse amino acids (how much protein complexity does our species need). Through four billion years of evolution, 20 has come out as a good answer to that balance, though there are more than 20 (commonly used) amino acids. Perhaps, evolutionarily, since predators eat prey's muscle and consume their amino acids, it would be energetically favourable to be able to assimilate amino acids without digesting them. The fact that *all* life has these 20 common AAs suggests they evolved to be chemically dominant early on in the evolutionary timeline.

Other theories suggest that because of the shape of the tRNA molecule, the last base in the anti-codon forms weakest hydrogen bonds, and so has the least "coding potential" as it isn't always used to contribute to which amino acid is chosen. Another theory asserts that once life was based on just a doublet code, which meant that only 16 AAs could be coded for, and that's why the last AA isn't as discriminating. Or maybe the code *is* evolving steadily to increase in complexity, and we've just discovered it at the 20-AA phase.

A popular evolution-of-life theory is the RNA world theory, that posits that self-replicating RNA molecules existed before DNA or proteins. It's so popular because it's widely accepted that there must have been an intermediate between chemical molecules and cellular life— saying that DNA/proteins were this intermediate is difficult because it poses the chicken-and-egg problem: DNA requires enzymes to be constructed and enzymes require DNA to code for them. The RNA world outlines how RNA can act as both a storer of information ("gene") and enzyme (chemical actor) to catalyse its own self-replication. And so RNA must have developed and proliferated via this mechanism, eventually filling most niches until DNA—which is more chemically stable and durable—came around and displaced it from its role.

Evidence to suggest humans are still evolving:

- Change in tooth composition compared to ancestors—smaller jaws and less molars because we have to do less grinding on hard plant matter to obtain nutrients
- Brain cavity decreasing in size, symbolic of increased efficiency.

- Genes encoding malarial resistance increasing in prevalence to show how even today we're seeing the results of natural selection in Africa.

- Frequency of polymorphisms causing age-onset diseases like Alzheimer's is decreasing (which, given that it only sets in later, shouldn't be the case)—explained by “grandmother hypothesis”.

- Dutch men are very tall because that's what women prefer (culture as a cause for evolution).

- We're mostly lactose tolerant, where we once were all intolerant as adults because at one point it became advantageous to be able to digest lactose as an adult.

Problems with our current taxonomic system:

- Although ideally it would accurately reflect mating/genetic compatibility of species, we sometimes make these judgements inaccurately based on external morphology, behaviour, anatomy— there have been polar bear/brown bear hybrids, showing some species to be genetically compatible.

- Linnaeus' binomial nomenclature and these assumptions mean that we're now finding out that many species we assumed to be related are actually quite genetically different, but examples of convergent evolution.

The flu (influenza virus) is a slower mutating version of the common cold, and it can be quite dangerous, actually, with aches and high temperature in addition to the standard coughs and sneezes. You can, and should, vaccinate against it for this reason, and the vaccination works as per.

Possible reasons for these infections being particularly common during colder weather could involve their enzymes (like reverse transcriptase at the centre of HIV molecule) preferring these temperatures, or our nasal mucus being less fluid and viruses therefore being trapped in there for longer.

Why ATP?

because the whole point is that energy can't just exist "freely", that's just heat. we need the energy to be stored, could be longer term like in bonds of glucose, or momentarily in high energy phosphate groups of ATP

important to realise that these energy transfers manifest themselves as conformational shape changes that reflect different energy levels of molecules, and for molecules to couple to others to enact shape changes, phosphorylation can be a common tactic of changing the thing's energy

and, of course, if ATP didn't exist, how would we harness energy gains that come later in respiration, like during oxidative phosphorylation- glycolysis is terribly energy inefficient, as it only breaks on flippin' bond

the smaller the molecules that store the energy packets, the more efficient the storage is because the smaller amount is lost. so storing all the energy in 2 packets would mean much would be residual because you'd have to use half of the total energy at a time as minimum

also, glucose is a large, unwieldy molecule that stores its energy in bonds central to the ring, which would be mechanically difficult to conformationally couple with other reactions in the biochemical system, unlike ATP which holds its energy in its extremities

How can you measure how long a mutation/disease has been in a population?

it all comes down to DNA. either the DNA of the human that's had the mutation, or of the virus/bacteria that has infected it; you compare the mutated DNA (of human or pathogen) to uninfected DNA and look at natural mutation rate (say, 10 mutations per second), and actual differences in loci, i.e. mutations (say, 30 differences) to know that time that they've been separated and been mutating separately (here, 3 seconds)

there has also been success taking a more anthropological approach by looking at symptoms shown by ancient figures throughout history, or even a pathogenic analysis inside burial sites used in tandem with the above two methods.

There are three major buffer systems in the body:

- Bicarbonate (just dissociation of H₂O and CO₂ into bicarbonate and H⁺)—most important
- Bisphosphate (phosphate in cells becoming H₂PO₄⁻ and H⁺)
- Protein (like haemoglobin mopping things up in blood by binding to H⁺)

These buffer systems rely on the concentrations of the H⁺ and HCO₃⁻ being much larger than the disturbing mixture, so that the pH doesn't change much even after some of those two are used to mop up the disturbing mixture.

Fats provide more energy than carbohydrates because, carbon for carbon, lipids need more oxygen to become CO₂ and H₂O than do carbohydrates, which usually already have an oxygen for each carbon on their skeleton. Moreover, when you look at it from a mass perspective, since oxygen is a heavy element and carbohydrates have more of it, more carbon can fit into each gram of fats, making it *even* more energy dense.

Common myth: not *everything* has to be a product of evolution. Most things haven't been selected for, or against. Take male nipples; they don't cost much to be produced, and so have no reason to be eliminated from a population. Moreover, traits are often linked. Male homosexuality gene may also affect fertility, which means that certain traits tend to stay in a population if coupled with evolutionarily advantageous ones.

There was a study showing how carnivorous plants actually mutualise with ants, which kill mosquitos that would otherwise steal nitrogen from the plant by feeding on insect remains inside of it. The ants get to forage a bit, and leave much decomposed nitrogen behind for the plants to use that they wouldn't otherwise have access to.

Bacterial flagella are often used as a common argument for intelligent design, where people say that it's "irreducibly complex"; i.e., that it couldn't have evolved in a series of steps because it needs every single part of it to function properly, and so must be the object of an intelligent designer. But, in fact, the flagella shares most genes with bacterial injectosomes, organelles that poke holes in target cells, and the protein machinery used to construct the injectosome is very similar to that of the flagella, suggesting that this could have been the origin of it, showing that it's not "irreducibly complex"—i.e., serving a non-motile function. This is paralleled by the fact that different strains of bacteria have slightly different protein sequences encoding their flagella motors, suggesting they've evolved from a common ancestor. Also, archaea have been found to have motors powered by ATP hydrolysis rather than ions turning a protein, suggesting that there's been convergent evolution by the two domains.

Cyclins are proteins in cells that collect over time (maybe by being a decomposition product of a timed pathway like respiration, or perhaps being made by a reaction that only happens so often), like sand in an hour glass. Cyclin Dependent Kinases (CDKs) are inherently present in all cells. When Cyclins reach a level where it can bind to lots of CDKs, Mitosis Promoting Factors are produced, stimulating mitosis to begin. This is an example mechanism for how changes in cells can occur seemingly randomly to cause changes.

Basic developmental biology:

- zygote
 - germinal stages
 - mitosis to make a ball of cells
 - cleavage into a hollow blastula
 - histogenesis (differentiation into three germ layers) into morula
 - neurula
 - implantation into uterus wall
 - organogenesis occurs (more differentiation) -> foetus at 8 weeks—> resembles human

Mechanisms of cell differentiation (histogenesis, organogenesis) include:

- transcriptional control of which proteins are produced (like by manipulating operators of genes corresponding to environmental changes in the lac operon, gibberellins stopping inhibition of amylase transcription, hormone-receptor complex moving into nucleus to act as enhancer etc.)
- RNA processing control (splicing of exons/introns, 5' caps, polyAA tails, methylation)
- RNA transport control (regulation of the movement of mRNA through nuclear pores)
- translational control of which proteins are produced (like siRNA forming a complex breaking down mRNA before it's translated into a protein or rRNA express more of some genes)
- gene transposition (genes jump to a site where they're expressed from a more silent one)

Circadian rhythms can be tied to actual time by the SCN (biological master-clock) that gets information about light, a chemical stimulus to do certain things associated with the day. Usually, biological clocks are emergent properties arising from several neural units interacting.

Non-coding DNA comprises the majority of genetic information, and they are used for:

- regulatory genes
 - encode for transcription factors, repressors, siRNA etc. that regulate gene expression
 - transcriptional control
 - translational control
- encode for scaffold attachment regions for the nuclear matrix (cytoskeleton-like scaffold on the inside of the nucleus) that helps organise chromatin and therefore regulate gene expression
 - encode centromeres and telomeres
 - encode some structural regions like rRNA for ribosomes, tRNA for amino acids, v and t SNAREs for vesicle fusion
 - some is *literally* junk DNA/ evolutionary remnants

A protein domain is a little “library function” that can be used in different proteins—a sequence of amino acids that isn’t a full peptide on itself, but a protein building block nonetheless.

You can detect a virus using a few genetic detection methods (since the point of viruses is that they integrate their DNA/RNA into your own genetic materials to destroy host cell):

- > mABs specific for a known virus to check which type of virus (diagnostic tool)
- > ELISA test to detect quantitatively how many viruses there seem to be
 - > antigen immobilised on surface-> antibody with attached enzyme binds to it-> substrate is produced by reaction with enzyme causing colour change of mixture-> measure colour change against calibrated standards to determine how many original viruses there were
 - > microarrays on a potentially infected cell to check gene expression that can then be computationally compared against library of commonly expressed viral genes

Plant immunity:

- Innate immune system (not as specific to antigens as our own Adaptive Immune System)
- They do have receptors, however, that can trigger local or systemic responses
- Pre-infection responses include:
 - Physical barriers (analogous to our mucus and skin, they have cell wall/cuticle)
 - Enzyme inhibitors
 - Detoxifying enzymes
 - Receptors that can activate inducible defences
- Post-infection responses include:
 - Cell wall re-enforcement
 - Antimicrobial chemicals and proteins
 - Hypersensitive response (local destruction of cells to kill pathogen with itself)

These immune responses can be divided up into two in another way— into:

- Pattern Triggered Immunity (PTI— responds to certain general molecular sequences that have been conserved in common pathogens leading to a specific immune response combining much of the above)

- Effector Triggered Immunity (ETI— responds to a *specific strain* of pathogenic invader by directly binding or by recognising the hallmark changes it makes to the host genome, and this immunity sets off a pre-stored “library function” response that is usually sufficient to stop invasion by that specific strain)

Sabre tooth tigers were commonly thought to have gone extinct via starvation due to competition with early humans and due to climate change. This we believed because we saw some tiger remains that had broken teeth which we believed came from gnawing. But now with the advent of newer dental texture analysis technology, we’re finding that the micro tears on the surface of the bones mirrored species that luxuriously eat meat, not gnaw on bones because they’re starving, which hints at the fact that they had enough to eat until the very end. We explain the increased broken bones by examining the prey they hunted, which were often very large (mammoths and giant sloths) and so teeth could easily be broken in the process of trying to take them down (since sabre-teeth are relatively fragile due to their size and shape).

Plankton are not actually a taxonomic organisation. It’s just a blanket term for many organisms that occupy many trophic levels, organisms that are tiny (micrometers to centimetres), and, crucially, unable to flow against a current, they comprise fodder in the millions for larger fish and whales. Phytoplankton, zooplankton, bacterioplankton and mycoplankton are their large divisions, which also have overlap between them.

Do all plants die?

Plants undergo indeterminate growth, i.e. there’s no set point at which they’re considered ‘mature’ or ‘old’. Many trees keep growing until they hit the barriers of physics (material composition not strong enough to hold up its own weight/ water can’t move everywhere around the plant). Also, plant cells are perpetually embryonic, so any cell can become any cell; plants don’t die because of cell senescence in this way so they don’t have an age limit as such. Vertical growth rate decreases over time, but horizontal growth rate continues.

What makes us human?

- Tool use? No, dolphins do that.
- Fire use? No, hawks do that.
- Non-reproductive sex? No, giraffes do that.
- Language & sophistication of the FOXP2 gene? No, songbirds like finches have that.
- Our ability to teach is unique— why did behavioural modernity evolve when it did (40 kya as opposed to 100kya, even though our genetics/morphology hasn’t really changed in the last 100kya?) The answer was population explosion forcing us to teach—groups that could relay information by teaching each other had a selective advantage in that living as a collective was therefore beneficial.

Why are some seeds so big? It seems evolutionarily counter-intuitive because you want seeds to be light so they can be dispersed far away to avoid competition.

Seeds of some plants, like coco de mer, are so big essentially because it’s important that it has a lot of nutrients inside of it. This is because it’s an island species, and so isn’t going to be dispersed anywhere as it’s stuck on the island—it grows up in its parent’s shadow and so lacks access to light—a store of nutrients are important for it to be able to compete in this environment since it can’t photosynthesise much initially. This is why colonising plants develop larger seeds over time. This plant species is also known for funnelling nutrients into a dense ring in the soil directly around it.

Darwin called the evolution of flowers “abominable” because it seemingly defied his principle of natural selection because they evolve and diverge so fast, as opposed to incrementally. We saw this initially when we observed the fossil record, where it showed that they emerged as an offshoot from gymnosperms, and then completely dominated all plant life. This was reconciled with evolution since then because we’ve found fossil records that suggest that angiosperms date further back than we thought, and so their population explosion happened slower than we thought.

The question of how they've grown so spectacularly diverse, however, is still an open one, with only partial answers. An attempted answer suggested that they co-evolved with insects that pollinated them, driving diversity (just like marine viruses encourage marine speciation of bacteria in the essay)—but this led to the chicken/egg problem. It was then attempted to be explained by looking at their historical structure and finding that they are on average more vascular and more efficient at capturing light, which might give them an advantage in being more productive. This was then refuted by the fact that gymnosperms would have still had a larger *total* vascular area/leaf production due to sheer volume of tissue, so there is still no one conclusive answer to this question.

The idea of biological trade-offs comes from the side that one biological trait cannot increase without a decrease in another, such as the size and number of eggs that a given bird can produce during a mating season, or a pea-cock increasing the pomp of its tail display to attract more mates, in the process making it harder to run away from potential predators. The handicap principle suggests that some of these maples are purposefully wasteful to show how evolutionarily fit an organism is to mates. For example, a peacock with a huge and ornate tail is severely handicapped, so the tail's message to the potential mates may be "hey look I survived despite this huge handicap, I must be incredibly fit in evolutionary terms so you should mate with me". The handicap signal asserts that this is an easy way to ensure signals about mating are honest.

Seed structure includes:

- Testa (seed coat)
- Embryo
 - Plumule (tip of epicotyl)
 - Epicotyl (leaves and shoot)
 - Hypocotyl (transition between root/shoot)
 - Radicle (what grows first—into the roots)

Algae are photosynthetic protists; phytoplankton are a type of algae.

Ocean has:

- Surface/mixed layer (as wind and convection mean that gases in air are same as gases in this first 200m of ocean and that it is mixed frequently)
- Deep ocean (separated from the surface ocean by a thermocline (steep temperature gradient), it has an incredibly different density to the surface ocean because it's so much colder and so the two don't mix for thousands of years)
- Sediment layer on bottom

This separation of ocean layers is called stratification and only is mixed when there are natural disasters.

Bacteria are magneto-tactic through use of magneto-some organelles with actual Fe₃O₄ in them that makes them act as a compass. As far as birds are concerned, this may also be the case, or , alternatively, crypto chrome proteins in their eyes may respond to magnetic fields via changes in electrochemistry/excitement of electrons that could, then, say, respond with an enzyme cascade that leads to some macroscopic change in behaviour/direction of migration.

Development in organisms can be done by actual mRNA starting at one end of the cell after fusion, and diffuse through where amount of mRNA corresponds to germ layer/developmental phase that are concentration dependent. Hox genes control organogenesis.

The isoelectric point of an amino acid is when it is in a Zwitter-ion form, with no movement in electrophoretic gel, often a little below 7 because the dissociation as acid EQM lies to the right of the dislocation as base, so some acid needs to be added to keep them equal (EQM also depends on chemical environment, i.e. R group)

DNA is double helix twisty in the way it is because:

- if you stack blocks on top of each other they line up in a straight column, but if the blocks are wedged and staggered, then it can become a helix very easily—this is what happens with bond angles in the sugar-phosphate backbone of the material.

- most of all, *thermodynamic stability*. the driving forces for binding of the two strands together include hydrogen bonding between bases, hydrophobic interactions that come w/ twisting around, increased entropy by disruption of H-bonds of water, whereas opposing factors include phosphate repulsion, salvation enthalpy and DNA strand entropy decrease. As the binding factors are greater than the opposing factors, it binds, and staggers int he way described above to minimise repulsion between phosphate groups in the backbone (this is what I meant by bond angles).

Peptide bonds have resonance dipoles, and alpha helices have overall dipoles due to the alignment of all these individual micro-dipoles, which is an advantageous feature when it comes to protein channeling.

X-ray crystallography involves firing x-rays through a crystal of a material, and creating 2D diffraction patterns of the x-rays that come out at several angles which are then translated into an electron density map using Fourier transforms.

Why living systems need hormones:

- growth, development, homeostasis, reproductive control, time-cycles/awareness
- they are long term messengers that act on tissue by various mechanisms, including changing gene activity by, say, a steroid hormone diffusing into nucleus and binding w/ a promoter to change transcription of a gene

DNA replication process (in detail):

1. Helicase unwinds DNA at origins to create localised replication fork
2. Single Stranded Binding proteins (SSBs) sit on strands to keep them apart
3. Primase makes the RNA primer to set the stage for polymerase on both strands
4. DNA polymerase goes 5'-3' to create new strand on the leading strand
 1. DNA polymerase can't replicate the lagging strand as it only works in the 5'-3' direction, so primase has to set out a lot of extra primers which are filled in by the polymerase working in that new direction intermittently
 2. These little nucleotide sequences set out are called Okazaki fragments, and are glued together by DNA ligase
5. Topoisomerase temporarily breaks the phosphate backbone to keep the topology of the DNA sound ahead of the replication fork