Stowe Science Review

Stowe's Mathematics, Technology & Science Newsletter

Sherlock Holmes: The Science of Deduction

Personalised Medicine: The Future?

Fractals: the beauty of Maths

Welcome to Stowe Science Review!

The magazine that gives you a fascinating insight into the miraculous world of Mathematics, Technology and Science.

Written and produced by...
Skye Longworth
Georgina Skinner
Fabiola Koenig
Jonny Dale
Stuart Milner
Gabe Chauveau

With thanks to...
Stowe Science Department
Mr Tearle
Mrs Roddy
and thank you also to the General Office.

Get involved with...

Stowe Quantum Society
Stowe Biomedical Society
to quench your thirst for scientific knowledge!

Contact the Editorial Team for details.

What do you think of Science Review?

Do you have any ideas about how we could make the read more enjoyable?
Email sciencereview@stowe.co.uk
Speak to a member of staff in the Biology, Chemistry, Physics or Mathematics Departments and ask if they can pass on your comments. Your feedback is much appreciated.

Contents

1 Optogenetics and the brain. By Skye Longworth
2 Is Creatine good for you? By Gabe Chauveau
3 Personalised Medicine: The Future? By Georgie Skinner
4 Sherlock Holmes: The Science of Deduction. By Skye Longworth
5 If you weren't scared already... Snakes and their venom! By Stuart Milner
6 The Future of Batteries. By Fabiola Koenig
7 Fabiola also explores the maths of fractals!
8 Fun facts!
9 Further Reading page
10 Space Crossword

Have your say...

Science Review wants to know what you think about scientific affairs - please email sciencereview@stowe.co.uk with your views on the topics discussed in this issue.

We look forward to hearing your views!

Optogenetics and the Brain

Optogenetics can be likened to the flicking on and off of a light switch. This treatment could hold promise for the future of severe brain diseases and even blindness. This is a revolutionary new field in which cells, commonly neurons, are supplied with a gene which creates light sensitive channels. When light of a specific wave length is shone on to these cells the channels open, allowing ions to pass through activating or deactivating the target neuron. All that is needed is a virus carrying the gene, and a fibre optic implant.

This treatment offers a lot more control for neuroscience researchers - the brain is incredibly complex and dense, and as a result incredibly hard to treat specifically. Deep brain simulation, for example, can have negative effects as it has no target. It effects all the cells in the surrounding area, with obvious unreliable results. By implanting this gene into a virus, specific cells can be targeted as individual channels are opened in selected areas of neurons.

Trials for retinitis pigmentosa are being carried out as genes are inserted into the relatively accessible eye area. No fibre optic light implant is necessary as the eyes are already exposed to light. Chronic pain is also targeted as this is associated with a reasonably accessible area of the brain, and the light sensitive channels can be activated as a response to when the pain starts. The future possibilities for this sort of treatment are astounding: treatments for brain diseases such as Parkinsons, depression or Alzheimers could be possible, as well as epilepsy. Researchers are looking into ways to genetically modify cells so they are sensitive to magnetic or sound waves instead of light, which needs invasive surgery to get deeper into areas of the human body. This avenue of research holds promise for a better way of understanding the functions of the whole brain, bringing the possibility of recreating it one step closer.

The issue with this seemingly miraculous treatment lies in its staying power. Gene therapy is irreversible, and you also need an implant in the brain which could be dangerous depending on the location of the target neurons. The brain, as mentioned above, is incredibly complex and dense, so if the implantation was carried out incorrectly the results could be catastrophic.

Less controversial applications lie in medical research. With this exciting new tool researchers can see the effect of activating specific neurons in the brain. If you can know the effects of such specific neurons being both activated and deactivated by the easy reversibility of this treatment, researchers can discover long term effects or the stem of certain neurological diseases. It could lead to a lot deeper understanding on how the brains work - how neurons interact and the effect of certain areas on behaviours. Optogenetics holds promise in its clinical applications and will hopefully further our understanding of the most complex organ in the human body.

By Skye Longworth

By Gabe Chauveau

Creatine is useful. Weightlifters know this, professors know this and the guys that sell this supplement know this.

However, no one should take a supplement without weighing up the benefits and risks beforehand. Creatine essentially increases the body's ability to produce energy rapidly and is typically bought in flavoured powders and mixed with water. With the extra energy you get from creatine you can train harder and longer and see increased results.

Most tests about creatine show that it helps with high intensity, 'explosive' sports such as powerlifting, football and sprinting. This is not the same for endurance events, however, as there is less evidence that creatine helps aerobic styles of exercise, as creatine phosphate helps resynthesize ATP in the absence of oxygen.

Paul Greenhaff, Ph.D, professor of muscle metabolism at the University of Nottingham, says that the initial gain of weight from creatine is water, about 2-4 pounds in the first week of supplementation, subsequent gains will be muscle as you can see from the increased work load you can handle. Due to creatine being an 'osmotically active substance' it will draw water into your muscle cells which will increase the rate of protein synthesis. The only catch to this is that creatine only works if you actually use it, like going to the gym, otherwise it is just water weight.

Where is creatine used?

Creatine phosphate is used when the ATP-Pc system is the predominant energy system being used in the body; this usually occurs during periods of immensely high intensity of about 3 seconds when the ATP stores will have been depleted. For high intensity activities to continue, the immediate recycling of ATP is necessary. However, due to the rapid increase in intensity, there will be a resulting oxygen deficit and insufficient amounts of oxygen available to sustain this ATP resynthesize. The body then relies on the energy rich compounds found alongside the muscle cells called phosphocreatine. Like ATP the breakdown of phosphocreatine occurs in the sarcoplasm and is facilitated by the enzyme creatine kinase. The increase of ADP and inorganic phosphates stimulates the release of creatine kinase. This results in the equation:

Phosphocreatine $\longrightarrow$ Creatine + Pi + Energy.

The re-synthesis of phosphocreatine normally takes 2-3 minutes for all of the stores to be full again, which is beneficial to interval training. This is totally inhibited however if the local circulation in the muscle is occluded or if there is a low intramuscular pH.

What we're actually interested in however is if this supplement is good or bad for you. There have been extensive studies into this topic but the one we are most interested in is the power output studies. To take one study as an example: it was a double blind study for 18-27 year olds with body types of trained, overweight and average. The study lasted 1-6 weeks and all of the test subjects saw an increase in their muscle mass. None of the test subjects felt or saw any side effects from using creatine as a supplement. The test measured the subject's anaerobic capacity on the Wingate test with the aim to test creatine monohydrate against a placebo after loading for 2 days, but 5 days were found to produce better results. The men who took creatine monohydrate saw faster gains than the men who took the placebo.

When to take creatine?

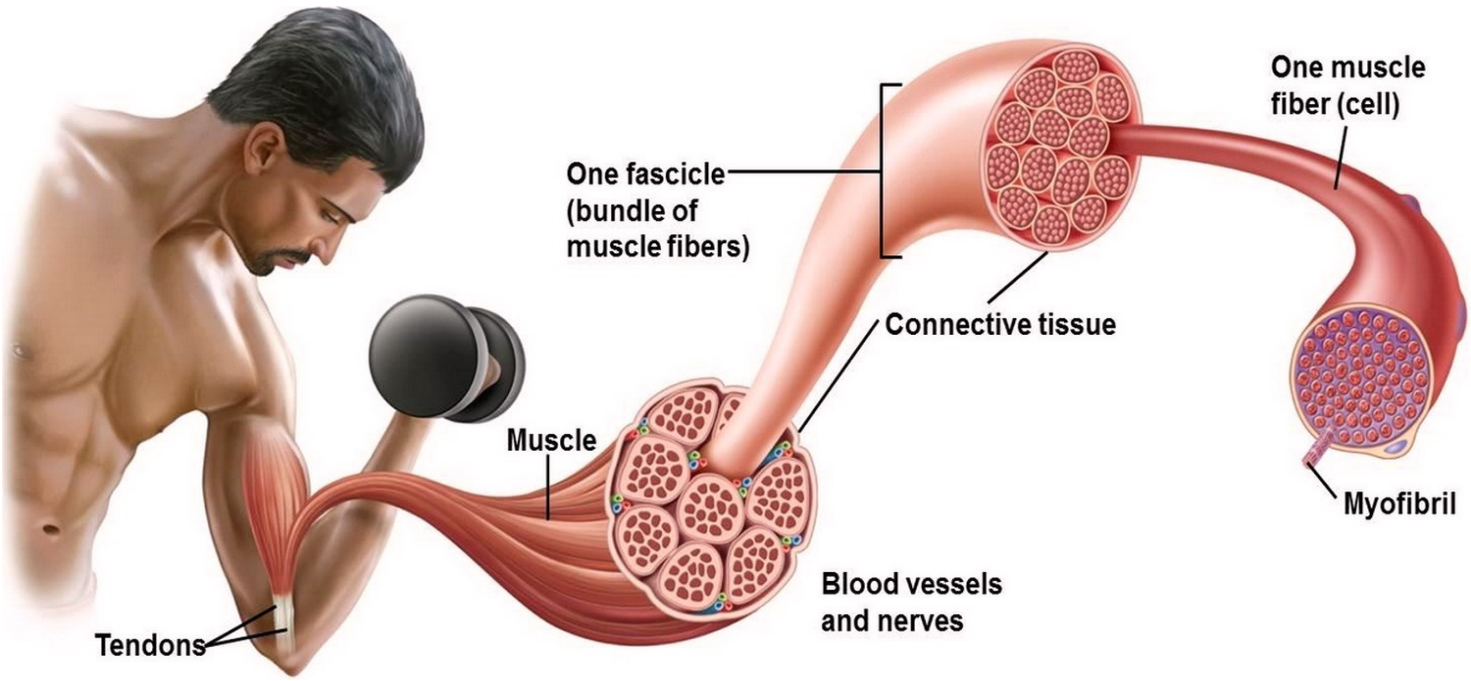
It is possible, and now generally recommended, to produce the same end result by taking a single 5g dose once a day for 4 or 5 weeks to slowly build up stores. Once creatine stores are loaded athletes can maintain levels by taking 2-5g a day. Alternatively you can let your levels taper back down and re-load after 2 or 3 months.

The side effects of creatine.

The side effects related to kidneys, liver damage and increased rick of injury have not been shown in clinical studies. However there have been no long-term studies that examine the use of creatine. There is evidence that creatine supplementation can damage unhealthy kidneys, and dehydration is also a common side effect. Also due to a lack of regulation, toxins, and impurities of the product are always a concern.

The benefits of creatine in summary are; increase in muscle size, improved athletic performance and increased muscle synthesis.

Therefore to conclude, creatine is safe for most people. However since liver and kidney disease, in their early stages, may not produce any symptoms, it is a good idea for your doctor to test your liver and kidney function, especially if you plan on using supplements.



Personalised Medicine:
The Future?

Personalised medicine is a type of medical care in which treatment is customised for an individual. It has the ability to offer the right drug, to the right patient, for the right disease, with the right dosage. As a result, patients receive specific therapies that work best for them, and with no adverse side effects of trial and error treatments.

The rise of personalised medicine is revolutionising the way doctors and pharmaceutical companies approach disease. Using genetic sequencing, medical professionals are now able to separate people with similar symptoms into far narrower groups and target medicines at them individually. The benefits are enormous. It means that patients are initially matched better to their drugs, resulting in less of a "trial and error" method of prescribing. Personalised medicine also offers support financially; as healthcare costs are rising across the UK due to the ageing population and prevalence of chronic diseases, personalised medicine has the potential to reduce the costs of clinical trials so that drug testing will become more effective and cheaper. Furthermore, customised pharmaceuticals may eliminate life-threatening adverse reactions to drugs that do not suit a particular individual. It will also greatly improve the efficacy of drugs.

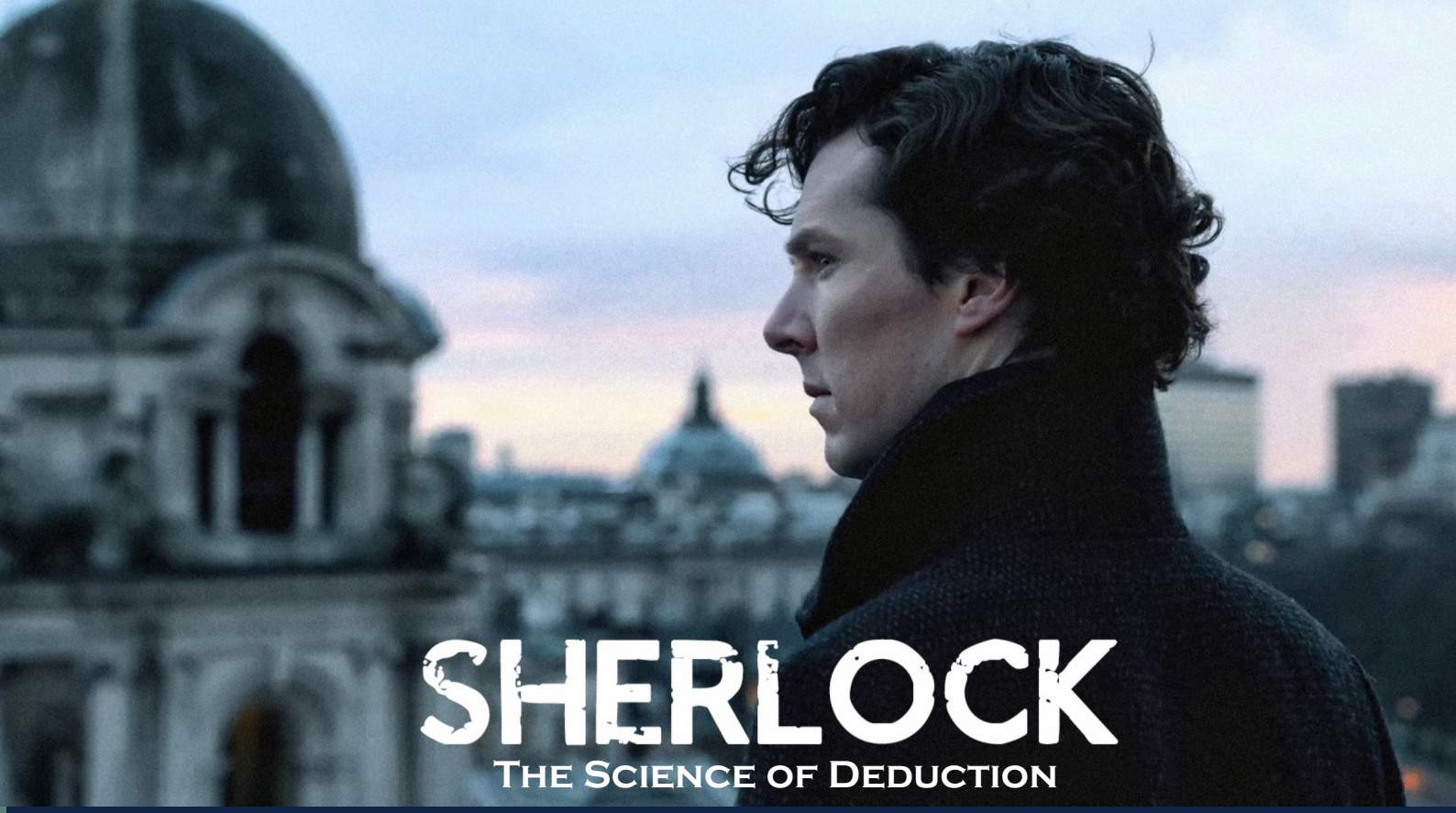
In humans it is only 0.1% of our DNA which makes us different each other. The variations in 0.1% of our DNA are what give us different attributes and characteristics. Unfortunately, it is also these variations that can give rise to harmful diseases such as diabetes or cancer.

In addition, the variations can be latent, meaning that they are not harmful on their own, but have the potential under certain conditions, to cause harm.

Personalised medicine can be applied to many stages of treatment including the diagnosis of a disease, development of a specific drug to treat a disease and most interestingly, tailoring doses to a patient individually. The "one-size-fits-all paradigm" is constantly disproved in medicine. For example, individuals respond differently to the anti-leukaemia drug 6-mercaptopurine: most metabolise the drug quickly and need higher doses to treat the leukaemia and prevent relapses; others metabolise the drug slowly and need lower doses to avoid toxic side effects of the drug; and a small proportion of people metabolise the drug so poorly that's its effects can be fatal. The diversity in responses is due to variations in the gene for an enzyme called TPMT. Therefore after a blood test individuals are given doses that are tailored to their genetic profile.

It comes as no surprise that a lot of investment is targeted towards personalised medicine, and even before DNA was completely understood, the famous physician William Osler said, "if it were not for the great variability among individuals, medicine might as well be a science and not an art." Arguably, it is now both the science of genetics and the art of patient welfare.

By Georgie Skinner



Sherlock Holmes is a character to capture the imagination of generations; being reincarnated in almost every age, bringing us right up to the modern TV series “Sherlock" starring Benedict Cumberbatch. One of the most captivating aspects of Conan Doyle’s stories is Sherlock’s incredible deductions - his logical chain of reasoning has been likened to medical diagnosis: encompassing history, physical examination and investigation. Holmes' ability to ascertain facts about someone, such as when he deduces John Watson was an army doctor by his appearance in the BBC version, particularly demonstrates his detached method of reasoning, or “the science of deduction” His profound practical knowledge of chemistry, forensics, and psychology helped him solve the most difficult of cases and inspire detectives in literature for many years to come. So, are Sherlock’s abilities rooted in fiction or is there any scientific basis?

Sherlock’s cognitive abilities may in fact be rooted in neuroscience. In A Study In Scarlett, he calls his memory technique the “brain attic”. A recent study (by a group led by Janice Chen, a postdoc in the Psychology Department at Princeton University) showed that we compartmentalise memories just as Sherlock Holmes may have done; the findings may help in treatment of Alzheimer's. 22 participants were placed in an fMRI machine which traces blood flow in the brain to measure activity. They watched the first half of A Study in Pink (the BBC Sherlock adaptation) and were asked to recall as much as they could. Participants were able to talk for about 20 minutes about what they had seen. The patterns of brain activity when talking through the show were so similar that researchers were able to tell which part was being discussed just by looking at the fMRI results. The results were also similar to each other, showing when humans experience events they organise memories in a very similar way. Furthermore, this finding disproved the belief that the similarities in different people’s memory is confined to “lower-order” brain regions as the study found similarities in higher order cortical brain regions. This goes to show that all of us may perhaps have the “brain attic” memory technique of Sherlock Holmes and with the right combination of imagination and memory, we may be able to master the science of deduction.

However, Sherlock’s abilities seem extraordinary, even for such a memory technique. Another explanation may be that Holmes had an overdeveloped hippocampus. Reading deeper into Sherlock’s behaviour may lead us to the conclusion that he was on the autistic spectrum. Typically symptoms include a lack of social awareness, rigidity of routine and obsessive behaviour; traits all fitting in with Sherlock’s character which ultimately help him solve crime. He could be classed as a savant, a rare group of people who demonstrate extraordinary abilities in a limited field due to different synaptic connections in the brain - savantism has been linked to increased memory capacity in some cases.

From the many iconic quotes in the detective stories, Sherlock’s statement that “When you have eliminated the impossible, whatever remains, however improbable, must be the truth” neatly sums up Sherlock’s scientific mind.

By Skye Longworth

If you weren't scared already, you will be now...

By Stuart Milner

Snake venom has evolved for one reason, to kill and maim. Whether this is used in hunting or as a defence mechanism completely depends on the type of snake. There are three main types of venom that have evolved: hemotoxic, neurotoxic and cytotoxic. Most snake species use a cocktail of different venoms and the composition of these venoms gives them different potencies to a variety of animals.

What is venom?

Snake venom is a modified saliva, which contains enzymes, proteins and amino acids. These have a variety of properties: anticoagulant, necrotic and hydrolytic. Around 90-95% of venoms dry mass is proteins.

Hemotoxic venom:

Hemotoxic venom affects the circulatory system. This can range from the destruction of red blood cells, the prevention of blood clotting or the breakdown of blood vessels which can lead to severe internal bleeding. However, this venom type has been somewhat misnamed as although it is targeted at the circulatory system it can affect all tissues and lead to generalised tissue damage. There are also some snakes whose hemotoxic venom is designed to breakdown tissues slowly to aid digestion. If injected by this type of venom the affects can be severe. Extreme pain, necrosis, disorientation, nausea, headaches, loss of muscle control and death in many cases.

Neurotoxic venom:
This type of venom, as the name suggests, targets the nervous system. It mostly inhibits neuron control over ion concentration in cells or prevents the neurotransmitters from crossing the synapse. Neurotoxic venoms only target the nervous system and can be very lethal: paralysis, widespread central nervous system damage, seizures and, should the prey survive, memory impairments, loss of muscle control and dementia.

Cytotoxic venom:
Cytotoxic venom targets general tissues; it mostly breaks down tissues through digestive enzymes (causing severe pain). Swelling and inflammation are common immediately after a bite, necrosis will occur around 24-48 hours after the bite and blisters and blackened or dead tissue will be prevalent. This is the type of venom that is prevalent in spat venom, and can lead to eye swelling and even blindness.

However, the severity of a snake bite also depends on the type of bite. There are four recognised bite types:

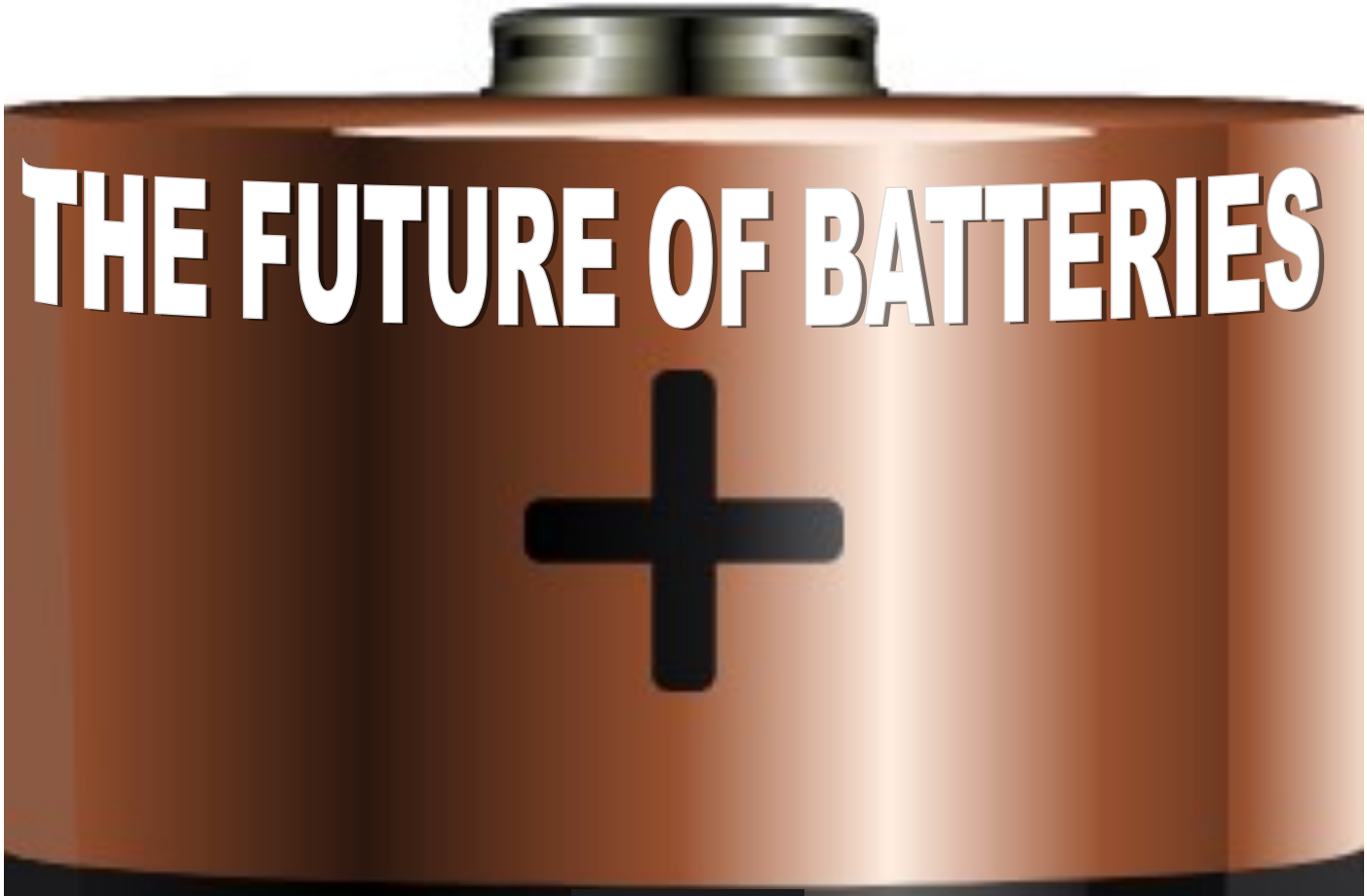
Subcutaneous: a bite under the skin is the most common.

Intramuscular: Only large specimens of Gaboon Vipers, Puff Adders, Rhino Vipers, Rattlesnakes, Bushmasters, and South American

Intravenous: The most fatal bite: these are extremely rare and very, very unfortunate.

Intraperitoneal: Bites directly into the abdominal cavity. These are again very rare for humans.

However, snake venom isn't all bad. Through medical and scientific research many types of venom are currently being used or tested to help combat strokes, a variety of cancer notably the copperheads venom for treating breast cancer, and excessive bleeding (taipan venom). Also, neurological diseases like Parkinson's and Alzheimer's are being investigated, but this research is still in early phases.



THE FUTURE OF BATTERIES

In 1780, Luigi Galvani was dissecting a frog attached to his desk by brass hooks when he touched its leg with his iron scalpel and the leg twitched. His friend Alessandro Volta believed that two different metals joined together by an aqueous substance caused this phenomenon. Through experimentation he verified his theory and in 1800, Volta invented the first proper battery.

Two hundred years later we still see his invention everywhere we look. From our smartphones to a simple torch: without the battery our lives would be far less mobile. Like most useful technology, it is constantly being improved: at this very moment technologies that could very well change the way we travel and store energy are being developed.

One of the most interesting developments seems to be with Aluminum-air batteries. The advantage of using Aluminum over Lithium is that it is easy to recycle and is actually the most recycled metal present today. Lithium, on the other hand, is in short supply and expensive. Its extraction causes environmental destruction and serious pollution. The company Phinergy has already used this technology to drive an electric car 1,100 miles in one charge. In comparison, current electric cars like the Tesla Model S can only achieve 300 miles. The reason is the huge 8,100W/kg capacity of the aluminum–air battery. The cathode in the battery is fueled with oxygen making the battery far lighter than a liquid fueled lithium-ion battery. The aim at the moment is to produce a hybrid car using both our existing and our new technology to make a car that has two batteries: one for long distances and the other for short distances.

The Al-air battery would have to be swapped every couple of months as the aluminum reacts forming aluminum hydroxide, but this could easily be recycled therefore providing a closed system of renewable energy. If this technology flourishes, this process could soon become so affordable and advanced that it could be a serious option for reducing our CO2 emission.

A second technological advance in the field of energy storage is slightly different. Inductive charging could completely replace our need for batteries in the sense that we know them today, therefore opening new doors into the development of other energy storage systems. “Wireless charging” as it is often known, uses electro- magnetic fields to transfer energy between two objects.

This knowledge is over 100 years old as Tesla was the first man to demonstrate wireless power transmission in 1891. The aim is to normalize wireless charging so it is commonplace wherever we go. This would mean we would be able to charge our mobile phones and laptops on the go wherever we are. Many companies like the Wireless Power Consortium and the Alliance for Wireless Power are trying to standardize wireless charging across the world. The process uses an induction coil, which creates an alternating electromagnetic field from within the charging device. There is a second induction coil in the mobile phone that converts the power from the electromagnetic field back into electric current to charge the battery. This could also have medical benefits for those fitted with a battery device located in their body, as the skin would not have to be penetrated to charge the device.

The problem used to be that, just like a charger, you needed to be in close proximity to a charging base. uBeam, a technology that uses the energy from ultrasonic vibrations to charge devices, could rid us of that problem. Ultrasound has been used for decades in cleaning and medical technology and has no known health risks. Ultrasound is sound emitted above the range of human hearing (20Hz-20kHz) although it is in the range of some animals, e.g. bats (18-120kHz). A targeted, focused beam to the device that is requesting it, delivers the power. When the sound reaches the device, the receiver that converts it into electrical energy picks it up. If our devices could always be charged wherever we go, the battery in them could be greatly reduced in power, size and weight therefore making the products lighter, slimmer and wireless. This could improve waterproof technology, innovate flexible screens and reduce the amount of lithium used in the battery, which would be beneficial to the environment. At present, there are discussions about the reliability of the product. However, multiple scientists have agreed with the manufacturers that it is achievable to produce a dependable and beneficial device. The product should be on the market in the near future and should prove to all the skeptics that this is the future of energy usage. Until then, batteries are just going to have to do.

References

1. When was the battery invented? (2001) When was the battery invented? Available at: http://www.buchmann.ca/article3-page1.asp (Accessed: 27th January 2016).
2. Tzidon A., Khasin E. (2013) Aluminum air, available at: http://www.phinergy.com/default.asp?catid=%7B00658B18-2755-468E-92CB-E66021BB4D4C%7D (Accessed: 28th January 2016).
3. Curtis S. (2016) Wireless charging: everything you need to know, Available at: http:// www.telegraph.co.uk/technology/news/11434736/Wireless-charging-everything-you- need-to-know.html (Accessed: 28th January 2016).
4. Perry M. (2015) The Power of Sound, Available at: http://ubeam.com/technology/ (Accessed: 30th January 2016).

By Fabiola Koenig

Fractals and the Mandelbrot set

The complex and beautiful patterns known as fractals look so organic and intricate that at a glance it seems impossible to find a way to describe them. Yet just such a way exists and it is astonishingly simple. It is based on two concepts: iterations and complex numbers.

Complex numbers are often written as a+bi where i denotes √-1 and can be represented on the complex plane as shown below. (see diagram 1)

Iteration is the process of repeating an operation again and again. Consider: $x \rightarrow 2x$ starting at 1. This forms a sequence $1 \rightarrow 2$, $2 \rightarrow 4$, $4 \rightarrow 8$ and so on which is iterative because the output of each operation is the input for the next operation. If we consider the iteration $x \rightarrow x^2$ starting at 1, the sequence stays at 1 indefinitely, starting at 2, the sequence heads to infinity ($2 \rightarrow 4$, $4 \rightarrow 16$, $16 \rightarrow 256$…) and starting at a value smaller than 1, the sequence tends to zero. If we consider $x \rightarrow x^2 + c$, the values that tend to infinity change drastically. For example when c=1, starting at 1, the iteration looks as follows: $1 \rightarrow 2$, $2 \rightarrow 5$, $5 \rightarrow 26$ and heads to infinity unlike before.

If these two ideas are combined, an iterative process can be represented on the complex plane. To start simply, using $z \rightarrow z^2$, where the first term is i, the iteration looks like this: $i \rightarrow i^2 = -1$, $-1 \rightarrow 1$, $1 \rightarrow 1$. Represented on the complex plane it would look like a unit circle where the black represents those values that do not tend to infinity when the iteration is applied to them. (see diagram 2)

In 1978 Benoit B Mandelbrot, a French mathematician, became interested in $z \rightarrow z^2 + c$ where c is the starting point in the iteration. When he plotted the graph a peculiar shape appeared that was surrounded by tiny splotches that looked like dust. In this diagram again, the black areas are numbers that are in the Mandelbrot set and do not tend to infinity after the iteration is applied to them. (see diagram 3)

When Mandelbrot zoomed into these areas strikingly ornate patterns emerged. These can not be predicted but can only be found by doing the iteration thousands of times. The rate at which numbers tend to infinity can be represented by colour, giving the mesmerizing patterns shown. Mandelbrot wrote of his discovery: “It leaves us no way to become bored, because new things appear all the time, and no way to become lost, because familiar things come back time and time again.”

There are still so many unanswered questions about the Mandelbrot set. One of the most exciting queries was whether the set could be represented in 3D. In 2009 Daniel White and Paul Nylander produced a set using $z \grave{O} z^8 + c$ often called the Mandelbulb. Its surface is inconceivably intricate yet is only described by one line of code.

Fractals connect maths to the natural world and have stirred fascination within not only countless maths enthusiasts but also those just enthralled by the mesmerising patterns. The simplicity of the code that produces such an organic and vast design raises questions about fundamental laws that define our universe and how simple they really could be. It gives us one more example of a modest instruction producing breath-taking variety that could contribute another piece of the puzzle to figuring out why we are here.

Which ever way you look and how ever far you zoom there is an ever changing landscape of paisley filigrees and seahorse-like spirals, giving it the name the Seahorse Valley. Mandelbrot coined the word 'fractal' to describe any shape that contains miniature versions of itself. In fact, a joke circulated that the B in Benoit B Mandelbrot stood for Benoit B Mandelbrot.
But not only does this simple concept form spectacular designs, it also has another trick up its sleeve. All numbers in the set give values that are less than 2 when the iteration is applied to them. The value furthest along the real axis that is still part of the set, is called the cusp (labelled C) and is 1/4. By looking at values that are close to the cusp, p can be approximated. If we take a small, real and positive value e, add it to C and do the iteration, the number of iterations it takes for the values to be greater than 2 give us an ever closer approximation to p the smaller e is. Although this is probably one of the most time consuming ways to approximate p, its fascinating to observe such a relationship between two comparatively unrelated areas of maths.

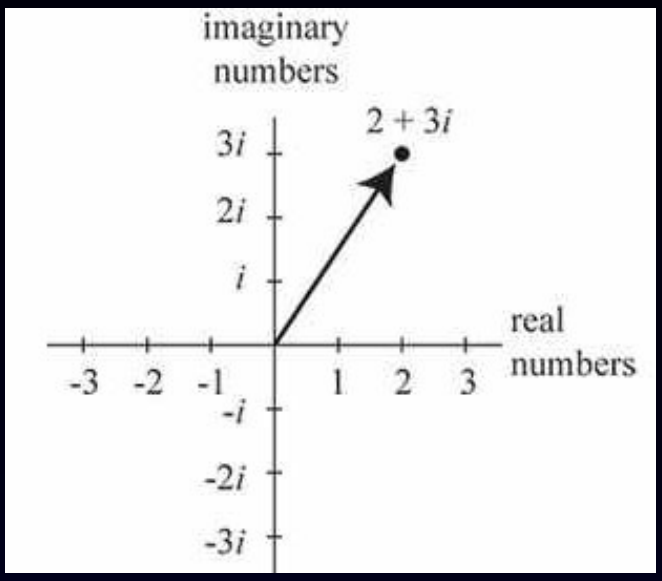


Diagram 1 - complex plane

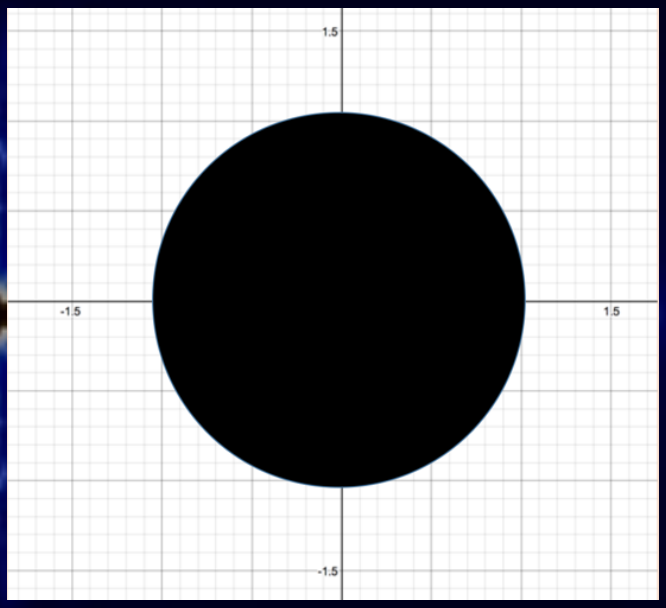


Diagram 2 - unit circle

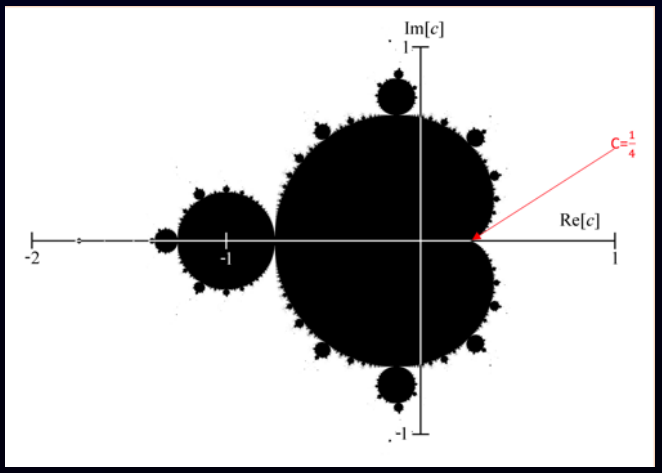


Diagram 3 - Mandelbrot's graph

Fun Facts

According to an old English system of time units, a moment is one and a half minutes.

There are 60,000 miles of blood vessels in every human.

SHARKS ARE IMMUNE TO CANCER

The heart of giraffe is two feet long, and can weigh as much as 24 pounds.

Rats multiply so quickly that in 18 months, two rats could have over 1 million descendants.

There are more living organisms on the skin of a single human being than there are human beings on the surface of the earth

Further Reading suggested by Jonny Dale

BOOKS

Revolutions that made the Earth by Tim Lenton and Andrew Watson
A bit dense for casual reading but takes a really informed and interesting view on early life. It explores all the background required for a balanced understanding of the known information on the origins of life.

Thinking fast and slow by Daniel Kannerman -
A psychology book, but a really good one.

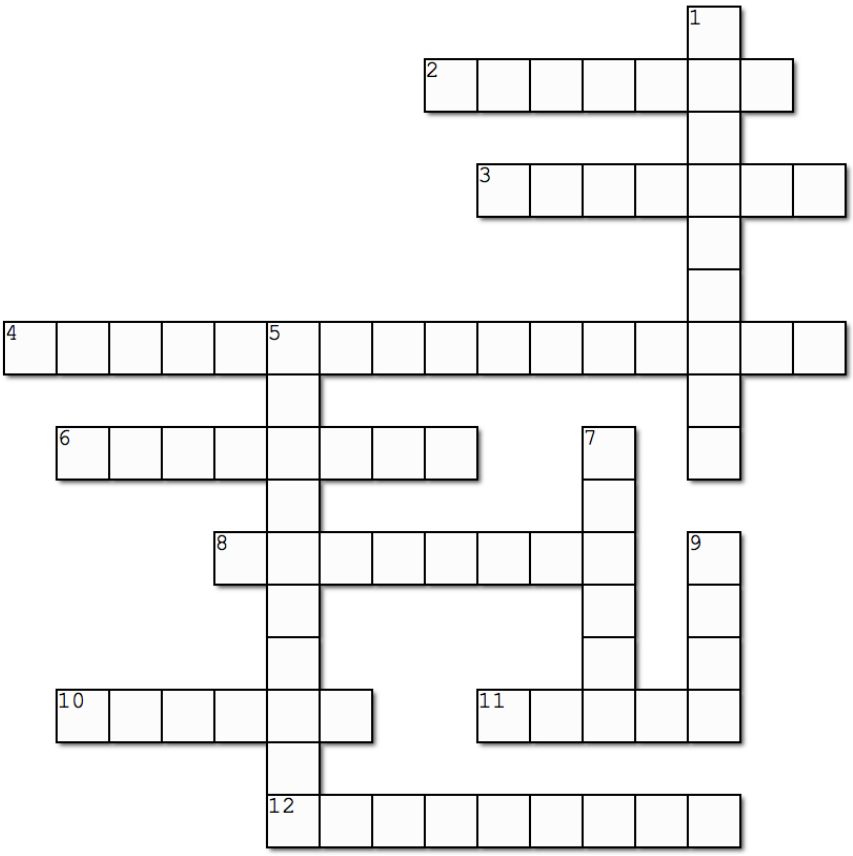
David and Goliath
(Malcom Gladwell)
Also a good psychology book

Youtube channels:

Kurzgeagt

Veritasium
TED-ed
SciShow

Space



Across

2. The planet with the most moons in our solar system
3. The first man who theorised that Saturn had rings
4. The process of falling into a black hole and getting more and more stretched
6. The shape of the earth
8. A large rocky body in space, in orbit around the Sun
10. The greek word for star
11. The hottest planet in the solar system
12. The nearest major galaxy to the Milky Way

Down

1. A piece of space rock that lands on earth
5. The first woman in space
7. The second person to land on the moon
9. The planet with the largest mountain in the solar system

Note from the Publisher

This is the second Science Review issue to be edited and developed by Fabiola Koenig, Skye Longworth, and Georgie Skinner. We have worked hard to get this one out and would like to extend our thanks to the writers for their articles and further reading recommendations.

Finally, we would like to thank Mr Tearle and Mrs Roddy for their help and support with the editing process.