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Editors' Note

Tēnā koutou katoa e te Scientific community,

Welcome to our very first summer edition! With a reshuffling of our executives, some brand new additions to the team and some farewells to founding members, we're thrilled to produce our first publication with the new team.

We decided to publish a summer edition to work out the dynamics of our team, and have a publication ready to promote at O-Week. The quality of articles from all of the authors in this edition is simply outstanding, and better yet, we continue to grow our repertoire of guest writers. We'd like to say an enormous thank you to all of our committed writers for working during the conventional break period from academia. Your passion for science communication and continued production of stellar work does not go unnoticed.

This year we hope to engage further with our wonderful community of readers, and reach out to incoming undergraduate scientists. Our mission has always been outreach and connection, and 2022 is looking like it will help us continue to fulfill that. Stay tuned throughout the year for calls for guest writers, updates on recent science, our quarterly issues (Volume 2 starts in Semester One!) and more exciting projects that we haven't yet fully realised.

For our experimental summer issue, we have guest writers from all sectors of science. From passionate marine scientists advocating for the spotlight to turn upon soft-sediment ecology, to mathematicians approaching the teaching of maths from a different angle. Our very first series that will span the year begins with this issue, titled 'Einstein's Year of Miracles'. Caleb Todd (one of our founders) returns to the publication as a guest writer (footnotes and all) with the first installment — Part One: Quanta. Of course, our existing executive team continues to contribute intriguing content: creative director Gene explains why a minute feels so long in different contexts, our secretary Jasmine lets us know the best of sharks, marketing manager Struan details a fraught history of a coding package with the ability to break the internet, and marketing coordinator Celina recounts the importance of the launch of the James Webb telescope.

As always, thank you for reading — a publication truly is not much more than talking into the abyss without its readership, and that's a fate no scientist wants to meet.

Kia ora rawa atu,
Stella Huggins, President for UoA Scientific 2022

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The Dynamics of Time Perception

Gene Tang

How much time does one spend waiting in a lifetime? This is a fascinating question to which no one seems to have a definite answer. We have perhaps spent more hours than we could have ever imagined, waiting for both events that have happened, as well as those that never happened. Though, what is curious about this question is that it is rather disparate from the question of how much time does one 'feel' like they have spent waiting in a lifetime. One way to understand this is by using the subjective versus objective reality debate — does the reality that one perceived equate to what actually happened? Indeed, the representation of time is subjected to one's own reality. Context substantially influences one's own time perception. The passage of time is thus dependent on intrinsic contexts, such as the concurrent emotional state [1], or extrinsic contexts such as the rhythm of other actions (e.g., the rate of speech), and the feedback of our actions (e.g., the reaction of others). So, despite an intact and fully functional biological clock, homogenous temporal perceptions do not seem to exist [1]. This multiplicity of factors can thus explain why no single experience of time is the same—days may shrink into minutes, minutes may stretch into eternity. In this literature review, we will take a deep dive into the progress of research and explore the dynamics of time perception.

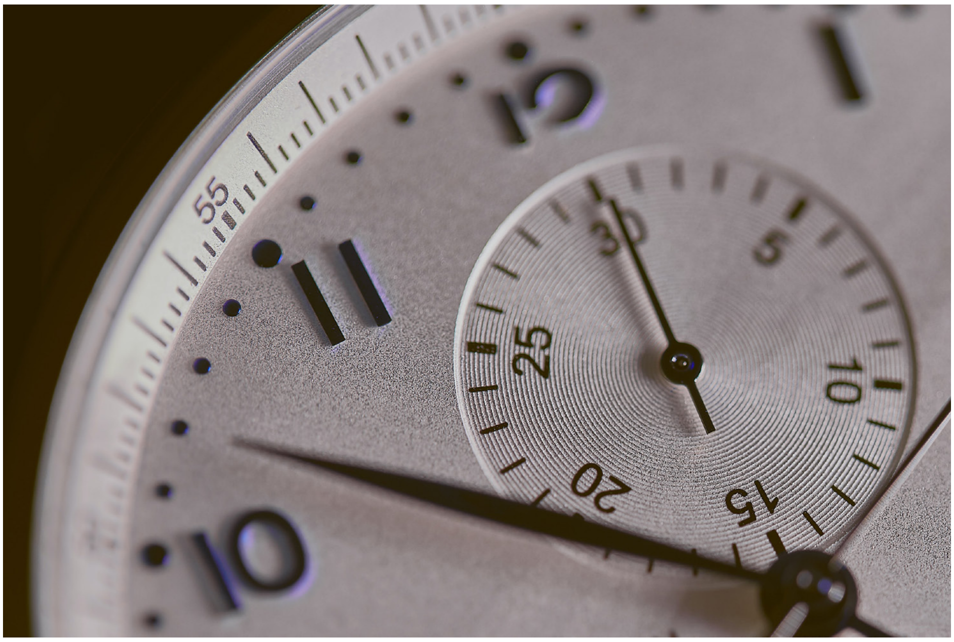


Image by Agê Barros on Unsplash

"On doit mettre de côté le temps unique, seuls comptent les temps multiples, ceux de l'expérience' (we must put aside the idea of a single time, all that counts are the multiple times that make up experience) ([2] as cited in [1])."

In 2009, Droit-Volet and Gil [1] wrote an intriguing paper on the time-emotion paradox. The paper highlighted that individuals' emotional context is greatly capable of distorting time perception, creating discrepancies between one's own experience of time and the objective measurement. A plausible mechanism explaining this phenomenon can be understood using the internal ticking clock metaphor [1, 3-4]. Droit-Volet and Meck [3] conceptualised that our resources (i.e., cognitive capacity) get redirected away from our internal clock as our attention is captured by a pleasant event. As a result of the resources being diverted away, the 'tick' of the clock may be missed. This causes underestimation of time perception, which means that the subjective time perception becomes shorter than its objective reality. Contrarily, the overestimation of time can be induced by increased arousal, such as a stressful event. What these events do is increase the ticks on our internal clock. As the same amount of time passes by, but with a larger number of ticks in-between, the subjective experience of time is lengthened — we start to feel like the duration is getting longer than it actually is [1, 3]. The essence of this notion is that our internal clock is incredibly vulnerable to manipulations and distortions, giving rise to subjective time experience.

The nature of time perception — its vulnerability to distortions and manipulations — is undoubtedly captivating. The body of literature surrounding time perception is continuously growing, and numerous studies have closely investigated the fragility of time perception and its relationship with multitudes of events, particularly waiting. Rankin et al. [5] conducted interesting studies that looked closely at the association between subjective time perception during stressful waiting periods. They examined undergraduate and graduate students as they waited for their exam results. The results from the studies suggest that there is a robust association between distress and time perception. At the between-individuals level, those who reported greater levels of worry and anxiety also reported perceiving the time waited to have been moving slower. The results also suggest that there is an intra-individual variability. That is, the time passage is slowest for a person experiencing the most anxiety and distress.

These findings are very closely related to prior research conducted by different laboratories on the relationships between emotions and temporal perception using facial expression [6-8], which may offer us another plausible mechanism explaining the results from Rankin et al. [5]. The original study by Droit-Volet et al. [6] revealed an association between the overestimation of time and emotional arousal. Later, these findings were well replicated by Tipples [7-8] and Effron et al. [9]. Tipples [7] suggests that the increased level of overestimation of time perception can, indeed, be linked to negative emotionality such as angry and fearful facial expressions. These findings offer us a new explanation that time perception can not only be explained by attention-based processes (such as the ticking clock metaphor mentioned previously), but can also be understood in terms of emotional arousal. That is, the modulation of emotions can influence a person's sense of time, and the fact that multiple processes can influence one's time perception well-reconciles its fragility.

Rankin et al. [5] wasn't the only group who found the relationship between stressful events and waiting time perception. Recently, another study was conducted by Droit-Volet et al. to investigate time perception and Covid-19 stress [10]. The study revealed that the significant increase in boredom and sadness during lockdown had constituted changes in time perception. They stated that boredom and sadness were predictors of the experienced "slowing down" of time during the lockdown [10]. The negative relationship between time perception, sadness, and boredom came as no surprise. As sadness and boredom exacerbate, the perceived passage of time becomes slower. Indeed, the results here are congruent with the previous study that pointed out the negative emotional arousal and the slowing down of time [6-9].

During the pandemic when negative emotional arousal such as sadness, fear, anger, and boredom are endured for an extensive period of time, a slowing down of time can take a toll on mental health and wellbeing [11]. If this is the case, is it possible for us to take advantage of what we know about time perception? If our temporal perception is truly fragile, the modulation should work both ways. Because our sense of time is subjected to factors such as emotions [6, 8, 12] and attention [13-14] that can slow down time perception, the reverse should also be true. A study by Sweeny and colleagues [15] may have offered us an example of how we may achieve this; the study probes into the potential coping resources such as mindfulness and flow during COVID-19. Flow can be simply understood as the state of being 'in the zone' [16]. It is when one is completely absorbed into what they are doing, thereby influencing their sense of time [17]. Sure enough, flow was found to help mitigate the deleterious effects of lengthy quarantines [15]. The paper suggests that pleasant activities can fully attract a person's attention. As they fully immerse themselves in those activities, days will feel shorter. This finding thus fits very well with the attention-based ticking clock metaphor [3-4]; activities such as writing, gaming, and exercising that one may enjoy doing during stressful events such as lockdowns can divert one's attention away from the actual amount of time passing [18]. Additionally, engaging in flow will not only help speed up subjective time experiences, but also draw benefits to one's mental health and wellbeing.

Time and perceived time are not always necessarily the same. As the existing body of literature grows, we are starting to gain much more insight into how it works and its implications. It may be safe to say that the existing models and metaphors have yet to cover a myriad of phenomena. Besides the cognitive perspective, there is so much to learn about how neurobiological processes are tied into one's sense of time. Our temporal perception is closely associated with our wellbeing in different ways. It will be interesting to see additional studies in the future as this knowledge may help improve the well-being of individuals during stressful times.

Gene Tang - BAdvSci(Hons), Psychology

Gene is a 3rd-year Psychology student at The University of Auckland who is currently doing his research under the school of Optometry and Vision science. His summer research project focuses on comparing retinotopic maps generated from functional connectivity with those obtained from a conventional population receptive field analysis.

Einstein's Miracles, Part 1: Quanta

Caleb Todd

"There is nothing new to be discovered in physics now. All that remains is more and more precise measurement."
—Lord Kelvin, 1900[1]

"Hold my beer."
—Albert Einstein, at some point in 1905 probably[2]

As the 19th century came to a close, there was a strong sense that physics was complete. Isaac Newton had long since formulated his three laws of motion, which described the behaviour of all physical objects. James Clerk Maxwell's electromagnetic theory explained how light and electrically charged matter interacted. Even systems too complex for analysis from first-principles were being conquered using the tools of statistical mechanics. Sure, there were a few wrinkles to iron out, but physicists had formalisms to deal with any conceivable problem. These formalisms — collectively called the tools of classical physics — appeared to work. To many, it seemed that there was nothing really new to be discovered.

However, within the first five years of the new century, all illusions of the completeness of physics were utterly dispelled. The wrinkles in classical mechanics instead turned out to be loose threads which, when pulled on, would unravel the entire tapestry. A series of death blows were dealt to the very foundations of how we understood the universe, and the chief executioner was a little-known patent clerk called Albert Einstein. In 1905, fresh out of his PhD, the 26-year-old Einstein published four papers that revolutionised physics. Producing any one of them was itself an extraordinary achievement; to publish all four in a single year was nothing short of miraculous. 1905 is now called Einstein's *annus mirabilis* — his "miracle year" — and is arguably the most inspired single year in the history of science.

There are three main topics that a university course on 'modern physics' will cover: quantum mechanics, atomic physics, and special relativity. Quantum mechanics was established by the first of Einstein's 1905 papers. The existence of atoms was proven by his second. His third paper founded the field of special relativity. Einstein's fourth paper presented what is now the most famous equation on Earth: $E = mc^2$. Einstein's work in 1905 was seminal in taking physics beyond the classical domain. A series of articles this year, of which this is the first, will discuss what each of these papers really mean. I hope to convey how extraordinary they are as intellectual achievements, and how significant they have been to physics as a whole.

(1) "On a Heuristic Viewpoint Concerning the Production and Transformation of Light"
Annalen der Physik, June 9th, 1905

To understand why this paper was so important in the early days of quantum mechanics, we must first discuss how classical physicists understood light.

Maxwell's equations were developed to describe how electric and magnetic fields interact with each other and with charged particles. The moment Maxwell discovered that his equations predicted the existence of electromagnetic waves that travelled at the speed of light was one of the greatest moments in physics[3]. The nature of light had finally been revealed. Young's double-slit experiment had confirmed that light was fundamentally a wave long before [1], but now physicists knew what was 'waving' — the electric and magnetic fields.

Imagine you and a friend[4] are holding one end of a rope each. Now suppose you begin rapidly moving your end up and down so as to induce wave motion in the rope. How much energy you put into the rope wave can be varied continuously. You can increase or decrease how vigorously you move the rope by any amount you choose (within the limits of your strength). Such is the case with any wave in classical physics, and such was assumed about electromagnetic waves. However, this assumption caused some issues; in particular, it was responsible for the 'ultraviolet catastrophe'. If you assume that electromagnetic waves can transfer energy to matter in arbitrary amounts, a neat piece of mathematics demonstrates that the intensity of light being radiated at each wavelength increases vastly as you decrease the wavelength [2]. Not only does this prediction disagree with experiments (as shown in Fig. 1), it also implies the matter is radiating infinite energy, which is an impossibility. The assumption must be incorrect.

Max Planck resolved the ultraviolet catastrophe in 1901 by proposing an alternative theoretical starting point. He assumed that energy would be exchanged between light and matter only in discrete chunks — so-called "quanta" of energy [3]. In our rope analogy, this would correspond to you being able to increase the amplitude of your oscillation only in increments of, say, 10 cm. You could have 40 cm tall waves or 50 cm tall waves, but not 45 cm tall waves. An absurd assumption at face value, but it leads to correct mathematical predictions regarding the intensity of radiation from matter [3].

Planck's proposal is now regarded as the birthplace of quantum mechanics, but Planck himself thought very little

[1] This quote is almost certainly apocryphal, but who wants to let facts get in the way of a good story?
[2] You can't prove I'm wrong.
[3] This fact will be extremely significant when we come to discuss Einstein's third paper.
[4] Imagine you have a friend if needed.

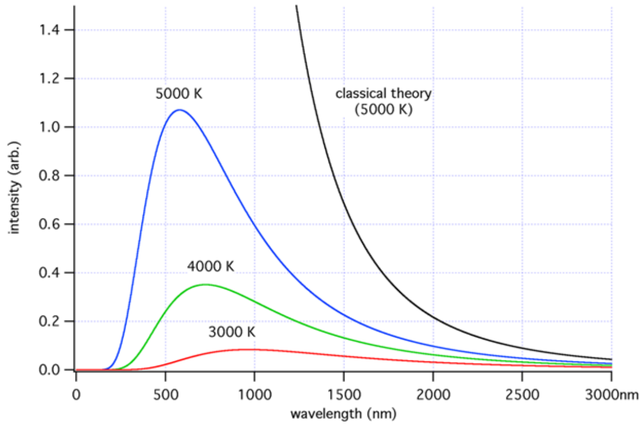


Figure 1: The intensity of radiated light from an ideal blackbody. The black curve shows the prediction obtained when assuming light and matter can exchange arbitrary quantities of energy at a temperature of 5000 K. The blue, green, and red curves show the experimental measurements at 5000 K, 4000 K, and 3000 K respectively. There is a clear disagreement between the classical prediction and the true values, particularly at short wavelengths — this is referred to as the ultraviolet catastrophe.

of his technique. Einstein, however, dared to consider what would happen if you took the idea of quanta seriously. Rather than supposing only that energy left and entered the electromagnetic field in discrete chunks, he proposed that light itself was separated into discrete chunks. Rather than a continuous electromagnetic wave, completely distributed throughout space, light is instead composed of localised, particle-like packets that we call photons. The transfer of energy quanta as per Planck's work was really the absorption or emission of these photons. This is the "heuristic viewpoint concerning the production and transformation of light" of which the paper's title speaks.

On what basis, though, could Einstein make this claim? Planck's theory required only that the exchange of energy happens discretely — for light itself to be discretised is a far stronger statement. Einstein's approach was to show how his new theory could explain phenomena beyond Planck's radiation intensities. There were two principle phenomena he dealt with: he showed that the entropy of a light field behaved as a gas of particles, and he used his quantum theory to explain the photoelectric effect. While the photoelectric effect is the most famous result from this paper, Einstein's explanation of it does not necessarily require light itself to be quantised — it depends only on the exchanges of energy being quantised, as in Planck's paper. So, let's talk about entropy.

The entropy of a system, in essence, describes how many ways that system can be configured without changing its macroscopic state. For example, you could switch the position of two atoms, but the temperature or volume (indeed, any important large-scale quantity) will be unchanged. The more configurations exist for a given state, the more likely it is that the system will be found in that state, so entropy tells you how probable different states are for a given system. For example, given a gas of helium molecules confined in a box, you can determine the probability that all of the molecules are found in the top half of the box at any given time using entropy.

Einstein demonstrated a correspondence between the entropy of light and that of a gas of particles; in particular, their volume-dependence. If an ideal, low-density gas of N particles is confined in a box of volume V_0, then the probability, P, that all N particles will be simultaneously found in a sub-volume, $V < V_0$, is $P = (V/V_0)^N$. Einstein showed that the entropy of a low-density light field in a box had exactly the same form as that of the ideal gas. Moreover, by comparing the two expressions he deduced that the probability of all the light being found in a sub-volume $V < V_0$, is $P = (V/V0)^{E/(hf)}$, where E is the total energy in the light field, h is Planck's constant, and f is the frequency of the light (i.e. its colour, determined by its wavelength). The product hf is precisely the size of one of Planck's quanta of energy (hence why the constant h is given his name), which, if Einstein is right about the light field itself being quantised, would make $E/(hf)$ exactly the number of photons in the box. In other words, light in a box behaves exactly as a collection of discrete particles. Light is quantised.

This result had exceptional significance in the development of quantum physics. As you may have guessed, quantum physics gets its name from the discretisations — the quantisations — which occur as a motif in the theory. One of the core features of quantum mechanics is that quantities (like energy or the amount of light) must often take on discrete values, and photons were the first quanta to be (knowingly) discovered. From this beginning, supplied by Einstein and Planck, quantum theory would rewrite virtually everything we thought we knew about physics. Indeed, quantum theory and general relativity together now form the basis for all of physics as we understand it. Quantum theory was accepted only slowly at first, but it would eventually become the most influential idea of the 20th century.

This paper, *Über einen die Erzeugung und Verwandlung des Lichtes betreffenden heuristischen Gesichtspunkt* in its original language, won Einstein the Nobel Prize in 1921. It would prove to be his only Nobel prize, but a strong case can be made that at least one of his other papers in 1905 deserved to win him a second. In the next edition of the *UoA Scientific*, we will delve into Einstein's work on the statistical mechanics of atoms and how he finally put to rest the question of their existence — a result we now take for granted.

Caleb Todd - BSc (Hons), Physics

Caleb is a research and teaching assistant in the Department of Physics at UoA newly finished with his BSc(Hons) degree. His research is in nonlinear optics and laser physics; in particular, the dynamics and control of ultrashort pulses of light.

What Makes The Shark Form Optimal?

Jasmine Gunton

Image by Colton Jones from Unsplash

It is commonly known that sharks have existed for a long time on Earth. They are near the top of the ocean food chain and have few predators. However, few people know that sharks appeared in the fossil record before trees [1], [2]. Sharks are thought to have existed before the formation of Saturn's rings [3]. For context, the first recognisable shark fossils appeared in the fossil record 450 million years ago during the Ordovician period [1]. The first true tree genus, Archaeopteris, appeared 370 million years ago, during the Late Devonian [2]. Since the first sharks appeared, an inconceivable number of marine species have emerged and then died out. Some notable extinct marine predator species include the Thalassomedon and the Mosasaurus. These were giant animals, much larger than many present-day species of shark [4-6]. So what makes the shark form optimal for surviving several thousand millennia of natural disasters and mass extinctions?

Humans frequently misunderstand sharks. In film and media, sharks are commonly portrayed as indestructible killing machines, consuming every creature they encounter. Although sharks are highly specialised predators, they do have several physical features that can act as a hindrance. For example, unlike other fish, sharks cannot swim backwards due to the structure of their respiratory system [7]. In fact, certain species of shark, such as the great white, suffocate and die if they don't keep moving [8]. Sharks have likely received their formidable reputation because of the occurrence of several shark attack events on humans. However, shark attacks usually occur because the shark has mistaken the human for a seal [9]. The majority of shark species prefer to hunt marine animals rather than take on a scary hairless primate. Because of this, marine biologists are able to study sharks and their unique adaptations.

Often exploited by shark scientists is the behavioural phenomenon known as 'tonic immobility'. Essentially, if one were to flip a shark so that it was floating on its back, it would enter a trance-like state similar to hypnosis. The shark would become temporarily paralysed until it managed to flip back to a normal swimming position [10]. If a large animal were able to move a shark in such a way, then the shark would be powerless to stop its attack. Dolphin species such as the orca (yes, orcas are dolphins, not whales) use this technique to their advantage [11]. The relationship between great white sharks and orcas is especially interesting. Orcas are thought to hunt and kill great white sharks, usually consuming only their livers [12]. This behaviour is likely explained by the fact that shark livers are very fatty and contain up to 270 kilograms of meat [13]. Some studies suggest that the presence of orcas in an area drives the population of great whites away [14]. The evident domination of orcas over sharks suggests that orcas must have also existed for a very long time. However, the oceanic dolphin family has only existed for around 11 million years [15]. One tends to wonder how sharks have managed to outlive so many of their natural predators.

Since their first appearance in the Late Devonian, sharks have survived 5 mass extinctions [16]. After each mass extinction event the shark family diversified, filling several ecological niches [17]. The diversity of ecological niches can still be seen in modern sharks. For example, the cookiecutter shark (*Isistius brasiliensis*) is an ectoparasite that feeds on the tissue of large marine animals [18]. The complete opposite to the cookiecutter shark is the whale shark (*Rhincodon typus*), which is 33 times larger [19-20]. However, the whale shark mainly feeds on zooplankton through a filter, similar to an actual whale [21]. The great biodiversity and range of physical adaptations seen in sharks can explain why they have survived for so long.

Another reason for sharks' longevity can be explained by their diet. Sharks are generalist predators, meaning they have a wide range of food sources [22]. Therefore, if one prey species disappears, the shark will easily be able to find other food. Furthermore, it cannot be ignored that sharks are excellent predators. One adaptation that separates sharks from other fish species is their cartilaginous skeleton. The light cartilage tissue enables sharks to expend little energy swimming long distances [23]. Moreover, the shape of the shark and its specialised scales allow high-speed movement through the water. Indeed, the fastest known species, the mako shark (*Isurus oxyrinchus*), can swim up to 70 kilometres per hour [24]. This is 1.5 times higher than the fastest recorded human running speed on land [25]. Fossil evidence suggests that early sharks maintained the same tapered form as modern sharks [26]. This makes the shark form one of the most efficient for surviving in the ocean.

Image by Gerald Schömbs from Unsplash

Just when you thought the shark couldn't get any cooler, it turns out the shark has a specialised organ that can sense electromagnetic fields. Through this adaptation, there arise two distinct benefits. Firstly, the shark can efficiently navigate long distances through the expansive ocean [27]. Secondly, sharks are able to sense the electromagnetic fields of their prey and therefore locate camouflaged benthic animals [28]. However, this is not the only sense that sharks rely on to detect prey. Like other fish, sharks possess a sensory organ known as a 'lateral line' across the middle of their torsos. This lateral line allows the shark to sense vibrations in the water created by small animals [29]. Essentially, if you are a fish in the ocean and you encounter a shark, it's game over.

Unfortunately, it is not other marine animals that are the sharks' greatest predators. Instead, it is humans to blame for the steadily declining global shark population. This is mainly due to the highly popular shark fin fishing industry [30]. Consequently, many shark species are now considered endangered, and some are on the verge of extinction [31]. This issue is important to resolve as sharks are extremely important to their ecosystems. One of their crucial ecological roles is controlling potentially destructive fish populations [32]. Uncontrolled fish populations can take over certain areas and devastate other local marine species populations. Sharks further influence the spatial distribution of their prey through intimidation tactics [32]. Sharks are both very important to the marine ecosystem and a particularly hardy species, and the biological and ecological importance of sharks should be heavily prioritised when managing the global fishing industry.

Jasmine Gunton - BAdvSci(Hons), Ecology

Jasmine is a 2nd-year Bachelor of Advanced Science (Hons) student specialising in Ecology. She is particularly interested in researching areas in marine ecology and evolutionary biology. This year she is also a part of the Science Scholars programme.

The 11 Lines of Code Which Broke The Internet

Struan Caughey

One of the founding principles of the internet was openness, which has led to incredible communities that build upon each other's works. Even large companies such as Facebook and Google rely on other people and companies' work so that they do not have to write their code from scratch.

This system is brilliant — it allows for faster development of programs and means that people do not have to rewrite the same code. The name behind this principle is open-source code [1] and while generally accepted as an important and integral part of the internet, there are some unintended consequences. Firstly, you are relying on the code being efficient and secure. Secondly, this makes you reliant on the developers of that package to keep it up to date if any issues do occur. Lastly, this can also create chains where packages are dependent on packages, resulting in the final programmer not knowing exactly what code their own program is executing.

Most programming languages contain all of the essential functions within their 'standard library', meaning that you do not have to rely on third-party authors'. Javascript, however, utilises third-party depositories instead of a standard library [2]. One of the largest of these is called npm [3]. People essentially place their code onto npm and then others can access it just through their code. One contributor to this platform was called Azer Koçulu. Koçulu was a high school graduate who taught himself how to code. In an email he sent to Quartz magazine he stated that "I owe everything I have to the people who never gave up with the open-source philosophy" [4]. With this belief, one of his core principles is pushing against the commercialisation of code and instead empowering creators such as Azer to have full control over their code.

The issues started with a single project of Koçulu's which was under a package named "kik" (unrelated to the code which would later cause further problems). The instant messaging app also named Kik based out of Canada decided that they too wanted to create a depository called kik, however, they would not be able to due to Koçulu's existing project [5]. Initially, Kik reached out to Koçulu to ask

Image by Mohammad Rahmani from Unsplash

if he would remove his project. He refused their request, as he perceived it as an overly aggressive interaction. This in turn resulted in Koçulu asking for $30,000 (USD) "for the hassle of giving up with my pet project for [a] bunch of corporate dicks" [6]. Kik then reached out directly to npm who sided with them, and agreed to turn over the package's name to them from Koçulu. On this they said, "In this case, we believe that most users who would come across a kik package, would reasonably expect it to be related to kik.com," [6].

As you would expect, this did not go down well with Koçulu, who had been an avid proponent of open-source philosophy and npm. He sent out an email stating that he was very disappointed and no longer wanted to be a part of npm — that he wanted all of his packages registered on npm to be taken down [6].

This ended up happening and sure enough, two days later coders around the world started getting the error message: "Npm ERR! 404 'left-pad' is not in the npm directory" [4].

Left pad was an incredibly simple piece of code written in full below [4]:

```
module.exports = leftpad;
 function leftpad (str, len, ch) {
        str = String(str);
        Var i = -1;
        If (!ch && ch !== 0) ch = ' ';
        Len = len - str.length;
        While (++i < ln) {
                Str = ch + str;
        }
        Return str;
}
```

All this code does is add characters to the left of the text to ensure that the length of a line stays consistent. For example, if I was to feed in "17, 5, 0" into the code it would print "00017", adding padding to the left of the text [7].

It soon became evident what had occurred. This one small piece of code had been used in several other packages, which, in-turn, was propagated across all sorts of different programs, many of which did not explicitly use this package. One of these large packages which indirectly used it was called Babel which utilised left-pad; it was itself used by the likes of Facebook, Netflix, and Reddit amongst others. With left-pad gone, Babel became unable to install. For context, despite being relatively unknown, left-pad at its peak was downloaded over 4 million times per week [7].

Ironically, things came full circle when on March 24, 2016 Mike Roberts (head of messaging at Kik) found that his team was encountering the exact same issue due to their use of a package called LSCS, which through a long chain of dependencies relied on left-pad. In Mike's piece on the self publishing site Medium, he also discusses the situation from Kik's side as well as publishing all the emails between Kik's patent agent, Koçulu and npm [6].

Immediately there was a scramble for a fix. The removal of this simple package was causing errors across the globe with people from Australia, Germany, the US, and more commenting on the left-pad npm page, trying to find out what happened. Babel quickly replaced the package and within 2 hours npm took the 'un-un-published' left-pad code. On the restoration of the code, npm said that "Un-un-publishing is an unprecedented action that we're taking given the severity and widespread nature of breakage, and isn't done lightly," [4].

While in the end there were no long term issues resulting from this action, it did show there are some significant vulnerabilities within our current systems. While dependencies are vital, to ensure security of your code you should know what your code contains. If you think that issues like this must have been resolved you would be half right — npm has instituted new policies to make sure that unpublished code won't cause widespread breakages [5], however, the system still has other issues, such as trust that your dependencies are secure. In November 2021 we saw in a catastrophic bug that this may not be the case.

On November 24th 2021, a 0-day bug was found (0-day meaning 0 days notice was given to fix it before the exploit went public). It was given a 10/10 criticality rating and is part of the language Java [8]. The flaw called Log4j immediately began being exploited [9]. On December 22, 2021, Tenable found that 10% of all assets that they assessed were vulnerable to the exploit and yet only 70% of organisations had begun looking at whether they are vulnerable [10]. While there have been several patches we are yet to see whether these can be navigated around.

One of the big issues which lie with Log4j is again dependencies, as even if Java updates their code, all the programs which are dependent on Java also have to update theirs, and so on. Because of this the issues created by Log4j could last for years and has been described by some in the industry as the "most serious (cybersecurity flaw) in decades" [11].

The world of tech is exciting and fast-paced but as it continues to grow new systems will have to be put in place to ensure that these kinds of domino effects cannot happen in the future. In no other industry would we accept industry-wide vulnerabilities as something that just happens and needs to be fixed. We instead need to learn to prevent this from occurring.

Struan Caughey - BSc, Computer Science
Struan is a computer science graduate from the University of Auckland. He was a member of the Science Students Association in 2020 as the communications officer. When he was there, one of his projects was to start the Moonshot publication which ran across that year. It was a small undergraduate-focused quick read publication that lightly covered news and research in science. In 2021, he brought the processes developed from this and co-founded UoA scientific becoming the inaugural Secretary.

Facilitating Friendship: The Future of Mathematics Education?

Alicia Anderson

My relationship with maths class over the years has been sinusoidal, to say the least. I really took to the patterns and logic of mathematics as a kid. I loved measuring my classmates' arm-spans and heights to use as coordinates on a line graph to show a linear trendline. Then, somewhere in the silence of paper pages and the scribble of pens, my spark went out. Equations that used to glitter, faded into a dull, anxious greyscale. While some subtopics were fun, I mostly slogged through NCEA and university maths in a disengaged haze only because it was a requirement for my new love — physics.

My mathematics journey — one in which I grit my teeth for the sake of another pursuit — is not unique. Maths has a notorious reputation for "gatekeeping" career opportunities — being necessary for finance, construction, and technology to name a few examples — which makes its pervasiveness of low achievement and low engagement all the more troubling.

In the 2019 Trends in International Mathematics and Science Study (TIMSS), the scores of New Zealand year nine students had the most significant drop since the study began in 1994 [1]. And while the 2020 NCEA Annual Report shows improvement in NCEA Level 1 literacy attainment over the last ten years, very little has changed with regard to gaining NCEA Level 1 numeracy. Figure 1 shows a steadily increasing trendline from 79.3% to 85.1% of year eleven students attaining Level 1 literacy from 2011 to 2020, respectively, with a range of 7.8% across the data set. For level 1 numeracy, however, the range is only 5.1% over the last ten years, with 82.4% of year eleven students in 2011 passing numeracy requirements and 83.6% passing in 2020 [2]. Many students, both in New Zealand and overseas, stop learning mathematics altogether as soon as it's no longer compulsory [3]. For many schools in New Zealand, this is after NCEA Level 1. Most students are 16 years old by this time as well, and therefore are no longer required by law to attend school. Numeracy attainment data at NCEA levels 2 and 3 is skewed to be in the 90% [2]. A likely reason for this is that those who failed the compulsory NCEA Level 1 have either dropped maths, or dropped school entirely. These achievement statistics don't speak for those who stay in maths solely for a particular career path where maths is still necessary, but learning those skills feels more like removing wisdom teeth.

Literacy and Numeracy for NCEA Level 1

Table I shows the percentage of Year 11 students attaining NCEA Level 1 Literacy and Numeracy by the end of each year

Year	Literacy	Numeracy
2011	79.3%	82.4%
2012	82.4%	80.4%
2013	83.9%	81.1%
2014	85.3%	82.9%
2015	86.4%	84.6%
2016	86.5%	85.1%
2017	87.1%	85.5%
2018	86.2%	84.4%
2019	85.5%	83.4%
2020	85.1%	83.6%

* This figure has been adapted from the 2019 Trends in International Mathematics and Science Study (TIMSS)

So although I had the persistence to continue until I was back on the positive gradient, what I couldn't understand for the longest time was how I could love physics as much as I hated maths. If maths is so essential to physics, then what happened for a paradox like this to occur?

Despite ongoing research and pleas from mathematics education academics to make significant changes in teaching practice, maths is still being taught in classrooms in a very outdated, solitary manner that is no longer seen in the rest of the sciences or the humanities. The International Academy of Education has recommended collaboration through small-group learning as an effective teaching tool since at least as early as 2000 [4]. However, classrooms across schooling levels still operate under solitary textbook exercises and worksheets from even as early as year three [5].

For me as a struggling student, this made the absence of noise the most memorable aspect of my first university mathematics tutorial. We were permitted to raise a hand for assistance, but that semester I was the only student to ever do so. The silence offered no anonymity, so, with no friends to lean on, each request for help required fresh courage. Every time the tutor taught a question to me, I felt the entire class learn how stupid I was. It reinforced my internal rhetoric that I was the dumbest student in the room; no one else needed help because they must be getting all the answers right. When I spent more tutorial time crying in the bathroom stall than getting help from the tutor, I stopped attending tutorials. I failed that paper.

More research has been done in investigating students who attend education but under-achieve. One journal summarised their findings under the acronym T.I.R.E.D for Tedium, Isolation, Rote-learning, Elitism, and Depersonalisation [6]. Varying combinations of these reasons result in the limiting belief that the only people who succeed in mathematics are those who are exceptionally talented. I believe solutions targeted towards addressing isolation would have knock-on effects that would mitigate the remaining four issues listed.

When I had a polar opposite experience to that first tutorial in a later semester, my performance and engagement skyrocketed. In the first session, the tutor asked who liked group work, in which there were a fair few of us who answered that we did. Having a tutor who promoted collaboration gave me a study group I could sit in lectures with, which led to a more efficient understanding of the content due to how much less stressful it was receiving explanations from my classmates, who were now becoming my friends [6]. My newfound sense of belonging in maths resulted in grades of As and Bs. From these new friendships, I felt a new identity as a learner of mathematics develop within myself.

This belonging continued into the following semesters where I was now confident enough to ask questions during the lectures, which often had around 40 students in attendance. With the additional hurdle of classmates spectating, dynamic participation in higher-level maths requires confidence that isn't just overcoming shyness but being either certain of contributing intelligent answers and questions or being unafraid of the contrary. Overcoming such feelings is not an instantaneous process, but class friendships appear important in mitigating them [3-4, 6]. The 2019 TIMSS results were also better for students who felt a belonging in the classroom [1]. Feeling a sense of belonging through friendship with peers fosters increased participation in front of the whole class. This leads on to both greater engagement with the class material and high test performance, which is why it would benefit educators to prioritise facilitating such connection in their classes.

Of all the schooling subjects, mathematics class evokes the most emotive response from the general population. Such strong opinions on maths are created informally through social experiences and social interactions. Schools and universities by nature are socialising hubs, implying a need for teachers to set up a classroom culture, so students become familiar with each other quickly [3]. Games, when selected carefully, can also help reinforce learning outcomes and team-building [7]. The games which are most successful at building classroom belonging are ones that encourage teamwork and creative problem solving, rather than rote-memorisation and speed [8]. Opportunities to collaborate on problems in groups of about four or five, then presenting worked solutions as a group are also needed [3], as is class material which acknowledges the cultural identities in the classroom [9].

The art of learning has always been a social affair: from learning to walk, to being taught your first curse words, much to the distaste of caregivers. It turns out I didn't magically start hating maths, then re-enjoying it just as mythically. As much as I liked applying maths skills to the physics experiments we were writing reports on, my true joy stemmed from tackling challenges together with my classmates as a community of learners. Put simply, physics just allowed me to do maths with some friends.

Alicia Anderson - BSc, Geophysics

Alicia is an undergraduate BSc student majoring in geophysics. She is particularly enthusiastic about exploring how different disciplines relate to each other, and spreading the message that science is for everyone. If not in a lab or a library, you will likely find her kicking it around the wop-wops in tramping boots, kayak kit, some skiis, or a wetsuit.

Benthic-Dwelling Heroes: How Soft Sediment Creates Healthy Oceans

Ella Speers

Marine science is a diverse branch of the life sciences that spans a broad range of disciplines from fluid dynamics to the biological web of life. While each subdiscipline within marine science is as important as one another, it is the ecological study of marine systems that focuses on living organisms and the environments in which they interact. I believe this is the most fascinating aspect of all due to the scope of life that exists beneath the surface.

Ecosystem function is an imperative element of biological science across both terrestrial and aquatic realms, which is paramount to the survival and success of all the species that inhabit the ecosystem in question. It can be defined as the flow of matter and energy through biological organisation, which involves primary and secondary production and decomposition [1]. Each occupying species has a particular niche in which it carries out a set of roles, each with their own specific functions. Subsequently, the loss or gain of these species and their niches alters the net effects of their ecosystem [2]. All processes and species are deeply interconnected, and are therefore essential for the functioning of the ecosystem [1].

As the vast majority of our biosphere is aquatic, the seafloor (hereafter referred to as the benthoscape) comprises 70% of the earth's surface, and therefore is one of the largest landscapes on Earth [3]. As per ecological theory, species richness tends to increase with ecosystem heterogeneity [4], and such is true within a benthoscape. Typically, benthoscapes tend to be sediment patches of minimum relief defined by their sediment type and any abiotic features that may be present, such as sandwaves [3]. The immense richness of interstitial species can be attributed to a benthoscape's specific framework, which allows organisms at high concentrations to live in its three-dimensional structure. Across time and space, characteristics of soft-sediment communities that are of importance for global oceans range from animal-sediment relationships to disturbance-recovery and succession processes [3].

Within marine ecology, there is a diverse array of systems and communities that impact one another, yet many of these are not readily understood by the general public. I, too, am guilty of associating only well-adored pelagic swimmers such as dolphins and whales with the ocean before majoring in Marine Science. After becoming aware of the microscopic world which lay beneath the sediment, I became fascinated with this ecosystem that exists unbeknownst to us, despite being so vital in its operation.

Image by Katya Wolf from Pexels

Tiny benthic-dwelling organisms (hereafter referred to as microphytobenthos) that live in the upper layers of marine sediment also play a significant role in contributing to the healthy cycling of our global oceans. The richness of these unicellular eukaryotic algae and cyanobacteria species that inhabit the surface layers of sediment means that the upper several millimeters are a zone of intense microbial activity. It is therefore under constant physical reworking [5]. The dense aggregations of microphytobenthos play an especially significant role in coastal ecosystems through their contribution to primary production, food web functioning, and sediment stability [6]. The density of these primary producers can be significantly attributed to the amount of solar irradiance, temperature, and nutrient availability. The reactive zone in which microphytobenthos occupy therefore represents a region of strong gradients across physical, fluid, sediment, chemical, and biological properties [5].

Microphytobenthos can inhabit a range of aquatic systems from high-energy beaches to mudflats [5]. The output of their physical sediment reconstruction (known as habitat engineering) can be understood as critical to these regional environmental dynamics, as it creates habitat heterogeneity. This in turn creates habitat opportunities for

Image by Taryn Elliott from Pexels

other species in the same ecosystem. Their close proximity to the sediment-water interface allows these microscopic organisms to play a key role in modulating the exchange of nutrients between the sediments and the water column [5]. Through biodeposition and bioturbation, microphytobenthos species enhance organic matter mineralisation, which is a vital element in nutrient cycling [6].

Oxygen is vital in all marine ecosystems as it is a key element in metabolic processes [7]. However, as the dissipation of sunlight does not sustain the life processes of these photosynthetic species at increasing depth, the crucial turnover of oxygenated sediment does not occur. As a result, sediment is often black and anoxic. Anoxic sediment cannot sustain the same amount of life that normoxic sediments can, so this zone tends to be barren in comparison.

With a growing global population, there is increased pressure on resource extraction and facilitation. Warming of the ocean can significantly limit the growth and diversity of microphytobenthic species, which will have severe implications for the global nutrient cycle [7]. Furthermore, an increase in anthropogenic activities in many coastal areas in recent decades has been proposed as the culprit for the declining trends in bottom water oxygen concentrations [8]. Microphytobenthos are autotrophs, so their productivity is directly linked to the amount of sunlight they receive. Rubbish, sedimentation, and toxic algal blooms caused by nitrogen runoffs are preventing optimum levels of sunlight from reaching the benthoscape. Without normal levels of productivity, the level of nutrient cycling is severely impacted, and thus the layer of anoxic sediment increases. The loss of benthic keystone species may further remove larger pelagic species from the ecosystem as their food sources become depleted. These microscopic species are evidently crucial for our oceans, and our activities on land need to become wholly more sustainable in order to prevent the creation of anoxic habitats. If we do this, we can continue to marvel at the marine life we all love so much.

Ella Speers - BSc, Marine Science, Biological Sciences
Ella is a third-year student majoring in Marine Science and Biological Science. She is extremely passionate about counteractive measures against climate change, and marine ecology. Her area of interest is in restoration and conservation of marine habitats. She cannot wait to make a difference in fragile ecosystems.

James Webb Space ~~Telescope~~ Time Machine

Celina Turner

It's a question everyone asks sooner or later: how did the universe start? How are planets and stars and galaxies created? What else is out there? Throughout the thousands of years during which humans have had consciousness that allowed them to question the origins and vastness of the universe, we've lacked an ability to find definitive answers. However, we are now living in a time where the possibility of seeing the universe at its earliest is becoming reality. In the last century, astronomy has made great strides in our understanding of what is possible, and what tools are needed to discover the creation of both the universe and the structures within it. The James Webb Space Telescope (JWST) has been a twenty-year project costing $10 billion (USD), with the aim of providing us the information that shows us the beginning of our universe [1]. But first, let's back up a bit to understand how it will be able to do that, and why it is a technological marvel.

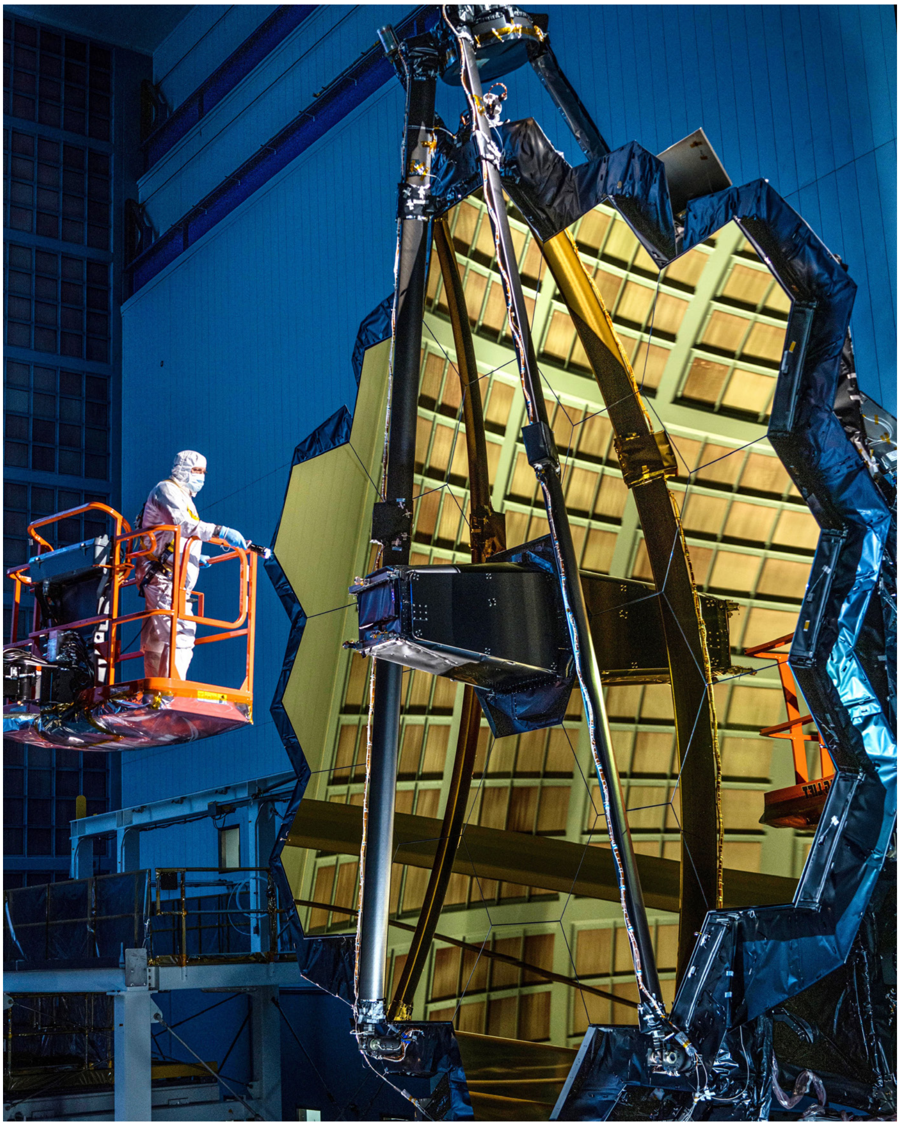


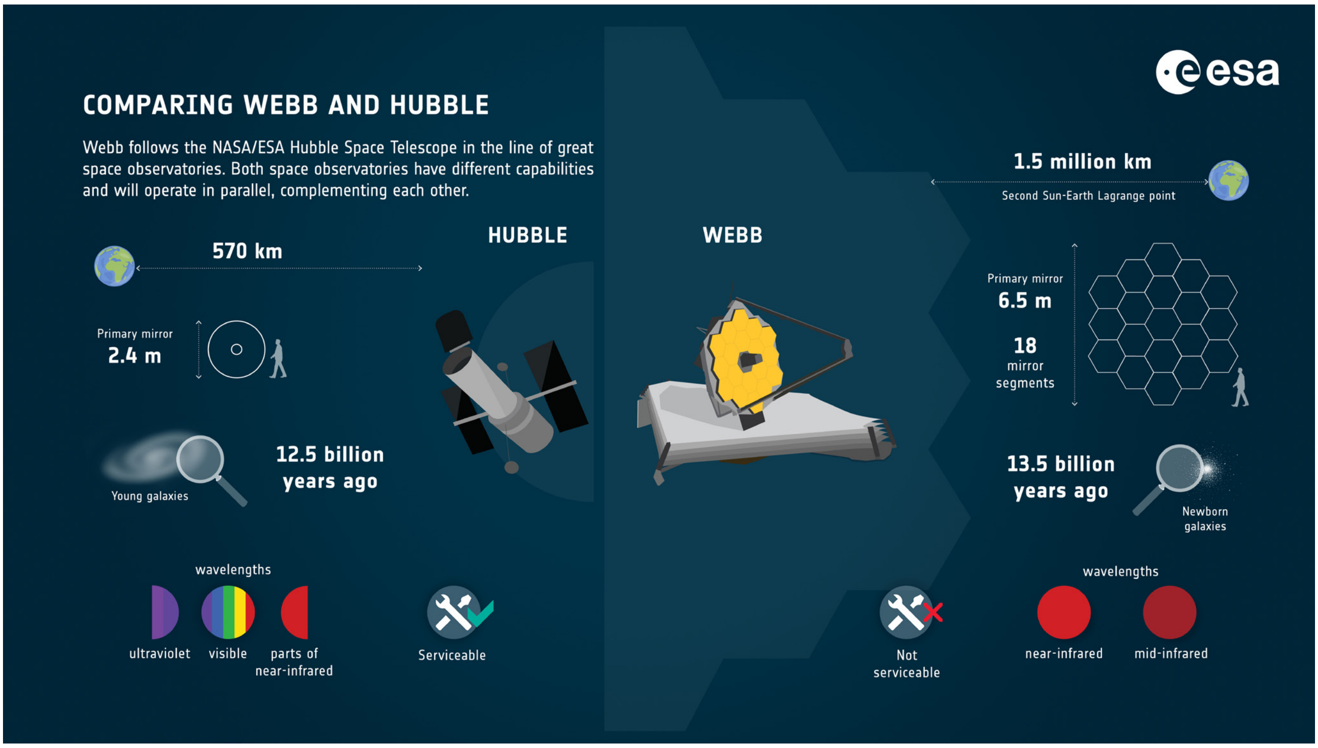
Image credit: NASA/Chris Gunn

We know there was a beginning to the universe — otherwise, as Olbers' Paradox points out, the sky would be perpetually blindingly-bright from infinite stars in infinite directions sending infinite rays of light towards Earth. The Big Bang theory explains how our universe was created: in a fraction of a second ($1/10^{43}$ of a second, to be precise), the universe exploded into existence — just a billion-degree hot pool of protons and neutrons and intense radiation that continuously expanded to fill a limitless space [2]. Particles collided to create elements such as hydrogen and helium, and eventually the first star blazed into existence.

Because light takes time to travel over distances, we can look back in time by looking at light originating from really far points; i.e. if you were to look at a star that is one light-year away, one year is required for the light from that star to be seen. Thereby, looking at stars that are billions of lightyears away shows us what they were like billions of years ago, as their light has only just reached us. However, just as the Doppler Effect changes the wavelength of an ambulance's siren when it passes from behind you to in front of you, the expansion of the universe stretches the wavelengths of the light traveling to us — known as redshift. This puts some of the possible observations in the infrared spectrum or lower instead of the optical spectrum as observable light. Even high-energy radiation that was released in the Big Bang, which is still found to be travelling across the universe, has had its wavelengths stretched into the microwave spectrum. This leftover radiation was found (accidentally) in 1965; now known as the Cosmic Microwave Background, this discovery is what ultimately convinced those who were on the fence about the Big Bang — that the universe was not a steady state, and that some beginning had to exist.

The Hubble telescope gave us a much better view into deep space, providing data that allowed us to deepen our understanding of some intricacies relating to what happened after the beginning, but it simply wasn't enough to answer questions fully. In 1995, Bob Williams (the then director of the Space Telescope Institute) used his allocated time with Hubble to do something many astronomers considered a waste at the time — he pointed it at the darkest spot in the sky to see if it was truly dark [3]. The 100 hours of exposure time would allow the telescope to soak up as much faint light that may shine from within the black void, and indeed, there was light. Now known as the Hubble Deep Field photo, his resulting image changed how astrophysicists understood the evolution of galaxies. Thousands of galaxies revealed themselves from the depths of the tiny fraction of the sky. The seemingly endless collection of worlds of different ages painted a picture of the universe over millions to billions of years. A colleague of Bob Williams stated that, "What Hubble succeeded in doing with the Hubble Deep Field is finding that there were galaxies at redshifts much higher than we thought" [3]. This conclusive proof of an evolving universe, however, only led to more questions about its very beginning, and how galaxies form at all. Seeing the universe closer in time to the Big Bang would require light that not even Hubble can detect. Interestingly, the idea of a Hubble successor that could look further back in time began to form even before the launch of the Hubble itself [3]. The majority of celestial bodies emit infrared radiation, but this of course also includes Earth, which drowns out anything that equipment on the ground could detect [4]. Thus, any invention used for the purpose of seeing the cosmos in infrared would need to be off-planet, and the concepts for such a telescope were already being discussed before Hubble was in orbit. With the discoveries of the Hubble Deep Field, such as that the oldest galaxies would be redshifted so far that there would be no other way to view them, the need for the James Webb Space Telescope became clear.

Hubble uses a mirror with approximately 4.5 m^2 of collecting area, and operates in the optical and ultraviolet spectrums while orbiting Earth [5]. The JWST instead will have approximately 25.4 m^2 of collecting area, while operating in the infrared spectrum from the L2 Sun-Earth Lagrange point [5]. Dr Elizabeth Howell explains: "A Lagrange point is a location in space where the combined gravitational forces of two large bodies, such as the Earth and the sun or the Earth and the moon, equal the centrifugal force felt by a much smaller third body. The interaction of the forces creates a point of equilibrium where a spacecraft may be 'parked' to make observations" [6]. The L2 point will enable the JWST to sit in perpetual darkness with the sun being blocked by the Earth. Aside from there being no infrared radiation produced by the sun or the Earth, there are the added benefits of this placement such as allowing for constant observations and helping keep the JWST incredibly cold, which is crucial for its detectors to ensure accurate readings as they "need to be at a temperature of less than 7 kelvin to operate properly" [7]. However, this means that if reparations are needed, as Hubble has in the past, the JWST will be out of luck as it is too far away from Earth to send a service mission. Knowing



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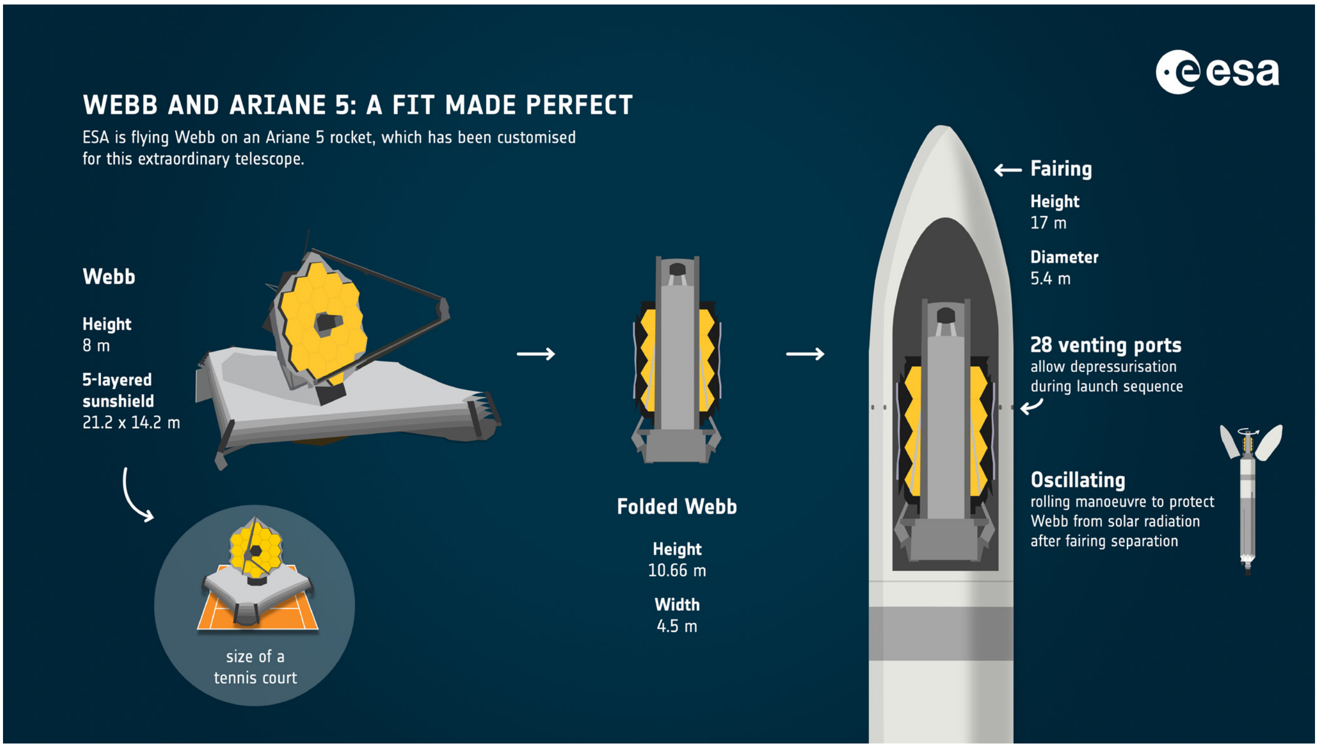

Image: ESA/NASA

that mistakes will not be able to be fixed has required every aspect to be expected to work flawlessly on its first and only try [1].

The threat of having a single attempt becomes more intimidating when considering the technological requirements JWST needs to fulfill while adhering to the limitations of bringing the rocket into space. In order to have as much precision as the Hubble telescope, the mirror of the JWST needs to be much larger, as the wavelengths of the light it is capturing are larger and fainter. But with the diameter of the mirror at 6.5 m and the diameter of the Ariane 5 rocket carrying it being only 5.4 m, engineers needed to design a mirror that could fold for launch, unfold itself in space, and align each mirror with incredible precision [8]. "Aligning the primary mirror segments as though they are a single large mirror means each mirror is aligned to 1/10,000th the thickness of a human hair. What's even more amazing is that the engineers and scientists working on the Webb telescope literally had to invent how to do this," says Lee Feinberg, the Webb Optical Telescope Element Manager [9]. The solution includes 18 hexagonal mirrors, each 1.32 m wide and made of beryllium with gold plating, that can unfold similarly to a flower blossoming [9]. Additionally, the sunshield will also need to be able to unfold in space. It may be 22 m by 12 m in size (roughly the size of a tennis court), but it is made of only five thin layers of kapton which carry the responsibility of keeping the scientific equipment cool as JWST makes its voyage to L2 [5].

Said equipment includes the Cam, NIRSpec, and MIRI — each of which have their own part to play. NIRCam is the primary imager that will detect smaller infrared wavelengths between 0.6 μm and 5 μm in size [10]. Equipped with coronagraphs, it will be able to take photos of exoplanets without being blinded by their stars. Although there are various methods for imaging exoplanets, using coronagraphs helps to image them directly by working similarly to using something to block the sun in order to see the road while driving. This is where NIRSpec takes over: creating spectroscopies of

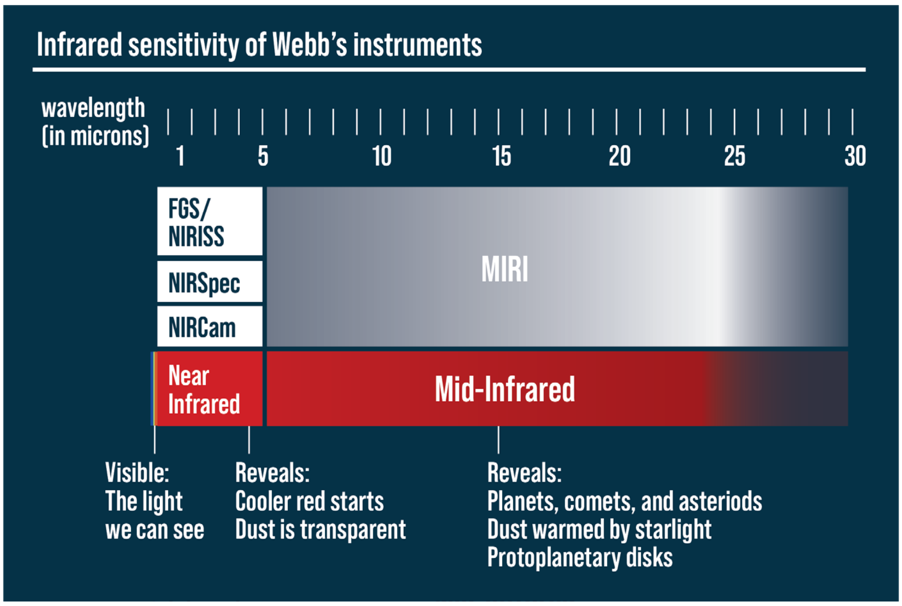

Diagram adapted from NASA's Infrared sensitivity of Webb's instruments exoplanets to identify their chemical composition [11]. Similar to the coronagraph NIRCam has, NIRSpec has a microshutter system that blocks out irrelevant areas in order to reduce light pollution [11]. However, as stated, NIRCam and NIRSpec work in the near-infrared spectrum, and are therefore more useful in exoplanet research. MIRI is both an imager and a spectrograph, but detects infrared radiation with wavelengths from 5 μm to 28.3 μm in size [12]. These longer waves can travel through clouds of dust that are scattered throughout the cosmos. MIRI will be the instrument for detecting the objects with the highest redshift. However, in order for MIRI to work accurately, its temperature needs to stay below 7 K or it begins to detect its own heat [12].

Each piece of the JWST has required multiple decades of designing and testing. With the capability of looking at the universe at a younger age than ever before, the JWST will undeniably change the field of astrophysics. We will be able to peer at the birth of some of the first galaxies, and understand how stars and planets begin to accrue mass. When pointed at nearby stars, such as Trappist, we will be able to see each exoplanet's atmospheric composition and determine if they are indeed habitable. Possibly, if we are lucky, JWST could identify biosignatures from life on other planets and redefine our existence. Learning about the beginning of the universe and looking for signs of life and habitable planets doesn't simply fulfill the curiosity we innately have. This knowledge can help us to understand how our own solar system and galaxy was created, how to reveal the mysteries of dark matter, whether life is rare and how it comes into existence, and could even help us with concepts such as how we could terraform other planets such as Mars and Venus. Any findings made by the JWST will certainly build the foundations for future missions or research studies in any range of fields. The JWST is arguably one of the most important inventions of the 21st century with the potential to forever change the way we view the universe and live within it. Launched on Christmas Day of 2021, it is now taking its month-long passage to get to the L2 point [1]. If all goes well, we can expect some incredible new discoveries throughout 2022 and onwards as it looks into the depths of our universe.

Celina Turner - BSc Physics, Statistics

Celina is studying a BSc in Physics and Statistics, with plans to do a Masters in Astrophysics when she finishes her undergrad. She works at Stardome and has spent her semester breaks working as a research assistant in projects related to astronomy.

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Fun Fact

Australia is wider than the moon

Closing Comments

That's a wrap on the very first summer edition of Scientific. We are so immensely proud of our new executive members, and the fresh perspectives they bring to the publication. The reshuffling of the team has gone swimmingly, and we can't wait to bring you four more issues, events, and exciting new social media content in 2022.

This issue concludes the run of volume 1, and volume 2 starts in semester one. Sign up to our mailing list and follow all of our socials so you don't miss a beat. All the best for the academic year, and we hope to see our inbox flooded with pitches for issue 1 of volume 2.

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