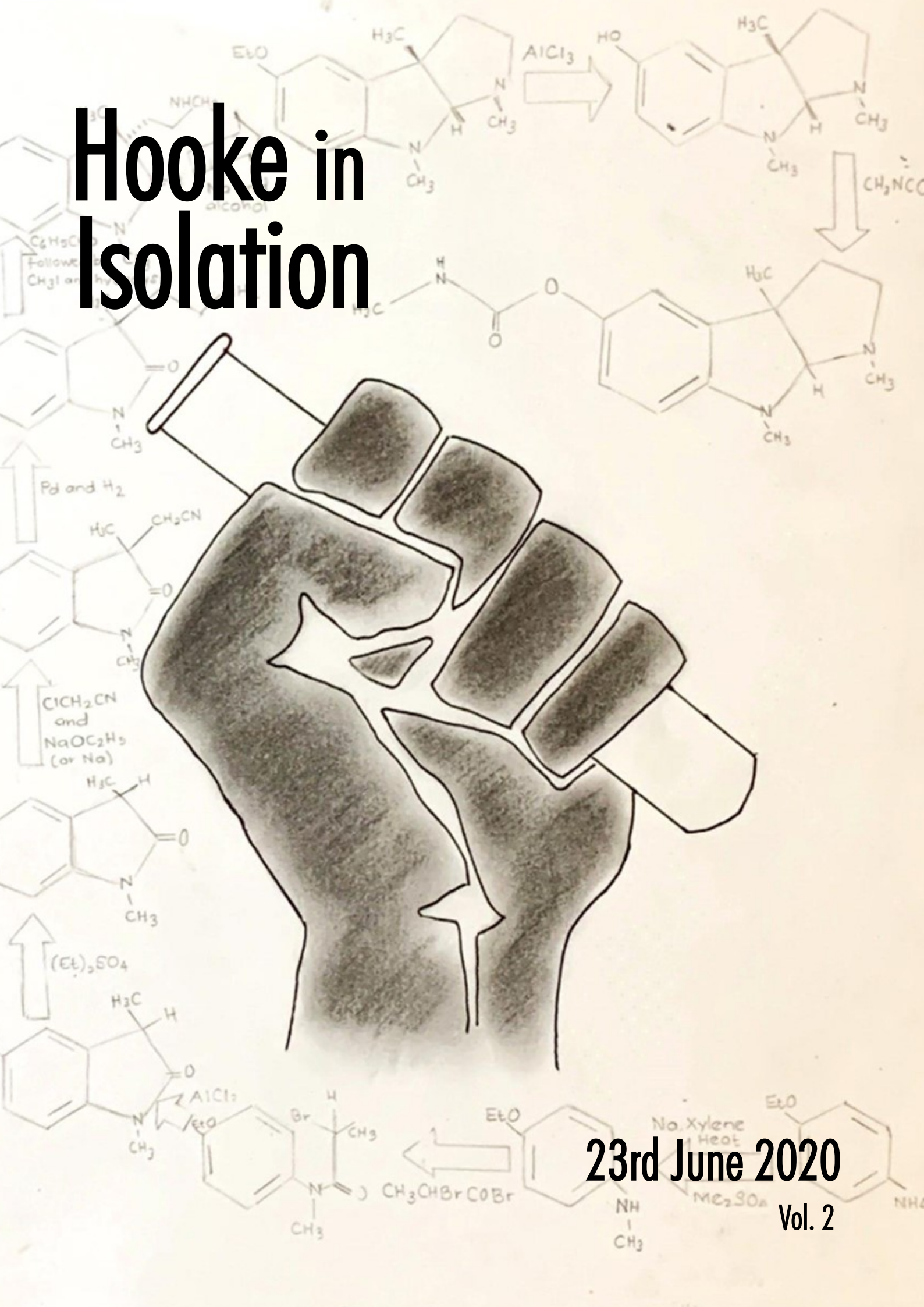
Hooke in Isolation



23rd June 2020

Vol. 2

Contents

- With thanks to Sinan Aramaz for the cover art

A Brief Note from the Editors

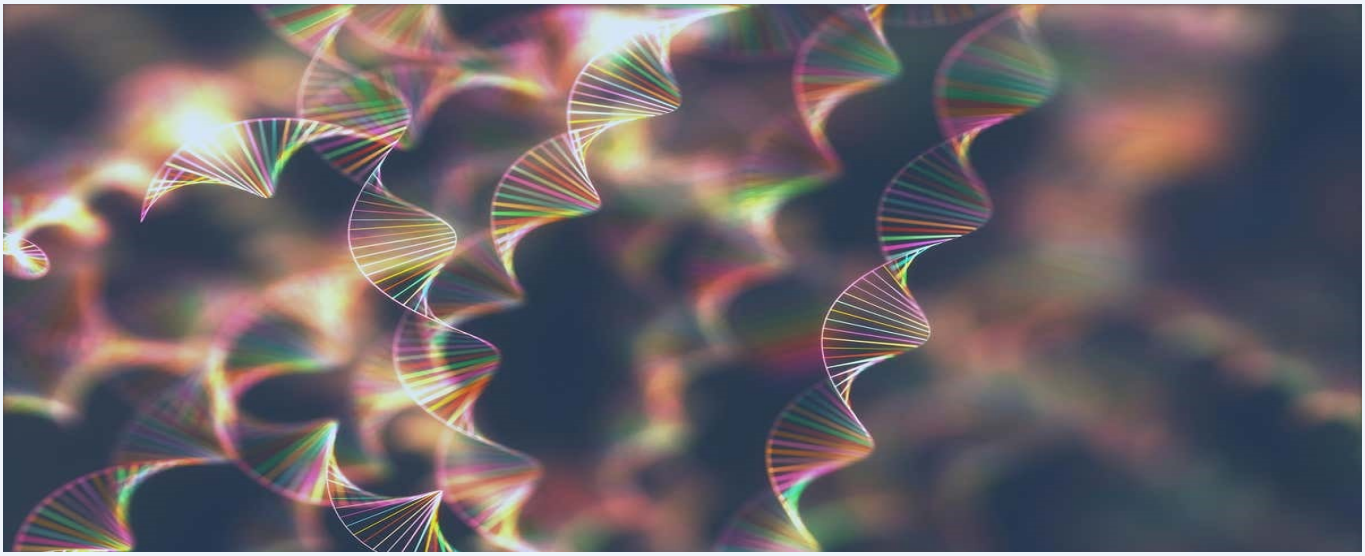
Given the recent tragedies in the US and the need for more awareness of inequality and racism, the Hooke in Isolation team has decided to shine a light on the lesser-known figures in the BAME community such as Percy Lavon Julian (see page 7), whose ground-breaking work on chemical synthesis of medicinal drugs was undermined in a segregated America. This edition also features the beginning of a discussion on the underlying biases propagated by curricula in the academic world.

Editors: Daniel O'Keefe and Adam Moëc

Decolonising the Biology Curriculum

Dr Evans

– It's about more than the content



Genetics was the first topic in Biology at school that I fell in love with. A degree and PhD followed, always with genetics at their heart. At university I learned more about the deeply troubled past of the subject, the eugenicists who used the emerging discipline to erroneously justify their racist ideologies, and lately it has been clear this attitude has not been dismissed even as the science has shown it to be wrong. What we do know is that genetics offers a powerful tool in dismantling structural racism and discrimination, but it is just a tool, and used too bluntly it can ignore the importance of the cultural diversity of humans, and individual lived experience which might be dependent on your race.

Back to genetics at school... I learned about Mendel at school in much the way it is still taught now. However, I have come to realise that this embeds serious misconceptions about the discipline, and more worryingly, reinforces some of the ideas that 'scientific' racism relies on.

There is a conflict here – teaching anything with complexity requires careful scaffolding and the use of well-chosen examples. There are good reasons as to why we teach genetics the way we do. However, by simplifying things to make them accessible we potentially foster a poor understanding of the discipline, and the implications are serious.

So what's so wrong with the way you were taught genetics? We start at the beginning: we teach you what a gene is, and how they are inherited; we teach you how to draw genetic crosses. Then we teach you that there are clear links between genotypes and phenotypes. We use examples to show what we mean. We talk about blue eyes and brown eyes, black fur and white fur in mice, petal colour in flowers. We tell you that of course eye colour is not in fact a single gene trait, but we continue to leave you with a strong association between genes and visible

traits. When we teach you about evolution we use visible examples to illustrate evolution as descent with modification, like the beaks of Galapagos finches. The principles illustrated here are not incorrect. But the inferences that many people draw are.

There are very few visible single gene traits. The vast majority of visible traits in humans are caused by multiple genes, with multiple possible alleles, and there is an environmental component too. I expect you know this, but I suspect it was not used to illustrate the limitations of Medelian genetics as explicitly as it could be? This leaves us with two problems: the importance of heritability is overstated and the idea that genetic traits are visible is reinforced.

When, in lessons, we imply that genetics is responsible for the way we look, and we live in a society that categorises people on something visible like skin colour, we might artificially link the two. We now have a situation in which people instinctively assume there are key genetic differences between people of different races. What genetics tells us is - of course - quite the opposite. Human genetic diversity does not align with visible traits like skin colour. What we are seeing here is conflation of population genetics, a biological construct, and race, a social construct.

This might seem like a justifiable simplification to have made, with few significant problems. However, it leaves the vast majority of the population with this incorrect idea embedded. Sadly, most people do not study genetics at a level higher than GCSE. And as the well-known warning from Alexander Pope goes, "a little learning is a dangerous thing." When this simplified knowledge is incorrectly, and confidently, extrapolated by influential people, discriminatory ideas can be embedded. This is how structural discrimination remains deeply rooted. These ideas actively feed into the dangerous narratives that we have seen recently - for example Andrew Sabisky (who was briefly hired by the government) stating a belief in the discredited and incorrect link between IQ and race, or the eugenics conference held at UCL attended by Toby Young who was given a prominent government position relating to education. Proponents of Murray's Bell Curve still refer to it as a piece of scientific research, when of course it is a political book with a clear ideological, and racist, agenda. Mighty figures in science like James Watson have bought into this fallacy. The original study by Richard Lynn was widely discredited due to its poor experimental design, but there are still those who insist that science can explain differences that do not exist. 'Scientific' racism relies on people not understanding genetics. And while I hope this does not apply to those in the Westminster community we can see that this view is sadly held by powerful people who influence policy and government.

"IQ and intelligence are incredibly complex traits with heritable and environmental components."

Genetics cannot explain differences in IQ between people of different races because there are no proven differences to explain. IQ and intelligence are incredibly complex traits with heritable and environmental components. The evident importance of

socio-economic status with respect to academic attainment is known and yet appears to be ignored in these discussions. Instead genetics is often used as the explanation, and I worry this is because it feels instinctive. But this instinct is poorly founded.

but are also aware of the limitations of their own knowledge. This needs to be as important a part of the curriculum as the specification points. It must be explicit in a curriculum or it will be inconsistently delivered, or even neglected.

our curriculum. There are countless others, many of which are far more apparent in their omission of crucial facts and context which leaves them incomplete. One of the most obvious omissions is in the (untold) story of Carl Linnaeus, the

It seems clear to me that the way we teach genetics actively contributes to this misconception, and I don't think the implications of this for maintaining a white supremacist structure need to be explained.

Of course we should continue to teach the underlying principles of genetics as we do, because pedagogically this makes sense. But we should also actively address the implications that we leave students with and ensure they are not only aware of these,

Research on unconscious bias shows that we rely on quick thinking, which depends on instinct and assumptions. Even when we think we know something at a deeper level, it will be the superficial that wins unless we make time to ask critical questions. This is why it matters that we consider these possible associations and incorrect assumptions that might result from the way we approach topics and ideas.

Of course this is just one narrative in the many that scatter

father of classification. Yes he came up with the binomial classification system still used today, an essential tool in conservation for example, but he also classified humans. (See the references section for further reading on this story). The ideas he presented were clearly incorrect, and it can be easy to dismiss them due to the inherently offensive nature, or say they were 'of their time' and there is no benefit in acknowledging them now.

But looking at the language he uses, it is hard to ignore the similarity with the racist language still used today. Studying this, and discussing why it is wrong, not only offers an opportunity for dialogue around racism but also demonstrates starkly how these ideas have morphed and changed to become part of the fabric of our society. Highlighting historic biases, one of the known ways to eliminate them, will also help us see what structural racism looks like. This undoubtedly helps us to then understand the serious underrepresentation of black scientists both historically, and currently, and reinforces the importance of ensuring we address this in our own departments and across the school in general. It has been noted that as well as understanding how our colonial past has contributed to the racist structures we live with now, we also need to actively celebrate success, achievement and progress, and this is where representation is essential. This issue is worthy of its own separate discussion of course, so while I acknowledge it here I am aware it is not possible to offer the necessary attention it needs in this single article.

Being aware of such context contributes to understanding how it is we have ended up here with a structurally racist society. This is not only about the amplification of oppressed voices from our past and our present. It is also about questioning incorrect and damaging assumptions and adjusting curricula to actively tackle these so we do not continue to be a part of the problem. Decolonising the curriculum in science therefore might seem less obvious than say History, or English, but there is ample opportunity to explore not only the content of what we teach, but *how* we do so, and what implications we might inadvertently reinforce. Because structural racism and mechanisms of discrimination pervade, and they arose from somewhere, it saddens me to think how much science and scientists have contributed to this.

This does not diminish or erase the achievements, discoveries and progress made by the scientists of our past, but it does give us a richer idea of how some of their ideas have been bent and misused, based on the societal expectations of the time they were first presented.

A decolonised curriculum is infinitely more enriching and more academic, one befitting of a liberal and rounded education. It is right to probe and question in this way because education is a powerful solution. Education should not pick and choose: it should be full, contextual and complete. It is the responsibility of the Common Room to explore this within their own curricula, but as part of the school community I would encourage you, our pupils, to share any thoughts you have in this regard This should be as collaborative, wide-reaching and impactful as we can make it. We want to hear your ideas. Scrutinising the content and how it's taught are just the first steps in developing a curriculum fit for the times we live in now. But it is an exciting path to be on.

References:

I think referencing this stream of consciousness might overstating its academic nature somewhat but reading Adam Rutherford's 'A brief history of everyone who ever lived' and 'How to argue with a racist', Angela Saini's 'Superior', and posts from The Black Curriculum, significantly informed this article. Philip Ball's recent review of Charles Murray's new book in The New Statesman also played a part as I can't possibly bring myself to spend money supporting the book itself.

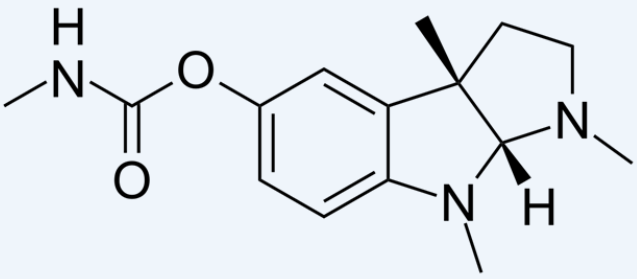
Further reading on Carl Linnaeus: http://www.leeds.ac.uk/educol/documents/157423.htm

The Life and Work of Percy Lavon Julian

Sinan Aramaz

Percy Lavon Julian was born on April 11, 1899 in Montgomery Alabama. He pursued primary education in his youth until the 8th grade, but as an African-American teen in a world of segregation and Jim Crow laws only 40-something years after the USA abolished slavery, he was barred from attending high school on the sole basis of his race. Moreover, he recalled coming across a lynched man at the age of 12. Despite such setbacks, he went on to be one of few African-Americans to study at DePauw university in Indiana and graduated with honours in spite of the several social humiliations he faced there[1]. Post-graduation, Julian took up work as a chemistry instructor and received a scholarship at Harvard to finish his master's degree. However, he was not allowed to pursue a doctorate due to his race. He travelled and taught in black-only colleges before completing his doctorate at the university of Vienna in 1931. Soon after, he returned to DePauw as a research fellow. It was there that he first performed a total synthesis of Physostigmine[2], an anti-glaucoma drug, as represented on this issue's cover art.

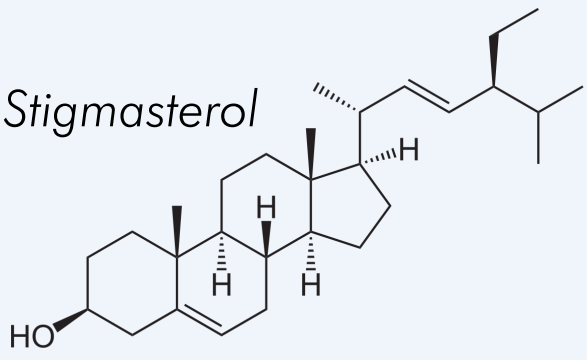
Physostigmine is an alkaloid naturally found in the poisonous Calabar bean and has the property of dilating outflow channels in the eye. Glaucoma is the damage to the optic nerve resultant of built-up pressure in the eyes as a result of aqueous humour accumulation. Hence, increased outflow or drainage from the eye is beneficial in treatment.



Physostigmine

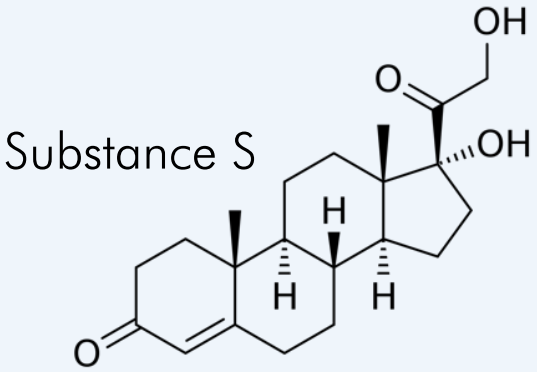
This achievement facilitated industrial mass-production, helping the drug to reach and help more people and earning Julian international acclaim. Nonetheless, Julian once again would fall victim to prejudicial injustice, being prevented from becoming a full professor at DePauw due to his race. He shifted his work into industry yet continued to suffer from racism and prejudice, being turned down from several chemical companies in favour of lesser-qualified white applicants before finally being accepted as a lab director at the Glidden Company. There he continued to excel in biomedicine, pioneering in industrial-scale drug synthesis. For example, he discovered a method to industrially mass-produce progesterone and testosterone[3]. As progesterone is a steroid, Julian had experimented with soybean steroids in his research due to their similar structures. By serendipity, he recognised that water and soybean oil form crystals containing the plant steroid stigmasterol when combined thanks to previous encounters with the chemical during his time working on physostigmine.

1993 Percy Lavon Julian Stamp



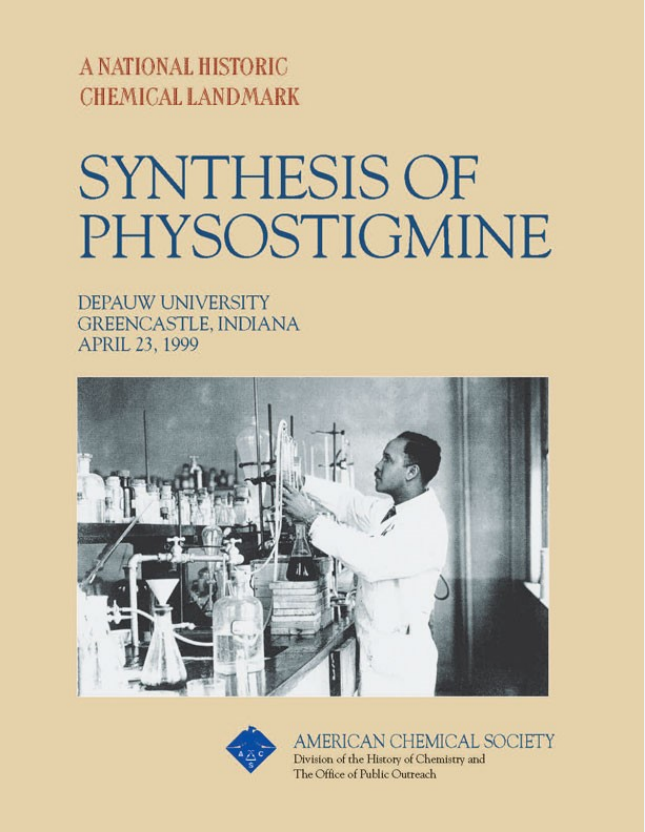
Stigmasterol could then be converted to progesterone by processes developed by German chemists Butenandt and Fernholz some years earlier[4]. This process was later expanded to produce Testosterone and birth control pills after Glidden had produced the first commercial shipment of sex hormones[5] in the USA.

After leaving Glidden, Julian started his own company, Julian Laboratories Inc, and brought with him some of his strongest colleagues including women and African-Americans. There he continued to do research work. Most notably, he discovered a way to synthesise Reichstein's Substance S[6]: a cortical hormone closely related to Cortisone, an anti-inflammatory drug used to treat several conditions such as rheumatoid arthritis which was worth around 100 times the value of gold then[7]. From there, he went on to synthesise cortisone and the related hydrocortisone alongside his colleagues, making the drug widely accessible and laying the foundation from which most syntheses of hydrocortisone and hydrocortisone derivatives are conducted to this day.



He sold the company some years later in 1961, making him one of the first African-American millionaires.

Two years before his death, he became the first African-American chemist and second African-American scientist elected into the National Academy of Sciences in 1973[8]. Since his death, he has been honoured in a multitude of forms from induction into the National Inventors Hall of Fame in 1990[9] to creation of a stamp bearing his likeness issued by the United States Postal Service as shown above. In 1999, his aforementioned synthesis of physostigmine was honoured by the American Chemical Society as a National Historic Chemical Landmark[10].



Going up against tremendous odds, Julian managed to flourish despite being held back by an oppressive system and a hostile environment geared towards seeing his failure. Fuelled by passion for science, unwavering resilience and determination to help others as well as to succeed himself, he lives on as a beacon of hope for the marginalised everywhere. However, despite his academic and financial successes, his personal life was consistently troubled by racism. Alongside social humiliation and intellectual suppression was physical violence: his house in the Chicago suburbs was the target of a firebombing in 1950 as well as a dynamite attack the next year. His son recalled that he would sit in a tree outside the property with a shotgun, afflicted by a paranoia permeated by prejudices that recent tragic events have reminded us still exist and plague BAME communities to this day.

As we take up the fight against racism, let's take the time to address our own innate prejudices and remember that, as the struggles of Julian and the silence of many more have illustrated, the familiar world of academia isn't immune to systemic issues and harmful prejudices. Moving forwards, let's challenge ourselves to learn and grow, to avoid complacency and to join the fray with scientific acumen and invigorated grit so we can match the encompassing universality of science to its institutions.

References:

[1] https://www.depauw.edu/news-media/latest-news/details/22969/

[2] https://pubs.acs.org/doi/pdf/10.1021/ja01307a051

[3] https://www.pbs.org/wgbh/aso/databank/entries/bmjuli.html

[4] Butenandt A Westphal U Cobler H . Berichte Deutsche chemische Gesellschaft. 1934; 67:1611–1616, 2085–2087; , Fernholz E . Berichte Deutsche chemische Gesellschaft. 1934; 67:2027–2031.

[5] https://academic.oup.com/labmed/article/41/11/688/2504925

[6] https://pubs.acs.org/doi/pdf/10.1021/ja01167a094

[7 8] NOVA: Percy Julian—Forgotten Genius [DVD], 2007.

[9] https://www.invent.org/inductees/percy-lavon-julian

[10] https://www.acs.org/content/acs/en/education/whatischemistry/landmarks/julian.html

Coral Bleaching as an Indicator of Climate Change

Ben Weiss

Coral reefs are a vital part of global marine ecosystems – indeed, despite covering less than 0.1% of the ocean floor, they are home to almost 25% of all known marine species[1] and are some of the most biodiverse habitats in the world. Scientists estimate that more than a million species of plants and animals are associated with the coral reef ecosystem[2], and the sheer variety of coral is apparent just by looking at a healthy coral reef (see Fig 1). Furthermore, hundreds of millions of people rely on coral reefs for essential nutrition, livelihoods, protection from storms and crucial economic opportunity.

This is why it is all the more tragic that coral reefs are disappearing at the shockingly rapid rate that they are. Research presented at the recent Ocean Sciences Meeting 2020 estimates that over the next 20 years, about 70 to 90% of all coral reefs will disappear primarily as a result of warming ocean waters, ocean acidity, and pollution.[3] This article will examine the process by which coral reefs die, coral bleaching, and how it can be used as a clear indicator of how quickly humans are changing the surrounding natural world, potentially irreversibly.

In order to first understand coral bleaching, one must first understand coral anatomy. Coral is a symbiosis between cnidarians and algae. Cnidarians are a class of very simple invertebrates which include anemones and jellyfish, anatomically very similar to coral polyps. A coral polyp can be pictured as an upside-down jellyfish (see Fig 2): the base of the body is anchored to the ground and contains the gut of the animal, which is used to

Fig 1: Australia's Great Barrier Reef

digest the food it ingests through an opening at the top, the mouth. On the outside, the mouth is surrounded by numerous tentacles, which act as the predatory weapon of the organism, trying to catch plankton and small organisms to eat. The polyp is anchored to the ground (or to the rest of its colony) at its base, which in most cases secretes a limestone 'cup' as its protective skeleton. The polyp can retract within its cup to protect itself from predators (usually during the day) and then only extend its tentacles at night to hunt, when most fish are resting and it is relatively more safe.

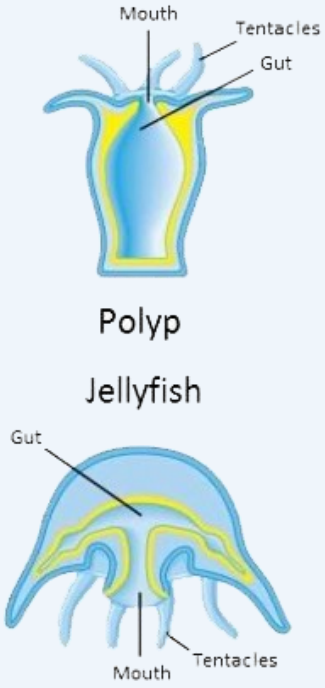


Fig 2: Comparison between different cnidarians

There are two main types of coral, which determines whether a coral is considered a 'reef builder' or not. Corals that lay down a skeleton which will remain in place after the death of the colony and act as a substrate for new organisms to develop on are called *hermatypic* corals, or hard corals. Corals that do not secrete a long-lasting structure are known as *ahermatypic* corals, or soft corals. They are not considered reef builders, but nevertheless play a key role in the ecology of the coral reef, offering greater biodiversity, sustenance and protection to the reef.

The coral skeleton is composed of calcium carbonate ($CaCO_3$) secreted by a layer of cells underneath the polyp called *calicoblast*. The calicoblast extracts calcium ions and carbonate ions from the sea water to create the aragonite skeleton and carbon dioxide and water as byproducts (see Fig 3). Aragonite is calcium carbonate that contains impurities such as strontium (Sr) or magnesium (Mg), which occur naturally in sea water as trace elements.

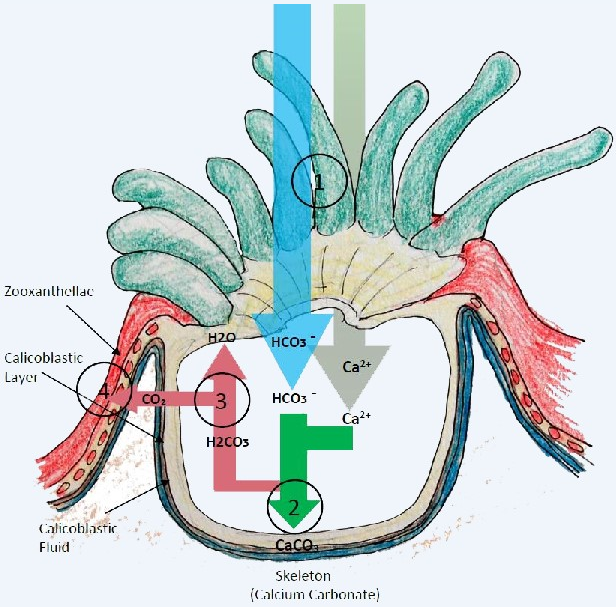


Fig 3: Formation of $CaCO_3$ skeleton of coral colonies

Looking at how corals sustain themselves provides a key to understand why coral bleaching occurs. Coral polyps feed on microscopic organisms generally called zooplankton which they capture using their tentacles. Zooplankton such as copepods, sea lice, larvae of fish and other corals are all part of their diet. However, most reef-building corals also live in symbiosis with photosynthetic algae called zooxanthellae. The coral provides the algae with a protected environment and the compounds they need for photosynthesis. In return, the algae supply the coral with glucose for energy. Corals that take advantage of both these food sources are called *polytrophic*.

The relationship between the algae and the coral polyp facilitates a tight recycling of nutrients in nutrient-poor tropical waters. In fact, as much as 90% of the organic material photosynthetically produced by the zooxanthellae is transferred to the host coral tissue.[4] In addition to providing corals with essential nutrients, zooxanthellae are responsible for the unique and bright colours of many stony corals.

Because of their intimate relationship with zooxanthellae, reef-building corals respond to their environment like plants. Reef corals require clear water so that sunlight can reach their algal cells for photosynthesis. For this reason, they are generally found only in waters with small amounts of suspended material, or water of low turbidity and low productivity.

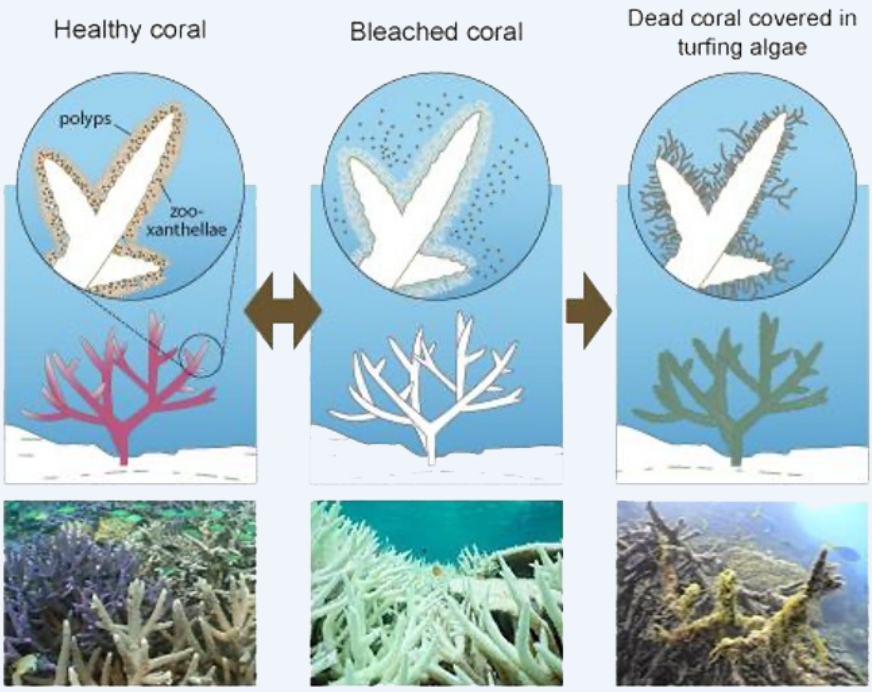


Fig. 4: Process of coral bleaching

The collaboration between polyp and algae is so tight that if the two organisms stop working together, they will most probably both die: when the algae leaves the tentacles' cells they will be preyed upon by other organisms, while a polyp left without algae can survive through active predation for a few weeks at most. It is this disruption of the symbiotic relationship between the two organisms that causes coral bleaching (see Fig 4).

Coral bleaching is a reversible state, meaning that the algae can recolonise the 'empty' cells if the stress factor is removed and the conditions fall back into acceptable parameters. Unfortunately, this generally does not happen in time to allow the coral to fully recover. Coral colonies often starve and die before the algae can recolonise them. Bleaching and successive recovery also weakens the colony, increasing the change of disease epidemics and reducing the long term survival chance even further. It can take decades for coral reefs to fully recover from a bleaching event, so it is vital that these events do not occur frequently. If global warming continues at its current rate, then severe bleaching events are likely to hit reefs annually by the middle of the century[5], meaning they would have no chance to recover (see Fig 5).

Coral bleaching can be caused by multiple factors including, but not limited to, chemical pollution, excessive UV radiation or an increase in water temperature. As global warming due to increased burning of fossil fuels causing an amplified greenhouse effect continues, the average water temperature rises. A temperature of about 1^{O}C above average can cause bleaching[6]. Furthermore, oxygen starvation caused by an increase in zooplankton levels as a result of overfishing[7] and increased solar irradiance (from photosynthetically active radiation and ultraviolet light) can also cause the polyps to expel the algae, leaving behind a white, ghostly skeleton (see Fig 6).

It has been posited that coral bleaching is an adaptive mechanism by which the coral colony reacts to environmental change.[8] [9] At 30^{O}C (moderate thermal stress) corals selectively digest the damaged algal cells or immediately expel them without digestion by exocytosis,

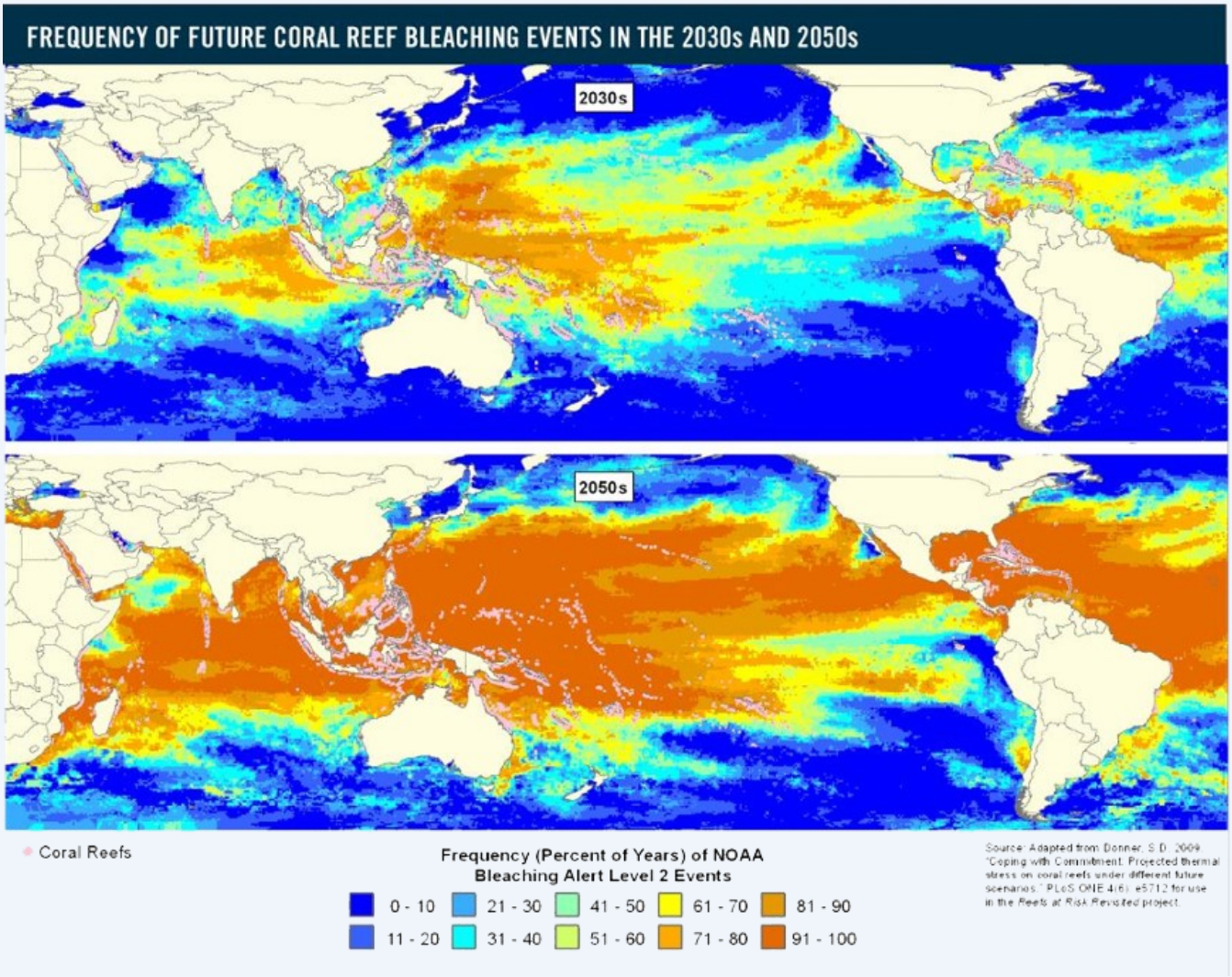


Fig. 5: Frequency of future coral reef bleaching events in the 2030s and 2050s

which is most likely to reflect adaptation in response to this thermal stress to avoid the accumulation of damaged cells. However, the accumulation of damaged cells may exceed the increased rate of expulsion of digested zooxanthella. As a result, this response may be an adaptive strategy to moderate stress to ensure survival, but the accumulation of damaged cells which causes subsequent coral deterioration may occur when this response cannot cope with the magnitude or duration of environmental stress.

Fig. 6: A bleached coral, with healthy coral visible behind

The increased frequency of mass bleaching events has caused the death of over 50% of the world's coral reefs in the last 30 years.[10] Given that thousands of marine species depend on coral reefs for survival – they provide shelter, spawning grounds and protection from predators, as well as supporting organisms at the base of ocean food chains – with the collapse of reef ecosystems, already at-risk species may face extinction. However, it is not just wildlife who are at risk from the disappearance of coral reefs… Coral reefs are natural barriers that absorb the force of waves and storm surges, keeping coastal communities safe. Bleached coral also compounds the overfishing crisis by removing links in the food web and depriving fish and crustacean species of a place to spawn and develop. Finally reef tourism brings in billions of dollars each year. Indeed, by one estimate coral reefs provide economic goods and services worth about $375 billion each year.[11]

The future for coral reefs looks grim if global warming continues at its current rapid rate. There do exist corals (such as *Acropora aspera)* in places with widely fluctuating temperatures, such as areas of extreme high and low tides, that are naturally more resistant to temperature stress, however their resilience is limited after adapting to a warmer climate.[12] Without a doubt the most effective, and possibly only, way to prevent the shockingly quick deterioration of these incredibly biodiverse habitats is to dramatically slow global warming caused by human activity. Perhaps the coronavirus pandemic, tragic though it is, is the perfect opportunity to turn the corner to a greener future.

"The increased frequency of mass bleaching events has caused the death of over 50% of the world's coral reefs in the last 30 years."

References:

[1] https://wwf.panda.org/our_work/oceans/coasts/coral_reefs/
[2] https://coral.org/coral-reefs-101/why-care-about-reefs/biodiversity/
[3] https://www.forbes.com/sites/trevornace/2020/02/24/70-90-percent-of-coral-reefs-will-disappear-over-the-next-20-years-scientists-say/#4762df837d87

[4] https://oceanservice.noaa.gov/education/tutorial_corals/coral02_zooxanthellae.html

[5] https://www.marineconservation.org.au/coral-bleaching/

[6] https://ocean.si.edu/ocean-life/invertebrates/corals-and-coral-reefs

[7] http://www.fisherycrisis.com/coral1.html

[8] https://www.sciencedaily.com/releases/2014/12/141229092600.htm
[9] https://www.researchgate.net/publication/247843807_Coral_Bleaching_as_an_Adaptive_Mechanism
[10] http://www.secore.org/site/corals/detail/coral-reefs-are-dying.23.html

[11] https://floridakeys.noaa.gov/corals/economy.html

[12] https://www.the-scientist.com/image-of-the-day/image-of-the-day--stress-resistant-corals-66441

The Stopped Clock Illusion

Daniel O'Keefe

Have you ever glanced at an analogue clock, only to feel time briefly stop?

Don't worry. This is perfectly normal. It even has a name: the "Stopped Clock Illusion", an example of chronostasis. It's a temporal illusion we experience whenever we move our eyes away from one object and quickly focus on another.

To understand how this happens, we need to recognise the relationship between visual sensation and perception. Visual sensation refers to the information collected by our eyes, whilst perception refers to the way our brain interprets this information. The action is fairly streamlined. We see something and our brain processes it so that we can respond in an appropriate manner.

However, this flow of information is regularly disrupted by quick eye movements shifting our focus from one point to another. These movements are known as "saccades". It would make logical sense for us to feel some sort of motion blur during saccades in the same way that a camera does. But if you hold out your arms and try flicking your eyes from one index finger to the other, you won't see any blur at all. Furthermore, you may be able to detect an almost instant flash of darkness. This is the interruption in consciousness that allows chronostasis to occur.

Our brains detect this interruption and automatically fill it in. We erase the few milliseconds of motion blur and replace these "frames" with whatever comes after the break. We call this "saccadic masking". It explains the stopped clock illusion; our minds fill the "frames" of motion blur with a still image of the

clock. These extra frames are added to the 1 second image of the still clock. The second hand appears to stay still for a bit longer than normal. We internalise this as a long-lasting second.

A team at University College London investigated chronostasis in the early 2000s by asking volunteers to look away from and then suddenly look towards a digital counter. When they were asked how long they thought they had been looking at the digit that first appeared, they consistently overestimated the length of time. Their research also found that longer eye movements resulted in longer perceived pauses. When we think about it, this makes sense. The brain has more "frames" of motion blur to replace with a still image, so the time stop illusion is greater.

Despite chronostasis lasting only a fraction of a second, it occurs so often that we end up losing around 40 minutes in total every day! And yet we never really notice it happening. The human brain has become so good at hiding its tracks that the transfer of focus is seamless. But if you look at something that moves with constant and familiar precision, like a clock, you will observe the irregularity and your brain will interpret it as a lengthened second.

It has been suggested that chronostasis doesn't rely on eye movements, but merely a shift in attention. The most common way that we shift attention is by moving our eyes, but we can also shift our auditory focus. There is an effect very similar to the stopped clock illusion, but for our ears, known as the "dead phone illusion". When you first pick up a telephone and hear the periodic tone, you sometimes find that the initial silence is longer than the others. We cannot explain this in the exact same way that we explained the stopped clock illusion; there are no saccadic eye movements involved here. This supports the theory that our perception of time doesn't just rely on motor acts by certain organs, but also on a cognitive timing system, estimations and mental interest.

"Our experience of time passing is devised by our brains, rather than some objective and accurate internal measure."

Whatever the reason, these illusions show us that our experience of time passing is devised by our brains, rather than some objective and accurate internal measure. It's why we perceive time to move faster when we're doing something we enjoy. Or why everything seems to slow down for people in emergencies. It's amazing to think that even our perception of time hinges on our brain essentially guessing based on past patterns and experiences. We can only experience it through the filter of the brain and thus we will never know time directly.

References:

https://www.bbc.com/future/article/20120827-how-to-make-time-stand-still

Stafford T, Webb M. "Mind Hacks: Tips and Tricks for Using Your Brain". (2004). p54.

Alexander I, Thilo KV, Cowey A *et al*. "Chronostasis without voluntary action". *Exp Brain Res*. Vol. 161, Issue 1. (2005). p125-132. https://doi.org/10.1007/s00221-004-2054-3

Hodinott-Hill I, Thilo KV, Cowey A, Walsh V. "Auditory chronostasis: hanging on the telephone". *Curr Biol*. Vol. 12, Issue 20. (2002). p1779-1781. https://doi.org/10.1016/s0960-9822(02)01219-8

Yarrow K, Haggard P, Heal R, Brown P, Rothwell JC. "Illusory perceptions of space and time preserve cross-saccadic perceptual continuity". *Nature*. Vol. 414, Issue 6861. (2001). p302-305. https://doi.org/10.1038/35104551

SpaceX and their Bid to Send us to Mars

Adam Moëc

On 30th May, with over 10 million people watching live on various streaming services, SpaceX's Crew Dragon Demo-2 rocket took off with NASA astronauts Bob Behnken and Doug Hurley aboard from the historic pad LC-39A which saw the launch of Apollo 11. This momentous occasion marked the end of American reliance on Russian Soyuz rockets to launch their astronauts to the ISS, and to the SpaceX team it meant the beginning of human transportation to space for a company that up until then had only been authorised to send cargo to the ISS and earth orbit. This is an immense achievement for a private space company and particularly for SpaceX, narrowly managing to beat its main competitor Boeing in order to become the first privately held company to send astronauts to space.

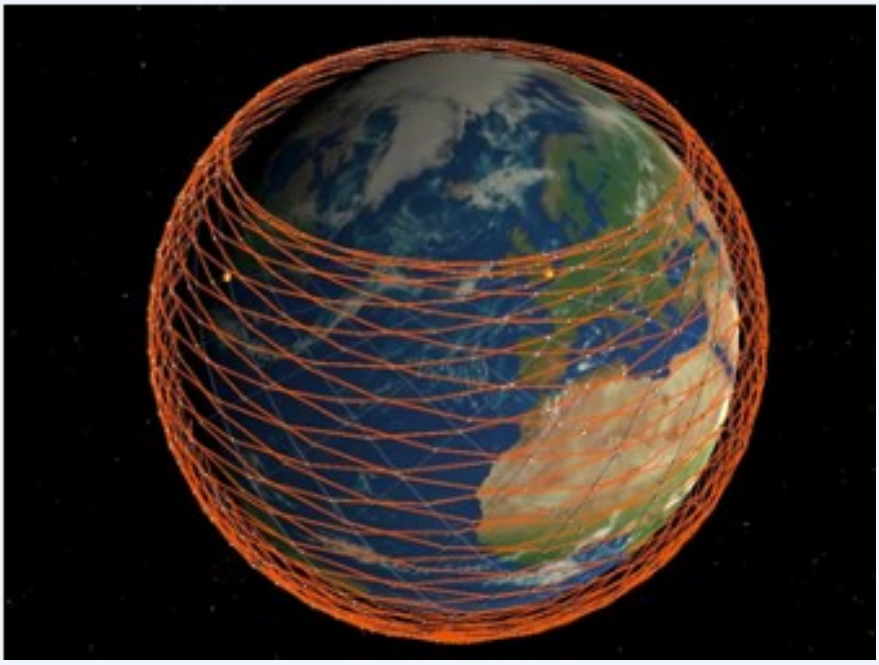
The launch went by with no hitches and 19 hours later the Crew Dragon capsule docked 10 minutes ahead of schedule. The Falcon 9 booster landed perfectly on SpaceX's droneship "Of Course I Still Love You" and was later recovered to be refurbished. The team will be on the ISS for 30 to 119 days before the Crew Dragon is once again put to the test as it re-enters the earth's atmosphere on the return trip.

From its humble beginnings in 2002 under the leadership of Elon Musk, SpaceX has grown into a globally recognised company with over 7,000 employees scattered over California and Texas[1]. Following its first successful launch with the RazakSAT satellite aboard the Falcon 1 rocket in 2009, it quickly became apparent that the price of launch greatly outweighed demand for such a small rocket, and consequently a small payload capacity. SpaceX made the

dangerous and almost suicidal move to exclusively pursue development of the Flacon 9 rocket which had begun in 2005. Funded almost entirely by NASA, its designs would eventually allow the Falcon 9 to send payloads of up to 22,800kg into Low-Earth-Orbit, compared to the hypothetical 670 kg of the Falcon 1. To NASA, Falcon 9 would be the first step towards American resupply and crewed missions to the ISS and further, a capability that had been lost since the Space Shuttle was retired in 2011 due to unacceptable failure rates and high costs of the program. With the development of Falcon 9 came the idea of reusability. Although the Space Shuttle was partially reusable (since the actual Shuttle could land and be recovered), the price of each launch hovered around $450 million per launch[2]. The huge cost of launch came from the boosters which were dumped into the ocean and only partially recovered, whilst refurbishment of the actual Shuttle was also costly. The first iteration of Falcon 9 did not attempt booster recovery, but it became increasingly important to reduce launch costs to become a true competitor to existing cargo mission alternatives. The current substitutes posing the most threat to SpaceX are the Ariane 5 rocket of the ESA (European Space Agency) with launch costs around $137 million[3] and Roscosmos' (Russian space agency) Soyuz and Proton rockets with costs said to be around $50 million[4].

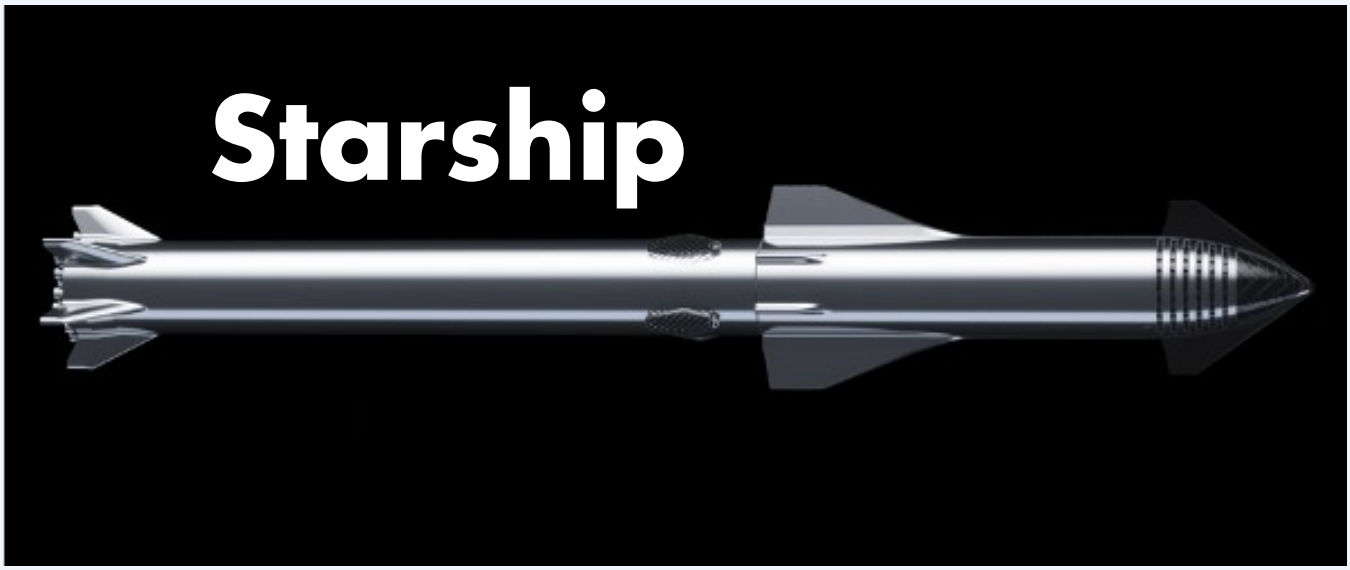
True reusability became one step closer to reality with SpaceX's initial successful landing of their first stage booster in April 2014. With that, SpaceX was one step closer to getting us back to the Moon and establishing a colony on Mars. To Elon Musk, the creation of SpaceX was entirely based on getting humans to Mars and staying there in a self-sustaining colony. Musk recognises with deep regret the lack of motivation in space exploration following the end of the space race and the termination of the Apollo program. Indeed, the following quote by Elon Musk introduces SpaceX's page on the exploration of Mars titled "Mars & Beyond: The road to making humanity multiplanetary":

"You want to wake up in the morning and think the future is going to be great - and that's what being a spacefaring civilization is all about. It's about believing in the future and thinking that the future will be better than the past. And I can't think of anything more exciting than going out there and being among the stars."[5]



This philosophy is indeed what has governed most of the decision-making processes at SpaceX: everything is framed within the question of whether it will bring us closer to establishing a permanent presence on Mars. The Falcon 9 rocket was used to test partial reusability as a milestone towards full reusability it was also intended to generate revenue for SpaceX in terms of government and private contracts to haul satellites and other precious cargo to Low Earth Orbit and beyond. Most recently the development of Crew Dragon allows SpaceX to secure quasi-constant funding straight from NASA until at least 2028 when the ISS is due to be decommissioned. More importantly Crew Dragon demonstrates SpaceX's ability to launch astronauts into space and therefore being greenlighted for their other projects. The construction of the Starlink Satellite Constellation around the Earth is yet another example of SpaceX's goal-oriented development. It is intended to provide incredibly high-speed internet to regions of the earth with no cabled connections. As of the time of writing this, SpaceX has successfully launched 538 of these small Starlink satellites into a correct orbit and with an incredible launch pace of one every fortnight (thanks to the quick turnaround time of reusable boosters) it is hoped that people could start connecting to this network (through a subscription service) in North America either later this year or by early 2021. This revenue will almost certainly be fully reinvested in transportation services between the Earth, Moon and Mars.

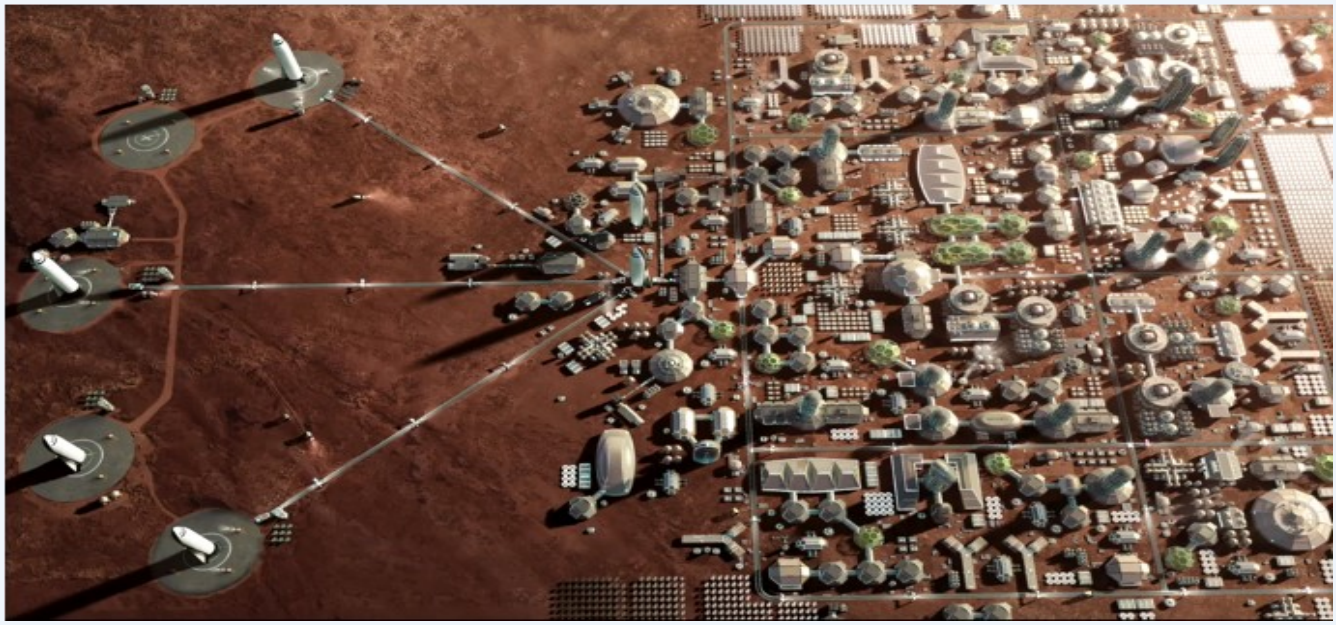
In Musk's aims to send the first people to Mars, SpaceX is now ardently concentrating on the development of Starship and Super Heavy, the fully reusable rocket designed to send up to 100 people at a time to the Moon or Mars. It is a rocket of truly epic proportions with **at least** 37 methane-oxygen Raptor engines. The Starship itself would then have to be refuelled in orbit for the journey to either the Moon or Mars. Since the successful launch of Crew



Dragon to the ISS, development of Starship and Super Heavy has been accelerated. This isn't just one of Musk's whims, but rather a direct response to the deadline of 2021 given by NASA when SpaceX was chosen as one of the private companies developing landers for the Moon. Although NASA have been building their own rocket for years to take astronauts back to the Moon called the SLS (Space Launch System) it has now also chosen 3 private companies (SpaceX, Blue Origin and Dynetics) to develop landers, of which SpaceX and Blue Origin's would be sent on their own rockets Starship and New Glenn respectively[6]. Were SpaceX to be the first of the three to put humans back on the moon in 2024 not only would it be a huge PR boost for the company but it would also prove Starship's promise as a regular-use vehicle to quickly ferry large numbers of colonists, researchers and astronauts to other celestial bodies.

A base on the Moon would not only be a huge achievement for mankind but would also help determine the effects of low gravity on humans, the best building methods and how to make colonies on different planets a worthwhile financial investment.

Eventually Elon Musk sees the Moon as a spaceport on the way to Mars and beyond whilst Mars would become an independent trading entity in the solar system with millions of inhabitants in ever-expanding cities. Whilst these ideas may seem far off, with the current attentions and funds being diverted towards Lunar exploration (and by extension Martian exploration) and the development of a new space station around the Moon called Lunar Gateway, interest in outer space has possibly never been this high since the construction of the ISS. If interest, funding and competition between the growing number of space enterprises continues at this rate I can envisage extremely exciting events in the not so distant future.



References:

[1] Joe Rogan Experience podcast #1425 with SpaceX employee Garret Reisman

[2] https://www.nasa.gov/centers/kennedy/about/information/shuttle_faq.html

[3] https://www.space.com/41936-ariane-5-rocket-aces-100th-launch.html

[4] https://www.ruaviation.com/news/2018/10/3/12074/?h

[5] https://www.spacex.com/human-spaceflight/mars/

[6] https://www.nasa.gov/press-release/nasa-names-companies-to-develop-human-landers-for-artemis-moon-missions

Frequently Asked Science Questions

George Weston

"What is so distinct about the event horizon of a black hole?"

The event horizon of a black hole is the point of no return. Beyond the event horizon, the escape velocity is greater than the speed of light. According to special relativity, information cannot travel faster than the speed of light. Therefore, nothing, not even light, can escape a black hole once it has gone beyond the event horizon.

First ever picture of a black hole's event horizon

"Why is the sky blue?"

Different wavelengths of visible light correspond to different colours. Upon entering the Earth's atmosphere, light collides with nitrogen and oxygen molecules. Light waves with the shortest wavelengths are scattered the most. Blue light is thus scattered the most so the sky appears to be blue.

Violet light actually has the shortest wavelength, but less violet light is emitted by the Sun than blue light. Furthermore, the retina only contains red, green, and blue cone cells so the eye is sensitive to these three wavelengths of light.

"What causes the Earth's tides?"

The Moon's gravitational pull; the Earth exerts a gravitational force on the Moon. By Newton's Third Law, the Moon exerts an equal and opposite force on the Earth. The Moon exerts a greater force on the nearer side of the Earth than the further side of the Earth. This is equivalent to two equal and opposite forces acting on the Earth. These forces are referred to as tidal forces since they cause the Earth's tides. Therefore, the Earth experiences high and low tides. The parts of the Earth in line with the Moon experience high tides; the parts of the Earth at right angles to the Moon experience low tides.

"Why do dogs pant?"

Panting for dogs is a homeostatic response. Dogs pant to cool down. Because of their thick fur, dogs have few sweat glands so they cannot sweat much. Therefore, panting is essential in order to lower the body temperature of dogs.

Bernese Mountain Dog lowering their body temperature

"What is so special about Bitcoin and its blockchain technology?"

Instead of being governed by a central authority, bitcoin is controlled by the community. Miners are responsible for adding new blocks to the blockchain after solving a computational puzzle. The new block records the latest transactions involving bitcoin. Each block connects to the previous block using hashes. This means that one single block cannot be altered in isolation. Therefore, the whole blockchain is immutable and it provides a definitive log of transactions. Every change to the blockchain and the open source code needs to be approved by the majority of computers on the network. Bitcoin's operation and its future are thus in the hands of individuals due to the underlying blockchain technology.

"Are bats blind?"

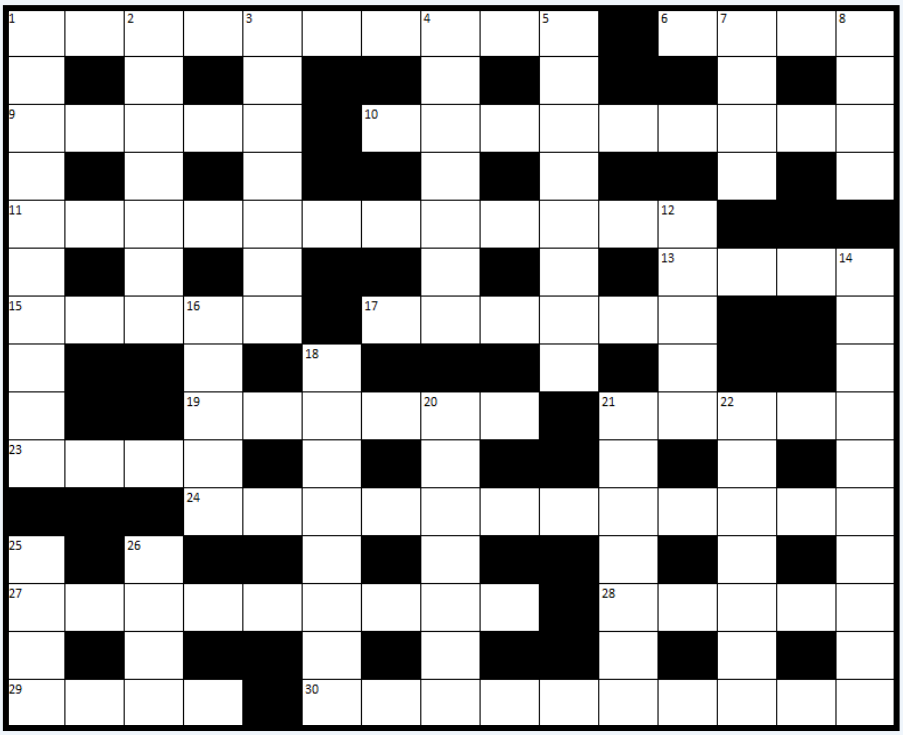
No. Even though bats mostly use echolocation to navigate, they are not actually blind and sometimes use their eyes to hunt. Fruit bats, in fact, have very good eyesight and hunt only using their eyes, not using echolocation at all.

"Why are certain sounds unpleasant?"

After sound waves travel to our ears, the energy is converted into electrical impulses. The auditory cortex processes these impulses. The structure in the brain known as the amygdala plays a key role in processing emotions. Interestingly, the amygdala interacts with the auditory cortex. This heightens our perception of the sound and results in the sound being associated with a particular emotion. That emotion is in this case pain, so the sound seems to be unpleasant.

Cryptic Crossword

Mr Coward



ACROSS

1 Sort of 17 that maps clue on clue (10)

6 Some polypropylene is of poor quality (4)

9 Limited memory after temperature and pressure stamp (5)

10 Scared of getting this collision with waterfowl? (9)

11 Fine about a hundred actors? Cutthroat, but the simplest solution (7,5)

13 Some hear pistol-shots by this lawman (4)

15 How cockney spells missing letter? (5)

17 Identical even odder back swellings (6)

19 Fruitless instruction to male chicken? He knows little! (6)

21 They'll never again resist! (5)

23 So far setter hasn't found this animal (4)

24 Run amok with comical new timepiece (7,5)

27 Messy noontime drinking, left immobile (3-6)

28 Girl taking part in Station has the characteristic trait (5)

29 Start off entirely black, for example (4)

30 Do these ensure consistency in School's location? (10)

DOWN

1 Helping friend… within reason (10)

2 Steal back gear in workbox (4,3)

3 Weak liquor made from asphalt (7)

4 New age colour… and a version of it (4,3)

5 Twice agree to keep apology inside left me immune response (8)

7 Hesitate after no voltage in cell (4)

8 Youth are initially very quiet about bookbinding (4)

12 Wrong again about this adhesive (5)

14 Birds seen in outskirts of park and rest area by arrangement (10)

16 Suffer, being in charge of back hair! (5)

18 Never odd or even clue shows this (8)

20 Ring and cancel Art – there's no time! (7)

21 Placebo dosage, perhaps, one given out of sight (7)

22 Twitching elegantly conceals alternative energy source (7)

25 Symbol associated with Frank Herbert (4)

26 Reactive group back on its own (4)