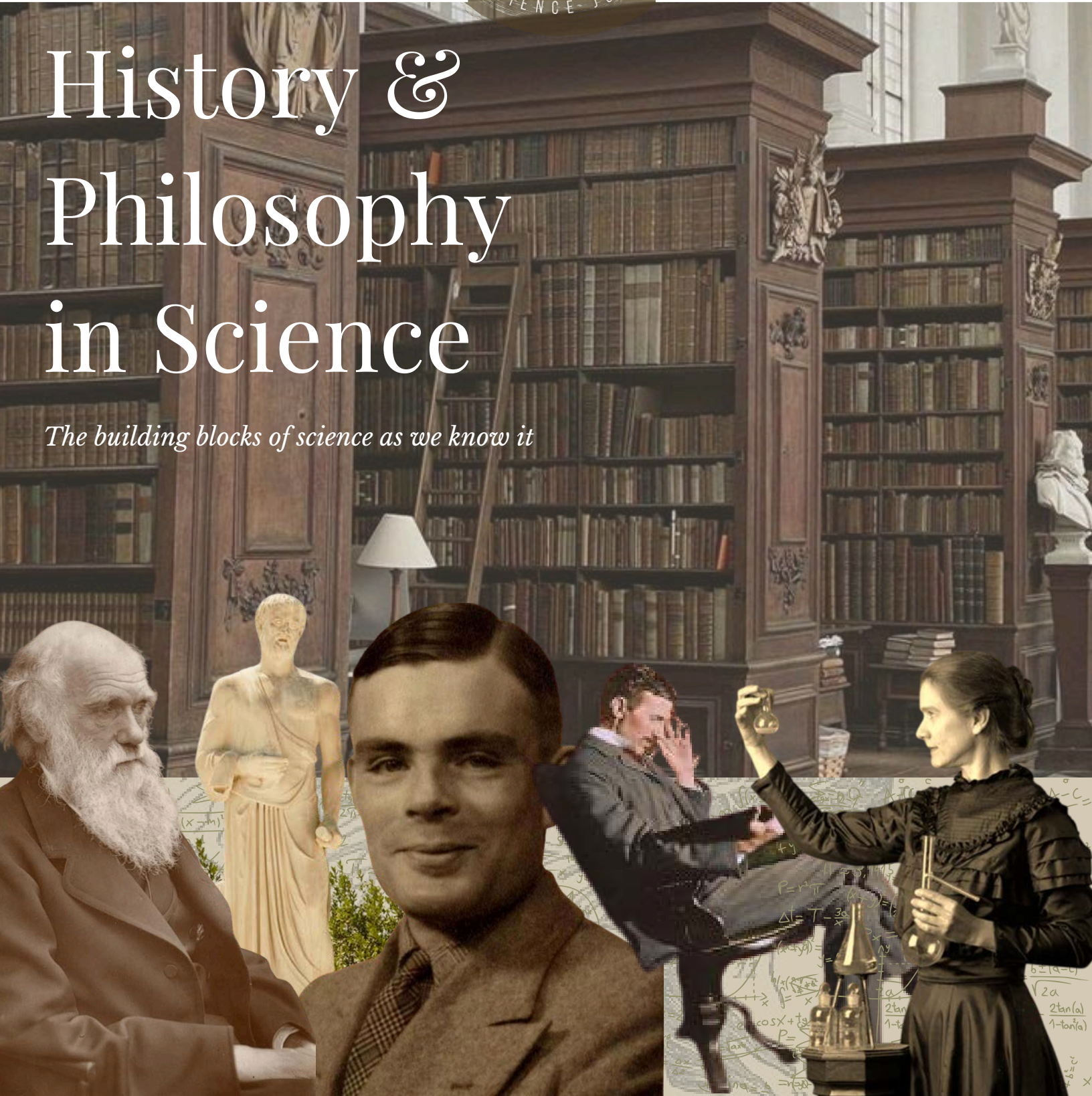




History & Philosophy in Science

The building blocks of science as we know it



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contact! Drop us an email at:

25621@mynsb.school (Hunsil)

25703@mynsb.school (Isaac)



MEDICINE &
DENTISTRY

LEAD EDITOR: NAATHIM DRSKA

Holism vs Reductionism in Medicine

By: Yomna Awad



ABSTRACT

Medicine can be approached in several unique ways based on a person's views, beliefs and needs. The two most common yet contrasting approaches are the medical model and the holistic model that are represented by the concepts of holism and reductionism.

Nowadays, medicine is following the philosophy of reductionism: meaning deconstructing a complex process into its component parts to enable better comprehension [1]. This relates to the Medical Model, which is believed by 75-80% of people, that includes disease being a series of biochemical processes where the treatment is often **interventionist** e.g drugs, surgery. It also emphasises the believe of preventing death by diagnosis and cure rather than prevention and wellness. This can be effective for **acute conditions** as well as preventing communicable disease due to more patient compliance [2]. However, this approach may overlook mental, emotional and social aspects of health which was clear by the several Alzheimer's Drug Failure particularly the Amyloid Hypothesis where drugs that target and remove amyloid **plaques** have been developed. As a result, the reductionist view ignoring multifactorial causes of Alzheimer's such as lifestyle led to a failure rate of 99.6%. [3]

On the other hand, the Holistic Model is an attitudinal approach to health care rather than a particular set of techniques. It addresses the whole person including mind, body, spirit and social context. The holistic approach highlights the uniqueness of each patient and their individualised care [4]. It believes in finding the source of the problem and fixing it rather than finding the "magic bullet" [5], which results in both long-term wellness and promoting patient empowerment and self-care. It also believes in restoration over substitution through conventional and alternative treatments e.g nutrition and mindfulness. Nonetheless, this approach may not be suitable for some patients due to the lack of scientific validation as it can be harder to measure outcomes. Not only that, for instance, in some holistic approaches, mental health issues are seen primarily as spiritual imbalances or stress. While this can be true, ignoring clinical diagnostics can delay proper care. For example, patients with major depressive disorders may not receive early intervention if they're focused solely on holistic or lifestyle-based interventions. According to the National Alliance on Mental Illness, early intervention in **psychosis** can reduce the long-term disability by up to 60%. [6]

Both holism and reductionism raise several important ethical implications. For instance, in the Medical Model patients may be given treatments based solely on biological diagnosis with limited discussion to lifestyle, preference or even non-pharmaceutical or preventative options. Similarly, some holistic practitioners may steer patients away from evidence-based treatments which may cause patients to reject life-saving therapies due to biased non-scientific evidence. This has an impact on the respect for patient's **autonomy** as patients are required to be fully informed about both holistic and reductionist treatment options including their risks and benefits. Moreover, reductionism deals with focused interventions to treat disease effectively but may ignore the root cause that can lead to overmedication of drugs and therefore side-effects. In holism, avoiding necessary medical interventions while aiming to promote well-being can be ethically irresponsible and result in preventable deaths. Therefore, a balanced approach can lead to **beneficence** and **non-maleficence**.

In conclusion, being able to interpret both reductionism and holism in a person-centered care has been proven effective by the Lifestyle Heart Trial that showed that intensive lifestyle changes reversed heart disease, with a 4.5% reduction in arterial blockage. The reductionist tools measured the outcome while the holistic tools drove the results.[7]

Interventionist - someone who advocates for or practices invasive medical procedures.

Acute conditions - medical conditions that have a sudden onset, a relatively short duration and is often severe or intense.

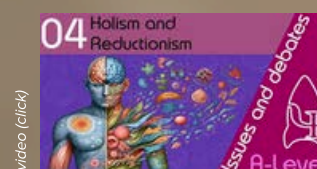
Amyloid plaques - clumps of a protein fragment called beta-amyloid that accumulate in the spaces between nerve cells in the brain.

Psychosis - a mental state where a person's thoughts and perceptions are significantly disrupted, causing a loss of contact with reality.

Autonomy - the capacity of an individual to make their own decisions and govern themselves without external control.

Beneficence - the principle of doing good and acting in ways that promote the welfare and well-being of others.

Non-maleficence - avoiding causing harm.



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Ethics of Human and Animal Testing

By: Abdirahman Mahamed



ABSTRACT

Testing on humans and animals has always been a crucial part of scientific progress, yet it remains one of the biggest ethical practices in research. While testing on human and animals has led to the development of life saving drugs e.g. insulin, it raises serious moral concerns about consent and treatment of sentient beings. Animal testing is increasingly being challenged following the emergence of humane alternatives such as artificial intelligence and in vitro methods. On the other hand, human testing must follow strict guidelines, especially considering historical events such as the Nazi experiments during World War II, which ultimately led to the establishment of the Nuremberg code. This remains a foundation of modern research ethics today, ensuring that all medical experiments involving humans are conducted ethically.

Animal experimentation is commonly used around the world, allowing researchers to study and treat diseases using lifesaving treatments. However, this practice raises serious ethical concerns as animals cannot consent so must endure the pain associated with testing them. This led to the development of the '3Rs' principle (replacement, reduction, and refinement), providing a framework for performing more humane animal research. Replacement refers to using alternatives such as artificial intelligence, reduction refers to using fewer animals, and refinement refers to improving animal care and reducing pain. Furthermore, in 2022, over 2.76 million scientific procedures involving live animals in the UK alone, with 96% involving mice, fish, rats, and birds, according to the UK home office. Moreover, it is estimated that 192 million animals are tested annually around the world. However, according to the US Food and Drug Administration approximately 90% of drugs that pass animal tests fail during human clinical trials often due to unexpected side effects or lack of effectiveness. This raises questions on whether it is worth testing 192 million animals globally per year, given the high failure rate. Nevertheless, animal testing remains a crucial role in science, but its future may lie in more ethical substitutions.

Human testing has long been an ethical dilemma, particularly following World War II when Nazi doctors conducted inhumane medical procedures on prisoners in concentration camps. These included freezing experiments to study hypothermia, high altitude experiments, deliberately infecting prisoners with diseases like malaria, and more. These investigations caused extreme suffering, deaths, and had little to no scientific value. This resulted in the creation of the Nuremberg code during the Nuremberg trials, which established 10 key principles for carrying out experiments ethically, including the avoidance of unnecessary suffering and participants must give consent. These ethical standards have influenced modern day research, ensuring the protection of human rights in scientific studies.

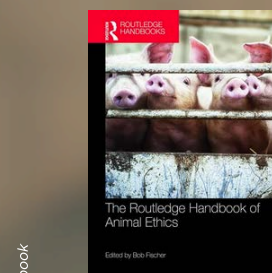
In conclusion, testing on humans and animals is undoubtedly an extremely valuable and important aspect of scientific testing, but it is essential to consider the problems associated with it. Necessary steps must be taken to guarantee all research is carried out ethically by respecting the rights of animals and humans.

Humane - Showing kindness, care, and sympathy toward others

Nuremberg code - Set of 10 ethical rules created in 1947 after World War II to protect people in medical experiments, outlining points such as voluntary consent and safety

Dilemma - A situation in which a difficult choice has to be made between two or more alternatives, especially ones that are equally undesirable.

Hypothermia - Medical condition that happens when the body temperature drops below 35°C as the body loses heat faster than it can produce, due to the exposure of cold weather.



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The Ethics of Placebo in Clinical Trials

By: Chloe Alcazar

ABSTRACT

Initially, when there is uncertainty about the efficacy of a new, possible treatment, placebos are used to compare with the treatment, showing the true effects of the newly introduced treatment by minimising the psychological aspect of the patient's expectations of the outcome. However, there is controversy and agreement surrounding the use of placebos. Including how they can be deceptive, how they violate patient autonomy, and whether they are beneficial to the clinical trial or not.

One of the four pillars of medical ethics is autonomy. During clinical trials where placebos are used, there is a grey area as to when the usage of these can be considered as violating a patient's autonomy or not. Using placebos without informing the patient can be seen as a form of deception, which potentially violates their autonomy since they were not able to choose whether to receive the placebo or not. However, usually the trial participants are notified about the diagnostic or therapeutic procedure, its risks and benefits, and the chance that they will receive a placebo. This is through the process of informed consent.

There are several main justifications for placebo controls, which include that is okay to use placebos when: there is no proven effective intervention for a condition, no harm will come if treatment is delayed, and placebos are not helpful for determining a treatment's efficacy. Additionally, if there is inconsistent evidence of the efficacy of some treatments, adding more placebo controls can help with new treatments for conditions which response to both established treatments and placebos are highly variable. For example, depression has fluctuating symptoms and levels of intensity, thus meaning a high placebo response rate. Clinical drug trials are important, as researchers of the drug developed need to prove their suspicion of it working. If they knew that already, then they would not need a trial at all.

Some may argue that there is an issue regarding the fact that there is a possibility that participants are harmed by receiving a placebo instead of active treatment. This then poses as a moral issue since the patients on the placebo would be harmed solely for the benefit of third parties and scientific reasons, making this almost dehumanising to an extent. Furthermore, there is the grand question of 'is deception justifiable?'. It is a basic principle of medicine that lying to a patient is never acceptable, since there is a clear recognition for patient autonomy and beneficence. But it can also be argued that beneficence is not being fully violated because the use of placebos is used in good intention, but sometimes it would bring harm to the participants.

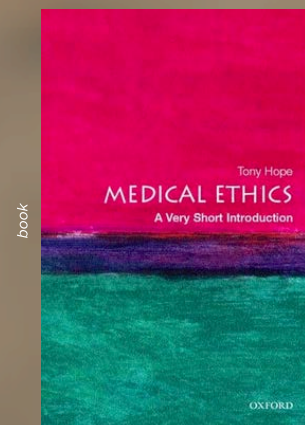
In conclusion, it is hard to determine whether the usage of placebos in clinical trials is inherently ethical or not, since there are many factors to include, like informed consent, and reference to the Four Pillars of Medical Ethics. However, they are highly important to the work of clinical researchers, and in the development of new life-saving drugs.

Autonomy - a patient's right to make their own informed decisions about their healthcare, free from coercion or undue influence.

Efficacy - the ability to produce a desired or intended result.

Placebo - a medicine or procedure prescribed for the psychological benefit to the patient rather than for any physiological effect.

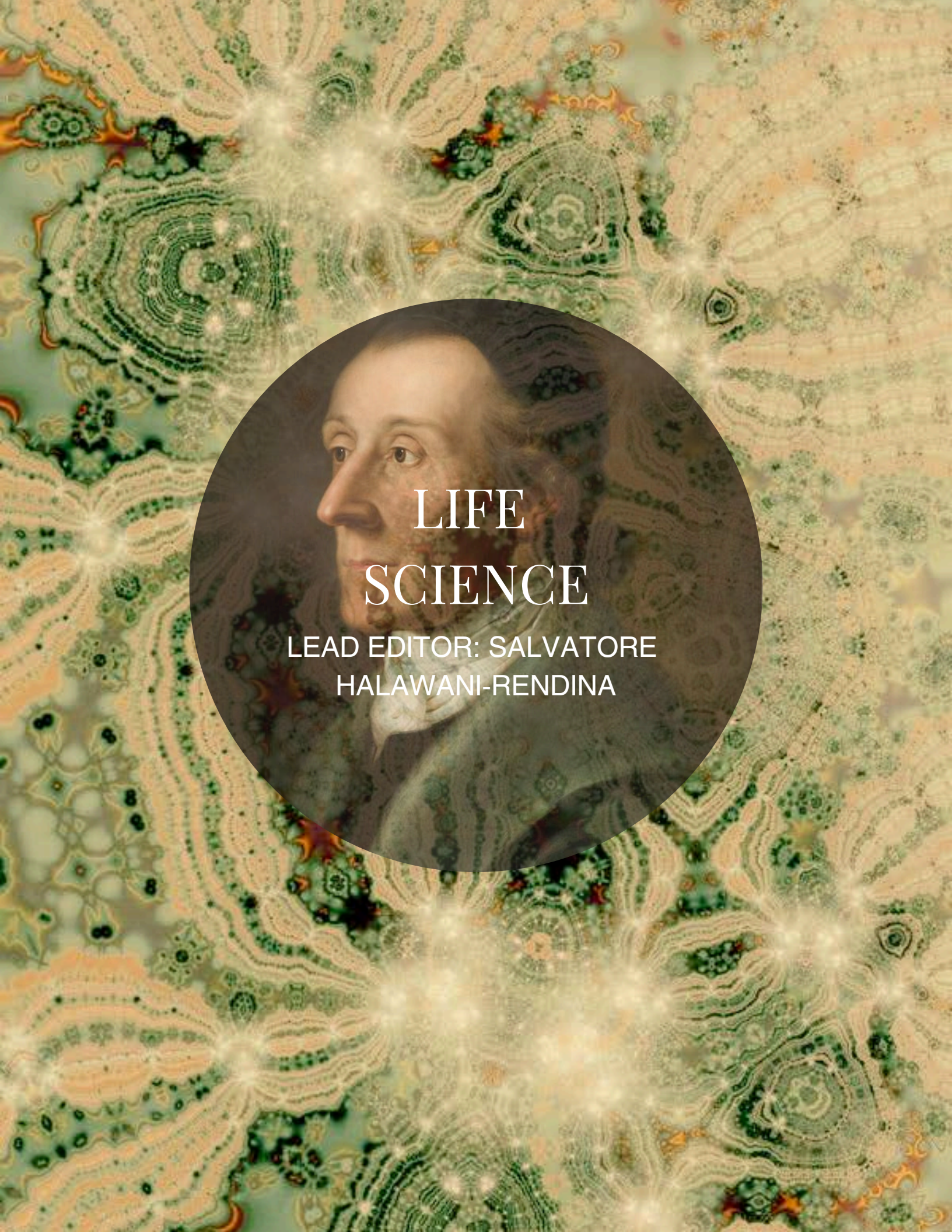
Beneficence - the quality or state of doing good.



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LIFE
SCIENCE

LEAD EDITOR: SALVATORE
HALAWANI-RENDINA

The Face of Judgement: The History and Ethics of Physiognomy



By: Loraine Nombo

ABSTRACT

Physiognomy is the study of determining a person's character from their physical appearance, especially the face, and has a long and controversial history. Once regarded as a legitimate scientific pursuit, it has since been discredited for its pseudoscientific basis and association with racism, eugenics, and other social prejudices.

The roots of physiognomy trace back to Ancient Greece. Philosophers like Pythagoras and Aristotle promoted the belief that the soul manifests as physical traits. Aristotle, especially, believed that these features reflected moral character. His ideas were later expanded upon by Roman thinkers and remained influential through the Middle Ages, often linked with astrology and other occult sciences.

In the 18th century, Swiss pastor Johann Kaspar Lavater published "Essays on Physiognomy", which became widely popular in Europe. Lavater argued that facial features could reveal divine insights into personality and morality. His work influenced artists, scientists, and even political figures, helping embed physiognomic thinking into European culture. Not long after, physiognomy combined with emerging scientific research. Figures like Franz Joseph Gall and Johann Spurzheim developed phrenology—a related field that claimed skull shape could predict personality traits. This era saw the rise of criminological physiognomy through the work of Cesare Lombroso, who believed criminal behavior could be diagnosed by facial and cranial (skull) features. These theories were widely influential but are now recognised as deeply flawed and prejudice.

By the 20th century, physiognomy lost credibility in the scientific community. Advances in psychology, genetics, and neuroscience exposed its lack of empirical support. Controlled experiments failed to validate its claims, and most of its supporting evidence was found to be from biased observations. Yet despite its scientific rejection, physiognomic thinking persisted in popular culture and informal social judgment. Stereotypes based on appearance continue to influence media, hiring decisions, and legal outcomes. Moreover, the arrival of AI and facial recognition technologies has revived debates around automated personality detection, often echoing physiognomic ideas.

The ethical concerns surrounding physiognomy are profound. At its core, it encourages judgment based on appearance, reinforcing discrimination – especially along racial, gender, and class lines. Historically, physiognomy was used for racist and colonial propaganda; this pseudoscience played a role in the development of eugenics and the marginalisation of certain groups.

In modern times, AI-driven "emotion recognition" and "personality prediction" technologies have raised new ethical alarms. Critics argue that these systems often replicate historical biases under the guise of objectivity. Using facial data to make decisions about employment, or criminal risk echoes physiognomic thinking and risks perpetuating discriminatory behaviour.

In conclusion, history of physiognomy is a cautionary tale about the misuse of science in the service of prejudice. Once embraced by intellectuals and institutions, it is now largely regarded as a pseudoscience with harmful consequences. Yet its legacy lingers, reminding us of the importance of ethical scrutiny in both science and technology. As we navigate the challenges of the modern world, the cult of physiognomy proves to be a cautionary tale on resisting reductive thinking, and to uphold the values of critical inquiry and human dignity.

Physiognomy - assessing a person's character, personality, or moral qualities based on their facial features or physical appearance

Pseudoscientific - theory, method, or belief that claims to be scientific but cannot be reliably tested

Phrenology – a 19th-century pseudoscience which claimed that the shape and bumps on a person's skull could reveal their mental traits, intelligence, and character

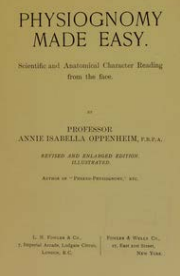
Eugenics - the belief and practice of 'improving' the genetic quality of the human population, typically by controlling who is allowed to reproduce; often involves encouraging reproduction among people with traits considered "desirable" and discouraging or preventing reproduction among those with traits labeled "undesirable"

Johann Kaspar Lavater (1741 – 1801) – a Swiss theologian and philosopher who popularised modern physiognomy in Europe with his book *Essays on Physiognomy* (1775–78)

Franz Joseph Gall (1758 – 1828) – a German physician who founded phrenology, asserting that the brain is divided into specific areas responsible for different character traits, and that the skull's shape reflects these regions

Johann Spurzheim (1776 – 1832) - student and collaborator of Franz Gall; he expanded and systematised Gall's ideas, helping spread the belief that skull analysis could reveal personality

Cesare Lombroso (1835 – 1909) - an Italian criminologist who proposed that criminals were biologically different and could be identified by physical traits such as jaw size, sloping foreheads, and asymmetry



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Discovery of DNA

By: Rebekah Fajebe



ABSTRACT

DNA carries the genetic information vital for an organism's development and functioning. This article explores the historical discovery of DNA and key figures. It emphasises DNA's role in genetics and modern applications, while also addressing ethical challenges.

The discovery of DNA was a pivotal moment, laying the foundations for modern genetics; and whilst countless figures have made contributions, five stand out: Mendel, Miescher, Franklin, Watson, and Crick (an NSB alumnus).

Early History

Before DNA was discovered, heredity was primarily understood through the work of Gregor Mendel, often referred to as the father of genetics. His experiments with crossbreeding pea plants showed how traits like petal colour and seed shape were inherited and referred to these traits as 'discrete units', now known as genes.

Friedrich Miescher, a Swiss scientist, is often cited as the first person to identify DNA. In 1869, Miescher, though initially intending to study the composition of cells, isolated phosphorus-rich proteins from **lymphocytes**. Extracting these cells from the lymph glands was challenging but were more readily available in the pus of infected wounds. Consequently, Miescher collected them from a nearby hospital. This molecule embodied one of the earliest discoveries of DNA in the 19th century, paving the way for future researchers.

In the early 1950s, scientists James Watson and Francis Crick used X-ray crystallography to study DNA, building on the work of Maurice Wilkins and Rosalind Franklin. One key image was 'Photo 51', which clearly showed DNA's helical structure. This photo was created by diffracting X-rays off a pure fibre of DNA in an X-ray tube. The X-rays scattered as they passed through the crystal and interacted with the electrons of the atoms. This scattering resulted in patterns left on film which allowed scientists to deduce the arrangement of atoms and, thus, analyse the DNA crystal's structure.

DNA's Structure

Watson and Crick published an article, which received an internal award at KCL. Their findings detailed that DNA is a twisted ladder (double helix) made of two long strands running opposite each other (antiparallel). It was later found that each strand is a chain of nucleotides (sugar-phosphate backbone) with one of four bases attached. The bases pair, held together by hydrogen bonds, specifically between strands: adenine (A) with thymine (T); and cytosine (C) with guanine (G). The base-pairing and sugar-phosphate backbone give DNA its stability and code.

Every cell's nucleus contains DNA. These sequences are transcribed and translated to build the organism's proteins and RNA. In other words, DNA safely stores genetic information that determines traits and coordinates development. Each cell in an individual has essentially the same DNA 'blueprint', ensuring coordinated growth and function across the body.

Applications

Today, **genomics** and gene editing are rapidly advancing. **Whole-genome sequencing** allows doctors to tailor treatments to a patient's genetic profile – a practice called personalised medicine. For example, a patient's genotype can reveal disease risks and drug responses, allowing doctors to target therapies more effectively. In research and agriculture, powerful tools like CRISPR-Cas9 enable precise DNA editing: Cas9 (guided by RNA) can cut or modify specific genes with high accuracy.

DNA data now underpins species identification and **phylogeny**. Scientists use short 'DNA barcodes' (standard gene segments) to identify organisms and discover cryptic species. For instance, DNA barcoding helped identify dozens of previously unknown mushroom species in Romania. Comparing DNA sequences across organisms also lets researchers build evolutionary trees, clarifying how species are related and helping reclassify organisms more accurately. In this way, genomics has greatly refined **taxonomy** and our understanding of life's history.

Genetic research poses ethical challenges, mainly concerning privacy and discrimination, as individuals should control access to their genomic data to prevent misuse by insurers or employers. Editing human DNA raises additional moral concerns, with experts agreeing that editing **germline cells** is too risky currently. Ongoing debates focus on human gene therapy, designer babies, and the regulation of emerging technologies. Public dialogue and safeguards are essential in ensuring DNA science benefits society while minimising harm.

Overall, there is no doubt that the progression in our understanding of DNA is testament to the hard-work of numerous people and the future progressions and technologies in development will shape the world for centuries to come.

1. Lymphocytes – A type of white blood cell that plays a central role in the immune system, especially in recognising and responding to pathogens.

2. Genomics – The branch of molecular biology that focuses on the structure, function, evolution, mapping and editing of genomes, which are the complete set of DNA in an organism.

3. Genome Sequencing – A laboratory method used to determine the exact sequence of DNA bases (A, T, C, G) in an organism's genome. This process provides a blueprint of an organism's genetic makeup.

4. Phylogeny – The study of the evolutionary relationships among organisms. It is often represented as a phylogenetic tree, which shows how species or groups are related through common ancestors.

5. Germline Cells – Reproductive cells (such as sperm and egg cells) that carry genetic information, forming offspring. Mutations in germline cells can be inherited, unlike mutations in somatic (non-reproductive) cells.

6. Taxonomy – The study of classification (especially of organisms).

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PHYSICAL
SCIENCE

LEAD EDITOR: BRYONY COOK

Does everything revolve around us? – The discovery of a heliocentric solar system.

By: Bryony Cook

$$(\sqrt{a})^m = \sqrt{a^m} = a^{m/2}$$

ABSTRACT

For hundreds of years, humanity has been fascinated by the stars scattering our night skies. Before our current scientific advancements all we had to go off was what we could see before us. It isn't too silly to understand how the Greek philosophers thought that the solar system revolved around us. But how has this discovery really affected our understanding of the world?

When we had no artificial light, the view from the skies was immense; quite something to observe. As you can imagine, many people were fascinated by the stars. One Greek called Eudoxus, initially proposed the idea of a geocentric model. A geocentric model simply means that the planets and stars all revolve around us on Earth. Aristotle and Ptolemy then later refined this theory. However, they later discovered one massive issue. Planets weren't going round in a perfect path across the sky. They appeared to be turning back on themselves and looping round. So, how did they try to solve this problem? The development of the theory was that each planet was rotating in its own epicycle whilst rotating around us. For anyone that has any understanding of maths, the proof behind this theory was way too complicated but due to the heavy influence of religion on science, the theory was still accepted.

In 1543, Nicolaus Copernicus published a new theory. The theory that everything really didn't revolve around us. Copernicus looked to simplify the previous theory to use the mathematical knowledge of the universe and marry what they observed in the simplest way possible- a very common trait amongst physicists. He proposed that the Earth revolved around a stationary sun, spun on its axis and had an annual tilting of its axis. This new theory explained the issue of retrograde motion perfectly. At the start, this theory was still deemed as heretical and if anyone pushed for it the church disapproved, as they believed that it went against what they deemed true and what God must have decided.

Unfortunately for the church the evidence began piling up. The most famous piece being Galileo's discovery of Jupiter's moons. He observed that the moons orbited Jupiter. Now if we took the geocentric model to be correct then this would be defying the rules; everything had to revolve around us. This piece of evidence was damning almost completely disproving the geocentric model. Galileo also received a lot of backlash for his discovery with him being placed on house arrest in 1633 after being proved guilty of heresy. Despite this, his discovery was pivotal in our understanding of the universe. With the heliocentric theory being properly accepted in the 18th century.

This theory has allowed scientists to understand the make-up of our universe and the laws that govern it (Newton's theories of gravity). This is still important today as we continue to question old theories to try and find the best answers to the questions we have.

Geocentric Model- the idea that the planets and stars orbit around the Earth

Heliocentric Model- the idea that the planets and stars orbit the stationary sun rather than Earth

Epicycle - a small circle whose centre moves round the circumference of a larger one. - an epicycle used to describe planetary orbits in the Ptolemaic system.

Heresy- belief or opinion contrary to orthodox religious (especially Christian) doctrine.

Orbit- the curved path of a celestial object or spacecraft round a star, planet, or moon, especially a periodic elliptical revolution.

Retrograde motion- the apparent backward movement of a planet across the sky, as viewed from Earth



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Deterrents or Tactical Advantage?

By: Leon Sloanes-Ford

$$(\sqrt{a})^m = \sqrt{a^m} = a^{\frac{m}{2}}$$

ABSTRACT

Practically all engineers hope that what they create has a net positive on the world, either by creating something revolutionary, or something that prevents the worst case scenarios from taking place. In most cases, such as with the lightbulb or the car, the world has benefited and created major developments for the modern world. However, this is not always what happens.

Alfred Nobel was a scientist many recognise for the Nobel Awards, however he was also credited with inventing dynamite in 1867, after trying to stabilise nitroglycerin, a highly explosive compound, in order to make mining, blasting and demolition safer for the workers. He thought about dynamite's potential use in war but concluded that it would never be used as an actual weapon and instead used as a deterrent. Alfred Nobel was wrong about this however, as dynamite was being used as a weapon as early as 1880 in political revolts and later used in war.

During this time, many directly blamed Nobel for the use of dynamite as weapons, and his obituary even claimed him as the merchant of death. While Nobel intended for dynamite to be used as a commercial tool and a deterrent for war, however, can be directly blamed for the use of dynamite as a weapon, or is that blame reserved for those who actually use the weapon for violence in the first place?

Another example of a famous scientist, in this case, a theoretical physicist, creating a weapon with the purpose of using it as a deterrent, and not for violence, is J. Robert Oppenheimer.

During WW2, the Manhattan project was set up, a top secret project to develop a bomb with near catastrophic capabilities. Everyone today knows this as the nuclear bomb. Oppenheimer only imagined that the nuclear bomb would be used to scare people, to dissuade the idea of war, practically forever. This, as with Nobel, was not the case, as soon after the bomb was completed, 2 of them were dropped on Hiroshima and Nagasaki in Japan. Also like Nobel, Oppenheimer was overcome with guilt about the use of the nuclear bombs, wishing he had never considered making them in the first place.

Both Nobel and Oppenheimer had a very similar story when it came to trying to create deterrents from war, however in both scenarios, they were used as a strategical advantage to win wars or commit acts of violence. The biggest debate around this topic is whether or not scientists are responsible for the deaths caused, by creating weapons used as deterrents. One argument is that they usually understand that what they create can and may be used as weapons, even if they don't intend them to be. The other argument is that the creators should not be blamed for how others use the creation, as if that was the case, then the creator of the computer should be blamed for cyber attacks on medical and government sites. There is a very large grey area around whether or not a scientist should be blamed for anything that they develop.

Deterrent – A method or object designed to prevent something, presenting it as a negative outcome in all cases

Catastrophic – causing major damage or suffering

Nitroglycerin – A dangerous and sensitive chemical, prone to accidental explosion

Obituary – An announcement of death containing biographical information

Theoretical – Area involving theory, not concerning practical work.



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What the Standard model tells us about being, reality, and ourselves?

By: Anika Chatterjee

$$(\sqrt{a})^m = \sqrt[m]{a^m} = a^{m/2}$$

ABSTRACT

During the late 20th century, a ground-breaking shift in the world of physics was at work. This shift would result in remarkable insights into the fundamental structure of matter. However, the standard model did more than just introduce humanity to new particles. Instead, it challenged current philosophical ideas and raised unsettling questions about the universe. Is 'empty' space truly empty? Can the human experience be summarised just by physics? Is this universe specifically structured to contain matter? These are some of the challenges faced, which extended the model beyond mathematics.

What is the standard model? CERN states: "The Standard Model explains how the basic building blocks of matter interact, governed by four fundamental forces" (1). The model consists of seventeen fundamental particles, and only three forces, excluding gravity (2). Despite this missing force, many sources agree on the success and accuracy of the model, often describing it as elegant. However, does this elegance suggest the universe is formed by design, or is it a coincidence? The symmetry of the standard model aligns with Kant's arguments that human reason imposes structure onto the world, implying that humans can only perceive a structured universe, which may not be true (3). This implication from the model touches upon a core philosophical idea, questioning reality.

Reality further came into question upon the discovery of the Higgs boson in 2012 (4). Often referred to as 'the God particle', the Higgs boson is a quantum particle that gives all other particles their mass, when the particles interact with the Higgs field. However, while answering the age-old question of where mass comes from, the Higgs boson shattered the illusion of an empty space. Until recently, physics leaned closer to Newton's belief that an empty region of space is inactive. The Higgs field challenged Newton's views by suggesting even the emptiest region is active and has structure (5). For many, this changed their understanding of reality and opened up a deeper question: what constitutes true emptiness?

The Higgs boson helped complete the standard model. But what does this represent? Many realists argue that the model uncovers the true nature of reality.

However, instrumentalists argue instead that the model is simply an excellent construct of the truth, helping humans process it. Furthermore, debates about the precision of the mass of the Higgs boson have given rise to the multiverse theory. Some argue that this precision means the universe has been specifically structured to exist since stars would not have formed given any other value of the mass. While others argue that there exists multiple universes with a different mass constant, raising the ultimate question of what lies beyond our universe. Finally, while the standard model presents a reality reduced to fields and particles, the question remains: is that all there is?

To conclude, the ground-breaking shift of the late 20th century raises more questions than it answers, as with most of physics. But ultimately furthers our understanding of reality: truth or not.

The Standard model - a theory in physics that describes the fundamental particles and forces that make up our universe, excluding gravity.

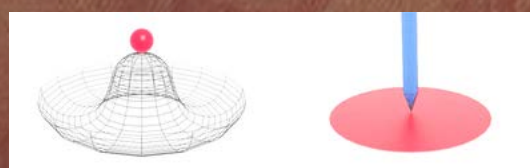
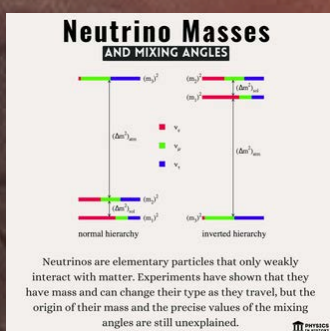
The Higgs boson - a fundamental particle associated with the Higgs field, a field that permeates the universe and gives other fundamental particles their mass.

Realists – A person with the view that certain things exist independently of being known or perceived by a mind.

Instrumentalists – A person with the view that the value of an idea, theory, or concept lies in its usefulness or practical application, rather than its truth or correspondence to reality.

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Engineering failures – Chernobyl

By: Vlad Cucu

$$(\sqrt{a})^m = \sqrt{a^m} = a^{\frac{m}{2}}$$

ABSTRACT

On April 26, 1986, Reactor No. 4 of the Chernobyl Nuclear Power Plant near Pripyat, Ukraine (then part of the Soviet Union) failed catastrophically. The disaster resulted from a flawed reactor design, inadequate safety procedures, and significant human error. A safety test during a routine shutdown spiraled out of control, causing an explosion that released radioactive materials into the atmosphere. The event remains one of the worst nuclear accidents in history, with severe environmental and health consequences.

The Chernobyl disaster occurred during a late-night safety test on April 26, 1986. Operators at Reactor No. 4 sought to determine whether, in the event of a power failure, the slowing turbine could produce enough electricity to run cooling pumps until emergency diesel generators activated. A previous attempt had failed, so they repeated the test using newly developed voltage regulators.

To proceed with the test, operators disabled several safety systems. The reactor was running at a dangerously low power level, which caused a build-up of xenon-135, a neutron-absorbing isotope that suppressed the nuclear reaction. In an attempt to increase power, the operators withdrew too many control rods—many of which were graphite-tipped—further destabilising the reactor.

The RBMK-1000 reactor used at Chernobyl had a dangerous design flaw: a positive void coefficient, meaning that when steam bubbles formed in the coolant, they increased the reactor's power output instead of decreasing it. This made the reactor inherently unstable, especially at low power.

At 1:23 a.m., the operators initiated an emergency shutdown by inserting all control rods. However, the graphite tips momentarily increased reactivity, causing a massive power surge. This led to a rupture of the reactor core and a powerful explosion, releasing more than 100 radioactive substances into the atmosphere. Radioactive fallout spread across Europe in the following days, and the nearby area—now known as the Chernobyl Exclusion Zone—became uninhabitable.

One critical factor in the disaster was the absence of a containment structure. Unlike most Western reactors, the Chernobyl plant lacked a steel- and-concrete barrier to contain radioactive materials in the event of an accident. As a result, between 13% and 30% of the 190 metric tons of uranium dioxide fuel and fission products were released into the atmosphere—some of which still persist today.

Of the approximately 600 workers present during the explosion, 134 received high doses of radiation, and 28 died within the first three months. An additional 19 died between 1987 and 2004, though not all deaths were conclusively linked to radiation exposure.

The disaster caused widespread radioactive contamination in Ukraine, Belarus, and parts of Russia. Millions were exposed to radiation, leading to long-term health issues, particularly thyroid cancer in children. The Chernobyl incident has had a lasting impact on global nuclear safety policies, reactor design, and public perception of nuclear energy.

RBMK-1000 - A type of nuclear reactor designed in the Soviet Union. It had a known safety flaw where steam increased reactivity, making it unstable in certain conditions.

Positive Void Coefficient - A reactor characteristic where the formation of steam increases the nuclear reaction rate, which can lead to instability and dangerous power surges.

Xenon-135 - A chemical element and strong neutron absorber that builds up in a reactor and can reduce its power output if not managed properly.

Neutron Absorbing Isotope - A material that slows or stops the nuclear chain reaction by capturing neutrons.

Reactivity - A measure of how quickly a nuclear reaction is increasing or decreasing. High reactivity means the reactor is producing more power.

Radioactive Contamination - The presence of radioactive substances on surfaces, or within solids, liquids, or gases, including the human body.

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ENGINEERING & TECHNOLOGY

LEAD EDITOR: JASMINE CARTER

Why is x86 and ARM architecture leading our life?

By: Ryan Chen



ABSTRACT

From time to time, more and more decisions are aided by microchips. Industries desire products that operate at their optimum and at the lowest cost and energy consumption. Thanks to persistent research and development of microchip nanotechnology, multiple types of processor architectures are developed; each targeting a specific application scenario with alternating performance characteristics and requirements to further enhance our living quality and reduce cost of living.

The story of the microchip begins in the late 1950s. Engineer Jack Kilby integrated all circuit and electrical components onto a semi-conductor, creating the first microchip. In a few months, Robert Noyce developed a similar chip with silicon, forming the prototypical structure of modern microchips.

In the late 20th century, the innovation of the microchip had just begun. The definition of the instruction set was heavily dependent upon the manufacturers of microchips; programs written in a specific instruction set could not be run by another microchip without the corresponding instruction set – though this was not a problem at the time, as the market is dominated by large corporations.

The first type of standardised microchip was CISC – Complex Instruction Set Computer. x86 is a 64-bit architecture, one of the most successful CISC architectures. Due to its powerful backward compatibility that allows its programs (developed in legacy architectures) to be run with the current hardware implementation. x86 also allows software developers to use high-level programming languages to build applications. High-level languages provide rapid development features based on abstractions of peripheral management and data structures – making the software easy to build and maintain.

But everything comes with a cost. While CISC microchips provide a massive ease of usability for developers, it is also expensive to produce, as it requires more circuit components for large instruction sets to run – which may introduce inefficiencies if the software is not optimised.

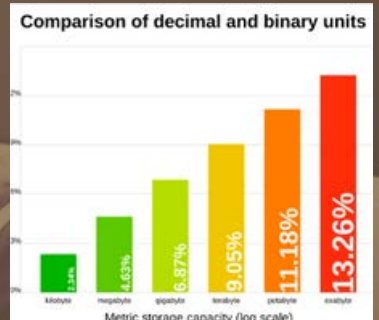
CISC microchips also target intensive data operations, resulting in inefficiencies, high power consumption, and greater heat dissipation requirements.

The RISC (Reduced Instruction Set Computer) microchip challenges the suitability and efficiency of CISC microchips surrounding limited physical resources and available features. The success of RISC microchips is mostly due to the market of mobile devices. Similar to PCs, smart phones can complete most tasks a computer can perform; and most importantly – they are cheaper and easier to produce. RISC microchips often offer incredible performance at a desirable power consumption rate, making it more suitable for portable device implementation. This opportunity promotes the rise of ARM architecture.

ARM microchips are gradually being favoured over other models. They can execute x86 applications with the aid of compatibility software – like Wine – with a reasonable performance loss. A reduced instruction set helps to simplify the complexity of circuitry and permits technologies like pipelining to be applied to enhance overall performance. The best example is Apple's best performing M-series processor. It has caused a phenomenal impact to CISC microchips. One of the benefits is that servers could be established with distributed systems on Macs by connecting them in series with a Thunderbolt 4 socket. The product has an exceptional performance in multitasking and float-point calculations in comparison to existing servers.

These creations led to the infinite possibilities of ARM – but x86 is still irreplaceable. More advanced architecture will be developed in the future, although when the time comes, will ARM and x86 still be considered as “products of the century”?

- **Microchip (chip) / Integrated Circuit (IC)** - a set of electronic circuits, consisting of various electronic components (often packaged).
- **64-bits Architecture** - processor can process 64 bits of data at an instance.
- **Legacy** - (computing) denoting or relating to software or hardware that has been superseded but is difficult to replace because of its wide use.
- **Backward Compatibility** – the capability of running earlier built versions of software on newer hardware.



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Channels of Innovation: How Ancient Roman Aqueducts Shaped Modern Waterways



By: Sophie Adeleye

ABSTRACT

The ancient Roman aqueducts revolutionised water transport with sophisticated engineering utilising gravity-fed channels, arches, and durable materials. Sourcing millions of gallons daily, their breakthrough techniques – from gradient control to waterproofing – set the standard that still influences modern infrastructure today, making Roman aqueducts an iconic example of hydraulic engineering and city planning.

The Romans were renowned for their extravagant way of life, with large urban centres and intricate infrastructure. Their skilled engineers developed advanced technologies to accommodate the demands of growing city populations, leaving a legacy that still shapes modern engineering today. Among these were the phenomenal aqueducts, structures first created by the Greeks and Persians, but refined over 500 years by the Romans. These water transport systems depended on gravity to pull water from springs, streams, and reservoirs, drawing it slowly downhill through intentionally designed channels. It flowed naturally on a precise slope of approximately 5cm per 100m – which was measured using simple surveying tools, like the chorobates and groma.

Aqueducts tended to run below ground level in tunnels, and sometimes cut through hills to achieve this. To avoid obstacles or valleys, vast arches were built on bridges – like the famous Pont du Gard in France – or U-shaped pipes (called inverted siphons) were used that allowed water to slope down and rise again due to pressure differences. The first major aqueduct, Aqua Appia (312 b.c.e), was a tunnel-like route which ran 10 miles underground, although later projects like Aqua Marcia (144-140 b.c.e) and Aqua Claudia (38 b.c.e) had high arches and double-tiered structures – some of the known characteristics of Roman architecture.

Roman aqueducts were constructed using locally sourced materials such as stone, brick, concrete, and lead. Channels – being normally about 0.7m wide and 1.5m high – were lined with waterproof mortar called opus signinum, composed of crushed pottery and tiles. In addition to protecting the water quality, this prevented leaks. Regular maintenance was necessary: workers would clean, plaster and inspect the pipes to prevent blockages and ensure a steady water supply.

These great structures supplied millions of gallons of water daily to Rome and other cities, powering public baths, fountains and agriculture by irrigation. The provision of free, potable water to the masses promoted public health and sanitation, which the large populations needed to thrive. Even after the fall of the Roman Empire, their aqueducts went on to inspire future generations. During the Renaissance, architects like Pope Nicholas V restored ancient infrastructure, like the Aqua Virgo, to serve growing cities. Roman engineers' principles of balancing water speed, pressure and structural support continue to influence water structures from tunnels to gravity-fed city mains in cities like New York.

Water transport systems and engineering continue to rely on concepts first mastered by the Romans. Today, aqueducts and pipelines follow similar design principles, with precise gradient control and durable materials to efficiently move water over long distances. Their use of arches for support inspired the bridges and elevated channels found in contemporary architecture.

Good practices such as regular maintenance and reservoir storage have been adopted in modern systems, ensuring clean water is reliably delivered to growing urban populations. These early successes were more than just marvels of their time; they laid the foundational groundwork for centuries of innovation in the design and operation of water transportation – a legacy still visible today.

- **Aqueduct:** an artificial channel for moving water from a distance, usually by gravity.
- **Chorobates:** an instrument for finding the level of water.
- **Groma:** a Roman surveying instrument which enabled the construction of right angles.
- **Hydraulics:** the scientific study of water and other liquids, in particular their behaviour under mechanical forces and their related uses in engineering
- **Infrastructure:** the basic physical and organisational structures and facilities (e.g. buildings, roads, power supplies) needed to run a society.
- **Irrigation:** the supply of water to land or crops to help growth, typically using channels

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The Rescue of Manhattan's Citicorp Center

By: Karl Edochie

ABSTRACT

Sitting at his desk, coffee cup emptied by the day's assignments, structural engineer William 'Bill' LeMessurier discovered a frightening flaw. Just a year after New York's Citicorp Center skyscraper had been constructed on Lexington Avenue in 1977, a miscalculation and cost-cutting oversight set off a race against the elements to avoid a fatal disaster.

The structural engineering behind constructing the Center was the first of its kind, and rightly so. The design emerged from a unique constraint: any new building on the site had to accommodate St. Peter's Lutheran Church at the northwest corner. Removing a corner of the skyscraper was an option, however LeMessurier made the architectural decision to remove all four corners, effectively building it on stilts.

The unconventional design of the building meant the building's weight had to be directed through massive diagonal braces to the stilts. To achieve this, LeMessurier used stacked, inverted chevrons that were welded together. But skyscrapers don't just stand; they sway. To counteract wind-induced movement, LeMessurier used something that had commonplace in bridges, powerlines and ships, but never in buildings—a tuned mass damper.

A year later, in May 1978, while consulting on a similar project, LeMessurier was asked whether bolted joints could replace welded ones. Curious, LeMessurier asked his office how the Citicorp Center joints had been built – only to discover that cost-cutting decisions meant that the welded joints he'd specified had been substituted for bolted joints. Around the same time, an architectural student contacted him with questions about the skyscraper's wind load assumptions. Together, these events prompted LeMessurier to revisit his calculations, and what he found was devastating. LeMessurier discovered that while the original design accounted for perpendicular winds, it ignored quartering winds, which turned out to be far more dangerous due to the unique structural layout. With quartering winds and bolted joints factored in, in any given year, there was a one-in-fifty-five chance of the building collapsing, which could increase to one-in-sixteen if the tuned mass damper couldn't operate.

Deeply worried by his discovery, LeMessurier rushed to apply reinforcement. Hurricane season was only weeks away and if publicized, he would lose professional credibility and cause mass panic. Every night from August 1978, welding plates were installed. Fortunately, major newspapers were on strike during the process and officials barely acknowledged the issue, despite that, they had not weathered the storm. Six weeks into repairs, Hurricane Ella was heading towards New York. With only hours away before considering emergency evacuation, and only half of the reinforcements installed, Ella veered away.

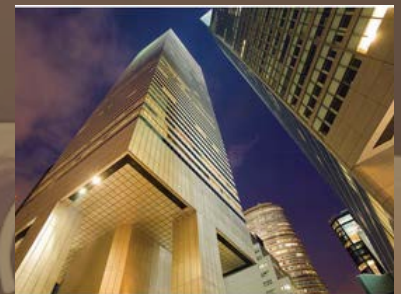
There are many lessons that existing and aspiring engineers can learn about this historical event, it's a story of unselfconscious humility and prioritising public safety over reputation and costs; a willingness to acknowledge mistakes and be proactive in solving them. Naturally, as engineers we want to solve the world's problems and move onto the next one, but when we introduce a problem into the world, fixing the issue is just as important.

Chevrons – triangular steel frames

Tuned Mass Damper – A 400 tonne concrete block designed to shift opposite to the direction of sway of the building

Perpendicular Winds – Winds that blow perpendicular the surface i.e. head on.

Quartering Winds – Winds that blow diagonally across a surface as opposed to perpendicular to the surface. See also: perpendicular winds



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Beyond the Blueprint: Exploring Engineering Failures

By: Moumin Yassin



ABSTRACT

On the morning of January 28th, 1986, the Space Shuttle Challenger exploded barely one minute after launch, killing all 7 people on board. The Challenger disaster was not only one of the worst space-related tragedies in the history of NASA, but it also exposed many ethical and organisational deficiencies throughout the institution. It highlighted the importance of balancing political pressure with safety and engineering integrity, and it remains one of NASA's most significant lessons in risk management and institutional accountability.

Titan submersible implosion (2023)

Titan, previously named *Cyclops 2*, was a submersible created and operated by the American underwater-tourism company OceanGate for deep-sea tourism. It was the first privately-owned submersible with a claimed maximum depth of 4,000 meters, and the first completed crewed submersible with a hull constructed of titanium and carbon fiber composite materials. On 18th June 2023, the titan imploded during an expedition to view the wreck of the titanic in the North Atlantic Ocean off the coast of Newfoundland, Canada, resulting in the instantaneous death of all five occupants, including the CEO of OceanGate.

Quite simply, an implosion is the opposite of an explosion. In an explosion, the force acts outwards, but in an implosion the force acts inwards. When a submersible is deep in the ocean it experiences the force on its surface due to water pressure. When this force becomes larger than the force hull can withstand, the vessel collapses inward – a phenomenon known as implosion. The likely cause was a combination of factors related to its experimental design and the immense pressure at the Titanic's depth. The primary cause is believed to be a catastrophic failure of the carbon fiber hull, possibly due to delamination (separation of the layers) or micro-buckling under pressure. Other contributing factors may have included manufacturing defects, stress concentrations at the joints, and the vessel's oblong shape, which could have led to uneven pressure distribution. The key is the design of the hull that protects the vessel against the large external water pressure that is trying to crush the hull. Much of the existing technology is based on steel, titanium and aluminium. The performance of these materials under extreme stress is well understood. However, the Titan's hull had an experimental design. It used mostly carbon fibers, which have the advantage of being lighter than titanium or steel, so Titan could have more space for passengers. Properties of carbon fibers for deep sea applications are, however, not that well understood. It can crack and break suddenly. The destruction was the more devastating, because it was accompanied by a secondary explosion due to the heat exchange between the collapsing air volume and the ambient sea water.

It is worth noting that authorities have not yet confirmed the cause of the disaster, however all of the evidence (ship footage) present led to the speculation that the submersible imploded due to the use of carbon fiber. Analysis presented during the MBI hearing indicated a primary failure mechanism initiated at bond interfaces between the multi-layers of the carbon fiber hull.

The Titan tragedy serves as a stark reminder of the risks associated with cutting-edge, but unverified engineering. It reinforces the lesson: innovative design mustn't ever compromise safety.

Diligent: having or showing care and conscientiousness in one's work or duties.
Hull: the main body of a ship or other vessel, including the bottom, sides, and deck.
Instantaneous: occurring or done instantly.
Stress: pressure or tension exerted on a material object.
Ambient: relating to the immediate surroundings of something.
MBI: Marine Board of Investigation
Interfaces: a point where two systems, subjects, organizations, etc. meet and interact.



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A War Between Engineers and Politics

By: Alexander Hu



ABSTRACT

On the morning of January 28th, 1986, the Space Shuttle Challenger exploded barely one minute after launch, killing all 7 people on board. The Challenger disaster was not only one of the worst space-related tragedies in the history of NASA, but it also exposed many ethical and organisational deficiencies throughout the institution. It highlighted the importance of balancing political pressure with safety and engineering integrity, and it remains one of NASA's most significant lessons in risk management and institutional accountability.

Many people believe that spacecraft launch dates are dictated by how long it takes to refurbish or build the vehicle. In reality, launch dates are often set far in advance, and engineers are often under immense pressure to meet these deadlines. This pressure was particularly intense during the years leading up to 1986, as the culture of "Go Fever" gripped NASA – especially after a string of successful launches. In fact, a record 9 space shuttle missions had flown the previous year, the most in a single year up to that point. As a result, many engineers felt compelled to downplay risks to keep up with the high launch cadence.

In light of the previous 9 successful launches, the Reagan administration was eager to demonstrate the reliability of their space agency's shuttles, especially with the planned participation of the first civilian in space: Christa McAuliffe, a school teacher. Her involvement brought international attention, symbolising the promise of commercialised spaceflight and expanding access to space. Delaying the launch wouldn't just be a technical issue – it would be a political embarrassment to NASA, and could damage public confidence in the organisation. As a result, when engineers raised serious concerns about the launch and recommended delaying it, they were met with hard opposition from NASA.

The mounting pressure on NASA to keep the launch on time, led to the infamous teleconference call between engineers from Morton Thiokol, who was responsible for the SRBs (Solid Rocket Boosters) and the Marshall Space Flight Centre in Florida the night before the scheduled launch. The discussion was focused around the shuttle's rubber O-rings – which sealed joints in the boosters. These had been known from previous flights to be very brittle at low temperatures and considering the unusually cold weather forecast for the next day, they pushed to delay the launch. If the O-rings failed, hot exhaust gasses could leak through the joints, leading to a hole and henceforth catastrophic booster failure.

Unfortunately, they were overruled by NASA's Lawrence Mulloy, the SRB project manager, who argued that there was not enough evidence to support the claim and even asked whether Morton Thiokol expected him to wait until April for warmer temperatures.

Tragically, the O-ring failed exactly as engineers feared. Just 73 seconds after liftoff, the Challenger broke apart, killing all seven crew members.

Regrettably, NASA did not learn much from this incident, as seventeen years later, NASA faced another major disaster with the Columbia accident, again rooted in ignored safety concerns.

Only after these tragedies did the agency begin to adopt more robust safety protocols and contingency planning. The Challenger disaster remains a powerful reminder that no political goal should be prioritised over life of any kind.

"Go fever"

- Represents the rush to launch rockets. Coined after the Apollo 1 disaster.

"O-Rings"

correct place.

- A sealing device that was used in Challenger to keep exhaust gasses leaving the

"SRB"

- Solid Rocket Booster – used to generate large amounts of propulsion.

"Commercialise"

- To manage something in a way designed to make profit.



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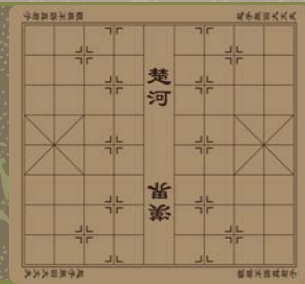


MATHS

LEAD EDITOR: AARON CHEN

A Brief Chronicle on Xiangqi

By: Aaron Chen



ABSTRACT

Although its origins are unclear, Xiangqi (also known as Chinese Chess or Elephant Chess) is said to have existed for over two millennia. From Hong Kong to Houston, it is still being played by over a billion people today. Whereas Xiangqi is indeed less popular than its Western counterpart, the game equally tests a player's logic and strategy, whilst still being accessible and entertaining for all!

Background

Many claim the board symbolises a battle between the Qin and Han **Dynasties** around 200 BCE. Following this interpretation, the Han leader (Liu Bang) created the game to commemorate his victory and overthrow of the Qin **autocracy**. This would certainly justify particular aspects, such as the "Flying General Rule", which states the two "generals" (more information on them later) cannot face each other without pieces between them. After all, legend claims Liu Bang was inches away from being killed with an arrow from his rival, Xiang Yu. Furthermore, the red and black colouring of the pieces may represent the two armies within the war, as Liu Bang was sometimes remarked as the "Crimson Emperor".¹

Board

Xiangqi is played on a 9x10 grid, with pieces on the intersections, creating a more unrestricted atmosphere compared to a Western chessboard, which is 8x8 in size. Additionally, each side has a 3x3 box marked by diagonals - this is named "the Palace". A final noticeable difference is "the River", which **bisects** the board horizontally.

Pieces

Often, the same piece on either side is branded with synonyms (e.g. both 卒 and 兵 mean soldier), as most were too underprivileged to have the pieces coloured to differentiate. This section will provide an overview of how all the pieces move, as well as what piece they resemble in Western chess. If you are unfamiliar with how pieces move in Western chess and want to know more, there is a link in Further Reading with all the details:

Soldiers (卒/兵) are like pawns in that they initially move and capture one position vertically upwards at a time. However, if they cross the river, they then gain the same abilities horizontally. There are five a side, and (unlike pawns) they do not constrain many other pieces from moving, meaning players may develop their more powerful pieces early on in matches.

Chariots (車/俚) and Cannons (砲/炮) can be thought of as rooks, as both can move any **orthogonal** distance. However, a cannon must jump over a piece, regardless of whether it is their own, before taking an opponent's material. Meanwhile, horses (馬/馬) correspond to knights, moving in a distinctive "L" shape. Unlike knights, though, they cannot jump over a piece.

Advisors (士/仕) and Elephants (象/相) are both like a weaker variety of bishop. They can only move one and two diagonal spaces respectively. Advisors may only move within "the Palace". Elephants are unable to cross "the River", meaning they are primarily used for defence.

Lastly, the General (將/帥) resembles the king, both in terms of movement and role. The objective is to put the other general in **checkmate** using the rest of your pieces. Like advisors, the General may only travel inside "the Palace" and, as mentioned previously, there must be at least 1 piece between the generals if on the same column.²

So...now you know the rules? Good. Let's play!

Dynasties – A group of leaders or rulers all from the same family
Autocracy – A government where one person has absolute power
Bisects – Divides into two equal parts
Orthogonal – Up, down, left, right, but not diagonally!
Checkmate – When the general/king is unable to move without being captured

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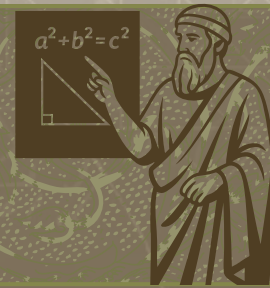


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The Three Mathematical Crises

By: Isaac So



ABSTRACT

The study of mathematics began from about 3000 BC and is often perceived as a field dedicated by structure and harmony. However, throughout these 5000 years, there have been three mathematical crises and each of them have had a huge impact on Maths. Although these crises are often grouped together, they span across multiple eras of history, as well as a wide range of topics, from number theory to calculus and to **set** theory.

The First Mathematical Crisis

Around 520 BC, a famous ancient Greek philosopher named Pythagoras taught others mathematical beliefs, such as how every number is rational. At that time, the Pythagorean theorem has already been discovered, but Hippasus found a problem. He posed that a right-angled isosceles triangle with "leg" side length 1 would have a hypotenuse of length $\sqrt{2}$, which he further deemed as irrational. As the Pythagoreans became distraught by the existence of irrational numbers, legend claims they threw Hippasus into the sea, so as not to spread his ideas further.

The Second Mathematical Crisis

In late 17th century, Leibniz and Newton discovered infinitesimal calculus. However, a bishop called George Berkeley questioned the use of infinitesimal in calculus. In a typical question in calculus (example below), one of the steps is to divide the denominator by an infinitesimal (h in the example). Conversely, in a step afterwards, Newton removes the term that contains it. So, Berkeley questioned, "What is infinitesimal?"

The first step shows that infinitesimal isn't 0 as it is not possible to divide something by 0. On the other hand, if it is anything other than 0, then it is not possible to remove the terms that contains it. Even though the use of infinitesimal is shown to be correct through mechanics, there is still a contradiction in the mathematical derivation process. After 150 years, Cauchy was finally able to rigorously define infinitesimal through the δ - ϵ (delta-epsilon) definition of limits to resolve the problem.

Example Question

The Third Mathematical Crisis

In 19th century, Georg Cantor developed the naive set theory. Within naive set theory, there is an assumption called the Unrestricted Axiom of Comprehension, which states "for any property $P(x)$, there exists a set $Y = \{x : P(x)\}$ ". This assumption then leads to Russell's paradox, more commonly named the Barber's paradox. Imagine that there is a barber in a village who shaves all and only those villagers who don't shave themselves. The problem is – does the barber shave himself? If the barber shaves himself, then he is not a "villager who does not shave himself", meaning he should not. If the barber doesn't shave himself, he is a "villager who does not shave himself", meaning he should!

According to a rule called the Unrestricted Comprehension Schema, there must be a set that contains all those sets that satisfies the property. If we consider the set of all sets that don't contain themselves (R), does this set (R) contain itself? If R contains itself, it must satisfy the condition of "R doesn't contain itself" and so it doesn't. If R doesn't contain itself, it must not satisfy the condition of "R doesn't contain itself" so it does. So, R contains R but R doesn't contain R . Hence, there is a contradiction. In order to resolve Russell's paradox, the ZFC set theorem is introduced.

Set – A well-defined group of objects and objects. For example, 3 is a member of the set of prime numbers.

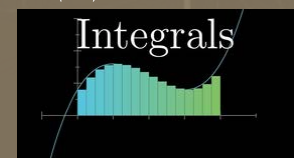
Infinitesimal – A non-zero quantity that is closer to 0 than any non-zero real number is but it is not 0 – it only approaches 0

Rational – Numbers that can be expressed as a fraction where both the numerator and denominator are coprime integers, and the denominator is not 0

Pythagorean Theorem – $a^2 + b^2 = c^2$, which a and b are the 2 shorter sides and c is the longest side of a right-angled triangle (hypotenuse).

$Y = \{x : P(x)\}$ – You can define a set, Y , by collecting all objects, x , that have some logical property, $P(x)$

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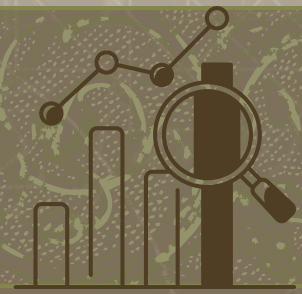


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Statistics: Lying Made Easy

By: Lorraine Nombo



ABSTRACT

From the Middle Ages to the modern algorithm, statistical data has been consistently repurposed to mobilise and control the masses. Governments and corporations alike have skewed data through **selective sampling**, suppression, and **narrative framing**, and modern digital tools – such as **algorithms** and short-form video content – have caused information to spread faster than ever, making calculated control all too easy.

One of the first documented instances of statistical manipulation was during the bubonic plague of the 14th century; the Italian government surveyed public health data: they underreported diagnoses and overstated recoveries, causing citizens to see the plague as something no more deadly than a common cold and effectively minimising their hysteria over the disease.

You could argue that the Italian government had noble intentions – unlike the corporations of the 20th century, whose avaricious intentions were exposed by Edward Bernays in his seminal work, “Propaganda [1928]”. Bernays explores how surveying people who are believed to be more credible (i.e. scientists) effectively warps the public opinion in favour of the survey. This occurred when scientists were commissioned to endorse bacon and eggs as a healthy breakfast option – which only recently has been debunked.

The most infamous case of data manipulation was the **propaganda** which led to the persecution of Jewish people between 1933 and 1945: the Nazis published pseudo-scientific “racial **statistics**” which portrayed the Jews, Roma and other races as inferior, fabricated and elongated numbers so that Jews appeared to be responsible for the majority of crimes. Furthermore, the regime misrepresented wealth distribution statistics which became the origins of the miserly Jewish banker stereotype today.

And finally, we come to the modern day. As people have become more cautious, and less afraid to expose corporations, more knowledge than ever is being shared across the globe. Unfortunately, this has arguably facilitated the spread of myths and misinformation. This was evident when influencers and small organisations fear mongered the public by claiming that vaccinated individuals were more likely to die than unvaccinated individuals: they used absolute counts as opposed to death rates per capita, which would have given completely different (and far more accurate) mortality rates.

Our ever-developing technology has made it simpler for companies to bypass our precautions and continue to manipulate the public. Who could have predicted that a simple poll would result in manipulation of the masses? Well, that’s just how easy it is to lie using statistics.

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Misuse of Statistics

Misuse of statistics refers to the incorrect application or interpretation of statistical data, which can lead to misleading conclusions. Both descriptive and inferential statistics can be misused if the user does not understand their limitations and the assumptions underlying their use.

Descriptive statistics summarize and organize data but do not allow for predictions or inferences about broader populations. For instance, different measures of central tendency, like mean, median, and mode, can yield distinct interpretations depending on the distribution of the data, yet they are often presented interchangeably, leading to confusion.

Statistics - collecting, analysing, and interpreting data to help make decisions or understand patterns and trends

Selective sampling - certain individuals or groups are chosen (intentionally or unintentionally), leading to a sample that doesn't represent the whole population - this can bias the results

Narrative framing - information is presented or structured to promote a particular interpretation or viewpoint, often influencing public perception

Algorithms – a set of rules or instructions that are followed to solve problems or make decisions based on data

Propaganda - information, often biased or misleading, spread deliberately to influence people's opinions or behaviours, usually for political purposes

Absolute counts – the raw number of occurrences or cases in a dataset, without adjusting for population size or other factors

Death rates per capita - number of deaths relative to the total population - typically expressed as deaths per 100,000 or million people – allowing for fair comparisons between areas or groups of different sizes

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Nature of Transcendental Numbers

By: Ryan Chen

$$\frac{d}{dx}(x^n) = nx^{n-1}$$

ABSTRACT

Imagine you have an endless ruler displaying every possible value: would you be able to see every real number? Surprisingly, mathematics shows us that some real numbers are fundamentally "uncatchable". Despite the ruler being uniformly continuous, its values are not. This article will describe what **discrete** mathematics is and how it is used to prove that transcendental numbers exist.

The first concept of discrete mathematics is that numbers are discrete. Numbers are categorised into different **sets** based on their attributes. To find out what transcendental numbers are, and the set that they belong to, you may need to know two real number sub-sets that relate to them.

Irrational (Quotient) Numbers (\mathbb{Q})

If it can be written as a fraction with a **co-prime** numerator and denominator, it is rational. When written as decimals, rational numbers terminate or recur (repeat themselves). Conversely, an irrational number cannot be written as a fraction this way, and its decimal form contains an infinite number of non-repeating digits.

Algebraic Numbers (\mathbb{A})

If it can be expressed as a root of a polynomial with integer coefficients and **exponent**. For instance, the equation " $x^2 - 2 = 0$ " has the roots $\pm\sqrt{2}$.

Now the question is: if we had an infinite number of roots, from every polynomial to exist, would they cover all the numbers in the real set?

Proof of Transcendental Numbers

Following Liouville's **theorem**, we may establish a **conjecture** that "if β approaches α and the **modulus** of $\alpha - \beta$ (denoted as $|\alpha - \beta|$) is greater or equal to a constant, then at least one transcendental number must exist between α and β ."

To show this, suppose we have two real numbers α and β . Let α be a real constant and β be a rational variable that is denoted as p/q and $\alpha < \beta$.

As α is a real number, it satisfies the condition of an algebraic number. So, we denote an integer coefficient polynomial expression as $f(x)$ and let α be a real root of $f(x)$; hence $f(\alpha) = 0$.

Here, we need the value of $f(\beta)$. Once we found that $f(\beta) = f(\alpha)$, it means that all values in the real number set can be algebraically expressed, as the theoretical gaps do not exist.

To find $f(\beta)$ in its simplest form, we differentiate $f(\alpha)$ using first principles. From there, we then deduce $f(\beta)$ or $f(p/q)$ equals the product of "the rate of change of $f(\alpha)$ and the difference of α and β ."

Unfortunately, we get the expression for $f(p/q)$. Despite $f(p/q)$ not being a numerical value, it can still be simplified:

Multiply $f(p/q)$ by qn to cancel out the denominator of $f(p/q)$. We deduce $|qn f(p/q)| \geq 1$, hence $|f(p/q)| \geq 1/qn$ as the polynomial $qn f(p/q)$ now has integer coefficients.

By substituting the expression of $f(p/q)$ back and divide both side by the derivative of $f(\alpha)$, we get $|\beta - \alpha|$ is greater than or equal to "one over (the rate of change of $f(\alpha)$ times by qn)".

The rate of change of $f(\alpha)$ is a constant as α is a constant. Thus, we deduce $|\beta - \alpha|$ is greater than or equal to a constant divided by qn , which is still a constant.

Finally, we can conclude that β cannot approach α as there is a number in between α and β . Hence, transcendental numbers must exist within the real number set that are irrational and cannot be expressed as roots of polynomials.

Discrete – not continuous, exist gaps in between a range.

Set – a collection of number that follows defined rules.

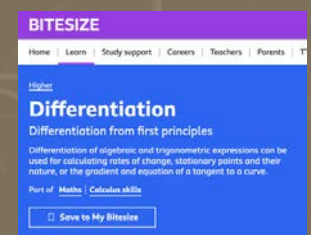
Co-prime – two integers that does not share any common factors except one.

Modulus – a function only returns positive value regardless of the input value. Exponent – same as "power" and "index", is the number of times that a number is multiplied by itself.

Conjecture - a statement that mathematicians believe is true, but which hasn't been proven yet.

Theorem - a mathematical statement that has been proven to be true.

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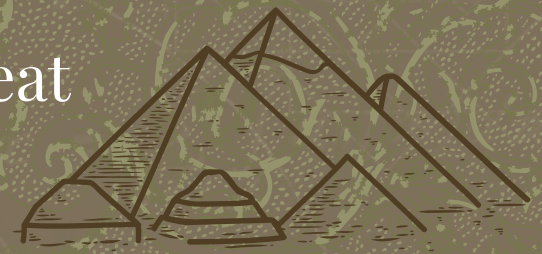


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The Mathematics behind the Great Pyramid of Giza

By: Zoonera Yasir



ABSTRACT

Built by the Pharaoh Khufu in 2600 BCE, the Great Pyramid of Giza embodies both a **homage** to his reign, and an attempt to immortalise himself in history. Today, it stands as the last surviving wonder of the ancient world and one of the earliest large-scale demonstrations of applied mathematics in human history.

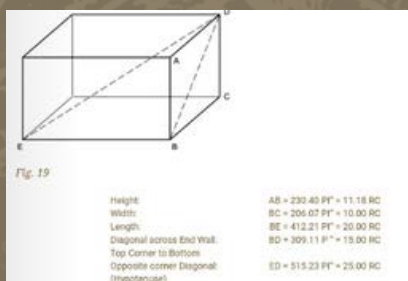
Achieving such a monumental feat required a standardised unit of length: the cubit. At around 52.4 cm, the cubit was based on the length of the arm - from the elbow to the tip of the middle finger (1). This unit would have allowed for consistency in measurement during construction and enabled the base of the Great Pyramid to be nearly a perfect square, with only slight variations inside lengths. The precise dimensions of the Great Pyramid despite its immense scale demonstrate how the architects of the time were capable of extraordinary accuracy, without current systems such as the metric and imperial.

In addition to its geometric precision, the proportions of the Great Pyramid are believed to closely approximate the golden ratio. Around 1:1.61803, it is **ubiquitous** in many parts of nature, art, and architecture, from the spirals in nautilus shells to Leonardo da Vinci's Mona Lisa 2. Due to its universal prevalence, the ratio is believed to embody beauty, balance, and aesthetic harmony, making its presence in the pyramid's design especially fascinating.

By taking the slant height of the Great Pyramid (186.39 m) and dividing it by half the base (115.182 m), the result is incredibly close to the golden ratio (1.61804, accurate to the golden ratio to 4 decimal places) 3. These dimensions were used by the Egyptians to increase stability of the structure, shedding light on why the pyramid was able to withstand strong desert winds and collapse for over 4,000 years. Even before its discovery by the Greeks over 4000 years later, the close resemblance raises intriguing questions about the Egyptians' **comprehension** of harmonious proportions and mathematical ideas long before they were formally defined.

In addition to the outer dimensions of the Great Pyramid, the interior reveals sophisticated applications of mathematical reasoning. As shown in the diagram, the two internal diagonals and the length- $BD=15$ cubits, $BE=20$ cubits, and $DE=25$ cubits-form the classic ratio 3:4:5 when divided by 5 4. The use of the 3:4:5 triangle—which would later be formalised as the Pythagorean Theorem—suggests that Egyptian architects deliberately incorporated geometric principles into their designs. Such precise proportions reflect careful planning but reveal a remarkable level of architectural sophistication, even without the use of modern mathematical notation.

Although the Great Pyramid was built primarily as a tomb to honour Pharaoh Khufu, its enduring legacy today lies far beyond its original purpose. The remarkable mathematical precision and deliberate proportions are symbolic of the advanced geometry possessed by the Egyptians. Not only does the Great Pyramid of Giza stand as a symbol of historical prosperity but also as humanity's earliest monument to applied mathematics through the remarkable mathematical precision and deliberate proportions of the structure.



Glossary

Ubiquitous - present, appearing or found everywhere

Comprehension - the ability to understand something

Homage - special honour or respect shown publicly

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Unraveling the Mathematical Genius of Ancient Egyptian Pyramids

Oct 20, 2023 0 comments

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