HOOKE

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Editors' Note

Science is inexorably marching forward. The past year has seen us dig ever-deeper into natural phenomena, almost as far as we have pushed the boundaries in manipulating them. Groundbreaking new immunological cancer treatments have been discovered, the quantum Internet of the future seems to be a real possibility, and fossils are rapidly being unearthed that overhaul what we thought we knew about who we are and where we came from. It appears that there's no shortage of discovery nowadays to excite and humble us.

Yet the uncertainty of post-truth politics hangs over science. Donald Trump's recently published R&D priorities co-opt scientific research into an insular, retrospective vision to "make America great again", describing it as playing a key role in the development of American military superiority, security, prosperity, energy dominance, and health. The environment, of course, is not mentioned. Trump thus sets a dangerous precedent for other countries by lauding "beautiful, clean coal" instead – sidestepping questions about the link between climate change and the devastating Hurricanes Irma and Harvey, from which around 200 people are thought to have been killed. So, as global warming paces onwards, the possibility of not exceeding the 1.5°C increase limit set in the Paris Agreement seems to wane.

UK science is similarly under threat from Brexit. While it would seem fortunate for both sides to maintain a positive working relationship, leaving the EU will inevitably mean that the UK will have to sacrifice some of its power in important EU projects such as Horizon 2020, the European Defence Research Programme, and nuclear R&D. Our future as a global science superpower, alongside so much else, is now cast under the shadow of the unknown Brexit repercussions.

Despite all this anxiety, science insists on relentless progress and innovation - as can be seen within Westminster itself. The previously scattered science societies have now been integrated into one, cross-disciplinary Huxley Society, named after the OW Sir Andrew Huxley. Better still, 2017 marks the 25th anniversary of the magazine. As editors, we knew right from the outset that this issue couldn't disappoint. This edition of Hooke is the longest ever – testament to the magnificent quality and depth of research of all the article submissions and a fitting tribute to mark 25 years of great scientific journalism. Finally, the new seventh floor of the Hooke building is now complete, along with a roof observatory – featured, in fact, on our cover. New heights are still being achieved; hope is not yet unreasonable.

We hope you enjoy reading this edition of Hooke as much we did compiling it.

The Editors

October 2017

Editors: Lorna Bo, Ryan Kang, Navyaa Mathur, Raghav Nayak, Brandon Tang & Hannah Virji

The editors would like to express their immense gratitude to Matthew Bradshaw, Abigail Farr, Charles Ullathorne, and of course all the writers, without whom the publication of this magazine would not have been possible. Submissions for next issue of Hooke are warmly invited: please email hooke.editors@westminster.org.uk for more information.

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Cloning a Mammoth: When or Why?

Tavleen Wasan

If asked to clone a mammoth, would "When?" or "Why?" be the right response?

When I first read this question, it wasn't just the cloning aspect that intrigued me; I felt that 'when or why' raises many interesting questions about the purpose of science. Why do we, as scientists, have an unquenchable thirst to push the limits of our knowledge, even though we may never have practical applications for it? When do we, as scientists, draw the line between doing something because it's useful and doing something just because we can?

Both 'when' and 'why' are very valid responses. 'When' raises many issues about the nature of the experiments and the advances in technology that need to be made before cloning a mammoth becomes a reality. The question in hand is worded such that the cloning of mammoths appears to be a matter of 'when', not 'if', suggesting that the de-extinction of the mammoth is an inevitability, not just a possibility. Scientists then need to work out how long it would take for this process to occur, which would also raise questions about the current technology available, and what advances would need to occur to make this a reality.

De-extinction is not new. Perhaps one of the most famous examples of bringing an extinct species back to life was in 2003, when a Pyrenean Ibex, or bucardo, was born—3 years after the last of its species had died. However, it was far from a success. There were 57 attempts at implanting the embryo containing the bucardo DNA into surrogate mothers, of which 7 became pregnant but only 1 gave birth to a live bucardo. Moreover, this newborn survived less than 10 minutes because of a severe lung defect. So even when we have the technical capability to carry out the process of cloning the mammoth, it will not guarantee instant victory as it is highly unlikely that the first of the cloned mammoths will be a success. This makes the question 'when' even more interesting; it makes it very hard for teams of scientists to say exactly when mammoths will walk the earth again.

The actual definition of a clone is an organism that is completely genetically identical to another. Because it is highly improbable—if not impossible—that scientists will find a completely intact cell of a mammoth with a complete set of chromosomes and undamaged DNA, one could argue that this therefore means that we will never be able to create a clone of a mammoth.

However, gene editing technology will allow us to create an elephant-mammoth hybrid, popularly called a mammophant, and whilst this animal will not be the same as a mammoth, it is as close as we are likely to come within the next few years, and still brings us much closer to having mammoths roam the earth once again. This hybrid can be achieved by using gene editing techniques such as the CRISPR-Cas9 system. This revolutionary technology was inspired by a natural defence mechanism in bacteria to protect them from viruses. A synthetic guide RNA and the endonuclease enzyme Cas9 allow scientists to cut out sections of DNA (and add new sections as well). This technology will allow genes to be inserted into the nucleus of an elephant cell, which, once inserted into an enucleated embryonic cell, will hopefully give rise to an elephant with mammoth features. The genomes of 3 Asian elephants and 2 woolly mammoths have already been sequenced to a high degree of accuracy and coverage by Vincent Lynch, an evolutionary geneticist at the University of Chicago in Illinois, and his team. They found that the main functional genetic differences were those that were related to 'circadian biology, skin and hair development and physiology, lipid metabolism, adipose development and physiology, and temperature sensation'; these adaptations would have enabled mammoths to withstand extreme cold, so if the corresponding sections of elephant DNA were removed and replaced with these genes, it could allow the modified mammoth to live in a similar way to the woolly mammoth (provided that the rest of the long and complicated process is successful).

George Church is a Professor of Genetics at Harvard Medical School, and is currently leading a team that aims to clone a mammoth within 2 years. He has already created elephant embryos that have been genetically modified using CRISPR to have mammoth features such as more subcutaneous fat and hair. His team plan on creating artificial wombs so the embryos can be grown ex vivo, as elephants are rather large to keep in laboratories and are also an endangered species. The creation of an artificial womb on its own would be a great achievement, and would undoubtedly have many benefits unrelated to cloning. According to Womb Transplant UK, as many as 50,000 women in the UK of childbearing age have uterine infertility. The creation of artificial wombs could provide an alternative way for these women to have children of their own, as there are many challenges that scientists need to overcome with uterine transplantation. This also helps with the argument as to why we should clone a mammoth; technology initially developed for the cloning process could be then modified and used for many other purposes. However, developing the artificial womb will take time and therefore delay the overall process. It is possible, however, that scientists would be willing to sacrifice some time and take a holistic view in order to observe ethical standards; some may believe that it could be dangerous for endangered Asian elephants to give birth to a new species that has not yet been studied. Nonetheless, George Church and his team seem to have a pretty definite answer as to 'when'.

Why would we want to clone a mammoth? I think that there are two different ways that one could look at this question. The first would be to study the scientific benefits or drawbacks of having mammoths walk the earth again, and how this would be achieved. The second way, however, would be to step back and look at science as a whole. Why do we do anything in science? Should we do something just because we can, or does there need to be a specific set of reasons why, which are presented before starting? Why have we done certain things in the past? The 'why' aspect of science inevitably leads to much debate. It is one of the very few areas of science in which there isn't a definitive answer – there is no mathematical formula or set of instructions that tells one what to decide.

The landscape of northern Russia is changing rapidly. As this ice melts, it releases greenhouse gases that scientists believe could release 2.5 times the amount that would be released if all the forests in the world were burned down. They believe that mammoths could potentially help to keep these regions cold and slow down this process, by insulating the top layer of ice to keep it at a cooler temperature. Additionally, they would make holes in the ice which allows cold air to come into contact with layers beneath the surface, which again helps to reduce the rate at which ice melts. The revive&restore project also puts forward the idea that by introducing a previously extinct animal back into the wild (not necessarily just the woolly mammoth) their behaviour can show scientists their gene expression which in turn may lead to the development of new drugs and treatments. It is debatable to what extent this justifies cloning a mammoth—this may be a potential advantageous side effect—but in my view it is not one of the major reasons as to why mammoths should be cloned.

One of the reasons why we would want to clone a mammoth is simply because we can. It sounds foolish, yet this is one of the main reasons for many other previous scientific advances. Many would say that the money invested in technology and research could be much better spent on, for example, providing better infrastructure for developing countries, or providing clean water and better sanitation for those living in low-income regions. However, the achievement of cloning a woolly mammoth, one of the most iconic extinct species, would be inspirational for so many, including the wider scientific community. It would mark the beginning of a new era in the field—if a mammoth were to be cloned successfully then it would open up a vast array of new opportunities for potential future experiments. One could compare it to travelling to the moon—what was the purpose of sending man to the moon? I can imagine my grandparents flinching at the thought of $150 billion (in today's money) being used for such a seemingly superfluous mission. Yet it was perhaps the most famous scientific mission to be executed of all time, and 48 years later people still remember it as an amazing achievement. It opened a gateway of discovery into the rest of the solar system, galaxy, and universe. I believe that the cloning of a woolly mammoth has the potential to be (almost) as awe-inspiring. However, the consequences of the two missions would be very different. The moon landing was incredible, but ultimately life on earth continued as normal. But what would happen if we were to suddenly introduce mammoths to earth? The consequences are much harder to predict, but the impacts are likely to affect a lot more of the population on a day-to-day basis.

Scientists in Russia have planned well ahead, having already built a 16km^2 'Pleistocene Park' dedicated solely to providing a habitat for animals that lived in the Pleistocene era. The park currently has bison, ox, moose, horses, and reindeer, and will provide mammoths with a Steppe ecosystem. This will be beneficial to both the mammoths and the local population; the mammoths will have a home similar to that of 10,000 years ago and so are likely to be more comfortable than if they were held elsewhere, and having mammoths wandering around a park will inevitably attract tourists from all over the world. This will improve the local economy as more jobs are likely to be created as a result, and tourists will spend money in the region, which will in turn help the Park to potentially expand, or fund more research into mammoths.

There are, however, a number or ethical concerns that people may have about the welfare of the mammoths themselves. Scientists believe that mammoths were very sociable creatures that lived together in big groups. It is unlikely that many mammoths will be created at any one given time, and so the first mammoths to walk the earth again will be lonely. This will be an unnatural environment for them, and the effects this will have on them are unknown, but may cause distress. Another concern is their natural environment. The earth has changed significantly in the past 10,000 years and even though Pleistocene Park may provide a home as similar to the Steppe tundra as possible, it is unlikely to be as it was millennia ago. And how will mammoths cope with constant human attention, from scientists and tourists alike? Poachers would pose a large threat; it is unfortunate but likely that mammoth tusks will become coveted pieces and this could lead to the killing of mammoths that scientists worked so hard to bring back to life. When will mammoths be released from captivity, if ever? And if they are free in the wild, would they be dangerous to people? These questions need to be considered, but can only be truly answered once mammoths are actually risen from extinction; it is very hard to predict the long-term effects of mammoths when we haven't yet got the technology to actually create one.

In an age where scientific advances rely very heavily on funding by both the government and private parties, 'when' and 'why' are both questions that financial backers will want to ask. 'When' is important because donors inevitably want to invest in the team that will be successful first; this will give them the most publicity and reward in return. 'Why' will be asked because if a mammoth is created yet has no purpose on Earth, the hype around it will soon die down and large companies will only have short-lived fame. However, it is highly unlikely that any technology created, for example artificial wombs, will become redundant after the experiments are completed. Investors will want concrete responses for all their questions, yet as we have seen, there are few definite answers.

I think that 'when' and 'why' are both right responses to this question; one should never be asked without the other also being asked. Scientists yearn to stretch the boundaries of their understanding, and this can only be achieved by running with ideas and looking forward to when goals can be reached. 'Why' can often hinder progress, highlighting the importance of 'when'. However, when I first read the question, my response was 'why'. I think that people have a responsibility to hold the interests of future generations at heart; the immediate, short-term and long-term impacts of all undertakings have to be taken seriously into account. Science teaches us to question and challenge ideas, and this inevitably leads us to ask more questions and develop new concepts. As George Bernard Shaw famously said, 'Science never solves a problem without creating ten more.'

The Significance of the Conscious Mind in Quantum Physics

Hannah Virji

"I regard consciousness as fundamental. I regard matter as derivative from consciousness. We cannot get behind consciousness. Everything that we talk about, everything that we regard as existing, postulates consciousness." — Max Planck

In December 1900, Max Planck succeeded in deriving a formula originally designed to relate the energy of black body radiation to its frequency. In doing so, he kick-started the most important scientific revolution of the 20th century: the development of quantum theory. Planck's paper on black body radiation and the subsequent equations he derived only worked after he introduced the idea of "quanta": packets of energy (now known as photons). The idea that light was not an infinitely divisible wave but instead came in discrete quantities was not accepted by either the rest of the scientific community or Planck himself at first. However, Planck's theory of quanta explained several phenomena which had been previously inexplicable. Arguably most significant of these was Einstein's explanation of the photoelectric effect. The photoelectric effect is observed when a high frequency stream of light is directed at the surface of a metal. The delocalised electrons within the surface of the metal can only escape when they gain enough energy from the light to overcome the work function (which is specific to the metal).

The results produced by Einstein's experiment provides evidence for Planck's quantum theory. For example, as there is a specific threshold frequency of light, below which no electrons will be able to escape from the metal, this shows that light cannot be travelling in waves, as a wave of very low frequency would still eventually cause the electrons to build up enough energy to escape. Another key piece of evidence for quantum theory is that the maximum kinetic energy of the electrons is seen to be solely proportional to frequency of the light, confirmed by the quantum equation of $KEmax = hf - \text{work function}$. However in classical wave theory, the maximum kinetic energy of the photoelectrons would also be determined by the amplitude of the light wave, which is not the case in this experiment.

Both Einstein and Planck won Nobel Prizes in Physics for their discoveries, yet light's identity as solely a particle is not entirely clear. For example, in Young's double slits experiment, which shines light through two very thin slits onto a screen, interference patterns of light can be seen. As only waves can interfere, this experiment (performed first in 1801) was taken as proof that light travels in waves. Richard Feynman developed a thought experiment in 1961 to further consider this apparent disparity. If, rather than a beam of light, individual electrons were fired through double slits onto an electron-detecting screen (such as photographic paper) what would happen? The logical answer given to this question is that a random spattering of dots will appear on the paper. However, in 1989 this exact experiment was performed in Japan, and the results were individual dots as predicted, yet these dots together formed the dark-light fringe pattern characteristic of the classic double slit experiment with light. The experiment was conducted with the electrons travelling at such a low speed that no two electrons were passing through the slits at the same time. This ensured that there was no interaction between any two electrons, and so each individual electron apparently "knew" independently which slit to travel through and where to land on the paper to fit with the fringe pattern. This confusing result led to physicists creating the idea of 'wave-particle duality' - describing all particles, such as electrons, as having both wave and particle nature.

The core concept of quantum mechanics and the wave-particle duality is based around the wave function. This function enables us to describe the probability of finding an electron within a particular place in space and time. The wave function is a complex mathematical function involving both imaginary and real numbers, the values of position of the particle in space (for example) and time. A wave function can be used to determine several physical properties of a particle, such as position, energy or momentum, by adapting the values used in the equation. When the wave function is squared, it is possible to find the probability of a particle being located at any point by seeing the value of that point on the resulting wave. As it is seemingly possible for any particle to take any one of the paths available, we cannot determine exactly where the particle will be. Therefore, we are forced to look at how likely it is that a particle will be doing any one thing at a moment in time, rather than being able to accurately predict where it would be. This random nature of particles is different to events which are perceived as "random" in everyday life. Take the classic example of rolling a dice. Although to an observer it may seem as though it were impossible to accurately predict which side the dice will land on, when considering all the external factors such as the movement of air around the dice, the force it is thrown with etc., one could actually predict how the dice will move and land. This is not the case in quantum theory though, where the nature of particles is inherently unpredictable - an idea which is integral to the entire theory. Thus, there can be no further certainty than probability determination.

Most developments in physics for centuries have been centred around simplifying and explaining observations of the world around us, and producing equations and theories which allow physicists to accurately and reliably predict what will happen in many given situations. When quantum theory arrived and disrupted this, by seemingly suggesting that no particle could have its physical properties completely accurately predicted any longer, understandably many physicists disliked the implications of accepting the theory.

One other particular aspect of quantum theory has provoked much debate amongst both physicists and philosophers. The Copenhagen Interpretation was developed by a number of physicists: Neils Bohr, Weiner Heisenberg, and Erwin Schrodinger. The key idea within the Copenhagen Interpretation is that a quantum particle has the potential to be in all its possible forms and to possess all its possible properties until these properties have been measured. In *Physics and Philosophy*, Heisenberg compares these undecided states to Aristotle's concept of *dunamis,* or *potentia* - an object's *"capacity to be in a different and more completed state"*. This idea is brought up by Aristotle in *Metaphysics*, and is crucial to the role of the conscious observer in quantum physics.

The existence of the wave function (as mentioned earlier) allows physicists to determine the probability of various properties of a particle existing at any one point in space and time, through taking the complex square of the function. In London and Bauer's writings from 1939, they were the first to suggest that the "objective" world outside the human observer can be directly altered through the understanding of a measurement of this objective world. This is indicated mathematically by the collapse of the wave function, reducing all the possible probabilities of a particle's location/properties to a single fixed point in time and space (see below Fig. 1 and Fig. 2).

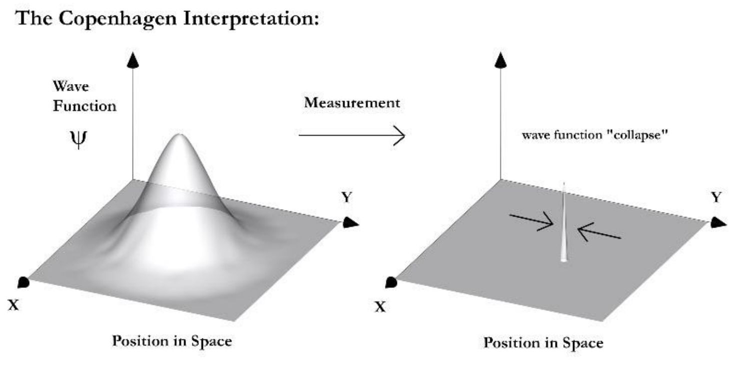


Fig. 1.

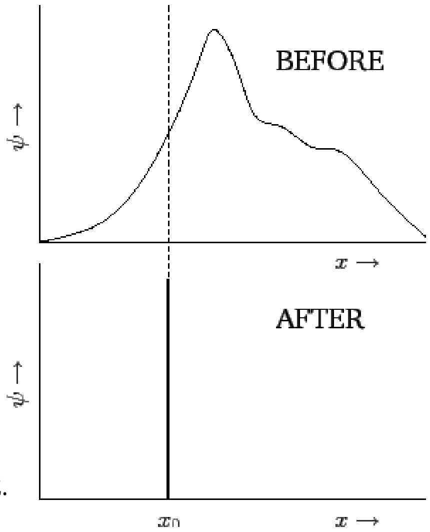


Fig. 2.

A major criticism still remains that the act of measurement through a physical recorder may in some way disturb the relationship between particles or the area around the particle, thus causing the wave function collapse. However, this criticism can be dismissed as a result of an experiment conducted at the Weizmann Institute of Science, Israel in 1998. When firing a stream of electrons at two tiny gaps, it was observed that the particles interfere whilst passing through the gaps. A small electronic detector which recorded the electrons as they passed was placed near the gaps, designed so that it did not affect the current at all. However, despite the detector's complete lack of involvement in the experiment, when the level of observance was increased (by altering the electrical conductivity of the detector) the amount of interference between electrons decreased, and vice versa. This shows that the act of observance has a direct effect on the actions of particles.

Experiments such as this have shown that whether or not there is a recorder at the experiment determines the actions of the particles. However, an automatic recorder is different to a conscious human observer. A mechanical recorder will be part of the quantum system, and thus its measurements will be uncertain until another mechanical recorder has observed it, leading to an endless chain of measurements.

It has been suggested (again by London and Bauer) that a conscious awareness of the state of the particle observed and what this observation of state means is needed to alter the particle's properties. London and Bauer argue that the human observer's mind is something separate within quantum mechanics to a simple recorder and thus is able to trigger a wave function collapse. The idea that the conscious mind is separated from a mechanical recording instrument is generally held. The main difference is the elusive, seemingly indefinable "consciousness" - the "mind" separate from the matter. This idea is instinctive within almost all people, and was shown to hold within a quantum theory context as well, in the thought experiment known as 'Wigner's Friend'. A friend is placed in an enclosed room, and undergoes the same experiment as described in Schrödinger's Cat (see details below) but with a simple signal to indicate whether decay has occurred instead of a gun. When we then go into the room and ask the friend when and whether she saw decay or not, she will answer confidently. Her conscious mind is clearly different from the quantum system, as she had a certain answer before we asked her. Consciousness in the human mind is therefore the only certain idea within quantum theory.

Despite the logical difference between consciousness and mechanical observance, and the apparent experimental data showing that observance can alter the properties of particles by seemingly collapsing the wave function (although this idea may simply be a manifestation of the gaps in our understanding of quantum theory), many physicists do not agree with the importance placed on the influence of the human mind.

The infamous 'Schrödinger's Cat' thought-experiment (also shown in Fig. 3) illustrates one criticism of the Copenhagen Interpretation:

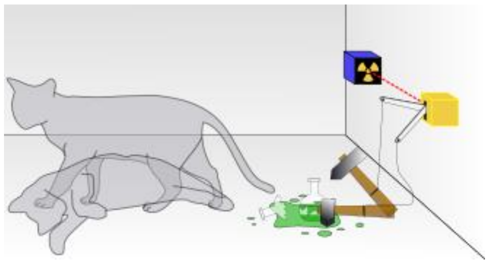


Fig. 3. Schrodinger's Cat thought experiment

"A cat is penned up in a steel chamber, along with the following device (which must be secured against direct interference by the cat): in a Geiger counter, there is a tiny bit of radioactive substance, so small, that perhaps in the course of the hour one of the atoms decays, but also, with equal probability, perhaps none; if it happens, the counter tube discharges and through a relay releases a hammer that shatters a small flask of hydrocyanic acid. If one has left this entire system to itself for an hour, one would say that the cat still lives if meanwhile no atom has decayed. The first atomic decay would have poisoned it. The psi-function of the entire system would express this by having in it the living and dead cat (pardon the expression) mixed or smeared out in equal parts."

If the Copenhagen Interpretation's assumptions about the unpredictable indefinite qualities of particles are applied on a macroscopic scale to everyday objects such as a cat, this seems to directly oppose our own logic. Until the observer opens the box and looks at the cat, it is apparently both dead and alive at the same time, according to quantum theory. And yet, ask anybody, physicist or philosopher, whether a cat can be both alive and dead simultaneously and the instinctive answer will be no. When literally applying the Copenhagen Interpretation, it seems completely unrealistic and counterintuitive to our observations of the world in our scale. Surely the cat is definitely either alive or dead, and *we* just do not know until we open the box?

This argument suggests that the act of conscious observance is not transformative for the thing being observed (the electron, the cat) but rather for the observer - the act gives us the knowledge of the true state of the object and thus changes our perception, leaving the objective properties of the object unchanged. This idea still does not, however, explain any way to incorporate the collapse of the wave function in the mathematics, as it is still not technically accounted for in any equations. The consciousness is important but cannot change the properties of the particle, rather changing its own opinion.

Other, apparently less plausible, interpretations include for example Everett's 'Many Worlds' Interpretation, which suggests that upon the point of observance many parallel universes are generated, each containing the object under observance in a different state which was probable before the observance. This accounts for our view that the object existed in a constant state all along, as we have only ever experienced a universe in which it has existed like this. Despite the nature of this argument allowing for the denial of a collapse of the wave function, as all the probabilities still exist, the existence of an infinite number of parallel universes is almost impossible to prove experimentally. This interpretation is therefore not particularly useful when advancing quantum theory and its applications to everyday life.

Fundamentally, the problem of coherence still presents itself as the main obstacle to the complete acceptance of the Copenhagen Interpretation. If there is coherence, then the particle or object under observation is separate from all its surroundings, thus still in a state of superpositions (all options are still possible). However, in practice there will always be interactions with other influence, no matter how tiny. For example, the cat's movements will affect the movement of the box, or its body will exert a gravitational pull on another object within the box. All these interactions disrupt the superposition and cause decoherence, which will immediately cause the cat to be firmly either alive or dead. Whilst this decoherence theory does not disprove any of the above ideas, it does suggest that in real life, these are not practical ideas to apply.

The importance of human consciousness has been acknowledged within philosophy for thousands of years, and yet the introduction of the mind as a powerful force in physics is relatively new. The above theories about the role of human observation have been applied to wide-ranging arguments, including the proof of God's existence. For example, if it is unrealistic for humans (as we are physically bound by quantum laws) to be the ones who determine the nature of every particle in the universe, yet all things appear to have definite properties in everyday life, the suggestion is that there must be a universal mind which observes and thus defines everything. With more advanced experiments in the future, the currently ambiguous role of the conscious mind in quantum physics will hopefully become clearer in the future.

Let's Get It On: Music's Potential Role in Evolution

Tomás Pfeffer

Professor Steven Pinker of Harvard University, a renowned evolutionary psychologist, linguist and cognitive scientist, famously argued that: 'as far as biological cause and effect are concerned, music is useless. It shows no signs of design for attaining a goal such as long life, grand-children, or accurate perception and prediction of the world. Compared with language, vision, social reasoning, and physical know-how, music could vanish from our species and the rest of our lifestyle would be virtually unchanged'. However, it is my belief that this view of music as 'auditory cheesecake', a pleasantry with no real, significant value, is incorrect, taking an overly narrow view of music as a form of entertainment, rather than a feature of true evolutionary value, preferring to concentrate on the inherent lack of 'survival value' than the potential reproductive value of music. Geoffrey Miller, who has written various papers on the subject, cites a very interesting example of a simple counterargument, which quickly demonstrates a gaping fault in Pinker's argument: dying at 27, Jimi Hendrix's music career was, despite its artistic excellence, evidently not in any way helpful in a 'survival' sense. However, there is no question that what it did give him was a very distinct reproductive advantage. Hendrix had hundreds of 'sexual liaisons' with groupies and fathered three children in three different countries. The musical skill Hendrix possessed, in combination with the musical appreciation held by his millions of fans, was a clear recipe for sexual success, and from an evolutionary perspective, it demonstrates how musical competence as a genetic property could have spread so quickly. Unfortunately, Hendrix, although not the ideal poster-boy for safe-sex, did not manage to actually use this reproductive advantage to the fullest (I'm sure he had fun though). The question is, how can this serve as an example to help us further understand music as a fundamentally sexual catalyst, and beyond that, as an advantageous feature of the rituals of human reproduction? And not in the last 50 years, but potentially in the last 500,000 years, the time scale during which the human voice has been developed enough to potentially have allowed for singing and, of course, more basic rhythmic instrumentation.

At a glance, the very fact that the innate ability to appreciate and understand music is not only universally present in humans but more to the point uniquely human seems to suggest that there is some sort of evolutionary factor in play. Furthermore, the fact that music is found as a usually key element of practically every culture in the world suggests that it is important enough to rival other universal human traits, of which language is the most obvious. Music could potentially be even more 'useful' than language in a reproductive context, as unlike language, music is so deeply linked to the physical as well as the cognitive. Here, the 'physical' refers to the link between music and movement, which has been described by many as 'inextricable' by academics such as John Blacking, a field-defining ethnomusicologist, who felt that the relation between music and movement could not be overlooked when attempting to define 'music', especially when acknowledging that for almost all of human history and across almost every culture in the world, the idea of 'music' involves movement (whether dancing, playing instruments or just tapping, clapping or swaying to the rhythm) just as much as sound. Blacking goes on to state that 'the almost universal distribution of musical competence in African societies suggested that musical ability [is] a general characteristic of the human species rather than a rare talent'. One possible explanation for the role of music in a reproductive context is that of assessing reproductive fitness. Like many animals, a key part of the rituals of reproduction involves a degree of assessment of criteria, almost always largely aesthetic. However, as a species, it is logical to conclude that humans, being far more cognitively developed than any other, must also include a degree of cognitive assessment, as intelligence is hugely useful to survival. Much as the processing required to manage complex language is an indication of incredible cerebral complexity and thus a genetic advantage, music, both in its 'understanding' and creation, requires an extraordinary degree of cognitive capacity. This is something which scientists have begun to understand more as more advanced brain imaging techniques develop, putting to rest the traditionally held idea of music being processed in only one area of the brain. The reality is that processing music actually requires many differing components of the brain, which is unsurprising, considering for example that music can have extremely profound relationships with not only emotions but memory as well. Emotional effects are not the only part of the processing of music, however. When we consider the subtle components that make up the 'sound' part of music such as rhythm or tone, it would not be outlandish to propose that, in an evolutionary context, the ability to understand music could have been an easy way to assess the cognitive fitness of a potential mate. Of course, there is still the 'movement' side of music to consider, or more specifically, the motor skills required to process rhythm and tone into dance, as well as those for signalling physical strength, endurance and motor coordination to a potential mate. This signalling of motor skills is taken a step further by the fine manipulation of musical instruments, which have been around for at least 40,000 years (instruments tend to be made of perishable materials so, although no instrument older than 40,000 years old has been found, they could have feasibly have been around for much longer). In short, when assessing a potential human mate, three main factors of assessment tend to dominate: not just aesthetics but also motor skills and, uniquely for humans, cognitive ability. Music, unlike verbal communication, which is comparatively limited in its role as an assessment of reproductive fitness, can offer all three.

From a social perspective, the role of music culturally is one of social cohesion, which in turn is a catalyst itself for sexual reproduction, as it was common in many tribal cultures for the young to be gathered by musical activity, therefore providing an efficient way to weed a potential mate out of a crowd of other possibilities. This has remained true even to this day, where most social interaction still revolves around music. This idea of cohesion does not only have to be useful for reproduction but also, going against Pinker's view, for survival, as music helps promote an identity and therefore social closeness in a tribe. Music also has the effect, it seems, to 'reduce the psychological distance between singer and listener'. This is seen to great effect in maternal singing, where the emotional ties between mother and infant are reinforced, but even more obviously, as a part of courtship rituals. Putting his hypothesis of music as a courtship display to 'attract females' to the test, Geoffrey Miller analysed the trends in output of recorded material from prominent rock, jazz and classical musicians, and perhaps unsurprisingly found that the average male musician's peak output was during the 'age of his peak mating effort'. Miller sees music performance as a 'sexual selection arms race' which directly takes advantage of music's aesthetic and emotional qualities to produce a sexual advantage amongst other competing members of a group, be it a primitive tribe tens of thousands of years ago, Glastonbury or the MMC. This sexual advantage, as discussed, is not just the listener having a 'good feeling' or making an arbitrary decision to favour one potential mate over the other based on what Pinker would refer to as 'auditory cheesecake', but rather, a potentially quantifiable assessment of cognitive ability, motor skills and social integration, all essential components of the evolutionary history of humans.

The Influence of CO_2 Fertilisation on World Vegetation

Lorna Bo

Rising levels of atmospheric CO_2 are impacting world vegetation – but is that a bad thing?

For ten thousand years before the industrial revolution, the concentration of atmospheric CO_2 remained at an almost constant 280ppm. Now, just 250 years later, it has reached 400ppm, and is increasing at a current rate of around 2ppm per year – due to accelerate, of course, as more fossil fuels are burned, more forests are cut down and more people are born. The indisputable empirical evidence correlating anthropogenic CO_2 emissions with climate change have led us to associate this simple molecule with apocalyptic images of black fumes being pumped into the sky as sea levels rise, global temperatures climb and humanity inches to its demise. Its negative implications are undeniable. Yet this inextricable correlation with global warming means we often fail to consider the effects of rising atmospheric CO_2 'in their own right'. As all GCSE Biology students should know, increasing the atmospheric concentration of CO_2 increases the rate of photosynthesis and plant growth. This effect, on a global scale, has led to a phenomenon known as 'CO_2 fertilisation', the disseminating implications of which are spatially and temporally diverse, and, most importantly, ethically uncertain. Only by picking them apart will we be able to make accurate climate predictions essential for the preservation of our future.

How rising levels of CO_2 affect photosynthesis

It may be useful to first tackle how plants fix CO_2 from the atmosphere. The process of photosynthesis cannot be homogenised across all types of plant, and can be divided into three metabolic pathways: C3, C4 and CAM (crassulacean acid metabolism, a subset of C4). C3 plants – which represent more than 90% of Earth's plant biomass– and their method of carbon fixation involves only the Calvin cycle, in which CO_2 and ribulose biphosphate (a 5-carbon sugar) is converted into 3-phosphoglycerate (a 3-carbon compound, hence the name 'C3') using the enzyme ribulose bisphosphate carboxylase (also known as rubisco). However, rubisco has a greater affinity for oxygen than it does for CO_2, meaning that a process called photorespiration can reverse CO_2 assimilation by converting the 3-phosphoglycerate back into CO_2 and ribulose biphosphate. This issue is addressed by C4 plants, which still use rubisco and the Calvin cycle, but have adapted to primarily fix CO_2 in mesophyll cells as the 4-C organic acid malate by an enzyme with no affinity for O_2. The malate is then shuttled to bundle-sheath cells, where it is oxidised to a 3-C organic acid, producing one molecule of CO_2 for every malate molecule. It is this CO_2 that is then taken up and used in the Calvin cycle. This process therefore reduces photorespiration, although at the cost of more ATP due to fixing carbon twice. While C4 plants separate light-dependent reaction and carbon fixation spatially (they occur in different cells), CAM plants separate them temporally - at night, CO_2 is fixed as an organic acid, and during the day, the light-dependent reactions that supply the ATP and NADPH necessary for the Calvin cycle occur. This allows CAM plants the greatest water efficacy, giving them a great advantage in water-limited environments, as the stomata are only open at night, when humidity is higher and temperatures are cooler (this lowers the gradient driving water loss from leaves).

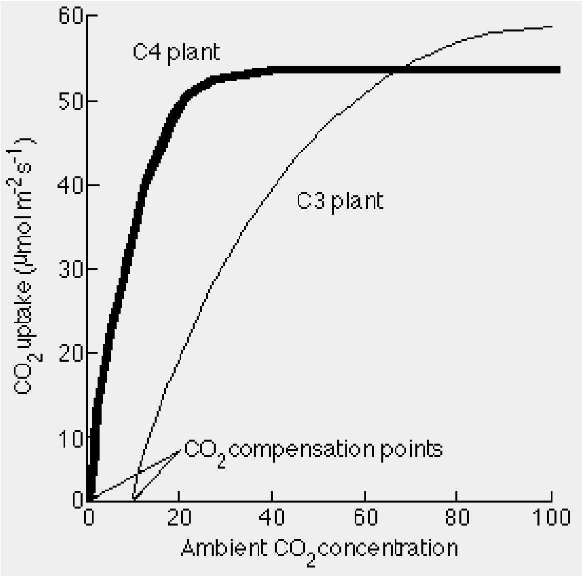


Fig. 1. Net photosynthetic curves for C3 and C4 species of plant. At high levels of CO2, the C3 plant has greater photosynthetic efficacy due to the extra ATP cost required by the C4 plant.

But how does an elevated CO_2 concentration affect these pathways? If we first consider the rubisco kinetics of C3 plants, an elevated partial pressure of CO_2 will 'stimulate the carboxylation and suppress the oxygenation [of rubisco]', increasing the efficacy of photosynthesis by reducing the negative effects of photorespiration on plant growth. In C4 and CAM plants that are already adapted to mitigate the effects of this process, the benefit of increased CO_2 is therefore lower (see Fig. 1), possibly allowing C3 plants to outcompete troublesome C4 weeds including nutgrass, crabgrass, and barnyard. Yet another benefit of increased CO_2 for C3 plants is that it reduces the time needed for C3 plants to keep their stomata open for CO_2 to enter, reducing the negative side effect of water loss and increasing stomatal conductance (the rate of the entry/exit of CO_2 through the stomata of a leaf).

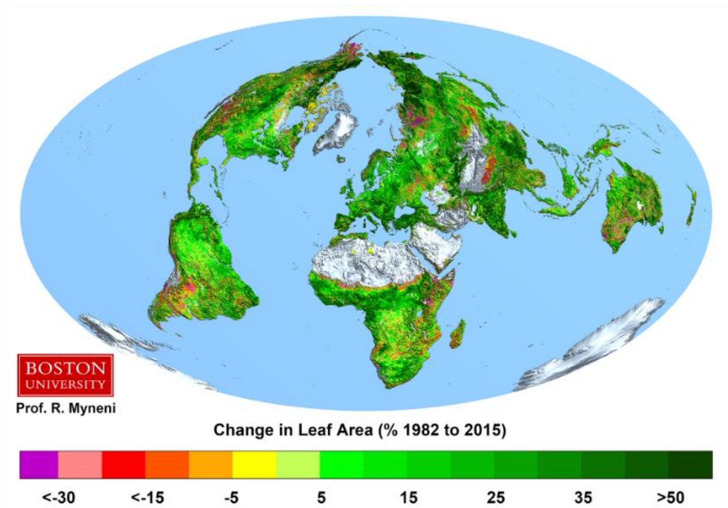


Fig. 2. The vast majority of the Earth's surface has increased its leaf area, up to 50% in some areas.

Global greening

It is these two factors that are thought to cause 'CO_2 fertilisation', which plays a role in the 'greening of the globe over recent decades' (see Fig. 2) as observed by satellite. Using a technique called 'fingerprinting' alongside complex ecosystem models, it is estimated that 70% of this growth is due to rising CO_2, followed by 'nitrogen deposition (9%), climate change (8%) and land cover change (LCC) (4%)'. However, in a rebuttal to climate change 'lukewarmer' Matt Ridley, Professor Ranga Myneni et al. claimed that CO_2 fertilisation may not have as large an impact on global greening as other factors. In their studies, it was found that around 42% of greening can be attributed to 'climactic changes in temperature, precipitation and solar radiation' and the rest to anthropogenic factors including CO_2 fertilisation.

The ability of C3 plants to conserve water has also allowed them to expand into semi-arid areas, with some even worrying that they will outcompete the C4 plants established there and decrease biodiversity (although Professor Richard Allan, in the aforementioned rebuttal, stated that the greening of the Sahara Desert is more related to a 'northward shift in the rainy belt linked to rising CO_2 concentrations and also a recovery from drought in the 1980s, which has been linked with aerosol particle pollution').

Effect on crop yield

Given the clear role of CO_2 fertilisation in global greening, is it possible that an increase in agricultural activity brought on by elevated CO_2 levels could mitigate the decrease in agricultural activity caused by climate change stresses such as higher temperature and changes in soil moisture? Perhaps the most conclusive evidence of this is provided by Free Air Enrichment Experiments (FACE), an established method for studying how ecosystems respond to increased CO_2 concentrations expected in the future. It methodology involves releasing CO_2 into the air around an area of ecosystem or crop under study, improving significantly on lab work or greenhouse experiments, where other factors such as plant competition are not accounted for. Yet from a meta-analysis performed in 2004, these experiments have shown that there is a large heterogeneity in how CO_2 levels affect different plant species in different areas of the world, with increased CO_2 levels decreasing the rate of photosynthesis in some plants. Crop yields showed 'overall smaller increases than were expected based on earlier enclosure studies'. The increase in production that correlated with the increase in CO_2 levels also showed diminishing returns. For example, in open-top chambers of wheat, there was an increased crop yield of 27% upon elevation of CO_2 from 259 to 534 ppm, but only a further 3% increase was observed when comparing plants grown at 649 to 534ppm.

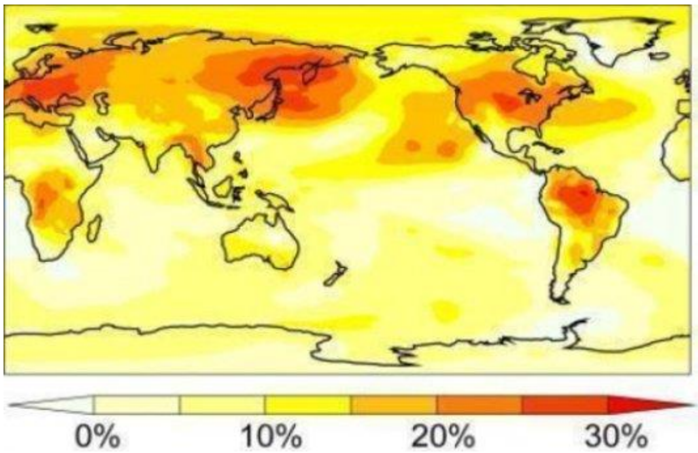


Fig. 3. Shows percentage of land warming due to the effect of elevated CO_2 levels on plants. Dark orange/red areas in North American and eastern Asia are affected the

Effects on global warming

So, the increase in agriculture associated with elevated CO_2 falls short of expectations. Will this also apply to the expected ameliorating effects of more plants on global warming, however? Global greening would allow vegetation to improve its efficacy as a terrestrial sink, a concept which centres around plants taking CO_2 from the atmosphere through photosynthesis, retaining it within the plant body and preserving some of it in the soil when it dies. The IPCC (Intergovernmental Panel on Climate Change) itself reported that in more than two thirds of experiments, there is an 'increased net primary productivity (NPP) [the rate at which an ecosystem stores carbon as biomass] of about 20 to 25% at double CO_2 from pre-industrial concentrations'. This fits with historical trends that can be traced back to the Atlantic Holocene period around seven thousand years ago, in which 'modelling studies suggest that CO_2 fertilisation in response to increasing atmospheric CO2 concentration contributed to a substantially increased terrestrial carbon storage (>100 PgC)'.

Yet this negative feedback-driven moderation of the progression of global warming cannot be relied upon. Carbon absorbed by trees is dynamic, and moves between the atmosphere and the tree in a continuous 'carbon cycle'. The increased absorption of CO_2 from the atmosphere is, if not completely, partly offset by increased plant respiration, and increased respiration of microbes that decompose dead plant matter.

In fact, it has been found that the effects of increased levels of CO_2 on plants can exacerbate global warming (see Fig. 3), in addition to its more infamous effect as a greenhouse gas. As aforementioned, increased CO_2 levels cause stomata to shrink so less water is lost. Yet this also means that less evapotranspiration occurs, a process which transfers heat from the surface of the plant to the atmosphere through the evaporation of water, thereby cooling the plant and its surroundings. Carnegie scientist Long Cao says that this reduced flux of surface latent heat 'would cause significant warming even if carbon dioxide were not a greenhouse gas.' In this model, the effects of evapotranspiration account for 16% of warming of the land surface across the globe, climbing up to 25% in regions such as North American and eastern Asia.

The same model predicts that this reduction in evapotranspiration would leave more water at the land surface, since more water from precipitation would bypass this 'air-conditioning' system and instead flow directly into rivers and oceans, to a greater degree than had been predicted in earlier models. This 'physiological forcing' has been already observed by measuring continental runoff over the twentieth century.

Biochemical effects

Increased CO_2 levels may also affect the chemical reactions within plants themselves, perhaps affecting competition, disease resistance, or predator resistance. Soy beans, for example, become more attractive to Japanese beetles when grown in conditions with a CO_2 concentration of 550ppm compared with their counterparts grown in ambient 370ppm. Usually when these beetles eat the leaves, soybeans produce a hormone, jasmonic acid, that initiates a chain of chemical reactions leading to the production of a protease inhibitor, which, when ingested by the insect, inhibits their ability to digest the leaves. It was found that 'elevated CO_2 down-regulated the expression of *lox* and *acc* synthase, which are the genes that code for the crucial enzymes in the pathway of [jasmonic acid and ethylene]'. Zavala, the presenter of the study, suggested that this phenomenon of predatory insects exploiting lowered resistance could apply to at least 50% of crops predicted to benefit from increased CO_2 levels.

CO_2 acclimation

Although models predict that plants growth can increase by up to 76% if atmospheric CO_2 is doubled, this is only the case if nothing else is a limiting factor. Plants need water, sunlight, and nutrients (especially nitrogen and phosphorus) to grow, not just CO_2. If only the level of CO_2 is increased, there will be a threshold at which point the concentration of CO_2 ceases to be the limiting factor, and another requirement for growth becomes the dominant constraint – for example, water. Rainwater is not sufficient for the needs of larger plants, and aquifers have started to run out. Intense storms caused by CO_2-induced climate change cannot be relied upon either, as when rain falls quickly, it builds up above the soil and floods, causing damage to crops. This water then floods into rivers and oceans, carrying soil and fertiliser with it. Other extreme weather such as drought and extreme temperatures would only be detrimental to plant growth.

It is nutrient limitation, however, that is thought to be the primary cause of CO_2 acclimation, this limiting nutrient being nitrogen in temperate and boreal ecosystems, and phosphorus in the tropics. Experiments on grasses suggest that nitrogen depletion becomes a significant constraint on plant growth as CO_2 levels rise. One meta-analysis also showed that elevated CO_2 levels led to protein concentrations in wheat, rice, barley, and potato tubers to decrease by 5-14%. Decreases in iron and zinc have also been seen in a study by Professor Samuel Myers of Harvard University, who has said that with around two billion people already suffering from dietary deficiencies, a lowering of these nutrients could pose a public health threat. This lack of nitrogen is often associated with long-term CO_2 acclimation, also known as down regulation (although the basis of this relationship remains unknown), which is often seen in agricultural species, and is characterised by reduced rates of photosynthesis due to decreasing activity of rubisco (perhaps acting as a nitrogen sink), accompanied by an increased carbohydrate content of leaves, which in turn inhibits photosynthesis. For example, soybeans grown at a CO_2 concentration of 720ppm initially exhibited photosynthetic rates 50% greater than their counterparts grown at 360ppm. Yet after acclimation, this decreased to 30%. It is only when the 'nitrogen supply keeps pace with the relative growth rate of the plants' that photosynthetic acclimation does not occur, as was proven in a 1998 study. Artificially increased nitrogen levels would require the increased production of fertilisers made from natural gas, a limited resource also in demand for electricity and heating. The benefits of increased CO_2 levels therefore seem restricted to plants that have other means of supplying nitrogen, such as legumes with their symbiotic nitrogen-fixing bacteria.

Conclusion

Although increased CO_2 levels may seem to have a positive impact on vegetation, ultimately, it is indeed a 'bad thing'. It does not necessarily equate to better agriculture and the benefit of the increased uptake of terrestrial carbon sinks does not come close to outweighing the effects of CO_2 as a greenhouse gas (extreme weather, sea level rise, ocean acidification, etc.). In fact, the extent of its impact on plant growth is inherently limited - despite the short-term increases in growth and CO_2 assimilation, CO_2 acclimation is inevitable in the long term. Thanks to the media, CO_2 emission has become little more than a metonym for global warming, and the nuances associated with its superficially positive effects are swept under the rug. This, however, only strengthens the recently growing cries of climate change denialists who can claim, because of this lack of coverage, that they are being ignored. Their rise, catalysed by political events such as Trump's election, poses a threat to climate change research, reflective, ironically, of the threat increased CO_2 emission poses to humanity.

The Origins of Alchemy

James Stirling & Rock Bell

The Beginning of Alchemy

It is impossible to pinpoint an exact date for the "beginning" of alchemy unless one clearly defines what alchemy is. The Oxford Dictionary defines alchemy as "the medieval forerunner of chemistry, concerned with the transmutation of matter, in particular with attempts to convert base metals into gold or find a universal elixir." This basic definition is very vague regarding the exact timescale that "medieval" refers to. However, it is our opinion that the "alchemy" (in the form of metallurgy) which preceded the medieval era is far more closely connected to the medieval alchemy which followed than we are led to believe, especially regarding what motivated the alchemists themselves. Early metallurgy, whilst not actually alchemy, was what medieval alchemy and hence modern chemistry eventually evolved from and so must be investigated before alchemy itself can be analysed, especially early alchemy.

However, this is hardly surprising as there wasn't really very much in the way of "metallurgy", compared to Alchemy or modern Chemistry at least. This is because in this case metallurgy refers to the discovery and use of basic metals such as gold and the formation of a few simple alloys like bronze, from copper and tin, and other more advanced metals such as steel. We know that gold had been "discovered" by humans as early as 40,000 BC due to findings of golden flakes in Paleolithic caves in Spain. By 3,500 BC gold was valuable in Egypt - "one piece of gold is equal to two and a half parts of silver" - and was a symbol of prestige, immortality and wealth in most early civilisations due to parallels being drawn between its non-corrosive nature and immortality on top of its shiny and aesthetically pleasing appearance. The Roman Empire is an example of an ancient empire renowned for their extensive coinage in both gold and silver, but it is important to realise how significant gold was even millennia before this to understand why such impetus was given to finding a method of transmuting less valuable elements, like lead, into gold all throughout alchemy's history. Even before any of the great ancient empires such as Egypt and Sumer were formed and began assigning monetary value to everything, certain materials like gold, silver or gemstones had a greater value than other seemingly similar materials like lead.

A Gold "Mycenaean brooch found in the 2nd millennium BCE" shows clear evidence of skilled metalworking. The brooch itself looks like it was very valuable and potentially a status symbol at the time, mostly due to the Gold that it is made of.

Early Metallurgical Advances

Before the period which we have now determined should be referred to as alchemy (around the 5th century B.C. onwards is a rough approximation, for reasons which will be discussed later) began, there were few advances. But the advances which did take place were often major and while quite basic, these were the vital foundations upon which alchemy was later built. An example of this is the discovery of bronze and progressively better methods not just to produce it, but to improve and purify it. Before bronze, all tools were made of either copper or stone but the discovery of harder, more durable bronze, quickly made them obsolete. But it didn't stop there. The version of bronze which was first discovered was known as "arsenic bronze" and was made of copper and arsenic. There are artefacts from Tepe Yahya in Iran which have been dated as early as the fifth millennium BC. This "arsenic bronze" was still a major upgrade to the copper and stone tools which preceded it and remained prevalent for 2000 years until the major replacement of 'arsenic bronze' by 'tin bronze' in the late third millennium BC. This new 'tin bronze' did not release toxic gases during refining and was stronger and easier to work with. The earliest example of this new form of Bronze dates to 4500BCE in a Serbian archaeological site with a further find in Egypt dated just a few hundred years later. This shows that change was being driven by a desire to develop more durable and therefore more effective tools and the ancient trading networks quickly distributed any major advancements in these tools. This desire for innovation to improve the quality of life of the people at the time by making their own lives easier is mirrored in the alchemists of millennia later, as being able to make your own gold was a sure-fire path to having a much better life.

Bronze and Stone tools found in a shipwreck off the coast of Turkey dating to the late Bronze age (about 1200BC).

East Asian Early Alchemy

Perhaps the most fascinating region in which alchemy took place was East Asia, or more specifically China. Unlike Western alchemy, Chinese alchemy was far more focused on the purification of a person's body and spirit in order to gain immortality. This meant there was a much greater emphasis placed on medicine in general, leading to the development of a number of elixirs and treatments like acupuncture as they sought the "Grand Elixir of Immortality". Gunpowder, one of the most famous and influential discoveries by an alchemist throughout the entire Alchemical era, is believed to have been discovered by accident whilst trying to find the Grand Elixir, and by the end of the 13th century it had revolutionised warfare. Fireworks in the 10th century preceded the military use of gunpowder and were a "money tree" for alchemists at the time: an example of alchemy as a means of making seriously large amounts of money through milking the aristocracy with these pretty devices. This was one of many driving forces for alchemists at the time.

Islamic Early Alchemy

Arguably the most important region when it came to alchemy, after the fall of the Roman Empire, the Islamic area became the undisputed leader of the alchemical world. Jabir Ibn Hayan (Geber), often referred to as the "father of chemistry", was from this region and placed a greater emphasis on lab work and scientific method than any before him. This was to become typical of Islamic alchemy which was a huge step up from the very hard to understand sources remaining from the ancient Greek and Egyptians. This logical and scientific method would slowly infiltrate the other regions in which alchemy existed and replace the existing methods of doing things. Islamic Alchemy was highly advanced with texts referencing many processes such as distillation, evaporation, crystallization, sublimation and filtration to name a few. This far more scientific version of alchemy than had ever been seen was to become the generally practiced form of alchemy with Islamic alchemists leading the charge towards the discovery of new materials and techniques as will be mentioned later along with Geber himself.

Uses of Early Alchemy in the West

The dawn of Western alchemy is usually associated with the rise of influential early alchemists like Empedocles in 500BC. Some of the earliest surviving evidence of alchemy is from the Stockholm and Leyden papyri which date from 300-500 AD. These papers contain information on dying fabrics and making artificial gemstones, cleaning and fabricating pearls, and making imitation gold and silver. During this period, there was almost no conflict between religion and alchemy. Alchemy and religion coexisted peacefully, with religion even influencing alchemy e.g. the fact that gold does not tarnish was associated with immortality and therefore God, which made alchemists keen to discover a method of transmutation, though the wealth, prestige and power which would result probably were a good incentive too. Western alchemy was not quite as advanced as its Asian and Middle Eastern counterparts but the religious connection, evident in alchemy in general, was particularly of note and importance in the West. Great philosophers and thinkers like Aristotle also came up with some of the earliest theories about what the world was composed of and so Western alchemy was still influential in the long run, becoming far more advanced and globally relevant centuries later. Western alchemy dawned in Egypt, mostly in Alexandria (close to the Islamic nations where alchemy was even more developed, centuries later) where Zosimos of Panopolis wrote the oldest known books on alchemy. It was in Alexandria that metallurgy evolved into a "Hermetic art" according to the ideas of 'Thrice-Great Hermes' symbolised by the caduceus. It was from Alexandria, a melting pot of ideas and philosophy, from which the Core Principles emerged.

A Caduceus. This was the God Hermes' serpent staff and became the symbol of Alchemy in the Western world.

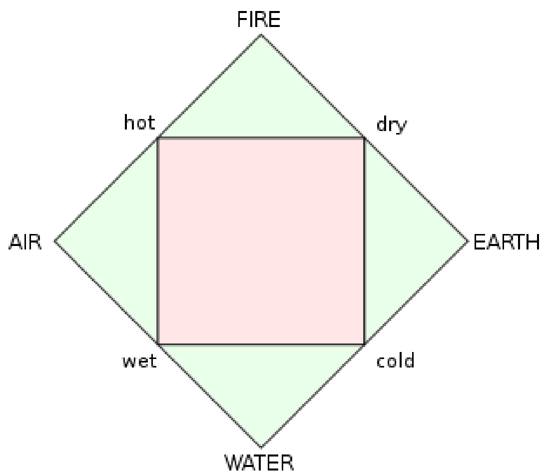
Core Principles of Alchemy

The idea of four elements – Fire, Air, Water and Earth– originated with a man called Empedocles (490-c.430 BC), a Greek philosopher who is considered the last to have written his works in verse. As can be expected, his ideas were partially driven by myth and religion, as shown his naming the four elements Zeus, Hera, Nestis and Aidoneus after Greek mythological figures.

This portrayal of the elements was continued chiefly by Aristotle, who both added to it and developed it. He was the first to relate each element to two separate properties: warmth and humidity. Any non-elemental substances were therefore characterised as intermediate degrees of the same element. Aristotle first thought that this meant the elements could be found in the compounds both "potentially", meaning the elements could be extracted from their compounds in theory (as with our concept of a reversible reaction); and "in actuality", meaning the four elements were actually present in their compounds. However, he later amended his theory to say that when the elements react with each other, they neutralise each other to different extents to form a balance between them that creates the new element and that this balance is uniform throughout the entire compound. Therefore, the original elements cannot "in actuality", be present in their compounds.

Both Water and Earth have a set volume of their own but Fire and Air do not. Water is a liquid because it is Moist and so readily adaptable and not limited in shape. Earth is a solid because it is Dry and so not adaptable and has a determinable limit for its shape. Air is a gas because it is Hot and Moist, a vapour.

Air	Hot	Moist
Fire	Hot	Dry
Water	Cold	Moist
Earth	Cold	Dry



Aristotle also added a fifth element, Aether, which was thought to make up the universe as well as deities and so could be used to heal. It was neither Hot nor Cold, and neither Moist nor Dry and was used by medieval alchemists to explain both light and gravity. Sir Isaac Newton even used this as his starting point for his theory of gravitation.

Extract from "Early Alchemy" by James Stirling & Rock Bell

The Neuroscience of Déjà Vu

Jay Chitnavis

Ever had that instantaneous, other-worldly sense of having previously lived through a seemingly novel situation? No need to feel disconcerted though; this is a neurological phenomenon known as 'déjà vu' (meaning 'already seen' in French) and is reported to be experienced by around 70% of people, most of whom are young (15-25). We do not yet have a complete explanation as to how and why the brain is stimulated in such a way, rather many plausible hypotheses. Plenty of speculative approaches have been advanced to explain the phenomenon since the Arabian physician and surgeon Abu al-Qasim Al-Zahrawi first acknowledged and partially described déjà vu during the 10th century. Predictions about its nature have been voiced by many notable psychologists, philosophers, and neuroscientists including Sigmund Freud. Even so, the view that déjà vu is a neural-based 'illusion' stemming from the inadvertent activation of neurons has now gained a clear consensus. These neurons or brain nerve cells are located between the hippocampus and amygdala in the temporal lobe. These parts of our brain are known to display the highest neuroplasticity (the ability of neurons to reorganize themselves); quite literally, they change and evolve their neural connections constantly and are thought to be concerned with certain types of memory and emotion. A less often experienced and what at first glance appears to be the opposite phenomenon of a feeling of unfamiliarity in an otherwise everyday or routinely encountered situation is also recognised and termed 'jamais vu'. It is also believed, not unsurprisingly, to arise from the same area of the brain. These phenomena have been difficult to study owing both to their fleeting but also unpredictable nature. There are some individuals, however, who experience these types of events more frequently. They generally have epilepsy and sensations such as déjà vu often coincide with seizures. These people have often provided our 'model' of déjà vu until the recent past. Doctors have studied, observed and occasionally induced their epilepsy medically to locate its source within their brains, the aim being to cure intractable epilepsy by surgically removing the part of the brain responsible for the epilepsy. The late 19th century saw the first significant breakthrough with the studies of Hughlings Jackson. The surgical era of Wilder Penfield meant such pre-surgical observations were in part confirmed and it was at this time that we developed our formative understanding of déjà vu. Finally, the modern epoch of virtual reality stimulation combined with functional Magnetic Resonance Imaging (fMRI) has built on both previous eras.

In the 1889 issue of 'Brain" (the foremost journal of neurology at the time), Dr John Hughlings Jackson, an eminent English neurologist, whose wife is said to have had epilepsy, described and first defined déjà vu, highlighting a region of the brain, the temporal lobe, as its source. Jackson's definition of déjà vu, as experienced by his epileptic patients, involved a feeling of 'reminiscence' – the experience feels like it has been encountered before yet one intrinsically feels this is not the case. This was termed 'mental diplopia' (quite literally mental double vision) due to a doubling of consciousness; a depressed form of normal consciousness responsible for the feeling of familiarity, and a second 'parasitic' form responsible for the sense of illegitimacy. It is remarkable that Hughlings' definition has stood the test of time, as well as the fact that he was able to deduce the source as the temporal lobe from such a small set of observations. Whilst Dr Hughlings Jackson described déjà vu within the context of his epilepsy patients, it is likely that the same areas of the brain are active when we all experience déjà vu.

The first half of the 20th century saw the coming age of surgery, giving neurologists the ability to examine electrical activity in the brain directly with electrodes, whilst simultaneously making clinical observations on the patient. The multitude of studies conducted in this way had an important role in accurately locating the main areas of abnormal electrical activity in the brain prior to an epileptic attack, enabling safer and more accurate surgical removal. These studies also confirmed the deductions made by Jackson and went further in suggesting that déjà vu occurs because of specific communications between two or more parts of the brain, observed as electrical impulses spreading between nerve cells, especially those located in the temporal lobe, amygdala, and hippocampus.

Hypotheses on the nature of memory have also arisen based on the observation that the hippocampus contains the most neuroplastic cells in the brain. Wilder Penfield, a prominent mid-20th century American neurosurgeon, stated that déjà vu, along with a few other types of memories (even those potentially generated in dreams), could be evoked by direct electrical stimulation of the lateral temporal neocortex. It was at this time that the notion arose that memories may have a direct relationship with the specific 3-D shape and structure of nerve cells, as well as the ways in which they behave. Input from such senses as vision are collected, processed and then assimilated by nerves into a form that gives them meaning. This is thought to occur first in the hippocampus, where the information is temporarily stored. The information is then distributed and finally stored more permanently within the structure of neurons on the outer surface of the temporal lobe (neocortex) of the brain. Importantly, it is not just the neurons' physical shape that determines the storage of the memory and what we perceive but also how these nerve cells electrically and chemically interact with other neurons over time. A hypothesis for déjà vu has subsequently arisen. A visual trigger (but not necessarily one which is consciously recollected), when conveyed to the processing areas of the amygdalo-hippocampal and temporal regions of the brain, shares many but not all features with a certain pre-existing memory. Hence it gives rise to the feeling of familiarity and precognition but at the same time the feeling that it is an illusion.

While these medical observations in patients have helped in deepening our understanding on how the brain works, progress was not always possible in epileptic patients until recently. The advent of new technology has allowed both the stimulation of the brain, inciting it to experience déjà vu, and the observation of those effects in the brains of normal subjects, creating a new way to investigate the functioning of our brains. This new era has come with the invention of two new pieces of technology: 3-D virtual reality and functional MRI (fMRI), both of which can study the brain in real time. The hypothesis that certain visual cues may trigger déjà vu has led to a search for those cues to better study the phenomenon. Indeed, a method was devised for just this using a 3-D virtual reality depiction of a village. The results revealed that test subjects most frequently experienced déjà vu when they were in new rooms which resembled, in spatial layout, a previously visited room that was similar enough for them to recognise a feeling of familiarity but not similar enough for them to consciously recognise the resemblance. For example, a virtual reality art classroom might trigger déjà vu because it has the same spatial configuration as Busby's Yard - that is, the sculpture and cabinets being in the same location relative to the phone box and benches. This particular method of more reliably eliciting déjà vu proves to be especially useful considering the otherwise elusive nature of the phenomenon. The ability to isolate déjà vu in a lab also allows scientists to explore in more detail the anatomical origin of déjà vu in people without epilepsy.

However, the utility of these investigations potentially go beyond the specific field of understanding déjà vu, with great potential to exploit this research in the treatment of patients not just with epilepsy but also those with memory disorders. The rather jarring juxtaposition of the senses that accompany déjà vu, with novelty and realisation reigning simultaneously, may hold a role in retraining brains. People with memory impairment may benefit from training on how to rely on the sense of familiarity to retrieve memory. Even if this is an endeavour that has only just begun, it is a field ripe for research and holds clear promise for helping manage memory related diseases such as Alzheimer's.

Reliably triggering déjà vu in people using visual cues is extremely useful for study of this phenomenon. Studying the brains of subjects experiencing déjà vu reveals the changes in activity that occur in regions of the brain such as the temporal lobe. Recent research confirms previous hypotheses that during déjà vu such regions communicate with each other. However, even more widespread brain cell activation than ever previously hypothesised has also been hinted at and such observations are helping to build a better understanding of how our brains make sense of the world around it.

As shown, déjà vu may be used to help those with memory impairments in their later years, as well as in improving the way we learn in the early years of our lives, when the experience appears to be more commonplace. Once considered merely an epi-phenomenon in epilepsy, déjà vu has been demonstrated to hold important insights in helping to unravel the way our brains work.

The Cheerios Effect

Rae Zhao

The amazing phenomenon thanks to surface tension

Introduction

Have you ever noticed that when you pour the Cheerios into your milk bowl, they tend to clump together or cling to the edge of the bowl after only a short while? Surprisingly, this phenomenon has already been discovered and thoroughly explained by scientists and they even named it the "Cheerios Effect". Nowadays, the Cheerios effect does not only refer to the famous American Breakfast cereal. It is a general description of the phenomenon when light objects that do not usually float not only float, but also attract each other in fluids. The Cheerios effect can also refer to the behaviour of the clustering bubbles in fizzy drinks, or floating paper clips that attract each other. The effect is not observable for boats and other huge floating objects because the impact of surface tension is comparably small.

Fig. 1

In my research essay, I am going to explain this amazing phenomenon. When we poured Cheerios into the milk bowl, we observed two phenomena (shown in Fig. 1). One is that the Cheerios are attracted to each other. The second phenomenon is that some Cheerios will be attracted to the edge of the milk bowl.

Buoyancy

To understand the two phenomena, we first need to understand buoyancy, the force that allows items to float on a liquid. According to Archimedes' principle, when an object is placed in a fluid (liquid or gas), the buoyant (upward) force on it is equal to the weight of the fluid displaced. Buoyancy determines whether an object immersed in water will sink, float, or remain in the same position. If the object is denser than the liquid, the weight of the liquid that fills the object's volume will be less than the weight of the object. The buoyant force will not be strong enough to overpower the object's weight. Thus, the object will sink. If the liquid is denser than the object, then the opposite will happen.

Surface Tension

In direct contrast to this, due to surface tension, even objects that are denser than the liquid can float. For example, insects like water striders are able to stride on a water surface due to surface tension between their legs and the water. This goes against the traditional theory of buoyancy, so how are these objects able to float?

To understand surface tension, we first need to know a few definitions. Firstly, the cohesive force is the attractive force exerted on a liquid molecule by the neighbouring liquid molecules. Conversely, the adhesive force is the attractive force exerted on a liquid molecule by the molecules of a

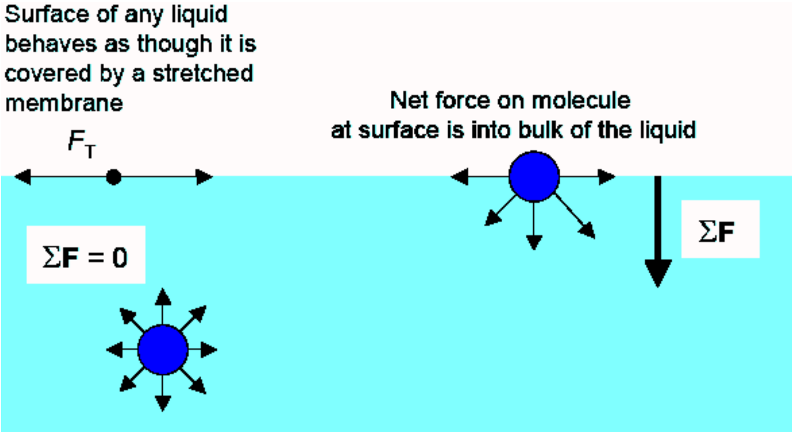


Fig. 2

different substance. Assume that we have not poured the Cheerios yet and we now only have milk in the bowl. At the milk-air interface, milk molecules attract each other more, so that the cohesive force between milk molecules overtakes the adhesive force between the milk and air molecules. This is explained by the fact that milk molecules below the surface have equal forces acting on them in all directions (as seen in Fig. 2) whilst molecules on the surface pull towards each other horizontally. As a result, surface tension takes place and the milk molecules cling to each other tightly while experiencing a weak outward pull from air molecules. The net effect is an inward pull at its surface, which acts as if covers the milk with a stretched elastic film.

On the other hand, at the edge of the milk touching the ceramic, where the adhesive forces between milk and ceramic overcome the cohesive forces between milk molecules, the milk molecules will be attracted to the sides of the ceramic by overcoming the force of surface tension. For this reason, the milk will climb the ceramic slightly.

To sum up what I have just stated, surface tension is the tendency of a liquid surface to have the least surface area possible. It wants to obtain minimum area as the tensions are all acting inwards and compressing the shape. Surface tension has the dimension of force per unit length and its SI unit is newton per metre. Surface tension is usually denoted by the symbol γ.

$$1\frac{dyne}{cm} = 1\frac{erg}{cm^2} = 0.001\frac{N}{m} = 0.001\frac{J}{m^2}$$

Meniscus Effect

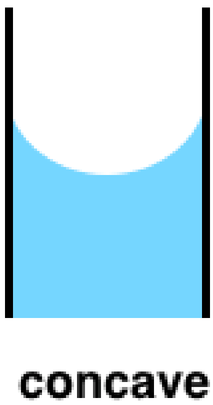


Fig. 3

The meniscus is the curvature of the upper surface in any liquid (as shown in Fig. 3). The nature of surface tension allows the surface of a liquid to operate as a flexible skin. At the interface between water and air, water molecules within the liquid forcefully pull the water molecules at the surface downwards, while the surface water molecules experience only a feeble external pull from the air molecules on top. Therefore, the surface of the water bends in slightly, creating a curve known as a meniscus. As I mentioned above, the milk curves outward at the edge of the glass as adhesive forces overcomes cohesive forces and is relatively flat in the centre. Overall, it bulges inward, thus creating a concave meniscus.

Explanation of the phenomena based on knowledge of buoyancy, surface tension and the meniscus effect

The first phenomenon is that when two Cheerios meet, they are attracted to each other. When Cheerios distort the milk interface, it creates irregularity in the meniscus, leading to spontaneous interactions.

When floating in the liquid, Cheerios dent the surface slightly. They displace the milk within leading the milk to climb upwards onto the Cheerios. When one Cheerio floats close enough to another, they float each other's upwards-curving meniscus. As we know, surface tension causes the tendency to form the least possible surface area. Therefore, the two Cheerios will be attracted to each other and float up each other's meniscus as the combination allows them to reduce the interfacial area of the liquid (as shown in Fig. 4).

However, the behaviour of the Cheerios when they are attracted to the edge of the bowl is due to a different reason. This second phenomenon is explained by the fact that Cheerios will tend to go to the highest point of milk surface. As the milk has a higher density than the Cheerio, the weight of the milk that would fill the Cheerio 's volume is more than the weight of the Cheerio, and so the buoyant force is strong enough to offset the weight, lifting the Cheerio up. But as the Cheerio rises, its submerged volume becomes smaller, and consequently the buoyant force will reduce. Up to a certain point, the buoyant force will be equal to the weight of the Cheerio, and then the Cheerio will stop rising and maintain that level. Therefore, buoyancy lifts the Cheerio up as much as it can, until it displaces its own weight of milk, according to Archimedes' principle. This is the reason why the Cheerios will seek the highest point of the milk level (The reverse effect will happen for the objects that are denser than milk).

Liquid located near the side of a container can curve upward or downward, depending on whether the liquid is attracted to or repelled by the material of the wall. Since milk is attracted to ceramic (adhesive forces are greater than cohesive forces), in order to increase the contact area between the milk and the ceramic, the milk surface in a ceramic bowl will curve upwards near the walls. Hence, the milk forms a concave meniscus and the edge will then be the highest point of the milk. The floating Cheerio, aiming to find the highest point, will eventually find its way to the edges of the bowl.

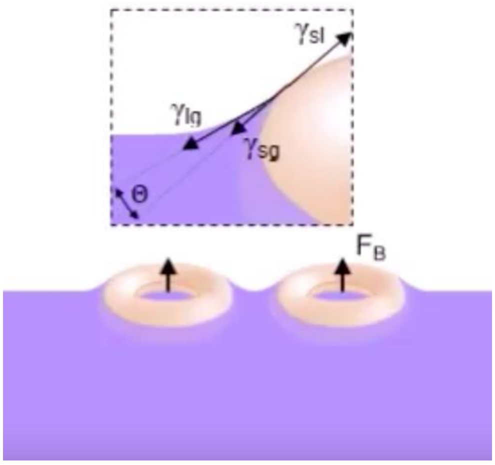


Fig. 4

Further Exploration of the "Cheerios Effect"

We can now investigate objects that are denser then cereals and see if they show different behaviours.

We can investigate paperclips, which are denser than Cheerios. If we have both Cheerios and paperclips in the milk, they will clump together but due to different reasons, which will be further explained below.

On a floating Cheerio, the buoyancy that tries to push the Cheerio out of the milk and the surface tension that tries to keep the Cheerio in the milk will balance each other. Therefore, the Cheerio is pushed partially out of the milk, deforming the surface and forming a small 'hill'.

Cheerios nearby are then affected by this deformation. A floating Cheerio seeks the highest point in milk, so it will move towards the 'hill' formed by the other Cheerio. Therefore, Cheerios will rapidly snap together with other Cheerios in the milk and form a cluster.

For paper clips, the opposite is the case. They are denser than milk and they float as well thanks to surface tension. The weight forces the milk meniscus around the paper clips to curve down, creating a small 'valley'. Since paper clips will seek the lowest point on the milk surface, this means that nearby paper clips will be attracted to each other. Therefore,paper clips also cling to each other.

We have seen that the Cheerios attract each other and so do the paper clips. However, paper clips and Cheerios repel each other. The question is, why do paper clips and cereal repel each other? The answer lies in the difference in the meniscus effect of the two distinct objects.

Cheerios create a hill (upward meniscus) and seeks the highest point whereas the paper clip creates a valley (downward meniscus) and seeks the lowest point. Resulting from these different objectives, they will repel each other. We can hereby conclude that an object less dense than the liquid (e.g. a cheerio) will repel the object denser than the liquid (e.g. a paper clip) due to the contrasting menisci.

This is why Cheerios and paper clips repel each other - the water around them is curved in different directions. Therefore, opposite repels and like attracts will explain the behaviours of objects with different densities towards each in other in liquids (as shown in Fig. 5).

Now we will try to explain the phenomena seen by taking a closer look at nature. As we can imagine, living and surviving on a water surface must require special adaptations. Surprisingly, this is also achieved by surface tension.

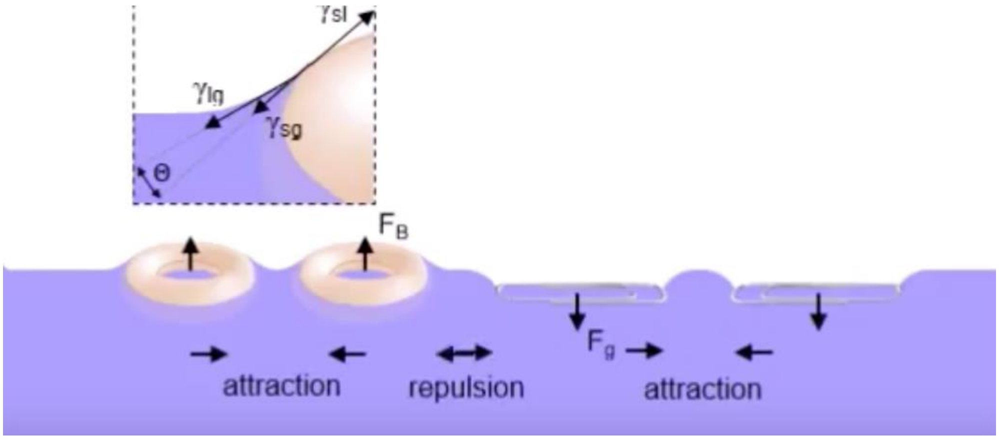


Fig. 5

Cheerios Effect In Nature

In nature, one can observe many instances where the "Cheerios effect" occurs. The majority of animals and insects in nature are denser than water yet are able to float. Objects denser than water float when the object is non-wettable and its weight is small enough to be supported by the forces resulting from surface tension. One notable example in nature is the water strider (shown in Fig. 6). The reason it does not sink into the water is due to surface tension and the hydrophobic structure of its legs. The legs of the water strider create dents in the water. However, because the water is not attracted to the molecules on the legs of the water strider due to the legs' hydrophobic qualities, the water only seeks to recover flatness of surface area creating an elastic film effect. Similarly, Haripriya Mukundarajan from Stanford University and her colleagues investigated the behaviour of water lily beetles in the laboratory. The beetles travel at 0.5 metres per second – which would be equivalent to a human travelling at about 500km/h. The team noticed that the beetles are well adapted for skimming on water. Their wings are stronger than flies and mosquitoes, which generate a huge amount of lift to oppose the drag from the surface. The water beetle's legs are covered with tiny hairs that are hydrophobic (repel water) while a claw at the tip is hydrophilic (attracts water), allowing them to effectively pin themselves to the water's surface. "This structure is critical for the beetle to maintain its level exactly on the water surface," says Mukundarajan. Since the water concentrates on the claw of the beetle, this creates an attractive force that pins the beetle to the water to ensure more efficient movement.

Fig. 6

Conclusion

In conclusion, the Cheerios effect is a very interesting theory that leads to various explanations of different phenomena that occur when objects with different densities interact with each other and the liquid they are placed in. When objects denser than the liquid are placed close to each other, the downwards-curving menisci they create lead to them being attracted towards each other; however, for objects less dense than the liquid, the menisci curve upwards, which also explains why they are attracted to each other. This is also the reason why two objects where one object is denser than water and one is less dense than water repel each other, since their menisci are curved in different directions. This can be applied to a whole variety of examples, whether they are Cheerios, paperclips or in nature, where organisms such as water striders and water beetles are able to use these forces to effectively float and move on water. Overall, it is very important to understand the Cheerios effect, as it resolves many of the interesting behaviours that one sees in the world.

The Effectiveness of Hypnosis and Past-Life Regression as Therapeutic Treatments

Charles Fruitman

Psychotherapy is a discipline that has existed in some form or other for well over a century. The vast majority of the types of therapy it encompasses are by and large scientifically endorsed methods of mental health treatment. Today there are millions of people every year seeing a psychotherapist. Yet there are increasing numbers of people who are opting for more unorthodox forms of therapy, so-called "alternative" therapies, many of which involve hypnosis. The question of whether these practices are legitimate methods with valid scientific basis remains highly contested between scientists as well as practitioners. While psychologists and psychiatrists must for now be wary of the dangers of questionable and under-researched techniques; they should not remain closed off to their evident potential.

In the past hypnosis was simply dismissed by many as a phenomenon that had stronger roots in magic than in science. Today that is becoming less and less the case with scientists now realising that understanding of hypnosis is essential as its use becomes more widespread in the modern world. Unlike many alternative therapies, hypnotherapy is widely accepted as a legitimate therapeutic process. The uses of hypnotherapy vary greatly, common ones being treating addictions such as helping in the cessation of smoking or even as a cognitive therapy to treat mental illnesses like depression. While one would be justified in being impressed by hypnotherapy's capacity for success, there is an important caveat to bear in mind when opting for hypnotherapy, being that it is proven to be useful as an adjunct to other forms of therapy and there is little evidence to support its effectiveness when used solely. When dealing with addiction, a mental health professional will often suggest hypnotherapy as a supplementary treatment to the ongoing treatment.[1] It would therefore be appropriate to consider hypnotherapy's effectiveness at enhancing the effectiveness of other therapies rather than its own effectiveness in most cases.

While the general scientific community is becoming more and more comfortable with the use of hypnosis in treatment under sensible and expedient circumstances, the weaknesses in the arguments in its favour lie in the lack of knowledge of what hypnosis really is. The word itself is derived from the Greek word 'hupnos' meaning 'sleep'. However this is very misleading as the state of hypnosis is not at all similar to the state of sleep. Clinical hypnosis involves the hypnotherapist leading the patient into a so-called 'trance' state where consciousness is maintained. Many therapists and scientists, known as state theorists, believe that this trance is a different state of consciousness altogether, a hypnotic state, characterised by hypersuggestibility (i.e. patients in the hypnotic state become more open and susceptible to suggestion from the hypnotherapist), an ability to recall memories more easily and vividly and a greater acceptance of inconsistencies in logic. However other theorists, known as non-state theorists, reject this idea of a hypnotic state, instead characterising the procedure of hypnosis as leading into deep relaxation and focus, with patients becoming more susceptible to suggestion simply through positive beliefs and attitudes towards the hypnotherapy, as with a placebo effect. Research into cognitive neuroscience has shown indication of an altered state of consciousness after hypnotic induction where there is reduced activity in parts of the brain's default mode network and increased activity in the prefrontal attentional systems. However it remains unknown if these changes are unique to hypnosis and yet more research is required. The concept of an altered state of consciousness presumes a theoretical view with a lack of scientific proof, and the idea of this hypnotic state is often one of the main barriers facing the therapeutic use of hypnosis. Therefore, for the time being it would most likely be better to characterise hypnosis without invoking the hypnotic state to maintain a theoretically neutral outlook.

Despite this ambiguity over the very essence of the hypnotic procedure and the degree of uncertainty it brings about, the scientific community's approval of the use of hypnotherapy is in no way jeopardised by this alone. Both state theorists and non-state theorists agree that hypnosis is effective as an adjunct form of treatment, albeit using different explanations. However, the fact that a treatment is widely used and accepted does not make it an empirically supported treatment (EST), widely defined as a treatment that is "shown to be efficacious in controlled research with a delineated population". For a treatment to be "shown to be efficacious", at least two studies in different research settings that meet the stringent methodological criteria to be considered valid and reliable must show that the treatment is superior to a no-treatment control and/or equal in effectiveness to a treatment of established efficacy. The trouble for hypnosis in this regard is that it is not often that studies are able to meet the stringent criteria. For example, in a meta-analysis of 59 studies of hypnosis and smoking cessation only 3 studies met the full criteria in determining whether or not hypnotherapy is an EST, and none of them provided conclusive evidence to give hypnotherapy the EST status. While there were several studies showing hypnosis to be effective as an adjunct therapy, these supportive studies would be rendered inadequate by the EST criteria. Therefore, based on these findings, it is untimely to conclude that hypnotherapy is effective as a procedure to help people quit smoking.

However, while it remains difficult to prove the effectiveness of hypnosis by obtaining empirical support, it is worth remembering that the guidelines for proving effectiveness are not set in stone and have evolved over the years, still a subject of debate. It would therefore be foolish to be servile to the criteria at all times, especially when significant findings in treatment efficacy can still be made without them. This has been shown to be the case concerning cognitive-behavioral therapies, for example by the meta-analysis of studies comparing the effectiveness of cognitive therapies with and without adjunct hypnotherapy for a variety of disorders (the effect on weight loss is shown in Fig. 1).

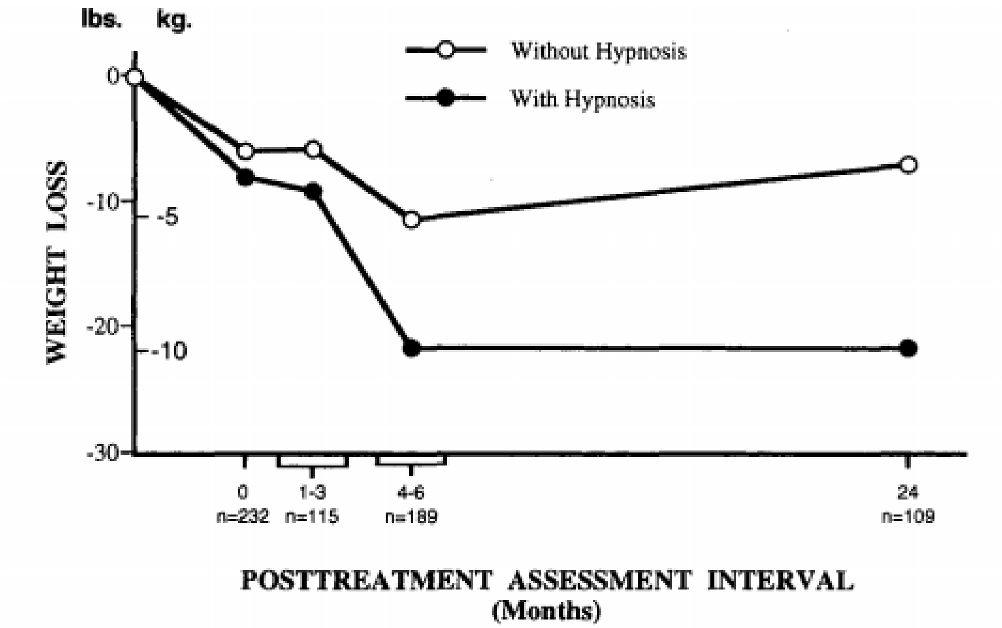


Fig. 1. Weight loss against assessment interval. As shown, the treatment was more effective with the inclusion of hypnosis in adjunction.

The meta-analysis indicated that hypnotherapy improved the mean effectiveness of the treatments, showing that the average patient receiving it alongside their treatment showed more improvement than 90% of patients receiving treatment with no hypnotherapy.

While the cognitive-behavioral results may help hypnotherapy look advantageous, it is worth noting that its efficacy will depend on the individual undergoing hypnosis. Indeed, many studies do not delineate the patient samples based on their perceived susceptibility to hypnosis and this often skews the results of the treatment effects. Some people have difficulty falling into the trance (obsessive-compulsive patients being a prime example); while others simply are not positive in their attitudes towards the desired outcome (i.e. hypnosis will not help someone quit smoking if that person does not actively want to quit) and some lack the susceptibility to suggestion, the 'motor' force that the hypnotherapist uses to drive the treatment. Other issues can also play a role in skewing the results, as was the case for many of the studies in both meta-analyses, such as differences in treatment history, age, social factors, the therapeutic method to which hypnosis is acting as an adjunct and other medications and health issues (e.g. hypertension when taking part in a smoking cessation study). In accounting for all of this, it often becomes difficult to assign participants randomly to different styles of treatment and have adequate numbers of participants in a study. These limitations along with a lack of follow-up studies makes it almost impossible for a hypnosis study to have a high level of validity.

While this can be a source of frustration for researchers and mainstream practitioners who are eager to demonstrate hypnotherapy's effectiveness and legitimacy, it is only the tip of the iceberg. More and more people are now seeing practitioners of alternative therapies using hypnosis for which there is very little scientific acceptance or evidence of their effectiveness, such as past-life regression therapy (PLR). PLR therapy is a fringe practice that focuses on the recollection of memories from a previous life that the patient’s spirit had lived in order to learn practical life lessons from these recollections. Future studies into PLR would have to aim to prove both the reality of the past life recollections as well as the effectiveness as a therapeutic method. Since there is no viable way of proving the existence of reincarnation, the first of these aims would be rendered virtually impossible. However, research into the effectiveness of the treatment has the potential to yield results. While it may seem ridiculous, scientists and mental health professionals may have more to gain by researching PLR than dismissing it, given that people are paying for it and its apparent successful results.

Despite the numerous criticisms that have been and are still being directed at hypnotherapy, it has gained widespread approval in recent times. While it is still sometimes perceived as a sort of magician's trick and there is no clear evidence to explain the phenomenon or why it has such potent effects, its positive powers as a method of treatment and the considerable extent of the evidence supporting it cannot be denied. Future research into hypnosis and smoking cessation should not only seek to outright prove that hypnosis is more effective than a placebo, but also use biochemical measures of abstinence while also showing its effectiveness as an adjunct treatment. While empirical support may be out of reach for now, if research is conducted along these lines, hypnosis could very soon be recognised as a legitimate and cost-effective approach in smoking cessation therapy. In fact, the scope of hypnosis extends beyond the mentioned areas and it is also proven to be effective in treatments of stress, phobias and irritable bowel syndrome as well as pain relief during dental care or childbirth. The evidence for PLR is less convincing. While there are stories of positive benefits and it would be a mistake to dismiss PLR straight away, the lack of authentic evidence for such an unorthodox form of treatment means it cannot be scientifically accepted.

NMR Ring Currents: what are they and why are they useful?

Navyaa Mathur

Ring currents are observed when electrons circulate in the aromatic (or antiaromatic) part of a molecule when it is exposed to a magnetic field. They are useful in NMR spectroscopy and could potentially have a number of other applications. In order to explain their importance to NMR spectroscopy, it is necessary to first explain the principles behind NMR itself.

NMR, or nuclear magnetic resonance, is a phenomenon observed when nuclei, exposed to electromagnetic radiation while in a magnetic field, absorb and re-emit specific electromagnetic frequencies. This phenomenon can be used as a qualitative analysis technique to determine the structure of organic molecules by deducing the relative locations of nuclei from their interactions with each other's magnetic fields.

Subatomic particles in a nucleus have an intrinsic property called spin, which is analogous to classical angular momentum and has the same S.I. units (though in practice a different value is used: one step of the calculation involves dividing by the reduced Planck constant, which has the same units, thereby giving a dimensionless spin quantum number which is always an integer or a half-integer). Spin is associated with a magnetic dipole moment; the magnitude of this moment is the same for all elementary particles of the same kind, but the direction can differ. Indeed, in certain cases they must differ, as dictated by the Pauli Exclusion Principle: for this reason, if a nucleus has an even number of protons, dipoles pointing in opposite directions pair up. This gives rise to an overall magnetic moment of zero magnitude due to the effects of the protons. The same principle applies for neutrons, and therefore if both numbers are even, the nucleus has zero spin and no magnetic dipole moment. An unpaired neutron and/or proton gives the whole nucleus a magnetic dipole moment equal to that of the particle itself as the dipoles on all the other particles are cancelled out by the other member of the pair, which has opposite spin. When there is an unpaired neutron *and* an unpaired proton, the observed magnetic dipole moment of the nucleus will be a combination of these two particles. Therefore, in both these cases the nucleus will interact with a magnetic field, and nuclear magnetic resonance will be observed when this nucleus is under the right conditions; the only case where this will not happen is where the number of neutrons and the number of protons are both even.

This is why NMR spectroscopy, when used for the qualitative analysis of organic molecules, requires the presence of ^{13}C in the substance being analysed as ^{12}C nuclei will not interact with the magnetic field being applied, and so will not display nuclear magnetic resonance. This is provided for by the fact that the ^{13}C isotope makes up approximately 1% of all carbon: in any given sample being analysed, there will be a high enough number of molecules that any position in the molecule will be occupied in some cases by ^{13}C nuclei, which will give a detectable NMR signal.

NMR spectroscopy works on the basic principle that the magnetic dipole moment of a nucleus (henceforth the word 'nucleus' will be used to refer to a nucleus with a magnetic dipole moment, for the sake of convenience, and the word 'proton' will be used interchangeably with '^{1}H nucleus') in a magnetic field causes it to line up with the field in one of two orientations: parallel or antiparallel. The parallel orientation is the lower energy state of the two. Outside a magnetic field different directions of angular momentum have the same energy so there is no preference between them. The number of possible directions is a function of the spin number of the nucleus: it is (2I + 1), where I is the integer or half-integer spin number. Therefore, a proton or a ^{13}C nucleus, both of which have a spin number of ½, have two possible orientations.

When nuclei are interacting with a magnetic field, the two orientations no longer have the same energy. For a nucleus with two possible orientations, the ratio of nuclei in the higher-energy state, N_β, to the ratio of nuclei in the lower-energy state, N_α, is a function of the nucleus's magnetogyric ratio, the strength of the applied magnetic field, and the temperature.

When the nuclei are exposed to electromagnetic radiation while in a magnetic field, the nuclei in the parallel state absorb energy to flip to the antiparallel state, and then release this energy when they relax to the parallel state once more. The frequency of electromagnetic radiation absorbed and released is directly proportional to the strength of the magnetic field and is given by $= \frac{\gamma B}{2\pi}$, where ν is the resonant frequency in hertz, γ is the magnetogyric ratio of the nucleus and B is the strength of the applied magnetic field. The slight difference in the number of nuclei in each state means that the resonant frequencies of the nuclei in a compound are detectable by examining the absorption and emission spectra: NMR spectroscopy harnesses this fact.

The electron density around a nucleus, as well as other nuclei in close proximity, affects the strength of the magnetic field experienced by the nucleus and therefore changes the resonant frequency of the nucleus. The motion of an electron generates a magnetic field in opposition to the applied magnetic field, so nuclei close to regions of high electron density experience a lower effective magnetic field than a standard, and are said to be shielded. Similarly, a deshielded nucleus is one which is far away from regions of high electron frequency, and therefore experiences a higher magnetic field than the standard.

The effective magnetic field on a nucleus, $B_{effective}$ is given by $B_0(1 - \sigma)$, where B_0 is the applied magnetic field and σ is the shielding constant (the result of the chemical environment of the nucleus). The resonant frequency of a nucleus is directly proportional to the strength of the effective magnetic field: the ratio of the resonant frequency to the operating or reference frequency is therefore a constant for a particular nucleus, independent of the strength of the applied magnetic field. This is measured as the chemical shift δ (in parts per million), calculated by the formula:

$$\frac{resonant\ freqency\ of\ nucleus - resonant\ frequency\ of\ standard}{operating\ frequency}$$

NMR spectroscopy makes use of the detected chemical shifts to deduce the bonds and distances between nuclei, and so find the structure of a complex molecule, since a nucleus's proximity to functional groups and to other nuclei change the effective magnetic field it experiences. The effect of a functional group is due to the effect it has on the distribution of electron density, which may move closer to or farther away from the nucleus in question, changing the chemical shift as discussed above. Other nuclei, in addition to causing this effect, may cause a phenomenon known as spin-spin coupling where the different orientations of magnetic moment have an effect on the chemical shift: this can help deduce the number of bonds between two nuclei as the effect grows weaker with distance, and a nucleus two bonds away will cause peaks within the peaks caused by a nucleus one bond away.

When a molecule has multiple functional groups, the effects of the functional groups on nuclei are more or less additive. Cyclic parts of a molecule can have a pronounced effect on the chemical shifts of the surrounding nuclei due to ring currents, and this is especially the case with aromatic rings. Aromatic rings have proved difficult to define, but one factor that defines them is that they have (4n + 2) electrons in the conjugated π orbital, which is delocalised, and these electrons contribute significantly to the high stability of the aromatic system. The structure of an aromatic ring can often be represented by alternating single and double bonds, but in reality all the bond lengths are somewhere in between the length of a single bond and a double bond between two carbon atoms. This is due to the fact that the system is a hybrid of two resonant structures: a single bond in one resonance structure is a double bond between the same two atoms in the other, and vice versa (see Fig. 1 for a pictorial representation of this) - all the atoms in the ring contribute electrons to the system. Such rings are called annulenes and are generally unexpectedly stable due to the extra strength of the delocalised electrons, even when reasonably large, such as in $C_{18}H_{18}$.

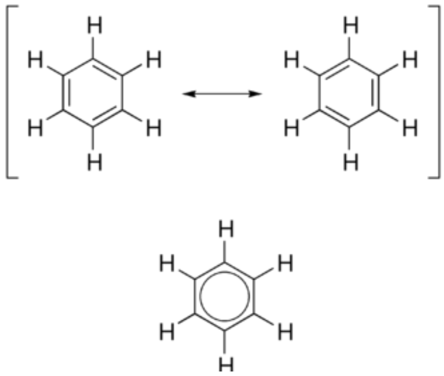


Fig. 1. The two resonant structures of benzene (in the square brackets) combine to give an average structure, represented by a ring within a hexagon.

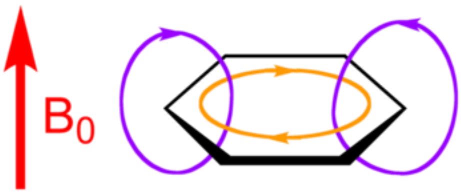


Fig. 2. B_0 is the applied magnetic field, the loop in the horizontal plane is the ring current, and the rings in the vertical plane are the induced magnetic field.

When the plane of the aromatic ring is perpendicular to the direction of the applied magnetic field, an electric current is induced in the π-orbital electrons in the ring, which are delocalised. This in turn induces a secondary magnetic field 'wrapping' around the ring (see Fig. 2 for a pictorial representation of this). Inside the ring, this magnetic field is in opposition to the applied magnetic field, but outside the ring, the two act in the same direction. This means that nuclei inside the ring are shielded while those outside are deshielded.

For this reason, aromatic rings have a very strong effect on NMR chemical shifts in the nuclei close to them. This makes them useful when trying to find or to confirm the structure of a molecule - if the chemical shifts observed are considered anomalous or otherwise, this points to the presence of an aromatic ring. Structural determination of organic molecules is important in the fields of organic chemistry and biochemistry, since many biological molecules include carbon atoms. Carbon's propensity to form four covalent bonds means it can form a vast number of different compounds, and the exact structure of these molecules can be significant. An obvious example is in drug synthesis: a marginally different isomer of a drug could interact completely differently with macromolecules in a cell. For example, it may not fit into the highly specific 'lock' area of an enzyme, and so cannot be catalysed by it. Producers of the drug would wish to optimise the synthesis of the required isomer or separate the isomers after production if this is unviable. It is useful to consider aromatic rings when analysing the structures of such molecules, as they are commonly found in biological molecules. For example, their interactions have been found to exert a stabilizing effect on proteins, helping them stay in the correct structure.

Ring currents have also been proposed as a criterion for aromaticity itself. The nucleus-independent chemical shift (NICS) of a ring is a measure of the chemical shift for a probe (test dipole) at the centre of the ring. It is defined as the negative of the absolute magnetic shielding experienced at the geometric centre of a ring, or one ångström above it. A highly negative NICS value would indicate a diatropic current, and therefore aromaticity. Defining aromatic rings in this way could be useful because their magnetic behaviour and their high stability are largely a consequence of the delocalised π electrons, so using this as a criterion could provide a litmus test for whether an unsaturated ring is more likely to undergo substitution or addition reactions.

Ring currents are also present in fullerenes, three-dimensional organic molecules shaped like spheres, ellipsoids and cylinders, of which buckminsterfullerene (C_{60}) and carbon nanotubes are the best-known examples. The shielding in the centre of a C_{60} cage has been found to be diamagnetic, which, if this is being used as a criterion for aromaticity as discussed above, shows that such molecules are aromatic. Besides this, the chemical shift of a nucleus trapped within such a cage has been proposed as a measure of its magnetic properties. This is feasible since a C_{60} cage can contain a metal atom, and the magnetic properties of an atom within the cage would have an effect on the electron density distribution of the cage itself and thus change the shielding on itself.

A device to detect and measure magnetism could use ring currents in fullerenes. An ammeter placed on a point on a very large fullerene (possibly synthesized using a sheet of graphene) would detect a current flowing when the fullerene was exposed to a magnetic current. This would not require the generation, detection and interpretation of electromagnetic waves, which a magnetism detector based on the same principles as an NMR spectroscope would, and could be useful as a sabotage detector for information storage devices that are vulnerable to strong magnetic fields.

A possible application of ring currents in the biological sphere is in drug delivery. Over the past few years there has been interest in molecules which fold themselves into a particular structure, especially those constructed from DNA. A proposed application has been in the delivery of drugs directly to cancer cells, by recognising markers on diseased cells and releasing drugs at that point. A similar system could be constructed using a nanobot made of an organic macromolecule which includes a number of aromatic rings, encapsulating or inhibiting a drug to be released at a particular time. The magnetic fields of these rings, when the relevant area of the body is exposed to a strong magnetic field, repel magnetic atoms 'below' them (this would work because the magnetic field of the magnetic atom would line up with the applied field, whereas the diatropic ring current in an aromatic ring would cause the side of the ring facing away from the direction of the applied current to experience a magnetic field in opposition to the applied field – see Fig. 2 for a pictorial representation). Depending on the structure and composition of the nanobot, it could either be metabolised or excreted after it had released the drug. A patient could take medication in this form at any time of the day before it was required, and a wearable electromagnet could automatically release the medication at a pre-programmed time, thus eliminating the need to carry medication and to remember to take it on time in the middle of the day. Alternatively, a similar system could precisely release a drug exactly where it was required by creating nanobots that only had enough aromatic rings to generate a strong enough field to release the drug once they had reacted with or attached to a particular macromolecule found at that site, at which point an applied magnetic field would release the drug. This method could reduce side effects caused by drugs acting at the wrong location.

An example of a useful application of this idea is the contraceptive pill, which often uses the hormones oestrogen, progesterone, or a combination of the two, and must be taken to a strict timetable to prevent pregnancy: missing a day in the wrong place can greatly reduce effectiveness. A delayed-release system could ensure that contraceptive hormones are released at the same time every day, possibly in the evening so that the patient has the whole day to remember to take the pill. More importantly, a local-release system could be used to limit the action of the hormone to the reproductive system. This could greatly reduce unwanted neurological effects such as mood swings, which are commonly experienced by women taking the contraceptive pill and can have a highly detrimental effect on their quality of life.

Another possible use of such nanobots could be in the localised delivery of muscle relaxants which work directly on the muscle, such as dantrolene: after allowing a period of time for the nanobots to spread through the body after they have been ingested, a magnetic field could be applied to the area of the body where their action is required. As in the case of contraceptives, this could limit those side effects which are experienced due to the general circulation of the drug through the body.

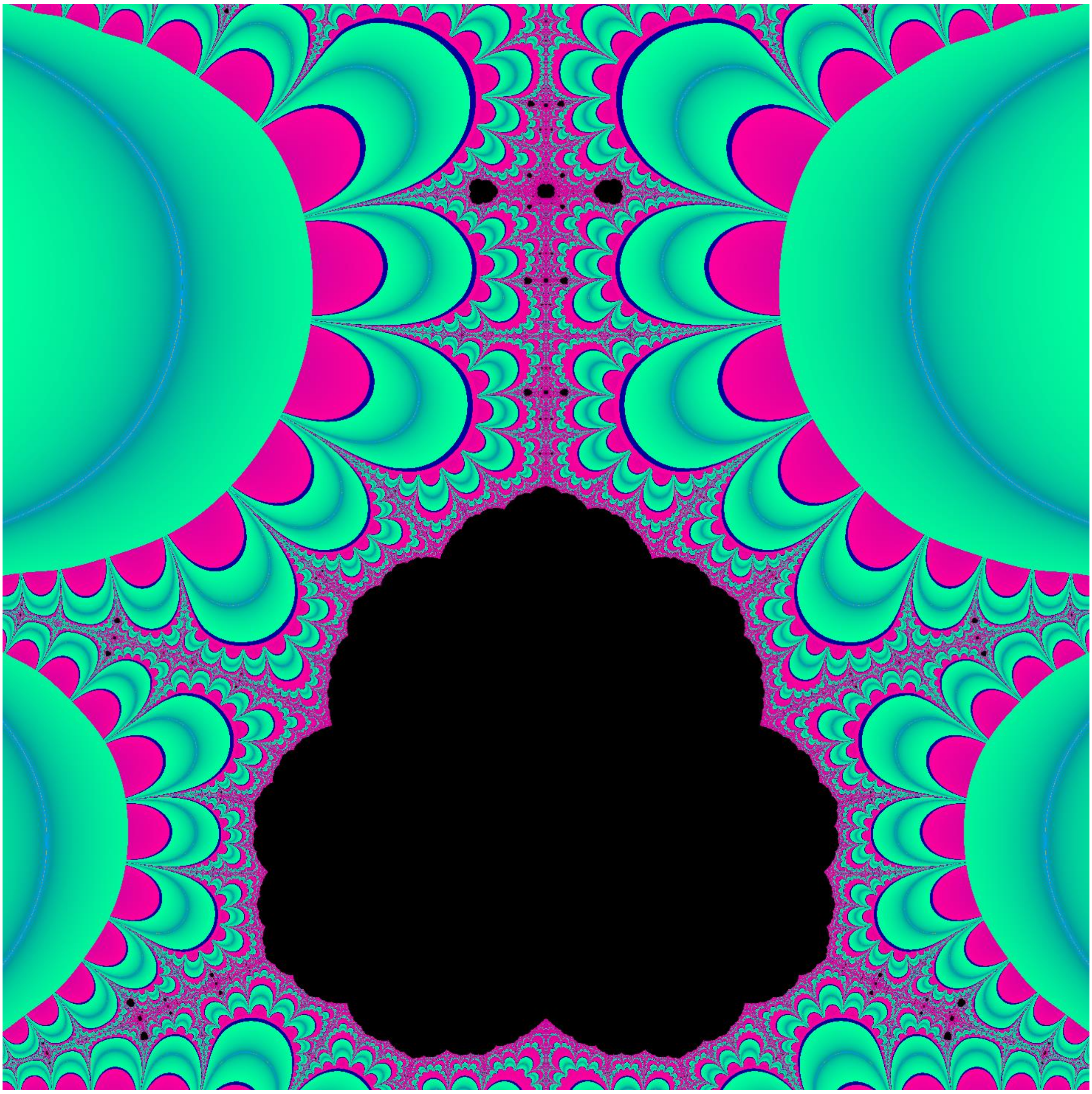
In conclusion, besides their usefulness in NMR spectroscopy, ring currents could potentially have uses in fields as wide-ranging as drug delivery and security.

Science Picture Competition

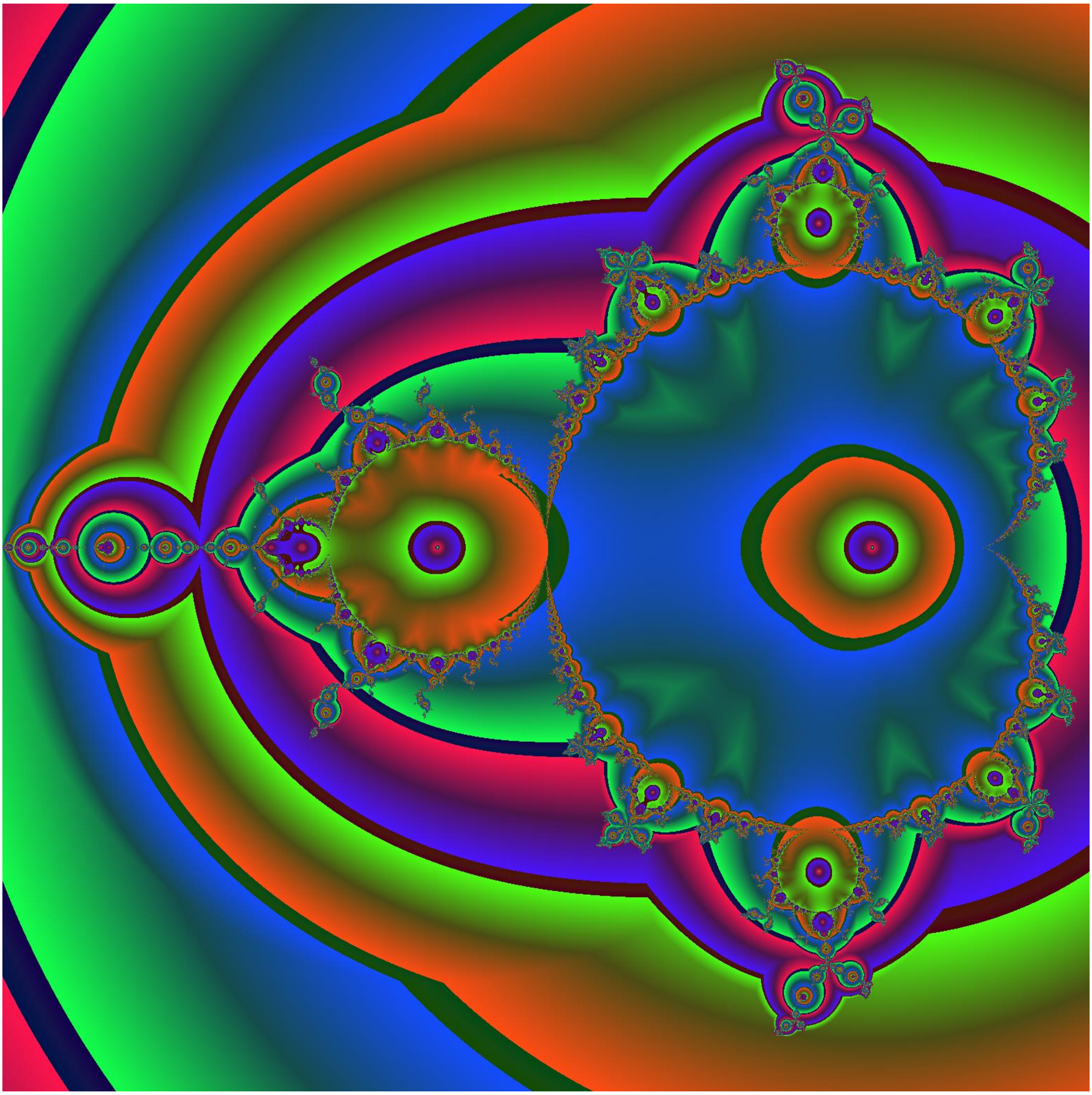
First Prize: *Butterfly* by Callum McDougall

Second Prize: *Collatz, Clifford & Julia* by Isky Matthews

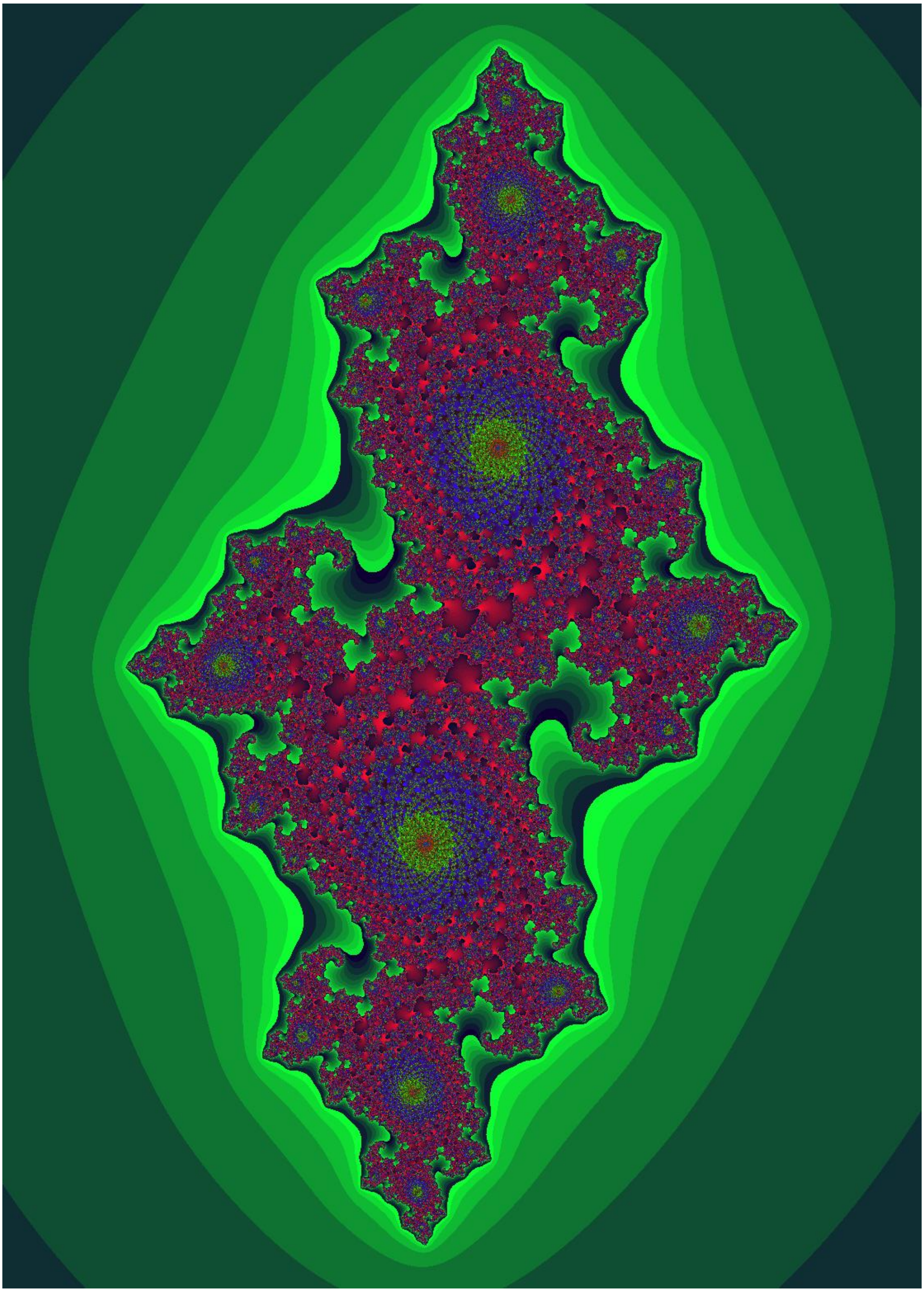
"The image called *Collatz* is a rendering of the iteration of an analytic continuation of the function used to describe the famous Collatz Conjecture. The conjecture suggests that the function 3n+1 (for odd n) or n/2 (for even n) iterated always leads any natural number to one. I took this function and, while not entirely canonical but purely for interest's sake, made an analytic continuation of the function, first for reals and then complex numbers: (1/4)*(2+7z-cos(z*pi)*(2+5z)). By iterating it between Real: -1.25 to +0.25 and Imag: -0.75 to +0.75, I was able to create this 576 megapixel image which I believe to be one the first of its kind."



“The image called *Clifford* is a rendering of the Mandelbrot set between Real: -2.0 to +0.5 and Imag: 1.25 to +1.25 using an *orbit trap* on (0,0i). The rendering technique iterates the traditional z^2+c formula on a given point, checks the distance of that point at each step from it to (0,0i) and finally colours the pixel/number by the *shortest distance* that point ever gets to (0,0i).”



"The image called *Julia* is a rendering of a Julia Set of C-value (-0.7269, 0.1889i), leading to an extremely aesthetically pleasing mirage of infinitely complex spirals and snakes. The rendering technique is the traditional iterative system with a logarithmic colouring scale to give a greater visual spread. The image was generated between Real: -1.6 to +1.6 and Imag: -1.2 to +1.2."



Highly Commended:

Drop by Callum McDougall

Geyser
by Polly Ruppel

Ripples
by Michelle Yang

All these pictures will soon be adorning the walls of the Hooke building

An Exploration of Evolutionary Psychology

Chloé Pitts

In the modern world, it seems to be popular belief that human morality and psychological prowess is what distinguishes us as enlightened beings capable of making informed decisions and observations about both our environment and ourselves, due to societal structures and influences in our early stages of development or upbringing. However, many fail to realise that our genes and DNA contribute to our psychological habits and how we as human beings owe our emotions, and societal structures, to evolution. Evolutionary psychology proposes a set of evolved psychological mechanisms to account for much, if not all, of human behaviour. The extent to which natural selection is responsible for our psychological traits is, however, highly questionable. Through exploring recurring patterns in the structures of friendship, family, politics and morality, which seem to be present in the core of human individual behaviour no matter which culture they originate from, we can begin to examine and decode why many human traits recur across different environments, cultures, and upbringing.

The dominant view of human nature in intellectual life is comprised of "the blank slate", or empiricism (a theory that states that knowledge comes only or primarily from sensory experience), "the noble savage" (the belief that people are born good then corrupted by society), and the theory developed by Gilbert Ryle, a British Philosopher of "the ghost in the machine" (each of us has a soul that makes choices free from biology). However, evolutionary psychologists argue that genes determine a large part of human traits and behaviour, and therefore these are a product of natural selection.

One of the key elements particular to human beings is our tendency for monogamous relationships. Some claim that monogamy has been inflicted on us by society, but there is increasing evidence that monogamy was a favoured psychological trait as humans evolved, and therefore is engrained within our nature. This is explored in Wright's *The Moral Animal* (2010), which suggests that the increasing male parental investment within human behaviour is highly linked with why humans developed a tendency for monogamy and deep emotional connections with their partners. The reason behind a high male parental investment could be traced back to when our ancestors moved from the forests onto the savanna with the new threat of fleet predators. As humans began to walk upright, babies could no longer cling to their mother as she walked around unencumbered, as is the case with chimps. Instead, human babies were an immense hindrance to mothers and compromised their ability for food gathering. This helplessness of human babies meant that they were ideal prey for predators, and meant that the generic male sexual strategy of seducing then abandoning was futile - if his offspring were then eaten, his genes could not be passed on. Therefore, it would be more logical if the male invested in his offspring to ensure its survival and thus the continuation of his genes, leading to a higher male parental investment than seen in other primate species. Furthermore, as the human brain increased in size, humans became more dependent on early cultural programming, meaning children with two parents had an educational edge. Natural selection appears to have taken this cost-benefit calculus and transmuted it into a feeling - the sensation of love towards offspring. This deep emotional connection is not only beneficial between a male and his child, but also between mates, in order to form a strong parental unit and ensure the survival of offspring - leading to a monogamous relationship. Romantic love is often thought to be an invention of Western culture, but the 'pair bonding' hypothesis, (introduced by Desmond Morris), suggests that this is an innate part of human nature. Therefore, the human psychological trait of developing long-lasting emotional 'love', both between parents, and their offspring, could be seen as a product of natural selection. The emotion is therefore a manifestation of the need to ensure the survival of genes within offspring, and has caused human beings to develop as a monogamous species via evolution.

The apparent innate human tendency for monogamy to ensure the survival of an individual's genes brings up the common question in evolutionary psychology of whether men are predisposed to infidelity. Even if long term investment is their main aim, seduction and abandonment can make genetic sense, provided not too much time or resources are taken from the offspring in which the male does invest. However, Symons argues that the lifestyle of a modern philandering bachelor (seduction and abandonment without ongoing investment) is not a distinct sexual strategy. It is merely what happens when you take the male mind, with its preference towards varied sexual partners, and place it in an environment replete with contraceptive technology. Yet female cheating is also addressed within Wright's *The Moral Animal*, in which he links the psychological aspects of cheating with the physical adaptation of concealed ovulation of human women. The reason behind unfaithfulness in women can be traced to the assumption that in high-MPI (Male Parental Investment) species, the female seeks good genes and high ongoing investment. However, she may not find them both in the same male individual, so the solution would be to trick a devoted male (with comparatively bad genes) into raising the offspring of another male (with comparatively good genes). Another explanation is for women to leave several men under the impression that they could be the father of particular offspring, leading to much multiple investment in their offspring, and therefore a better chance of the survival of their genes. David Buss has argued that there are major differences between males and females regarding mate choice and jealousy that are evolved responses to different selection pressures. He conducted a study in which he placed electrodes on men and women and had them envision their mates doing various disturbing things and measured heart rate amongst other signs of distress. The result of this experiment concluded that men were more enraged by sexual infidelity in comparison to emotional infidelity whereas women were more enraged by emotional infidelity compared to sexual infidelity. This variation of jealousy between men and women as a human psychological trait makes sense when linked to natural selection. Women do not seem to mind as much if men engage in sexual infidelity without any emotional attachments as it would not compromise his male parental investment in her own children, as they would still receive the most resources due to his already established emotional connection towards her offspring. Men do not mind emotional infidelity but are enraged at sexual infidelity, due to the aforementioned idea of women tricking a devoted male into raising another male's offspring, as he cannot be sure it is his own genes that he is investing in. This study can provide some basis of evidence concerning how the evolutionary differences between men and women with regards to infidelity-linked jealousy could be due to natural selection from hunter-gatherer societies. However, the study does not provide any concrete proof that these specific forms of jealousy within men and women are evolved adaptations, as it does not consider the influence of societal prejudices inflicted on women regarding sexual activity and the cultural belief that women should engage in less sexual activity than men.

Another trait which can be explored in relation to evolutionary psychology is reciprocal altruism among humans. Reciprocal altruism constitutes behaviour that benefits another unrelated organism, carried out in the expectation of its being reciprocated; the theory proposes that behaviour of this type has evolved because it is likely to increase the chances of survival or reproductive success for the apparently altruistic organism. The idea of reciprocal altruism can be outlined through the feelings of gratitude, compassion, and sympathy, which Pinker details in *The Blank Slate: The Modern Denial of Human Nature*. The evolutionary advantage of gratitude is that it can get people to repay favours without them being self-aware of this. If compassion is felt more strongly for specific people, such as people to whom we're grateful to, it can lead us, again with scarce consciousness of the fact, to repay kindness. Gratitude, by reflecting the value of the benefit received, calibrates the repayment in order, and therefore, linked with compassion, could be viewed as a selfish evolutionary behaviour disguised in the form of selfless emotion. This is reiterated in Wright's *The Moral Animal* as he suggests that, for the benefactor, the moral of the story is clear: the more desperate the plight of the beneficiary, the larger the I.O.U. Therefore, sensitive sympathy can be viewed as just a piece of highly nuanced investment advice - our deepest compassion is our best bargain hunting. This could also double as a social way of bringing tribes closer together. Williams' summary of this idea states that: "an individual who maximises his friendships and minimises his antagonisms will have an evolutionary advantage, and selection should favour those characters that promote the optimisation of personal relationships."

A similar argument proposed by Barrett et al. in *Human Evolutionary Psychology* claims that human beings are simultaneously the most social and the most violent creatures on Earth. This combination of cooperation and aggression enabled us to dominate our ecosystem. However, the existence of violent impulses would have made it difficult or impossible for humans to live in close-knit families and clans without destroying each other. Nature's answer was the development of guilt, shame, and anxiety -internal emotional inhibitions or restraints specifically repressing aggressive self-assertion within the family and other close relationships. The theory of negative legacy emotions proposes the first unitary concept for the biopsychosocial function of guilt, shame, and anxiety, and seeks their origin in biological evolution and natural selection. Natural selection favoured individuals with ingrained emotional restraints that reduced conflicts within their family and tribal unit, optimising their capacity to survive and reproduce within the protection of their small, intimate societies, while maintaining their capacity for violence against outsiders. Unfortunately, these negative legacy emotions are rudimentary and often ineffective in their psychosocial and developmental function. As a result, they produce many unintended untoward effects, including the frequent breakdown of restraints in the family and the uninhibited unleashing of violence against outsiders.

Similar to the trait of violence, human traits or behaviours generally viewed by society as negative and unproductive, such as depression, could have some evolutionary explanation. Allen and Braddock suggest that depression is a self-defence mechanism by which some individual attempts to prevent his or herself from being cast out of a group. Individuals in a depressed state avoid socially risky behaviour, become hypersensitive to social risk, and send out signals in an attempt to elicit support from others in the social group. Depressed people are likewise less confrontational or competitive than they might normally be, since these are traits that would lead to high-risk situations. People sensing that they are close to being evicted from a group that is important, either for survival or reproduction, adopt these behaviours in an attempt to stay within the group and stave off exclusion. By becoming a very low-risk individual, people experiencing depression attempt to show to others that there is no reason to exclude them from the group. Studies have been done that show there are specific traits that are only apparent in individuals experiencing depression. Therefore, depression is a highly specialised response to the perceived social environment and Allen and Braddock find it very hard to believe that it could be anything but an evolved adaptation to the human social world.

However there have been multiple criticisms of the concept of evolutionary psychology. One of these is the lack of conclusive experimental evidence. In *Adapting Minds: Evolutionary Psychology and the Persistent Quest for Human Nature*, David Buller argues that "not only that the theoretical and methodological doctrines of Evolutionary Psychology are problematic, but that Evolutionary Psychology has not, in fact, produced any solid empirical results". The problem is that the psychological experiments used to establish the existence of the hypothesised cognitive mechanisms in current humans are flawed because the data are exiguous, inconclusive, and do not support some claims made by evolutionary psychologists.

Another method of criticism of evolutionary psychology is the example of maladaptive behaviours such as homosexuality and suicide which seem to reduce reproductive success. Regarding homosexuality, evolutionary psychologists, such as Kremer in *The Evolutionary Puzzle of Homosexuality* have proposed explanations, such that there may be higher fertility rates for the female relatives of homosexual men, thus progressing a potential homosexual gene, or that they may be by-products of adaptive behaviours that usually increase reproductive success. However, a review by Confer states that they "remain at least somewhat inexplicable on the basis of current evolutionary psychological accounts." If seen to be of a maladaptive nature, and therefore disregarding the evolutionary psychological evidence for things such as homosexuality, these behaviours can simply be seen in no different manner than other maladaptations such as poor eyesight. However, the criticism of suicide is countered by Wright in *The Moral Animal*, in which he attempts to construct scenarios in which suicidal behaviour could be an evolutionary adaptation. He suggests that a person in the ancestral environment who had become a burden on his family would maximise inclusive fitness through removing himself. This would make sense in an environment where food is scarce and through continuing to eat, he would deprive more reproductively valuable relatives of nutrients to the point of endangering their lives. Yet this argument is clearly flawed as in the modern environment, suicidal people rarely are part of families near starvation and that is the only circumstance which would make any Darwinian sense.

Evolutionary psychology has been further criticised for its ethical implications. Richardson, Wilson et al. have cited the theories in *A Natural History of Rape* where rape is described as a form of mate choice that enhances male fitness as examples. Critics have expressed concern over the moral consequences of such evolutionary theories and some critics have understood them to justify rape. However, the authors of *A Natural History of Rape*, Thornhill and Palmer, as well as McKibbin, respond to allegations that evolutionary psychologists legitimise rape by arguing that their critics' reasoning is a naturalistic fallacy - in the same way it would be a fallacy to accuse scientists researching the causes of cancer of justifying cancer. Instead, they argue that understanding the causes of rape may help create preventive measures.

The idea of a naturalistic fallacy is further explored in *The Blank Slate*, when Pinker contends: "The naturalistic fallacy is the idea that what is found in nature is good. It was the basis for Social Darwinism, the belief that helping the poor and sick would get in the way of evolution, which depends on the survival of the fittest." Today, biologists denounce the naturalistic fallacy because they want to describe the natural world honestly, without people deriving morals about how we ought to behave.

Overall, evolutionary psychology explores the idea that natural selection is responsible for the development of human psychological traits, claiming that evolved psychological mechanisms make up modern day human behaviour. The recurring patterns throughout human behaviour commonly observed across all cultures and environments seem to support this view and provide an - albeit shaky - form of evidence. Complex social constructs such as monogamy/high MPI in humans and the differences in the type of jealousy in men and women regarding infidelity of their partner, can be linked back to logical interpretations of how they could have arisen from natural selection. Furthermore, the exploration of certain traits, both positive (for example, reciprocal altruism) and negative, (for example, violence and depression) can both be found to have links to natural selection. However, there have also been many criticisms of the concept, such as evidence of maladaptive behaviours of homosexuality and suicide, and controversial ethical implications.

Through looking at both sides of the argument, it seems that genetic differences among individuals do play a role in our societal construct, but perhaps a larger role is played by genetic commonalities: by a generic, species-wide developmental program, created as a result of evolution and natural selection, that absorbs information from the social environment and adjusts the maturing mind accordingly. However, most human beings don't live in an environment for which their minds were designed. Environments, even if the organism is designed for them, are unpredictable. That is perhaps why behavioural flexibility evolved in the first place. One could also consider the political implications of evolutionary psychology, as it suggests that there are innate inequalities among humans due to their DNA, implying that humans are indeed not born, or supposed to be viewed as, equal. So, are we in fact genetically structured to be unequal, and therefore are governments defying our human nature through egalitarianism? Finally, in reference to naturalistic fallacy: is living by human nature (and genetics), or culturally created morals the right way to build a society, or has evolution and natural selection determined the development of these morals in the first place?

Lavoisier: Father of Modern Chemistry?

Beatrice Shah Scott

To what extent was Lavoisier responsible for the chemical revolution in the 18th century?

The 18th century is widely regarded as one of the most important periods of chemical progression, as conceptual as well as instrumental advancement in chemistry was made. These developments focused primarily on the importance of oxygen in chemistry are often attributed to Antoine Lavoisier, 'the father of modern chemistry'. His work is considered to constitute a chemical revolution, as vigorous chemical methods were introduced, and belief in the phlogiston theory was eradicated. Indeed, it was Lavoisier's intention to permanently change chemical practice, as he believed that his work "seemed destined to bring about a revolution in chemistry". Alchemy, Aristotle's belief in the four elements, and phlogiston were rejected, in favour of more sound chemical beliefs. However, to attribute this change solely to one scientist is obviously misleading, as it ignores the longer-term changes in chemical practice that occurred prior to Lavoisier's work and the work of other scientists. Lavoisier's work was also arguably not ground breaking enough to constitute a 'revolution' as few groundbreaking discoveries were made. Moreover, any change was facilitated by the 'scientific revolution' that preceded it, suggesting that whilst one individual may have encouraged, and perhaps triggered a change in chemical practice, this was part of a broader trend of improvement within chemistry at the time.

Lavoisier can firstly be considered responsible for the chemical revolution because his work was crucial in causing the phlogiston theory to be disregarded. In 1669, Johann Becher proposed that when substances were burned, or metals were oxidised, a substance called phlogiston was released. Thus, he believed that substances consisted of phlogiston and calx, or metallic ash. This theory was accepted, even though substances appeared to gain rather than lose mass on combustion, and phlogiston came to be considered a 'true substance'. Indeed, when hydrogen was discovered, due to its low mass, it was believed to be pure phlogiston - indicative of how the theory was preventing correct chemical progression from being made. However, through experimentation with sulphur, tin, lead, and phosphorous, Lavoisier could show that both oxidation and reduction involved the newly discovered element oxygen. This was done by combusting, or oxidising, materials in closed vessels to show that there was no overall change in mass as a result of chemical reaction, solving the 'mass paradox' posed by the phlogiston theory. Thus, Lavoisier's theory, whilst not immediately adopted by the established scientific community, "exposed the many weaknesses of the accepted chemical philosophy", and ultimately lead the phlogiston theory to be disregarded, and to more rigorous chemical practice. Therefore, by altering the fundamental belief concerning the nature of substances, Lavoisier is arguably responsible for any chemical revolution that occurred.

Lavoisier's work extended beyond disproving the existence of phlogiston, as he went on to produce and interpret further experimental results that arguably laid down the foundation for modern chemistry. These included the discovery that water, previously considered an element, was in fact a compound of oxygen and 'inflammable air', or hydrogen. This in turn lead to the finding that metals reacted with acid to form salt and hydrogen, whilst previously the gas emitted, inflammable air, was widely considered to be phlogiston. Thus, Lavoisier's vigorous experimentation brought about the dominance of current chemical fact. Indeed, he was determined to disprove the existence of phlogiston - his discoveries about water came about following Cavendish's experiments, whereby the formation of water by burning air and 'inflammable air', was explained through the existence of phlogiston. Equally significant perhaps, was Lavoisier's establishment, for the first time, of the principle of the conservation of mass. Whilst this arguably restated the results of Lavoisier's earlier work in closed vessels, the 'law' in turn led to a greater understanding of chemical elements. Moreover, upon understanding this, scientists were better able to undertake quantitative studies on the reaction of such elements, contributing significantly to the evolution of chemistry from alchemy. These discoveries and ideas were laid out in 'The Elements of Chemistry', and are often considered to have founded modern chemistry, again suggesting that Lavoisier was largely responsible for any chemical revolution that occurred.

However, although Lavoisier seemed to believe that his theory was 'not the work of French chemists' but instead that 'it is mine', this is obviously an exaggeration - many of his achievements were the result of lengthy collaborative work and discussion. This is particularly evident when the completion of Lavoisier's phlogiston theory is considered. In this case, although Lavoisier could show that materials such as a sulphur gained weight when combusted in air, and realised that this was not explained by phlogiston, he was unaware of the actual cause of this change in mass. Indeed, it was through repeating the experiments of phlogistonist Joseph Priestley, that Lavoisier could propose his new theory of combustion which excluded phlogiston (these involved heating mercury calx, or oxide, and collecting the gas produced – this was found to be pure, and oxygen was hence discovered). Lavoisier proposed that air consisted of two parts, a combustible and non-combustible part, the first of which reacted with a metal. Thus, by using and building upon others' discoveries, Lavoisier could disregard the theory of phlogiston and make way for more stringent chemical practice. Yet this should not be taken to diminish Lavoisier's responsibility for any chemical revolution. This is because, naturally, and obviously, nearly all scientific discoveries are made by building on and interpreting others' experiments, as expressed by Isaac Newton. Moreover, Lavoisier's ability to see the faults in the widely accepted theory of the time, despite support for phlogiston continuing until the beginning of the 18th century, is extremely impressive. Therefore, whilst Lavoisier was not the only chemist responsible for gaining evidence needed to disprove the phlogiston theory, he remains an extremely important figure in the chemical revolution.

Other chemists were also responsible for Lavoisier's other noteworthy achievement: the reformation of chemical nomenclature. Although, according the American Chemical Society, Lavoisier was the leader of the group of scientists who brought about this reform, it was in fact Guyton de Morveau, a reformed phlogonist, who shaped new nomenclature. On 18th April 1787, Lavoisier read a paper to the Academy, constructed by him and others, including Louis Bernard, Guytonde Morveau, Claude Louis Berthollet, Antoine François Fourcroy, stating that "it is impossible to improve the science without perfecting its language". However, such perfection was carried out not by Lavoisier but by de Morveau on 2nd May 1787, and, apart from a few terms which were previously used by Lavoisier, was primarily de Morveau's work. Therefore, a key element of the 'chemical revolution', which allowed new ideas to be refined and conveyed accurately, was not a result of Lavoisier's work, even though he encouraged it. This is especially significant when deciding whether Lavoisier was responsible for a chemical revolution, as it led to new concepts of elements and compounds becoming clearly and permanently defined and embedded within the scientific community. Indeed, according to one scientific historian, the "technical terms carry the results of deep and laborious research. They convey the mental treasures of one period to the generations that follow". Thus, whilst perhaps responsible for discarding the phlogiston theory, the creation of a tradition of rigorous chemical practice for a future generation was inspired but not carried out by

Lavoisier, reinforcing the need to recognise the contribution of other reforming chemists of the 18th century.

The creation of chemistry from alchemy can also be placed above the work of any individual when considered in the context of the general 'scientific revolution' that had begun in the late 16th century and continued until the beginning of the 18th century. Whilst this earlier revolution had greater implications for physical than chemical science (evident in the ground-breaking work of Isaac Newton amongst others) it still was significant in shaping chemical practice. This is because it led to an overall shift in the process of scientific experimentation, as, in the 16th century, Francis Bacon established the practice whereby scientists created a hypothesis which they then attempted to disprove. By the time of Lavoisier's work, such methods had become common practice after they were adopted by Boyle, and then others, creating a respected method with which Lavoisier could disprove the phlogiston theory. Therefore, Lavoisier's own success can be considered a result of a wider reform movement. This is especially the case when one considers that the 'scientific revolution created a widespread culture of reform which chemical science was part of, if slightly behind'. Indeed, the need for the creation of 'chemistry' from alchemy was expressed by Robert Boyle, in his paper 'The Sceptical Chemist'. This shows that, due to widespread support from important contemporary scientific figures, reform to the chemical science was perhaps inevitable. Thus, whilst Lavoisier certainly was crucial in bringing about a new form of chemistry in the 18th century, such reform was not a result of his own initiative, and was perhaps inevitable in the context of the broader changes in practice at the time.

Overall, I believe that Lavoisier was responsible for the chemical revolution of the 18th century, as his success and determination in disproving the existence of phlogiston paved the way for accurate future discoveries, and greater understanding of the composition of materials. However, this should not be taken to mean that Lavoisier was solely responsible for such a reformation, as his work with others at around the same time was crucial in allowing him to refine his theory in which phlogiston was discarded. Moreover, other important elements of the 'revolution', such as the reformation of chemical nomenclature, were the complete work of others, even if supported by Lavoisier. The tide of reform at the time perhaps made the reforming of chemical practice, which had long been advocated, inevitable. Therefore, whilst Lavoisier ultimately reformed chemical practice, it was a number of cumulative factors that allowed him to do so. However, to contemporaries, Lavoisier's success, despite opposition from other leading scientists, such as Priestley, must have been particularly remarkable, especially given his background as a non-scientist. An outsider had managed to refine and reinterpret chemical experiment in a ground-breaking way, allowing for future discoveries to be made. Where chemical science had previously been largely excluded from the 'scientific revolution', it was now able to progress alongside other sciences. Therefore, whilst Lavoisier was ultimately responsible for the chemical revolution, and certainly would have appeared so at the time, his discoveries were made due to the great support from the wider scientific community, and the other reforming experiments being carried out by his contemporaries.

Taking to the Skies: Bird Flight and its Impact on Aeronautical Engineering

Senkai Hsia

Flight has captivated the imagination of mankind for millennia, with many dreaming of the day when humans could take to the skies and soar among the birds. This dream became a reality with the maiden flight of the Wright Flyer in 1903, and was made possible through the intensive study and observation of birds in motion. From the first kite 2000 years ago to the first heavier-than-air aircraft at the start of aeronautical engineering, bird flight has been instrumental to the development of human flight. The evolution of bird wings, whether to maximise their speed, manoeuvrability, or energy efficiency over long distances, continues to have an important impact in the design of the latest aircraft today. Thus, birds have indirectly enabled the world to be connected through the skies.

Before looking at the influence of bird flight on human aviation, it is necessary to explain the physical mechanism of bird flight that is mimicked by modern aircraft wings, and why birds have evolved this adaptation. There is a common misconception that the flapping motion of a bird's wing generates the lift force that sustains the bird in flight. Rather, it is the airflow over the relatively stationary wing when the bird is in motion that creates the necessary lift counteracting the gravity acting on the bird. This allows the bird to stay aloft, in line with Newton's First Law of Motion, which states that objects will continue to travel with the same direction and speed if all forces acting upon them are balanced. Bird wings have evolved over millennia to have the curved shape of an aerofoil which is mimicked by aircraft wings as shown in Fig. 1.

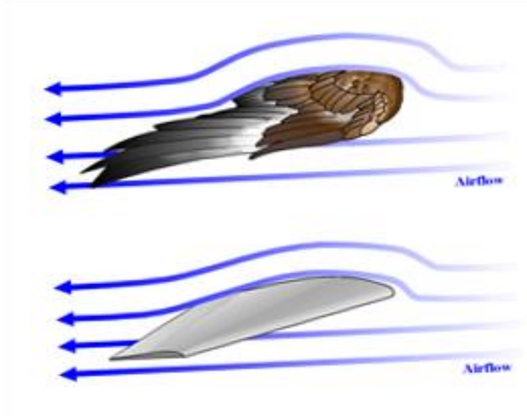


Fig. 1. Airflow around a bird's wing and Aerofoil

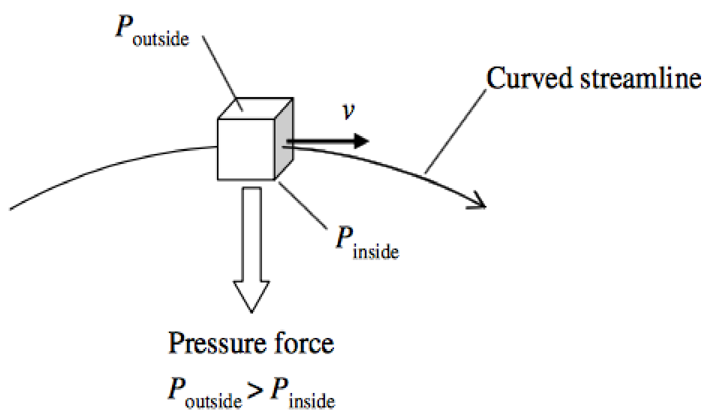


Fig. 2. Diagram of pressure acting on an air particle in a curved fluid streamline

This demonstrates that bird wings create curvatures in the airflow, with an upwardly curved airflow around the upper and lower surfaces of the wing. Since air particles in motion have a minute size and mass, the effect on them from gravity and surface tension is negligible. In fluid dynamics, a change in the direction or speed of a particle is caused by a force generated from a pressure differential between one side of the fluid relative to the other. This is shown in Fig. 2 when in a curved fluid streamline, this results in the pressure on the outside of the curve being higher than the pressure on the inside, causing the particle to bend downwards. If applied to airflow around a wing, this means that the upward curvature on the upper surface of the wing creates a low-pressure zone on the inside of the curve, while a high-pressure zone forms on the lower surface owing to the wing being on the outside of the curve. This pressure differential caused by the air being forced to curve around the wing causes a lift force to be generated with the pressure below the wing being greater than the pressure above it. Additional lift is generated from the reaction force from air being forced downwards as it flows away from the wing. The combination of these factors enables birds to stay aloft, with species like the Albatross capable of flying 10,000 miles without flapping their wings.

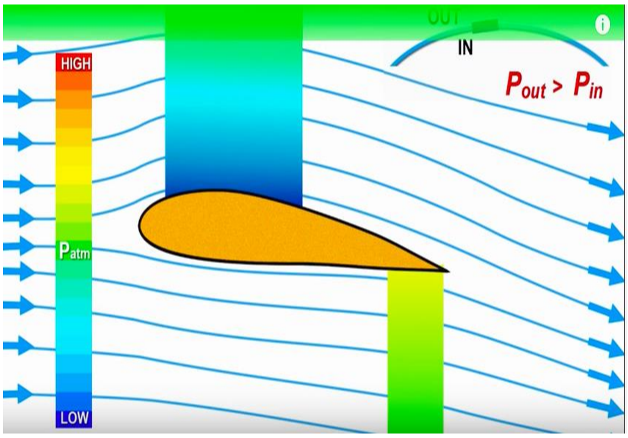


Fig. 3. Pressure acting on the surfaces of an aerofoil: note the low-pressure region above the wing and high-pressure region at the trailing edge below

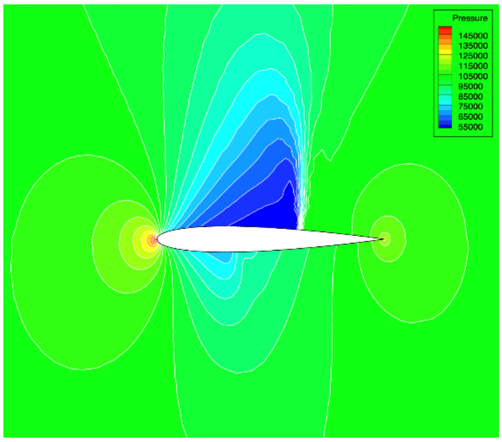


Fig. 4. Computational Fluid Dynamics simulation (Reynolds Averaged Navier-Stokes) showing pressure regions around an aerofoil

The evolutionary advantage of birds using wings to fly is twofold. The first is that it gives them a highly competitive advantage when seeking prey. Being high up gives birds a greater range of sight, with many species evolving precise eyesight to spot prey while flying, reducing the chance of the prey on the ground being alerted to the bird's presence. Some birds then use the high speeds achieved whilst flying downwards and the adaptation of claws and beaks to chase down the prey before it flees. A pertinent example would be the Peregrine Falcon, which thrives in urbanised areas by using upward air currents to effortlessly maintain flight for extended periods of time. Once it identifies prey, it tucks in its feet and folds its wings inwards, deploying its stiff, thin and unslotted feathers in a streamlined shape to reduce drag. This allows it to travel up to 389 km/h when diving to intercept unsuspecting airborne pigeons at lower altitudes.

Fig. 5. Peregrine Falcon in a dive; note the streamlined shape caused by tucking in its wings

Fig. 6. The Artic Tern in flight with high aspect ratio wings

The second advantage is that it allows birds to cover greater distances at faster velocities. Flying enables birds to traverse geographical obstacles from oceans to mountains with far less energy than comparable migrating mammals, with the result that migratory birds are able to travel for thousands of miles to reach warmer climates during the winter when prey is scarcer in the northern hemisphere. There is no better example of this than the Arctic Tern, which undergoes the longest migration in the animal kingdom, with birds nesting in the Arctic Circle travelling 90,000km to their Antarctic wintering grounds. The Arctic Term achieves this by having wings with a high aspect ratio, that is, they are long and narrow.

The first benefit that this creates is that it gives the Arctic Tern greater stability by adding mass on either side of the bird in flight. This increases the bird's moment of inertia, where a greater moment about the roll axis is required to cause the bird to tilt, in a similar effect to a pole held by a tightrope walker.

The second benefit is that it reduces induced drag from turbulent vortices at the tip of the wing where the high-pressure air below the wing curves over into the low-pressure air above it. The greater stability and flatter edge of high aspect ratio wings reduces the size of these vortices and enables the Arctic Tern to spend less energy in the flapping that generates the thrust to sustain flight. Thus, birds have evolved wings that have been optimised for the nature of their flight, whether to traverse long distances efficiently or to maximise speed to catch prey.

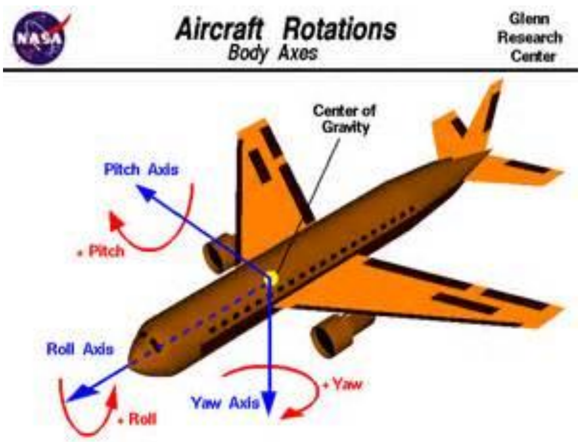


Fig. 7. Aircraft and bird axis of rotation

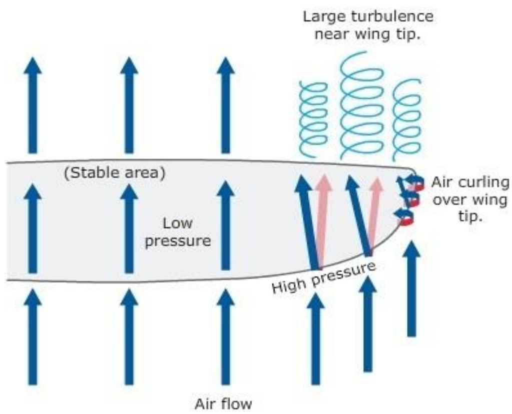


Fig. 8. Diagram of high aspect ratio wings and their impact on vortices

After hundreds of years of attempting to unlock the great secret behind flight, in December 1903, the Wright Flyer flew for 12 seconds, becoming the first heavier-than-air object to achieve sustained powered flight. The key to the Wright Brothers' success was their decision to focus on pilot control, with many early aviators being killed after losing control of their gliders. As no mechanism for this had yet been developed, they turned to birds for guidance. After spending months observing birds and noting the work done by fellow pioneers such as Otto Lilienthal, the Wright Brothers concluded that they change the shape of their wings by twisting the trailing edge in opposite directions (as shown in Fig. 9), altering their roll in flight. This causes lift to increase on the side where the tip is raised and to decrease where the tip has been lowered, with the resulting difference in lift allowing birds to bank to the left and right. The Wright Brothers developed the first system for aeronautical control, using wires to warp the shape of the wing to mimic the bird's motion. This allowed the Wright brothers to control their craft and in doing so they facilitated the first powered human flight, heralding an era of aviation advances.

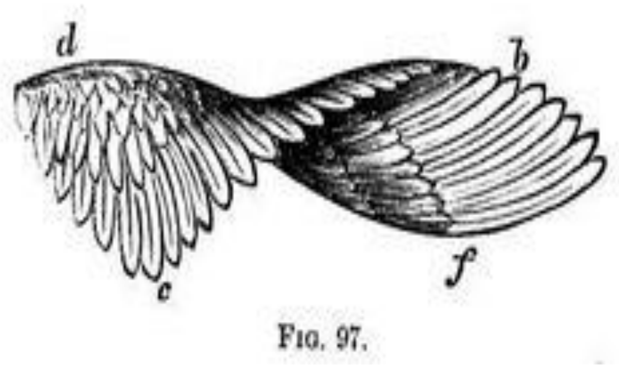


Fig. 9. Bird wing warping as observed and noted in *Animal Locomotion*; Pettigrew, James Bell 1873

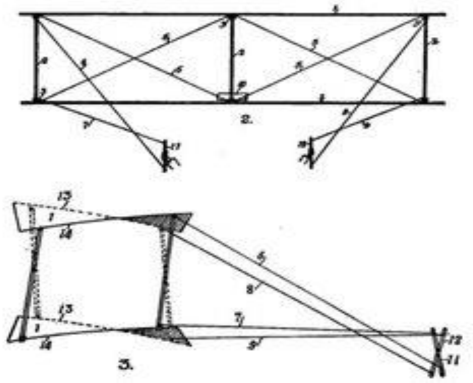


Fig. 10. Orville Wright's diagram of The Wright Glider's wing warping mechanism

The study of bird flight continues to be instrumental in aircraft design today, with the similarities visible simply by looking out of an airplane window. Airplanes also encounter similar problems from the vortices that form at the end of the wing, which increase induced drag. Aeronautical engineers were inspired by the wings of long distance birds to design the solution: winglets. Most aircrafts today have these devices which curve the wing at its tip, as shown in Fig. 12. During flight, the Wandering Albatross' feathers at the tips of their wings bend upwards to an almost vertical position as shown in Fig. 11. Engineers attempting to mimic this adaptation through winglets discovered that, through wind tunnel testing, it effectively increases the aspect ratio of the wing without increasing the actual wing length and so reduces the size of the vortices. This allows modern aircrafts to save 2 billion litres of fuel worldwide and to fly farther with greater loads through the biomimicry of the adaptations of gliding birds.

Therefore, the adaptations of bird wings allow birds to alter the curvature of the air and to generate the lift necessary for flight. This gives them the crucial competitive advantages of being able to catch more prey and to travel long distances with minimal effort. It is through the study and inspiration of such adaptations that the development of human flight emerged, from the Wright Flyer in 1903 to the winglets and raked wingtips on aircrafts today. It was the starting point for the era of flight in the 20th century, going from cloth biplanes to moon rockets in the space of 60 years. Without the influence of bird flight, and the captivation it created in engineers who were perplexed by its seeming physical impossibility for humans, the world would be a much bigger place than it is today. For just as wings allow birds to take to the skies, now so can we.

Fig. 11. Wandering Albatross in flight: note the high aspect ratio wings with raised curved wingtips

Fig. 12. Boeing Advanced Technology Winglet on the 737 MAX-8

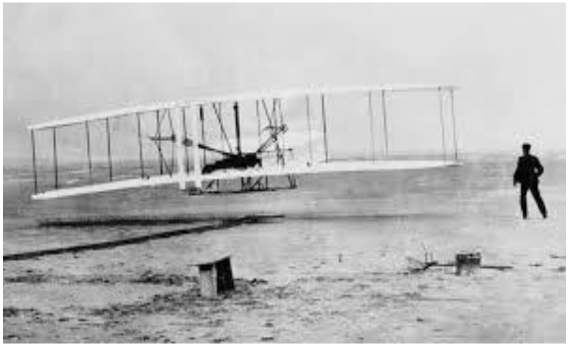


Fig. 13. The 1903 Wright Flyer

Fig. 14. 2013 Boeing 787-9; note the raked wing that also mimics the raised wingtips of birds

Parasites: A Re-Evaluation?

Jonathan Guo

The word "parasite" carries distinctly negative connotations, and this is reflected in its etymology: the Greek word *"parasitos"* literally means "beside food", or rather, someone who ate at another's table. Worse still, the word induces horrifying images of worms longer than limbs and tiny creatures inhabiting the nooks and crannies of our bodies. These "worms" and their relatives can, for example, take over the cells of their hosts and change their DNA, evade an immune system highly adapted over millions of years to deal with disease and foreign bodies, and even in some cases completely hijack their hosts with terrifying intentions. Perhaps it is this taboo around such creatures that has often meant that research into them has been overlooked in favour of more glamourous subjects. However, these "pariahs of science" are perhaps some of the most diverse, interesting and successful organisms in existence, residing in billions of unsuspecting hosts. Alongside this, it is theorised that parasites are some of the drivers of evolution and sexual selection, and the existence of parasites provides many other untold benefits rarely discussed or associated with them. So, are parasites the disgusting scourges on the world that many think them to be, or rather, an integral component of nature and evolution?

Fig. 1. Rod of Asclepius

It is likely that parasites and humans share a long history, and not a happy one at that. Fossilised remains of various parasitic worms have been found in humans dating back to around 5900BC. Indeed, many theorise that the very symbol of medicine, the Rod of Asclepius, which features a snake entwined around a stick, is a direct representation of the traditional extraction of the Guinea worm, one of the oldest parasites to have plagued humans. Since the worm could not be extracted whole for fear of it snapping and parts remaining to cause infections in the body, the traditional method of extraction involved slowly pulling it out over the course of several days to weeks, winding it round a stick to prevent re-entry.

The existence and spread of parasites was first "explained" by the popular theory of spontaneous generation, before the Louis Pasteur's experiments and proposal of germ theory. At the time, parasites were viewed as a symptom of disease rather than as living organisms at all, as then it seemed too bizarre for such a creature to exist. For example, the superintending surgeon of Bombay said in reference to the guinea worm: "The substance in question cannot be a worm, because its situation, functions and properties are those of a lymphatic vessel and hence the idea of its being an animal is an absurdity". Even after it seemed undeniable that these strange creatures were in fact living, scientists asserted that they must have come from the body itself, perhaps like a rash or fever. It seemed intuitive that since parasites were never seen entering the human body, they must have materialised from within.

These theories were first disproved in the 1830s by Danish zoologist Johann Steenstrup, who was one of the first to observe the growth of a parasite (specifically flukes) from eggs into the adult form, and the many different variations in between which were previously thought to have been creatures of other species. This explained why "baby" or child stage parasites had never been observed, whilst also highlighting the unique life cycles that parasites possess. This was compounded by the work of Friedrich Kuchenmeister around ten years later, who theorised that bladder worms were simply an early stage of the more common tapeworm, and that this early form would only grow when transferred into a new host (i.e. from prey to predator), explaining why bladder worms were prevalent in animals such as mice and cows, while tapeworms were common in predators such as humans and cats. Kuchenmeister began performing (morally questionable) experiments from 1850 onwards to prove his theory, infecting animals and humans alike with bladder worms and observing their growth in the latter into tapeworms. His work proved that parasites operated by transferring from one host to the next, rather than through spontaneous generation or simply lying in wait in the environment.

When Darwin's theory of evolution became popularised, however, the scientific community began to develop a different view on parasites. They began to believe that evolution had a driving force: to create better, more complex organisms capable of surviving better independently, as well as being able to outlast competitors. It was zoologist Ray Lankester who first pointed out that, unlike other organisms, parasites often simplified and degenerated their bodies. The barnacle *Sacculina carcini*, for instance, hatches from its egg with a fully developed body, legs, a head, and a tail, but quickly finds a host crab and degenerates all of its limbs therein, growing tendrils which spread through the crab's body to absorb nutrients. These sorts of parasites soon came to be known as "a breach of the law of Evolution" (as coined by Henry Drummond in 1883): in other words, a literal degenerate. It was from this definition that derogatory use of the word became prevalent.

Fig. 2. The extravagant plumages of peacocks

As Darwin presented his theory of evolution via natural selection, he also talked about the concept of sexual selection in order to explain the existence of traits which seemed to contradict his observations, such as the large tail feathers of male peacocks or the large antlers of mammals such as moose, which appear to make them much more noticeable to predators and thus much more vulnerable. He suggested that such traits arise owing to a second type of selection: sexual selection, in which males compete with each other in terms of trait or behaviour to reproduce with the opposite sex. However, after these observations, there was still much debate in the scientific community as to why females would develop these preferences for exaggerated traits.

An explanation was offered in the form of the Hamilton-Zuk hypothesis in 1982, which utilised the ideas of the Red Queen Hypothesis. The Red Queen Hypothesis states that there is a constant "arms race" between humans and diseases. As diseases mutate over time due to evolution or antigenic drift/shift, humans eventually also become immune to these new variants due to our immune system's adaptability and the rise of genes conferring resistance, thus increasing selection pressures on pathogens to further mutate to increase their potency. If there is a host and a parasite population where some hosts develop a gene resistant to the dominant parasite at that time, then females would choose the males with this gene as it will give the offspring a better chance of survival. The next generation of offspring would then be resistant to parasite 1: however, this means that parasite 2 then becomes the dominant parasite (parasite 1 has now lost almost all of its potency), and in this generation, resistance genes to parasite 2 would be preferred. Much like the Red Queen Hypothesis, this cycle would continue forever as the evolution of new resistance genotypes in the host population lead to the engenderment of new parasite genotypes, and so on. Therefore, heritability for parasite resistance would always be high.

This raises the question of how females would detect genes resistant to the dominant parasite in potential mates. Hamilton and Zuk concluded that they would have to have a physiological indicator of some measure, such as an extremely exaggerated bright cluster of feathers or the ability to produce a very energy-costly song, which would show that the necessary genes for resistance are likely present from the displayed healthiness of the male. This led Hamilton and Zuk to predict that species with strongly sexually selected traits should be subject to a much larger variety of parasites and vice versa - this proved correct in their investigation of blood parasites with respect to the flamboyance of various species of North American birds, where they found a strong correlation between the two.

But why does sexual selection even exist? It appears much more efficient to reproduce asexually, or at least have the option to if no sexual partners are available. For example, 10 asexually reproducing lizards could give rise to far more offspring than 5 male and 5 female lizards, as would be the case from sexual reproduction. So why does it happen? The "Lottery" hypothesis states that in unstable environments genetically diverse organisms would have better chances of survival than that of clones. This hypothesis was tested in 1985 by Curtis Lively, using a species of snail named *Potamopyrgus antipodarum*. Most populations of the snail were identical clones who reproduced asexually (via parthenogenesis: that is, reproduction from an unfertilised ovum), while a significant minority of populations utilised sexual reproduction. Lively decided to test whether the environments the snail populations lived in would affect their method of reproduction, as the Lottery hypothesis surmised. Thus, he tested populations not only in streams which faced constantly changing conditions and floods, but also in lakes where the habitat conditions would be much more stable. However, when Lively began examining the snails he realised that some of the populations were riddled with fluke parasites.

Lively therefore decided to also test whether the presence of parasites affected the means of reproduction, as in theory variation among the population would make it harder for a parasite to thrive. Lively was however, unconvinced by this, stating: "if you're going to have a selective pressure that's intense enough, it should be something that has big, immediately obvious effects. At least in humans in this country, we don't see those big effects." Nevertheless, it soon became clear to Lively that the snails in the lakes (stable conditions) had a much higher rate of infection by the fluke parasites than those in the streams (changing conditions), and yet there were more males in populations in the lake than in the streams (note the method of asexual reproduction in these snails occurred in females), and the higher the rate of parasite infection the more males he found. This went against the results expected from the Lottery hypothesis, as in theory the lake is a more stable environment and therefore should favour asexual reproduction in comparison to the streams, again supporting the idea that parasites cause sexual selection/reproduction.

Finally, in an experiment run by North Carolina State University, some of a population of fruit flies with two mutant genes affecting appearance were infected with parasitic wasps and some were not. The offspring of both groups of flies were then examined for signs of genetic recombination (traits found in the offspring with no discernible link to either parent), and it was found that in flies which survived the wasp infection there was a higher rate of recombination, indicating a higher rate of variation in the offspring.

Another theory related to the role of parasites is the "hygiene hypothesis", first reported by British epidemiologist David Strachan in researching the increasing incidence of allergies in the modern world, mirrored by an increase in the rates of autoimmune diseases. It is therefore hypothesised that exposure to germs and parasitic attacks early on in our life aids the strengthening and development of our immune system and helps reduce the likelihood of developing autoimmune disease, and that the increasingly sanitary conditions children are growing up in is conversely leading to an increase in autoimmune conditions.

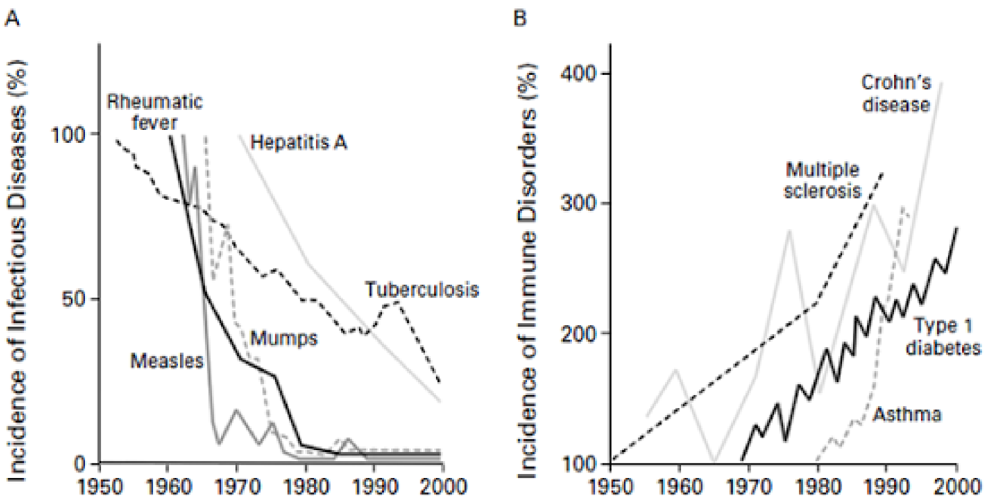


Fig. 3. Graph showing relationship between falling infectious disease rates and increasing autoimmune disease rates

It has been shown that infection with helminths (parasitic worms) can help to prevent autoimmunity and allergies. For example, in areas of the world where helminth infections are more common, there is a lower incidence of allergies and autoimmune conditions, but this could simply be due to the less sanitary conditions, also implied by the prevalence of such organisms in these areas. In fact, evidence from animal models of autoimmune conditions such as multiple sclerosis and Crohn's disease has shown that helminth infections can protect against these diseases whilst simultaneously reducing the severity of their effects. Helminth infections have also been shown to reduce the frequency of allergic reactions, perhaps owing to the tendency of these organisms to modulate their host's immune system. Although it is ostensibly not the most pleasant from of treatment, it opens new avenues of research into possible alternatives to immunosuppressants, perhaps stemming from immunomodulatory secretions.

Furthermore, parasites play a fundamental role in natural population control and regulation in ecosystems, with an estimated 50% of all organisms being parasitic. Without these organisms, populations would explode, resulting in imbalances in population sizes and a likely growth in predatory species, in turn resulting in an increase in harsh defensive traits in vulnerable plants and animals.

In conclusion, parasites can be seen to be a unique, endlessly fascinating and yet distinctly terrifying group of organisms. Although the very mention of the word is enough to evoke feelings of disgust and contempt in many, it has become increasingly evident that these historically undesirable organisms were one of the key driving forces in developing evolution and the world as we know it today. Indeed, it was Johann Steenstrup, the man who first revealed some of the remarkable characteristics of parasites, who wrote thus: *"I believe that I have given only the first rough outlines of a province of a great terra incognita which lies unexplored before us and the exploration of which promises a return such as we can at present scarcely appreciate."*

Where is the Cure for Cancer?

Hein Mante

Cancer has haunted humanity for thousands of years. From the first known case of cancer, recorded by Imhotep as being incurable, to modern day hospitals with a wealth of sophisticated machinery, cancer has plagued us, with no cure in sight. Cancer is the second largest killer in the world, after cardiovascular disease, causing 13% of all deaths in 2008. The scale of the problem is indicative of the desperate situation which we find ourselves in. There are well-established forms of therapy to treat cancer. Foremost amongst these are surgery, radiotherapy and chemotherapy, each presenting its own limitations and each hampered by a paucity of innovation. Yet cancer is not a single disease. Rather, it is a group of over 100 distinct diseases. Herein lies the true challenge presented by cancer; the lack of homogeneity in different forms of cancer means that no single cure is likely to ever be achievable. We cannot hope to cure uniformly what is not uniform. This problem is compounded by the fact that cancer, unlike many other diseases, is the result of our own cells going out of control, meaning that each cancer is unique; different genetic causes, different immune systems, varying antigens and different resources available to the cancer, mean that each will proliferate differently. The defining feature of cancer, the link between each of the different forms of the disease, is the uncontrolled proliferation of cells, with the ability to metastasise. This makes cancer one of the most ruthless and complex diseases known, requiring that any cures are equally extraordinary both in the research needed for their discovery and their inner workings. For death from such a complex class of diseases to be prevented (as a cure need only prevent death, I would accept a vaccine as a type of cure), a unified, innovative response is needed, one which doesn't rest on its laurels, nor is restricted by conflicting evidence or over-caution.

The very nature of cancer doesn't lend itself to a cure. The great variety of different forms of cancer means that there is no uniform reaction to any form of treatment: each cancer is unique to the patient's genetic code, and caused by specific alterations to turn their proto-oncogenes into true oncogenes. Cancers of different tissues behave and respond to various treatments in different manners. In addition, cancers are the great imitators of diseases, with a marked lack of distinct symptoms leading to much later diagnosis than desirable, giving the cancer far more time to establish itself, with the hope for a cure diminishing drastically as the cancer progresses. Indeed, cancers display a vastly greater mutation rate than any other cell in the body (ironically, the mutation which destroys our body is itself strengthened by more mutation). For example, when a cancer is rendered hypoxic through antiangiogenic drugs, which were at first believed to be a 'silver bullet' to cure all the forms of cancer, there are two effects: they become more resistant to radiotherapy (three times the dose is needed to kill a hypoxic cell), and become far more likely to metastasise. This encapsulates precisely the nature of cancer: it constantly adapts to its environment, ensuring its survival; to use the words of Mukherjee, "If we, as a species, are the ultimate product of Darwinian selection, then so, too, is this incredible disease that lurks inside us". Cancer, through its inherent genetic instability, is able to replicate and adapt at an extraordinary rate, providing those who seek to cure it with a shifting target. Thus cancer becomes resistant to many different forms of therapy (for example, after Sidney Farber's miraculous discovery of antifolates, despite genuine remissions, the leukemia returned within months for most patients). Therefore, just as with the problem with superbugs and overuse of antibiotics, unless every cancer cell is destroyed, the fittest will remain alive, and proliferate further. For this reason, several potential cures which aim to attack one particular symptom or type of cell, such as monoclonal antibodies, are already one step behind their adversary: they don't evolve even as their target does. This, combined with the numerous varieties of cancer, each of which responds to a varying degree to different treatments, results in a many headed hydra of a disease, one ever changing, which is hopeless to pin down, even before considering the shortcomings of methods of treatment.

The pathological features of cancer greatly affect prognosis thereof. Cancer is inextricably linked to age, with the risk of developing cancer being a thousand times greater at the age of 80 than during the teenage years. The effects of this upon therapy are numerous. Being a disease of age, cancer has only come to the forefront of our mentality relatively recently (due to increased life expectancies), with the Second World War marking the start of the era of cancer treatment. Prior to this, although known as a disease, other diseases such as tuberculosis were much greater killers, and therefore there was little focus upon cures for cancer. As a result, the body of cancer research (in particular an understanding of the mechanisms of carcinogenesis) has been somewhat constrained compared to a number of other diseases. Moreover, as cancer is most common in one of the frailest groups of the population - a group with less active immune systems, who can handle only smaller quantities of toxic drugs - the sufferers are more likely to be overcome by the disease. The fact that cancer stems from an uncontrolled growth of the body's own cells further complicates this problem, as it means that no vaccination for cancer is possible. The only sure way to prevent cancer is to stop all cell growth (which is problematic for obvious reasons). As such, vaccination, a great tool against other diseases (as people can be made to fight a weakened form of the disease when they are in best health) is removed as an option when considering how to cure cancer. Therefore, the demographics of cancer - the fact that it targets those older, the condition of the sufferers, and lack of research - all conspire to make curing it a phenomenally difficult task.

Surgery and radiotherapy are two of the most widely used forms of cancer therapy available, both dating from the 19th century. Surgery is the oldest form of cancer treatment and needs little introduction: it involves physical removal of the cancer in order to stop its proliferation. There have been significant improvements to surgical practices since the barbaric mastectomies of Victorian times. The use of keyhole operating techniques, sterilized equipment, and robot arms, have all resulted in a decrease in patient mortality, both from the operations and the cancers themselves. Radiotherapy has also seen significant refinement since its discovery by Roentgen in 1895. Image-Guided Radiotherapy and Intensity-Modulated Radiotherapy both reduced the irradiation of nearby tissues, as the radiation became more and more precisely shaped to the tumour. However, despite significant refinements in techniques, both types of treatment appear to be nearing the limit of their potential. Radiotherapy still has some potential to be refined in the form of proton therapy, which, due to the Bragg Peak, deposits most of its energy far nearer to the end of a trajectory. This allows far greater irradiation of the tumour, while reducing the exposure of surrounding tissues. On the whole, due to the lack of radical innovation in these fields, although thousands of lives have been saved by surgery and radiotherapy, to cure cancers which currently have very low survival rates, we must look to other sources.

Chemotherapy is the other mainstay of current cancer treatment. Chemotherapy has the advantage over surgery and radiotherapy, as it is continually being improved and refined in significant, and occasionally radical ways. Indeed, most of the improvements of post-war cancer treatment stem from chemotherapy, the basic ideology of which is a prime example of scorched-earth medicine: if you attack the whole of the body with cytotoxic chemicals, then cancer cells, which divide rapidly, should be the most affected. Chemotherapy attacks the division of cells in a number of ways, ranging from drugs such as tamoxifen, which blocks the hormone oestrogen, to targeted therapy drugs such as Imatinib which aim to interfere with specific molecules (in this case bcr-abl). However, the problem with chemotherapy, as with any cancer therapy, is totality: it kills most of the cancer, but, for both of the drugs mentioned above, remission is only temporary. Therefore, although precious months, or even years of life may be bought back, fundamentally, a large proportion of chemotherapy represents only a temporary cure. This problem arises from the method of application - similar to radiotherapy in its nascent stage, chemotherapy suffers from a lack of precision: it affects the whole body, causing a host of complications and side-effects. As a result, due to the lack of specific targeting of the tumour, in the interests of reducing the suffering of the patient as much as possible, chemotherapy cannot be used above certain levels. Therefore, although chemotherapy has a greater potential for innovation in terms of methodology than surgery and radiotherapy, it lacks the precise targeting of either of those, restricting dosages and causing many side effects.

One must also consider the economics of the matter. Global health costs are only rising. The global cancer market, valued at US $36 billion in 2006, rose to $43 billion by 2008, and the trend looks to increase further, as medical inflation is much higher than normal inflation. This is in large part due to the expense of chemotherapies, which provide a small survival benefit for a large cost compared with other forms of treatment. For example, Herceptin, which costs £30,000 per year, only improves life expectancy for those with advanced breast cancer by 6 months. This holds true for many other forms of chemotherapy, and, as such, cancer treatment is becoming very expensive. For a country such as the UK, where healthcare is a public service, it is economically unsustainable to provide the most advanced (and expensive) chemotherapy for all of its citizens. Therefore, while drugs remain so expensive, even if cancer can be put into remission to a certain extent, the widespread application thereof is simply not feasible in the long term.

Provision of even the most expensive drugs would be possible, if they were cheaper. However, due to patent rights, drugs remain very expensive, as companies need to earn back the huge investment they made developing the drug. This is indicative of another deep-rooted cause for the lack of cures for cancers. In the wake of the thalidomide disaster, where lack of drug trialing led to widespread unforeseen side effects, the requirements for a drug to be licensed became far more demanding. Although this had the advantage of resulting in considerably greater certainty of the effectiveness of drugs and sparseness of side effects, it also drove up the cost of obtaining a license for a new drug over 30 times. This led to the creation of large conglomerate pharmaceutical companies, which, as large companies do, prioritised profit, rather than providing the best care that they possibly could for their customers. In addition, in the 60s, the nature of research changed. Before that, new drugs were discovered by the somewhat haphazard method of synthesizing millions of different compounds and testing them for their potential effectiveness. In the 60s, the industry changed their method in favour of ‘designing drugs’, which involved applying knowledge of cellular biochemistry in order to determine the precise molecules needed, and then synthesizing them. The problem with this apparently more effective method of generating new drugs, is that it presupposes a very sophisticated knowledge of cell biochemistry, which simply isn’t the case in a system as complex as that of a tumour. Together, both of these factors led to the shift of pharmaceutical companies away from markets such as cancer drugs, which are far more high-risk investments. With a few exceptions (such as insulin), this has meant that most chemicals created since then are merely variations on previous drugs. The areas which were more profitable, namely ‘lifestyle drugs’ such as Prozac, Viagra, and Xenical, became the focus of these companies. Therefore, in attempting to improve the pharmaceutical industry from the days of thalidomide, we have now moved to the other extreme, where the great rigor of drug trials is actually stifling (although not stopping) the investigation of new ideas. For a disease which causes death on as large a scale as cancer, ensuring that those treated are at an absolute minimal risk of suffering any harm from their medication is a rigid mindset which is unlikely to yield many cures. Some hope can be found in the process which the Ebola vaccine went through: due to the large scare during the recent Ebola outbreak in West Africa, the pressure to develop a vaccine led to a greatly accelerated trialing phase, with the drug taking about 8 months to go from Phase I trialing to Phase III trialing. If trialing time and costs were reduced, then a situation in which cancer drug research is infused with new innovation could well arise.

Just as the economic situation is unconducive to a cure for cancer, so too is the scientific situation. Although statistical analysis is a useful tool, and can help identify trends (such as the connection of lung cancer to smoking, or the fact that prostate cancer rates increase in Europe with distance from the equator), the mechanism of carcinogenesis and the proliferation of cancers aren't fully understood. Take the idea of prevention being better than cure. Although intuitively pleasing, the lack of definitive knowledge on the subject is alarming. There are many known carcinogens, ranging from obvious culprits, such as plutonium, to the most unavoidable, including wood dust, glass wool, ethanol, and air pollution. Yet despite all of these risk factors (which, it should be noted, are in no way universally avoidable), mysteries such as the Sellafield outbreak of leukemia (which, according to James Le Fanu was instigated by some unknown infectious disease) remain. Such lack of knowledge has led to a degree of quackery amongst even the most respected institutions. Sir Richard Doll of Oxford University, for example, insisted that the Western diet was the greatest cause of cancer in the world (not even admitting that aging was a greater cause). Another example is Harvard's Professor Howard Hu, who cited minute traces of carcinogens in water sources, which were calculated to contribute about 0.1% to the total carcinogenic exposure of humans, as the main source of cancer. The extent of this uncertainty, leading to fad diets, and to misinformation about cancer on a very large scale has acted as a distraction to useful cancer research, muddying the waters and thus hindering the accumulation of useful research. Moreover, there are inconsistencies in results - not just in prevention, but in other field of research too. Various research groups, such as the Cancer Cell Line Encyclopedia and Cancer Genome Project, are unable to obtain consistent results for effectiveness of chemotherapy. Even when they do, there are still inconsistencies in the dosage required. In summary, a lack of knowledge, and confusion over the origin and nature of cancer means that the situation for the discovery and universal acceptance of a cure is not promising.

The most promising areas of research are still in development. Nicholas James referred to the 'gold-standard' of cancer treatment as therapy tailored to each patient. The sequencing of the human genome marks a significant breakthrough in the struggle against cancer. This greatly adds to the store of human knowledge, crucially opening up the genetic code, which, due to the fact that it is unique to each patient, has cleared a path for cures which are also unique to each patient. Indeed, given enough time, this may result in personalised treatments, which focus on methods that would be most effective for the individual. In addition, the use of stem cells has significant promise for curing cancers. Stem cells have a double use in treating cancer: they can also be used to replace tissues damaged by chemotherapy and radiotherapy. This would allow for much higher doses, as damaged tissues could be replaced by tissue grown from a culture of stem cells. Interestingly, it is believed that only cancer stem cells, which make up between 1 to 3% of tumours by mass, have the capacity for infinite division, and thus the eradication of all cancer stem cells is both necessary and sufficient for curing a patient thereof. The effects of treatments which would attack specific cells, adept at targeting them in each patient's own environment, would be transformative. Yet the novelty of this research, combined with the high costs (although it should be noted that the cost of sequencing a genome was as little as $5,000 in 2013) and a lack of infrastructure for the large scale implementation of these technologies, means that they have not yet taken off. All the same, if they were to be successful, they would herald a transformation in the nature of cancer treatment - a transformation which would make the treatment just as versatile as the disease.

In conclusion, the challenge of finding a cure for cancer is immense. Indeed, the question of finding one cure for cancer, due to the heterogeneity of its different forms, is, in some sense, absurd; it is like asking why there is no cure for infectious diseases. Yet even if one considers why there are not cures for more forms of cancer than at present, there are a multitude of reasons. There is some success already, with the classic treatment of surgery, radiotherapy and chemotherapy conferring the five-year survival rate of cancer of about 70% in 2000. However, as with any field of endeavor, success limits innovation, meaning that progress towards a cure is slowed by the relative success of these three therapies. From the scientific situation, where the degree of conflicting viewpoints and evidence is astounding, to the strict nature of drug trials, resulting in pharmaceuticals being less willing to investigate radically new drugs - the climate for investigation of a new cure is non-existent. Moreover, the economics of cancer, with social healthcare services being overwhelmed by the scale of the disease and cost of a cure (a problem which is only likely to worsen with the world's aging population) mean that, even if one were to be discovered, they wouldn't necessarily be available to the whole spectrum of cancer sufferers. The most promising areas of research - making use of genome sequencing technology and stem cells - reflect the shift that must occur in the climate of cancer treatment for a successful cure. Radical new thought is required, with cures as numerous and varied as the disease which they seek to combat. If an environment where innovation is encouraged and treatments are tailored ever more precisely to individuals were to arise, then a situation in which the prospects for cancer patients would improve radically and where the medicine mimics the disease in its variety and evolution, could arise in tandem. Only if such a shift occurs will we be truly ready to embark upon what Nixon called the "War on Cancer".

Reducing Rising Economic Inequality

Krishna Hemant Kotta

Introduction

Inequality is an economic idea that has existed ever since modern civilisation was established. It is a measure of the distribution of wealth and income in a country. There are two main types of inequality: inequality of opportunity (e.g. quality of education and the availability of jobs) and inequality of outcome (e.g. income and wealth distribution). Some inequality in outcome is good for the economy; it incentivises hard work and entrepreneurship. However, global inequality (i.e. the gap between rich and poor in many countries around the world) has become very high in recent years. This has negative impacts on the health of an economy, social cohesion and political support. Hence reducing inequality should be a major priority for all countries that face this problem. This article will outline different policies that can be used to reduce inequality in the UK and the rest of the world. Firstly, it will argue that the process through which human capital is accumulated must adapt to fit the needs of the modern economy. Secondly, it will outline how the Gig economy can be properly regulated. Finally, it will also analyse how different deciles of society should pay for the changes that are happening in the energy sector as we shift to renewable energy.

Reforms to the Human Capital Accumulation Process

75% of businesses are predicted to increase their high-skilled job offerings. By contrast, the net job offerings for low-skilled workers are to decrease by 10%. Businesses' demand for skills are changing rapidly as we go through the digital revolution. This megatrend is likely to affect people of all skill levels, from accountants to train drivers. Therefore, if the workforce is not upskilled, we may see a rise in structural unemployment. However, if we do make the transition into a digital economy successfully, many new jobs will be created by it. These jobs are likely to be high-skilled, high-productivity jobs, boosting salaries. Therefore, this transition has the potential to reduce inequality. However, if we are to be successful in this transition, life-long learning and increased training should be established and made available for all. To this end, the growth of Massive Open Online Courses (MOOCs) such as Lynda and Udacity is encouraging. However, the problem is these courses are currently used predominantly by the well-off. The average number of training hours per week in the UK has roughly halved since 1997.

In order to change these trends, the government could adopt elements of the model used by Singapore, where the government consults with businesses every five years to establish what skills are required. These are then provided by official skills training organisations. Those at the bottom and middle of the income distribution are given credits to spend every year encouraging them to retrain. Funds can part come from the apprenticeship levy and there may also be a role for unions. The tripartite system in Denmark where unions, government and employers meet regularly has also been effective in up-skilling the workforce. Therefore, unions should have increased responsibility of organising retaining opportunities in the future. Apart from reducing inequality, this will also improve productivity of the workforce which is well below the pre-crisis trend. Improved productivity will encourage growth. The process of human capital accumulation should be reformed to reduce inequality of opportunity (which leads to inequality of outcomes) rather than exacerbate it in a fast-changing working environment.

The Gig Economy

Another recent trend in the labour market is the emergence of the gig economy and increased demand for the self-employed. This new business model, adopted by companies like Uber, can be explained by the tax incentives that exist in the system: companied do not have to pay taxes on self-employed workers (meaning the government also loses out), or provide perks like paid holidays. The power of a self-employed worker in the employee-employer relationship is often weaker than a conventionally employed worker's, which can lead to lower wages. This power dynamic can partly be explained through the lack of unions available for the self-employed.

Estimates suggest that the government loses £5.1 billion as a result of lower taxes paid by the self-employed every year. This loss is likely to rise as 12% of the conventional workforce are considering taking part in the gig economy the coming year; currently, only 4% of the entire workforce work in the gig economy. Hence ensuring the gig economy is properly regulated is very important to ensure workers are not unfairly paid. One of the options is to use technology to allow the self-employed to come together and discuss issues affecting them, providing a platform for their express their views similar to a union. Higher minimum wages for unguaranteed hours can also reduce the disparities in pay. Another option, recently suggested by the Conservative government in their 2017 manifesto, is to increase taxation on the self-employed. This went down disastrously politically, despite being a good policy on paper, and was subsequently scrapped, highlighting how difficult reform can be politically. In general, government regulation has to keep up with changing work practices. This should help reduce inequality. The recent ruling that Uber drivers are employees rather than self-employed is a step in the right direction. However, more must be done to regulate the whole of the gig economy rather than focusing on individual companies.

Changing the Energy Sector

The energy market is undergoing rapid changes due to the renewable energy revolution. Research from the Joseph Rowntree Foundation (JRF) suggests that the rich will reduce their energy bills more than the poor as a proportion of income by 2020 under current government proposals. The impact on bills under current policy is shown in Fig. 1.

This is because the rich are more likely to adopt renewable energy faster than the poor owing to costs involved. This can be considered unfair. The poor release less emissions than the rich, as illustrated below, yet they stand to benefit less from the current energy policy (due to lower cuts in bills as a proportion of income). Research shows the average impact on household bills for the lowest decile of households is a 7% reduction in costs. For the top decile, it is a 12% reduction. Indeed, if technology doesn't improve as expected by the government, the bill will actually rise for the poorest 10%. Hence, inequality after basic necessities will rise as a result of this policy.

JRF have proposed an alternative, more ambitious energy policy. This entails replacing all energy systems in the country costing £293 billion. The bottom 4 deciles will receive these changes for free. The other 6 deciles will be given a loan which they will have to repay, dependent on their energy savings. The agenda will also be funded through the energy levies that already exist such as EU ETS. The graph in Fig. 2 illustrates the estimated changes in bills if this alternative policy is adopted.

As can be seen, this new policy is a lot more progressive. It will reduce inequality of outcome (after basic necessities) rather than increase it in the way that the current policy has. Even so, this policy option is just one of the many available to the government. The principle of the argument is what is important. As we go through this energy revolution, more help should be given to the poor so that they are not the ones paying the most (subsequently leading to an increase in inequality) for the changes going on. It is up to governments how they plan achieve this and fund the new strategy. Maybe an increase in taxes...

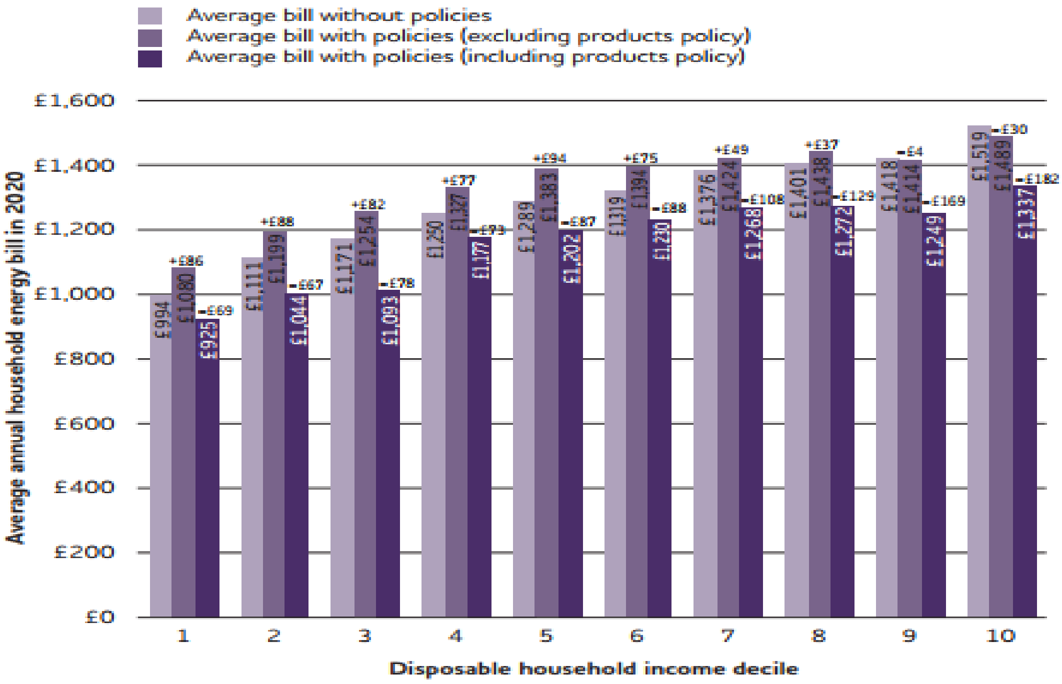


Fig. 1. Average household energy bill without policies and with policies in 2020 by disposable household income decile.

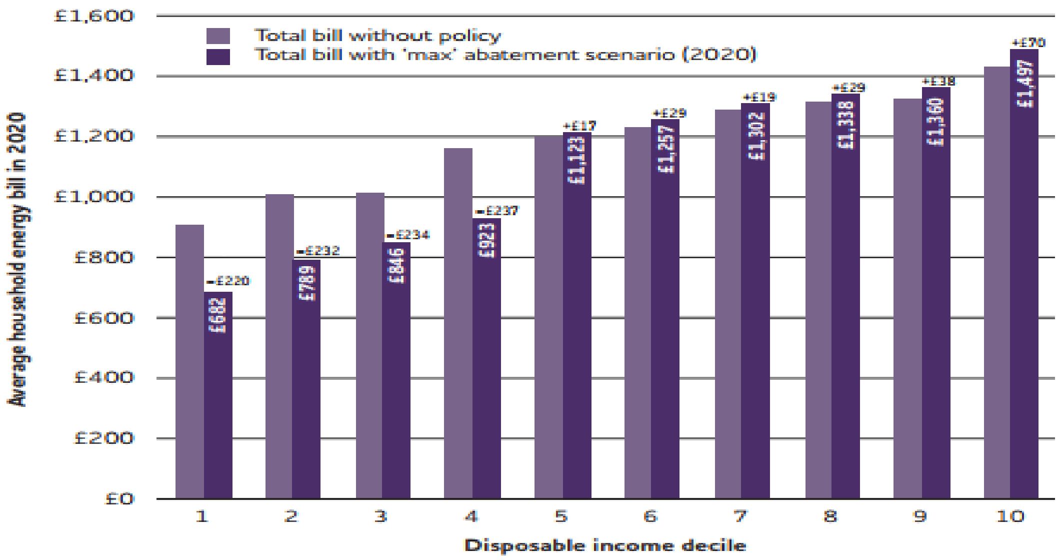


Fig. 2. Distributional impacts of alternative policy approach by disposable income deciles (effect on energy bills).

Extract from 'Reducing Inequality' by Krishna Hemant Kotta

The Varying Forms of Intelligence in Birds

Constantine Holle

Although the term "birdbrain" is still understood to be an insult, there has been a surge recently in research showing that birds are actually far more intelligent than we believed for hundreds of years. Considering population size and dispersion, they are the most successful class of vertebrates, occupying every single major land mass in the world, and their intelligence is crucial to their success. Birds are capable of extraordinary mental feats, and what really sets them apart from other creatures is how many different forms of intelligence they display: social, navigational musical and adaptive.

Everyone has heard the phrase "Birds of a feather flock together" and there are many well-known examples of the sociability of birds. Geese fly in a "V" formation and chickens have a strict, distinct social hierarchy or "pecking order". However, some less well-known examples are even more astonishing. Many birds have a strong sense of reciprocity, a trait once thought to belong solely to humans. Crows, for example, will often give "gifts" (shiny trinkets or worms) to humans who regularly feed them.

This sense of reciprocity also implies that some birds practise delayed gratification. A team researching Goffin's cockatoos found that the birds, in order to receive a prize of a more delicious cashew, would hold a pecan in their beaks for up to 80 seconds. This level of intelligence is at least on a par with that of human children doing the "marshmallow test"; while the children merely had to sit still and consider the marshmallow before them, the birds had to hold the pecan against their taste organ. Practising delayed gratification requires a level of intelligence which is rare in animals, but highly useful: the plentiful supplies of food available in the summer allow birds to build stores for the winter.

Evidence of even more sophisticated social skills was found by researchers at Cambridge, who observed that Eurasian Jays anticipate what kind of food another bird prefers. Birds enjoy variety, and prefer to mix up their diet given the choice. The researchers saw that when jay A knew what kind of food jay B preferred, jay A would attempt to provide jay B with that type of food, regardless of what jay A had eaten. Delayed gratification and reciprocity allow for the effective functioning of societies in both birds and humans.

While their social intelligence is not unique, birds are far more advanced than most other animals in their navigational intelligence. Birds mainly rely on the earth's magnetic field to navigate: even without any visual cues, caged European robins (who migrate south every year) consistently tried to escape towards the south but when their cages were magnetised, they lost their bearings and flew in every direction.

Although the magnetic field is important, most birds navigate using multiple factors, including landmarks, scent and the North Star. Therefore, if one of these factors becomes unusable, a bird will usually be able to return home by utilising the other tools at its disposal. Some species also display excellent memory, with certain birds being able to memorize thousand-mile journeys after only one trip following their parents. For example, the Western scrub jay is a hoarder, storing nuts, insects, and fruit for later, ensuring it has the edge over competitors. Not only does it remember the precise location of its caches, but it also can remember their contents. A team of researchers at Cambridge discovered that Western Scrub Jays use their experience of what degrades fastest to choose which cache to dig up: they will eat perishable insects as quickly as possible, while leaving hardy nuts for later months. This remarkable feat implies that the jays have something like human episodic memory, and the capacity to learn from experience. This powerful memory, shared by many other birds, plays an important part in their navigational powers, and helps to explain how migratory birds travel thousands of miles using only a handful of landmarks.

The most fascinating and unique form of intelligence in birds is their musicality. Along with flight, it is their defining feature. Perhaps the most remarkable thing about birdsong is the number of similarities between how birds learn song and how humans learn speech. Birds learn to sing in a way that resembles the babbling heard from human babies: first repeating syllables or notes to learn them, then randomly stringing them together, then finally combining learnt syllables in ways that make sense or sound nice. Birdsong is not, as many people might assume, genetically encoded (with zebra finches being an interesting exception).

However, the real question is why birds have developed this almost entirely unique form of intelligence. Many studies show that females prefer males with a large repertoire, as well as considering the skill with which the songs are performed. This is likely to be because of the link between a bird's musical aptitude and its overall intelligence: a bird that knows more songs is likely to be smarter, and thus a better provider. Also, there is a surprising amount of motor control required to sing well. A bird's vocal organ is the syrinx, unique in that it requires complex small scale motor skills to utilise fully. It is split into two parts, and some of the most gifted songbirds, like the mockingbird, can use both parts independently, creating two voices from one bird. The mockingbird is also famous for its ability to mimic. After hearing the song of another bird a few times, a mockingbird can mimic the song so perfectly that it looks the same on a sonogram.

Finally, it is important to understand how these unique creatures populated the entire globe, and claimed the title of most widely dispersed class of vertebrates. Flight obviously has helped them to populate areas other creatures could not reach, but birds also have an ability to adapt to almost any environment. This is most obvious in the case of the common house sparrow, seen all over the world, in major cities and rural areas alike. Why did this bird populate such a vast range of habitats? The answer lies in its curiosity. When offered a completely novel object, sparrows not only were unperturbed, they were fascinated, and more likely to eat from a feeder close to an item they had never seen before. The author of the study, Lynn Martin, remarked that sparrows were the only vertebrate – other than humans – which displayed curiosity. Sparrows are so successful because they are not repelled by new possible food sources, but instead attracted to them, whereas many other birds avoid novelty entirely.

These are not the only ways in which birds are intelligent: there are many other areas that are still under research today, with notable examples including human-like speech in parrots, appreciation of beauty by bowerbirds, and memory in corvids. These strikingly illustrate how many similarities there are between human and avian intelligence. The ingenuity of birds is a major factor in their success as a class, allowing them to thrive and populate a large fraction of the world for millennia. What is certain is that the intelligence of birds is fascinating and multi-faceted, and hopefully even more light will be shed upon its many forms in the future.

Computational Biology: From Boids to Phyllotaxis

Isky Mathews

The application of computing to biology with the idea of understanding patterns within nature has only become viable in the last few decades. This article looks at history, philosophy and results in two of these fields - the study of emergent order in artificial life and the classification of growth in algorithmic biology.

Alife & Evolution

Ornithologists have observed starlings gather in flocks of thousands that seemingly move as a single body, parting around predators then swiftly returning to their formation. This sort of coordinated movement was named "flocking" and is admired both for its efficiency and its beauty. However, nobody understood the laws governing this motion because it was so fast that accurate observations were difficult. Furthermore, there was no way of testing any hypotheses through simulation.

In 1986, Craig Reynolds created his program *Boids* to simulate flocking. His model stated that each bird would choose its vector based on three forces:

1. A tendency to avoid crowding flockmates within a certain radius of the bird.
2. A tendency for a bird to alter its heading to be closer to the average vector of nearby birds.
3. A tendency to move towards the flock's "center of mass".

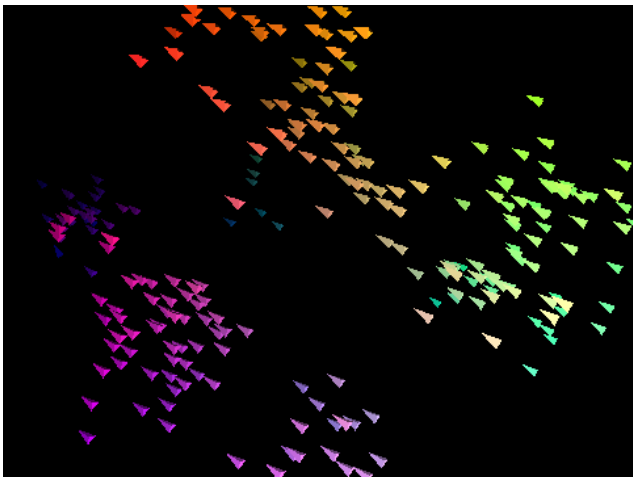


Fig. 1. Boids in flight

His program's accurate simulation was impressive and later, in his 1987 paper, he expanded upon this to incorporate predator and obstacle avoidance and food and goal seeking. The program demonstrated that the movement was deterministic rather than the stochastic-walk suggested by other biologists, introduced the concept of a swarm in which higher-level intelligence and organisation could appear as a property of simple governing dynamics and finally, created the field of 'artificial life' (coined by biologist Christopher Langton that same year) where the processes of "life as it is and life as it could be" are studied through the creation of rigorous models.

Fuelled by biology academics and amateur computer-science enthusiasts, simulations were developed further. *Tierra* is one such, written in the 1990s by Thomas Ray in which genetic-algorithms generate programs that compete to use the largest portion of CPU time and memory on a virtual machine. The evolution of these programs exhibited many phenomena found in nature such as host-parasite symbiosis and co-evolution, punctuated equilibrium as CPU saturation occurred and various forms of natural selection.

Most recently, the work of Lee Spector and Jon Klein has shown remarkable results. They co-developed a custom programming language (PUSH) and simulation environment referred to collectively as *SwarmEvolve*. *SwarmEvolve 1.0* simulated groups of 'boids' (species) that used the traditional Reynolds flocking algorithm:

$$V = c_1V_1+c_2V_2+c_3V_3+c_4V_4+c_5V_5$$

In this algorithm, the vectors V_1 to V_3 represent the rules stated above, V_4 is a vector towards the center of the world, V_5 is a random vector and c_n are parameters which are changed during evolution. The simulation required the species to gain "energy" from food sources in order to survive and "death" led to the birth of a new boid with "genes" (parameters) created through splicing those of the most successful of its species. Their simulations led to organised feeding systems, such as when collectives clustered on energy sources while others flew in wide orbits outside to repel other species, similar to the movement of bat swarms or groups of monkeys.

SwarmEvolve 2.0 was quite different. The boids' movement was governed by computer-written programs and they were able to share energy with other boids of opposite or the same hue. They demonstrated that after some iterations of this system, the dominant tactic in the majority of environments they defined was apparently altruistic sharing of energy, especially within stable environments – effectively showing how purely self-interested actors in an evolutionary context can engineer non-zero sum games and evolve to cooperate.

Structure & Phyllotaxis

In the 1960s, Hungarian biologist Aristid Lindenmayer was studying patterns in the growth of fungi and algae. He believed there were rules that could describe their growth beyond such qualitative statements as "The plants branch and reach out towards the areas of most sunlight and to perform space colonisation". Thus, he invented L-systems, a way of re-writing Chomsky formal grammar. One begins by defining an alphabet of symbols and what they represent, then defining the 'axiom' or starting configuration and finally, creating rules for iteration. To illustrate, let us take Lindenmayer's first ever system:

Variables: A, B

Axiom: B

Rules: A → AB, B → A

	String	String Length
(1)	B	1
(2)	A	1
(3)	AB	2
(4)	ABA	3
(5)	ABAAB	5
(6)	ABAABABA	8

…

This eventually leads to an infinite repetition of ABAAB – notice how successive string lengths match the famous Fibonacci sequence such that:

$\text{Stringlength}_{n} = \text{Stringlength}_{n-1}+\text{Stringlength}_{n-2}$

Lindenmayer himself used this sequence to model the way in which a particular fibrous algae branches.

Another, more visual, example is the creation of a realistic fractal plant: for this, we use a pen with a heading moving across a canvas: we say here that F means “draw forward”, “+” means “turn right by 25°”, “-“ means “turn left by 25°”, “[“ means “store location” and “]” means “restore location”. “X” signifies nothing here except to aid in the re-writing procedures. For iterations where n > 2, the string becomes very long so we simply note the string length.

Variables: X, F, +, -, [,]

Axiom: X

Rules: X → F – [[X] + X] + F[+ FX] – X, F → FF

(1) F – [[X] + X] + F[+ FX] - X
(2) 89
(3) 379
(4) 1551

...

Images showing the plant with increasing iterations displayed using my Python program:

Fig. 2. $n = 2$

Fig. 3. $n = 4$

Fig. 4. $n = 6$

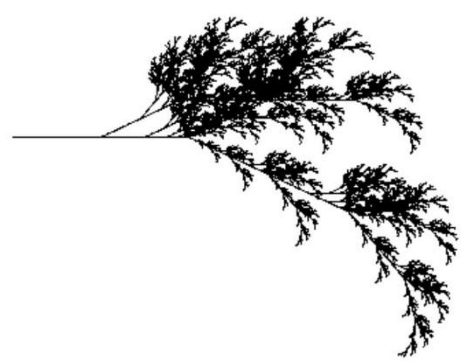


Fig. 5. $n = 8$

This allows for easy generation of structures that are startlingly life-like. With augmentations to L-Systems, such as probabilistic rules or context sensitive rules which replace strings, you can obtain shapes that directly correspond to certain species of fern, tree or weed. His novel research and understanding culminated in a book, co-authored by his colleague Przemyslaw Prusinkiewicz, called the *The Algorithmic Beauty of Plants***.** It was the first work in biology on computational simulations of mathematical patterns within nature.

L-systems since Lindenmayer's time have become fairly standard in computer science for generation of recursive structures due to their ease of use – most self-similar fractals, such as Peano Curves, Sierpinski's Triangle or the Cantor Set can be formed by them. Yet there are still many unsolved problems concerning their general use, such as the need for a more detailed classification of the objects that can and cannot be expressed using them and, more importantly, a general algorithm that can construct an L-system describing any given object.

Fig. 5. Leaves around a stalk

Lindenmayer also studied other structures in Phyllotaxis. He examined the ways in which plants arrange leaves on stalks to make sure that new leaves don't completely block out the sunlight for those below, thereby maximising the efficiency by which the plant can absorb the Sun's rays.

As illustrated by Fig. 5, in many plant species the placement of leaves twists by a regular angle as you move up the stalk. These twists are typically a fraction of 360° with a denominator and numerator drawn from the Fibonacci sequence such that the angle of the twist approximates 360° * (1 - 1/Golden-Ratio), which can be shown to be 180° * (3 – $5^{0.5}$).

With the plant in Fig. 5 having five leaves, if the angle of the twist was 360°/5, then successive sets of leaves and their shadows would fall directly beneath another. By introducing the irrational number $5^{0.5}$, the Golden Ratio-based twist means that no set of leaves will lie directly above another no matter how long the stalk!

Other plants, such as sunflowers and aloes with large compact amounts of biomass, use an arrangement known as Fermat's Spiral, whose change in angle moving outwards is again described by the Golden Ratio. It is a curve whose radius increases by the Golden Ratio every 360° it turns, as shown in Fig. 6 below.

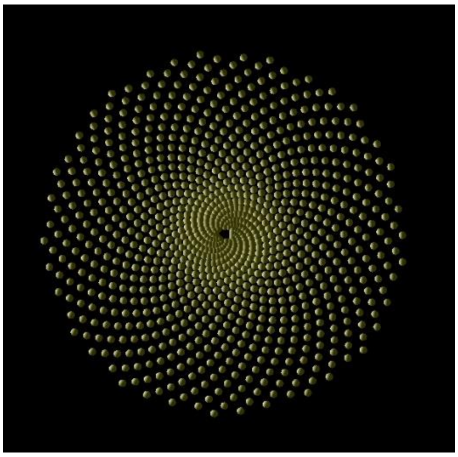


Fig. 6. Fermat's Spiral or a sunflower?

This article has outlined various uses of computer-based simulations of biological systems, from modelling the evolution of organisms in an ecosystem to the morphogenesis of structures commonly found in nature. Artificial life and its related fields are still extremely young, yet the results are fascinating – the hope is to one day create a simulation so realistic that intelligent agents evolve within it. This is a truly exciting moment in science that echoes the philosophy of Carl Sagan's words, "If you wish to make an apple pie from scratch, you must first invent the universe."

A Mammoth Decision

Brandon Tang

If asked to clone a mammoth, would "When?" or "Why?" be the right response?

In Pleistocene Park, a 16km^2 enclosure near the town of Chersky in northeast Siberia, Russian scientists have been introducing horses, reindeer, bison, and musk oxen since 1988 for an unusual purpose: to combat global warming. These species, while certainly not as symbolic as the mammoth of the Pleistocene Epoch which lasted from 2.6 million years ago to 11,700 years ago, essentially perform the same ecological role as their elephantine counterparts did in the same area an epoch ago: by trampling large plants and soil and actively grazing, they maintain grasslands that reflect solar radiation and act as carbon stores. It is argued that if the "mammoth steppe ecosystem" can be restored to the Russian tundra, it could help decrease the rate of global warming while increasing the productivity of the Russian expanses—with the hopes that this effort can be augmented with the reintroduction of this biome's namesake: cloned mammoths.

Indeed, for whatever purpose, the concept of bringing extinct species back to life, whether in reality or imagination, has intrigued many. Rapid advances in genome engineering, the complete sequencing of the woolly mammoth genome in 2015, and the exposure of more preserved mammoth corpses from the melting permafrost have allowed scientists to devise three methods to produce a living mammoth, or at least a lookalike (see Fig. 1 for a diagrammatical representation). The first involves the *in vitro* fertilization of an elephant egg cell with a mammoth sperm and the cross-breeding of offspring to resemble mammoths. The second involves somatic cell nuclear transfer, meaning that a mammoth cell nucleus is inserted into an enucleated elephant egg and the fertilized egg implanted in an elephant—similar to the procedure that produced Dolly the sheep. The last technique, which is being pioneered by George Church's Harvard Mammoth Revival Team, involves using the mammoth genome to construct and organise mammoth chromosomes in a cell nucleus or using the novel gene editing platform CRISPR to splice mammoth genes into an elephant cell, creating an embryo. Although some of these techniques do not conform closely to "cloning a mammoth" but rather creates a hybrid between it and an elephant, it is obvious that magnificent fruition seems ever closer on the horizon.

Yet amidst the excitement and anticipation of this biological spectacle, many have perhaps come to ignore the true elephant in the room. Regardless of the technological feasibility and the reason for recreating mammoths, ecological implications and ethical issues still exist concerning the matter, not to mention practical constraints. These must be well-understood and resolved if mammoths are to emerge from labs successfully. It is hence more prudent to consider first the why's and whether they justify mammoth de-extinction or not, instead of paying attention only to the when's and how's of the act, assuming that it is going to occur.

Surely, if the ultimate aim of cloning mammoths is to reintroduce them to their vast habitats where they will make an impact on existing ecosystems, then it must be very clear that this is the right thing to do. On a myriad of occasions already, humans have introduced changes to the environment without thorough consideration or understanding of the repercussions, sometimes ending with enormous ecological and economic impacts. These do not only involve the burning of fossil fuels and the release of ozone-depleting substances—take the widespread deployment of the pesticide DDT (dichloro-diphenyl-trichloroethane) in the mid-20th century, for example: despite its effectiveness and versatility, it was banned in the US in 1972 due to evidence of its bioaccumulation, toxicity, carcinogenicity, and reproductive effects in wildlife and humans.

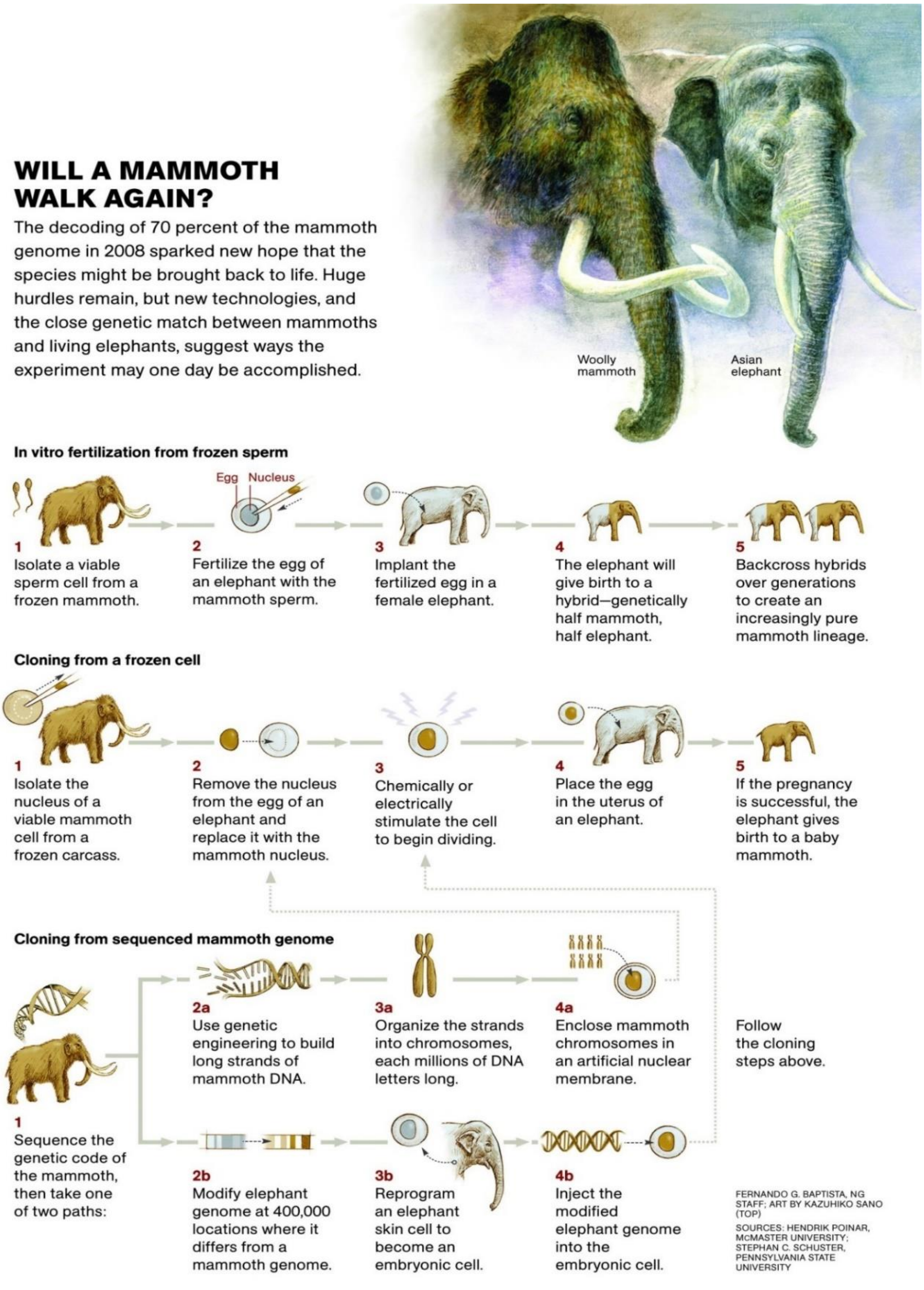


Fig. 1. A visual illustration of the multiple processes of recreating a mammoth.

Repopulating the world with mammoths without fully considering the need and the ecological implications is reminiscent of the heedless, intentional introduction of alien species in the past, which sometimes ended in disastrous biological invasions that continue to harm not only the environment but also humans. The case of the poisonous cane toad, native to the Americas, potently demonstrates the risks of such. Despite protests from naturalists and scientists, about 3000 were introduced in Australia in 1935 to control the cane beetle which was ravaging crops. While failing to prey on the beetle, because of a paucity of natural predators, the toads ate and poisoned much of the native fauna while causing health problems with their toxins: for instance, a 2004 study discovered that the toads disrupted one-third of the indigenous rainbow bee-eaters' nesting attempts and also preyed on their eggs and young. Ironically, the toads have spread across much of northern and western Australia while scientists are still desperately searching for biological controls for them, and now cost around 227.5 million AUD in agricultural and environmental damage per annum.

Should the reintroduction of mammoths to the wild become a reality, the creation of mammoth-elephant hybrids would only exacerbate the conundrum. Past experience has shown that subtle genotypic differences in species, in spite of similar physical appearances, can result in entirely disparate survival fitness and invasiveness, which can have multifarious effects—much like how a single point mutation in the human HBB gene in both alleles can lead to severe sickle cell anaemia. This is exemplified by the results of the house sparrow's and Eurasian tree sparrow's release in North America, intended to satisfy European immigrants' desires for familiar wildlife: while visually similar, it took the former only 50 years after its introduction in 1850 to colonize the whole United States and cause damage to agriculture, while the latter has remained around Missouri, Illinois, and Iowa, near where it was introduced in 1870, and has not become a pest. This example not only serves as another reminder of how human interference in nature could potentially lead to unmanageable outcomes, but also portends the risks of creating so-called "mammophants" and releasing them into the wild.

Granted, mammoth reintroduction may not end in an equally uncontrollable ecological catastrophe. Proponents of mammoth cloning may argue that the mammoth's or any "mammophant's" larger size, longer life cycle and special conservational status enable it to be easily monitored and controlled by humans. However, this does not always minimize the impact on the ecosystem—in fact, humans would most definitely try to protect any created mammoths from both anthropogenic and natural threats. This could mean relocating human habitations to reduce human presence, or reshaping the current local ecosystem, as is being undertaken at Pleistocene Park. Considering that the ultimate goal for some mammoth de-extinction teams, like that of the Long Now Foundation that supports George Church's team, is to *"produce new mammoths that are capable of repopulating the vast tracts of tundra and boreal forest in Eurasia and North America"*, and bring back the mammoth steppe ecosystem to vast areas, cloning mammoths for them to roam free again is ostensibly an impactful and irreversible decision to make. Most of the mammoths may have completely died out only 10,500 years ago (with isolated populations persisting for longer), a blink of an eye even in terms of the history of mammals, but humans have since radically reshaped the environment, particularly ecosystems, so that mammoth introduction may not be strictly considered a species' "repopulation" of its native ecosystem anymore. This brings up several critical worriments. How can anyone be certain about what could happen, given humanity's track record and lack of actual experience with living mammoths? Furthermore, although mammoths were the keystone species as the dominant herbivores in its ecosystem, is there a need to specifically reintroduce them now, when the currently mammoth-less Pleistocene Park has already been proven successful in changing tundra to grassland? Is there a pressing need for them, like there was for the cane toads, or can cloning mammoths be put on hold until any and all potential consequences are accounted for? If anything can be made clear by the uncertainty characterising the possible answers, it is that there still exists much room for deliberation, and for now it seems more reasonable to stick to the precautionary principle and utilise only existent mammals to recreate the mammoth steppe ecosystem. This brings us back to the original problem again: why else would mammoths be cloned?

It is more likely that mammoths, should they be brought back to life, will first be put into service for research: the Long Now Foundation notes that "genomes are an encyclopedia of how to survive billions of years of catastrophes, epidemics, and changing conditions", and perhaps a thorough study of a living product of the genome could reveal a trove of information that could be of significance to ecology, molecular biology, evolutionary biology and medicine, amongst other fields. The experience gained in this endeavour could also be used in current conservation efforts, such as by increasing the numbers and genetic diversity of existing endangered species. In addition, there is undoubtedly a social significance in successfully recreating the mammoth: from satisfying the sense of curiosity and wonder to rallying behind another of science's awesome display of power, there are many reasons for crowds to flock by the thousands to see a living mammoth—which might be used to remunerate some of the funding for the research that has gone into the effort. Famed UK biologist and evolutionist Richard Dawkins puts it this way in his 2013 Twitter post: "Why bother (to clone mammoths)? Why bother? Why bother to go on living? Why not just stop breathing if you are that incurious?"

Undeniably, the allure of these notions could easily compel one to promptly wonder when mammoths will start to emerge alive from labs. However, delving more deeply into the legitimacy and the implications of these given reasons, such as the idea of recreating the mammoth steppe ecosystem with its namesake, exposes a number of practical and ethical concerns that reveal the concept of cloning mammoths to be not as clear-cut and meritorious as it seems, even from a utilitarian perspective—these could very easily be missed if one was to become fixated only on the when's of mammoth cloning.

The first of these would be whether the suffering caused to the elephant surrogates by attempts to clone mammoths would outweigh the conceivable benefits of the research. Even today, more than 20 years after the successful cloning of Dolly the sheep, cloning mammals continues to be a challenge. In a 12-year-long study published in the journal *Proceedings of the National Academy of Sciences* in December 2016, cloned cattle had only less than 10% chance of surviving gestation, with common causes of mortality being cited as "embryonic death, a failure during the implantation process, or the development of a defective placenta". With such a low success rate even in an existing, heavily studied mammalian species, implanting a viable mammoth or "mammophant" embryo and keeping it alive through gestation in an elephant would seem to be an even more daunting task. What this could mean for the surrogate elephant is plenty of miscarriages, agony, and distress. While it is true that current scientific research still utilises many animal subjects like mice that die in the process, there are strict ethical guidelines concerning their use, one of which from the Committee on Animal Research and Ethics (CARE) stipulates that "the scientific purpose of the research should be of sufficient potential significance to justify the use of nonhuman animals". The possible insight gained from studying the reanimated products of a semi-ancient genome may probably be worth the moral cost that is the torment that will be inflicted on these elephant surrogates—but are the reasons for doing it merely because it can be done, or because of a so-called "moral obligation" to bring back a species to whose extinction we may have contributed? Probably not the latter. In fact, multiple theories still exist over the actual cause of the mammoth's extinction (although it is definite that humans did hunt mammoths), but who is right is not the most essential problem. Even if humans would supposedly be doing good both for the planet and for our species' conscience by reintroducing mammoths to the "vast tracts of tundra and boreal forest", we would have to construct a genetically diverse base population of mammoths to start with to safeguard against excessive inbreeding—which entails generous breeding attempts in surrogate elephants, and thus more suffering on their part. When there are only around 40,000-50,000 of endangered Asian elephants (which are the closest living relatives to the woolly mammoth and the prime choices for surrogates in the wild), and zoo breeding programmes for such have been plagued with low conception and high mortality rates (indicating insufficient knowledge of reproductive biology even for elephants), this may not be the most morally appropriate time to undertake such an ambitious attempt to resurrect the mammoth.

The wellbeing of the mammoth calves also raises concerns over the worthiness of pursuing mammoth cloning. Even if a mammoth embryo were successfully implanted and gestated, a healthy infant mammoth is definitely not a guarantee. Take the example of the Pyrenean ibex, a type of wild goat that lived in the Pyrenees but went extinct in 2000, and the first species to undergo de-extinction: when Spanish and French scientists attempted to clone it back to life in 2003, only one clone survived through 57 implantation attempts only to die within ten minutes post-partum—because of an extra lobe in a lung. Notwithstanding more than ten years of progress in cloning and reproductive technology, the risk of immorally creating only more suffering by pursuing work on a long-extinct species should still merit reconsideration. Another issue to take into account is whether the cloned mammoths would be suited to today's microbiome, whether they are released into the wild or not. A 2006 study concluded that tuberculosis had contributed to the extinction of mastodons, a close relative of mammoths—with the rise of drug-resistant TB along with other superbugs across the world (another product of human advances), it is already hard to imagine how cloned mammoths, without the chance to adapt to the pathogenic evolution of the past few thousand years, will be able to cope—that is, if they don't contribute to spreading diseases themselves should they roam in the wild as well.

Moreover, in the rush to create mammoths or mammoth-elephant hybrids, there has been a lack of consideration of what exactly defines a mammoth. Just like humans, mammoths should not and probably would not have been delineated merely by their genomes; elephants are intelligent and social creatures, and mammoths are likely to be similar. Studies of grouped mammoth bones and mammoth tracks have shown that mammoths had extended family structures and were likely matriarchal, like today's elephants. It is probably impossible to recreate the herds which would have greatly shaped mammoth behaviour, meaning that the knowledge embedded within this social structure will not be extracted even if cloned mammoths were created. Jacquelyn Gill, a paleoecologist specialising in the Pleistocene, highlights these problems in a 2013 post in *Scientific American*:

> *Is one lonely calf, raised in captivity and without the context of its herd and environment, really a mammoth? Does it matter that there are no mammoth matriarchs to nurse that calf, to inoculate it with necessary gut bacteria, to teach it how to care for itself, how to speak with other mammoths, where the ancestral migration paths are, and how to avoid sinkholes and find water? Does it matter that the permafrost is melting, and that the mammoth steppe is gone? As much as I love mammoths, the ecologist in me can't help but answer: no.*

The utility of recreating mammoths, no matter how tantalizingly presented, may have been overestimated—a more acute analysis of the reasons given reveals a multitude of practical problems and ethical concerns that negatively affect the prospect's legitimacy and elucidates the need to scrupulously approach the impetuses for mammoth de-extinction before focusing on the technologies required.

George Church's proposed method of creating elephant-mammoth hybrids by splicing mammoth genes into the elephant genome poses especially challenging ethical questions. Should CRISPR be used to engineer "Arctic elephants", as Church puts it in a 2015 *Nature* news article, even mammoth cloning will not be the correct term to describe this act—it is the engendering of a whole new artificial creation, even a scientific abomination, a "Frankenstein" that oversteps moral boundaries. Admittedly, genetically engineered animals have already existed for a long time in and out of the lab—and not only for research and practical purposes—but when one engineers an extinct species back to life, a philosophical and ethical Pandora's box is opened. Other than the quandary of the hybrid's potential harm to existing biodiversity, this action could promote the commonality of genetic manipulation as a solution to problems. This field is certainly progressing quickly with rapid innovations in gene editing technologies, but at the same time, it threatens to further blur the grey area between imperative, morally upright genome engineering and "off-limits", haphazard experiments for unrestrained, unnatural, and unethical purposes. A shaggy elephant, a featherless chicken, and even glow-in-the-dark cats may still be considered by most as animals, but when genetic variants of more sentient, anthropomorphous species like chimpanzees and Neanderthals start to be fiddled with, it may be too late to set regulations for such sorts of gene editing. In this fashion, engineering or even cloning mammoths is akin to the promising but controversial topics of human germline editing and human-animal chimeras. Perhaps it may be enlightening to consider the 2015 UNESCO bioethics panel moratorium on human germline editing, along with the implementation of a soon-to-be-lifted ban on federal funding for chimera studies by the US's National Institute of Health of the same year. This would shed light on the severity of the potential biological and ethical hazards that beleaguer attempts to effect lasting genetic alterations, and offer a suggestion as to how such genetic gambits as mammoth genome engineering, as promising but risky as they are, should be legally moderated for now. The precedence of considering the reasons and risks for mammoth cloning over focusing on the technological fulfilment of the promise to deliver cloned mammoths thus manifests itself again.

The permissibility of cloning mammoths has also come under attack for being a distraction from pressing conservation efforts, despite it being probable that the latter could reap benefits from the technological, technical, and conceptual experience gained in exploring the former. One argument is that successfully bringing back an extinct species, especially a relic as iconic and perceivably antediluvian as the mammoth, could promote a dangerous attitude that what has been done can be undone, that the scale and severity of the extinction events human activities conduce have been overestimated. This could lead to an increased tendency to accommodate human interests at the environment's expense, precipitating the annihilation of species and destruction of ecosystems ever more swiftly.

Another more conspicuous concern is that the intensive and sustained effort and funding required for cloning mammoths, despite its lauded boon, deprives urgent attempts to preserve existing threatened species of the resources and attention that they so desperately require. Reversing extinction may almost always be a more entrancing idea than preventing it, but it is undoubtedly incongruous. When the WWF estimates that anywhere from 200 to 100,000 species are being lost each year, it is hard to imagine that the resurrection of one species that may not even fit in with today' environment is much cause for triumph. Tori Herridge, a paleobiologist at the London Natural History Museum, reveals the irony in a

2014 Guardian article: "If we feel like that about the mammoth, just think how our kids might feel about the elephant if we let it become extinct." It is thus contended by some that humans should be directing efforts towards saving extant species and handling the crux of the problem—our own relationship with the environment and its detrimental influences—rather than trying to carry out modest mitigations with resurrection, or, as some would claim, delaying the inevitable for many already-lost species. It is after all not unreasonable that the disappearance of manifold existing species would do more harm to today's biomes than the reappearance of a keystone species of an ecosystem from hundreds, thousands, or millions of years ago would contribute benefit.

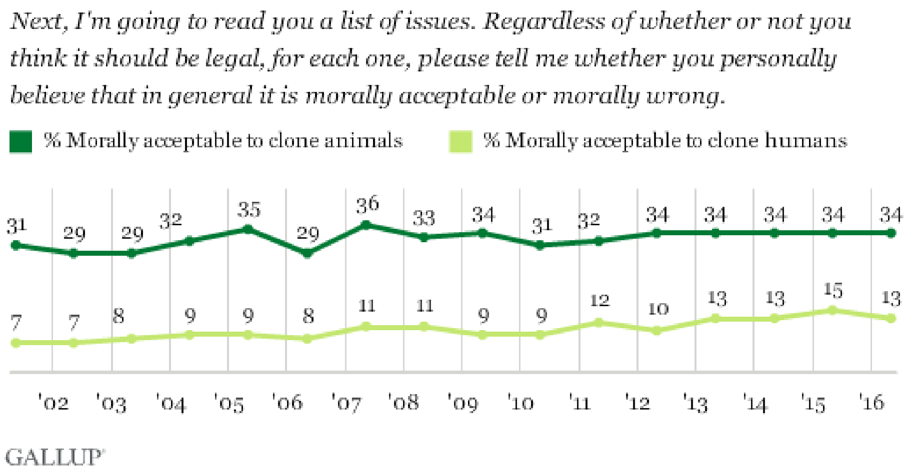


Fig. 2. The results of annual Gallup polls conducted on American adults on the morality of cloning animals and humans. A model question has been displayed.

But the point being made here is not that cloning mammoths is merely detrimental in nature or to simply dismiss the matter as folly. It is that cloning mammoths involves many complicated issues—issues that challenge us to justify our motives. This does not just include scientists whose vocations relate to mammoth de-extinction and reintroduction, and who may be more cognizant of the profundity of the ramifications their work carries, but also the public onto whom these consequences will be projected. The public has always been heavily divided over the possibility and morality of animal cloning (see Fig. 2 for results of a poll on the morality of cloning): in a 2013 Pew Research Survey, only 50% of American adults believed that scientists would be able to clone an extinct species back to life, while 48% disagreed. Technologies may have advanced rapidly since, but mistrust and skepticism from people both inside and outside of the scientific community continues to exist today, not just on BBC News but also in personal articles; this indicates a need for more direct dialogue between scientists and the public. Because of how far-reaching the impact of cloning mammoths may be, it is crucial for scientists and the wider community alike to discuss and comprehend all possible implications of cloning mammoths, instead of becoming fixated on the product.

As such, cloning mammoths should at this stage not be a matter of "when" but one of "why". The exciting developments of mammoth cloning research amid more sobering news accounts of the precariousness the environment is in may entice one to await the advent of resurrected mammoths exclusively with enthusiasm, but owing to the sundry practical and ethical issues that recreating mammoths encompasses, addressing the critical yet delicate questions of why we should be doing it by scientists and the public alike is cardinal to reaching a careful, collective verdict that could monumentally remodel the way we approach conservation. Although more intricate and less rousing, tackling the question of why we should be cloning mammoths could perhaps provide an interim answer to the question of when as well—in a nutshell: later. Until the question of 'why' has been thoroughly reviewed and satisfactorily resolved by us, it would be wise to keep the mammoths on ice.

We dedicate this issue of Hooke magazine to
Rose Mouse (01/04/15 – 06/06/17)

The following may be a very sad piece of news for many. It is with a heavy heart that I write with news that Rose, the Biology Department's resident rodent has passed away. Tucked away in her cage in Lab 504, the coy pupils may have missed her. However, for those who knew her, Rose was a friendly, benevolent member of the department. She had a veracious appetite; nuts, chocolate, pasta, linguine – a pig would have eaten less! Rose was over two years old; a very old age for an organism whose typical longevity is only about a year. For this reason, we should keep up our chin, chill and not get overly upset. When it came, her death was peaceful. She calmly and serenely fell into a deep stupor.

Cupin Edwards was one pupil who remembered Rose fondly; "She was an incredibly cute addition to the class. I would often place food in her cage, which she would then squirrel away into her burrow. She will be sorely missed."

Equally nice sentiments were expressed by another pupil, Katie Brown; "Rather than be fearful of rodents, Rose taught us that they are warm and charismatic animals who should be admired and cherished."

Mice like Rose are commonly found in science labs around the world. Her particular breed is known as a "Fancy Mouse". This breed is a form that was originally created through artificial selection in Japan 300 years ago. Utilising selective breeding techniques, various traits have been honed including a tame, docile nature and patterned fur. Their tails have scales, which aid in climbing and their whiskers can be used to measure the temperature of the air. Mice can communicate with each other through ultrasonic sounds as well as elaborate audible mating songs. They also undergo pheromonal secretions when exposed to food, threats or potential mates. Many research institutions use these mice when investigating aspects of physiology and biochemistry because they are easy to keep and have a similar anatomy to humans. At universities such as Manchester and Birmingham, sterling work is being carried out on cancer therapies using mice as the model organisms.

Rose was more than just an ordinary mouse. She was a symbol of a simpler way of living - an emblem, mingling amongst her sawdust without fuss or hassle. In the words of the singer Bill Withers, "Ain't no sunshine when she's gone".

JAM

The obituary above has been infested by rodents - animals which are characterised by their large, strong incisor teeth, which continuously grow throughout their lives. Hidden amongst the text are the names of 13 rodent species – see if you can find them.