The Tangent

STEM topics seen from our own angle

Issue 1 - Autumn term 2021

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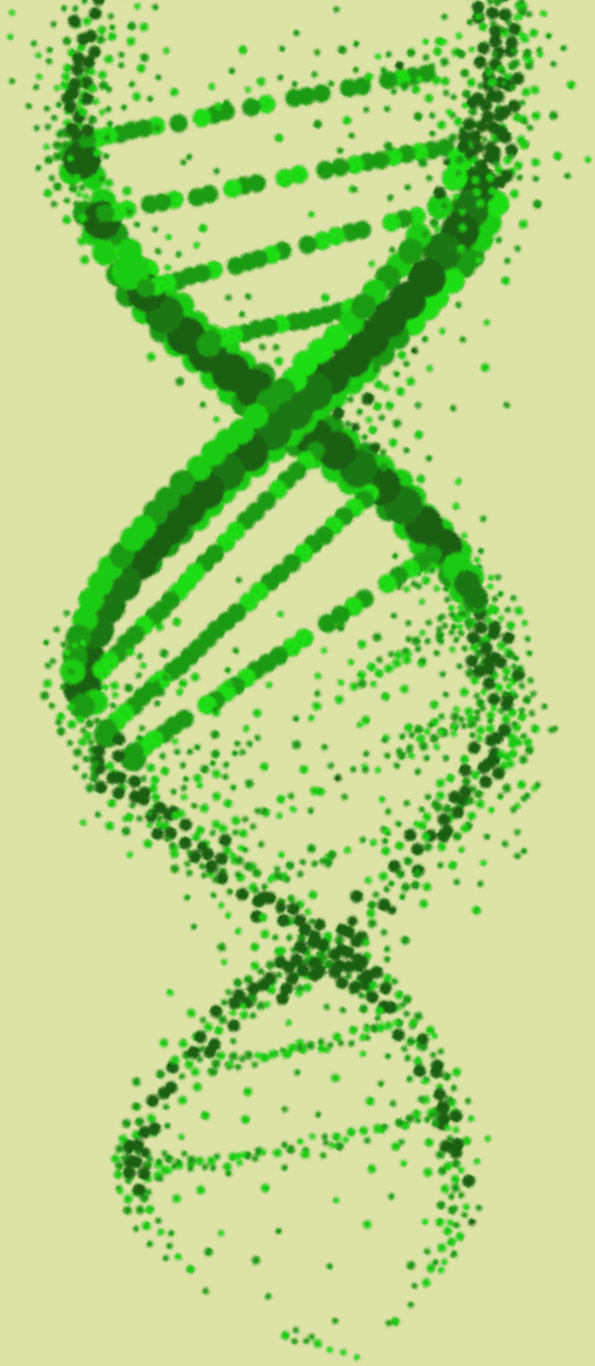

Welcome to The Tangent

Dear reader,

This is the first edition of "The Tangent", an Oxford High School student-led STEM magazine. It was initiated at the start of the Autumn Term 2021 - the idea being that interested Year 11s and 12s could write an article about a STEM topic that interests them twice this year. The second magazine will be put together and released in the Summer Term 2022.

In this magazine, you will find articles written by students who want to share their STEM interests with the school community. It has been fascinating exploring and researching our topics and it has been a lot of fun writing the articles.

I hope you will enjoy reading the first "The Tangent" magazine, as much as I did assembling all the contributions! Feel free to email me if you have any questions or comments.

Enjoy!

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The language of trees

By Kitty Robinson, Year 12

We often see trees in a forest as unconnected individuals, contending with each other for resources. They have evolved to have towering canopies, which block sunlight from competitors, and extensive root systems designed to maximise their own uptake of nutrients and starve those around them. However, this is far from the truth of the life and relationships of trees; the tallest ones in the forest are dependent on a complicated web of alliances and kinship networks to reach the heights they have, and now kindly offer support to the trees around them in turn in a fascinating display of altruism.

Noyes, Charles. "The 9 Oldest, Tallest, and Biggest Trees in the World." One Tree Planted, 2 August 2021, https://onetreeplanted.org/blogs/stories/oldest-tallest-biggest-trees.

This picture shows one of these organisms, a Matriarch or donor tree. They use their vast root systems to communicate with other established trees by sending out chemicals (Wohlleben, 2017), hormones and a voltage based signalling system to request nutrients. But they are not taking them for themselves, instead they are distributing them to the smaller trees and saplings around them, even if they are of a different species to the matriarch, who do not have access to the network or deep roots to gather their own resources. In an experiment performed by Suzanne Simard (Simmard and Teste, 2009) and her team, it was found that these matriarch trees favoured supplying a sugar solution to saplings which were seeded straight into the ground over those which were slightly larger and had been germinated in greenhouses, which had more sizeable roots, showing how they use their networks to support their weakest 'children' first. The experiment showed that the seedlings planted straight into the ground had a 26.1% higher chance of survival, showing how the matriarch trees are crucial for a successful forest establishment. Simard's research also found that matriarch trees are able to distinguish trees of their own species by their root tips, and although they help trees of other species, they seem to prefer their own, sending them more nutrients and even reducing their root systems to leave room for their younger kin to develop their own. Overall, their presence in a forest increases saplings survival by over 400% and when too many are cut down by humans the whole forests' network can collapse. If a matriarch tree is dying from natural causes such as disease however, they will send almost all of their resources to the surrounding trees, giving the forest a greater chance of survival when the matriarch dies.

"What Happens to Tree Roots When a Tree Is Cut Down and What Can I Do About Them?" Mr. Tree, Inc., https://mrtreeservices.com/blog/what-happens-to-tree-roots-when-a-tree-is-cut-down-and-what-can-i-do-about-them/.

However, trees do not just help their young, as in some cases, such as the tree in this photo, the forest will keep an old matriarch alive for hundreds of years after it has been felled, sometimes being able to supply enough nutrients that it can re-grow.

But how are they able to do this? The forests' roots are connected by webs of latticed fungi called mycorrhizal networks (Wohlleben, 2017). The root hair cells connect to microscopic fungal filaments, which connect the roots of other trees to form the vast underground networks. These mycorrhizal networks operate as a symbiotic relationship between the trees and the fungi, the trees use them to communicate and as payment offer the fungi roughly 30% of the sugar they produce from photosynthesis. The fungi also help scour the soil for minerals the trees need, such as nitrogen and phosphorus, which are then passed through the network for any tree in need to absorb and consume. Trees use this network to share water, nutrients and warnings about droughts or disease, but it is not the only mode of communication they have. They can also emit and detect sounds through their roots (Wohlleben, 2017), communicating in crackling sounds at 220 Hertz, which is outside of the human hearing range. Furthermore, they can communicate through the air using pheromones, a great example of this being the wide-crowned umbrella thorn acacia (Wohlleben, 2017). These trees grow in the savannas of sub-Saharan Africa, where they are under constant attack from giraffes, so they have evolved to send out a distress signal in the form of ethylene gas when a giraffe starts to eat their leaves. This signal travels up to 100 yards and alerts the other trees around of the presence of the giraffes, upon detection the acacias begin to fill their own leaves with tannins, compounds that are poisonous to giraffes and cause them to become sick or can even kill them in large enough doses.

These acts of supposed altruism do not seem to make sense evolutionarily, surely it would benefit the trees more to behave like resource grabbing individualists, if there are fewer competitors, trees would be able to access more sunlight to photosynthesise? However, it actually benefits the trees greatly to support their neighbours. Lone trees are very vulnerable, if the sun can beat down on the delicate forest floor it dries up the cool, damp microclimate trees prefer. Fast winds on a single tree are dangerous and can easily uproot it or break a branch, allowing hostile fungi to infect a tree, young seedlings are easily eaten by animals, the genes of the trees being passed on (Wohlleben, 2017).

A community of trees help maintain the perfect conditions, protect each other from threats and allow their offspring to grow, so for their own survival, the language of trees evolved.

Works Cited

Simmard, Suzanne W., and François P. Teste. "Access to Mycorrhizal Networks and Roots of Trees: Importance for Seedling Survival and Resource Transfer." JSTOR, Wiley, October 2009, https://www.jstor.org/stable/25592815. Accessed 7th November 2021.

Wohlleben, Peter. The Hidden Life of Trees: What They Feel, How They Communicate : Discoveries from a Secret World. Translated by Jane Billinghurst, HarperCollins Publishers, 2017.

How does technology affect sleep?

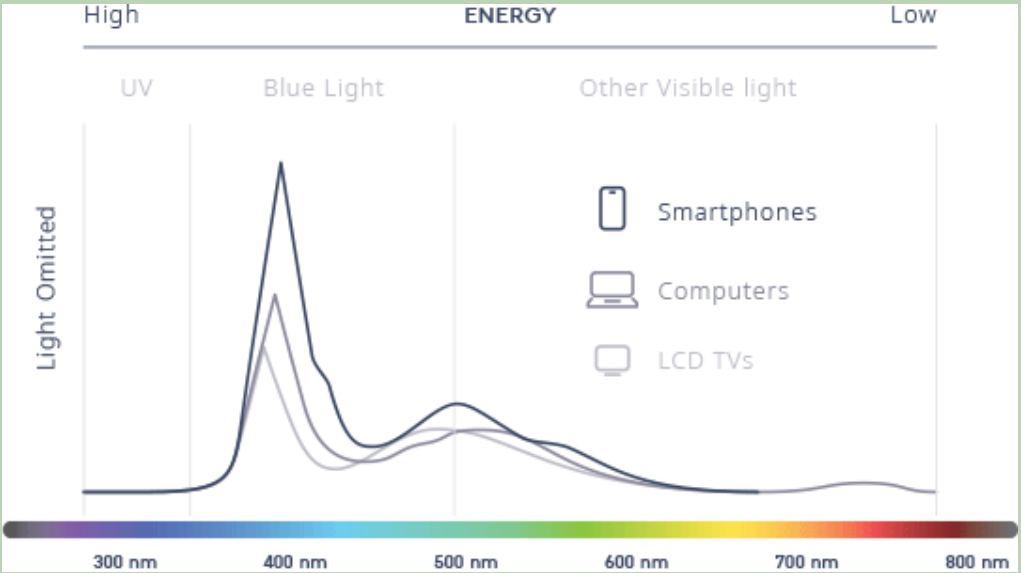
By Iman Malik, Year 12

At this point in time technology has become an essential part of many lives. Screens surround us day and night whether providing entertainment, information or a means of communication and money. Despite their many uses, these devices can interfere with our body's natural cycles and reduce our ability to get vital quality sleep.

Sleep is a crucial process that allows your body and mind to rejuvenate. It leaves you refreshed and alert when you wake up and helps the body remain healthy and stave off diseases. Without enough sleep, the brain cannot function properly. This can impair your abilities to think clearly, concentrate and process memories. Most adults require between 7 and 9 hours of sleep whilst children and teenagers need considerably more sleep, particularly if they are younger than 8. Once we fall asleep, our bodies follow a sleep cycle divided into four stages. The first three stages are known as non-rapid eye movement (NREM) sleep, and the final stage is known as rapid eye movement (REM) sleep. These four stages will repeat cyclically throughout the night until you wake up and for most people, the duration of each cycle will last about 90-120 minutes. Additionally, NREM sleep constitutes about 75% to 80% of each cycle – taking up most of your night. People also may experience waking up briefly during the night but not remembering it the next day, these episodes are known as "W" stages. [3,2]

Technology affects our sleep due to its toll on our circadian rhythm. We function on a circadian rhythm which is a biological process that takes place over 24-hours and controls when we feel tired and awake. It is controlled by the brain in a special region of nerve cells known as the hypothalamus, and a cluster of cells in the hypothalamus called the suprachiasmatic nucleus. The suprachiasmatic nucleus processes signals when the eyes are exposed to artificial or natural light which can then aid the brain in determining whether it is day or night. As natural light disappears in the evening - and a decrease in light is detected by the brain - the body will release melatonin, a hormone that induces drowsiness. When the sun rises in the morning, the body will release the hormone known as cortisol that promotes energy and alertness. This gives rise to issues as the suprachiasmatic nucleus is very sensitive to even small changes in our environments. Blue light emitted from electronic devices such as cell phones, tablets and computers has a short wavelength that is known to interfere with our circadian rhythm by delaying the production of melatonin in the evening and this interruption in the release can lead to poor sleep and insomnia. It also disrupts the timing of the natural cycle and leads to a shift in sleeping times and therefore productivity or lack of sleep. [1,3]

https://image.shutterstock.com/image-vector/circadian-rhythms-controlled-by-clocks-260nw-1351216835.jpg



A graph to show the types of artificial light emitted from electronic devices. (https://www.jins.com/us/jins-screen)

As well as causing poor sleep and insomnia studies have shown that it can also cause a reduction in time spent in slow-wave and REM sleep. These stages of sleep are crucial in maintaining mental and physical health. A reduction in slow-wave and REM sleep impacts many things such as long-term memory and mood. If it is reduced for a longer period of time, it may also lead to chronic daytime sleepiness such as hypersomnia which can deeply influence your quality of life.

Furthermore, with the increasing advancement in technology and popularity with people of all age groups these effects will become more widespread and hence we will need to continue to learn more about just how vital sleep is. Many experts recommend avoiding blue light-emitting devices within a few hours before bedtime. However, for many people this is not always possible due to work, school etc.

Nevertheless, there are some ways to limit the impact of technology and encourage a quality night of rest such as using a 'night mode' on your device or to consider investing in 'blue light blocker' glasses. [1,2]

Although technology use does affect our quality of sleep and so therefore daily lives, there are steps to promote good sleep hygiene that can keep you feeling healthy, alert, and well-rested. Furthermore, with continuous advancement in technology products, such as blue light blocking glasses, will become more advanced and widespread - helping to preserve quality sleep.

Sources

[1] https://www.sleep.org/ways-technology-affects-sleep/

[2] https://www.sleepfoundation.org/how-sleep-works/why-do-we-need-sleep

[3] https://www.earable.ai/post/why-do-we-need-sleep

The importance of stereochemistry: Thalidomide

By Maddie Watkins, Year 12

Perhaps no other drug in the history of modern medicine shares a story quite like this one: introduced by West German pharmaceutical company Chemie Grü nenthal in 1957, Thalidomide, or $C_{13}H_{10}N_2O_4$, was a sedative and antiemetic (anti-nausea) drug primarily marketed to pregnant women across 46 countries, and under at least 37 brand names. Tragically, it was found to have serious side-effects. In the following years, approximately 80,000 babies were born with phocomelia, or limb malformation. Less than half survived, and by 1961, most countries had banned Thalidomide. [2]

Despite its tainted legacy, Thalidomide has taught us a vital lesson: the life-and-death importance of stereochemistry.

What is drug chirality?

Enantiomers are optical isomers which are mirror-images, but cannot be superimposed on each other. This property of non-superimposability is known as chirality. An equal mixture (i.e., 50/50) of (+) and (-) enantiomers is called a racemic mixture. [1,3]

How does it relate to Thalidomide?

Thalidomide exists in two mirror-image forms of (R) and (S) enantiomers, as a racemic mixture. The (R)-enantiomer, as shown in Figure 1 below, is a safe and effective sedative, whereas the (S)-enantiomer, shown in Figure 2 below, is a teratogen - a substance which affects the development of the foetus, resulting in disability. But, in the 1950s, this had not yet been discovered. As such, the enantiomeric composition of a chiral substance is an issue of paramount importance to drug development. [2]

What can we learn?

While the exact mechanism that explains the teratogenic property of (S)-thalidomide is yet to be identified - in fact, over 30 potential

Figure 1: (R)-enantiomer of Thalidomide (Source: Lisa M. Arfons, 2011)

Figure 2: (S)-enantiomer of Thalidomide (Source: Lisa M. Arfons, 2011)

mechanisms have been suggested - it is clear that it is the undesirable enantiomer. Logically, pharmaceutical companies should be able to separate the enantiomers in the racemic mixture, allowing doctors to prescribe the useful (R)-thalidomide on its own. Unfortunately, this is not the case: the human liver secretes an enzyme that converts the desirable (R)-enantiomer to the dangerous (S)-enantiomer, producing a racemic mixture from a pure solution. [1,3]

Despite these enduring obstacles, the Thalidomide tragedy allowed enantiomers to be seen in a new light - as distinct molecules, rather than just different forms of the same substance - further stimulating potentially life-saving investigation into the properties of individual enantiomers in new chiral drugs before they are introduced to the public. [3]

References

[1] Caldwell, J. (1992) 'The Importance of Stereochemistry in Drug Action and Disposition'.*The Journal of Clinical Pharmacology*, Vol. 32, Issue10, pp.925-929. https://pubmed.ncbi.nlm.nih.gov/1447400/ [Accessed: 6th October 2021]

[2] Rehman, W., Arfons, L. M., Lazarus, H. (2011) 'The Rise, Fall and Subsequent Triumph of Thalidomide: Lessons Learned in Drug Development'.*Therapeutic Advances in Haematology*, Vol. 2, Issue 5, pp. 291-308. https://www.researchgate.net/publication/236106954_The_Rise_Fall_and_Subsequent_Triumph_of_Thalidomide_Lessons_Learned_in_Drug_Development [Accessed: 8th October 2021]

[3] Nguyen, L. A., He, H., Pham-Huy,C. (2006) 'Chiral Drugs: An Overview'.*International Journal of Biomedical Science*, Vol. 2, Issue 2, pp. 85-100. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3614593/ [Accessed: 18th October 2021]

DID YOU KNOW?

90% of the heat that maintains the underground temperature of our planet comes from the natural radioactivity of rocks, not from the high temperatures of the Earth's centre! A use of this underground heat is to generate geothermal energy,which is renewable.

How could we cure Type I diabetes?

By Claudia Bloom, Year 12

Type 1 diabetes is an autoimmune condition resulting in a person not producing their own insulin, leaving them reliant on an average of 4 daily insulin injections (3 novorapid before meals and 1 long-acting lantus or tresiba) or an insulin-pump. Autoimmune conditions are where the body's T-cells mistake your own cells as non-self and attack them. In the case of type 1 diabetes, T-cells destroy the beta cells located in your pancreas, which produce insulin. For the classicists out there, type 1 diabetes is also called diabetes mellitus, meaning honey in Latin, because before people are diagnosed, they often have high concentrations of glucose in their urine. Currently, type 1 diabetes is incurable and can only be managed, which is especially unfortunate because most type 1 diabetics develop the disease when they are children. However, scientists are currently researching several cures, many of which are showing promising results.

Firstly, giving islet cell (a group of hormone-producing cells which includes beta cells) transplants, a procedure currently done to people with severe type 2 diabetes, could be part of the solution. This is safer than a whole pancreas transplant, because if the body rejects the pancreas its other functions will be impaired. Furthermore, pancreas transplants are highly invasive operations whereas islet cell transplants can be performed under local anaesthetic using a needle. However, on its own transplants would not be sufficient, because the immune system would simply attack these cells again. Therefore, encapsulation would be needed in order to protect the beta cells. There are miniscule holes in the protective capsule, meaning mineral ions, oxygen, etc. can reach the cells so they can still function, however immune cells cannot reach them. Macro-encapsulation involves transplanting a device containing beta cells into the body, but there are other methods, for example micro-encapsulation. One substance which could be used in micro-encapsulation to coat the cells is alginate, a jelly-like substance which is biologically inert (meaning that the immune system does not respond to it). The last method is nano-encapsulation, where a web of protective substances and nutrients are woven round each individual cell, creating an extremely thin layer which also helps the cells to grow. Normally when transplanting a donor's cells into a patient, only a small number of cells can be transplanted at any one time to minimise the possibility of an immune reaction, causing the body to reject these cells. However, one of the benefits of encapsulation is that all the cells needed can be transplanted in one operation because the whole point is that the T-cells cannot get at the beta cells. [1, 2]

Common signs and symptoms of type 1 diabetes (https://www.chihealth.com/en/services/primary-care/diabetes/type-1-diabetes.html)

Another possible cure could be helping the body to regrow beta cells, which would also help in the study of type 1 diabetes *in vitro*. Unlike most cells, such as skin and liver cells, beta cells do not regrow once they have been destroyed. Most of you will have heard of stem cells, the cells which embryos in the early stages of development consist of, which can turn into any specialised cell in the body. Two independent trials have been able to convert stem cells into beta cells, a surprisingly difficult task. Alternatively, alpha cells, a type of islet cell which synthesise and secrete the hormone glucagon, are very similar to beta cells so could be switched, because they are not destroyed by the immune system. [3]

Lastly immune therapy, a very new area of research, could prevent the need for encapsulation in older type 1 diabetics and mean that newly diagnosed type 1 diabetics would not even need a transplant. One branch of immune therapy is retraining the immune system to stop attacking beta cells. This is done in a similar way to how allergies can be cured, reintroducing the offending food group in small quantities to prevent a reaction. In the case of type 1 diabetes, T-cells could be extracted from the patient's blood and placed in increasing concentrations of beta cells over time. An alternative method is growing stem cells to specifically target the rogue T-cells and kill them, effectively killing the killers. [4]

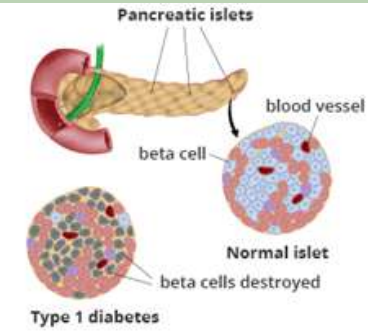


Diagram of the pancreas (https://medlineplus.gov/genetics/condition/type-1-diabetes/)

In conclusion, there are many possible pathways to curing type 1 diabetes and if our knowledge continues to grow exponentially as it has done in the past 20 years, I am hopeful that we will soon live in a world where nobody has this disease. The most likely cure will be a combination of two or more treatments, for example encouraging the body to regrow beta cells whilst performing immune therapy. Type 1 diabetes is linked with genetics, but unlike some diseases, such as sickle cell anemia and cystic fibrosis, it is not just one gene that causes it. A whole plethora of genes could be to blame, and it is clear that it is not the same for every type 1 diabetic. Currently, scientists do not understand most of the genetic factors, but as our bank of knowledge improves with technologies like gene probes, polymerase chain reactions and oligonucleotide arrays, this should also help with finding a cure for type 1 diabetes. If you would like to find out more about type 1 diabetes or how you can help improve the lives of approximately 400,000 people in the UK, please visit JDRF's website. Thank you!

'Encaptra' encapsulation device (https://onlinelibrary.wiley.com/doi/abs/10.1111/dme.13846)

References

[1] https://www.diabetes.co.uk/islet-cell-transplants.html

[2] https://www.embopress.org/doi/full/10.15252/embj.201490685

[3] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2989785/

[4] https://jdrf.org.uk/our-research/about-our-research/cure-research/

DID YOU KNOW?

Scientists can estimate the age of trees by looking at tree rings. This is known as dendrochronology. Not only does this method allow us to date trees but it also provides useful information on the climate during their life and so tree rings can be used as proxy data sources to know past climates.

DID YOU KNOW?

The element helium is named after Helios, the Greek God of the Sun. This is because it was first discovered when scientists looked at and studied the Sun's absorption spectrum.

DID YOU KNOW?

In some countries, insects form part of people's diet as a source of protein! In Mexico for example, agave is used to make a drink called "Mezcal" and this drink sometimes contains larvae found in that plant.

The idea of eating insects may seem weird to us at first because we are accustomed to getting our proteins from meat, fish and other foods like eggs and milk. However did you know that silkworms hold the same amount of proteins (g/100g) as hard boiled eggs? Grasshopper larvae contain about 14-18 proteins (g/100g) compared to milk, which has on average 3-5 proteins (g/100g). Also, adult termites have an average of 13-28 proteins (g/100g) while beef steak contains 19-26 proteins (g/100g).

Fractals: Maths found in nature

By Trisha Thakkar, Year 11

At its very basis, a fractal is a never-ending complex pattern formed across different scales. They are created by repeating a simple process over and over in an ongoing feedback loop. Every part of a fractal pattern, regardless of how near or far it is observed from, looks very similar to the whole image. Fractal patterns are extremely familiar to the human eye as nature is full of fractals. They can be seen in almost all aspects of our lives such as: trees, lightning, snowflakes, crystals, the circulatory and respiratory system, and geography. [4]

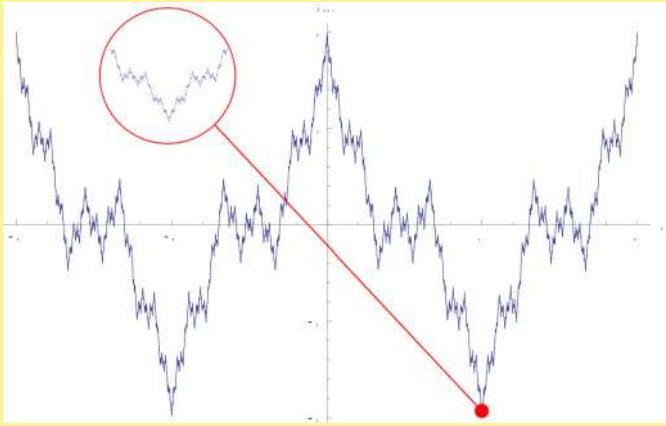


Image: https://theconversation.com/explainer-what-are-fractals-10865

Trees:

Fractals can be seen in tree branches from the way the separate limbs are grown. The main trunk of the tree serves as the origin point for the fractal. Each set of branches that then grow off of the trunk later have their own branches that themselves continue to grow and have even smaller branches. Eventually, the branches become small enough to be considered twigs. These twigs will eventually grow into bigger branches and have twigs of their own. Hence through the process of growing and expanding, a cycle is created to form a mathematically, though not biologically, infinite pattern of tree branches. Each branch of the tree also resembles a smaller scale version of the whole shape. [2,3]

Lightning

Lightning storms are one of nature's most powerful displays of fractals. When electricity passes through a medium that is not a suitable conductor of electricity, such as air, a fractal pattern is created. This phenomenon forms due to how the electricity interacts with the air. As the electric current passes through the air particles it superheats them. This superheating of the air changes its electrical conductivity and allows the electrical current to fragment out. This process is repeated for each level of fragmentation to form a fractal. [1,2]

Image: http://www.cindyjgomez.com/fractaltrees/

Image:https://www.bbvaopenmind.com/en/science/mathematics/applied-fractal-geometry-from-climate-change-to-cancer/

Snowflakes

No two snowflakes are the same. This uniqueness of snowflakes is due to their fractal formations which causes them to have astounding amounts of detail along with variation. The starting point of a snowflake's formation is the centre. As the centre of the ice crystal expands outward in all directions, fractal structures are formed in each direction getting smaller and more detailed as they grow. [2]

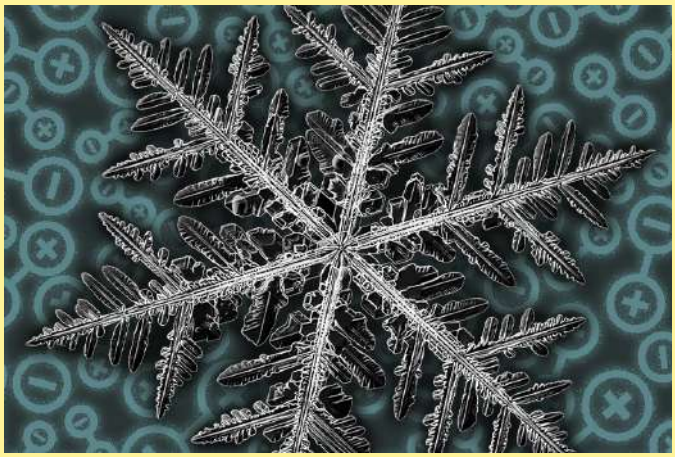


Image:https://news.mit.edu/2019/fractal-patterns-quantum-1016

Crystals

Similar to the crystal formations of snowflakes, other natural forms of crystals like those created from minerals can also exhibit fractal properties. Depending on the specific formation of crystal and the minerals used, some are more fractal in appearance than others. [2]

Image: https://iternal.us/what-is-a-fractal/

The circulatory and respiratory system

Another place where fractals can be observed is in the circulatory and respiratory system of animals. For example, in the human lungs, a fractal can be seen that begins with a single trunk and branches off and expands into a thinner network of cavities. The alveoli of the lungs also follow a fractal pattern which maximizes the surface area of the lungs and improves its efficiency. This branching pattern is greatly similar to that of trees since both have evolved to perform a similar function: breathing. [1]

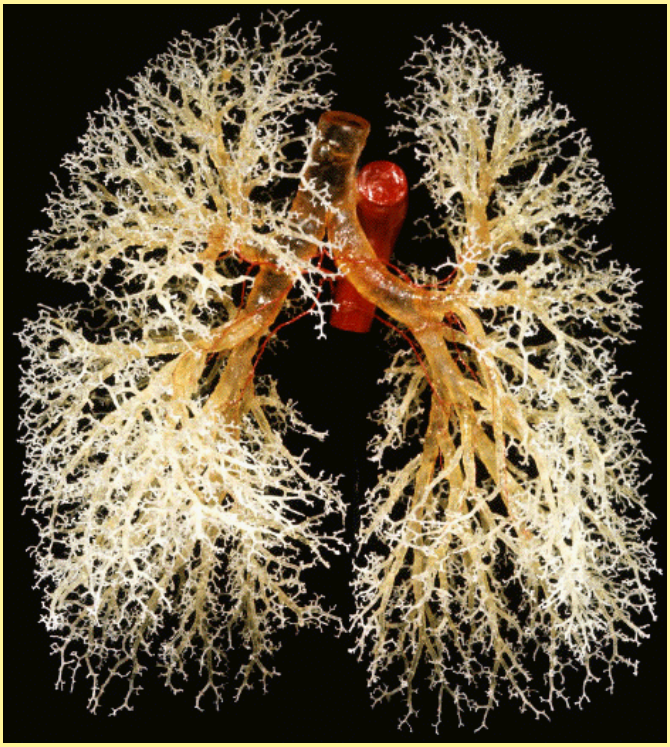


Image:https://medium.com/show-some-stempathy/fractals-dimensionality-and-more-54e573f6fa30

Geography

The geography of rivers and landscapes is also composed of fractal geometry. The shapes of rivers and other bodies of water throughout a landscape are greatly similar to the networks that distribute fluids throughout an organism. It begins at a single source and branches out into thinner networks which themselves branch out so on and so forth. As rivers and other bodies of water are formed, they are also carving out the geographic landscape which makes the land the bodies of water travel on fractals as well. [1,2]

Fractals are an innate part of our lives. They exist in every corner of the world and to discover them one need only look. Our gardens, skies, and the very earth beneath us itself is full of them. It truly goes to show that while maths is generally learned from books, it can be found anywhere.

Image: http://paulbourke.net/fractals/googleearth/

References:

[1] https://www.bbvaopenmind.com/en/science/mathematics/applied-fractal-geometry-from-climate-change-to-cancer/

[2] https://iternal.us/what-is-a-fractal/

[3] https://theconversation.com/explainer-what-are-fractals-10865

[4] https://fractalfoundation.org/resources/

Understanding stem cell-related illnesses and therapy

By Leen Al Tanger, Year 12

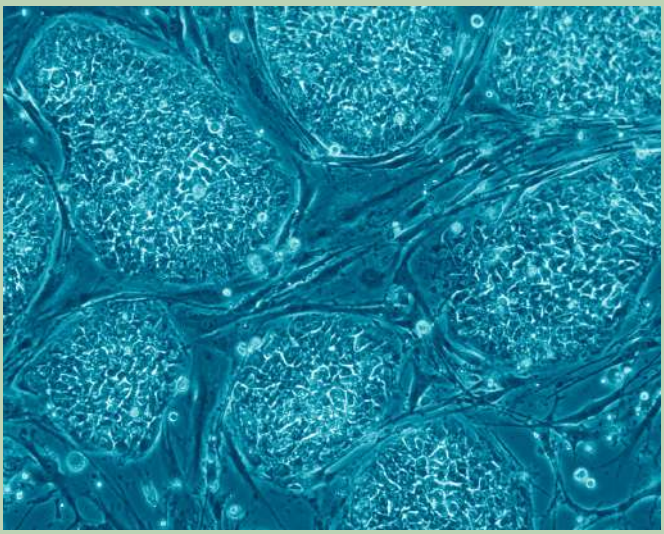
What are stem cells?

Stem cells are the body's "foundation" cells - they are able to differentiate and specialise into specific cell types. These include heart cells, blood cells and bone cells. Stem cells are unique in their ability to specialise in such a manner, giving them a crucial role in the development of a human and potential cure of many medical cases. They come from a variety of sources, including embryonic cells, adult cells, pluripotent cells (adult cells that have been altered to have the properties of embryonic cells using genetic reprogramming) and perinatal cells (obtained from the amniotic fluid and umbilical cord in pregnant women). Using stem cells in order to repair damaged cells is called stem cell therapy. [1]

How does stem cell therapy work?

Stem cell therapy entails the use of stem cells in order to regenerate damaged cells that would otherwise not repair themselves. This is because adult stem cells are not as flexible as embryonic stem cells when it comes to their ability to specialise, leaving various medical conditions, such as damage to the heart cells, requiring stem cell treatment (otherwise known as regenerative medicine).

In order to undertake treatment, researchers will grow stem cells in a lab, manipulating them into the specialised cells required by the patient (heart cells, muscle…). This is then injected into the patient at the required site. [2,3]



Human Embryonic Stem Cells (hESCs). Credit: Nissim Benvenisty, CC BY 2.5, via Wikimedia Commons

What ailments does stem cell therapy currently treat?

Currently, stem cell therapy is able to treat damaged bone marrow. Bone marrow can be damaged due to cancers, including leukaemia and lymphoma, which impact white blood cells. Additionally, stem cell therapy has great potential to help restore damaged neurons in chronic conditions such as Alzheimer's and Parkinson's. This is vital as such conditions often get worse with time and other treatments have proved underwhelming.

The London Project to Cure Blindness is one of the most notable projects in the field of stem cell treatments, and it is relatively recent, having been concluded in 2018. It was co-led by both Pete Coffey and Professor Lyndon da Cruz, the Project's Lead. The London Project to Cure Blindness' goal was to use embryonic

cells in order to treat patients with age-related macular degeneration, a condition that entails retinal pigment epithelial cells being damaged. As a result, the central area of the eye that processes visuals, aided by retinal pigment epithelial cells, including reading and recognising faces, deteriorates. This is a condition that impacts 700,000 people across the UK, generally above the age of 65-70.

Through collaboration between the University College London and the University of Sheffield, clinical-grade retinal pigment epithelial cells were made from embryonic stem cells. This was identified, at first, accidentally, as it was first assumed the black appearance of the cells indicated a failed result, although it was quickly discovered that retinal pigment epithelial cells were, in fact, one of the only black cells in the body - sending a clear indication that these embryonic cells could be worked with and developed on.
With the appropriate cells, Professor Pete Coffey selected two patients from Moorfields Eye Hospital who had age-related macular degeneration with bleeding who had unsuccessful conventional treatment - injections to the back of the eye. One of those patients had a very positive outcome, going from being unable to read to reading fifty words per minute and maintaining that for years after. [4,5]

What other stem-cell-related therapies are there?

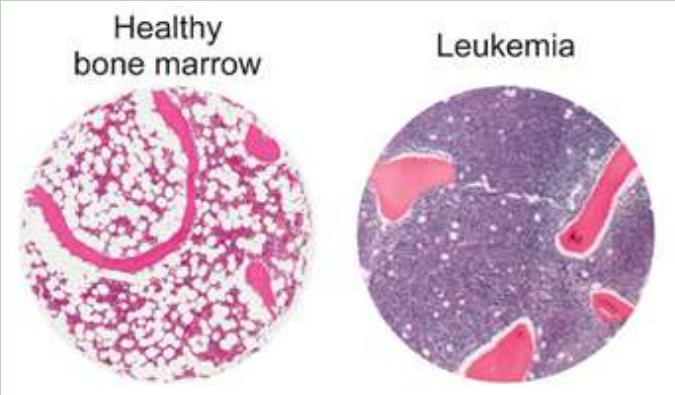
Approved by the FDA, there are two therapies that work with stem cells: Fedratinib and Glasdegib. [3]

Fedratinib is an oral treatment used to treat myelofibrosis, a rare type of blood cancer that changes the characteristically spongy interior of bone marrow into one that is scarred and fibrous. This is due to mutations in DNA, most specifically your red blood stem cells. Daughter cells will be produced, through division, from this mutated stem cell, resulting in the rapid spread of cancer and, in advanced cases, the complete replacement of healthy cells. An effect of this cancer is a compromised ability to produce blood.

Research has shown that a common genetic mutation is in the janus kinase 2 (JAK2) gene, a protein which signals when cells are to divide and grow.

Fedratinib is a selective inhibitor of the JAK2 gene. A selective inhibitor is a compound that binds to the protein, therefore preventing it from being able to bind to other substrates and, in the case of myelofibrosis, preventing the division of mutated red blood cells. Controlled studies have shown that, regardless of JAK2 mutation status, fedratinib is an effective therapeutic option against those with myelofibrosis. [7,8]

Within the UK, stem cell therapy has been successfully used in Great Ormond Street Hospital in children with severely compromised immune systems.



Fat cells (white circles) in healthy human bone marrow, left, compared to bone marrow in a patient with leukemia, right. McMaster University6

Conclusion

Stem cell therapy works with embryonic cells, which are the starting point of many cells that make up the human body that cannot regenerate themselves. Many medical conditions, using altered stem cells, have the potential to be cured, including cancers concerning bone marrow and blindness, with promising results. As this is still a new field of research, there is a limited scope of evidence, but recent publications by the London Project to Cure Blindness and the FDA approving myelofibrosis show that it is a rapidly evolving sector.

Sources

[1] https://www.mayoclinic.org/tests-procedures/bone-marrow-transplant/in-depth/stem-cells/art-20048117

[2] https://www.nhs.uk/conditions/stem-cell-transplant/

[3] https://www.cirm.ca.gov/patients/power-stem-cells

[4] https://acmedsci.ac.uk/more/news/what-does-the-future-hold-for-stem-cell-treatments-

[5] https://moorfieldsbrc.nihr.ac.uk/our-research/research-spotlight/london-project-to-cure-blindness

[6] https://globalnews.ca/news/3805664/boosting-fat-cells-in-bone-morrow-suppressed-cancerous-leukemia-cells-study/

[7] https://www.mayoclinic.org/diseases-conditions/myelofibrosis/symptoms-causes/syc-20355057 https://my.clevelandclinic.org/health/diseases/15672-myelofibrosis

[8] https://www.nature.com/articles/s41375-020-0954-2

DID YOU KNOW?

In geometry, two quantities are in the golden ratio if their ratio is the same as the ratio of their sum to the larger of the two quantities. The solution of this equation is an irrational number, often denoted by the Greek letter φ, which is about 1.618. Interestingly, the ratios of successive numbers in the Fibonacci sequence converge towards the golden ratio: the higher the successive numbers, the closer their ratio is to φ. But it is truly amazing to find this ratio not only in mathematics but also in art, architecture and nature - to the point that φ was sometimes called the "divine proportion". It appears in the Great Pyramids of Giza, built around 4600 years ago. In the human body, the measurement from the navel to the floor and the top of the head to the navel is also generally close to the golden ratio. Even more surprising is that the DNA molecule measures 34 angstroms long by 21 angstroms wide for each full cycle of its double helix spiral, with a ratio also very close to φ.

Homeopathy - what is it and how effective is it?

By Jessica Khaou, Year 11

Homeopathy is a medical system based on the practice of using small amounts of natural substances like plants and minerals to cause the body to heal itself. It is a type of alternative medicine, meaning it is different from the conventional Western methods of medicine. This system was introduced in 1796 by German physician Samuel Hahnemann. He believed that large doses of drugs will worsen the illness and highly diluting substances will produce a greater outcome. [1]

The principle behind homeopathy is "like cures like". This means that a substance that causes certain symptoms can also help to remove said symptoms. The substance is supposed to trigger the body's natural defences. Some natural ingredients that are used include poison ivy, stinging nettles, white arsenic and crushed whole bees. Red onions are a frequent substance used in homeopathic remedies for allergies as they make your eyes water. Homeopathic doctors, otherwise known as homeopaths, dilute ingredients by adding water or alcohol; this process is called potentization. This step is followed by succession, which is shaking the mixture, and is thought to transfer "healing essence". The theory of homeopathy is that the more dilute the dose, the more powerful the medicine. However, many of these remedies are so diluted that none of their original ingredients remain. The homeopathic remedies are often prescribed by a homeopath as it is tailored to each individual. In addition, the remedies come in various forms like creams, tablets, and sugar pellets. [2,3,4]

Homeopathy is commonly used to treat allergies, depression, nausea, headaches and many more. In general, most homeopathic remedies do not cause side effects as they are so watered down. Nevertheless, like all other medicines and forms of treatment, homeopathy comes with certain risks. In some cases, the medicines may contain a large amount of the active ingredient or an unsafe ingredient, for example, a heavy metal, which can be harmful to the body. Some homeopathic medicines can also contain a substance that would interfere with other medicines. [2,3,4]

Since the creation of homeopathy, there has been little evidence that supports the effectiveness of the practice. Many critics believe it works because of the placebo effect - when symptoms improve because you believe it is working, but not because it is; this triggers the brain to release chemicals to relieve the pain. There have been studies comparing the effects of homeopathy to the placebo effect. In a group of 500 adults with influenza, half were treated with the homeopathic remedy Oscillococcinum and the other placebo. The results show that 17% of the homeopathy group recovered and 10% in the placebo group. This indicates that homeopathy could be considered more effective than the placebo effect. [2,5]

https://www.statnews.com/2016/02/26/reject-pseudoscience-homeopathy/

In 2010, the House of Commons Science and Technology Committee said there is no

evidence that homeopathy is effective as a treatment for any health condition. The report says that the principle is "theoretically weak", and that it is scientifically implausible to have an "imprint" of the original substance in homeopathic remedies that are diluted to the extent that not a molecule of the original substance exists. A 2015 comprehensive assessment of evidence by the Australian government's National Health and Medical Research Council concluded that there is no reliable evidence that homeopathy is effective for any health condition. The studies included a systematic review of 176 individual pieces of evidence that were required to meet rigorous criteria. Subsequently, the theories of homeopathy do not match the principles of medicine and scientists argue it is unrealistic that medicine without an active ingredient could cure someone. It is not suggested that homeopathy should be used as an alternative to vaccines. In 2018, the Royal London Hospital of Integrated Medicine stopped providing NHS-funded homeopathic remedies. Now, homeopathy is not widely available in the NHS, and it is not recommended for homeopathy to be provided. [4,6]

To conclude, homeopathy is not a widely used form of practice and is not recommended as a treatment for medical issues as many studies over the years have shown that there have been no significant effects that improve the patient's health. It is not considered to be backed up by scientific evidence as the process of generating remedies does not line up with the actual effect it causes in humans. Consequently, scientists and doctors do not recommend homeopathy as a replacement for illnesses that have medically proven treatments.

https://www.medicalnewstoday.com/articles/325376#homeopathy-and-asthma

Sources

[1] https://www.britannica.com/science/homeopathy

[2] https://www.webmd.com/balance/what-is-homeopathy

[3] https://www.nhs.uk/conditions/homeopathy/

[4] https://www.nccih.nih.gov/health/homeopathy

[5] https://www.takingcharge.csh.umn.edu/explore-healing-practices/homeopathy/-there-good-scientific-evidence-homeopathy

[6] https://www.bbc.co.uk/news/health-43373817

How can we image atoms?
Focus on the Scanning Tunneling Microscope (STM)

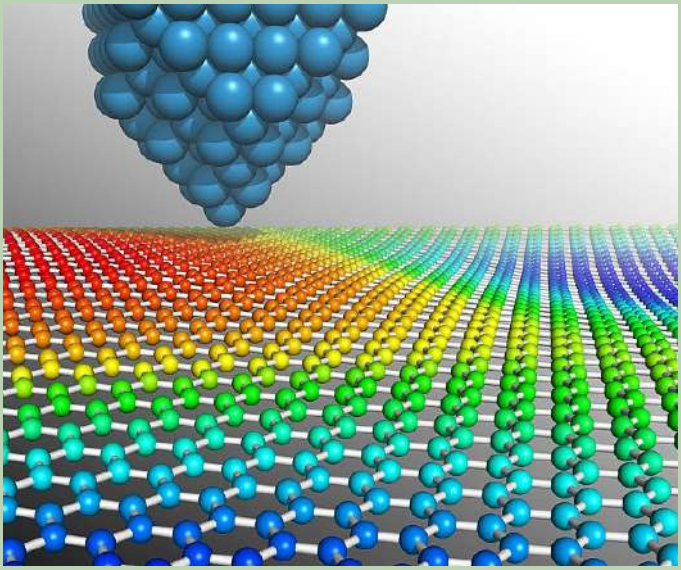
By Marianne Peuch, Year 12

For a long time, being able to look at individual atoms on surfaces seemed to be impossible. In 1986, the Physics Nobel Prize was awarded, in part, to Gerd Binnig (a German physicist) and Heinrich Rohrer (a Swiss physicist) for their groundbreaking innovation: The Scanning Tunneling Microscope (STM), which they worked on in Switzerland at IBM Zurich Research Laboratories. The other half of the prize was given to Ernst Ruska, a German physicist, for his design of the first electron microscope. Both of these scientific advances allow us to see matter at a very small scale.

In this article, I will be focusing on the STM. This microscope was invented in 1981 and it unlocked the possibility to see things on an atomic scale. In fact, its maximum magnification is a staggering 90 million times, hence letting us image structures of but a few nanometres (10^{-9} metres) in size. [1,2,3]

How it works

The tip of a small, sharp needle is brought close to the surface of a sample to be imaged and an electrical voltage is applied to the tip or sample, so that a current can travel between them. The needle is usually made from a platinum or tungsten wire. The current, established due to the movement of electrons between the tip and the sample, is measured to determine the distance of the sample to the needle. The principle is that the closer the needle is to the sample, the more current will flow. It is so accurate that the distances can be measured with extreme precision, like a fraction of the size of an atom! A computer is needed to render a three-dimensional image from the information obtained and colours can be added to make differences in heights more visual.

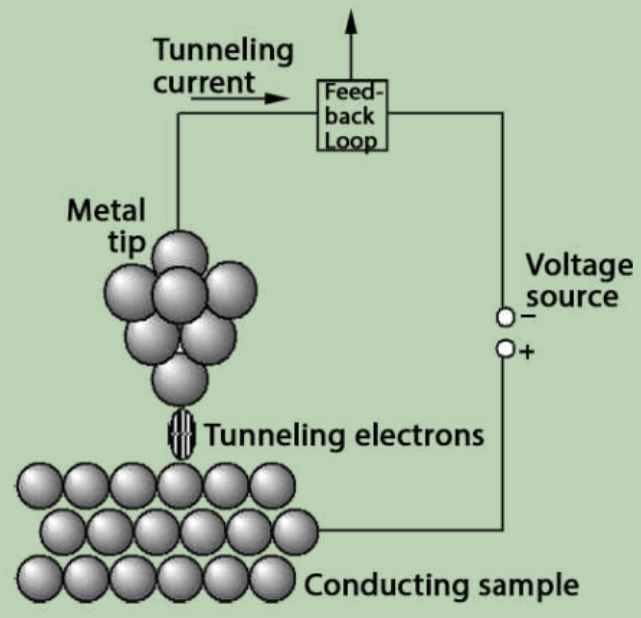


Credit: Duke University, Department of Physics (http://webhome.phy.duke.edu/~hsg/264L/images/stm.html)

The STM has two main modes of operation: the constant current mode and the constant height mode.

The constant current mode is maintained using a so-called "feedback loop", which adjusts the tip's height to ensure the tunneling current stays constant. These changes are recorded by the computer and used to produce the image. When the tunneling current is greater than the preselected value, the feedback will increase the distance between the tip and the sample's surface until it is again at the expected value. The opposite happens when the tunneling current is smaller than the preset value; the height of the tip is reduced.

The constant height mode is maintained by turning off the feedback loop and moving the tip of the needle at a fixed height above the surface. The tunneling current will vary according to the relief of the sample's surface. This mode is used for very flat surfaces. [2,4,5,6]



Schematic of the functioning of a STM. Credit: nanoScience instruments (https://www.nanoscience.com/techniques/scanning-tunneling-microscopy/)

Tunneling effect

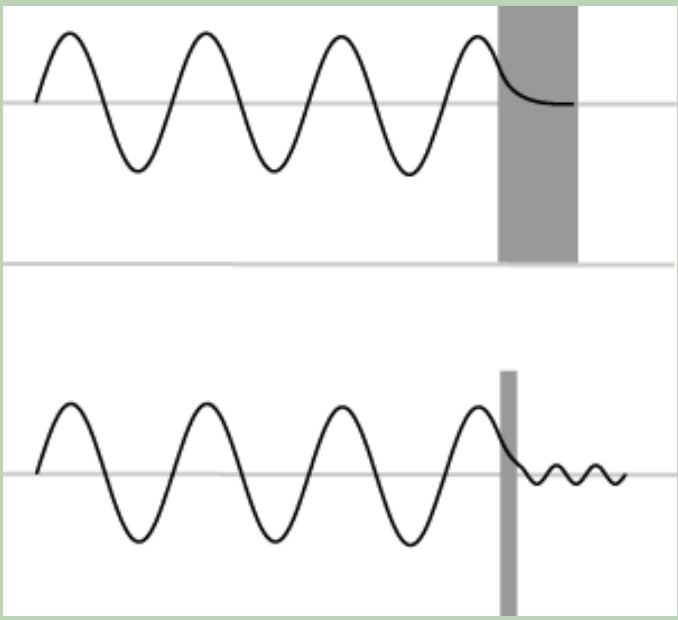
Not many real-world systems rely on quantum physics yet but the STM does!

In classical physics, electrons cannot just jump from the sample to the tip of the needle because there is a gap between the two. However, according to quantum physics, there is a probability that they can, albeit very small, and this probability grows as the tip and the sample's surface get closer to one another. This is called "electron tunneling".

"Tunneling" refers to electrons crossing a barrier that should conventionally be unpassable. In the STM, this barrier is the gap between the tip of the needle and the sample's surface.

According to quantum physics theory, electrons have particle-wave duality properties, which means they can act as both particles and waves. It is the wave-like properties that allow electrons to tunnel. Their wave characteristics mean their positions lie in a cloud of probability so they can exist on both sides of the barrier at the same time and hence, they do not "move across" the barrier but the current still flows from the sample's surface to the needle's tip.

In other words, when a wave hits a thick barrier, it cannot get through it, because there is no probability for the electron to exist beyond the barrier. However, when the barrier is thin enough (usually less or around a nanometre), the wave can travel through it. This leads to electrons being on the other side of the barrier. The thinner the barrier, the greater the current, hence by knowing how much current flows from the surface of the sample to the needle, we can judge the distance between them accurately. [4,6]



Impacts of a thick (top) and a thin (bottom) barrier on the tunnelling effect. In the case of a thin barrier, there is a probability that electrons will go through it. Credit: nanoScience instruments (https://www.nanoscience.com/techniques/scanning-tunneling-microscopy/)

Applications of the STM

The STM is used a lot to image the surface of metals down to their atoms, which is very useful in the industry sector and for scientific and engineering research. Data can be obtained from the STM to find out flaws in surfaces, how rough they are, and the arrangement and dimensions of individual atoms it is composed of. Looking at these lattices of atoms has proven very useful in

particular to gain a better understanding on and to engineer improved electronic chips and conductors.

In scientific research, it is used for surface chemistry (chemical reactions occurring at interfaces), electrochemistry (the relationship between chemical reactions and electricity production) and electronic properties of semiconductors (materials that can conduct in certain instances but not in others). It is also used to make progress with catalytic materials by allowing the study of reaction mechanisms on crystallographic surfaces at the molecular level. It can also be used in molecular biology and when looking at the topography of the surface of cells, like T24 cells (human urinary bladder cancer cells).

The STM is also essential for the development of nanotechnologies, which specialises in materials with dimensions of less than 100 nanometres. For example, contacts and connectors on nanodevices can be designed by depositing single atoms of metal (like gold, silver or tungsten) to form specific patterns. This paves the way for instance for electronic switches at the molecular level. Nanotechnologies are also now widely used in the automotive industry, with improvements brought to tires, the longevity of exterior body paints or to bumpers. In the near future, nanostructures may also allow delivering medicines to precise targets in the body. An application area could be chemotherapy, where nanotechnologies could support attacking cancer cells with increased accuracy and much reduced side effects. For example, we could utilise the nanostructure of a virus, which has 17 nanometres of storage space, to carry an atomic-scale drug payload. [3,4,7,8]

Conclusion

The STM invention was not only revolutionary as such but nowadays, new scanning microscopies also rely on the technology developed for the STM. In 1986, Binnig developed another microscope, called the atomic force microscope (AFM) based on what he had managed to do with the STM. The AFM allows us to image samples that are not electrically conductive (the STM only works with conductors and semiconductors as a current needs to be able to flow). The STM and AFM have opened doors to many other instruments, which allow us to see formerly imperceptible surfaces. [8]

References and further reading

[1] https://www.nobelprize.org/prizes/physics/1986/summary/

[2] https://www.sciencelearn.org.nz/videos/2044-scanning-tunnelling-microscope-stm

[3] https://www.thoughtco.com/scanning-tunneling-microscope-4075527

[4] https://afm.oxinst.com/modes/scanning-tunneling-microscopy-stm

[5] https://www.ntmdt-si.com/resources/spm-principles/stm-techniques/constant-height-mode

[6] https://www.nanoscience.com/techniques/scanning-tunneling-microscopy/

[7] https://pubmed.ncbi.nlm.nih.gov/2049086/

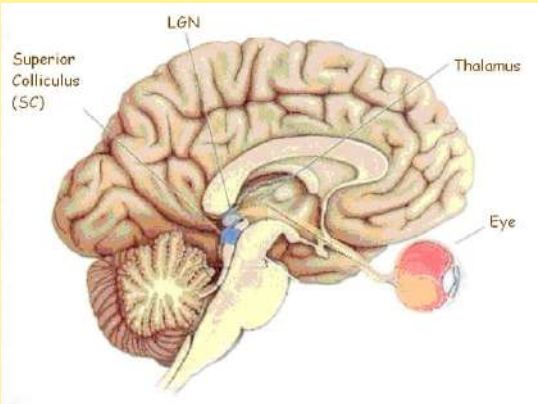
[8] https://www.ibm.com/ibm/history/ibm100/us/en/icons/microscope/

The internal model - our individual realities

By Jess Jarvis, Year 12

We all have the basic understanding of how vision works; it seems simple right? The photons enter your eye through the cornea, are diffracted through the lens and hit the retina lining the inside of the sclera. These photons are then absorbed by the photoreceptor cells (your rods and cones) and converted into electrochemical impulses which travel to the visual cortex at the back of the brain to be processed into an image of your surroundings. At first glance this appears relatively easy. However, the brain does not simply process the electrical signals coming from the retinas of the eye and produce an image from this data, there is another far more complex step in this process.

To gain a more detailed idea of the processing of visual information from the retinas, let us take a look into how it works. The electrochemical signals coming from the retinas in the eyes travel along the optical nerve on the way to the visual cortex, passing through the thalamus (specifically the lateral geniculate nucleus), located in the centre of the brain on the way. The visual cortex is responsible for processing the electrical signals from the retinas and differentiating between colour, depth, contours and other such categories of information needed for constructing an image within our minds. The visual cortex is split into many subsections responsible for dealing with different visual features, and the higher in the visual cortex the section is, the more complex the visual feature processed by it is. So due to the large volume of information being transported in through the thalamus to the visual cortex, you would expect to see many neural pathways directing electrochemical signals in this direction. However, the surprising thing is that there are ten times more neural pathways going from the visual cortex into the thalamus. This is because the cortex is drawing from all past experiences and memories, to form an expectation of the electrical information we are likely to receive from our retinas about our surroundings. The thalamus is then responsible for comparing the expectations from the visual cortex with the sensory information coming from the photoreceptors in our eyes. Any differences between the brain's expectation and the real sensory data is then identified by the thalamus and sent back up to the visual cortex. This explains why there are fewer neural pathways going from the thalamus to the visual cortex than in the opposite direction, as only the errors are fed back up to the visual cortex. This way we can learn from the shortcomings or errors of our brain's expectations, otherwise known as our internal model. We are able to constantly alter this model, in order to have a constant idea of our surroundings, even when they are not directly in our field of vision. [1,2,3]



Brain diagram (accessed: 08/11/2021): https://www.researchgate.net/figure/Brain-areas-involved-in-vision-and-visual-attention-between-the-retina-and-the-Primary_fig4_271076240

This process is such an important step in the huge task of perceiving our environment that it still continues to take place even when our eyes are starved of sensory stimulation. It is on these grounds that sensory deprivation chambers work. If the visual cortex and thalamus are not receiving visual information from the retinas, assuming that there is also no sound for the brain to process, the internal model is allowed to continue unhindered. This creates a vision of our surroundings despite the lack of sensory data to base it on and compare it with. The Internal Model is the brain's method of noting possibly useful information we notice from our environment and storing it in case we need to draw from it in a survival situation. However, these models are never exact representations of the scenery around us. An example of an optical illusion which plays on this is an image which first appeared in The American Journal of Psychology in 1930, in which both an old and a young woman can be seen. This presents the idea that when we perceive our surroundings, it is not our exact reality that we believe to be there, but our brains' own take on it; our own construction of the material world. [1,4]

All-About-Psychology.com, Optical illusions, author: David Webb, accessed: 08/11/2021, https://www.all-about-psychology.com/optical-illusions.html#top

References

[1] The brain by David Eagleman, published 2016, Chapter 2 - what is reality?

[2] The University of Queensland, Queensland Brain Institute, Visual perception, Author: Alan Woodruff, accessed: 07/11/2021, https://qbi.uq.edu.au/brain/brain-functions/visual-perception

[3] NCBI, Neuroanatomy, Thalamus, author: Tyler J. Torrico and Sunil Munakomi, accessed: 07/11/2021, https://www.ncbi.nlm.nih.gov/books/NBK542184/

How does the food we consume affect our brain, body and how they function?

By Ester Popescu, Year 12

We eat food every day, that is a fact, but we never take into consideration how it affects our brain, body and how it helps or affects the way they function. Our body could be described as a machine that needs the correct fuel, or if not, it will start crashing and breaking apart, however, how do we know which type of fuel will be most suitable for each person? We all have unique needs based on metabolism, exercise, sleep, and genetics. In addition, as if this was not complicated enough, this machine works because of the main component, the brain. The brain is the most important piece of the puzzle, yet we never take it into consideration when we talk about diet.
Our diet is composed of 3 macros: carbohydrates, fats, and protein; along with vitamins and minerals. However, how do these affect brain function? Well, let us start by breaking down the main components, and sectioning them.

Carbohydrates are simply starches, sugars, and fibres that at a chemical level, are made of oxygen, carbon, and hydrogen. Carbohydrates give energy and help with the function for the nervous system, and brain function. As you eat the carbohydrates, they are broken down in the gut, producing glucose, making the brain have a steady and continuous energy supply. However, society's new rule of low carb has been affecting this balance, by cutting carbs and increasing the intake of protein and fat. Carbs are important for the function of the brain, as it is a supply of energy, however, Keto, Atkin diets etc. have been linked with depression as brain chemicals, as the blood levels are low, producing serotonin ect.

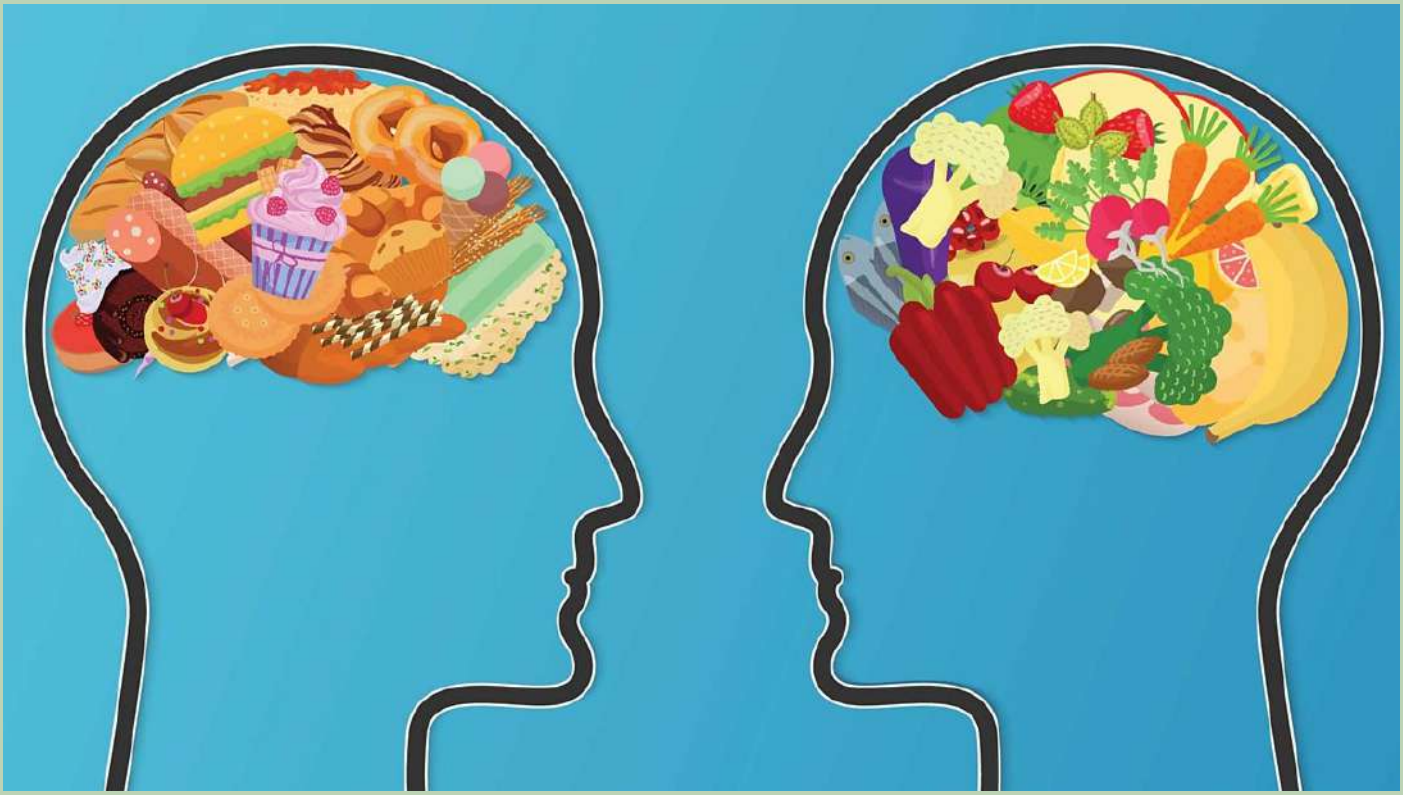
Protein is probably the "best" considered macro. When we hear protein, we immediately imagine a strong bodybuilder that can easily squat 150 kg as reps. However, protein is more than just for muscle building. Protein is composed of large molecules, amino acids and peptide chains and they have multiple roles from muscle building (we will turn into strong people that can fight bears in the forests), to repair tissues and cells, make enzymes and hormones etc. Furthermore, the role of protein for the brain is to optimise brain function and help get nutrients to the brain. Amino acids help produce key neurotransmitters to prevent and treat depression. Additionally, this is linked to higher levels of dopamine and brain chemicals, due to raising the levels of tyrosine (an amino acid).

Did you know that the brain is made of 60% fat? Fat is the major form of fuel and energy for the brain. However, we need to think about the types of fat, as there are four categories: Trans fats, unsaturated fats, polyunsaturated, and monounsaturated fats. Now, you might be asking, what is the difference, why does it matter? Well, it does matter because they have different properties, so they have distinct functions. For example, high saturated fat has been linked to more heart disease, as it can raise LDL cholesterol levels, which can clog your arteries. However, we cannot fully cut them out of our diet, as the body needs saturated fat for cell membranes, which helps with liver function etc.

Ironically, we have all heard about how important omega-3 is for our brain. This is because the body cannot produce these essential fatty acids itself. Additionally, it has been found that people with high (mostly unsaturated) fat diets have better brain function as the improved membrane integrity enables more efficient communication with other cells. Additionally, it is vital for building

and repairing body tissues (this is due to certain vitamins being better absorbed with fat). It provides structural integrity and fluidity to cells in the brain. Fat contributes to mental health and the brain due to the amount of fat consumed helping the cell membranes and the function of the brain cells.

In conclusion, what we eat is not just for pleasure, or because it will help us lose or gain weight, there is far more than meets the eye. Therefore, we need balanced meals with the main macros, along with a lifestyle of exercise, sleep, and personal indulgences. You know what they say, "nourish the cells and indulge for the soul."



https://www.bbc.co.uk/food/articles/diet_wellbeing

Sources

https://www.health.harvard.edu/blog/nutritional-psychiatry-your-brain-on-food-201511168626

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2738337/

https://www.bbc.co.uk/food/articles/diet_wellbeing

https://www.mind.org.uk/information-support/tips-for-everyday-living/food-and-mood/about-food-and-mood/

https://www.nhs.uk/live-well/healthy-weight/why-we-need-to-eat-carbs/

STEM news at OHS
Science outreach programme with a local primary school

By Marianne Peuch, Year 12

This term, the spotlight is on (drum roll please…) Science Outreach Perspectives!

As part of the "Perspectives" scheme for Sixth Formers at OHS, ten Year 12 students volunteered to take part in our ongoing Sixth Form Science Outreach programme. For some 9 years, every week, Year 5 pupils from our local primary schools come to OHS on a Thursday afternoon to learn and engage with hands-on science in a science lab. For the last 3 years our partner primary school has been New Marston school. No science is left out as we undertake biology, physics and chemistry experiments together!

The latest experiment we carried out was chromatography - a process that separates mixtures of dyes based on their different affinities to the chromatography paper and their solubilities in water. They carried out this experiment on colouring pens to see if the colours we see on the package are pure or a mixture of other colours. It was great to see how enthusiastic they were and see their faces of amazement as unexpected chromatograms formed on their chromatography papers. For example, while conducting this practical, they found out that the colour black consisted of a mixture of dark blue, purple and other colours!

Previously, we had also done an experiment on friction, seeing how different surfaces affect the distance a block travels when released from the top of a slope. The Year 5 pupils were incredibly careful controlling variables, they paid a lot of attention to the instructions and they ensured it was a reliable test at all times. We loved seeing them take care with their measurements.

One of the other most fun investigations was looking at bacterial growth on tables, the floor and even the soles of their shoes! They used agar plates and were very surprised to see how many bacteria had grown on those the following week. It was very funny hearing some say 'Yuck!' as they looked at their agar plates - no doubt they will look differently at the door handles now!

The children we work with are feisty, fun and fearless, and we learn so much from them about how best to simplify and communicate quite tricky concepts.

All of the Year 12 mentors really enjoyed the Autumn term Science Outreach Perspectives programme and we look forward to continuing it in 2022.

Acknowledgements

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Authors of articles in this issue

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