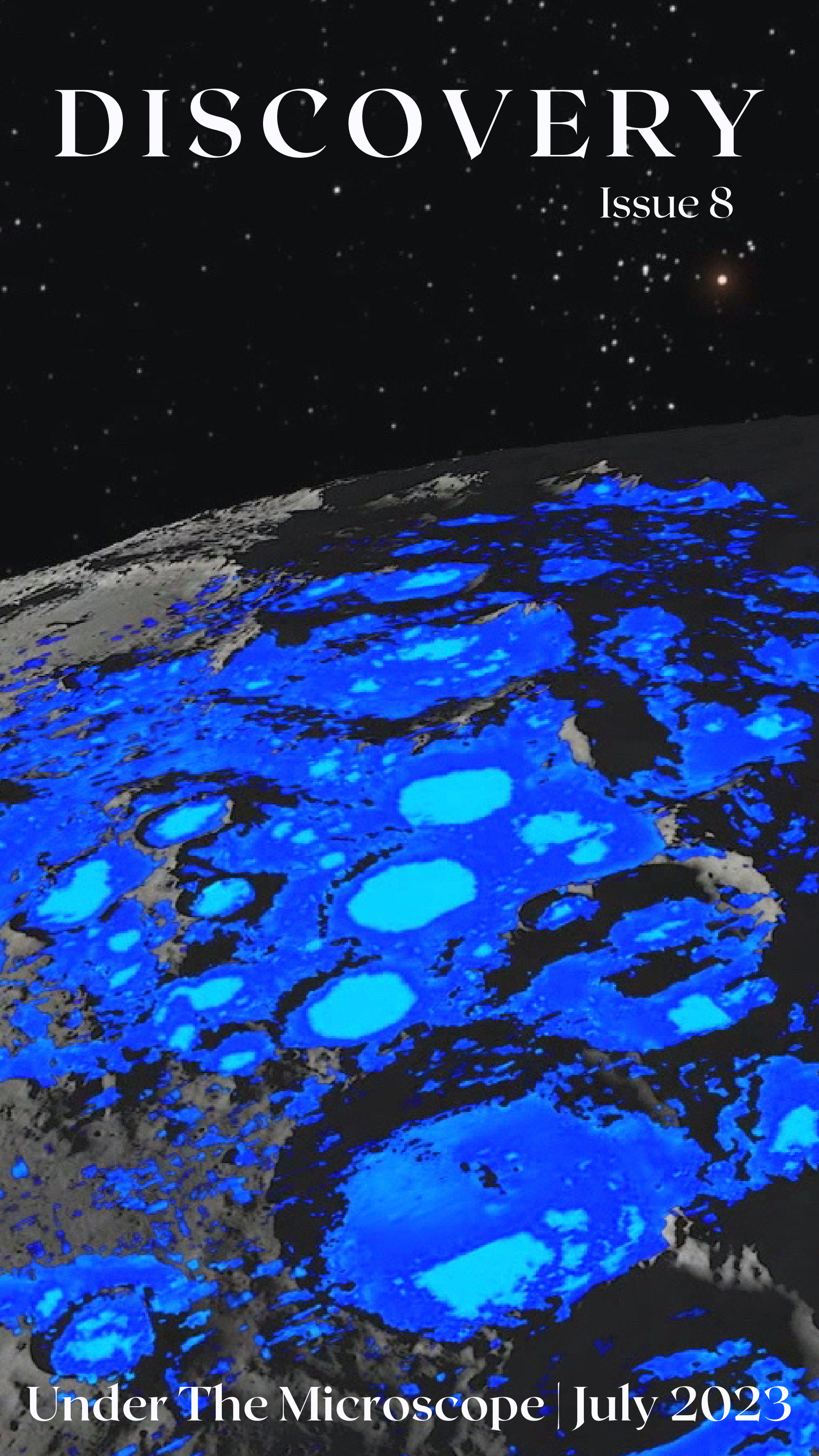
DISCOVERY

Issue 8



Under The Microscope | July 2023

Editors' note

We are so excited to introduce the 8th issue of the Under the Microscope magazine! We were impressed to receive a range of articles from many of our STEM enthusiasts in the school, covering everything from stars and lunar water to fish species and exchange transfusions. We were also particularly happy to receive some book and documentary recommendations from our year 12 biology students, to inspire you to further explore the world of science in our Features section.
We hope you enjoy looking at some interesting discoveries in the scientific world and are excited to read and write more about STEM for the next edition!

SORA:
Features editor (gets fun and original content for the magazine).

TILLY:
Commissioning and Development editor (helps get as many articles from across the school as possible).

RAWNAQ:
Copy editor (reads through each article to ensure scientific accuracy and that each one is an enjoyable read).

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

GHAZAL:
Copy editor (also reads through each article 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 and designs the front cover).

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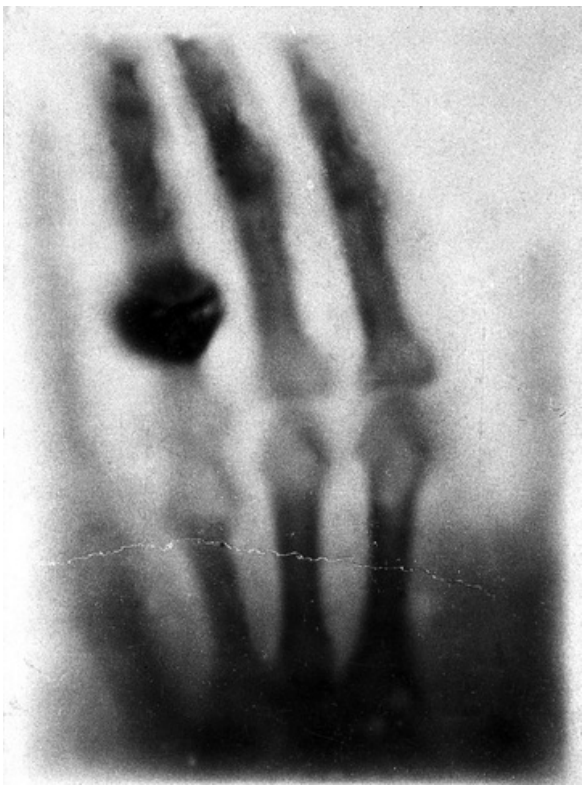
Features:

The Discovery of Medical Imaging

By Ghazal Ershadi-Oskoui

1895: X-rays discovered

Medical imaging is absolutely essential in order to confirm, assess and document the progress of many diseases as well as a patient's response to treatment. Some common examples of medical imaging include X-rays, computed tomography (CT) scans, and magnetic resonance imaging (MRI). Before 8 November 1895, there was no way for doctors to see what was happening inside patients' bodies. On that day, X-rays were discovered by Wilhelm Röntgen (a German professor of physics) as he was experimenting with a Crookes cathode ray (streams of electrons) tube. In fact, the first ever X-ray image was of the hand of Bertha (his wife). Labs worldwide hurried to replicate the Crookes tube Röntgen used; soon, it was used to examine bone fractures. In 1901, the Nobel Prize in Physics was awarded to Röntgen for his discovery.



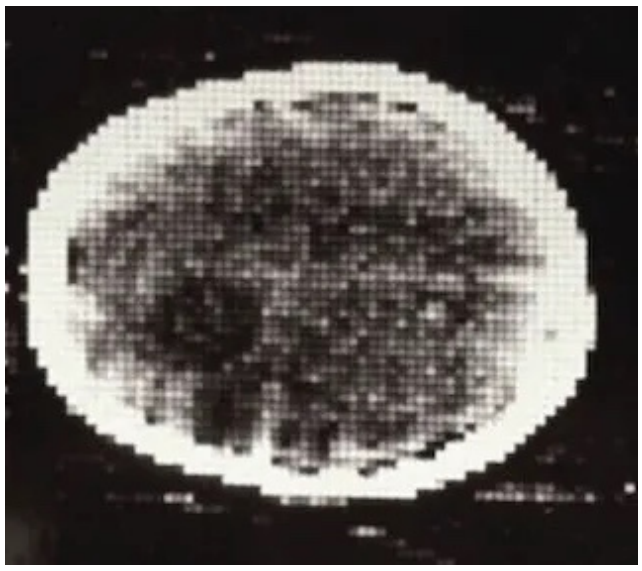
X-rays work by passing ionising radiation through the body and the image is then projected onto a photosensitive (light-responding) plate placed behind it; the varying densities of the body's tissues means the absorption of X rays differs depending on the density of the tissue. For example, bones absorb a lot of X-rays but soft tissues and fatty tissues absorb it less.

1971: First CT image

In the mid 1960s, Godfrey Hounsfield (a British engineer) started wondering whether it could be possible to detect hidden areas in Egyptian pyramids by capturing cosmic rays passing through unseen voids*. This idea can be paraphrased as "looking inside a box without opening it". He was determined to do this and he eventually did when he discovered a way of using high-energy rays to see the brain.

After meeting a doctor who complained about the poor quality of brain X-rays (which makes sense as the brain is a soft tissue which does not absorb X-rays as well as bones do); on an X-ray it was unrecognisable. Following this meeting, Hounsfield started thinking about his idea of "looking inside a box without opening it". Consequently, he started working on a computerised device with the ability to process hundreds of X-ray beams in order to display 2D images of soft tissues. First, he theoretically divided the brain into consecutive slices (picture a loaf of bread). A series of X-rays were beamed through each layer ("slice") and were recorded using sensors (instead of X-ray film) and by taking numerous pictures from a rotating photon source. He then created an algorithm to reconstruct an image of the brain, using all these images of the layers; he could calculate the strength of each X-ray after it passed through a layer (the strength of the X-ray depends on the density of the material). Really astonishing maths was used for this algorithm so I highly recommend you look into this if you are interested in maths. As a series of photographs had been taken of these layers at such narrow intervals, a 3D image could then be created on the computer.

The first patient (a middle aged woman with signs of a brain tumour) was scanned in 1971 at Atkinson Morley's Hospital in Wimbledon with the radiologist James Ambrose. The scan was done as the location of the cystic mass was uncertain. It was not a quick process: a 30-minute scan, a drive across London with the magnetic tapes, 2.5 hours of an EMI (Electric and Music Industries – the company Hounsfield worked for) mainframe computer, and then using a Polaroid camera to capture the CT image and then hurrying back to the hospital. It was all worth it as the CT scan gave Dr Ambrose a clear indication of the cyst's placement. It was a plum-sized cystic mass in her left frontal lobe.



In 1979, Hounsfield was awarded the Nobel Prize in Physiology or Medicine alongside Allan McLeod Cormack. Cormack was a physicist who independently developed the equations used for CT scanning as he worked on the theoretical maths used to reconstruct an image using a computer (which is what a CT does). Unusually, neither of them possessed a degree in medicine nor biology. In fact, Hounsfield did not possess a degree at all! Interestingly, Hounsfield spent half of his Nobel cash award on building a lab in his living room. He was knighted in 1981.

* In 1970, cosmic ray detectors were placed in the lowest chamber in the Pyramid of Khafre but it was concluded that there was no hidden chamber present. However, in 2017, cosmic rays were placed in the Great Pyramid of Giza by another team and a hidden but inaccessible chamber was found... (if you are interested to find out more, there is a 'Nature' article about it here)

MRI

The timeline for the development of MRI is a bit more complicated than those of X-rays and CT scans as it involves the discovery of nuclear magnetic resonance (NMR) – which is the basis for MRI technology – and includes the contributions of many different researchers. NMR was discovered by Edward Purcell and Felix Bloch independently in 1946 (for which they shared the Nobel Prize in Physics in 1952). An NMR instrument allows for analysis of the molecular structure of a material as it observes and measures the interaction of nuclear spins when the material is placed in a powerful magnetic field. The next significant milestone is 1969: Dr Raymond Damadian predicted that NMR could be used to detect cancerous cells. Therefore, he carried out experiments (the results of which were published in 1971) which proved that his theory was correct.

At the same time (1971), Paul Lauterbur theorised a method to use NMR for obtaining 2D and 3D images of living tissue. The following year, Lauterbur examined two test tubes (one containing regular water and the other containing heavy water – water containing only deuterium which is an isotope of hydrogen) using his NMR technique. He was able to obtain an accurate cross-sectional image of the test tubes; his paper was accepted and published by 'Nature' in 1973. That year (1973), Peter Mansfield separately published his research involving the use of magnetic field gradients to create 3D MR images.

By 1977, Dr Damadian had constructed 'Indomitable': the first whole-body human scanner and had performed the first full-body MRI on a patient. In 1980, his company (FONAR) introduced the world's first MRI scanner.

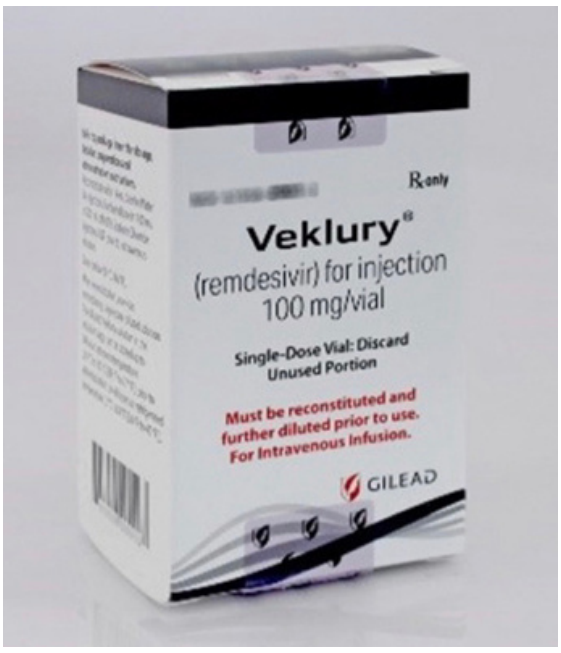
Lauterbur and Mansfield shared the Nobel Prize in Physiology or Medicine in 2003 for their contribution to the development of MRI.

Overall, you can see medical imaging has revolutionised almost all aspects of healthcare. There are many other examples of medical imaging which I haven't mentioned here (such as ultrasound imaging and positron emission technology) which have also greatly advanced medicine. Additionally, due to the ongoing advancements in technology such as artificial intelligence, medical imaging is constantly improving to allow for earlier diagnosis and reduce the need to perform exploratory surgery as well as help with training by creating immersive environments to make complex anatomical structures easier to conceptualise.

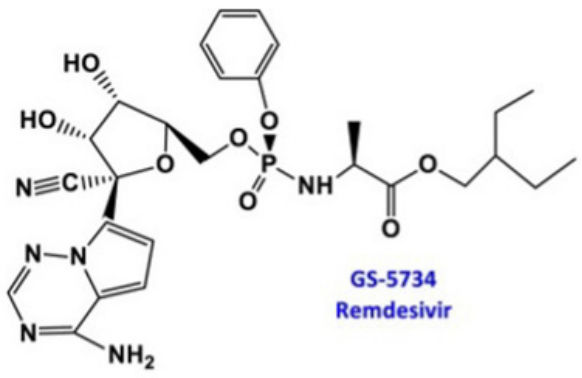
The Discovery of Remdesivir

By Laila Samarasinghe

Remdesivir, or as it is branded Veklury, was originally discovered in a collaboration between Gilead Sciences and the US Army Medical Research Institute of Infectious Diseases in 2009. The antiviral drug was synthesised to treat RNA viruses and was later found to be effective against SARS, MERS and Ebola.



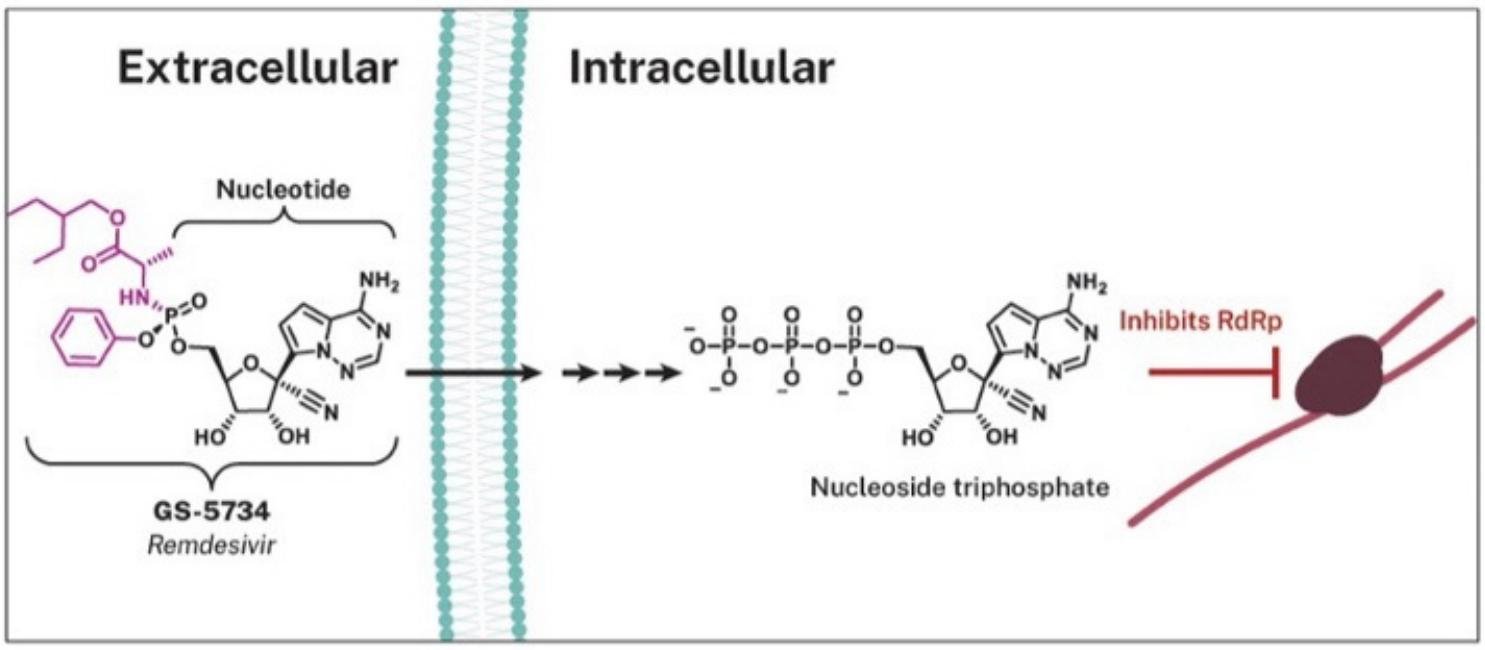
The drug was originally created by using a library of small molecules, mainly nucleoside analogues, which are compounds that look like viral RNA nucleotides. A primary compound (potential drug) was discovered when a compound called GS-441524 blocked viral replication. This compound was modified to make GS-5734 which is now commonly called Remdesivir.



Remdesivir was tested in vitro and was found to be effective in stopping COVID-19 replication in human cells. It was then tested in vivo where it was found to reduce viral load in the lungs of different monkey species and mice, then humans. In clinical trials, Remdesivir has been shown to improve recovery time in patients in hospital with COVID-19.

So how does Remdesivir work? Remdesivir is a prodrug which means that, when it is injected into the body, it is converted into an active molecule, remdesivir triphosphate (RTP). This active form is a nucleoside analogue, which means it looks like the viral RNA nucleotides.

When the enzyme RNA-dependent RNA polymerase transcribes the viral genome to replicate, it mistakes Remdesivir for its own RNA nucleotides and adds it to the RNA. This addition causes the virus to stop replicating because the structure of the RNA is now wrong. So, essentially, Remdesivir acts as an enzyme inhibitor to prevent the virus from replicating. This means it stays at a really low level in the body and cannot spread.



Remdesivir is mainly a treatment for patients with moderate to severe COVID-19; whilst the COVID-19 pandemic may no longer be a pressing issue for most of us, Remdesivir has shown to be an effective antiviral drug against other viruses too. It has been used to treat hepatitis and ebola since its discovery and may have potential uses to fight against other viral diseases in the future.

Walter & Louis Alvarez and the discovery of the ‘smoking gun’

By Mr Walia

The smoking gun I am referring to has partially settled the raging debate about what killed the dinosaurs 65-66 million years ago. The two opposing sides of this centred on whether there was a big asteroid impact (this has been the subject of many a Hollywood blockbuster - my favourite is the 1998 Bruce Willis movie: ‘Armageddon’) or whether the massive volcanic eruptions at around the same time known as ‘flood basalt events’ choked the air enough to kill them off. These geological formations form the ‘Deccan traps’ in central and western India, which are in places still over 1 km thick.

This photo shows from left Helen Michel, Frank Asaro, Walter Alvarez and Luis Alvarez, co-authors of a seminal

Walter Alvarez and his Nobel prize winning Physicist father Louis were an intrepid team and sought out conclusive evidence of one theory over the other. Certain thin layers of clay dated from the exact time the proposed impact occurred were scoured near Gubbio in Italy and spectroscopic methods found abnormally high layers of Iridium. This is a very uncommon rare earth element but it’s found in much higher concentrations in asteroids - particularly the ones left over from planetary formation that lie in the asteroid belt between Mars and Jupiter. These types of asteroids are referred to as ‘Carbonaceous Chondrites’ that have a relatively high percentage of carbon in them. Recent research from the University of Texas suggests that amongst the thousands of asteroids of various sizes in the belt there are ‘escape hatches’ where asteroids can get dislodged from their normal serene orbits around the Sun. Once out of their normal orbit, they can be hurled out into the interplanetary void and then can get captured and locked onto the potential path of a planetary collision.

The only thing missing was direct proof of an impact crater (the smoking gun). There was later found to be one in the Yucatan peninsula in Mexico corresponding to this exact time called the Chicxulub crater. Subsurface radar from oil drilling companies and NASA confirmed the outline of a huge 180 km wide crater which also had sinkholes around the crater rim filled with water that divers can still explore to this very day, called ‘cenotes’.

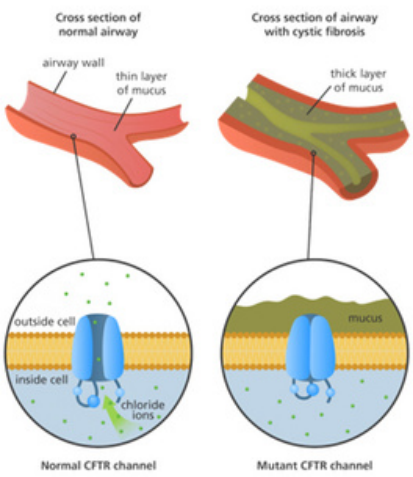
If we trace back Earth’s history of massive impacts, we can see these ‘planet killers’ hit the earth about once every 250 million years, so we aren’t due one soon. But we are often bombarded by much smaller ones that can burn up in the Earth’s atmosphere, called meteors or ‘shooting stars'. Just over a century ago, in 1908, a 50-60 m wide asteroid exploded over Siberia and flattened a forest the size of over 800 square miles - to put this in context, this is about 5 times bigger than Greater London. It has been calculated that it exploded at a speed of 60,000 mph and had the explosive power of 12 megatons, which is 500 times more powerful than the atom bomb dropped on Hiroshima in 1945. It is just blind luck that it hit a remote uninhabited frozen forest way to the north of us. If it had a slightly southerly and earlier trajectory, it could well have exploded over southern England around our location, and then it would have been adios London, and hello blazing inferno/ smouldering ruin. NASA's recent DART mission from last year showed that the path of an asteroid can be changed by firing a projectile into it, so there may be hope for humanity yet if 'the big one' comes into our path.

Discovering Kaftrio: the Revolutionary Drug for Cystic Fibrosis

By Rawnaq Islam

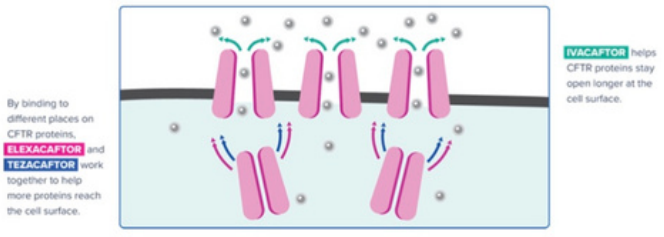
21st August 2020 marked a significant milestone for NHS patients with cystic fibrosis(CF). On this day patients gained access to a groundbreaking medication called Kaftrio. This treatment targets the underlying cause of CF, providing newfound hope and improved quality of life for individuals affected by the disease.

Cystic fibrosis is a genetic disease characterised by the build-up of sticky mucus in the lungs, digestive system and other organs. Ordinarily, mucus acts as a protective barrier by trapping inhaled particles, such as dirt, dust and pathogens, to prevent them from reaching deep into the lungs. Small, hair-like structures, called ciliated cells, can then beat rhythmically to waft away the mucus and trapped particles upwards, where the mucus can be either swallowed or expectorated (spat out). Mucus also plays a vital role in maintaining moisture and lubrication in the airways.



In most people, the mucus that lines the body cavities and organs is slippery and watery. However, in people with cystic fibrosis, mutations in the cystic fibrosis transmembrane conductance regulator (CFTR) gene result in the CFTR proteins becoming defective and not functioning the way they should. This means that the protein is unable to move chloride ions (a component of salt) across cell membranes. With fewer chloride ions diffusing across the membrane, the water potential gradient decreases. So, less water moves into the lining of the airways and other organs by osmosis, which causes the mucus to become sticky and thick.

In the lungs of someone with CF, the mucus clogs the airways as the cilia are unable to propel the mucus out of the lungs; this can lead to lung infections and difficulty in breathing. The buildup of this thick mucus in the pancreas also prevents digestive enzymes from being released and entering the small intestine; this prevents nutrients, from ingested food, from being digested or absorbed by the body (malabsorption), leading to malnutrition. Additionally, in the liver, this thick mucus can block the bile duct, which can unfortunately result in liver disease as it prevents bile from leaving the liver.



So, how does Kaftrio work?
Kaftrio is a 'triple-combination therapy' combining 3 drugs - ivacaftor, tezacaftor and elexacaftor - each performing a different function. Both elexafactor and tezacaftor work together to help more CFTR proteins reach the cell surface. When the proteins do reach the surface, ivacaftor helps the channels stay open for a longer period of time so that more chloride ions can move across the cell surface. With all 3 of these drugs working together, the function of the CFTR proteins can improve by doing a better job at moving chloride ions into and out of cells. This helps to maintain the balance of salt and water in various organs, so that the mucus is thinner and more free flowing.

In a study published in the New England Journal of Medicine, it was found that patients treated with Kaftrio experienced a remarkable 14.3% improvement in lung function compared to those receiving a placebo. Lung function was measured using the percent predicted forced expiratory volume in one second (ppFEV1), a metric that gauges the amount of air forcefully exhaled in one second.

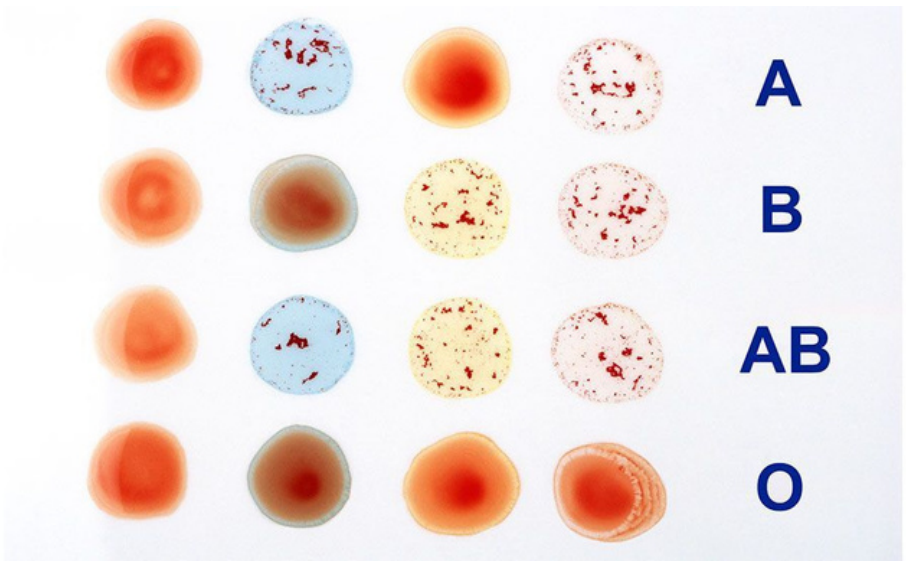
With cystic fibrosis affecting around 10,800 people in the UK, the introduction of Kaftrio has already improved the lives of thousands of people. The discovery and development of this cutting-edge treatment are a testament to the value of medical research and clinical trials.

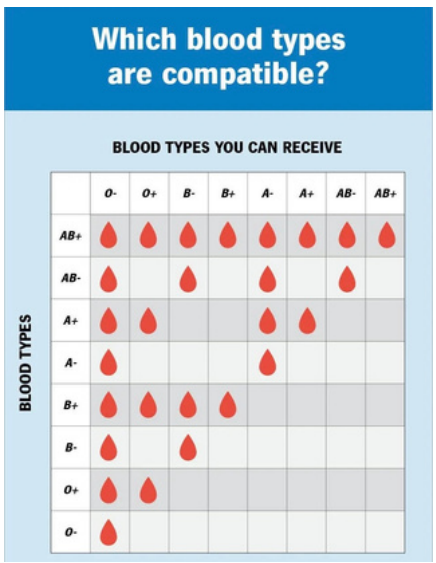
Who discovered blood groups and why are they so important?

By Daisy Hart

The first reported blood transfusion occurred in 1492 on Pope Innocent VII but was unfortunately unsuccessful and he died. The first reported successful human blood transfusion didn't happen until 1795. Up until 1900, it was assumed that any blood could be transfused to anyone; although there were common fatalities, these were not understood. However, in 1901, Karl Landsteiner discovered the ABO blood groups which landed him a Nobel Prize in 1930 after his revolutionary work in contributing to making blood transfusions safe.

There are 4 main blood groups: A, B, AB and O. These are inherited from your parents and are determined by the presence or absence of particular antigens and antibodies in your blood. Antigens are proteins found on the surface of red blood cells, whilst antibodies are part of the body's natural defence and are proteins found in plasma. If a person has the A blood group, they have A antigens on the surface of their red blood cells and anti-B antibodies circulating in their plasma. These anti-B antibodies detect and initiate an attack on any B blood type that may enter the body. If a person has the B blood group, they have B antigens with anti-A antibodies. Group O has no antigens and both anti-A and B antibodies and therefore is the universal donor blood group used in medical emergencies. On the other hand, Group AB has both A and B antigens but no antibodies making it the universal recipient blood group. This means that the small number of people with the AB blood group can have a blood transfusion from any donor. These were the 4 ABO blood groups discovered by Karl Landsteiner and one of his students.





In 1901, Landsteiner noticed how there was a reaction occurring between some people's red blood cells and other people's antibodies in serum. Agglutination, which is the clumping of the antibodies and antigens together, was occurring and Landsteiner started recording the patterns of this occurrence. These patterns led him to the discovery of the 4 ABO blood groups as it proved blood could be divided into categories.

However, there's a further blood group called the Rhesus group (RhD). Each ABO blood group is either RhD positive or negative, equating the number of blood groups to 8. The RhD group was discovered later in 1937 by Landsteiner and Alexander Wiener. Blood grouping is crucial; it enables safe blood transfusion as blood type matching allows us to check whether the donor blood is compatible with the patient being transfused. If a patient were to receive the wrong blood type, this ABO incompatibility could potentially be life threatening. Haemolytic transfusion reactions can be fatal and occur when the body's immune system attacks the red blood cells that were received during transfusion, causing them to haemolyse (burst). Blood grouping can be additionally advantageous in certain lawsuits (paternity suits), forensic science and for anthropologists studying populations.

Clinically, the improvement in the safety of blood transfusion has been vital. Transfusions are used frequently, whether that be after major blood loss as a result of trauma, surgery, childbirth or for the treatment of bone marrow failure. It's important to note that wide-spread transfusions and repeated transfusions don't come without risks such as iron overload and blood borne infection, but the risk has been greatly reduced by Landsteiner and fellow scientists.

The Discovery of Game Theory

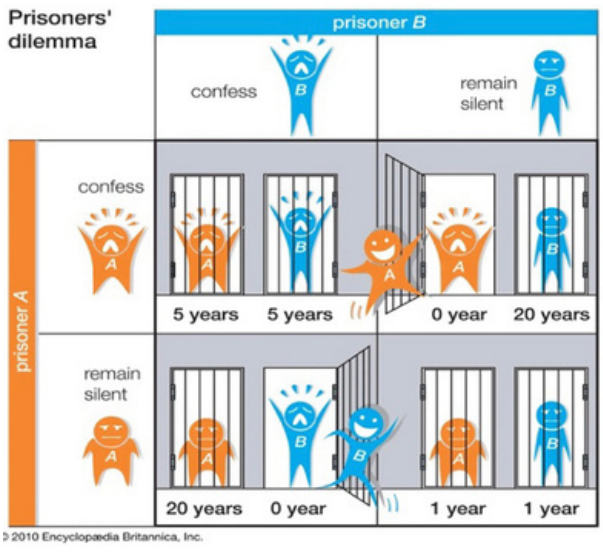
By Joanne Kong

In 1921, Emile Borel, a French mathematician, published several papers on the theory of games. He used poker as an example and addressed the problem of bluffing and second-guessing the opponent in a game of imperfect information. Borel envisioned game theory as being used in economic and military applications. Borel's ultimate goal was to determine whether a "best" strategy for a given game exists and to find that strategy. This idea has since been developed by John von Neuman, also credited as the father of Game Theory; it is a branch of mathematics that has revolutionised our understanding of strategic decision-making. It has been applied to a variety of fields, including economics, business, politics, international relations, biology, computer science, and environmental science.

At its core, game theory is the study of how individuals make decisions in situations where their outcomes depend on the decisions of others. In game theory, individuals are referred to as "players," and the decisions they make are referred to as "moves." The outcome of a game is determined by the moves made by all players and the payoffs that each player receives.

One of the most famous examples of game theory is the Prisoner's Dilemma, in which two individuals are arrested for a crime and are given the option to confess or remain silent. If both individuals remain silent, they both receive a light sentence. However, if one individual confesses and implicates the other, they receive a reduced sentence while the other receives a harsher sentence. If both individuals confess, they both receive a harsh sentence.

This dilemma illustrates the concept of a "dominant strategy," which is a strategy that is the best option for a player, regardless of the other player's move. In the Prisoner's Dilemma, the dominant strategy is to confess, as this guarantees a reduced sentence regardless of the other player's move. However, if both players choose to confess, they both receive a harsher sentence than if they had both remained silent. This scenario highlights the importance of cooperation and trust in strategic decision-making. When individuals cooperate, they can achieve a better outcome for both parties, known as a "win-win" outcome. However, when trust breaks down, as in the Prisoner's Dilemma, both parties can end up worse off.



This, alongside other models of game theory, can be implemented into many sectors, such as economics, businesses, politics and international relations. For example, in the field of industrial organisation, game theory is used to model how firms make strategic decisions regarding pricing and output. In a competitive market, firms must take into account the decisions of their competitors when making pricing and output decisions, and game theory provides a framework for modelling these interactions. In the case of auctions, bidders must consider the decisions of others when deciding how much to bid. Similarly in politics and international relations, game theory is used to model how countries make strategic decisions regarding nuclear weapons and arms control. By understanding the strategic interactions between countries, policymakers can make more informed decisions regarding national security and foreign policy. Game theory provides a framework for modelling these interactions and predicting the optimal strategies.

However, game theory has its limitations. For instance, it assumes that players are rational (based on reason or logic to maximise utility) and have complete information about the game they are playing. However, in real-world situations, such assumptions may not hold. Despite these limitations, game theory remains a valuable tool for modelling and predicting strategic interactions. Furthermore, game theory can be used to address practical problems such as climate change (a problem that requires international cooperation to solve). Game theory can be used to model the strategic interactions between countries regarding climate change policies and predict the outcomes of different policy decisions. Similarly, game theory can be used to address income inequality by modelling the interactions between individuals and predicting the effects of different policy interventions.

In conclusion, game theory has revolutionised our understanding of strategic decision-making. It provides a framework for modelling and predicting the outcomes of various scenarios and has important applications in economics, politics and the sciences. Despite its limitations, it remains a valuable tool for understanding strategic interactions and predicting outcomes. By applying game theory to practical problems, policymakers and researchers can identify potential solutions and predict their outcomes, leading to better decision-making and outcomes for everyone involved.

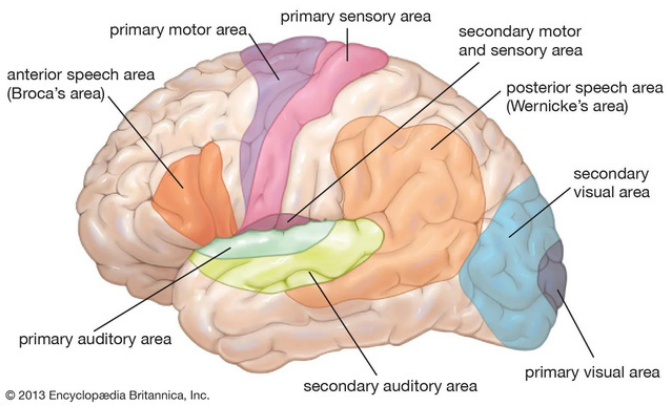
How the discovery of Broca's area revolutionised the field of cognitive neuroscience

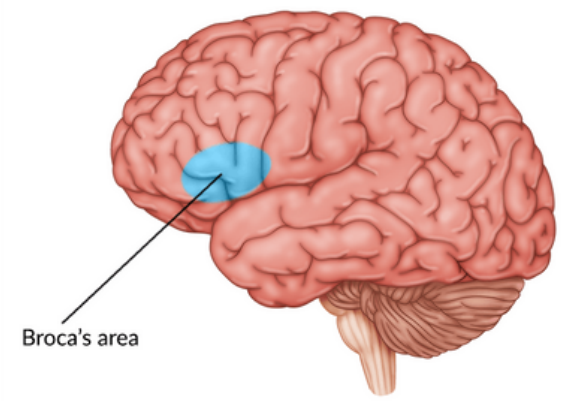
By Molly Smith

The discovery of Broca's area in the field of neuroscience is a significant milestone that revolutionised our understanding of the brain and its role in language production. Named after the French physician, Paul Broca, who identified it, this region is located in the frontal lobe, typically the left hemisphere in the majority of right-handed people.

In the mid-19th century, Paul Broca made a groundbreaking observation while studying patients with language impairments. One of his patients, known as 'Tan', had lost the ability to produce coherent speech but could still understand language. Broca noted that Tan's speech deficit was specifically related to the inability to produce words rather than understand them. Broca went on to conduct autopsies on patients who had suffered from similar language impairments during their lifetime. During the dissections, he discovered a lesion in the left frontal region of the brain in these individuals. This finding led Broca to propose a direct link between the observed language deficits and the damage in this brain region.

Broca's research and findings marked a significant turning point in neuroscience. He published his observations in 1861, presenting evidence that the left frontal cortex (now referred to as Broca's area) was responsible for speech production. This discovery challenged the long-held belief that language was primarily a function of the entire brain rather than a localised region. Over time, the understanding of Broca's area has increased through advancements in brain imaging techniques and further research. It is now known that Broca's area covers two main regions. These regions are interconnected with other language-related areas, forming a complex network responsible for the production and processing of language.





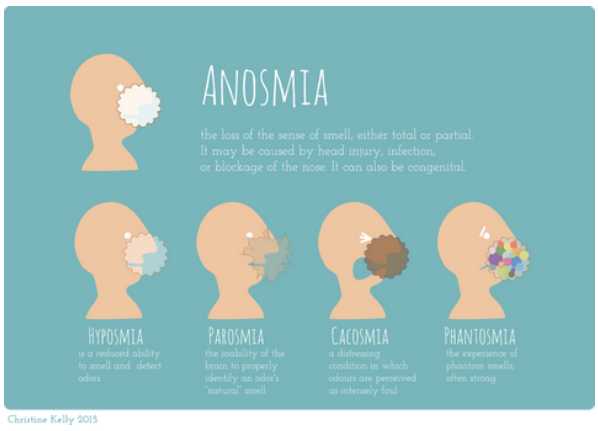
Modern technology has allowed for further research surrounding Broca's area and localisation of function in other areas. Advanced brain imaging techniques, such as functional magnetic resonance imaging (fMRI) and positron emission tomography (PET), allow scientists to observe brain activity, providing valuable insights into the neural processes that create language.

In conclusion, the discovery of Broca's area marked a significant breakthrough in our understanding of the brain's role in language production. This finding challenged existing theories at the time and laid the foundation for the study of brain localisation and its impact on various cognitive functions. Broca's area continues to be a focal point of research, further deepening our understanding of the complexities of human language and cognition.

Discovering Parosmia: what it is and it's impact

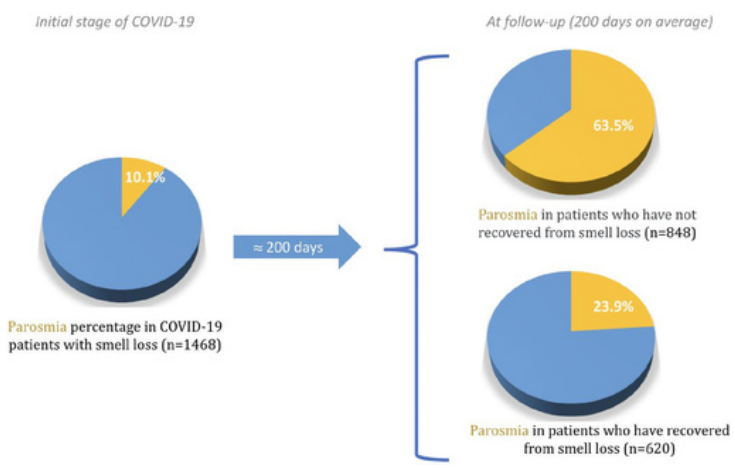
By Zoë Hopkins

Parosmia is a condition which causes a distorted sense of smell. Recently, it has become more common due to an increase in people with olfactory disorders. A large contributor to this has been the emergence of COVID-19. Parosmia often occurs when an infection or virus damages nerves from the nose to the brain. This condition has a huge impact on the quality of life of sufferers. Although it is not usually a permanent condition, recovery often takes several months and it can prevent people from continuing with their everyday activities (such as leaving the house) as well as causing them to struggle with their nutrition. Therefore, parosmia can have a significant impact on their mental and physical health (which we will look at in more detail).



The reason the condition occurs is due to damage to the olfactory nerves. In your nose there are many neurones which use different receptors to detect smells. This is because the receptors can each recognise the specific shapes of chemical compounds and then combine them to form an aroma profile. The neurones then send information to the brain about which receptors have been activated, allowing the brain to interpret this information to identify what is being smelt or tasted. However, in individuals with parosmia, the smell receptors in your nose are unable to detect odours or transmit them to the brain; research into the cause of this is limited: it is thought to be caused by a combination of damage to the receptors, and a lack of fine tuning in identifying smells. Specific molecules have been found to be more likely to trigger parosmia and, unfortunately, these molecules can be found in a range of smells.

Approximately 75% - 95% of what we perceive as taste is actually coming from our sense of smell. Consequently, many individuals with parosmia struggle with food being perceived as foul, disgusting and inedible. This leads to sufferers having a very limited diet and becoming malnourished due to nutritional deficiencies so many will also experience significant weight loss or gain, drastically impacting their mental and physical health.



Additionally, smell is a key contributor to our everyday life and is also important for personal safety and hygiene. Individuals with parosmia may not be able to identify the smell of gas or smoke and, therefore, would miss some of the key warning signs of dangerous events. Personal hygiene can also be difficult to manage as, although most people would identify hygiene products as having a pleasant smell, individuals with parosmia may find these products repulsive. This can make tasks such as brushing teeth or washing hair significantly more complicated and unpleasant for individuals to complete.

The Discovery of Wolf-Rayet Stars

by Austin Zwain

The discovery

The French astronomers Charles Wolf (1827-1918) and Georges Rayet (1839-1906) co-discovered these types of unusual, hot stars, which are now named after them. They discovered Wolf-Rayet stars by using the Paris Observatory's 40cm Foucault telescope in 1867 to observe three stars whose spectra had strong, broad emission lines, but few absorption lines, which is unusual for stars.

For decades, the reason for these emission bands remained a mystery. Eventually, it was discovered that these lines resulted from the presence of helium, which was discovered in 1868, one year after the original observation. E.C.Pickering also compared Wolf-Rayet spectra with nebula spectra, and noticed similarities between them. This led to his discovery that some or all Wolf-Rayet stars are in the centre of nebulae.

In 1929, doppler broadening (the broadening of spectral lines due to the Doppler effect caused by a distribution of velocities of atoms or molecules) was being used to explain the width of the emission bands. It was concluded that the gas surrounding Wolf-Rayet stars must be moving with velocities of 300-2400 km/s, and therefore they are continually ejecting gas into space. This produces an expanding envelope, or bubble, of nebulous gas. The force that ejects this gas was then discovered to be radiation pressure.

Later, Rayet became Director of the Bordeaux Observatory, and to this day, we have discovered over 500 Wolf-Rayet stars in our galaxy.

Some facts about Wolf-Rayet Stars

According to NASA, Wolf-Rayet stars are among the most luminous and most massive stars known. This is because their temperatures start at 30,000 degrees Celsius. They also have strong stellar winds which blow away their outer atmospheres, revealing the stars' inner layers; blowing at over ten million miles per hour, the stars shed about 2 thousand billion tons of material every year. That is three times the mass of the Earth! Wolf-Rayet stars are also the most briefly detectable stars known as they have trouble holding themselves together, burning up their fuel quickly and blasting mass into space and eventually tearing themselves apart. They are usually members of binary stars with O or B stars (types of stars classed by temperature) as companions.

R136a1

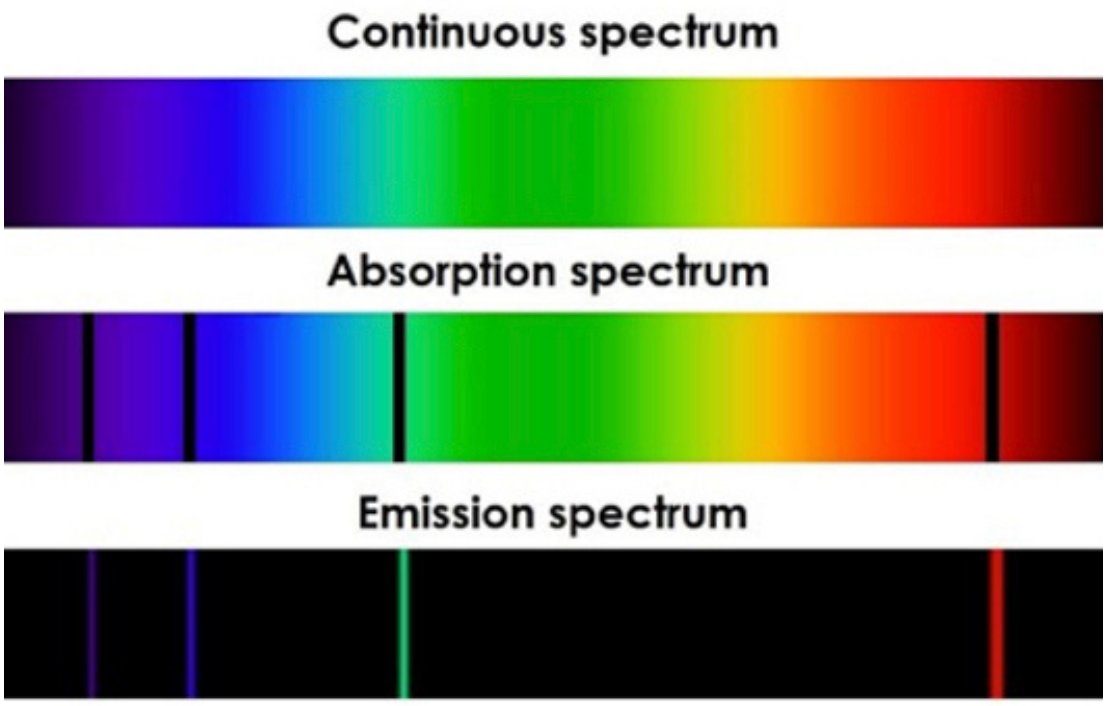
R136a1 is a Wolf-Rayet star and it is one of the most massive and luminous stars yet it still requires a telescope to be seen. It is 163,000 light years away from the Sun and is located in the Large Magellanic Cloud. R136a1 is also part of the R136 super star cluster and has the mass of 315 suns. An interesting fact about R136a1 is that it defies what scientists know about the formation of stars: a popular hypothesis amongst scientists is that R136a1 did not form directly from the collapse of a molecular hydrogen cloud, but rather from two massive stars colliding

WR 124

WR 124 is 15,000 light years away from the Sun. Its spectral type is WN, meaning it falls into the hottest 'O' spectral type of stars, but is referred to as 'W' from Wolf-Rayet. The 'N' means it shows strong emission lines of nitrogen. WR 124 is the glowing star in the centre of a huge, fiery nebula. WR 124 has a surface temperature of around 50,000 degrees Celsius, and is one of the hottest known Wolf-Rayet stars. It is a massive, unstable star which is blowing itself apart. Its material is travelling at speeds up to 150,000km/h. The nebula that surrounds the star, M1-67, consists of vast arcs of glowing gas which is violently expanding outwards into space. M1-67 is quite young, only 10,000 years old, and it contains clumps of material within it with masses 30 times the mass of Earth and diameters of 150 billion km.

WR 7

WR 7 is also 15,000 light years away from the Sun and, unusually, it lies at the edge of a dense, warm molecular cloud. WR 7 produced the emission nebula NGC 2359, which is also known as Thor's Helmet because it looks like a helmet with wings. The nebula has a diameter of around 30 light years and has WR 7 at its centre. Its surface temperature is between 30,000 and 50,000 degrees Celsius which is 6 to 10 times the temperature of the sun. WR 7 is an incredibly unstable star, ejecting stellar material into the interstellar medium at speeds approaching 7.2 million km/h! Despite being a massive star, it loses the mass of the Sun every thousand years. Material ejected from the star is done so in a spherical manner, producing a bubble of material. This bubble has been shaped further by its interactions with the surrounding interstellar medium



The radiation output of celestial objects like stars is a mixture of wavelengths. When passed through a prism, the light is split into its component wavelengths. This gives a record called a spectrum. Usually, a star's spectrum contains dark lines caused by photons being absorbed at certain wavelengths by atoms in the star's atmosphere. These dark lines are called absorption lines. Absorption lines are used to determine which elements are present in the star's atmosphere. However, a Wolf-Rayet star's spectrum has mostly emission lines, which shows different coloured lines in the spectrum rather than dark-coloured lines.

How dying fish lead to the discovery of the deepest river in the world

By Kayla Kirton

The Congo River is one of the longest rivers in the world, stretching over 4 700 km across central Africa. However, this river also holds another title; it is the deepest river in the world with the deepest points being about 700 feet (210 metres) below the surface- this is equivalent to the Twilight Zone in the ocean, which is beyond the reach of sunlight! However, the strangeness of the fish, that have been found dead in the river, prompted a study in 2008 into what the bottom of the river could look like and how deep it really is.

The people of the Bulu village have caught and coined a species of fish, the mondelli bureau meaning 'white man in an office', as this species is small, depigmented and eyeless, it resembles that of a fish that lives in a cave, though it actually lives in an environment without caves. When these species are caught or found dead, closer inspection can identify that their cause of death is not being taken from the water but decompression sickness. These fish experience a rapid ascent from the deep waters they are used to, causing depressurisation which results in the formation of nitrogen bubbles under their skin and gills. This is the same as 'the bends', which is what divers experience if they do not allow for adequate time to depressurise, as they return to the surface from a deep dive.

To gain more information about the Congo River and what lies beneath its surface, kayaks fitted with echo sounders, which emit sound pulses into the water and receive the reflected signal from solid objects, and equipment to measure the depths were sent down the river. Not only is the Congo River incredibly deep, but it is incredibly dangerous to traverse due to aggressive rapids moving tonnes and tonnes of water. This makes gathering any information a task and a half. However, the team working on this was able to discover that, due to the harsh landscape at the bottom of the river, the Congo is actually more like if two rivers were present in the same channel. There are towers of rock, massive gorges and extremely fast currents flowing both upstream and downstream towards the mouth leading into the Atlantic Ocean. These currents are so harsh that rocks are stripped of any plant life or sedimentation and they are also able to create 'pockets' of species, leading to an incredibly diverse river system; there are over 300 species of fish present in only the lower part of the Congo River. The species that occur on either side of a rapid can be completely different to one another as they cannot force their way through a current without dying to interact or breed, resulting in their separate evolution patterns and branched species. These currents have a similar effect to mountain ranges separating species on land.

The deepest canyons of the Congo River have sheer sides which create vortices of water acting as underwater waterfalls. The mondelli bureau is thought to live at the bottom of these canyons, meaning it can be easily caught in one of the fast-moving vortices, resulting in the fish being thrust out of its depth, rapidly reaching the surface and dying from the sudden decompression they experience (i.e the bends). In order to survive the otherworldly environment they live in, these fish have lost the gene to suppress their appetite, as food is definitely not in abundance at these depths. So when food is pulled down by a current, they are able to eat as much as they can, satisfying their needs for energy until the next meal ends up at their depth.

The diversity of fish occurring in the Congo River is unmatched to anywhere else in the world. Over time, these 'men in the office' have adopted very unique physical and physiological attributes, leaving us to wonder how much there is left to discover.

The importance of the discovery of exchange transfusions in the treatment and care of sickle cell patients

By Tilly Bowden

Sickle Cell Disease (SCD) is the most common genetic disease in the UK, which impacts approximately 1 in every 2000 live births. The prevalence and painful symptoms of SCD mean it has become increasingly important to treat the disease efficiently, and one method of doing so is using a red blood cell exchange transfusion.

SCD affects erythrocytes (red blood cells) and their ability to transport oxygen around the body. Inside each erythrocyte is the protein haemoglobin, which binds to oxygen and carries it to cells for respiration. Haemoglobin is made of four polypeptide chains, two alpha and two beta globin chains, which gives the haemoglobin its quaternary structure. However, a person with SCD will have a mutation in the base sequence of DNA on the beta-globin gene, meaning that the base adenine is replaced by thymine, and thus the amino acid glutamic acid is substituted for the incorrect amino acid valine. This change in the structure of the haemoglobin molecule is what causes problems for a person with SCD.

When the oxygen concentration in the blood becomes low, the mutated haemoglobin in the red blood cells disassociates from oxygen. This causes an increase in the density and rigidity of the red blood cells, which polymerise and become a sickle shape. This abnormal shape leads to the aggregation of the erythrocytes, blocking the blood vessels and starving the tissues of oxygen, causing pain, inflammation and Vaso-Occlusive Crises (VOCs). A VOC consists of a cascade of events that can prove fatal for an SCD patient if not treated properly. These include ischaemia (lack of blood flow through blood vessels) which causes the body to secrete cytokines and clotting factors, subsequently leading to further inflammation and thrombosis, increasing the risk of a stroke. Hypoxia (lack of oxygen) is also a major problem, as the cells begin to anaerobically respire and produce lactic acid, leading to acidosis and even multi-organ failure syndrome (MOFS).

In the long term, repetitive aggregation during VOCs causes chronic pain and damage to the body, including ischaemic tissue injuries, organ damage and avascular necrosis. Anaemia is another severe symptom because the erythrocytes of an SCD patient have a life span of 10-20 days. This is much shorter than normal because so many red blood cells are destroyed and used up in a sickle crisis and the body can't make enough fast enough to replace them. In turn, the heart works harder to pump blood around the body to get oxygen to the already oxygen-deprived tissues due to ischaemia, and cardiovascular issues can arise. These severe and sometimes fatal symptoms illustrate the need for effective and fast treatment. It is important to note that SCD doesn't just have a physical impact on the body, it also takes a huge mental toll on patients. Unfortunately, people suffering from SCD are forced to live in fear of when their next crisis will be, and how much time they will have to spend in the hospital away from their loved ones. However, with sufficient research and investment, vast improvements are being made in the quality of care of patients, allowing them to live more normal lives. These developments will become increasingly more important in the future because the number of people with SCD is predicted to increase exponentially, with 400,000 sickle babies estimated to be born annually by 2050.
One of the most important treatments for sickle cell is an exchange transfusion, revolutionising sickle cell care by providing safe and successful treatment to reduce the likelihood of patients enduring such painful VOCs and decreasing their time spent in the hospital.

An exchange transfusion is a type of red blood cell acute transfusion, where some of the patient's blood is removed and replaced by new, healthy donor blood without sickle red blood cells. This means that the new erythrocytes the patient receives won't have the same mutation as their previous erythrocytes and the oxygen-carrying capacity of their blood will increase. An increased proportion of the patient's blood will have healthy haemoglobin, decreasing the likelihood they will experience as many severe VOCs, and allowing them to live a more healthy lifestyle.

In the past, the exchange would be done manually, but we have now developed an automatic exchange machine called an ARCET (automated red cell exchange transfusion) and this works by apheresis. The nurse begins the process by inserting two cannulas into two of the patient's blood vessels (one on each arm). One of these cannulas is used to remove blood from the body, and at the same time, the other is used to transfuse warm, healthy donor blood into the patient. These cannulas are connected to tubes which are connected to the ARCET machine. The machine contains a centrifuge which then spins the donor blood and separates it into its different components. Only the erythrocytes are needed to enter the patient, so the centrifuge removes the plasma, platelets and white blood cells. The blood is also mixed with an anticoagulant to stop it from clotting in the body. Furthermore, the patient is given saline solution (sodium chloride) to keep them hydrated and maintain the same volume of bodily fluid as they had before the exchange. The use of an ARCET machine is advantageous because it is faster and more effective than manual exchange. A clinician aims to reduce the percentage of blood cells with sickle haemoglobin to 30%, and this is often achieved, meaning the patient has fewer cells susceptible to sickling which in turn reduces the number and length of their hospital admissions. Additionally, an ARCET machine is easier for staff to use because it requires less monitoring, time and effort than a manual transfusion. However, issues with ARCETs include a lack of specialised trained staff to operate them, and that they are very expensive, meaning clinicians must prioritise which patients can use them.

Exchange transfusions are currently offered to two categories of patients – those that are identified as chronically very high-risk and those that need a transfusion in an emergency. Red blood cell exchange transfusions are often used for chronically ill patients who are very young, very old, pregnant, having non-emergency surgeries, have frequent crises or aren't responding to other treatments such as hydroxycarbamide. One key use is in children with SCD to reduce their risk of stroke. Children suffering from SCD are over 100 times more likely to suffer a stroke than children without SCD. It is estimated that 11% of children with SCD have a stroke with physical symptoms by the age of 20, and 39% have an asymptomatic stroke by the age of 18. This is because when the erythrocytes change into a sickle shape, they are less able to fit through the tiny brain capillaries, causing blockages. To identify which children are most high-risk, doctors perform Transcranial Doppler Ultrasonography to measure the speed of the blood travelling through the brain. If the speed of blood flow is below 200 cm/s in the major brain arteries, the child is identified as high risk and put on the list for an exchange transfusion.

Furthermore, an exchange transfusion is used in an emergency, because if the transfusion is successful, and the percentage of sickle haemoglobin in the body is reduced, it can help reduce the effects of stroke, aplastic crisis, MOFS and acute chest syndrome. The normal haemoglobin level for males is 138-172 g/l and for females is 121-151 g/l. However, sickle cell patients have lower levels of haemoglobin, ranging from 70-110 g/l. But in an emergency, a doctor aims to increase the haemoglobin levels to the upper end of this range, between 100-110 g/l as this level ensures a patient's stability and stops their condition from worsening. An exchange transfusion can also replace haemoglobin lost in conditions such as acute anaemia and haemolysis, which are both indicated by a fall of haemoglobin over 20 g/l below the normal value. This top-up of haemoglobin ensures the patient can continue transferring sufficient oxygen levels around the body, and their condition won't deteriorate further.

Despite all these benefits, there are still improvements to be made with exchange transfusions. Like any medical procedure, there are risks and occasional side effects, such as a rash, fever, and iron overload. In the past, there were also issues with contamination from diseases such as HIV, but now blood is screened properly to avoid this from happening. Furthermore, there is a risk of an immune response, where the body rejects new blood by producing antibodies to destroy it. However, clinicians have now developed strategies to combat this, such as giving patient's a special card saying 'I need special blood' to let staff know if they have a known history of an immune response.

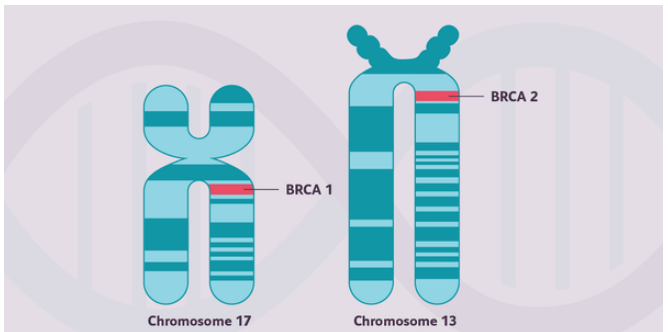
In conclusion, the increase in the number of people affected by sickle cell disease has increased the importance of the discovery of specialised, successful treatment. One of the major new methods of treatment is an automatic red blood cell exchange using an ARCET machine, which exchanges a patient's blood containing mutated red blood cells for healthy donor blood. This decreases the proportion of erythrocytes susceptible to sickling in the patient's body, thus decreasing the risk of a patient experiencing a VOC or other severe symptoms. An automated exchange is safe and effective, allowing those with sickle cell to be treated better and live a life closer to normality. Many clinicians are optimistic about the future use of exchange transfusions in treating blood diseases such as sickle cell, and it is hoped that with further investment these machines can continue to improve the lives of patients.

The discovery of the BRCA genes and how they have impacted our diagnosis of cancer

By Tilly Bowden

BRCA1 (BReast CAncer gene 1) and BRCA2 (BReast CAncer gene 2) are two crucial genes that allow for genetic testing to identify cancerous mutations. In fact, it has been shown that 55-72% of women who inherit a BRCA1 and 45-69% of women who inherit a BRCA2 mutation will develop breast cancer by the time they are 70-80 years old.

These two genes are known as tumour suppressor genes because they help to regulate cytokinesis and ensure it is performed correctly by repairing damaged DNA. However, if a person were to have a mutation in their BRCA1 or BRCA2 genes, they would be unable to correctly control cell division properly, meaning it increases their likelihood of developing certain cancers.



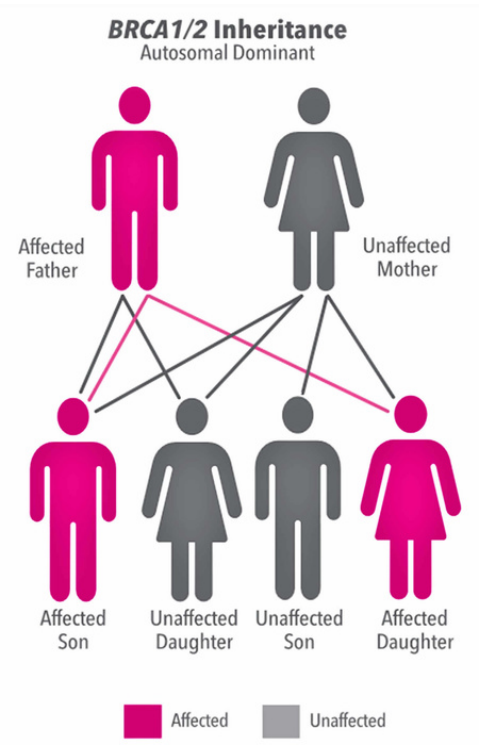
The association of BRCA1 with breast cancer was first discovered in 1994 by a company called Myriad Genetics. This then stimulated a global search for further breast cancer genes, and then one year later, in 1995 BRCA2 was discovered. The association of the mutation of the BRCA2 gene with cancer was first discovered by a team of 41 scientists at the Institute of Cancer Research. The team compared the DNA of patients with breast cancer to the DNA sequence on chromosome 13 of cancer-free patients. The majority of differences between the two were found to be silent mutations. However, eventually, the scientists found a possible mutation that was causing cancer. They began to focus their research on this gene, which has now become known as the BRCA2 gene.

Since its initial discovery, scientists have been analysing the BRCA2 gene further, and have discovered that having a mutation in this gene doesn't just impact a patient's chances of having breast cancer. It also increases the risk of ovarian cancer and pancreatic cancer. It's also important to note that the mutation of this gene and breast cancer doesn't just impact women. Breast cancer can also affect men, and a mutation in the BRCA2 gene also increases the likelihood of developing prostate cancer.

The discovery of the BRCA1 and BRCA2 genes and their relationship with cancer has enabled scientists to use genetic testing to identify individuals who are more at risk of developing cancer. Each person has two copies of the BRCA1 and BRCA2 genes (one from each parent), meaning that if there is a mutation in one copy of a gene passed on in inheritance (germline mutations), this won't increase the likelihood of developing cancer. However, this does mean that every cell in the body has the mutation. Issues begin to occur when the second copy of the gene becomes mutated in a cell (somatic alterations), meaning both copies in that cell are now faulty, and the cell can become cancerous. Therefore, a person is more likely to develop certain cancers if they have a family history of cancer because it is possible that they will inherit mutations in the BRCA genes.

Despite this, not everyone who has a family history of cancer will inherit the mutations in the BRCA genes, and not everyone who has these mutations will develop breast cancer. This means it is important to use genetic testing (in the form of a blood test) to evaluate the risks of developing cancer for particular patients.

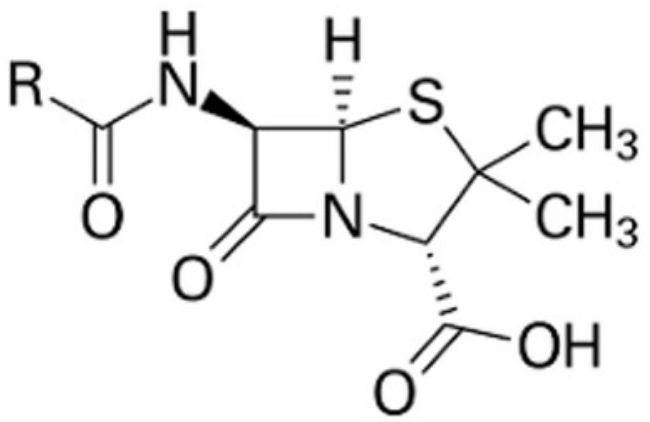
Overall, the discovery of the relationship between mutations in the BRCA genes and developing cancer has allowed scientists to focus their genetic diagnostic tests on these genes. These genetic tests allow medics to identify patients who are most at risk of developing breast cancer and thus they can be monitored carefully for symptoms.



A discovery that could fight antibiotic resistance

By Mollie Patterson

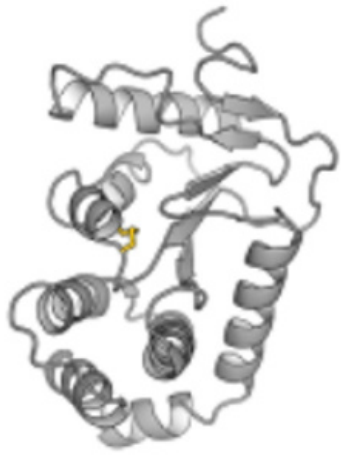
Since Fleming's discovery of penicillin in 1928 and the wave of discoveries that followed, antibiotics have revolutionised medicine and created a platform for pioneering treatments. However, the reliability of antibiotics is currently under threat due to the rise in drug resistant bacteria. Even more worryingly, new antibiotics are not readily available. No new classes of antibiotics have been discovered since the 1980s; the antibiotics brought to market since then have been variations of drugs already discovered. Additionally, the development required to discover new antibiotics is both time-consuming and incredibly costly. As a result, researchers at the University of Texas have turned to a new way of targeting antibiotic resistance, essentially reversing the trait responsible for acquiring resistance and enabling successful treatment using antibiotics that are already available.



^Skeletal formula of penicillin, where 'R' is a variable group. The arrow points to the beta-lactam ring

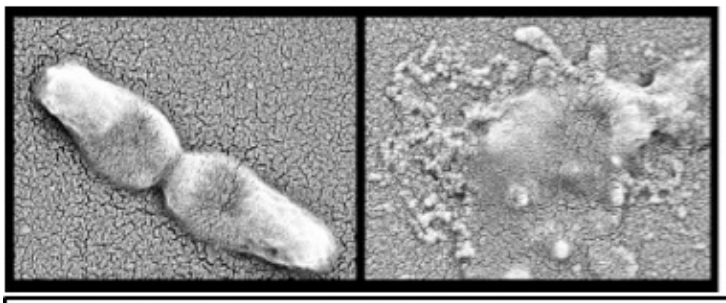
Antibiotics have many courses of action that result in the death of bacteria (bactericidal) or the inhibition of bacteria's growth processes (bacteriostatic). Penicillins, for example, are a class of beta-lactam antibiotics – chemically meaning they contain a four-membered beta-lactam ring (as indicated on the diagram). As a result of atoms being forced into bond angles different from their preferred bond angles within the four-membered ring, the structure is unstable and experiences ring strain. This instability accounts for the antibiotic activity of penicillin molecules. In the presence of a bacterial enzyme used for cell wall formation, the beta-lactam ring of the penicillin molecule splits open and, in the process, an -OH group on the bacterial enzyme is acylated (the H is replaced with an acyl group: R–C=O) and the opened ring attaches to the enzyme. This reaction prevents the action of the cell wall-forming enzyme and so the growth of new bacteria is inhibited.

Due to the selection pressure the presence of antibiotics creates, random mutations that allow bacteria to survive this intervention are passed on, creating a population with a higher frequency of resistant bacteria. The trait that provides resistance can come in many forms: some bacteria have produced enzymes that will inactivate the antibiotics, some have modified the enzyme or product the antibiotic targets and others have developed biochemical "pumps" that are able to remove an antibiotic before it even reaches its target. Critically, it is often the production of a new protein that is responsible for the displayed resistance.



Structure of DsbA

To target resistance, Despoina Mavridou and her team at the University of Texas have discovered a method that prevents the synthesis of these proteins altogether. DsbA (Disulphide bond isomerase A) is a bacterial enzyme that binds to unfolded proteins and catalyses the formation of disulphide bonds, allowing bacteria to produce proteins with the correct physical shape, consequently facilitating bacteria gaining resistance. By inhibiting DsbA, the production of resistance providing proteins is prevented in the first place.



An antibiotic resistant bacterium (Klebsiella pneumoniae) treated solely with the last-resort beta-lactam antibiotic, imipenem (left); and with a combination of imipenem and a DsbA inhibitor, causing it to rupture and die (right).

As inhibition of DsbA has shown to reverse antibiotic resistance across several major pathogens and resistance mechanisms, treatment of resistant infections may not be dependent on the discovery of new antibiotics, thus extending the lifespan of our existing antibiotics.

Currently the chemicals being used to inhibit DsbA are not safe to be used directly on human patients. However, Mavridou's team are working to develop inhibitors that achieve the same effect and are safe for clinical use. The aim for the future is to combine a safe DsbA inhibitor with antibiotics and, hopefully, restore the drug's ability to kill bacteria, even those that show resistance.

The discovery of the mind-gut connection

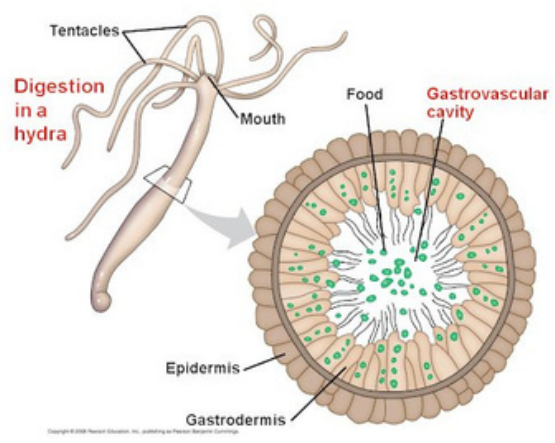
By Clarissa Soto-Rosa

In recent years, the relationship between the mind, the brain, and the body, specifically in terms of the mind-gut connection, has been a topic of much discussion, within a scientific context, but also within the wellness industry. The main role of the gut, or the enteric nervous system (ENS), commonly known as the 'second brain', is to control digestion. It is involved in many processes within the body, from swallowing, to the release of enzymes that break down food, to controlling blood flow, which helps with nutrient absorption. The ENS is made up of two thin layers of more than 100 million nerve cells lining the gastrointestinal tract from the oesophagus.

The origins

Going back from an evolutionary perspective, for billions of years microbes were the dominant life form on planet Earth, until, at some unknown point, algae in the ocean settled inside the digestive system of the Hydra. It is a primitive marine animal which was very similar to the GI tract of humans: a floating digestive tube with a nerve net around it. Using their own communication systems that they had developed over these billions of years, the microbes began communicating with the nerve cells of the floating digestive tubes, which helps to explain why the gut and the brain are very closely connected. It has been generally assumed that there is a common biological language that goes from the microbes to various cells and receptors in the gut, including nerve cells.

It has long been known that the gut communicates with the brain, particularly in terms of the stomach and intestines sending information about hunger or fullness, or about the presence of dangerous microbes. Scientists originally believed that this communication only happened through hormones released into the bloodstream. However, hormones move relatively slowly, taking whole minutes or longer to reach their target, which has led scientists to investigate whether there were more direct, and in turn more rapid, connections between the gut and the brain.



Experimental techniques

One of the most informative pieces of research on the mind-gut connection was made by researchers led by Dr Diego Bohórquez of Duke University, who found synapses (junctions between neurones that pass neurotransmitters) in a rare type of gut cell. Mice were used to have a better understanding of what the synapses in the gut were doing and to investigate how information moves from gut cells (enteroendocrine cells) to the brain. The team used a labelled version of the rabies virus to trace the neural circuit connected with enteroendocrine cells in mice, because rabies tends to spread through the body's neurones through synapses. They observed that the virus could spread directly from enteroendocrine cells in the gut to neurones in the vagus nerve (the longest cranial nerve), which runs from the brain all the way to the intestines and is responsible for the regulation of internal organ functions.

Researchers found that when growing vagal neurones in culture with enteroendocrine cells, synapses formed between the two different cells, and when sugar was added, neurones acted as they would when communicating a message. This, however, wasn't seen when sugar was added only to the vagal neurones, which suggests that the message originated from the enteroendocrine cells. It was also found that the speed of communication between the gut cells and vagal neurones was between 60 and 800 milliseconds: much quicker than the speed initially estimated with hormones. In further experiments, it was demonstrated that enteroendocrine cells can detect the presence of sugar in the gut and send signals to the vagal neurones within milliseconds-clearly demonstrating the connection between the gut and the mind.

What we know so far

It has been agreed by scientists that the mind and gut are in constant communication. The gut has its own nervous system, which is often referred to as 'the second brain' because of its ability to act independently of the brain and communicate directly with the central nervous system. Though there has been a lot of research of the past few years, research is in progress and we still have some way to go to have a full understanding of the topic.

The discovery of Chirality and how it changed chemistry forever

By Isobel Newall

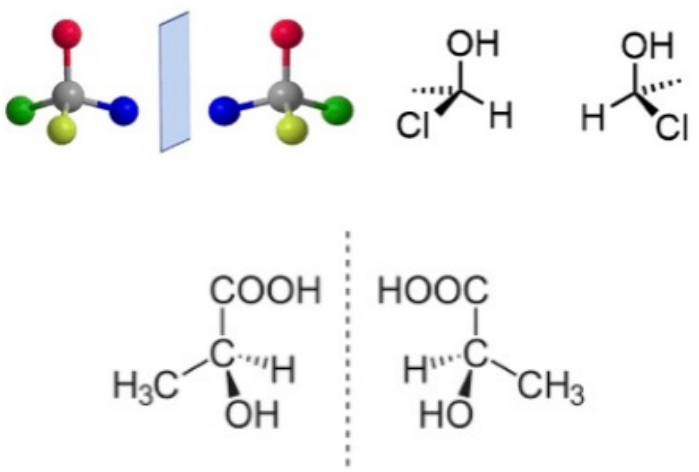
Chiral molecules affect everything from the building blocks of life, amino acids, to pharmaceuticals, yet the extent of the impact of chirality is still being explored.

WHAT IS CHIRALITY?

Chirality is a form of isomerism (compounds with the same numbers of the same elements and the same molecular formula but different chemical and physical properties).
There are two kinds of isomerism:

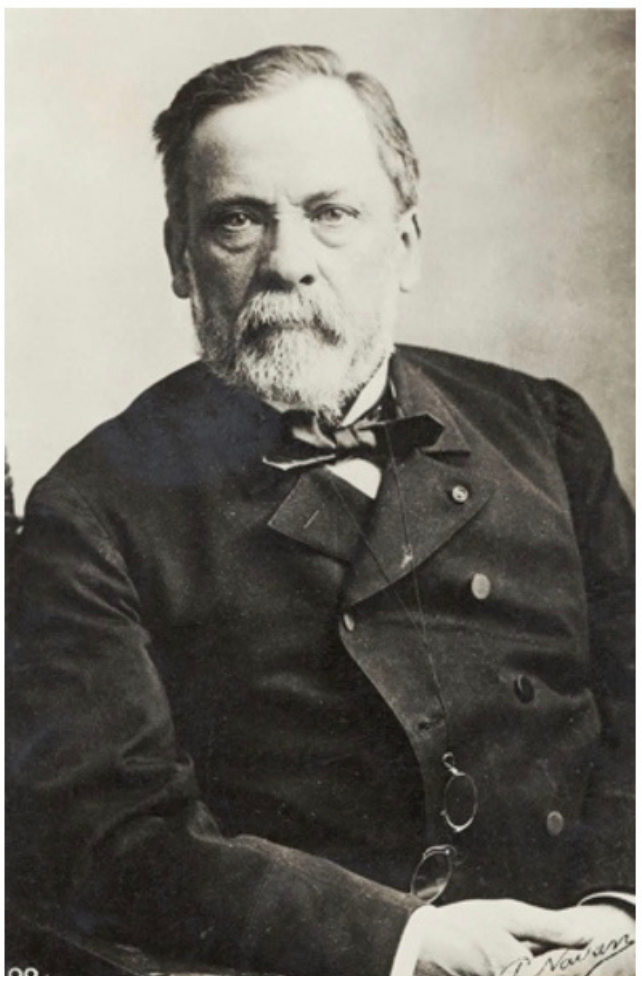
- **Structural** – same molecular formula but different structural formula because the atoms in the molecule are bonded differently
- **Stereo** – same molecular and structural formula, but the atoms are arranged differently in space.

Chirality is a type of stereoisomerism and describes molecules which have non-superimposable mirror images; the pair of mirror images are called enantiomers (there are many different notations, but in this article, I'll use (R) and (S)). This isn't as complicated as it sounds at first! If you put both hands in front of you, palms down and try to overlap them, you'll notice that they don't completely overlap, and this is an example of chirality, because you can't superimpose your hands, which are mirror images. Chiral molecules also have a chiral centre (often an asymmetric carbon atom). The structures below are examples of chiral molecules (bottom right is lactic acid).



THE DISCOVERY OF CHIRALITY

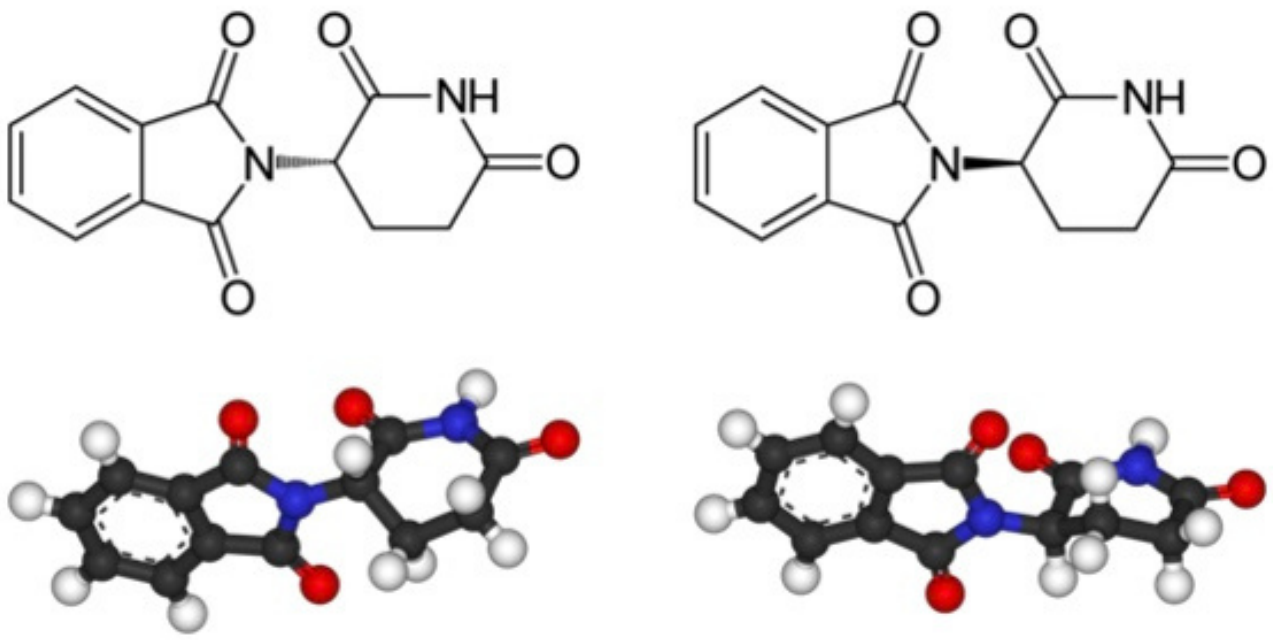
Louis Pasteur discovered molecular chirality in 1848 when investigating an acid with unique properties, paratartaric acid, that forms during winemaking. Whilst studying this acid, Pasteur discovered that it produced two mirror-opposite crystals. Another physicist, Jean-Baptiste Biot, discovered earlier in the 19th century that tartaric acid was optically active which means that when polarised light (moves in only one direction) was shone through the crystals, the light was either rotated clockwise or anticlockwise, but the reason for this was unknown. Pasteur discovered that the handedness of the paratartaric acid explained this observation and thus, at 24 years old, discovered chirality which irrevocably changed chemistry. Lord Kelvin, a famous mathematical physicist, coined the terms chirality and enantiomer in 1894. Until 1911, it was believed chirality was restricted to organic chemistry, but Alfred Werner disproved this by finding an inorganic compound called hexol was also chiral.



^Louis Pasteur

WHY CHIRALITY MATTERS

So why is the discovery of chiral molecules important? Chirality affects almost every field of chemistry, from pharmacology to organic to biochemistry. Even amino acids – the building blocks of life – are chiral.



The two enantiomers of thalidomide
Left: (S)-thalidomide. Riaht: (R)-thalidomide

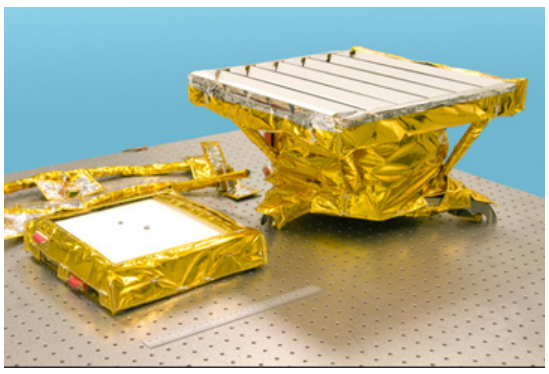
Different enantiomers in drugs can interact with the body differently, such as having different metabolic rates or adverse effects. A classic example of the significance of chirality is the drug thalidomide. Between 1957 and 1962, pregnant women were frequently prescribed thalidomide to reduce morning sickness. However, in the few years that it was available, thousands of women suffered miscarriages and over 10 000 babies were born with severe deformities. Approximately 40% of these babies died at or shortly after birth, and those who survived had complications such as heart defects and malformed limbs and often had shortened lifespans. In the aftermath of this tragedy, scientists investigated the cause and discovered that the drug was racemic which means that it was a 50/50 mixture of (R) and (S) enantiomers. Although (R)-thalidomide was effective, (S)-thalidomide was extremely toxic, and this demonstrates the importance of ensuring the correct chiral molecule is used to avoid tragedies like this.

There are also much less extreme examples of chirality in medicine. For instance, the anaesthetic ketamine is chiral, and the (S) enantiomer is the active anaesthetic and analgesic, while the (R) enantiomer causes undesired side effects such as hallucinations and agitation. Although one enantiomer might be more effective, pharmaceutical companies often don't separate them unless necessary because it's a very expensive process.

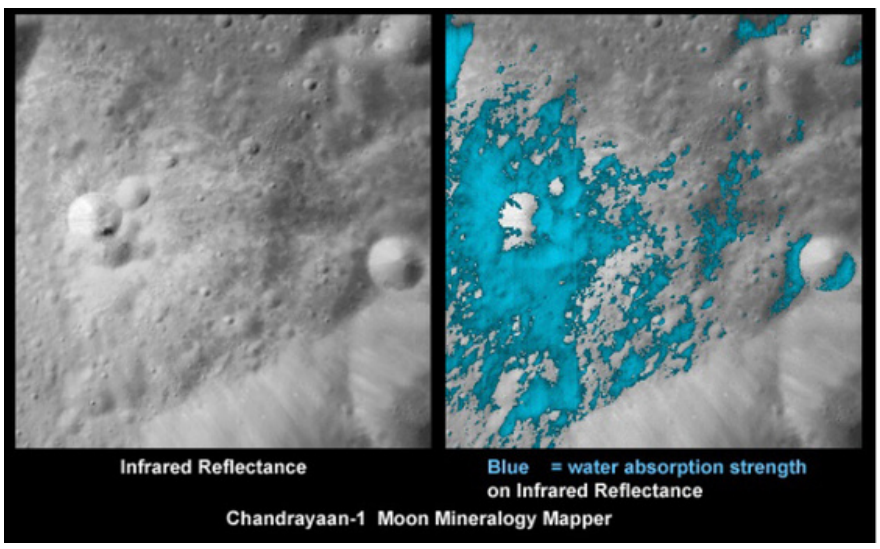
Discovering Lunar Water

By Helen Zheng

Back in the mid 1900s scientists had already thought of the idea of water existing on the moon due to the river-like patterns observed on the moon's surface. In October 2008, the Indian Space Agency launched Chandrayaan-1 with an instrument called the Moon Mineralogical Mapper (M3) and found water in the form of ice on shadowed regions on the moon. The Moon Mineralogical Mapper works by imaging spectroscopy, analysing the minerals on the surface of the moon. Its aim was to examine and record the surface of the moon at high resolution for the first time. Scientists expanded the spectral range of the detection in order to find small quantities of undiscovered compounds. Optical and thermal designs on the M3 were also essential; the signals were transmitted to the detector array by diffraction so gratings, slits and the detector array all had to be mounted with precision. The temperature on the moon can reach up to 400K, thus a reliable thermal shielding and cooler are required; the cooler is parabolic so it can reflect off radiation. Moreover, the M3 also had to be light-weighted hence aluminium was mainly used.



In 2020, the Stratospheric Observatory for Infrared Astronomy (SOFIA) confirmed that there is water underneath the sunlit surface on the moon, especially in the South Pole and places with lower temperatures. Cornell University made the Faint Object infrared Camera for the SOFIA Telescope (FORCAST) to distinguish between hydroxyl and water (since both contain oxygen and hydrogen) by detecting the wavelength of water. Scientists predict that much of this water is formed by micrometeorites hitting the surface of the moon: two hydroxyl molecules would join together at high temperatures, to produce water in the form of glass beads. This has been proven as, in 2009, the Lunar Crater Observation and Sensing Satellite (LCROSS) found approximately 155 kg of water in a crater. In the LRO, they used cameras, spectrometers and a radiometer. Near-infrared absorbance attributed to water vapour and ice and ultraviolet emissions attributable to hydroxyl radicals in the debris.



Lunar water is extremely relevant to the research of the origin of our planet and the moon. Additionally, it could be used for rockets propellants and oxygen in the future, making space exploration more sustainable.

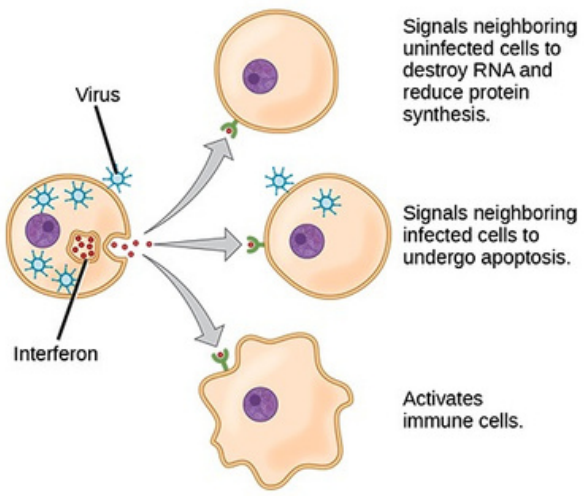
Interferons and their role in viral infections

By Sofia Cobham

One of the subgroups of cytokines are interferons (IFN). IFNs are a type of cell signalling molecule released in response to infection by a virus. They work by slowing down the rate of (or entirely inhibiting) protein production within the cell and aiding in the activation of the adaptive immune system. IFNs can be divided into three main subgroups: type I, type II, and type III IFNs, each with slightly different mechanisms of action.

Mechanism of action

Cells, such as the squamous epithelial cells in the lungs, contain pattern recognition receptors (such as Toll-like receptors) that are able to recognise specific protein sequences from pathogens. The binding of a protein to one of these pattern recognition receptors stimulates the secretion of IFNs. Once secreted, the interferons will then bind to specific receptors, such as the type I IFN receptor on squamous epithelial cells. Since IFNs are involved in both autocrine and paracrine signalling, both the original cell from which the IFNs were secreted, and the surrounding cells are affected by their actions. When bound, IFNs will slow down or inhibit the production of proteins by preventing protein synthesis. This is done via the dsRNA pathway, which causes viral degradation, achieved by activating the enzyme RNase L



Viruses and interferons

Interferons are vital to defence against viral pathogens due to their ability to inhibit and slow down protein production. This is due to the fact that viruses, at their simplest, are core genetic material and enzymes surrounded by a protein coat; without any of these three components, the virus would be unable to carry out its function. The inhibition of protein synthesis (and further protein production) therefore prevents these enzymes and protein coats from ever being produced, slowing down the rate at which viruses can be synthesised and released by infected cells. Fewer viruses means it is less likely for (nearby) somatic cells to be infected, slowing down the rate of infection. Whilst interferons are not capable of completely stopping a viral infection, the ability to slow down the rate of infection is crucial in buying time for the adaptive immune system to be activated.

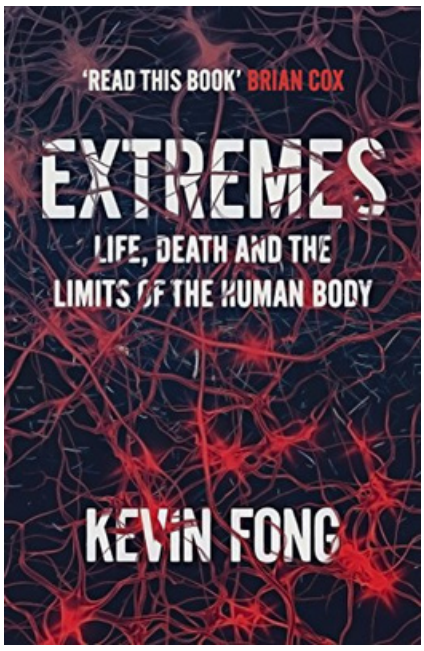
Dendritic cells and macrophages are capable of engulfing infected cells. They are then able to digest the majority of the pathogen, keeping the antigen fragments intact. They then present antigen fragments on the protein MHC class II, and exocytose the molecule onto their cell surface membrane to become antigen presenting cells (APCs). The APCs will then enter the lymphatic system, where they will encounter a variety of lymphocytes, including helper T cells and B effector cells. However, activation and proliferation of B effector cells typically takes several days as the APC will need to bind to the B effector cell with the complementary B-cell receptor to its antigen fragment. Interferons are therefore vital to the immune response to infection with a virus as, whilst the activation and proliferation of B effector cells occurs, somatic cells at the site of infection are still being infected by new viruses. Without interferons, the scale of infection may become too great for the immune system and could result in higher fatalities from viral infections.

Features section

Book & Documentary reviews

'Extremes: Life, Death and the Limits of the Human Body' by Kevin Fong

By Sophie Ray



The book 'Extremes: Life, Death and the Limits of the Human Body' explores the remarkable capabilities and boundaries of the human body. Written by Kevin Fong, an anaesthesiologist and expert in extreme medicine, this book delves into the extraordinary experience of certain individuals who have pushed the boundaries of the human body's abilities in various extreme environments.

Readers are taken on a journey through the world of extreme conditions, ranging from deep-sea diving to high-altitude climbing, and from space exploration to icy mountains. Fong examines how the human body adapts and responds to these extreme challenges through captivating storytelling and scientific explanations.

One of the key areas of focus in the book is the body's response to changes in altitude. One chapter delves into how the decrease in oxygen availability at high altitudes triggers a cascade of physiological responses. The role of blood cells carrying oxygen, the release of the hormone erythropoietin (EPO) to stimulate red blood cell production, and the process of acclimatisation (this is where the body gradually adjusts to higher altitudes). When we travel to high areas, we first increase our cardiac output; this is done by a rise in heart rate. In addition to this, our blood pressure rises. The effect of increasing cardiac output is to exactly match the decrease in blood oxygen content and to make sure the blood is not deprived of oxygen. Once we are at high altitudes, our body starts to produce more red blood cells, caused by the hormone EPO. These levels peak within the first 2-3 days of exposure. The rise in red blood cells provides humans with the ability to compensate for the dramatic drop in oxygen levels by creating more oxygen-carrying molecules.

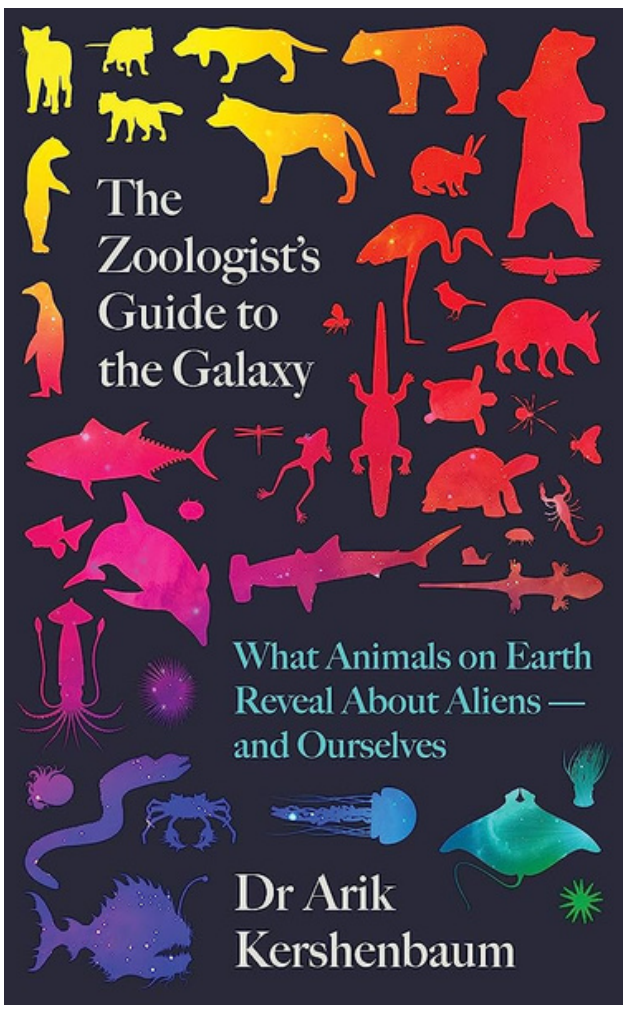
Another area that Fong dives into is the effects of extreme cold on the human body. He describes the mechanisms of hypothermia, how the body attempts to conserve heat through vasoconstriction (the narrowing of blood vessels) and shivering. Hypothermia occurs when the human body loses more heat than it can generate; the example used in the book is when a young woman falls into a river when skiing. Fong also delves into how this occurrence was then further developed into a medical procedure where people are put into induced deep hypothermia so that certain heart surgeries that would have to done in four minutes can then be done in forty five minutes instead.

Furthermore, the book covers the impact of extreme heat on the body. The body's mechanisms for thermoregulation, which includes sweating and vasodilation (the widening of the blood vessels) to dissipate heat are described. He also discusses the dangers of heat exhaustion and heatstroke when the body's cooling mechanisms are overwhelmed.

Additionally, the book delves into the effects of extreme pressure on the human body, particularly in deep-sea diving. Fong discusses the physiological challenges of withstanding high pressures underwater, including the risk of decompression sickness and the need for careful ascent to avoid nitrogen bubbles forming in the body (the bends).

'The Zoologist's Guide to the Galaxy: What Animals on Earth Reveal about Aliens - and Ourselves' by Dr Arik Kershenbaum

By Kayla Kirton



Natural selection is the process whereby organisms who are best adapted to survive in their environment will have the best chance to age to reproductive maturity and therefore reproduce, passing on the advantageous traits and alleles. A well-known example of this is peppered moths during the industrial revolution. Essentially, there was variation among the moths: some were dark, others were lighter, due to the pollution from the industrial revolution. The darker moths were less likely to be seen by predators (and, therefore, increased their chances of survival), leading to an increase in their population as they reproduced and passed on their advantageous alleles.

The Zoologist's Guide to the Galaxy by Dr Arik Kershenbaum considers how natural selection on other planets with different environments to Earth could lead to the evolution of different alien life forms. In one of the chapters, Dr Kershenbaum details how specific form is to function and how crucial this is to the evolution of organisms to survive. This is also something that we learnt about in Biology, although in a different context of cells and what gives them the ability to perform the required functions. He goes on to use the biological law of natural selection to attempt to hypothesise about what other life forms on different planets may have to adapt to have to survive their environments, for example, the different atmospheric conditions.

Evolution requires competition, and a fact I found very interesting was that life started about 3800 million years ago, but for the first 3200 million years evolution was incredibly slow because all organisms that existed only got energy from sunlight and this was available all over the earth. These conditions mean there is no advantage to innovate and, therefore, no real change happened until 'suddenly' excess sunlight was no longer available and organisms had to digest other organisms to gain energy. This was a vital step for diverse evolution to begin because suddenly those organisms that did not adapt would be eaten, so traits for defence or making an organism a better predator became advantageous. And although this example is what happened on Earth, it has the potential to be a general model for other planets.

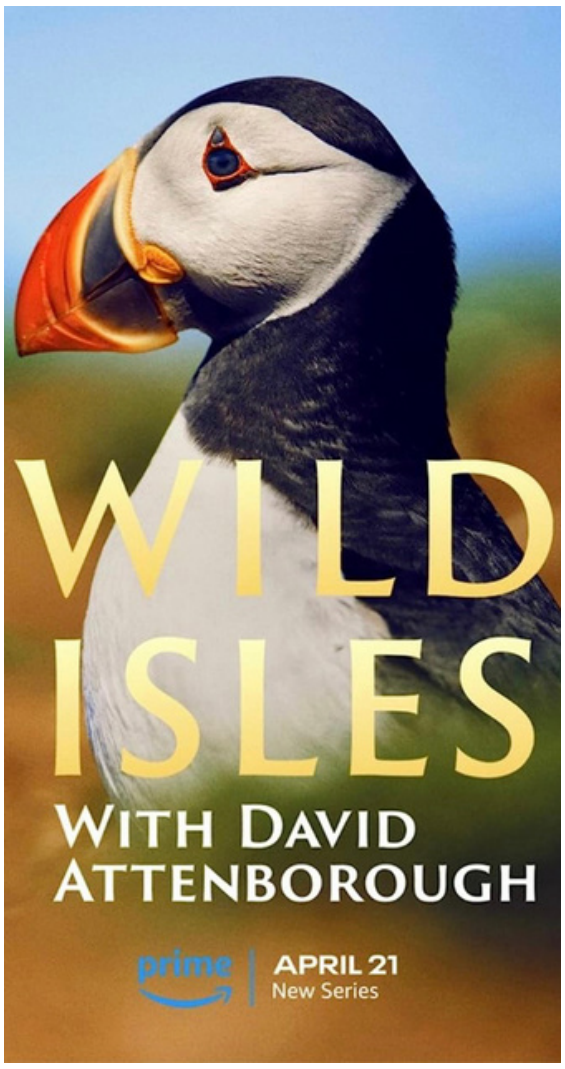
The first feature considered by the book is movement and how the movement of an organism is dependent on where it lives. Another fact I found incredibly interesting is the 'proof' for why movement is inevitable for organisms: because energy is limited, organisms will evolve ways in which to go in search of new energy, and movement must arise so that the organism can compete to gain energy. Therefore, as energy is required by literally anything, aliens must move; it may just not be by methods we are aware of because the planets they live on are so different to ours.

The next feature I read about is communication, the modalities it can take and the advantages/disadvantages of each. An interesting example mentioned is how in potential ecosystems where the surrounding environment is thick and tar-like, sound will travel so fast that the energy used to produce this communication is wasted and other forms of communication will be more efficient (very different to how it is on Earth). Dr Kershenbaum also mentions the use of light, body language and electricity as other methods for potential communication.

I have really enjoyed reading this book and I have found it very interesting.

Farming in the 'Wild Isles' Documentary

By Emma Penrose



David Attenborough's new documentary 'Wild Isles' is about the wonderful wildlife of the United Kingdom and how it has been affected by human activity. Throughout the documentary, Sir David challenges the viewer and makes us think about how humans have so drastically reduced and damaged our natural world. The UK has such an amazingly varied series of habitats, and yet we have destroyed so much of them and drastically reduced our biodiversity, particularly because of farming. However, our own survival does not need to be so damaging to our environment. I was particularly interested in the section on how farming affects nature, and how sustainable, natural methods of farming can help conserve it.

In the episode on grasslands, we see how ground nesting birds and a large range of other species depend on long grasses and hay meadows. However, in order to feed livestock, we cut our grasses so often that these ecosystems cannot survive. Pesticides used in farming seriously damage the insect populations, and the chemicals remain in the environment, causing bioaccumulation, killing and sickening top predators. Fertilisers cause eutrophication, damaging water habitats away from the farm – the documentary looks in particular at chalk streams in the episode entitled 'Freshwater'.

However, we learn in the documentary that it is possible to use sustainable, more natural methods of farming to help the survival of nature. For instance, cutting the grass later means that wild flowers have a chance to grow and set their seed for next year. This also enables more species of insect to thrive. Allowing the grasses to grow tall provides cover and a habitat for ground nesting birds to live and breed, which in turn enables the survival of the bigger predators who hunt them. In the series' extra episode entitled 'Saving Our Wild Isles', one farm reduced its flock of sheep and began keeping Belted Galloway Cattle. This introduction transformed the area, not only drastically improving biodiversity, but also making the farm more profitable. I found it fascinating to learn about how a healthy, working ecosystem on a farm can actually help the farm's function and profits, as well as biodiversity and the survival of nature. Minimising the use of pesticides means that some species such as lady birds can act as a form of biological control. Others are prey for birds and other species, and some are decomposers, helping to maintain the quality of the soil.

I found this documentary absolutely fascinating – it has made me want to read up on biodiversity and conservation more, and I have decided that I would like to focus on this topic in the future when studying biological sciences at university. It was also interesting to be able to relate parts of the documentary back to the A Level course. For instance, in the grasslands episode, we learn about how wild horses eat tree saplings, preventing the grasslands from becoming forests – an example of deflected succession and a subclimax community. This was a really inspiring documentary that I would definitely recommend.

Word Search

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AUTOPSY
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CYSTIC FIBROSIS
TRANSFUSION
PAROSMIA
STAR
BACTERIOSTATIC
CONGO
CANCER
CYTOKINE
HAEMOGLOBIN
HELIUM
LUNAR

Word Search

answers

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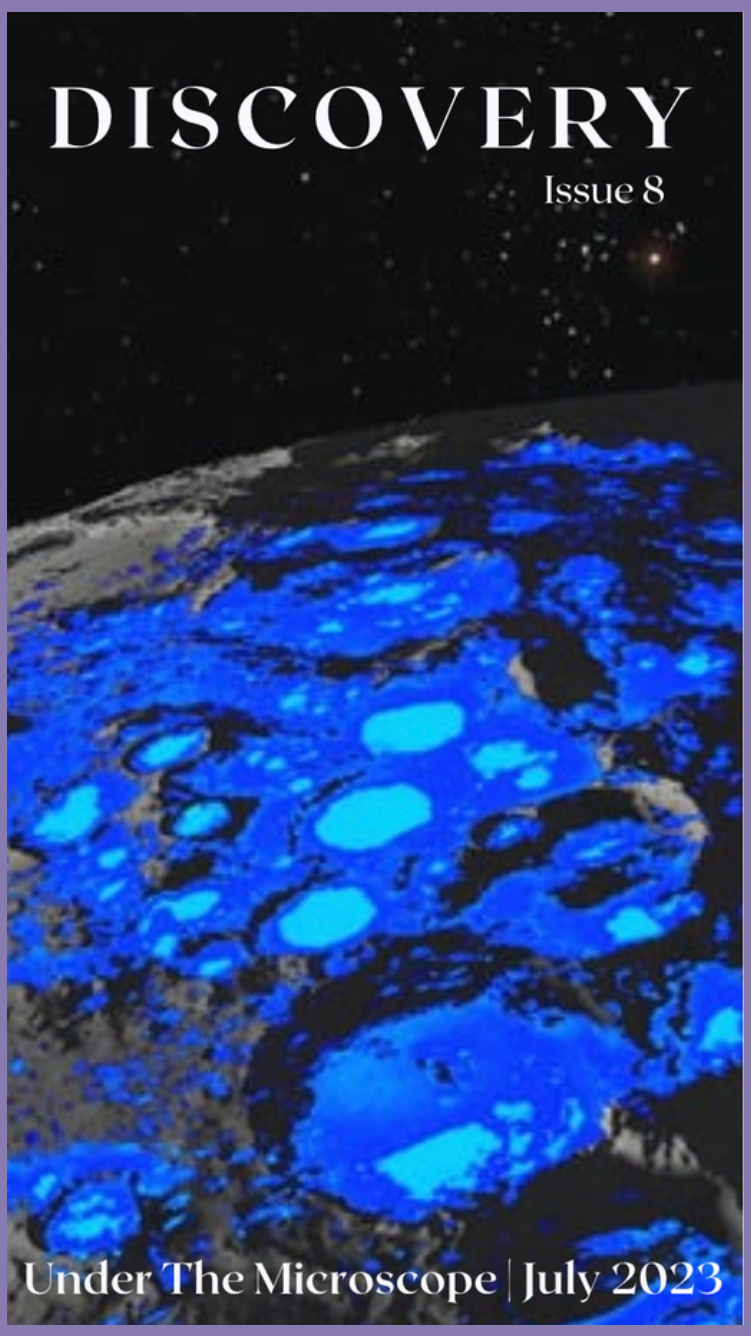
Thank you to everyone who gave a submission and we hope you enjoyed reading the magazine!



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