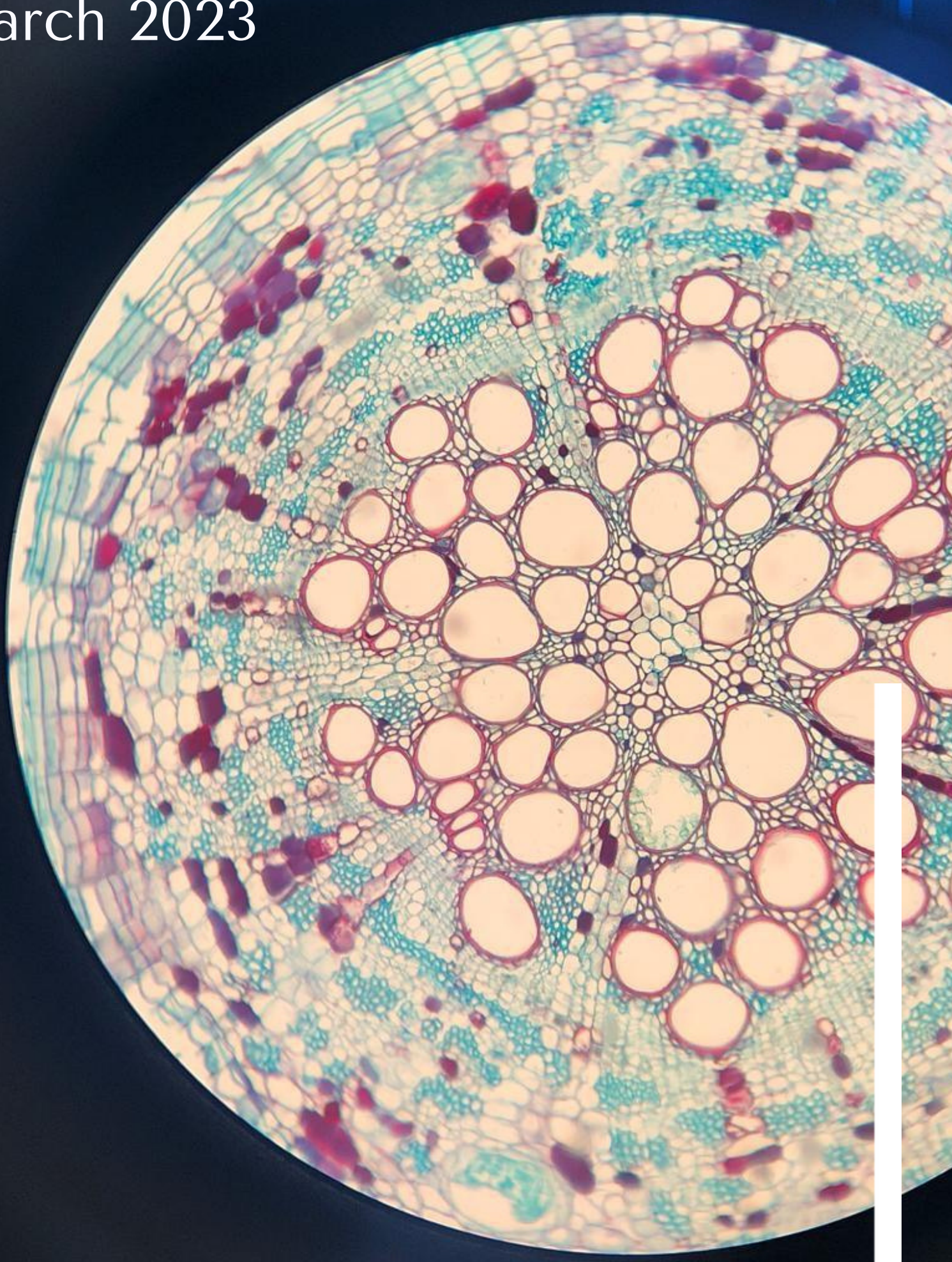
Under The Microscope

March 2023



Evolution

Issue 7

Editors' note

Welcome to the team's first edition of Under the Microscope! We are thrilled to share with you what excites the budding scientists, mathematicians, and engineers throughout the school. Our submissions are a compilation of cutting-edge treatments, innovations, and breakthroughs in various fields of study, all coming under the theme of 'Evolution'. We chose this theme because it has the potential to cover a wide range of topics, not only limited to species evolution but also encompassing the progression of anything in the scientific world. We were impressed to receive a huge range of articles linked to this theme, ranging from the strange glass frog to treatments for anxiety to the impacts of developing artificial intelligence. We were amazed by the incredible effort put forth by the entire school, including contributions from the junior school for the very first time. Additionally, we had the privilege of an interview with Professor Quinn, which made for a fantastically interesting addition to the Features Section.
We hope that you enjoy reading our magazine and that it inspires you to further explore the world of STEM!

Sora:
Features editor (gets fun and original content for the magazine! See this edition's interview with Professor John Quinn.)

Tilly:
Commissioning and Development editor (helps get as many articles from across the school as possible – including the addition of two fantastic submissions from the junior school for this edition.)

Rawnaq:
Copy editor (reads through each article to catch any slips in meaning or SPAG and ensure scientific accuracy.)

Laila:
Editor in chief (helps to organise the team to make sure everything is going to plan.)

Ghazal:
Copy editor (also looks through each submission and makes little changes to ensure scientific accuracy and that each one is an enjoyable read!)

Clarissa:
Creative editor (puts all the articles together to form a cohesive whole in an exciting format – see this issue's front cover!)

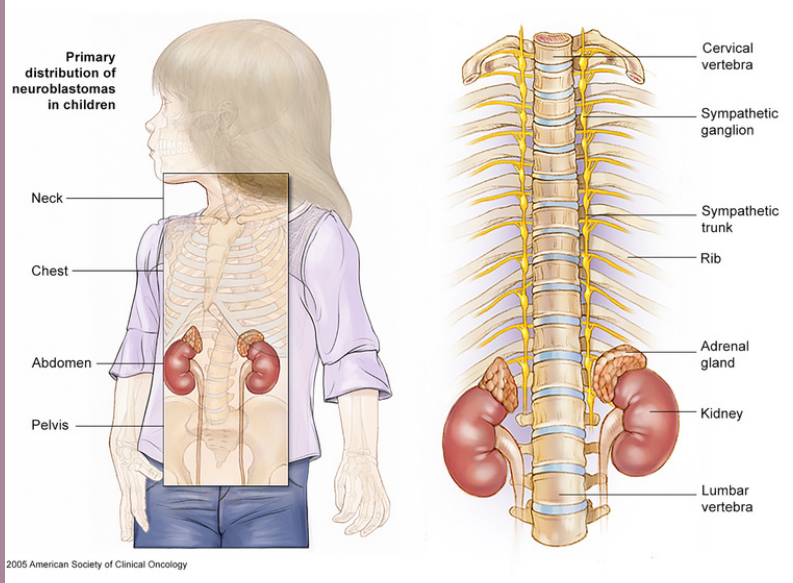
Contents:

The Evolution of Childhood Cancer Development

By Bettina Weiss

What is Neuroblastoma?

Neuroblastoma is a cancer found in several areas of the body that develops from immature nerve cells, mostly affecting babies and young children. This childhood cancer can go into remission on its own. According to the NHS - 'Neuroblastoma most commonly occurs in 1 of the adrenal glands situated above the kidneys, or in the nerve tissue that runs alongside the spinal cord in the neck, chest, tummy or pelvis.' Neuroblastoma is one of the most common cancers to spontaneously resolve on its own- this incident is usually seen in children under 18 months old.



What are the symptoms of Neuroblastoma?

The early symptoms of Neuroblastoma can be unclear and can often be misunderstood for common childhood conditions.
The symptoms recorded by the NHS include:

- A swollen, painful tummy, sometimes with constipation and difficulty peeing
- Breathlessness and difficulty swallowing
- A lump in the neck
- Bluish lumps in the skin and bruising, particularly around the eyes
- Weakness in the legs and an unsteady walk, with numbness in the lower body, constipation and difficulty peeing
- Fatigue, loss of energy, pale skin, loss of appetite and weight loss
- Bone pain, a limp and general irritability

What are the stages of neuroblastoma?

There are 4 stages of Neuroblastoma; they are: L1, L2, M and MS. This newer staging system has been developed by the International Neuroblastoma Risk Group (INRG).

Stage L1: This stage is referred to as having the lowest risk. Stage L1 tumours have not yet spread and are confined to one part of the body. The tumour also has no involvement with vital structures of the body and can be removed by surgery.

Stage L2: In this stage, there is involvement with vital structures of the body- this is located in 1 place and has not spread. However, it can't be safely removed through surgery.

Stage M: In this stage the tumour has spread to other parts of the body.

Stage MS: In this stage, the tumour has spread to the liver, skin or bone marrow, in a patient younger than 18 months.

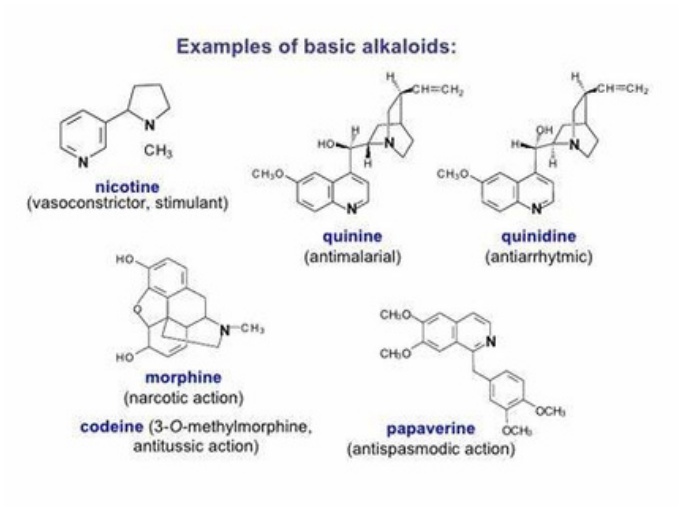
What research has been done into Neuroblastoma?

We may know why some childhood cancers resolve on their own...
Particular types of neuroblastoma have cells that depend on an amino acid to evade the immune system's attempts to destroy them. According to the New Scientist, 'Suppressing the production of this amino acid in mice led to a reduction in tumour sizes and remission of the cancer — a technique that could be used in future human trials.'
As Neuroblastoma is one of the most common cancers to resolve on its own, this research will help to explain this phenomenon.

The Evolution of Pain Killers

By Ghazal Ershadi-Oskoui

Opium poppies are the oldest source of analgesics (pain killers). Evidence of this is shown on the Sumerian clay tablet (dating to around 2100 BC) which is considered to be the world's oldest medical prescription list; according to scholars, opium poppies are mentioned on this list. In the first century the opium poppy and opium (derived from poppies) was known by Dioscorides (known as "the father of pharmacognosy" and wrote a 5-volume Greek encyclopaedia about herbal medicine and related medicinal substances), Pliny (a Roman natural philosopher), Celsus (a Greek philosopher), and later on by Galen (an influential physician and philosopher who developed a wide range of medical theories and discoveries). Celsus suggested the use of opium before surgery and Dioscorides recommended patients should take mandrake (contains scopolamine and atropine) mixed with wine before limb amputation. The Arabic physicians used opium very extensively and about 1000 AD it was recommended by Avicenna (a Persian polymath regarded as the father of early modern medicine).Alcohol was the main painkiller used in surgery during the mid-nineteenth century. However, other painkillers, such as narcotics (a drug which causes drowsiness or unconsciousness or relieves pain; common examples are opioids) and chloroform (discovered to be an analgesic in 1874 and used widely in midwifery – Queen Victoria used it for childbirth in 1853! - and during the American Civil War) became available over time but many patients still preferred the use of alcohol. In 1804, Friedrich Sertürner isolated morphine from opium and was the founder of alkaloid chemistry. Morphine is an opioid (a compound which resembles opium in addictive properties or physiological effects). Several morphine-like drugs have been synthesised to minimise adverse effects and abuse potential. In 1898, Bayer & Co introduced heroin as a pain reliever and cough suppressant (which was very important as lung diseases, like tuberculosis and pneumonia, were extremely common at the time). It was discovered by chemically modifying morphine (for eager chemists: heroin was discovered by the acetylation of morphine and aspirin was discovered by the acetylation of salicylic acid). Heroin was ommercialised as a safe and effective product; it was marketed as a non-addictive alternative to morphine. However, as early as a year later, doctors were starting to realise the dangerous and addictive nature of heroin. It was banned in the 1930s but by then it was being sold on the black market. Interestingly, heroin is still prescribed in the UK under the name diamorphine but only in palliative care for severe chronic pain experienced by patients with terminal illnesses such as cancer and to relieve distressing breathlessness at the end of life.



OxyContin (also known as oxycodone) is another opioid which was developed and patented in 1996 by Purdue pharma. It was marketed quite aggressively and highly promoted as a non-addictive opioid, although the company was well aware of its highly addictive nature. Their main priority was to sell it. In 2021, Purdue Pharma pled guilty to criminal charges related to its marketing of OxyContin and faces penalties of around $8.3 billion. It led to many patients becoming addicted and turning to the black market, planting the seeds of the opioid epidemic.

What do these substances all have in common? They are very addictive. Researchers are still trying to find non-addictive opioids as there currently is not a non-addictive solution available for public use. This topic interests me greatly which is why I am currently writing my EPQ (titled 'Will there ever be a non-addictive opioid?') which looks into the attempts made to make non-addictive opioids.

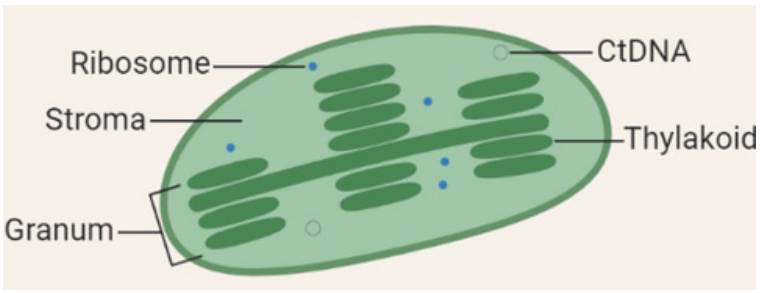
What makes grass so special? C4 yourself

By Sofia Cobham

A guide to C3 and C4 plants

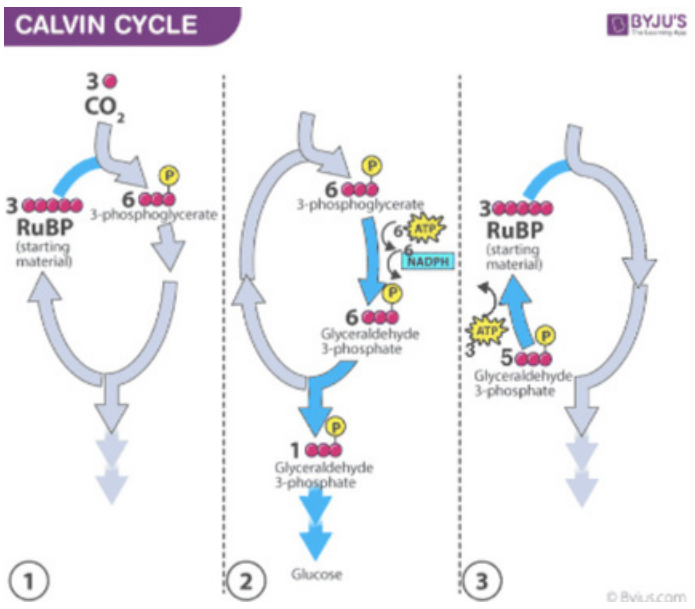
Photosynthesis first evolved in an ancestor to cyanobacteria around 3.5-3.8 billion years ago as anoxygenic photosynthesis. Anoxygenic photosynthesis occurs in bacteria, using carbon dioxide and hydrogen/hydrogen sulphide/iron in place of water. This process produces glucose, a sulphur-containing compound, water (and an iron ion). Over a period of 1.1 billion years, during the Great Oxidation Event, this process of anoxygenic photosynthesis evolved to what we now recognise photosynthesis to be – a reaction that uses carbon dioxide and water to form glucose and oxygen. However, the evolution of oxygenic photosynthesis was only possible with the evolution of cyanobacteria. Cyanobacteria evolved in the oceans from their ancestral organism – this meant that, like their ancestor, cyanobacteria could photosynthesise, but what made cyanobacteria different to their ancestral organism, was that cyanobacteria could perform oxygenic photosynthesis. As the population of cyanobacteria grew, so did the concentration of oxygen released into the oceans. Since oxygen cannot dissolve well in water, much of the oxygen produced by cyanobacteria entered the atmosphere, causing the concentration of oxygen in the atmosphere to increase rapidly. This led to the chemistry of the atmosphere and Earth's climate to change drastically, resulting in an ice age known as the Huronian glaciation. From that period onwards, new photosynthetic organisms evolved, eventually leading to the evolution of plants.

Until 24-35 million years ago, all plants photosynthesised in essentially the exact same way:



all plants followed the same process to produce glucose from carbon dioxide and water. There are two main stages to photosynthesis: the light-dependent stage, and the Calvin cycle

There are some problems with the way that the Calvin cycle works, leading to the evolution of two different photosynthetic pathways: C3 and C4 pathways. The main difference between the two is that C3 plants photosynthesise in a less efficient way than C4 plants. No matter these differences, in all plants, photosynthesis is reliant on two different stages: the light-dependent stage, and the Calvin cycle. The Calvin cycle is a series of reactions that occur in the stroma (see diagram) of chloroplasts in order to convert carbon dioxide into complex organic molecules like starch, sucrose, and cellulose. The first stage of the Calvin cycle is carbon fixation – carbon dioxide is combined with ribulose biphosphate (RuBP) to form an unstable compound by an enzyme known as Rubisco (ribulose bisphosphate carboxylase). RuBP is a pentose (five-carbon) sugar, and so when combined with carbon dioxide, forms a six-carbon compound. Due to instability, the six-carbon compound splits in two, giving way to two molecules of 3-phosphoglyceric acid (3-PGA), each formed of three carbons. Once the two molecules of 3-PGA have been formed, the carbon dioxide is described as 'fixed'. The Calvin cycle then moves onto the next stage, where the RuBP is reduced.



The method of carbon fixation described is what occurs in around 85% of all plants found on Earth – these plants are known as C3 plants as they form the three-carbon compound, 3-PGA.

C4 plants, however, are slightly different. They have evolved as the result of a process known as 'photorespiration'. Photorespiration occurs due to the way the enzyme rubisco works. As described previously, rubisco is responsible for catalysing the conversion of RuBP into a six-carbon intermediate. Photorespiration happens when rubisco combines with oxygen instead of carbon dioxide, causing RuBP to become oxidised to form 2-phosphoglycolate (2-PG). 2-PG cannot be used in the Calvin cycle, meaning that the yield of glucose produced is much lower. The ability of oxygen to bind to rubisco decreases the efficiency of the Calvin cycle, resulting in a wasteful metabolic pathway. The difference, therefore, between C3 and C4 plants is found in the carbon fixation stage of the Calvin cycle. C4 photosynthesis solves the problem of photorespiration by increasing the concentration of carbon dioxide around rubisco, thus minimising the likelihood of oxygen binding to the enzyme. To do this, photosynthesis takes place in two separate parts of the leaf: in the mesophyll cells, and in bundle-sheath cells (a type of cell that surrounds the veins of leaves). In C3 plants, both the light-dependent reactions and the Calvin cycle occur in the mesophyll cells, but in C4 plants, only the light-dependent reactions occur in the mesophyll cells, and instead, the Calvin cycle occurs in the bundle-sheath cells. In mesophyll cells, CO_2 is fixed by an enzyme known as PEP carboxylase to form a four-carbon acid called oxaloacetate. PEP carboxylase is different to rubisco as oxygen cannot bind to it, preventing the products from being oxidised, and therefore from becoming unusable. Oxaloacetate can then be converted to a similar molecule known as malate, which is actively transported into bundle-sheath cells. Inside of the bundle-sheath cells, malate is broken down to release a molecule of carbon dioxide. This carbon dioxide is fixed by rubisco, and the Calvin cycle occurs as normal. As rubisco never comes into direct contact with oxygen, the rate of photorespiration is greatly reduced, meaning that the Calvin cycle becomes much more efficient, and so a higher yield of glucose is produced as a result of photosynthesis.

But, if the metabolic pathway of C3 plants is so wasteful, why do 85% of all plants use this exact same mechanism, and not the mechanism C4 plants evolved to have? The answer lies in selective pressures. In order to reduce water loss, plants can close their stomata – this is far more common in hotter, drier climates, where the rate of transpiration is much higher than colder/more humid environments. If the environment is hotter, more water has the required energy to evaporate, and so water is lost from the leaf. If the air surrounding the leaves of a plant is dry, the water potential inside of the leaves is greater than that outside of the leaves, creating a steep concentration gradient. Water will therefore diffuse out of the leaves and into the surrounding air. This means that both high temperatures and a lack of moisture in the air cause the stomata to close. However, this does have repercussions on the photosynthetic ability of the plant. When the stomata close, carbon dioxide cannot diffuse into the leaves, reducing the concentration of carbon dioxide in the spongy mesophyll, where, in C3 plants, carbon fixation occurs. Since photosynthesis from previously fixed carbon dioxide can still occur, there is a higher concentration of oxygen to carbon dioxide in the leaf. This makes it more likely that oxygen will bind to rubisco, rather than carbon dioxide, leading to a higher rate of photorespiration. If the plant is situated in a hot and dry climate, it will produce a very low yield of glucose, as the stomata will need to close more often. This will cause the concentration of oxygen inside the leaf to increase, generating more unusable 2-PG. Energy is needed to make compounds, and as 2-PG is an unusable product, the energy used to produce it has been wasted. For plants 24-35 million years ago in these environments, the high rate of photorespiration was particularly unfavourable. A selective pressure was therefore exerted for the evolution of the C4 photosynthetic pathway.

Plants that were unable to adapt felt a selective disadvantage, as they wasted energy on photorespiration rather than photosynthesis. This resulted in a lower yield of glucose compared to plants that carried the genes necessary for C4 photosynthesis. Despite being an energetically expensive pathway (as it involves needing to actively transport malate from mesophyll cells to bundle-sheath cells), C4 plants produced a higher yield of glucose, compensating for the energy needed to carry out the process. This allowed more energy for the growth of C4 plants, giving them a selective advantage – they could easily outcompete the slower-growing C3 plants for nutrients, space, and light. This can be seen mainly in tropical and subtropical grasslands, such as savannas. Savannas are essentially plains of grass, with very little other vegetation.

The reason for this is due to the fact that most of the plants that use C4 photosynthesis are grasses. As a result, the grasses found in savannas are better adapted to the hot and dry climate, and so are able to grow faster than C3 plants, such as the occasional tree found in the midst of all the grass. Whilst the C4 photosynthetic pathway of grasses makes them particularly special, C3 photosynthesis had been the sole method of oxygenic photosynthesis for over 2 billion years prior – the evolution of C4 photosynthesis only evolved as the temperature of Earth rose to above 8°C than that of today. As we watch the events of global warming unfold, it is more likely that we will see an increase in the number of C4 plants as hot and dry climates expand further than just the edges of the equator. The IPCC (Intergovernmental Panel on Climate Change) have predicted a 1.5°C rise in global temperatures between 2030 and 2052 – as a result, plants must adapt to be able to survive in the new environment that we have created.

The evolution of the periodic table

By Rawnaq Islam

Arguably being chemistry's most important breakthrough, the periodic table revolutionised chemistry as we see it today. The table organises the elements based on their atomic weight, electron configuration, and chemical properties. Because of how it was arranged, it became possible to predict elements' behaviour and the reactions of compounds. Even today, the periodic table is a useful tool for quickly referring to information about an element and using the numbers on the table to make calculations. However, the periodic table has undergone many changes to get to what it looks like today.

Before the Periodic Table

In 1649, the first official scientific discovery of an element occurred, when Hennig Brand discovered phosphorus. Though, prior to this discovery, the elements gold, silver, tin, copper, lead and mercury had been known since ancient times. Following Brand's breakthrough, over the course of the next 200 years more elements were discovered, along with knowledge about the way some of them behaved. The pattern of the elements' properties began to become clearer, as more of them were discovered- schemes to classify the elements then started to develop and, by 1869, a sum of 63 elements were known.

The First List of Elements

In 1789, Antoine-Laurent de Lavoisier compiled the first extensive list of elements, where he defined an element as being "a substance that could not be broken down further". Lavoisier made the earliest attempt at classifying the elements as he grouped them based on their properties into metals, non-metals, gases and earths.

Changes to the Notation of Elements

In 1808, Jöns Berzelius invented the system of chemical notation which we currently use today! He suggested letters to symbolise each element, in order to simplify the characters. Prior to this, small illustrations were used as symbols to denote the elements.

The Law of Triads

Johann Dobereiner observed that the atomic weight of strontium fell in between the weight of its two adjacent elements, calcium and barium. He also noticed that the properties of these elements were similar. By 1829, Dobereiner proposed that certain groups of three elements (which he called triads) existed in nature, and that when they were ordered by atomic weight, the middle element would have a weight and properties that were roughly an average of the other two elements. Some of the triads he studied were:

- the halogen triad- chlorine, bromine and iodine
- the alkali triad- lithium, sodium and potassium
- the alkali earth triad- calcium, strontium, barium

The Law of Octaves

In 1864, John Newlands published a periodic table where the elements were arranged in order of their relative atomic masses. Newlands proposed that any given element would show similar properties to the eighth element following it in the table; he called this the "law of octaves". At the time, there were only 56 known elements; yet, Newlands did not leave any gaps for the undiscovered elements, in his version of the periodic table. As more elements were found, his rigid law seemed to hinder as he began to cram two elements into one box in order to keep the pattern

Mendeleev's Periodic Table

In 1869, Dmitri Mendeleev created the framework which would become the modern periodic table. Similar to Newlands, he ordered the elements by their atomic weight (relative atomic mass)- but Mendeleev ordered them horizontally to form periods. He also thought of arranging elements with similar properties (such as density and boiling point) into vertical columns, which we use today!

Along with ordering the elements in the correct way, Mendeleev rearranged any elements where their properties did not fit. Tellurium, for example, has a higher relative atomic mass than iodine; but he noticed that tellurium had similar properties to the group 6 elements, whilst iodine was more similar to the other halogens- so, he swapped them over.

Mendeleev was also notable for leaving gaps where no element fitted the repeating patterns; this indicated that an undiscovered element was to fill the gap. Since then, those missing elements have been discovered and their properties proved Mendeleev's predictions to be very accurate- notably the discovery of scandium, gallium and germanium.

Atomic Structure

In 1913, the final piece of the puzzle fell into place when Henry Mosley determined the atomic numbers of all the known elements. Moseley realised that, rather than their atomic weight, the properties of the elements varied periodically with atomic number. This finally explained why there were exceptions (e.g. iodine and tellurium) which did not work when the elements were arranged by their atomic weight.

The Modern Periodic Table

The final major change to the periodic table occurred in the middle of the 20th century, after Glenn Seaborg discovered all the transuranic elements from 94 (plutonium) to 102 (nobelium). Seaborg reconfigured the periodic table by placing the actinide series (elements 89 to 103) below the lanthanide series. His notable work awarded him the 1951 chemistry Nobel Prize, and element 106 was later formally named seaborgium (Sg) in his honour.

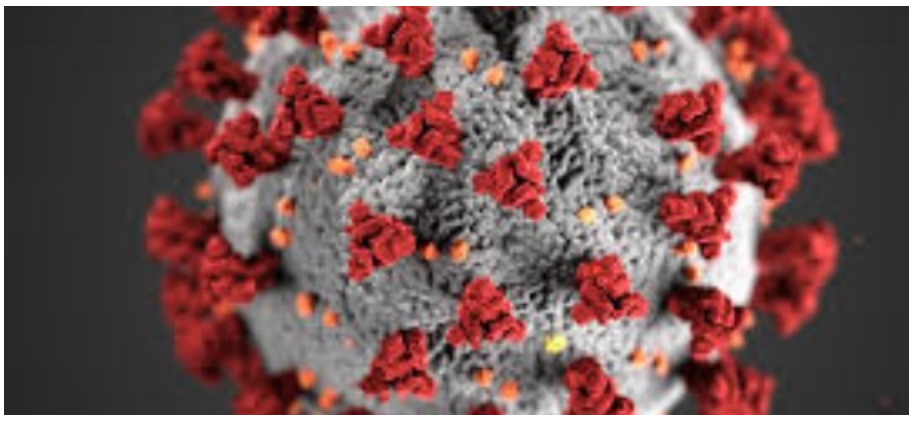
How COVID-19 is evolving

Laila Samarasinghe

Evolution is the idea that organisms adapt to have a better chance of survival. Those that are better suited to their environment flourish and become more widespread. Those which are not die. In the same way, the coronavirus has evolved. Originally there was just the Alpha variant, but then it adapted and new ones were formed.

There have been many variants of COVID-19, including Alpha, Beta, Gamma, Omicron, and (most recently) the Kraken variant. These variants have formed because, like all viruses, the coronavirus has changed over time. Many of these changes don't have much of an effect. However, some of them can cause a difference in the virus's properties, like making it more transmissible or causing less severe symptoms.

So how do variants form? As the virus replicates, it makes copies of its genes. However, it can make mistakes when copying. This is known as a mutation. These changed genes can code for a different surface protein on the virus, or in the case of covid, a changed spike protein on the surface. When the virus is replicating many times within many different hosts, the mutations can build up and the virus begins to evolve. This change in the antigen from many mutations is known as antigenic drift and can affect how well the body can fight against it.



So how might these mutations affect vaccine efficacy? There are multiple different vaccines against COVID-19. Both the Pfizer and Moderna use mRNA vaccines which work by injecting some of the viral genes (mRNA) into the body. The mRNA is used by the body cells to create part of the spike protein found on the surface of coronavirus. The immune system recognises the spike protein as foreign and responds by creating antibodies and memory cells. These memory cells stay in the body after vaccination and remember the spike protein. So, when the body encounters the same spike protein again because it has been infected with covid, the memory cells can work quickly to create antibodies which kill the virus before symptoms appear.

However, mutations can cause the spike protein to look different. This could mean that the memory cells do not remember it and there is not a rapid immune response, meaning the vaccine was ineffective. This is known as antigenic shift.

Thankfully, COVID-19 has not mutated this much to undergo antigenic shift; however, it is still a possibility.

So what causes a virus to mutate? There may be factors that increase its chance of mutating. For example, a drug that is used to treat COVID-19, called molnupiravir, may be a cause of mutated strains. It works by introducing so many mutations into the viral mRNA that it cannot replicate and therefore causes levels of covid to reduce in the body. However, it has recently been a concern that molnupiravir does not get rid of the virus completely so that in some cases, people who have taken the drug have low levels of a very mutated strain which they can transmit to others.

These little changes in the viral genotype can have huge repercussions on the world around us. As more mutations build up, the virus can become better adapted to get past our defences. This is the evolution of COVID-19.

The Evolution of Jellyfish

By Kayla Kirton

Jellyfish join sea anemones and corals in being classified as part of the Cnidarian phylum. The evolution of this phylum is one of the earliest: approximately 550 million years ago. However, this figure may not be very representative of their existence because the organisms were primarily soft-bodied (which did not fossilise well) until much later when skeletal structures developed that could form fossils and therefore give us an idea of the time period they existed. For this reason, it is agreed upon by most that the radial symmetry among organisms as well as the level of tissue organisation is primitive enough to indicate that their existence began much before many of the more complex organisms we see today. Radial symmetry is characterised by the arrangement of identical parts of an organism around a central 'axis' in a circular motion, while bilateral symmetry is where the left and right sides are mirrors of one another, this type of symmetry only developed much later (hence proving the distinction of cnidaria appearing earlier). In terms of the tissue organisation of cnidarians, it is exceptionally simple; they consist of only two tissue layers: the outer dermis and the inner gastrodermis, which lines the digestive cavity. Although it may seem small, this distinction is incredibly important as it was one of the first instances we have been able to identify tissue organisation which is now present in almost all organisms! For example, sponges (which were around before cnidarians and are still around today) were made of varying specialised cells that performed functions like gas exchange, but there were no organised tissues.

Jellyfish as well as cnidaria have specialised cells which allow them to 'sting'. These stingers appear on jellyfish and anemone tentacles. The cells that produce the sting are known as cnidocytes, which contain very specific organelles called nematocysts. These nematocysts contain coiled, hairlike threads that have millions of tiny barbs protruding off them as well as toxins. When prey (or an unsuspecting swimmer) makes contact with these tentacles, the cnidocytes will project the threads that were previously coiled and stored inside the nematocysts- these threads attach to the prey and release the toxins to stun them and that is how jellyfish hunt.

The evolution of this 'stinging' ability came from a very interesting place. Research shows that it was from the 're-purposing' of a neuron from a previous ancestor to the Cnidaria phylum that was able to produce cnidocytes. Both neurons and cnidocytes have a similar form and they both are capable of ejecting something out of the cell (neurons secrete neuropeptides and cnidocytes secrete poison-laced harpoons). But most organisms have neurons and only organisms within the phylum of cnidaria can sting like this, so what caused the change? Cnidocyte cells developed from a group of stem cells that could have also been neurons, they were able to do this by switching off the RFamide (the neuropeptide that could be secreted by neurons) and therefore repurposing the cell. It has been discovered that there is a single (cnidarian-specific) gene that is responsible for switching the cell from a neuropeptide-forming neuron to a harpoon-forming cnidocyte.

Jellyfish also have a rather interesting lifecycle. It can be split into two phases, the stalk phase (also known as the polyp phase) and the jellyfish stage (also known as the medusa phase). The medusa phase is the adulthood of the jellyfish, where reproduction will take place, eggs are fertilised and larvae are formed. These larvae will settle onto the seafloor and attach themselves at one end to the seabed. This is where polyps will develop; they will begin to feed and grow and when ready, some polyps will bud off into immature jellyfish. Jellyfish evolved this life cycle because they recycle existing genes to form polyps and then morph into medusas (essentially recycling damaged jellyfish to make more jellyfish). The change from an immobile polyp to a swimming medusa requires many changes within the jellyfish, these mainly having to do with the nervous system, muscles and defence mechanisms (their stinging cnidocyte cells).

Although jellyfish are not the most complex organisms to ever exist, they seem to have figured out how to survive early in their existence because not much has changed in their overall structure since then. They are incredibly interesting to study and are banks of information regarding the first specialisation of cells and tissue that we are able to study today. By sequencing and studying their genomes, we are able to access, evaluate and understand so much information about evolution. Jellyfish prove that evolution does not require complex genes to produce a long-surviving species.

May contain sensitive content – suicide, depression

The evolution of the recognition of the dangers of concussion in sport

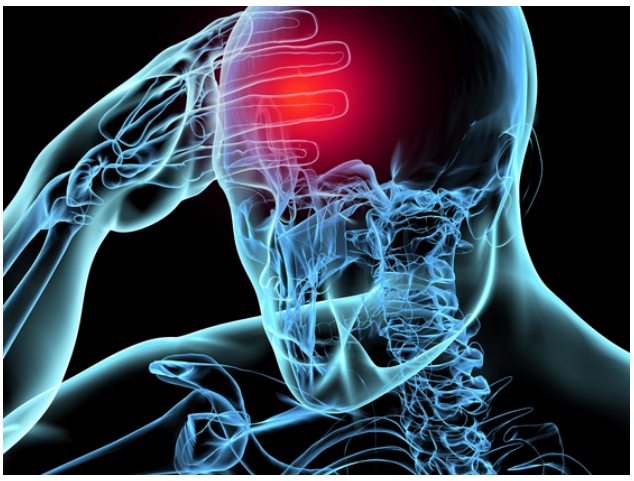
By Tilly Bowden

The concept that head injuries sustained during sports can cause long-term damage to the brain was first presented in the 1800s. Subsequent scientific research into this consequential damage has been progressive. However, the recognition by sporting bodies of the dangers of head injuries has been the opposite. In this article, I will be exploring what occurs in the brain during a concussion, the immediate and future problems that are caused by concussions, the history of research into these symptoms, and the evolution of how sporting bodies have reacted to this evidence.

A concussion is a traumatic brain injury (TBI) caused by a hit to the head, which results in the brain colliding with the skull. This impact can cause the relatively fragile neurons in the brain to stretch and even tear. These damaged neurons are now inhibited from relaying nervous impulses to and from the body, leading to impaired neurological function. Furthermore, when the damaged neurons begin to degenerate, they release harmful toxins, which can result in the death of other neurons around them.

Concussions can lead to a wide range of symptoms which vary from person to person. However, some of the most common symptoms include headaches, nausea, vomiting, memory loss, loss of consciousness and fatigue. However, a person may also develop post-concussion syndrome (PCS). PCS is when a person experiences the symptoms of a concussion but for longer than usual. PCS can last for months or even years, with a person experiencing mood swings, anxiety, depression, difficulty sleeping and difficulty concentrating. However, one of the major factors which increase the likelihood of developing PCS is exercising too soon after a concussion, a fact that in the past many sporting organisations have chosen to ignore.

Though PCS is an awful syndrome to live with, fortunately, it does get better over time with the right treatment and care. However, the same can't be said for other issues that concussion can cause, the most prevalent of which is chronic traumatic encephalopathy (CTE).



CTE is a degenerative brain disease, which is most common in athletes who play contact sports, but it is also found in the military and in those who have suffered domestic abuse. It is believed that the main cause of CTE is when a person is repeatedly subjected to head impacts, but these head impacts aren't so severe that they cause the symptoms of a concussion.

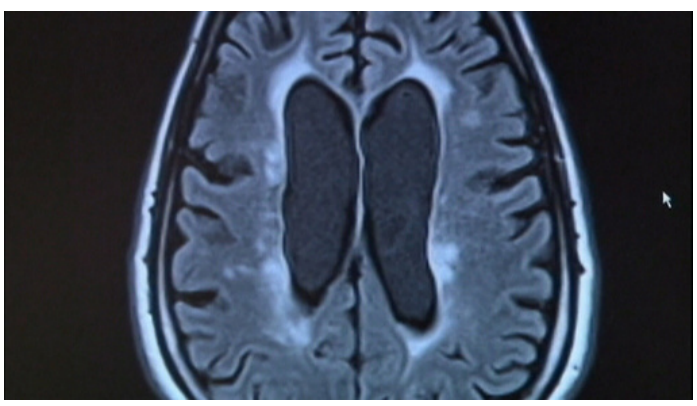
CTE can only be diagnosed by a brain biopsy when a person dies, and scientists use tissue staining to identify an irregular arrangement of the microtubule-associated protein tau (MAPT) in the brain. Tau is a protein used to stabilise the microtubules in the neurons in the brain, allowing nervous impulses to pass down the axon. In your brain, the MAPT must become phosphorylated, which it does by binding to certain parts of the brain. If it binds at the correct site, it will form trans p-tau, meaning the tau is healthy and can perform its normal function. However, if it binds to other parts of the brain, for example the C-terminal tail region and the proline-rich region, it can form the stereoisomer cis p-tau. Cis p-tau is very stable, meaning it's hard to dephosphorylate and becomes hyperphosphorylated. It will then dissociate from the microtubules (which it should be structurally supporting) and moves to other parts of the brain where it aggregates with other tau molecules to form neurofibrillary tangles (NFTs). These NFTs are what interrupt normal brain function and cause mood swings, aggression, anxiety, and dementia. Despite these severe symptoms, sporting bodies have chosen to ignore CTE and other effects of head injuries for over two centuries.

Concern about the dangers of head injuries began back in the 1800s when those who were most knowledgeable about the human brain worked in mental asylums as doctors. They coined terms such as “mental infirmity”, “traumatic insanity” and “moral delinquency” to describe the mental effects on those with previous TBIs. However, this knowledge progressed to the classification of types of brain injuries in 1841 by John Hunter, who divided them into three categories: concussion, compression, and brain wounds with loss of substance. John Hunter allowed scientists and doctors to base their treatment on the cause and type of injury, which allowed care to be much more effective. However, it wasn’t until 1928 that the concept of CTE was presented, although at the time they called it Punch-Drunk syndrome. Dr Harrison Martland discovered this syndrome when he noticed that when boxers were punched in the head they became unsteady, aggressive, developed impaired judgement and had poor memory. He believed that head blows created microscopic brain injuries, which eventually would develop into ‘degenerative progressive lesions’ in the brain. His ideas were made public in 1949, and so was the term CTE, when a British neurologist published a paper entitled ‘Punch-drunk syndromes: the chronic traumatic encephalopathy of boxers”.

At this point, the idea that head injuries had mental consequences had mainly been limited to the sport of boxing, thus other sports hadn’t started to implement safety measures. However, in 1952, a Harvard physician advised that athletes with 3 or more head injuries or concussions that caused them to lose consciousness should not play any contact sports again. This statement marked the beginning of the battle between science and sport, a battle that would eventually cost the NFL alone $1 billion.

The most famous example of a sport that has battled against CTE and its effects is American football when the NFL tried and failed to prioritise athlete safety after a head injury above the profile and profit of their sport.

The NFL only began to publicly address the concept of concussion in 1994, when they formed the Mild Traumatic Brain Injury committee (MTBI).



^CTE found in brain of 25-year-old football player

However, the MTBI was made of a football team doctor and a rheumatologist, who each had little knowledge of the human brain, and thus were unqualified to pass judgements and regulations about the actions athletes should take following a concussion. NFL commissioner Paul Tagliabue continued to refer to concussion as ‘pack journalism’, illustrating the NFL felt that concussion was a minor issue, something exaggerated by dramatic journalists who were overstating the dangers of concussion. Despite this, in 1997 the NFL did create new return-to-play guidelines, stating that athletes must be taken off the field if they had any symptoms of a concussion 15 minutes after the initial impacts. However, this guideline wasn’t often enforced, with athletes such as Wayne Sherbet (who was knocked out in a match in November 2003) being sent back onto the field.

However, it was from 2005 onwards that the problems for the NFL began. The early 2000s saw a flurry of suicides of ex-NFL football players. Some of these names include Mike Webster, Terry Long, Andre Waters, Dave Duerson and Junior Seau, the latter of whom killed himself after just two years of retirement. All these men had several traits in common – they were all retired football players, they all suffered from dementia/depression/other forms of mental illnesses, they were all aged 43-50, and should otherwise have lived long and healthy lives. However, most importantly, after their deaths, their brains were analysed by Dr Bennet Omalu who identified clumps of tau, thus evidence of CTE in their brains.

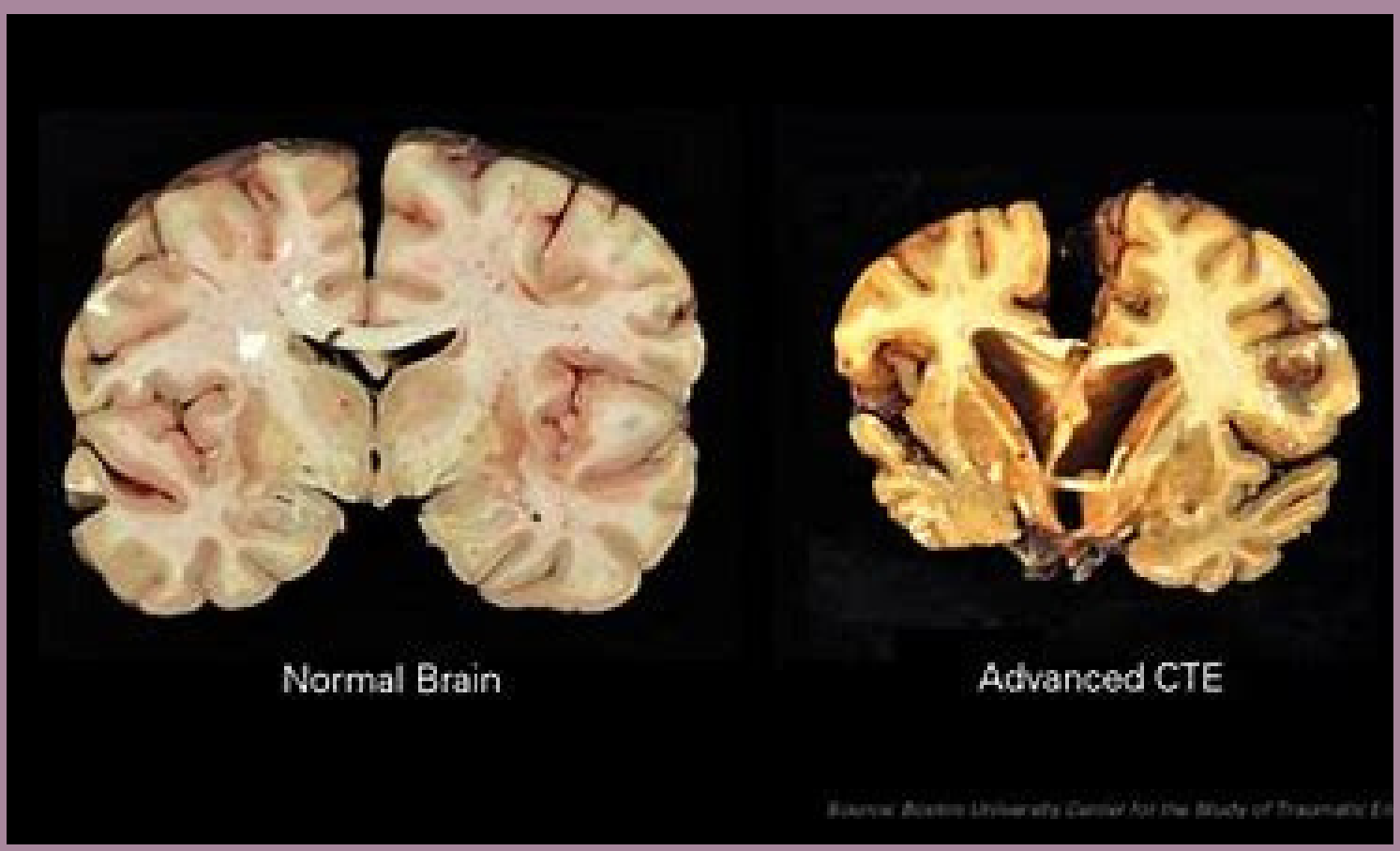
Despite this diagnosis, which clearly illustrates that there was a problem, the NFL tried to disprove these claims and even demanded that Dr Omalu retracted his report on the evidence he had found. They ignored a 2005 study published by Dr Kevin Guskiewicz and Dr Julian Bailes, who studied over 2500 former NFL players and concluded: “that the onset of dementia-related syndromes may be initiated by repetitive cerebral concussions in professional football players.” The NFL instead held a concussion summit, where they claimed that there is only evidence of CTE in boxers and it isn’t validly documented in football players. They also claimed that a study in early 2009 (which illustrated that former players are 19 times more likely to get dementia and/or Alzheimer’s) was flawed, and instead produced 16 papers disregarding and dismissing scientific evidence and the dangers of concussions.

They claimed that NFL players were actually less likely to sustain brain injuries because their players have tougher brains that were less susceptible to concussion than the rest of the general population.

Finally, a change began in November 2009 when the resignation of members of the MTBI committee resulted in the appointments of neurological surgeons as co-chairs. The MTBI was renamed the head, neck, and spine committee, and it began to recognise and act on the dangers of concussion. In fact, in December 2009, a spokesperson for the committee recognised that concussions could lead to long-term problems and they published new return-to-play guidelines, which stated that if an athlete was concussed, they weren't allowed to play again on the same day. The NFL also gave $30 million to the National Institute of Health for research on concussion and brain injuries and helped to create an athlete brain bank, headed by Dr Chris Nowinski and Dr Robert Cantu called the UNITE Brain Bank. They employed Dr Anne McKee and her team, who have now studied the brains of over 1300 athletes and military veterans. Unfortunately, the first 110/111 brains they studied from NFL had CTE, and 48/53 brains from college football players were also diagnosed with CTE. This data illustrates the severe problem that the NFL has, as they have created an environment where players are paying the price for their poor past regulations.

It's clear that the players have recognised the NFL's failings and are keen to bring justice to themselves and the families of those who have died from CTE. In 2011 a lawsuit was filed by over 4500 ex-players, led by Ray Easterling. The footballers said that the NFL engaged in a "concerted effort of deception and denial". However, before the hearing could begin Ray Easterling later committed suicide at age 62 and was then diagnosed with CTE. However, in his memory, the other players (over 1/3 of all the ex-NFL players) achieved justice. The NFL now must pay $765 million to players to compensate for the mental and physical damage they experienced due to the NFL's lack of acceptance of pure scientific evidence and fact.

In conclusion, over the last century concussion and its subsequent effects have had a vast negative impact on sports and the athletes who play them. Although scientific research into concussion and its most devastating consequence, CTE, has been accurate and valid, many sports (particularly the NFL) have refused to acknowledge and act on this research, because they are afraid of its consequences on the future of their sport. In not doing so, they have put the lives of thousands of athletes at risk and have failed in their biggest duty as sporting bodies, which is to keep their athletes safe.



One of Evolution's Wildest Creations: The Glass Frog

by Sophie Ray

Through evolution, nature has created many a wild and wacky things; one of the oddities it has crafted is the glass frog.

Glass frogs are found in the forests of Central and South America. The top part of the frog has a normal camouflage of either solid green, or green with white and yellow spots. The design of the green helps them blend into the forest, while the yellow pattern is very similar to their eggs. Male glass frogs use their camouflage of yellow spots to confuse the predators trying to get to their clutch (which is a mass of frog eggs).

The bizarre aspect of the glass frog is its underside (hence their name)- it is virtually completely transparent. This phenomenon is called edge diffusion. Edge diffusion helps to camouflage the frogs by making their edges blend into the relative brightness of their surroundings. Sometimes the transparency can extend onto their legs.

Many scientists have wondered how this eccentric trait arose. When these glass frogs sleep, 89% of their red blood cells travel to the liver. In the liver they have crystal-lined sacs, which reflect the light creating the frogs' transparency. Glass frogs are nocturnal, so they mainly sleep during the day. During the night they avoid being eaten by predators due to two thirds of their blood being hidden in the liver. The liver then increases in size and the absence of blood makes them nearly transparent.

The Pros and Cons of Technological Advancement

by Zoë Hopkins

Technology has evolved rapidly in the last few years. Nowadays, it is a major part of society and our dependency on it only continues to increase. Although there are many positive consequences to this, unfortunately, there are also negative implications and, as technology continues to evolve, you may wonder how this will impact you in the future. When you think of technology, most people only think of devices; however, in reality, technology is prevalent in many other aspects of our life. Dishwashers, microwaves and many other daily appliances use technology to allow us to complete tasks and handle our daily lives in easier, more practical ways.

The evolution of technology has helped to drastically improve efficiency in the workplace. Many businesses, for example, use technology to share information and automate tasks. This reduces work and costs for employees whilst increasing productivity. Technology also allows remote meetings and collaboration to take place, which means employees do not have to travel.

Another example of technology improving livelihoods is at home, where evolving technologies help us to cook and clean.

On the flip side, one of the biggest disadvantages of all of the progress is our increasing dependence on technology. Users can become completely engrossed in their mobile devices and can even develop nomophobia, the phobia of losing or being away from their phone. The technology that should be helping us can in fact severely impact people's lives and prevent them from leading a healthy lifestyle.

Research has shown that our dependence on technology can cause many problems with our mental, physical and emotional health. Problems can range from stiff necks to heightened levels of anxiety. It has also led to an increase in cyberbullying and reduced social interaction. As technology advances, we become more attached to and dependent upon these devices and this can be incredibly harmful.

I have only outlined the major pros and cons of the development of technology, and there are many other factors and arguments to consider. The evolution of technology has had a massive impact on everyone and will continue to impact us as it keeps evolving in years to come.

The Evolving Treatments for Female Reproductive Health Problems

By Holly Dulieu

Reproductive health problems are something which trouble many women each month. A new Public Health England survey has revealed that 31% of women experience severe reproductive health problems, with under half seeking help. In order to raise awareness and support those suffering from these, the Department of Health and Social Care (partnered with NHS England) has awarded sixteen different organisations funds, totalling £2 million, to support women in the workplace experiencing reproductive health issues.

One of the main reproductive health problems for women is endometriosis, with 1 in 10 women in the UK suffering from it, making it the second most common gynaecological condition and costing the UK economy £8.2 billion a year in treatment, loss of work, and healthcare costs. It is a condition where the kind of tissue that normally lines the uterus grows somewhere else, for example on the ovaries, the bowels, or on the bladder. This tissue can cause pain, infertility and heavy periods. Although it is a very common problem, it takes on average 8 years from the onset of symptoms to get a diagnosis.

Currently, there is no cure for endometriosis; however, there are different treatment options depending on the severity of the condition. Surgery can be used in more serious cases to alleviate pain by dividing adhesions or removing cysts. The surgery is usually done laparoscopically (keyhole surgery) and the surgeon can either cut out the endometriosis or destroy it using heat or laser. Another option is to use hormone treatments. These involve taking hormones which block or reduce the production of oestrogen: this means that the endometriosis will be unable to continue growing and will help relieve symptoms.

Although these treatments are effective in alleviating pain, a new treatment involving monthly antibody injections is now being trialled in people. Ayoko Nishimoto-Kakiuchi at Chugai Pharmaceutical in Japan has found that endometriosis tissue contains elevated levels of the gene IL8, which produces an inflammatory protein – IL-8. By blocking this protein, the inflammation associated with endometriosis tissue can be slowed or even reverse its progression. In order to test this theory, they developed an AMY109 antibody and injected it into macaques who were given surgically induced endometriosis. This was done by moving tissue from their endometrium to other areas of the body, such as the pelvis, imitating endometriosis in people. By the end of the six-week study, the lesions in the macaques with the antibody injected had shrunk to about half their original size whereas for those who didn't receive the treatment, their lesions continued to grow. A clinical trial is now taking place in humans which has the aim of providing a non-invasive treatment to help manage the symptoms of endometriosis.

Providing less invasive and more accessible treatments for endometriosis will not only help those suffering with the condition, but also the UK economy due to the amount of work missed each year by women suffering from it. The stigma surrounding female reproductive health problems makes it more difficult for women in the workplace to discuss these issues openly but by managing symptoms effectively using new and evolving treatments, women are able to feel more comfortable in their condition.

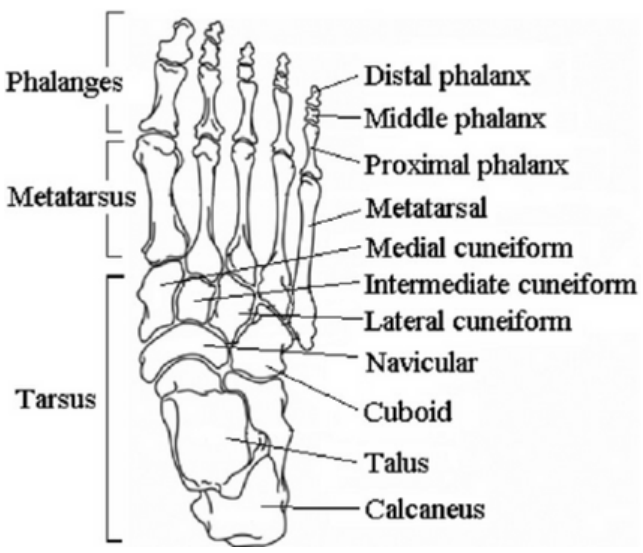
Why evolution is not a perfectionist – explaining some of the inefficiencies and flaws of nature

By Emma Penrose

Evolution and natural selection have resulted in the incredibly complex and diverse level of life that exists on Earth today. It means that organisms with advantageous characteristics are more likely to survive and pass on their genes to their offspring, and eventually the useful characteristic becomes common. However, there are many examples where organisms seem to be stuck with flaws and inefficient systems. Why do these flaws exist? Why do organisms evolve like that? A few examples include the human foot, the giraffe's recurrent laryngeal nerve, and pandas. I will be examining these flaws, and explaining how and why they evolved in such a seemingly disadvantageous way.

The Human Foot

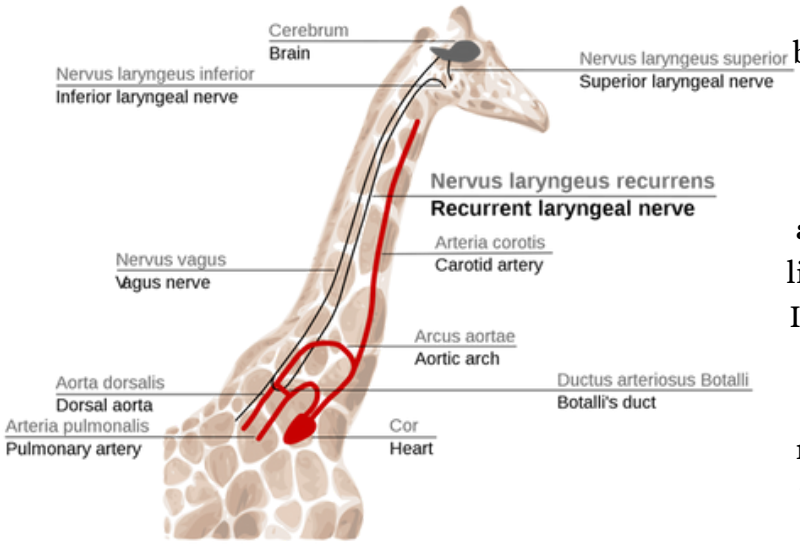
The human foot (shown below) is one example of evolution resulting in a flawed design. Our feet are too flexible and have too many bones – 26 in total – meaning that there is too much potential for them to twist inwards and outwards. The result is sprained ankles, broken ankles, plantar fasciitis, and more. This overcomplicated design evolved like this because of how the foot changed to enable our bipedalism.



Millions of years ago, Homo sapiens would have evolved from a species of primate that was quadrupedal (meaning they walked on four legs) and arboreal (meaning they lived in trees). The feet of arboreal primates need to be flexible and opposable in order to grip branches – their feet can be used in a similar way to our hands. To enable this, their feet have a large number of bones. However, when we evolved to be terrestrial (meaning we live on the ground) and bipedal (meaning we walk on two legs), our feet needed to become more stable in order to support and propel all of our weight. There were many adaptations for this purpose – our heel is very robust; we have an arch to act as a shock absorber; our big toe is no longer opposable and is aligned with the smaller toes. In some ways, the human foot is rather impressive. It helps to enable our effortless form of striding bipedalism, which makes us unique among mammals – other bipedal mammals (for instance, kangaroos) waddle or hop, while we stride. Regardless of this, as the foot evolved to be more rigid and stable, it didn't lose any of the 26 bones that belonged to our ancestors' feet. Therefore, the human foot has too many bones and is too flexible, and there is too much risk of injury. Evolution tends to result in something that is just good enough to survive, not necessarily perfect, and the flawed, overcomplicated design of our feet is a perfect example of this. So yes – to an extent, you can blame your sprained ankles on evolution.

The Giraffe's Recurrent Laryngeal Nerve

The recurrent laryngeal nerve goes from the brain to the larynx, and can be found in all tetrapods, which is a group of vertebrates that (in most cases) has four limbs. The larynx produces vocal sounds (it is where the vocal cords are, and is sometimes called the voice box) and helps to prevent foreign particles and food from entering the lower respiratory tracts. In giraffes, the larynx and the brain are only a few inches away, but their recurrent laryngeal nerve is much longer than that – it can be as long as 15 feet (about 4.5 metres). This is because instead of going the short, direct route, the nerve goes all the way down the giraffe's long neck and loops around the aorta before going up again to the larynx. The nerve takes the same indirect route in all tetrapods, but is particularly long in giraffes because of the length of their necks.



This indirect journey is pointless and inefficient, so why have tetrapods evolved like this? It is because of how they evolved from their fishlike ancestors. Tetrapods consist of all organisms descended from the last common ancestor of amphibians, reptiles, birds and mammals. This ancestor would have been a finned species that lived in water, similar to what we call fish today. In this fishlike ancestor, the recurrent laryngeal nerve would've taken a pretty direct route, as fish have no necks. However, as they began to move onto land and away from the water, their vertebral columns evolved to give them necks. Having necks allowed land animals to look around and down at the ground for food they might want to eat, and so was an advantage. Unfortunately, it also meant that the recurrent laryngeal nerve now had to be longer as it had to go down the neck and back up again. This way may not be the most efficient, but it gets the job done. As I said before, evolution doesn't always result in the best solution – just something good enough. Additionally, evolution can only work off of the original structures. The route of the nerve was established by tetrapods' ancestors, and this is simply the progression from that.

The Giant Panda

The giant panda, more commonly known simply as the panda, is a species of mammal in the bear family, Ursidae. Pandas are loved by the world for the simple reason that they are very, very cute. Despite this, pandas are often criticised for having systems and features that are extremely inefficient and seem to hinder their survival as a species. One of these features is their digestive system. Pandas are strange bears in that they are herbivores instead of carnivores. They eat almost exclusively bamboo – it makes up 90-98% of their diet. However, pandas' digestive systems haven't changed much from their carnivorous ancestors', meaning they are poorly adapted to their herbivore diet. They do not have the appropriate enzymes to digest cellulose, and instead rely on bacteria in their intestines to break it down. Despite the presence of these bacteria, pandas can only digest about 17% of the bamboo that they ingest. Their solution for this is to spend most of the day – about 16 hours out of 24 – eating. They must then eliminate waste about 50 times a day. It goes without saying that this is not exactly an efficient system.

Another problem with pandas is that they don't appear to be very good at reproducing. Females only ovulate once a year, and then they only stay in heat for about three days – a very small window. Additionally, males do not instinctually know how to mate. For instance, Hsing Hsing and Ling Ling, two pandas in the National Zoo, tried for 10 years to mate before they were successful. At first, Hsing Hsing attempted to mate with Ling Ling's ear, wrist and foot.

It must be acknowledged that they seem to have more success at mating in the wild than in captivity. In the past, we have not understood pandas' communication systems involving scents and vocal calls in the run up to mating. As a result, when we tried to skip this whole process when we bred them in zoos, we had little success. Behavioural research into the subject has resulted in an increased success rate in recent years. Additionally, even though females are only in heat for three days a year, this is normally enough to maintain their population, especially since pandas have very few natural predators. Pandas may appear to not reproduce very much, but it was enough for their species to survive until more recently.

So why have pandas evolved in such a detrimental way? Regarding their diet and digestive system, it is theorised that pandas split off from other bears at a time when meat food sources were in low supply. Therefore, pandas evolved to eat what was at the time a plentiful food source, instead of trying to outcompete other predators for meat. This food source was of course bamboo. Although their digestive system is flawed, pandas could survive just fine when bamboo was plentiful by ingesting very large amounts.

Pandas were able to survive like this – until humans destroyed the bamboo forests. As a result, pandas are now unable to ingest the large amounts of bamboo they need, and their inefficient systems cannot absorb enough nutrients. Their reliance on bamboo made sense as an adaptation long ago, but when their environment changed because of humans, it became a massive disadvantage.

There are countless other examples of such flaws and inefficiencies as a result of evolution, but I found these three particularly interesting. The common theme is that evolution does not result in the absolute best solution; just something that works well enough to survive. Indeed, evolution is very much not a perfectionist. If the aim is only something that is 'good enough', then can some of these flaws be excused? In some cases maybe, but that is perhaps more a matter of opinion.

A species that evolved past the need for men (sorry men)

By Mollie Patterson

The New Mexico Whiptail (A. neomexicanus) is a species of lizard found in the Southern United States (New Mexico and Arizona) and in parts of northern Mexico. What is particularly extraordinary about the New Mexico Whiptail is that their species is comprised entirely of females. With this in mind, these lizards are commonly nicknamed “leaping lesbian lizards”.

Being a unisex species, the New Mexico Whiptail faces some challenges when it comes to reproduction. Most animals reproduce by sexual reproduction; male and female gametes (sex cells), each containing half a complete set of chromosomes, fuse together during fertilisation. This forms a zygote with a full set of chromosomes, which will divide to form an embryo. The New Mexico Whiptail reproduces asexually instead in a process called parthenogenesis. Literally meaning “virgin birth”, parthenogenesis describes the method of reproduction by which an egg can develop into an embryo without fertilisation occurring.

Offspring produced from sexual reproduction are genetically varied, with the daughter organism having received a unique combination of maternal and paternal chromosomes. Asexual reproduction on the other hand, will typically produce a genetically identical genome in the offspring- they are clones of their parent. Members of a population sustained by asexual reproduction will therefore share all the same weaknesses, causing them to be particularly vulnerable to changes in the environment and disease (negative mutations will also accumulate over generations)!

Curiously, New Mexico Whiptail lizards show genetic diversity, and maintain their gene pool across generations, dodging the pitfalls of asexual reproduction. The New Mexico Whiptail achieves this as a result of cells duplicating chromosomes twice before undergoing meiosis to form egg cells that are diploid and haven’t lost genetic variation.
The all-female quality of the population is also maintained in the population as the mother will only have X chromosomes to pass on, determining the offspring’s sex as female. By this method of conserving genetic variation, the New Mexico Whiptail can harness the evolutionary benefits that asexual reproduction brings- this includes saving energy and resources that would otherwise be spent finding a mate and enabling population growth to occur at a much faster rate.

These remarkable lizards evolved from a hybridisation event of the Little Striped Whiptail and the Western Whiptail. The hybridisation of these species resulted in the males produced being sterile; this drove the evolution of the New Mexico Whiptail as a separate species that was capable of reproduction.
This combination of inter-species hybridisation and parthenogenesis isn’t a trait unique to the New Mexico Whiptail; however, it’s been recorded in many other species of animal. In fact parthenogenesis has been observed in over 80 species of vertebrate, about half of which are fish or lizards, in addition to those small invertebrates such as bees, wasps, ants, and aphids, which are able to alternate between sexual and asexual reproduction.

‘The Last of Us’: Science fiction or a premonition for the evolution of mind-controlling fungi

By Juliana Cotton

In the dystopian, post-apocalyptic world of ‘The Last of Us’, the parasitic fungus ‘*Cordyceps*’ has mutated to infect the brains of humans, reducing them to aggressive and violent creatures intent only on spreading the infectious fungus to the entirety of humanity.

Considering that we ourselves have only recently begun recovering from a pandemic of our own, the rising fame of HBO’s latest hit adaptation leaves us as a society to question whether this mysterious fungus could realistically evolve to take away the control we have over our own bodies, potentially wiping out humanity as we know it.

‘*Ophiocordyceps unilateralis*’, as it is officially named, currently can only infect formicine ants like carpenter or bullet ants (generally found in tropical rainforest ecosystems).
The exceptional chemical capability of cordyceps allows it to manipulate and take control of the motor functions of its host by growing and dispersing fungal cells all around the brain and throughout the muscles of the ant. By altering the ant’s behaviour, the infection causes it to become more erratic and furthermore possesses the ant’s muscles to seek high ground on plants—so as to access more sunlight and warmth as required for the ideal conditions for the growth of fungal reproductive structures, but also to maximise the distribution of the airborne fungal spores from the ant carcass to the rest of its own nest population.

In addition to this, on a more off-putting note, considering the fungal cells which permeate throughout the ant’s body never actually touch or invade the brain itself, the reality could be that throughout the whole process the ant is actually still conscious and its mind unaffected, like a prisoner trapped in its own body, doomed to knowingly endanger its entire nest.

What’s protected us from serious fungal infections like this thus far has been our own warm body temperature of around 37 degrees celsius, which has so far been too hot for most fungal species to survive, let alone successfully spread an infection as they generally prefer a range of between 25 to 30 degrees celsius. However, the hypothetical worry following many increasing concerns surrounding climate change and the rise of global temperatures, is that potentially the difference between the environment of the fungus and our own body temperature won’t be as dramatic, hence possibly making it easier for fungi that have evolved to cope with warmer outdoor temperatures to also be able to survive within human bodies.

Although luckily for us, we don't have to start preparing for the apocalypse just yet (at least not in the sense of a body-possessing fungi pandemic)! Despite the tremendous capabilities of Cordyceps fungi within insect populations, it is quite unlikely that a Cordyceps variant could ever be able to mutate or evolve enough to successfully invade and fully take over a mammalian host for a multitude of reasons.
Firstly, the majority of Cordyceps species are so specialised to their specific host that even jumping to another species of ant or simply an ant in a different area of the world is unlikely. Insects in themselves are so different to humans in terms of their composition (ie the carbohydrates that they're made of), that in order to be successful in manipulating a mammalian host, a fungal parasite would have to evolve new enzymes. As a result, despite the Cordyceps fungi having been evolved more than 65 million years ago (as theorised from fossil specimens identified from amber), they haven't yet made the switch to warm-blooded hosts.

Even if a mutated variant of Cordyceps managed to get into our systems via an infected food supply, as depicted in the world of 'The Last of Us', the likelihood of it causing a problem via ingestion is very low - for even if it somehow miraculously evolved to withstand the temperatures reached in a microwave or oven, it would still probably be killed off by the low pH acid in our stomachs.

We can also assume that the specific "mind-controlling" characteristic of '*Ophiocordyceps unilateralis*' might not even translate in humans based on how we're currently affected by fungi like psilocybin (more commonly known as magic mushrooms).

Psilocybin mushrooms have mind-altering properties in humans, although their effects fade upon the fungus leaving the digestive system— so if we applied this concept and say that a Cordyceps fungus did somehow against all odds manage to bypass all our defence systems and our mind was altered, so to speak, we highly likely would not be affected in a chronic sense or to the extreme extent that they are portrayed as in the video game/tv show.

So in conclusion, any strain of Cordyceps fungi would require masses of evolution to impact us as a species at all and there is no rational reason to be concerned about an imminent mushroom apocalypse... or is there?

Climate change is still a large risk factor for worrisome fungal diseases and pathogens - particularly the relatively new fungus (identified 2009) '*Candida auris*', which not only thrives in higher temperatures but can also cause severe infections and even death if it gets into the bloodstream (though the risk is significantly higher for those who are immunocompromised).

Contrary to Cordyceps, infected patients can transmit the pathogen to other people, which has already led to outbreaks across nursing homes and healthcare facilities. Furthermore, it is often multidrug-resistant, resulting in fewer treatment options and, despite its relatively new emergence, it can already be found on multiple continents and in more than 30 countries.

So even though 'The Last of Us' thankfully has more roots in fiction rather than fact, the awareness it brings to fungal infections and pathogens such as *Candida auris* is incredibly useful and will perhaps stimulate more research into the field and more drug companies to invest in more effective antifungals that could save many immunocompromised people.

Treating anxiety: the evolution of behavioural therapies

By Clarissa Soto-Rosa

What is anxiety?

Anxiety is defined as a feeling of unease, such as worry or fear, that can be mild or severe. It is, at its core, a part of evolution, activating a fight or flight response within the body to keep an individual safe from harm. Anxiety disorder, however, is when the fight or flight system is malfunctioning, and you get feelings of anxiety, when there is no stimulus to cause it. Everyone experiences feelings of anxiety at some point in their life, but some people find it harder to control, experiencing it constantly in such a way that can affect their daily life. Anxiety is the main symptom of many cognitive disorders, such as panic disorder, post-traumatic stress disorder, anxiety disorders and phobias. Therefore, targeting it directly can help to treat and alleviate symptoms of other disorders.

GAD

Generalised anxiety disorder (GAD) is a long-term condition that causes the individual to feel anxious about a wide range of situations on frequent occasions, rather than about one specific event. Furthermore, for those with GAD, once one anxious thought is resolved, they may soon begin to experience another, leading to constant feelings of anxiety. GAD can cause both psychological and physical symptoms. These vary from individual to individual, but often include feeling restless or worried, having trouble concentrating or sleeping, and experiencing dizziness or heart palpitations. The exact cause of GAD is unknown, but it is thought that many factors play a role. Amongst these are genetic influences, traumatic experiences and having a long-term health condition.

Treatment

Though self-help such as looking after your physical health is recommended for managing anxiety, there are a range of treatments available for those with GAD. These include psychological interventions such as talking therapies, and guided relaxations. One of the most effective therapies, which has increased significantly in popularity over recent years is cognitive behavioural therapy (CBT), which helps to manage anxiety by challenging thoughts and re-wiring thought patterns. Applied relaxation focuses on relaxing muscles in a specific way during situations that tend to cause anxiety. It often involves learning to relax muscles, particularly in response to a trigger, such as the word “relax” and practising relaxing your muscles in situations that make you anxious. Alternatively, medication can be used to treat GAD. Depending on symptoms, medication can be used to treat both physical and psychological ones. Often, the first medication offered is a type of antidepressant called selective serotonin reuptake inhibitors (SSRIs). It works by increasing the level of the chemical serotonin in the brain, which is associated with mood regulation.

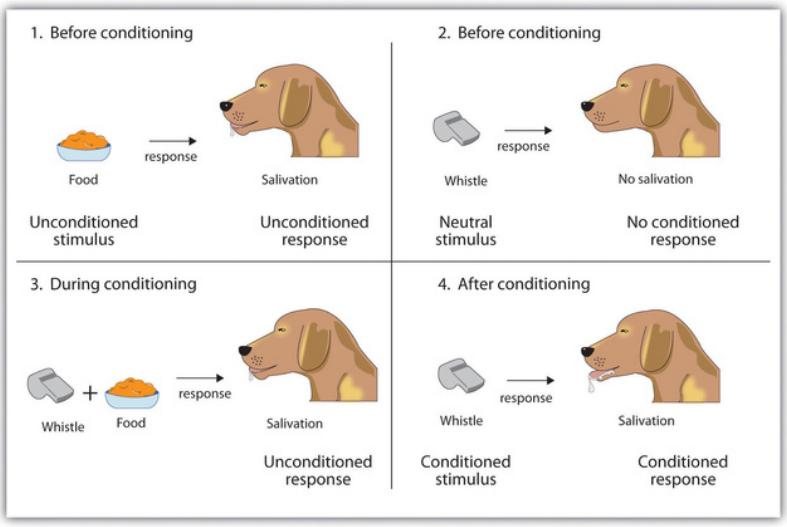
The emergence of behavioural therapy

Behavioural therapy began in the early 1900’s and became established as a psychological approach in the 1950s and 1960s. There were a number of psychologists that contributed to the development of behavioural therapy.

It is rooted in the principles of behaviourism, a school of thought that focuses on the idea that we learn from our environment. The three main assumptions of the behavioural approach are that external forces in the environment shape our behaviour (i.e., it is determined), explanations of behaviour emphasise the role of nurture more than nature, and that it aligns itself strongly with the scientific method.

The evolution of behavioural therapy

The origin of behavioural therapy began with Pavlov's work on the process of classical conditioning, where his discovery of conditioned salivary reflexes led to many new findings. He was investigating the salivary reflex in dogs when he noticed that animals not only salivated when food was placed in their mouths, but also reacted to stimuli that coincided with the presentation of food, such as the presence of the food bowl or the person who fed them, which led him to explore the conditions under which this would be likely to occur. Pavlov also discovered that if he rang a bell shortly before presenting the food to the dog, eventually the ringing of the bell on its own would be enough to produce the response of salivation.



The treatment of anxiety

The British form of behavioural therapy emerged in the early 1950s and concentrated on anxiety disorders in adults such as agoraphobia, obsessive-compulsive disorders (OCD) and social anxiety. Wolpe, a psychologist, used the findings of an investigation on experimental neuroses (mental disorders marked by anxiety or fear) in animals to develop practical clinical techniques for treating human neuroses. He perfected systematic desensitisation as an effective method for treating human anxiety. He discovered that unpleasant stimulation placed onto restricted animals can produce neurotic disturbances, which led him to develop a theory on the conditioning of human fears by adapting a method of overcoming phobias in his experimental cats onto the treatment of human phobias and anxiety. Wolpe's research on exposure treatment has become one of the most effective and used psychological treatments and is still used today. He also perfected systematic desensitisation as an effective method for treating human anxiety. It was first used on cats to overcome a fear by exposing them to situations of increasing intensity which evoked a fear response until all signs of anxiety disappeared.

This technique can be applied to humans, where patients may be asked either to imagine anxiety-inducing situations or to actually deal with feared objects or situations

Before beginning the procedure, however, a hierarchy of fears is constructed between the patient and the therapist in order to incrementally tackle it. The patient is also often taught relaxation techniques to be able to cope in this anxiety-producing situation. B. F. Skinner was another psychologist who was involved in the development of behaviour therapy. Throughout his work on animal learning, Skinner found that the establishment and extinction (elimination) of responses can be determined by reinforcing a behaviour, or in other words, by rewarding it. The times during which rewards are given are known as a "schedule of reinforcement", and the gradual change in behaviour towards a desired result is known as "shaping".

The combining of behaviour therapy and cognitive therapy

In the 1960s, therapist Aaron T. Beck set out to prove that the theories behind psychoanalysis, and the treatment of depression, in particular, were valid. However, he instead identified 'distorted, negative cognition (primarily thoughts and beliefs) as a primary feature of depression'. He used these findings to develop a short-term treatment designed to test and challenge the thought patterns of the patients with depression. This treatment was labelled cognitive therapy, which is now known as cognitive behavioural therapy, and proposes that dysfunctional thinking is behind all psychological disturbances. There are now several approaches within the scope of CBT, but they all share the theoretical view that cognition influences how a person feels and behaves, and that a person can use their cognition to change their behaviours. The therapist talks to the client to understand their beliefs and behavioural patterns and then uses that knowledge to produce cognitive, emotional and behaviour change by modifying their thinking and belief system. Treatments focus on the processes of cognition, cognitive reappraisal, behaviour change, and emotional regulation to reduce distress, improve functioning, and enhance wellbeing.

The adoption of these cognitive concepts into therapy was inspired by the development of cognitive psychology, but also by a desire among psychologists to be more attentive of humanistic needs and the emotional concerns of their patients. Within behaviourism clinical conversations and analyses were often seen as distractions for the patients to make their way up to the anxiety hierarchy, so cognitive behavioural therapy seemed to be an approach which looked at both the treatment and the well-being of the patient.

The Evolution of Immunity and Immune Systems

By Annissa Cheng

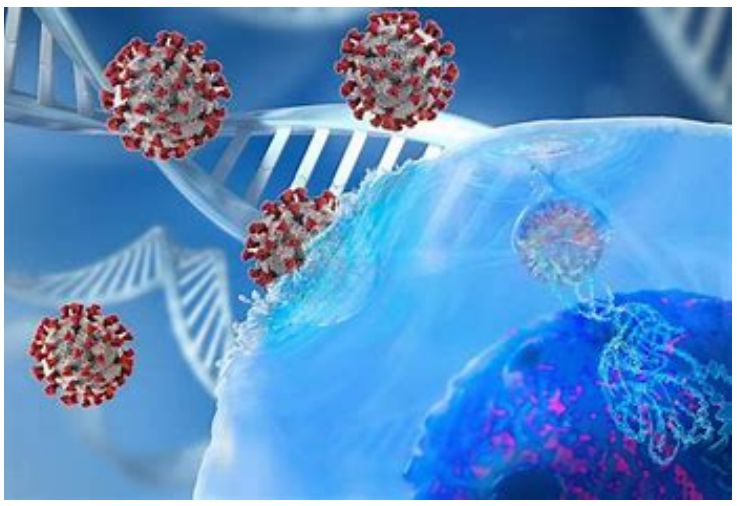
The study of the evolution of immunity and immune systems is an area of study that spans multiple fields of research, including immunology, genetics, ecology and evolution. To defend organisms from pathogens and other environmental dangers, the immune system has advanced in complexity and sophistication over time, enabling organisms to protect themselves against a vast range of pathogens. Below, I will explore the evolution of immunity and immune systems from the simple immune systems found in the earliest forms of life to the modern and sophisticated immune systems found in modern-day mammals.

Early-Day Immune Systems

The earliest forms of life on Earth had a rather simple immune system. They relied heavily on the more natural immune mechanisms in their bodies such as phagocytosis, antimicrobial peptides and physical barriers to protect themselves against pathogens. For instance, the mucous membranes and the outer layer of cells that cover the skin serve as a physical barrier to keep pathogens out of the body. These protections were basic, yet were successful in warding off pathogens and diseases.

Immune Systems in Invertebrates

Due to the emergence of multicellular organisms, immune systems have become more and more complex. For example, invertebrates (cold-blooded animals without a backbone) have a primitive immune system that consists of specialised cells called hemocytes, which sort of resemble white blood cells in the human body since hemocytes can recognise and engulf pathogens and produce antimicrobial peptides that kill bacteria and fungi.



Immune Systems in Vertebrates

Vertebrates (organisms with an internal backbone) have a much more complex and developed immune system compared to invertebrates, which includes both innate and adaptive immunity. Similar to the invertebrate immune system, it contains physical barriers, phagocytosis and antimicrobial peptides. However, the adaptive immune system, which is more complex and specific, is unique to vertebrates and is capable of identifying and reacting to a vast range of pathogens. This adaptive immune system is based on the cells of the immune system's ability to identify and react to specific antigens. Antigens are substances that cause the body to make an immune response against them. Immune cells in the body produce antibodies that can recognise specific antigens and bind to them, causing pathogens to stick together, making it easier for phagocytes to engulf them with their pseudopodia.

Along with the innate and adaptive immune systems, mammals also have specialised immune cells in certain organs, e.g. lymph nodes, spleen and the thymus, which are essential for the development and regulation of the immune system.

Evolution

The evolution of the immune system occurred in two different stages: the first stage involved the development of a diverse set of immune receptors that recognise a variety of antigens (developed through the process of genetic mutation); the second stage involved the development of mechanisms that could select and increase immune cells which can recognise particular antigens. This is known as clonal selection and ensures that the adaptive immune system is specific and effective.

The immune system has undergone complex development and is very different from how it used to function. However, it is still constantly evolving and adapting to the immune systems of its hosts. In order to keep up with the constantly changing environment, it is crucial to understand the importance of developing new ways to treat infectious diseases and pathogens, while maintaining the health and survival of living organisms.

AI: Could this evolving technology change the future of healthcare?

By Rawnaq Islam

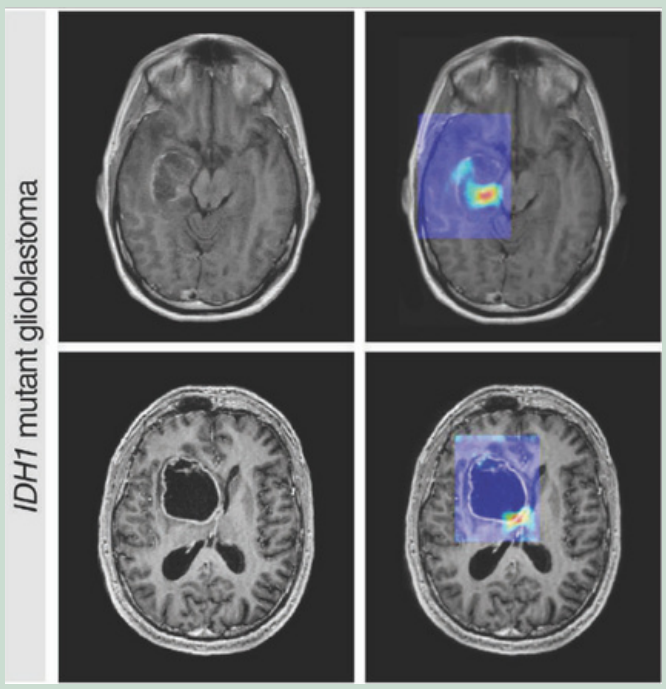
Being a controversial advancement in technology, artificial intelligence (AI) has often been depicted in the media as villainous robots that will "take over the world". However, artificial intelligence could revolutionise and personalise targeted healthcare for individual patients - this exciting technology has the potential of saving lives and improving healthcare for millions of people around the world.

Artificial intelligence is the process of educating and training a computer model by "feeding it" complex and large data sets. The AI model is then able to take in new information and make a decision or predict an outcome based on the information it already knows. Without even realising it, artificial intelligence has already found itself in so many aspects of our daily lives. For example, when Netflix uses your viewing history to deliver new show recommendations, or when you unlock your smartphone using Face ID, AI is used to compare the scan of your face with what it already has stored to determine if it's the correct person. But AI could also be used to determine whether a treatment option is likely to work, based on the experience and past information of thousands of other patients.

Cancer is an aggressive disease with, unfortunately, a low median survival rate. Diagnosing cancer can be especially complex, both for doctors when diagnosing a primary or secondary cancer, and for patients when understanding the risks and success rates of their treatment options. Although it is immensely difficult, it is essential to accurately diagnose cancer at its early stages and determine an accurate prognosis prediction to enhance a patient's chances of surviving. However, artificial intelligence could be used to help speed up this process so that the treatment which doctors know will work for a patient's specific cancer can be quickly delivered. This involves feeding an AI model: patients' genetic information from a tissue biopsy, data on their blood tests and X-ray images of their suspected lesions. The highly trained AI model can then interpret this data, making a highly subjective task that relies on humans more straightforward and accurate.

However, it is very challenging to translate AI research into routine clinical practice. There are privacy concerns surrounding AI because it develops and becomes more intelligent based on the information it is fed, it may be susceptible to security breaches and cyberattacks. It's also essential to ensure that the data used to train the algorithm is representative of the whole human population, to prevent bias and inequality. For example, if an AI model that is used to detect skin cancer has only been trained on a predominantly white population, it may fail to detect the skin cancer in a patient of colour. This, however, may prove to be difficult as skin cancer disproportionally affects white people, due to their lack of melanin; therefore, there are larger data sets available for those patients. This means that a functionality needs to be built in AI models to output something similar to "I don't know" or "this is my best guess based on a biased training population" for low-confidence results, such as an Asian patient in this example.

However, when used in conjunction with medical experts, artificial intelligence is a gateway to a more refined and detailed understanding of human health than we have ever had before. With quality oversight, this constantly evolving and adaptive technology could transform healthcare.



^On the LH side, a radiologist has outlined the area where he believes is a growing prostate cancer. On the RH side, AI has done the same thing- the results are close to identical.

How disease has impacted human evolution - a close look into malaria

By Sora Kamide

Infectious diseases have shaped the whole history of humanity.

The Antonine Plague, the unknown disease brought back to Rome by soldiers returning from Mesopotamia around 165AD, killed over 5 million people and decimated the Roman army.

The Plague of Justinian, an outbreak of the bubonic plague that afflicted the Byzantine Empire and Mediterranean port cities, killed up to 25 million people in 541-542, which included up to a quarter of the population of the Eastern Mediterranean and devastating the city of Constantinople, where at its height it was killing an estimated 5,000 people per day and eventually resulting in the deaths of 40% of the city's population.

The disease we are all familiar with, Covid-19, was first identified in an outbreak in the Chinese city of Wuhan in December 2019. There have been 672 million cases and 6.85 million deaths as of today.

Other diseases such as tuberculosis, malaria and fungal diseases still kill millions of people around the world.

Therefore, since the beginning of humanity, there has been a constant competition between humans and pathogens which triggers evolution. This is essential for the survival of our species.

Evolution is a gradual change to the DNA (allele frequencies) in a population over many generations which may result in a new species forming. One way it can occur is by natural selection, which is when certain traits created by genetic mutations give the organism a selective advantage, helping it survive and reproduce, passing their alleles on to the next generation. Gradually, these mutations and their associated traits become more common among the whole group.

However, the ability of modern medicine to keep humans alive makes it tempting to think human evolution may have stopped. Better healthcare disrupts a key trigger of evolution ("survival of the fittest") by keeping some people alive longer, making them more likely to pass on their genes. Yet, from looking at the rate of the human DNA's evolution, it is clear that our evolution has not stopped; it may even be happening faster than before.

By looking at global studies of our DNA, there is evidence that natural selection has recently made changes and continues to do so. Although modern healthcare frees us from many causes of death, populations are continuing to evolve in countries without access to good healthcare.

Malaria is a deadly disease caused by the microscopic Plasmodium parasites, which are most commonly passed on from person to person through the bites of infected female Anopheles mosquitoes. Survivors of malaria can drive natural selection by giving their genetic resistance to their offspring.

When the Plasmodium parasites enter the body, they first travel to the liver to mature and multiply. They then get released from the liver cells and attach to red blood cells. Once there, they feed off the haemoglobin found in red cells and continue to multiply. This eventually makes the cell explode and releases the parasites which continue the cycle of infecting, propagating, and damaging other cells. As the parasites multiply, it can reduce the number of healthy circulating red blood cells significantly, which are responsible for transporting oxygen around the body. This can lead to much more severe health complications like severe anaemia and cerebral malaria (when parasite-filled red blood cells block small veins in the brain). In the most serious cases, malaria results in death.

However, researchers have found that the human body is naturally evolving to reduce the hospitality of red blood cells towards the malaria-causing parasites. This mutation in our blood is called sickle cell disease (SCD).

So, is sickle cell disease a friend or a foe?

The main purpose of red blood cells is to carry oxygen around the body. To do this, they contain the haemoglobin protein for binding to oxygen molecules and maintain a flexible biconcave disc shape to easily pass through the smallest of blood vessels.

However, in SCD, the haemoglobin's structure is altered which results in red cells developing a rigid, sickle-cell form. This greatly interferes with the red cells' oxygen-binding abilities and even causes them to stick and block blood flow. The combination of these 2 factors leads to a lack of oxygen in different areas of the body. As a result, millions of SCD sufferers experience symptoms like intense pain, fatigue, organ damage, infection susceptibility, and early death.

Researchers found a genetic connection to the anatomical abnormalities seen in blood cells 70 years ago. A mutation seemed to be causing the moon-shaped blood cells. The most severe form of the disease occurs when two copies of the mutation are inherited. However, patients with one sickle cell gene, referred to as sickle cell trait, usually do not have any of the signs of the disease and live a normal life, but they can pass the trait on to their children.

Why does this genetic blood mutation continue to persist despite its serious consequences? The theory of natural selection would assume that something so harmful should have been eliminated by evolution to ensure survival.

This is because, despite its life-threatening symptoms, SCD has some favourable health benefits: it protects humans from malaria. The theoretical link between SCD and its malaria-protecting effects first came about after researchers started examining why SCD is so prevalent in areas where there is a high risk of malaria. Sub-Saharan Africa carries more than 75% of people globally with SCD, which is where malaria also remains endemic. Therefore, humans began developing the abnormal sickle cell gene as an evolutionary response to malaria as the parasite is halted by sickled cells, making people who carry this trait more resistant to the disease.

Our immune system is essential to combat pathogens, but the immune response can become dysregulated (cause a dysfunctional level of an activity or chemical in an organism by disrupting normal function of a regulatory mechanism), and cause other health problems. Some genetic mutations can help people fight off infections, but those same beneficial mutations may also make people more likely to have other diseases. This means that our ancestry can influence the likelihood to develop disease, depending on our environment.

Therefore, there is a balance.

Humans build defences to fight diseases but we cannot stop diseases from happening. What makes us strong on one hand can also make us weak on the other.

Should we colonise Mars?

By Sahana Pandya

“If we don’t colonise Mars and other planets, we may not survive climate change, disease and other versions of doom”, said Stephen Hawkings in 2017. In fact, this famous physicist’s DNA is currently stored in a time capsule at the International Space Station (ISS). Scientists have done this to preserve human DNA, in case a terrible calamity occurs on Earth, leading to the extinction of the human race.

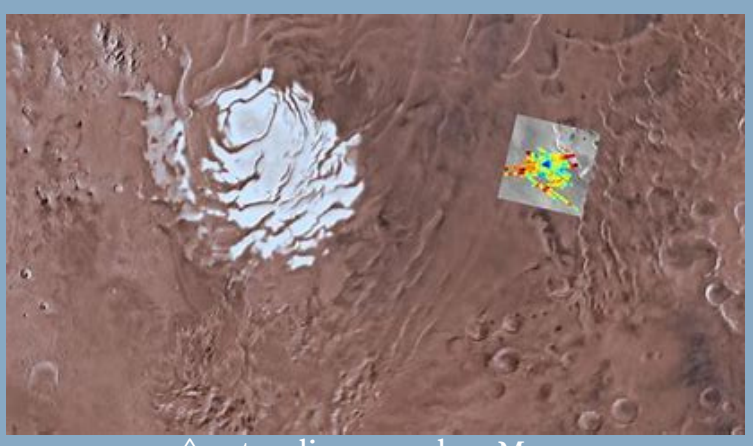
Earth's human population recently reached 8 billion people and is constantly growing every second. Scientists believe that our planet won’t have enough resources to support us in the future. Mars is considered our main refuge because it has gases needed for life (such as oxygen, carbon, hydrogen and nitrogen). Not only this, but there is also water (a vital compound needed for the existence of life) in the form of a huge frozen lake said to be 100m deep if melted.

Although this sounds very compelling, some believe that this is a terrible idea due to the large costs of trying to colonise a planet in outer space. Additionally, it will take a very, very long time to travel to Mars. Even if humans managed to get to Mars, it would be full of challenges such as the harsh temperatures and the atmosphere; the atmosphere on Mars is mainly made of carbon dioxide and is one hundred times thinner than on Earth. This would make breathing impossible without special breathing apparatus. As well as this, Mars doesn’t block the sun’s rays of ultraviolet radiation that much at all which would be very dangerous (due to risks of sunburn and skin cancer).

So, maybe this is not a good option after all. Perhaps we could change our ways and help our vulnerable planet before it is too late?

What do you think? Should we change? Can we change for the better future of our planet Earth?

^planet Mars



^water discovered on Mars

^ideas of what life could look like on Mars

My Trip to the Kennedy Space Centre

By Audrey Brown

February 18th 2023

Over the holidays, I went to the Kennedy Space Centre in Florida and I got to see most of the spacecrafts that have travelled into space. The one which I thought was most fascinating was Atlantis: a space shuttle designed to launch like a rocket and land like a glider.

The other thing I loved was the spacecraft simulator. It showed you what it was like to be in a spaceship in reality. First, it tipped us up so we faced the ceiling. We learned that astronauts may have to be upside down for hours! Then, when we were back upright, we started vibrating very hard. That was what it felt like to take off, just without the G-forces. (G-forces is when you are going REALLY fast, up or down, and your stomach lurches.)

Did you know?

Atlantis was designed to be reusable, so they didn't have to make one every time. In twenty-six years Atlantis had thirty-three missions and now it's on display at the Kennedy Space Centre. Also, the last flight happened at 10:59 pm on the 17th of February 2023.

At school, my favourite thing to learn about was the Apollo missions. Even though Apollo XI got to the moon, not all the missions after that succeeded. In Apollo XIII, (not NASA's finest hour) everything went wrong. The CO_2 levels were too high, the ground crew (the ones back on earth) shut off all the electricity to try and get the boosters to start working, and loads more. Even after all of it, they unfortunately didn't make it to the moon but they made it home in the end which I think is a big accomplishment.

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Did you know?

The first Apollo mission (Apollo I) was set to take off on February 21st 1967 at the Cape Kennedy Centre when, during a test on January 27th 1967, a fire broke out in the Command Module (the part of the spaceship that the astronauts would be in for most of their journey). The astronauts had just been sealed in the spacecraft so they tried to unlock the hatch, but unfortunately, it would take approximately five minutes to get the door open once they had closed it and within 5 seconds the fire was burning everything, so tragically, the would–be heroes died. It was interesting to learn from this how they kept making new spaceships until they got it right.

^Kennedy Space Centre

^Atlantis space shuttle

Features

Angry Birds, super-friendly dodos and birds losing teeth
An Exclusive In-depth Interview with Professor John Quinn

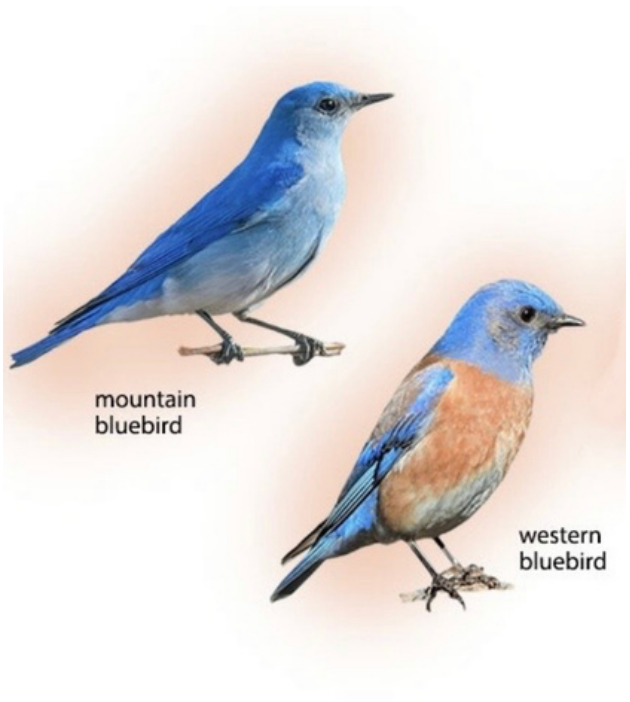
By Sora Kamide

Professor Quinn is an ornithologist (an expert on birds), sometimes describing himself as a behavioural ecologist. He is a lecturer at University College Cork Zoo Research Group.

Sora: Can you give me an example of birds having a personality, and how this influenced their evolution?

Prof. Quinn: Anyone who has had a pet would probably not be surprised to know that animals have personalities! When we say that, we specifically mean individuals have personalities and some individuals are different to others and are consistently different throughout their lifetime.

In North America there are the aggressive Western Bluebird, and the more shy Mountain Bluebird.



The Western Bluebird, over the last 50-60 years, has spread from Western America across into the midwest. Throughout this process, they have had to outcompete the Mountain Bluebird as they compete for the same nesting locations.

What you find is that those ones which are competing with the Mountain Bluebirds are very aggressive personality types and tend to disperse quite far. This aggressiveness has led to an expansion in the entire range of western bluebirds and it has been caused by a genetic basis.

Where the two bird populations overlap, the birds are very aggressive and so are genetically distinct from the birds on the western side of their population.

The reason for this is unknown, however, I believe that this is due to the availability of nesting cavities becoming restricted and less abundant meaning there was more pressure on the birds to expand and find new nesting areas.

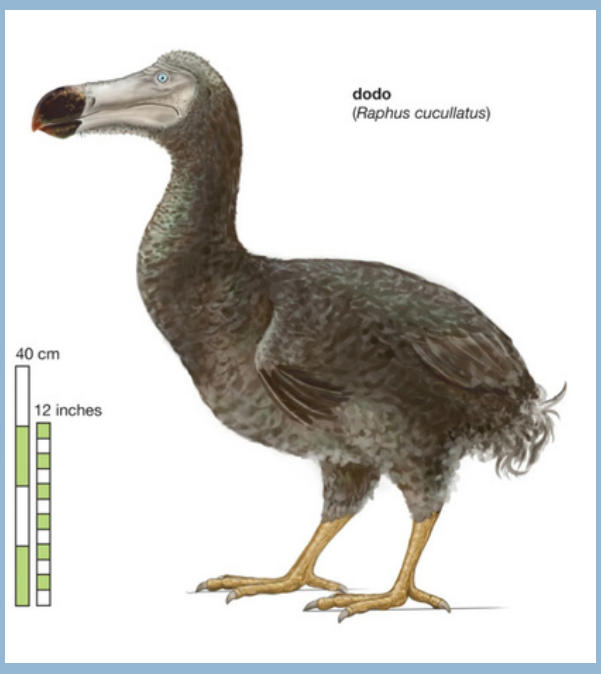
There is a cost to having an aggressive personality trait. Despite being good at outcompeting the other birds, the problem was that these birds were aggressive towards members of their own species and other species, and equally they were not very good parents! They weren't very good at taking care of their offspring and tended to have smaller broods and be less successful at breeding.

Initially, this trait was an advantage because it allowed them to outcompete the other species. Subsequently, this became costly as they were not good parents.

It was discovered that once they had become established, that aggressiveness was selected against in the population and they reverted back to being less aggressive.

Sora: Did you know the dodo became extinct because they were too fearless and friendly?

Prof. Quinn: They had a fearlessness of humans, whereas other birds would be fearful. Some species have evolved a fearlessness of anything as they have been in isolation from predators - the dodo is the classic example for this.
When they were first discovered in Mauritius, they were a large species, incredibly easy to catch and showed no fear of man- ultimately leading to their extinction.



Sora: So, how do you measure personality?

Prof. Quinn: Typical traits people are interested in measuring are aggressiveness, sociality (how much you seek the company of others or not), exploration behaviour, boldness and shyness.

One of the main traits Professor Quinn has measured is exploration behaviour.

This is done by trapping a wild bird and bringing it into captivity by putting it into its own cage (don't worry - the bird is very happy because it has a lot of free food and they do not mind being encaptured as long as they are not disturbed). On the second day the birds are released into a room, called the 'exploration room' and there is a series of 5 artificial trees. Some of the birds will come in and move around, constantly exploring the room and others will come in and sit in one spot.

After the test is finished, their activity is measured and the birds are then released.

When the same individuals are trapped a year later, they do pretty much exactly the same thing as last year.

This is the sign of a personality trait - it is a trait that is fixed in the individual over its lifetime.

Sora: So, why do you get variation in personality? Why is it that natural selection prefers one type of personality over another?

Prof. Quinn: An example being in the context of urban birds. Common bird species, typically found in the countryside, have adapted well to living in urban environments. These birds tend to be quite bold and not particularly shy, allowing them to adapt to the many disturbances that they face in urban environments. If they were nervous and shy, they would probably not be able to adapt to urban environments as they would be too nervous and never be able to feed sufficiently to be able to survive or feed their young.

In terms of evolution, it is basically about how the genetic makeup of populations changes over time. Urban species are different in a genetic sense to those in the countryside.

Gaining this genetic divergence is an early stage in the process of evolution. If the divergence is maintained for long enough, then theoretically, that can lead to genetic variation and potentially new species (although not aware of any examples).

The trait that you are interested in is heritable (transmissible between parent and offspring). Traits like personality are heritable.

Sora: How do you carry out a selection experiment?

Prof. Quinn: This is carried out by going to a population of birds and measuring their personalities and the following year you decide whether they are bold or shy.

You breed the bold males with the bold females and the shy males with the shy females and this is repeated with their offspring. This is repeated over a series of generations until effectively you have two separate populations. If one of them is very bold and the other, very shy, you can conclude that these traits are heritable as you have bred them to be like this. Effectively, this is a form of artificial natural selection.

This is exactly how we have domestic breeds of dogs and cats. They do not arise through chance but through an artificial selection process.

This trait is inheritable, but only partly.

Personality traits can be measured in all animals, one of Professor Quinn's favourite being measuring aggressiveness in jumping spiders (zebra spiders).

These spiders have fantastic eyesight and if you put them in front of a mirror, they see their own reflection, think it is another spider and attack it.
Some of them are very aggressive, constantly attacking their own reflection. Others less so.

In all behaviour, there is always or very commonly, an element of both genetics and environment.

Sora: Why are birds the one of the only surviving species from the mass extinction event 65 million years ago?

Prof. Quinn: Quite a few ancestors of birds evolved before the great extinction event 65 million years ago. Certainly all the large dinosaurs died - their size was definitely a big problem!

When the extinction event took place, all of the forests were destroyed globally. Most species relied on those forests for food. We also know that a lot of the ancestors of dinosaurs had teeth and were specialised in their diets - they were feeding predominantly on insects and small animals. Whereas some of the early birds had already lost their teeth. This is associated with their more general diet. Their diet allows them to feed not just on insects but also on seeds and vegetable matter.

One of the main reasons for losing teeth was not so much to do with diet but more to do with flight. Teeth are quite heavy and a heavy head means your centre of gravity is far forward and not ideal for an animal that flies.
Therefore, looking at evolution of birds generally, many birds now have evolved their centre of gravity to be in the middle of their body and their extremities are very light - their tail has no weight to it and their beak is very light.
Losing teeth is considered to be a weight saving mechanism. However, a cost of this was that it began to limit the kinds of food that they can take. They could not eat large prey and therefore were forced to diversify into smaller prey and seeds which did not require teeth.

Some species of birds which feed on fish have pseudoteeth, made from the same material as the beak (a keratin-like protein structure). They have the function of teeth but are extremely light.

Those species of birds which did survive were more generalist in what they could live on and as a result, some could cope with the loss of the habitat. Many did become extinct, but some of them managed to survive.

The birds were warm-blooded, generalists and could fly (some of them), as a result they could adapt.

The truth is that birds are generally quite successful as a group species. They are highly diverse. There are 280 different families of species and show a vast diversity. A lot of their success has been down to flight. They are very agile, warm-blooded, fast, generalist and also quite intelligent. A lot of birds have large brains for their size.

Sora: An ongoing question in evolution is, what is a species?

Prof. Quinn: One definition is that they are genetically distinct, but one of the problems with this is that it is rather a superficial basis. They may not overlap, but can they interbreed?

The biological definition of a species is a group of organisms that can reproduce with each other to produce fertile offspring. However, the problem with this is that unrelated species, like birds of prey, can interbreed.

Other factors cause change in species over time, not just natural selection. For example, genetic drift where random mutations happen. Due to isolation you get divergence in population.

Sora: How able are a species able to adapt to changes caused by humans like climate change?

Prof. Quinn: A lot of this is due to their underlying genetics but also their flexibility. How flexible are they in conditions that they can tolerate in order to survive.
It is generally thought that more specialised species are the ones who are going to find it more difficult to survive. However, species who are more generalist and who can feed on a wide variety of foods are ones that will actually survive a lot better.

Professor Quinn's favourite bird species:

^Peregrine falcon

^Cassowaries

^Hummingbirds

Thank you to everyone who submitted an article!

We hope you enjoyed reading the magazine!

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