Leicester Grammar School's

YOUNG SCIENTISTS journal

What could cause pain in body parts that are not there?

Amputation and Phantom Limb Pain — Page 6

The reality of if there is in fact extra-terrestrial life.

The Great Silence: Are we really alone in the Universe? — Page 10

An exploration of how proteins work, and why it is so disastrous when they don't.

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ISSUE 2 SUMMER TERM 2017

A Message from the Team:

"The student team of the Young Scientists' Journal wish to extend a warm welcome to our second issue. The overwhelming success of the Big Bang Fair, held in March this year, has allowed us to exhibit the project to a rather small audience of 3000 people. Our task was simple - to begin cooking up issues from scratch, with very few ingredients to start with. No pressure!

LGS joined the existing Young Scientist's Journal, as a representative, at the start of 2017. It is the only peer-reviewed publication that is written, edited and run entirely by young people. Through this, any student aged 12-20 from around the world can discover their passion in science through whatever way they wish - be it through building experiments, articles, book reviews, photography or even blogging. Moreover, our team can only flourish with a variety of skills; journalists, technology masters, film-makers and photographers alike are just as valued as our budding scientists.

One of the most prominent questions we are asked is: "but what can I write about?" The scope is boundless. This journal's identity is shaped completely and totally by the people involved. In fact, our philosophy is steadfast - the quirkier the better! Our first issue explored telemetry toasters, black holes, antelopes, full-dive virtual reality and even Cryptozoology - investigating the existence of the Loch Ness Monster!

To think that this all began as a hopeful flicker in a few minds gathered around a table is quite simply extraordinary. From September 2017, we are opening positions of responsibility to younger students, which will involve roles in editing, formatting and photography. We do this in the hope that the Young Scientists' Journal can continue to grow and flourish as the current Year 12 Editorial Team fly the nest at the end of next year. It has been a privilege to see this seedling establish its roots and begin to blossom, and we hope to see it continue a long and fruitful career.

We hold regular meetings, of which you will be informed in the morning Notices; alternatively, feel free to send us an email at lgsyoungscientists@gmail.com."

Maria Hancock — Chief Editor

We would like to acknowledge the following for their contribution:

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Our booth at this year's Big Bang Fair, held at Leicester Grammar School.

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Who are We?

We are a collection of Leicester Grammar School students who have come together to produce a variety of pieces of writing about the world of STEM. As a school, we have become a hub for the Young Scientists Journal, an international peer-review written and edited entirely by young people.

Contact Us

Anyone interested in joining the YSJ to help to write, edit and publish is more than welcome to meet us at our meetings during lunchtimes (specific details will be in the daily notices). We welcome submissions from all year groups on any scientifically-related topic; so come along to a meeting or email us at:

lgsyoungscientists@gmail.com

See more of the Young Scientists Journal at:

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Front Page Photo:

By Priyan Patel, Year 12 LGS Student

One of a collection of photos shot using the Huawei P9, see more in "Long Exposure Explained"

Extreme Physics

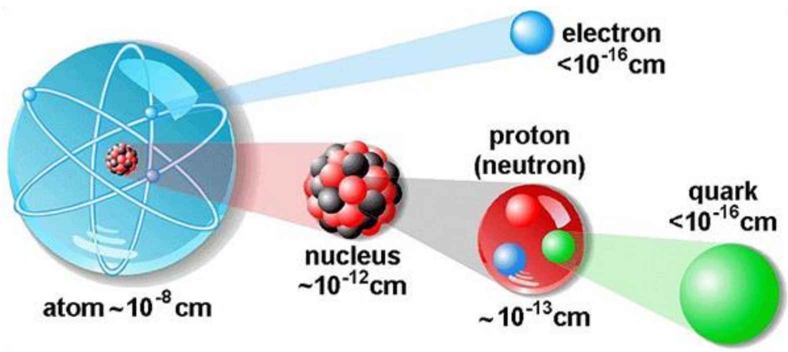
A description of a once in a lifetime opportunity to further Year 10 students' interests in Physics, from the point of view of Tejas Easwar.

I'm not usually a fan of extreme challenges, especially when they involve extreme difficulty. However, recently I went to the aptly named Extreme Physics, which stretched these boundaries quite literally to the extreme. These three adrenaline-fuelled days taught us Physics and its practical applications in an unprecedented way.

Our three days kick-started with an early morning rise. From Monday the 10th to Wednesday the 12th of April 2017, when most students were in bed having a well-deserved lie in during the Easter holidays, there were us four Year 10s who didn't quite fit that category. Though most of us were half-asleep when we arrived at school, we were all wide-awake by the time our Physics teacher Miss Allcoat had blasted her 90s-rock music in the minibus stereo. At our arrival, we saw what appeared to be a castle, with its own church, an old US army base and fields carrying on even past the horizon. Little did we know that in just a matter of minutes we would have to navigate through this vast unexplored territory - all in the name of Physics.

Before we were even given a chance to sit, we were sent off to a lab in preparation of a treasure hunt. We were each given a map and told set points and coordinates to gain maximum points, in a time scale of 30 minutes. Using the equation $velocity = \frac{Displacement}{Time}$, we could work out the average velocity needed to collect all the points, which we achieved using an app on our phones. After half an hour of constant sprinting around this huge school, we arrived back with all the points, but our shirts drenched in sweat. But it was all worth it in the end as we won that challenge. Famished, we indulged ourselves in a delicious lunch. Just as we began to enjoy ourselves, we were called back to the lab for our next task: a one-minute timer. After a few minutes of thought, we had made a concept involving fire, smashing magnets and electricity (as you do). We would light a fuse of rope, which would then cause a magnet to fall on a piece of aluminium foil (as shown by Newton's law of gravity). This would cause a current to flow through a circuit causing a lightbulb to light up. Our concept had worked in the test runs; however, the laws of Physics were trumped by the minimalist application of common sense (too thick a knot), thus we had failed. But all was not lost, for we did get a rosette for creativity.

After this challenge, we had an eye-opening lecture from a renowned particle physicist, Professor Cristina Lazzeroni. Here we learnt of the recent discoveries of many new particles.



A basic diagram describing the basic model for quarks within an atom.

Despite theories suggesting that the atom was the smallest particle in the universe, Professor Lazzeroni told us even the atom was made up of smaller particles, specifically six quarks, six leptons, four force carriers, one Higgs boson, and many other similar particles. However, our challenge was to identify how many Muons (a form of lepton, like an electron, but with a greater mass) were in our atmosphere. To detect these particles, we needed to use a cosmic ray detector. Overall our experiment was successful enough to draw out a meaningful conclusion, that muons truly existed and that Professor Lazzeroni's theory was successfully demonstrated in practice.

Day 2 began with us rushing off to Milton Keynes shopping centre to face our fears. As we cautiously trudged in, a looming rock tower was awaiting. It would have been an understatement to say I was the worst at climbing it. I can just about stand upright on my two legs defying the laws of gravity, but climbing was way out of the equation. Every attempt at a pull-up was countered by a fall, showing Newton's Third Law a little too clearly - that every action does indeed have an equal and opposite reaction. As I struggled to even go past the first hurdle, my teammate Jatin scampered past me. Despite our masses being similar his velocity gave him the momentum to overtake me. After my (not-so) amazing climbing skill was put on display to all, we were sent off to the skydiving centre, where a vertical wind tunnel was shunting air at over 120mph. Plummeting up and down this massive wind tunnel was no doubt scary but also quite exhilarating. We could remain in that horizontal position due to terminal velocity. The air being shunted up by the wind tunnel was producing enough air resistance to counter my weight pushing me to the ground, hence leaving me hovering. However later I could fly right up near the top of the wind tunnel, since the air resistance was now greater than my weight pushing me down.

Day 3 – All that was left to do was our presentations, with our topic being on the renowned physicist Robert Hooke. We cooked a plan, as we hooked our audience with a rap, song and even a guest appearance from "Professor Yash" from the University of Bombay with his trusted assistant. Hooke's Law states that the extension of an object such as a spring is proportional to the force applied. We broke plenty of springs, showing that after the elastic limit, springs disobey Hooke's Law and so deform and eventually break. We got the laughs, we got the praise, but most importantly we got the extra points, enough to let us come fifth overall. At this, all that was left was to go back home.

Extreme Physics is run for Year 10s all over the country, and is funded by the Ogden Trust. It is kept in motion by volunteers, who selflessly help out and design the challenges. Thanks to all, and I certainly recommend the experience for any Year 10.

Tejas Easwar, Year 10

An example of the wind tunnel the students were in, where you are kept in mid-air by a huge fan spinning beneath the netting, simulating a free-fall at terminal velocity.

Amputation and Phantom Limb Pain

Alice Weare delves into the study of Phantom Limb Pain, a topic which still produces new research and information after decades of research.

Approximately 5,000 amputations are carried out in the UK every year and it is estimated that there are around 10 million amputees in the world, making the incidence of amputation approximately 1.5 per 1000. Amputation, which is the surgical removal of a limb, is a last resort treatment in a number of circumstances, such as when a limb becomes infected, is deformed, has undergone a serious trauma or a patient is suffering from diseases such as gangrene or diabetes.

In extreme cases of infection, it is necessary the amputate to prevent the spread of the infection from the limb to the rest of the body, which could potentially be fatal. In cases of deformity from birth or during development, amputations are performed in order to improve a patient's movement if the limb function is limited. Amputations that are performed as a consequence of a trauma such as a car crash or serious burns and are necessary if the bone, muscle and nerves are too badly damaged and are unlikely to recover.

Side effects and Complications

As with any surgery there is a risk of infection and blood clotting but due to the nature of the operation there are increased risks that are specifically related to the loss of a limb; these include deep vein thrombosis, pneumonia and phantom limb pain.

Along with the physical there are many psychological side effects that can develop as a result of amputation due to the patient having to adapt to cope with the loss of sensation and function of their amputated limb and the change in people's perception of their appearance. It is common for amputees to experience depression, anxiety and grief post-surgery.

Phantom Limb Pain

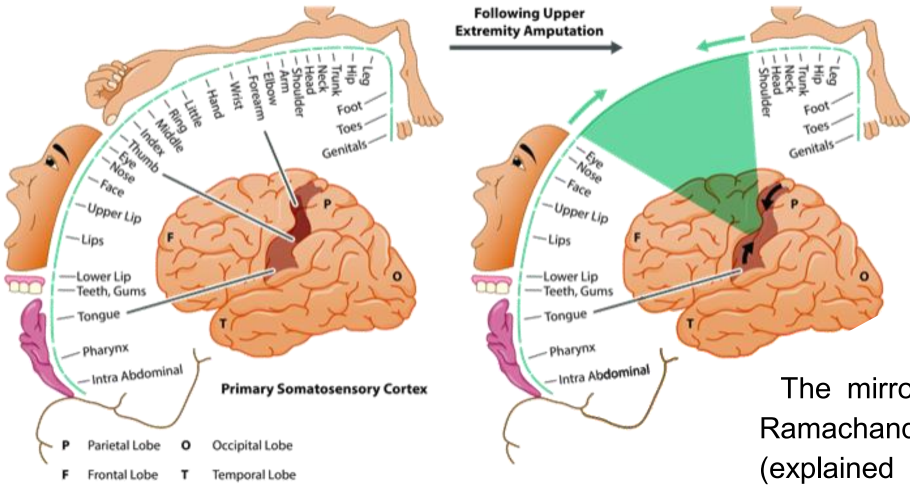
Phantom limb pain is when a pain is felt in the limb that is no longer there, the pains can include burning sensations, tingling and itching and also varies in severity with each person. The condition was formally named 'Phantom Limb Pain' in 1871 by Silas Weir Mitchell, an American neurologist who was treating soldiers in Philadelphia during the American civil war. It is a common side effect of amputation, with between 50 - 80 percent of amputees experiencing some form of pain. The pain can begin almost immediately after surgery and tends to reoccur periodically, most people's pain gradually disappears as the body, particularly the brain has adapted to the loss of the limb. However, research shows that if the pain persists for six months or more then it is unlikely to stop.

The Theories of why Phantom Limb Pain occurs

There are many theories for the cause of phantom limb pain and it is likely that there are many factors that contribute towards the pain…

Ben Seymour, is a neuroscientist working in Cambridge's Department of Engineering, researching a method of treating phantom limb pain through engineering rather than through drugs. According to Seymour a theory for phantom limb pain is that it is a result of faulty 'wiring' is the primary motor and sensory cortex, which is the area of the brain responsible for processing sensory inputs and executing movements of the body. So when a limb is amputated this results in a mismatch between a movement and the perception of that movement in the brain and the outcome of this mismatch is pain, felt in the missing limb.

Another related neurological cause, researched by phycologist and neurologist Dr Vilayanur Ramachandran from the University of California,



A diagram explaining the change in brain structure and sensory awareness before and after an amputation.

is that neurons in the brain that were previously associated with the amputated limb become inactive and as a result the brain's neuro connections reorganize and active, stimulated regions of the brain associated with other parts of the body begin to take over the inactive regions. This remapping process is called neural plasticity and is possible because of the malleability of connections in our brains. This is extremely common in arm amputations, as the closest region to the neurons belonging to the arm is the face, so the face neurons move into inactive regions of the brain, this can result in sensation or pain being felt in the amputated limb when a certain area of the face is touched, due to the faulty sensory rewiring that has occurred.

Many other factors combine to result in phantom limb pain including scar tissue at the site of amputation, pain and discomfort caused by poor fitting prosthetics as well as damaged nerve endings. Nerve damage anywhere in the body can result in a severe shooting pain and this sensation at a site of amputation can contribute to phantom pain being felt in the missing limb.

Treatment

As a specific cause of phantom limb pain has not been identified and confirmed it is difficult to develop a permanent solution or cure, instead most treatments are focused towards managing the pain. In most cases the pain is treated both medicinally, through opioids (narcotic pain medications), beta blockers and muscle relaxants and with complementary therapies simultaneously. These include acupuncture, massage of the residual limb as well as virtual reality therapy and mirror box therapy, which are used to combat the neurological causes of the condition.

The mirror box therapy was developed by Dr Ramachandran in correlation to his theory (explained above) that phantom limb pain is caused by inactive neurons in the brain rewiring to other areas of the body. Through using mirrors to reflect an image of the phantom limb, a patient is able to gradually retrain their brain and reverse the rewiring, a process which Dr Ramachandran calls 'learned paralysis', causing the pain to subside over time.

Research of phantom limb pain continues in numerous fields including neurology, psychology, pharmacology and clinical engineering, finding new innovative ways to treat phantom limb pain, through managing the pain or identifying the causes.

A patient undergoing a session of mirror box therapy.

Alice Weare, Year 12

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Challenger Mission at the National Space Centre

William Wale recounts his Year 7 school trip to the National Space Centre to take part in a simulated space mission to a comet.

There are two Challenger learning centres in the world outside North America, in tribute to those who died in the explosion of the Space Shuttle Challenger in 1986 including the teacher in space Christa McAuliffe. One centre is in South Korea.

The other is in Leicester.

Over the course of the first three weeks back at school after the Easter Holidays, every single year 7 class got to go on a trip to the National Space Centre, where the simulation is based. In the Science lessons leading up to the trip, we had had to apply for different positions on the mission. I was medical officer, but other roles included Navigation, Communication and Life Support. When we arrived, we were briefed, and told what we already knew, we were required to fly a spacecraft towards the comet Encke.

Once half of the group left to lift off and enter the spacecraft, we entered our positions at ground control. Once the craft crew were in the simulation of the spacecraft, we began our mission. One team had to build the Probe, which would be launched towards Encke, while another team had to navigate. Two separate teams, one urgent and one otherwise, were responsible for communication, while life support kept us all alive. Over at Isolation and Medical, we were merely performing tests. Apart from an issue with the humidity on board, a lack of power in the probe room and potential radiation caused us to return to Earth, so that ground control could swap with astronauts. Although we did eventually decide to launch the probe towards a new comet we discovered, which we inspiringly named comet 7D (our form, by the way), everything went to plan.

It was a thoroughly enjoyable trip.

William Wale, Year 7

Women in Engineering

At this point in time, there is a pressing social issue with regards to the number of females in STEM industries. Lucy Ring discusses how we can change this with regards to the huge disparity within the engineering sector.

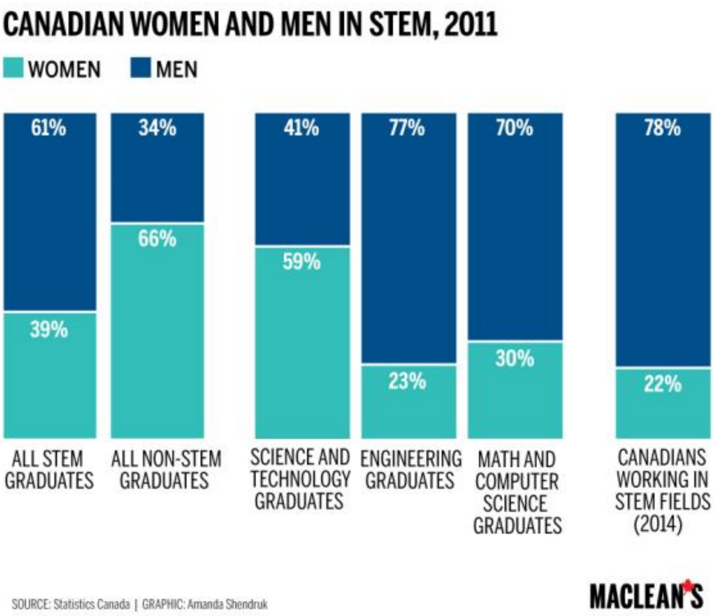
A Less that 10% of registered engineers are females. This is largely due to the misconceptions of what an engineer does and who an engineer should be. There is a common preconception that engineers are male, which may be preventing many young women from even considering it as a career. This lack of understanding has led to the huge gender gap that currently exists across the industry. However, companies and organisation are more aware of this issue than ever before. A conscious effort is being put in to try and increase the number of girls choosing to pursue careers not just in engineering but in all STEM subjects.

One obvious example is National Women in Engineering Day which celebrates those women who are achieving big things in the engineering world. Roma Agrawal is one of the best known female engineers in the UK. This is due to her role as a senior structural engineer on the Shard project in London. She was the only female featured in the Channel 4 documentary, “The Tallest Tower”, about the designing and construction of the Shard. She believes that lack awareness is the reason that so few women are in the industry. Fundamentally this comes back to a lack of education about the possibilities and career paths available. Roma now spends a lot of time going into schools and talking to groups about her career and all of the interesting things that she has achieved. This shows people more of the reality of being an engineer and the opportunities it can offer.

Another way in which STEM is being promoted to girls is through competitions, such as the Talent 2030 competition. This allows girls to tackle real life problems and work in groups to develop and produce a solution which is then judged. With the opportunity for the winners to get £500 for themselves and £500 for their schools, as well as all finalists presenting their work at the Big Bang Fair. These competitions can generate a basic interest in the subject and convince girls to consider pursuing it further.

Universities and big engineering firms have now recognised that recruiting women not only fulfils the need for more engineers but also brings a new skill set into the working environment. Currently there is a degree of positive discrimination for women. Now is the time to consider this challenging and rewarding career. The future looks bright for women in engineering.

Lucy Ring, Year 12

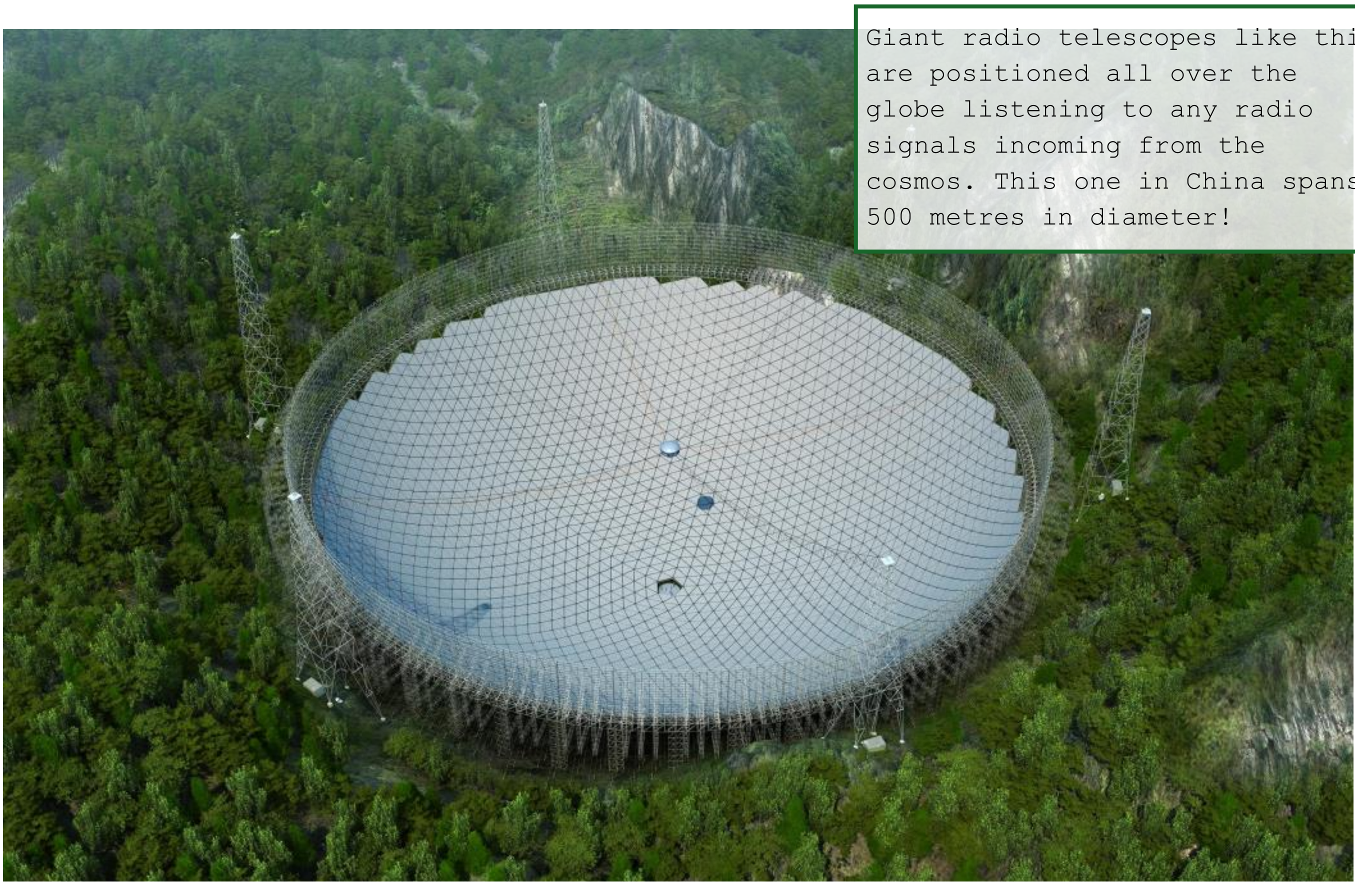


A recent study in Canada clearly showing the large difference between the genders when looking at graduates in STEM fields, with an especially large difference within engineering.

The Great Silence: Are we really alone in the universe?

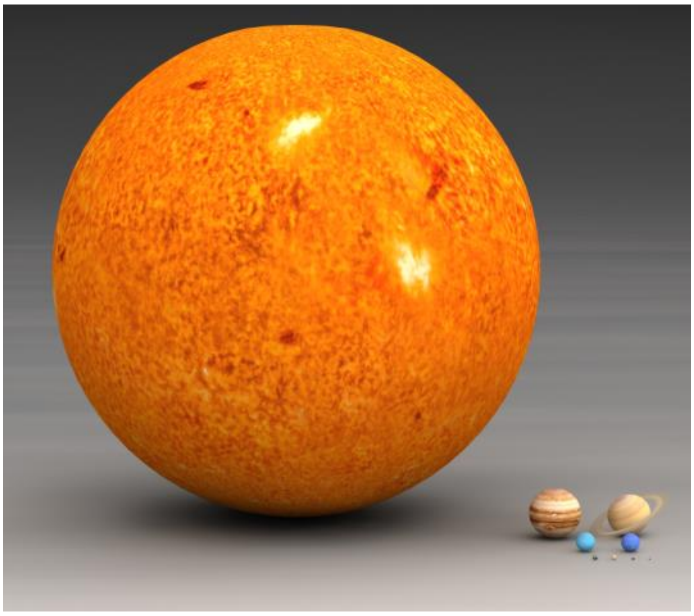
Andrew Higginson tackles the subject of our place in this universe, and the feasibility of intelligence life contacting Earth, or if they even exist.

"Two possibilities exist: either we are alone in the Universe or we are not. Both are equally terrifying." That quote is from Arthur C. Clarke, the famous British author, inventor and futurist. Personally I would disagree that both possibilities are equally terrifying; to me being all alone in the endless blackness of space takes a close second to an encounter with the real life equivalent of a Xenomorph from Alien. However, Clarke's quote also reveals something about our own knowledge of extraterrestrials (or lack thereof); mainly the sheer fact that we don't know whether or not life, and most importantly, intelligent life, has originated anywhere else in the Cosmos. On one hand many acclaimed scientists and mathematicians have calculated the sheer statistical improbability of Earth being the sole birthplace of life in the universe, indeed the numbers show that it is so low as to almost be an impossibility. But numbers are one thing, and actual encounters with little green men are another. Putting aside all talk of alien abductions and the alleged "grey-skin" bodies being kept in cold storage in Area 51 for the moment, to this day there have been no confirmed sightings, and no definite established contact with intelligent life from elsewhere in the Universe. For almost sixty years, our telescopes have been angled towards the stars, listening, our scientists awaiting with bated breath the almost inevitable signal. Yet it has not come. This is a phenomenon known as the "Great Silence." Physicist Enrico Fermi articulated the apparent contradiction between the statistical probability of intelligent life existing elsewhere in the universe, and our lack of contact with them, and his arguments and theories around this subject have come to be known as the Fermi Paradox. Simply put, if intelligent life, perhaps more intelligent and technologically advanced than our own, is so likely to exist elsewhere that it is almost a certainty, where is everybody? Why do we continue to send out signals that get no reply?



Giant radio telescopes like this are positioned all over the globe listening to any radio signals incoming from the cosmos. This one in China spans 500 metres in diameter!

The first and most obvious assumption of the Fermi Paradox is that the existence of intelligent life elsewhere in the universe is almost guaranteed. To some people, this may sound slightly strange and overly optimistic, but it really is a valid point once you begin to wrap your mind around the sheer scale of space. Space is big, sure. Everyone knows that. But the (literally) astronomical proportions involved by the smallest journey through the galaxy, or even our own Solar System, are so ridiculously large that the human brain has a seriously hard time comprehending it. For a start, the furthest point away from our home

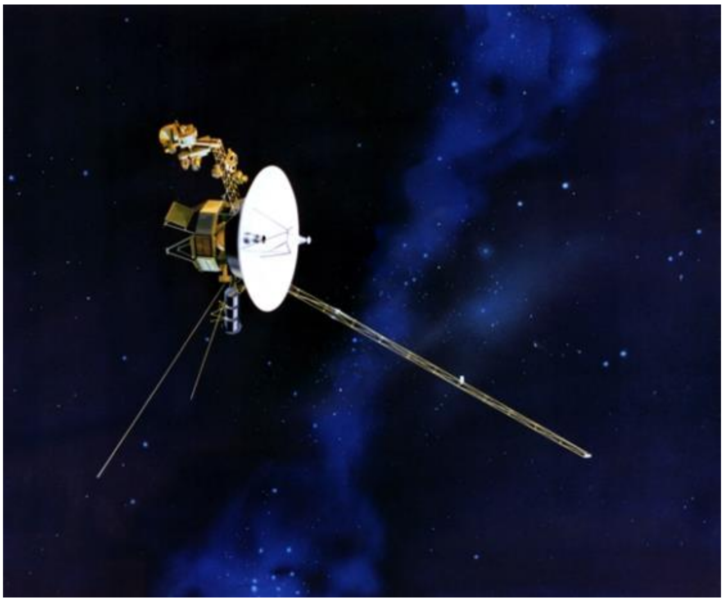


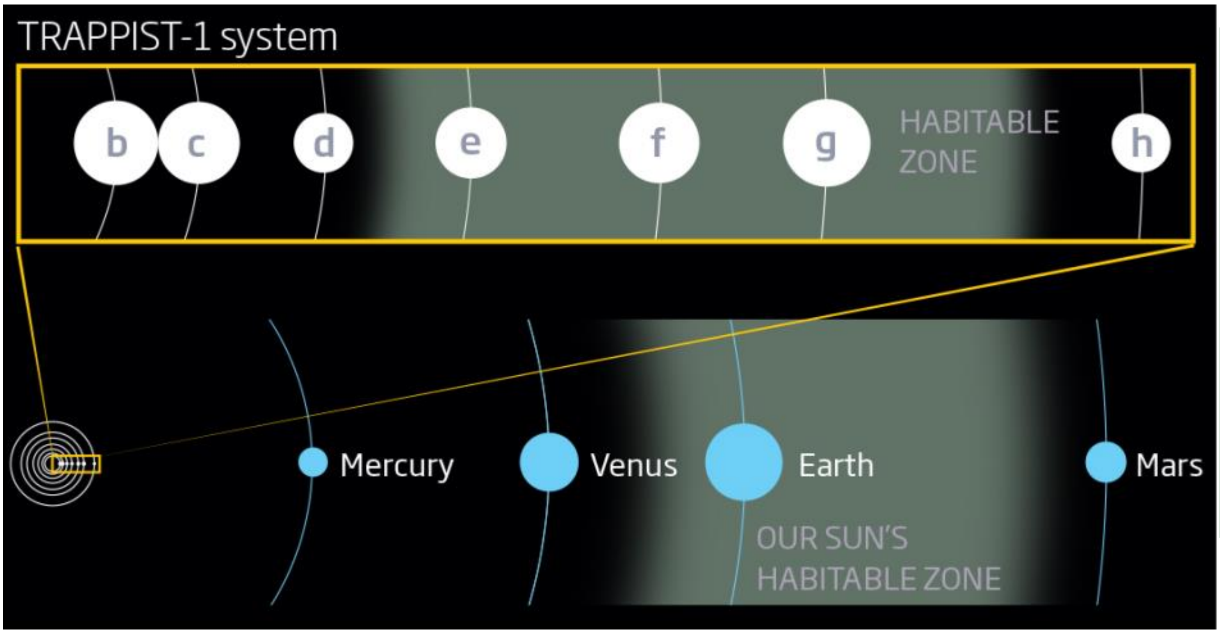
planet that humans so far have ever set foot is the Moon, which is on average 384,400 km away from the surface of the Earth. The next destination perhaps for us as our space travel technology advances would be the planet Mars. Mars is, in astronomical proportions, right next door to us. But if you managed to travel at the speed of light between the Earth and Mars, it would take you twenty minutes. That's travelling at $3x10^8$ metres per second! Mars, as it orbits the Sun, can be up to 401 million kilometres away from us. And this is again, to labour the point, in astronomical terms our next door neighbour. From here measuring distance with suitable-for-Earth units like kilometres becomes very awkward, so instead astronomers tend to use AU, Astronomical Units, when 1 AU equals the distance between the Earth and the Sun. The furthest away from us that any human made object has ever been is 138 AUs, and that's the Voyager 1 Space Probe (rendered right). This remarkable object is currently travelling away from us out into space at 17 kilometres per second, but even at these speeds, it will take it at least thirty thousand years to escape the outer reaches of our Solar System! And our Solar System is just a negligible speck within our interstellar neighbourhood. The closest star to our own, Proxima Centauri, is 4.24 light-years away. Again, at the interstellar scale, even Astronomical Units become too small to use, so we must use the distance that light can travel in a year. But again, just when you think that the universe is truly huge, it turns out you were off by several orders of magnitude. Proxima Centauri is nothing compared with the diameter of our galaxy, the Milky Way, which spans over 100,000 light-years! There are over 100 billion stars with their own solar systems within our galaxy alone. And

A rough scale of our own sun (a relatively small scale) with Earth which appears as a mere blue speck among 3 other specks at the bottom

the observable universe as we know it is home to at least two trillion (2,000,000,000,000) individual galaxies, and is at least 93 billion light-years across. (The universe itself is less than 14 billion years old!) And the observable universe is only what we can currently see. It is entirely possible that the true scale of the universe is several times larger than even this most astonishing expanse that literally encompasses all we know to be real.

So, we are literally less than a speck in the speck that is our solar system, within the speck that is our galaxy, within the unimaginably large universe that may well be a speck itself in comparison to the true universe, which may also be expanding faster than the speed of light. Essentially, without reiterating all those numbers, what it comes down to is that there are so many stars within even our





A diagram depicting the new TRAPPIST-1 system recently discovered to contain 3 exoplanets which lie comfortably within a habitable zone.

galaxy (which is still just a speck, remember!) with their own possibly habitable planets that the origin of life and its development to an intelligent and advanced stage of civilisation, similar to or eclipsing that of our own species, elsewhere in the Cosmos, is simply inevitable. A 2013 study using data from the Kepler Space Telescope suggested that one in five sun-like stars have an Earth-size planet orbiting in the habitable region, the zone where liquid water would be possible. Of course this does not by any means imply that life will originate on these planets, and once it does, there is equally no reason to assume that it will have evolved intelligence, or indeed survived long enough to evolve intelligence. But equally there is no reason not to. Until we can actually collect data from other Earth-like planets, and find life (or lack thereof), we have no real way of knowing exactly how often life originates given the correct conditions. What we can do, however, is make educated predictions, and that is exactly what many scientists have done.

Frank Drake, the world renowned astronomer and founder of SETI, the Search for Extraterrestrial Intelligence, is also the creator of the famous Drake Equation, an estimate for the number of technologically advanced civilisations that may exist in our galaxy. The equation itself has many variables that are purely theoretical, for example the average age of an advanced civilisation (we have only ever known of one: our own, and it hasn't ended quite yet!), but nevertheless it is a very good indicator of the sheer likelihood of intelligent life. Estimates by Drake himself and other leading astronomers, physicists, statisticians and biologists put the number of current existing advanced civilisations capable of communications within our galaxy alone at around 10,000. That is astonishingly many. So again, where are they?

Many factors may be used to explain the Great Silence despite these incredibly high likelihoods. One of them is, confusingly, one of the very same factors which makes intelligent alien life so likely, and that is the sheer scale of the universe. As I said before, our galaxy alone spans over 100,000 light-years. And because the fastest mode of communication that we currently know to be possible is via electromagnetic waves travelling at the speed of light (for example radio waves), a signal from an advanced civilisation 100,000 light-years away would take 100,000 years to reach us! Humans have only existed for a fraction of the time in which other civilisations elsewhere could have been flourishing, and we have only had the power to detect such signals for an even smaller fraction! What if a radio signal already reached us, back when we were banging rocks together, or during the Napoleonic wars? We would never have known. And what if such a civilisation sent us that signal today? I don't want to sound overly cynical, but I doubt very much that we stand a chance of surviving another 100,000 years as a technologically advanced civilisation. The reasons for this are numerous; essentially as technology improves, although in general our lives may be longer and easier than ever before, there are many more risks that we face, mainly from ourselves. Global warming, nuclear war, antibiotic resistant superbugs, cyber warfare, powerful artificial intelligence and who knows what else may endanger our existence in the decades to come. And if we predict that future technology might increase our chance of extinction, why should this not apply to other extraterrestrial civilisations? Even if we manage to survive long enough to receive a signal, the ones who sent it will almost certainly be long gone.

Finally, in the unlikely event that we were able to encounter an advanced extraterrestrial civilisation, would we want to? Science fiction has been littered with various horror stories ranging from invasions by otherworldly plants, to horrifying parasites that erupt from human ribcages, to aliens intent on enslaving humanity forever. These stories may say more about us and our society than what may happen in actuality. After all, it wouldn't be the first time in human history that two previously isolated worlds collided violently, resulting in the destruction and enslavement of one. To quote the film *Battleship*: "I told them that something like this would happen, that if something did find us, it would be like Columbus and the Indians, or the Incas and the Conquistadors." There have been many predictions of just how advanced a long lived civilisation could possibly become. One such measure of a civilisation's development is the Kardashev Scale. According to this scale, we are not even a Type I, capable of harvesting all the energy from their star that reaches their planet. Our solar technology is only just emerging, and we have yet to make use of it on a large scale. A Type II civilisation would be theoretically capable of utilising all the energy from their star. One possible way to do this would be to construct a so called "Dyson Sphere" – a gigantic structure encompassing the star, lined with solar collectors, which would yield unimaginably high amounts of energy. Any civilisation endeavouring to do this would need to have a huge reach; it's estimated that the sheer amount of matter needed to build a Dyson Sphere would require the complete harvesting of every single planet in a typical solar system! Beyond this point, the power and reach of theoretical civilisations becomes near ridiculous: Type III civilisations would control the energy capacity of an entire galaxy, harvesting thousands upon thousands of stars with an interconnected system of Dyson Spheres. Type IV civilisations would be universal in scale. And Type V civilisations, although now it starts to sound silly, would control all the universes, in all possible timelines: essentially becoming godlike in power and knowledge. Kardashev himself believed anything above a Type III too advanced to possibly ever exist. But again, since we have yet to encounter any extraterrestrials, who knows? We may be living at the same time as thousands of other isolated communities of aliens, wondering if we are truly alone, and due to the sheer scale of the universe, none of us may ever answer that question.

An artist's impression as to what a Dyson Sphere may look like as it fully encapsulates a star.

Andrew Higginson, Year 12

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What is Long Exposure?

As a keen photographer and physicist, Priyan Patel clarifies the features and effects of long exposure photography and why they occur.

A long exposure is often referred to a slow shutter photograph. This technique of photography is commonly used when taking photos in areas of low light intensity, thus many photographers take long exposures from dusk till dawn. Long exposures can be done during daylight, for example the blurred motion of water flowing down a waterfall is a common photograph in the photography world. However, photographers often avoid taking long exposures during daylight; this was common especially in the age of film photography, since there is a high risk of an over-exposed photograph. In this modern age however, the uncertainty of daylight long exposures can be overcome with editing software to allow the adjustment of exposure compensation.

This example shows a difference to the other picture, in this instance a shutter speed of 30 seconds was required to capture the stars shining in the sky. A longer exposure time would have allowed for more light from stars to reach the lens and sensor of the camera, resulting in more visible stars. It would also have allowed the trail of the stars to be more visible, since the Earth would have rotated more about its axis.

The common subject matters for long exposures taken in the evening are the trail of cars and vehicles, the street lights lighting up a city and the trail of stars situated in the sky. A tripod is usually used for most long exposures since the camera is required to capture stationary objects in relation to blurred elements. There is no specific set time period for which the shutter can be open for, 1/10 of a second may be used to capture a car passing by a few meters, whereas hours maybe required to capture the revolution of the Earth about its axis during the day. In many ways, long exposures can capture how time is continuous, unlike conventional photography, where it appears time is frozen.

This is an example of a long exposure using a shutter speed of 1/10 of a second. Although this isn't particularly a long period of time, the picture shows the visible trails of light situated on a stationary road.

Priyan Patel, Year 12

The Magic behind Chocolate

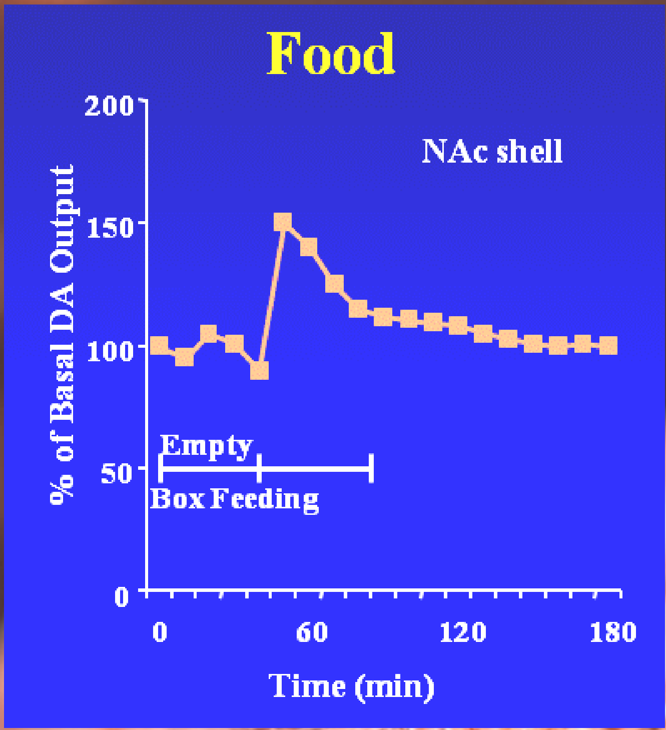
Sarah Beadle explains the basics of chocolate and its creation, and why it is that we find it so irresistible.

I'm sure many people find themselves what we called 'addicted' to chocolate and many sweet items. Chocolate has always been something I eat way too much of; I can't resist taking one more chunk than what I'm meant to have! Chocolate smells good, tastes good and feels good in the mouth. But why do we crave things like this so much, what causes the pleasant feelings we have when eating it?

Chocolate is made by firstly fermenting and drying the harvested beans. Next they roast the beans, this removes the acidic compounds formed in the previous fermenting process. After that the shells are removed, the valuable nibs are grinded and the remaining cocoa is conched to remove the remaining acidic compounds. Finally the chocolate is tempered to give the perfect chocolatey finish. Even though cocoa is considered to be a fruit, the chocolate which we gain from it is not so healthy. The process to make milk chocolate does not have a high content of the cocoa fruit and with its added ingredients is left rather unhealthy. However dark chocolate, which has a more powerful taste, has a higher amount of cocoa and is often recommended to be eaten in small amounts as it protects your heart, liver as well and produces antioxidants.

According to Professor Stavnezer on Psychology Today, our brain releases chemicals in response to the feelings we have when we eat chocolate. The main chemical produced is called Dopamine, this is released when you are doing something that you enjoy like laughing and watching your favourite programme.

As well as chemicals being produced by our brains chocolate itself contains chemicals. Stimulants such as Anandamides attract your brain. A report by BBC news states that Anandamides stimulate your mind in the same way cannabis does.



A graph showing the relative dopamine output levels in someone before and after eating food.

Next time you tear open that irresistible chocolate bar, think about the amount you eat and balance out how often you eat it. Maybe you could consider trying Dark chocolate more often.

Sarah Beadle, Year 9

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Music: A World Powered by Physics

Combining his knowledge of waves and music, James Cockcroft shows how fundamental an understanding of waves is in order for instruments to produce the correct, desired note.

Physics is what makes the Universe work. Everything from the most giant of supernovae to the tiniest photon is controlled by fundamental laws that dictate how everything in existence occurs. However, to some, it is music that makes the world spin. When the two are brought together, a beauty arises that must be appreciated.

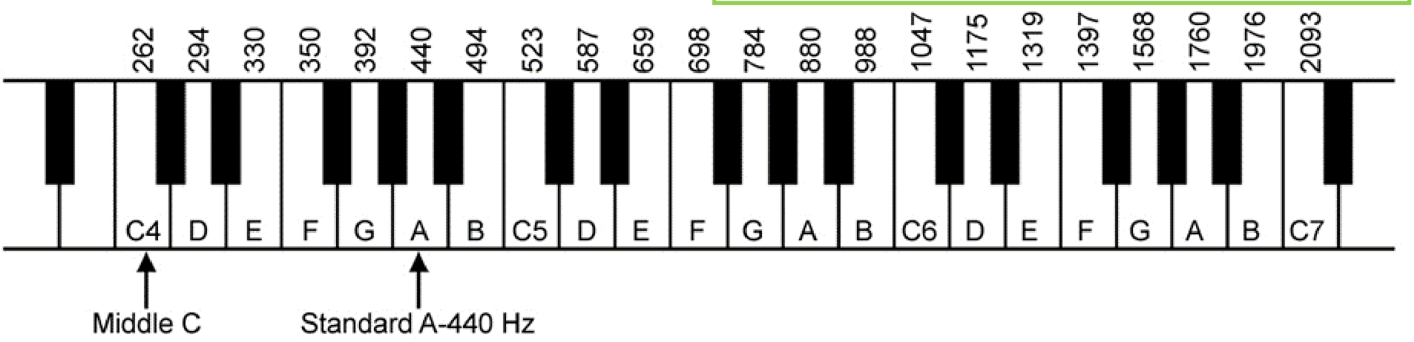
To grasp how Physics makes the world of music come alive with its wide-ranging styles and techniques, first the concept of sound must be considered. For a sound to be produced, there must be a disturbance in a medium, a vibration that causes a pattern through the air. It is the pattern of maximum and minimum displacement of particles that determines how we perceive a sound. In the human ear, the vibrations in the air hit the taught eardrum, the vibration passing through a tiny chain of bones as it does so. This transfers the signal through to the fluid of the cochlea, which then triggers a response in the auditory nerve.

A number of months ago, as part of my A-level Music course, I was assigned to write a synoptic essay on the difference between sound and music. The general point that essay was that "music is simply sound but ordered in such a way that is pleasing to the ear". Over the hundreds of years that music practise has been in existence, "notes" were developed. The note is determined by the pitch of the wave that is causing it, and the pitch is determined by the frequency of the wave, the number of oscillations per second measured in Hertz. For example, the note that symphony orchestras tune to, an A is at 440Hz. Notes ascend from A to G before starting at A again. Middle C on a piano, or known as C4 as it is the fourth C on a piano, is 261Hz, with the next note of the same letter being either twice or half the frequency of the previous note of that kind. So for example, the next C after middle C would be 522Hz, an octave higher.

Producing music on an instrument however is a much greater challenge. Take my instrument, the violin, for example. Quite obviously, the sound has to be something to do with the bow and those strings. But there are a number of variables that give the instrument its range. As many physicists will know, the sound created by a string depends on its thickness, its length and the tension in it. On a violin, there are 4 strings: a G (the one below C4), a D (the one just above C4) an A (the famous 440Hz one) and an E. These are a fifth apart (intervals are measured from the note that you start on, A, B, C, D, E, is five so a fifth). As you move from the G across to the violin to the E, the strings all:

- Decrease in length
- Decrease in thickness
- Increase in tension applied

A diagram showing the frequencies of sound waves for different notes on a piano.



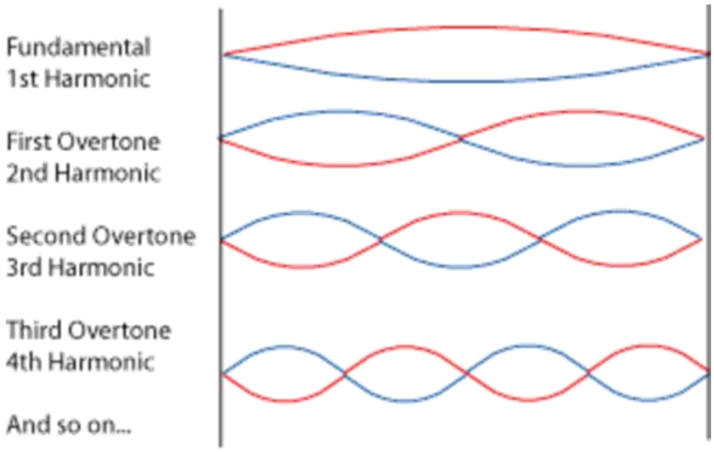


Diagram showing the different harmonics for a string fixed at both ends. Each fixed end acts as a node. Occurs in string instruments for example.

Obviously, the note played can be changed by pushing down on the string in certain places, and the starting note can be changed by altering the tension in the string by using the tuning pegs. When playing, the bow interacts with the string in a "slip-stick" way, the bow catching and skimming across the string. The strings themselves move very little air, so produce hardly any sound, but the signal is transferred through the bridge (yes it actually looks like a bridge) and into the bodywork, which acts as an amplifier for the sound.

The bane of many A-Level Physics students, harmonics, give each instrument its unique sound and are used to produce eerie special effects. For a primary exemplar, take a listen to Stravinsky's Firebird. Let's tackle this from the very start. On a violin, both ends of the string are fixed in place (at the pegs and the bridge). On a standing wave, these points are nodes, places of zero displacement (and so zero amplitude). In between the two nodes there will be one antinode, so taking A as an example, this frequency, the fundamental frequency, will be 440Hz. Then, by only lightly holding a finger over the halfway point on the string, another node will be produced. The frequency of this wave is now twice the fundamental frequency, so will be 880Hz. This note is exactly an octave above the A mentioned earlier. Harmonics can be produced in this way at certain points along the string to produce third harmonics and fourth harmonics until the range of the instrument is exceeded.

All wind instruments work in a similar way. For this reason we can compare everything from a flute to an organ. All wind instruments are open at one end, with the other end (where the player blows) acting as another open end. Because of this, both ends are considered as anti-nodes, where the wave has its maximum amplitude. The pitch of the note produced depends on the length of the column of air inside, which can be changed by placing fingers over keys or holes.

From understanding the physics of sound waves and the sounds we hear, we can begin to see how two seemingly different fields - the Arts and the Sciences – are in fact inextricably linked.

James Cockcroft, Year 12

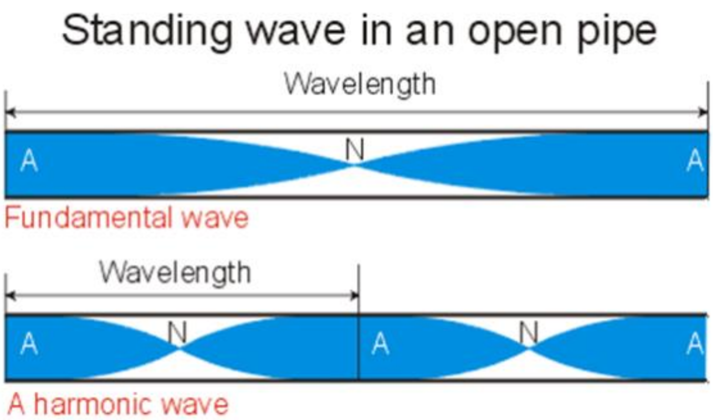


Diagram showing the different harmonics for a pipe open at both ends. Each open end acts as an antinode. Occurs in wind instruments for example.

Astronomy Masterclass

Ishan Rajput explains the different experiences he has witnessed via being a part of Space Club and thus being invited to the school's Astronomy Masterclasses

Astronomy Masterclass is one of the many highlights of Space Club at LGS, allowing you to see into Space. This year at LGS there have been three evening masterclasses led by Dr Boyce and Miss Allcoat, which are open to all students with some even open to parents and the public. With the help of the school's three telescopes, you can see galaxies and planets like Jupiter and Saturn. You can also see star constellations like the Big Dipper. Added to the telescopes brought in by the Leicester Astronomical Society, which allow you to see the sky at different magnifications, you will be able to see things beyond your imagination! With these telescopes, you can also see clearly the rings of Saturn or moons that are orbiting different planets like Jupiter – we are able to see them with our own eyes instead of looking at pictures.

Whilst you are waiting for it to turn dark, Dr Boyce or Miss Allcoat will teach you about aspects of Space to look out for, such as planets and moons. Every student is given an Astronomy Logbook in which you can write notes in about things that you have seen with the telescopes. You are also able to take these home so you can make notes on things in space that you have seen at your house, with a telescope or with your eyes.

The things that you can see at the Astronomy Masterclass are special and are quite spectacular. I really would recommend coming along because it is really fun and allows you to see the night sky in a completely different way.

Ishan Rajput, Year 7

(Above) A picture of Saturn through one of the school telescope's lenses, which was one of many sights to see.

(Left) A collection of Space Club members being shown the telescopes and how to operate them to view various astronomical objects.

Proteins, Prions and Procrastination

Maria Hancock explores how proteins in living organisms can malfunction, and the sinister consequences – and how you can help solve some of Biology's greatest mysteries through procrastinating online!

One of the realisations I have come to make about Medicine is that there is so much more to be discovered beneath the surface, and that everything is interlinked. In fact, one of the most memorable and defining moments of my work experience embodied this very idea. During a hospital shift, I witnessed a doctor having to break the news to a patient's family that their relative was likely to have Alzheimer's disease.

"But what caused it?" one relative implored, understandably distraught. The exact same question began to assail my mindset too. Through further burrowing into scientific literature and the articles we read at our school Journal Club, I began to delve into the more subtle undertones beneath such a distressing illness. To fully understand its mechanisms, we must first begin at one of the most fundamental ingredients of Biology - the role of proteins.

Proteins

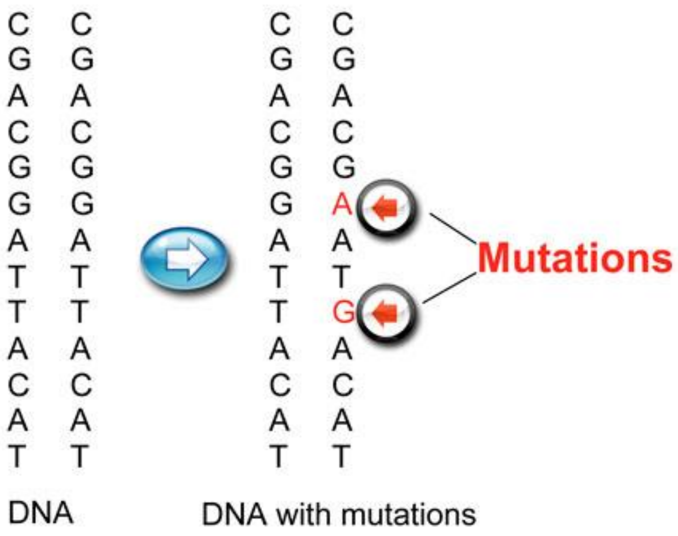
Whatever volume of biological knowledge you harbour, chances are there will be proteins involved somewhere within it. Proteins are integral to a living organism, orchestrating the structural and metabolic symphonies that make up virtually all echelons of life - in ways that are both subtle and remarkably significant. There are the structural proteins, which include collagen, keratin (in hair and nails), and muscle tissue (made of actin and myosin) to name but a few. Plunging to microscopic scales, one can discover the haemoglobin in the blood that carries oxygen to all living cells in the body, and the intrinsic and peripheral proteins embedded in the cell surface membrane - responsible for moving substances across the membrane and acting as markers for communication between cells. Proteins could be considered just as fundamental to life as the genetic code; after all, the primary role of genetic information is to code for proteins, which control our metabolism (via enzymes), construct our immune system (via antibodies), and more broadly determine our physical characteristics - our phenotype.

Proteins such as the one above are essential in DNA replication and other key processes. However their structure can be damaged and result in a range of different diseases and illnesses.

But we must still delve deeper. Their basic building-blocks are **amino acids**, which are assembled into a specific order (primary structure) by DNA's **triplet-code** protocol. That is, three consecutive bases (A,T,C or G) on the DNA strand (found in the nucleus) are responsible for the identity of one amino acid. The genetic code is **transcribed** onto a strand of **messenger RNA** (mRNA), which leaves the nucleus and delivers the code to the **ribosomes**; these assemble the chain of amino acids. The chain of amino acids is then folded into an immensely complicated secondary, tertiary and sometimes even quaternary structure, which can involve multiple chains of amino acids (now called **polypeptides**) working together.

When Proteins Go Wrong

The role of proteins is so widespread that if a protein malfunctions, the consequences are huge. But the source of a defective protein is, in fact, embedded within a cell's DNA, or genetic code. A **genetic mutation** can occur when there is a change in the order of bases in the DNA molecule. A base can be deleted, added, swapped with the one next to it or substituted for a completely different one. The altered base sequence therefore codes for a different sequence of amino acids, so a different protein is created. This altered protein is unable to form the correct bonds and interactions with nearby amino acids, so it is now considered "misfolded". In other words, the protein fails to be assembled into the correct (and incredibly complex!) 3D shape that allows it to function as it should. A protein can be misfolded for various reasons. Often there is a genetic factor involved, and the risk of a gene mutating to cause such misfolding increases with age and family history.

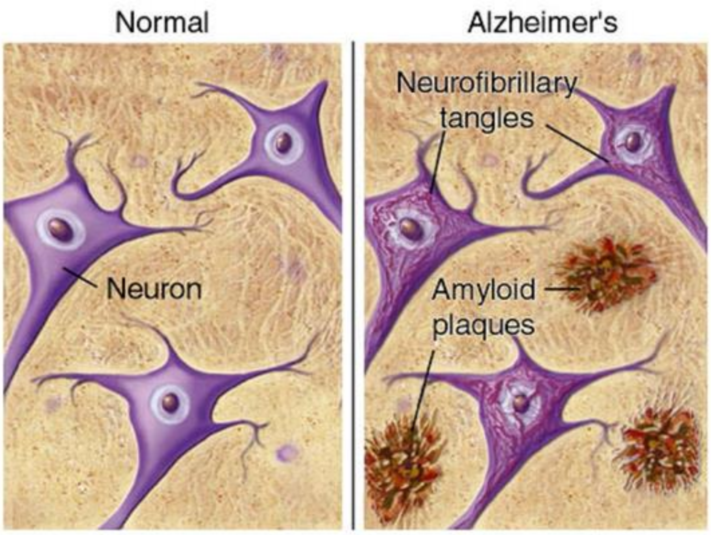


It's interesting to consider that the origin of many diseases is not in a faulty mechanism being created, but that a necessary and healthy mechanism (such as protein folding) stops functioning in its normal way. These examples illustrate the variety of consequences that misfolded proteins can perpetrate:

Alzheimer's Disease (AD)

AD is responsible for more than half of all cases of dementia; it is an irreversible, progressive condition that results in the destruction of memory and cognitive skills. Its effects upon an individual are substantial, but the fundamental source of the condition begins at a molecular level. The culprits responsible are the soluble proteins **tau** and **Aβ42**.

Tau is normally a soluble protein, but when it is misfolded it can interact with the proteins around it, forcing the protein chain to change its structure (from an alpha-helix to a beta-pleated sheet). Such interaction forces the protein chain to precipitate out of solution, so that it is now insoluble. Aβ42 is the form of Aβ protein that is more prone to forming insoluble deposits, called plaques. If more Aβ42 is produced in the brain, the risk of plaque formation increases.



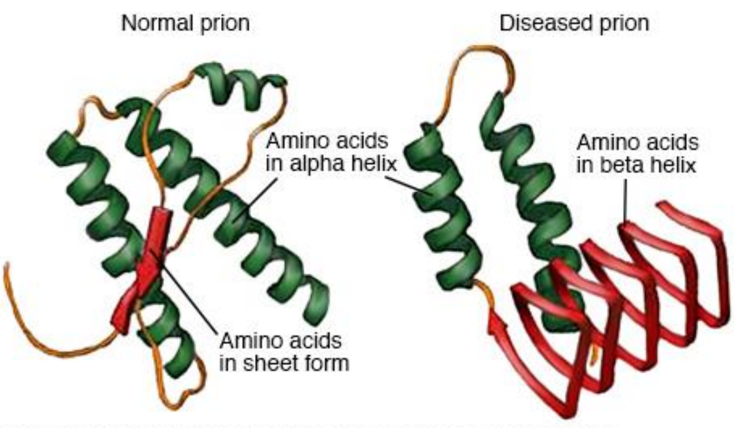
Together, these insoluble proteins can wreak havoc upon cerebral tissue, through the formation of **neurofibrillary tangles** (caused by misfolded tau) and **plaques** (made mainly of Aβ42). These insoluble deposits prevent signalling between neurones in the brain, so that essential nutrients cannot be moved across them. The neurones that are starved of these nutrients eventually die. The tangles and plaques may also cause an immune response to be activated, so that dying neurones are engulfed by white blood cells. When this occurs in areas of the brain responsible for learning and memory, we see a person gradually lose their language skills, orientation and memory.

Parkinson's

The effects of protein misfolding do not end at cognitive disruption; they can also have widespread consequences upon movement and co-ordination. Although Parkinson's disease is also caused by a misfolded protein in the brain, a person's memory and cognitive skills remain mostly intact. Instead, the accumulation of misfolded **alpha-synuclein** protein (in insoluble clumps called **Lewy bodies**) results in a resting tremor, rigidity and slow movement - **bradykinesia**.

However, these symptoms can also be found in other neurological conditions, so they cannot be relied upon to accurately diagnose Parkinson's. Only the presence of Lewy bodies can confirm that a patient has Parkinson's - but because Lewy bodies are only found in the brain, there cannot be absolute certainty of the diagnosis until a post-mortem is carried out, after the patient has died.

The molecular processes that lead to Parkinson's were discovered in a fascinating, and slightly unfortunate way. During the 1970s and 80s, some users of illegal drugs developed symptoms resembling Parkinson's disease. It was later found that the drugs contained a chemical called MPTP, which can cross the blood–brain barrier and be converted into a toxic MPP+ ion. The ion was taken up by neurones that produce the chemical messenger dopamine; it was found that the MPP+ attacked the mitochondria in the neurones, meaning that the neurone could no longer respire. Deprived of a vital process of life, the neurone was destroyed and the characteristic symptoms of Parkinson's began to emerge.



Prions

So far, we have seen how misfolding can have a huge effect upon an individual. But protein misfolding can also have much more sinister consequences - it can cause the proteins themselves to become toxic. These toxic proteins are known as **prions**, and they spread their toxicity to neighbouring proteins (so that they are misfolded in the same way). Prions can then spread "silently" across a person's brain for years without causing any symptoms. Eventually, prions begin to kill neurones, and once symptoms strike, a rapid decline in cognitive ability results. Most prion diseases are inevitably fatal within a few months, though some can last a few years - and there is no cure or means to even slow the progression of the disease.

Perhaps the most notable example of prion infection is Creutzfeld-Jakob disease. Like Alzheimer's and Parkinson's, it is an irreversible, neurodegenerative disease that can lead to imminent death in as soon as six months. The damage caused by prion spreading results in the brain acquiring holes, with a sponge-like texture.

The animal form of CJD is called BSE, which is more commonly known as Mad Cow Disease. This is because it was first discovered among cattle before it was realised that the disease could also be transmitted to humans. The UK was the most severely affected country in the epidemic between 1986–1998, in which over 180,000 cattle were infected and 4.4 million were slaughtered during the eradication program. In fact, the vast majority of the UK did not consume beef for most of this time frame. This is because the majority of cases of CJD were thought to be due to consumption of infected beef. However, it is worth noting that the disease can also rarely occur due to genetic mutation, or it can be passed on via infected surgical instruments.

Because prions are proteins by nature, any pathway to destroy them (high temperatures, extremes of pH) would inevitably denature the regular proteins in our body that are necessary for survival (as outlined above). In fact, prions can still remain intact at temperatures exceeding 600 ° C. They also fail to respond to antibiotics and antivirals, that commonly destroy bacteria and viruses. The most disturbing notion is that prions are nothing like bacteria, or viruses - yet they also replicate in a way that can spread disease between living organisms.

Action

Uncovering the science behind such conditions is vital for our understanding in finding treatments. But it's so much more important to recognise the person behind the illness - that they are not

merely a collection of symptoms, or yet another case of "hyperphosphorylated tau-protein aggregation". The emotional repercussions of these diseases cannot go unspoken of, not to mention the enormous distress felt by family and friends. In Alzheimer's, for example, the person affected can often remember their childhood memories perfectly, but are unable to recall what they did that morning or even recognise close members of their family. One pauses for thought at the idea that a surgeon, or musician, or a pilot diagnosed with Parkinson's will eventually lose the manual dexterity that they have spent their lives perfecting - not because of direct mental deterioration, but because of a tremor they cannot control.

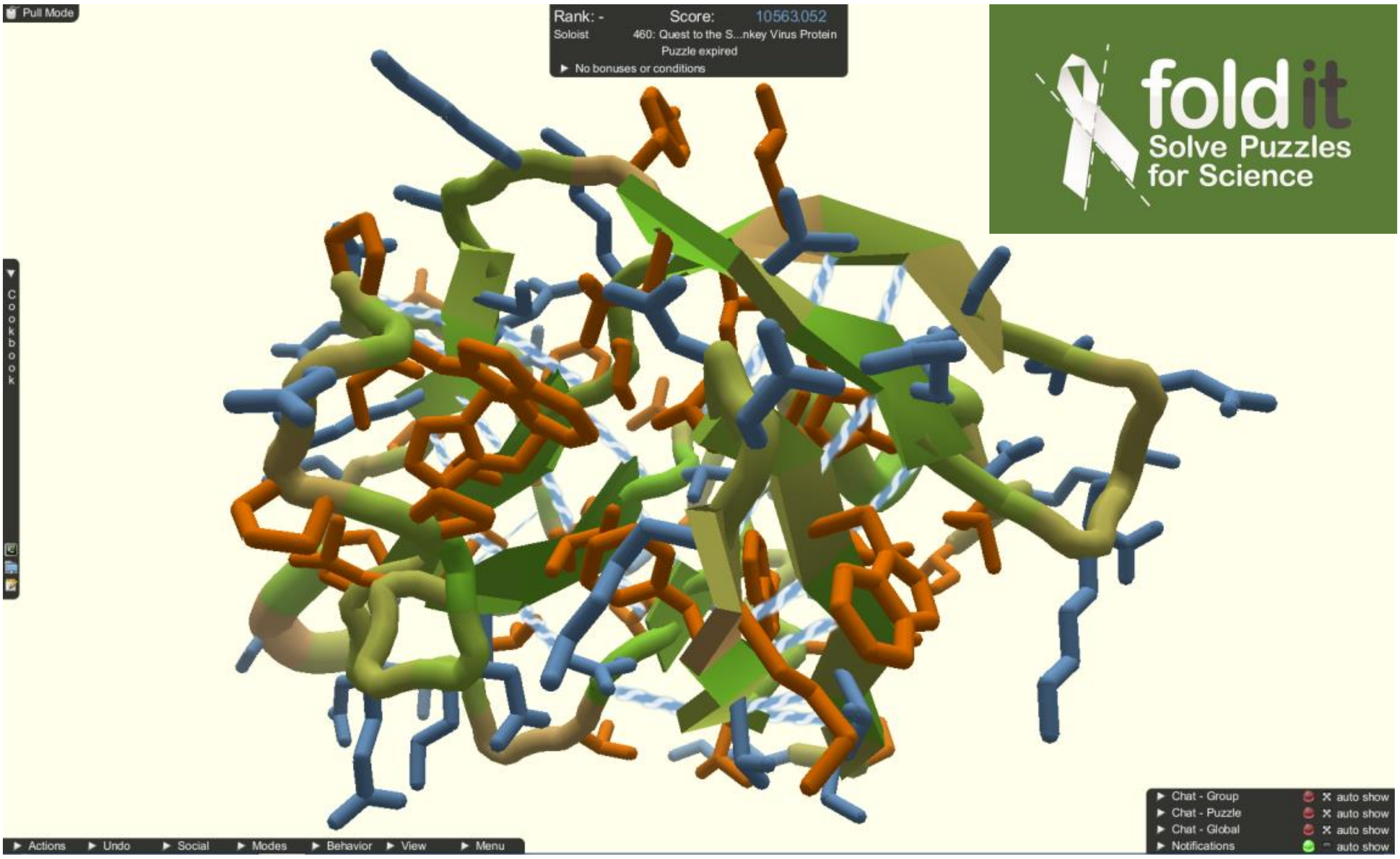
The Pathway Proceeds

Once these diseases are more clearly understood, scientists can begin combatting the processes that lead to them. Below are some of the most promising routes to progress:

- A more reliable diagnostic procedure is already underway for Alzheimer's disease; this involves measuring the levels of Aβ42 protein in the **cerebrospinal fluid** (surrounding the brain and spinal cord). Once this is determined, future medical developments will allow doctors to keep the levels of Aβ42 in a patient's body low enough so that tangles cannot form.
- Research is being undertaken in producing **enzymes** that will break down the excess Aβ42, or prevent it from forming.
- We could utilise the action of **antibodies**, which are responsible for recognising and attacking foreign agents in the body. They could be engineered to recognise Aβ42 and neutralise its toxic effects on the brain.
- Even more enticing is the possibility of using a drug that is currently prescribed - **trazodone** is currently used to treat depression, but has successfully passed clinical trials where it stopped neurones dying in mice with both prion and neurodegenerative disorders.
- The future of treatment may lie in altering the very genes that code for proteins, or even silencing them. This technique is called **RNA Interference** (RNAi), and involves injecting a large quantity of double-stranded RNA into a cell. This strangely shuts down a specific gene's ability to code for a protein. It is a natural response that organisms use, as protection against the RNA of viruses, but can be used to silence the action of genes that code for faulty proteins, such as excessive Aβ42, alpha-synuclein or even prions. This way, misfolded proteins can be targeted before they even have a chance to be produced in the first place.

Productive Procrastination

But the pathway to eradicating these illnesses is closer to you than you may think. In fact, you could even contribute to current scientific research through downloading and playing FoldIt in moments of boredom. The FoldIt program can be



downloaded for free on Mac, Windows and Linux. It takes the form of a competitive online puzzle, that sets you the challenge of building and folding a particular protein. The online community have previously managed to determine the structure of multiple unknown proteins. These models have helped university researchers build their understanding of protein structure, and begin developing potential drug targets! (An example can be found in the References.) The online game Mozak works in a similar way, allowing humans to use their unique puzzle-solving abilities to trace the structure of neurones more precisely than most computer software.

Despite steadfast progress, there is currently no cure or prevention for Alzheimer's (or Parkinson's); we can only slow the progression of the person's symptoms. But it doesn't always have to be this way. Potential drug targets and therapies to reverse or even prevent these are underway at this present moment. It's down to us, to our generation, to take what we know and search for solutions that could revolutionise the quality of life of generations to come.

Maria Hancock, Year 12

Games such as FoldIt and Mozak use large scale data collection from users playing as a way to form unique methods to try and treat various problems, as each user is likely to create a unique pattern using their own imagination.

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