ISSN (O): 3083-2594

AIMERS FOUNDATION

CREATING IMPACT - FOR ALL - BY ALL

Make A Mark

Academic Journal for Students

Creating Confident Science Communicators



Volume 1 | Issue 4 | September 2026

Published By

AIMERS Foundation

Publisher : **AIMERS Foundation**

Country of Publishing : **Australia**

Website : www.aimersfoundation.org

Email : mamjournal@aimersfoundation.org

ISSN(O): 3083-2594

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Compiled by Dr. Pradeep Murthy

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Make – A – Mark

Editorial

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1. Form to Formula

"Form" is derived from the Latin **"forma"**, meaning **shape, appearance, pattern, or model.** "**Formula"** is derived from the Latin "**formula"**, literally **a "little form" or "small model"**, that is, the diminutive or much smaller than usual of forma.

Over time, formula came to mean a fixed form of words or procedure, such as a standard expression used in law, religion, or rhetoric. Later, the word acquired its mathematical meaning: a fixed symbolic expression or rule used to calculate something.

It is important to note that the word "formula" did not originally mean a mathematical equation. Its mathematical sense developed much later. Early mathematics often began with forms: **point → line → surface → solid**.

Geometry would rank highly in representing the forms, as ancient civilizations faced urgent, real-world survival needs that were related in some way to physical space. The word geometry itself means "earth measurement", reflecting how early societies in Egypt, Mesopotamia, and the Indus Valley used shapes, lines, and angles to manage land, construct buildings, and track the seasons. Eventually, humans learned to represent quantities and relationships symbolically.

The following two progressions are vital to learn:

1. Form → a prescribed / small form → formula → a fixed rule or expression → mathematical formula
2. Physical form → Observation → Measurement → Abstraction → Relationship → Mathematical model → Formula

A physical form becomes a mathematical formula upon removing the extraneous object details and preserving the underlying relationships in symbolic form. There is therefore a beautiful conceptual connection:

- A physical form is recognized as a pattern.
- The pattern is abstracted.
- The abstraction is represented symbolically.
- The symbolic representation becomes a formula.

It is seldom **"shape → equation"**, but it is instead mostly **"thing → properties → quantities → relationships → symbols"**. Without any loss of generality, it can be understood that it is such **"things"** that originate from mathematics.

The standard form is a generalised means of representing any type of notation. As such, the standard form formula is a commonly accepted form of an equation.

Form is structure. Formula is structured rule. Format is structured representation. That is, **FORM → FORMULA → FORMAT** is one of the most useful conceptual chains especially in Science and Engineering.

The words form, formula, and format are closely related to the Latin word *forma*, meaning shape, form, figure, pattern, or model (see **Table 1**).

Table 1. Form, Formula and Format

Term	Basic definition	Evolution
Form	Shape of appearance	What something is shaped like
Formula	A prescribed form or pattern	The rules/patter by which something is constructed
Format	Arrangement or prescribed form	How something is organised/presented

2. Science and Engineering

Science and Engineering preserve the brilliance of any given shape becoming an abstract idea comprising of structures and rules. A formula expresses the underlying relationships among things after abstracting away their physical material. An engineer by profession can conjure forms from ideality to reality by leveraging labour-intensive methodologies.

An equation states that two expressions are equal using an equal sign, while a formula is a specific type of equation that shows a general rule or relationship between multiple quantities. All formulas are equations, but not all equations are formulas.

Table 2. Formula and its most common variants in Science and Engineering

Term	Definition	Key relationship symbol	Example
Formula	A fact or a rule that relates two or more quantities using mathematical symbols.	"="	$D = S \times T$
Equation	A statement showing that two mathematical expressions are equal. An equation contains an equal sign "=".	"="	$5 - 3x = 2x + 4$
Expression	A mathematical statement combining numbers, symbols and operators.	N/A	$2x^2 + 4x - 7$
Identity	A relationship showing that two mathematical statements are identical.	"≡"	$2(x + 1) \equiv 2x + 2$

3. The Dynamics of STEAM

The Foundational Formula: STEM + Arts = STEAM

The classical formula shows that technical execution (STEM) requires creative interpretation, aesthetics, and design thinking (Arts) to build human-centric solutions.

Georgette Yakman's Framework Formula: **S**cience & **T**echnology [Interpreted Through] → **E**ngineering & **A**rts [Based on Elements} → **M**athematics

The Competency Formula: Hard Technical Skills + Design Thinking + Automated Proof Innovation

STEAM has Forms and Formulae as the pivot.

Articles

MISSION SHAKTHISAT – GLOBAL CONCLAVE 2026 – PHASE 2
SUCCESSFUL COMPLETION

Sukruti Narayanan
Managing Editor – Make A Mark Journals
Founder & President – AIMERS Foundation

Mission ShakthiSAT is an international space education initiative conceptualised and led by Dr. Srimathy Kesan, Founder and CEO of Space Kidz India, with the objective of engaging approximately 12,000 girls from 108 countries in space science, satellite technology and STEM education. The programme included approximately 120 hours of training, followed by an international conclave bringing participating students, country representatives and ambassadors together in India.

The Mission ShakthiSAT Global Conclave was held at Gautam Buddha University, Greater Noida, Uttar Pradesh, from 22 to 31 August 2026. The programme commenced in conjunction with India's National Space Day and Gautam Buddha University's 19th Foundation Day. Participants representing the mission's international network took part in activities focused on space science, satellite technology and related STEM disciplines. The programme also provided a platform for interaction and collaboration among students, educators, space professionals and representatives from participating countries along with the opportunity to learn “hands-on” on how to build a satellite.

AIMERS Foundation, Australia, participated as the Global Fundraising Partner for Mission ShakthiSAT, with its Founder and President, Suk Narayanan, serving as Global Head of Partnerships and Australian Ambassador. AIMERS Foundation's primary responsibility was to support the participation of students in Australia and is glad to note that over 250 students have been part of the Mision with 4 students representing the country on the Global platform. Aarvi Chhabra (NSW), Dhanvi Deshpande (QLD), Evelyn Larsen (Regional Australia), Kathleen Roberts (VIC) represented Australia as student leaders with Sukruti Narayanan heading it as the Australian Ambassador.

Apart from National participation, through community fundraising, donor engagement, partnerships and international coordination, approximately AUD 40,000 was raised, enabling the AIMERS Foundation to facilitate travel arrangements and book international air tickets for students and ambassadors representing 11 countries to attend the Global Conclave.

A significant outcome of the programme was its recognition by the World Records Union (WRU). On 28 August 2026 at Gautam Buddha University, Mission ShakthiSAT was certified for the record of the “Most Nationalities Represented in a Women's Space Education Programme.” The WRU certificate records participation by young women from 108 countries in the global programme focused on space education and technology, organised by Space Kidz India and spearheaded by Dr. Srimathy Kesan.

The programme subsequently received national recognition when Prime Minister of India Narendra Modi referred to Mission ShakthiSAT during the 137th episode of *Mann Ki Baath* on 30 August 2026, highlighting the participation of approximately 12,000 girls from 108 countries in the initiative.

On 29th of August, the program witnessed the presence of the Group Captain of Indian Airforce and the pilot of Axiom Mission 4 – **Shubhanshu Shukla ,** the First Lady of SeyChelles - **Hon. Veronique Herminie ,** Director of IN-SPACe (Indian National Space Promotion and Authorisation Centre) – **Dr. Vinod Kumar** along with the Vice Chancellor of Gautam Buddha University – **Dr. Rana Pratap Singh.**

The Global Conclave therefore marked an important implementation milestone for Dr. Srimathy Kesan's Mission ShakthiSAT, combining international participation, space education, partnership development and coordinated support to enable students from diverse geographical and socioeconomic backgrounds to participate in the programme.



Figure 1. Australian representatives at Mission ShakthiSAT



Figure 2. International representatives at Mission ShakthiSAT



Figure 3.During the Indian National Anthem along with the dignitaries on 29th August



Figure 4. *Group Captain of Indian Airforce and the pilot of Axiom Mission 4 –* ***Shubhanshu Shukla (L)*** *Founder and Mission Director of Mission ShakthiSAT –* ***Dr. Srimathy Kesan (C),*** *the First Lady of Seychelles -* ***Hon. Veronique Herminie (R)***





Figure 5. Record-breaking for Mission ShakthiSAT for most nationalities represented in a Women's Space Education Programme.

EUKARYOTIC NITROGEN FIXATION: THE ABSURDITY OF *B. BIGELOWII*

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Abstract

A microscopic alga is rewriting an ironclad belief of scientists, fundamentally altering biology as we know it. It was the first known complex organism that could pull out and use nitrogen straight from the air, called nitrogen fixation. This paper is an introduction to the fascinating absurdity of Braarudosphaera bigelowii and the inspiring journey behind its discovery.

Keywords: *Braarudosphaera bigelowii; Eukaryotes; Nitroplast; Nitrogen Fixation; Symbiotic Relationships; Bacteria; Endosymbiosis; Nitroplast*

Introduction

There is something interesting, even laughable, about life on Earth. All living organisms require nitrogen to survive, as it is an important element in amino acids (which make up proteins) and an essential part of nucleic acids (including DNA and RNA). Fortunately for us, Earth's atmosphere is 78% nitrogen. To utilise nitrogen, nitrogenase, a complex enzyme that converts atmospheric nitrogen (N_2) into a usable form for living organisms, is required. However, nitrogenase itself breaks down in the presence of oxygen.

This means that all complex forms of life, including plants, birds, and so forth, are surrounded by potentially unusable nitrogen forms. Instead, organisms must typically be leveraged that do not require oxygen (simple bacteria and archaea) to access nitrogen. *Braarudosphaera bigelowii*, however, completely ignores this rule.

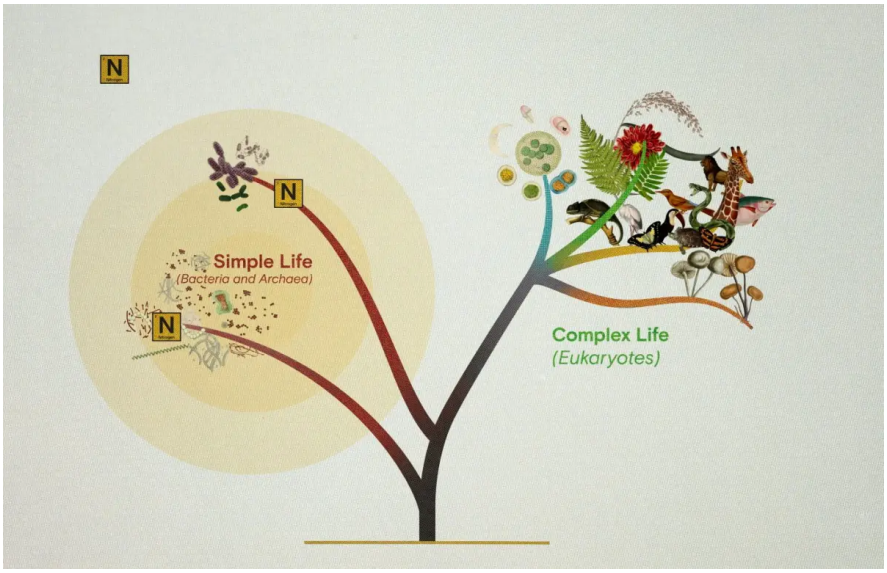


Figure 3. A diagram of how animals, plants, and fungi rely on simple microbes like bacteria and archaea for nitrogen. Jesse Nichols / Grist

Discovery

The discovery of *Braarudosphaera bigelowii* started in the 1990's when Jon Zehr, an oceanographer, was studying nitrogen-fixing bacteria, which are simple, microbial life forms that can use nitrogen directly from the air and make it bioavailable for plants and animals. Zehr planned to collect seawater samples and run DNA tests for the nitrogenase gene.

His endeavour was a success, and almost immediately, he found the gene he was looking for. The new organism was likely 3 μm-long cyanobacteria that fluoresces orange under the microscope. However, he could not find any bacteria that matched the description when he looked at his sample under the microscope. The genetic signature was there, but not the visible bacteria.

Another peculiar thing about the bacteria was that it seemed to have lost 80% of its genome, including several essential genes. For example, its genetic markers suggested that the bacterium was photosynthetic, but it did not have the genes to photosynthesise.

After studying the bacteria for many years, Zehr started to notice a pattern in the samples he collected. Whenever he found the DNA for the nitrogen-fixing bacteria, he also found the DNA of a particular type of algae. Zehr began to suspect that the bacterium was, instead of a standalone organism, living *inside* the algae, which explains its ability to survive despite the missing genes.

Further away, Kyoko Hagino, a Japanese algae scientist, was researching algae fossils in the ocean floor within a palaeontology team. Among the fossils she was researching, *Braarudosphaera bigelowii* caught her attention because of its interesting geometrical shape.

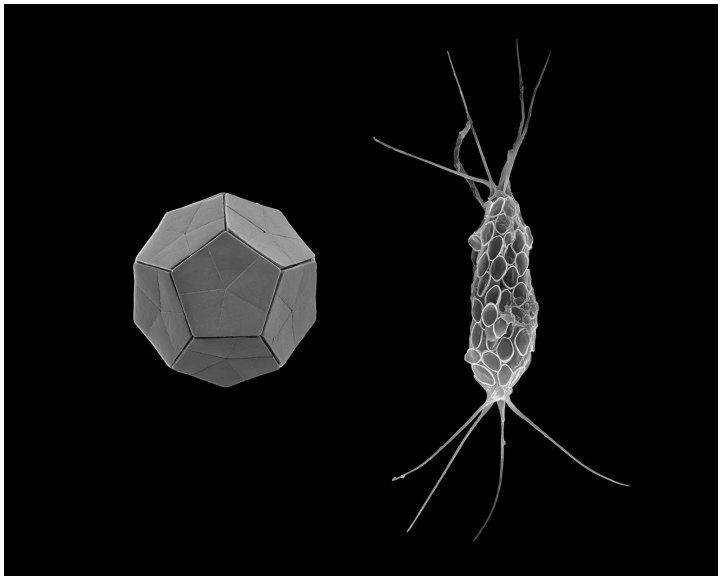


Figure 4. Braarudosphaera bigelowii in its jewel-like calcified (left) and non-calcified (right) forms. Courtesy of Kyoko Hagino

Hagino would visit the sea with her young daughter to collect samples. However, she found it difficult to study them due to their scarcity in the sample. To make ends meet, Hagino took up a part-time job to clean test-tubes. One of the scientists there suggested adding tokoroten, a traditional Japanese jelly noodle, to her culture. This greatly increased the number of cells grown, allowing Hagino to study it in greater detail.

Using a transmission electron microscope, Hagino discovered something odd in *Braarudosphaera bigelowii.* It had all the components of a cell, along with an extra structure.

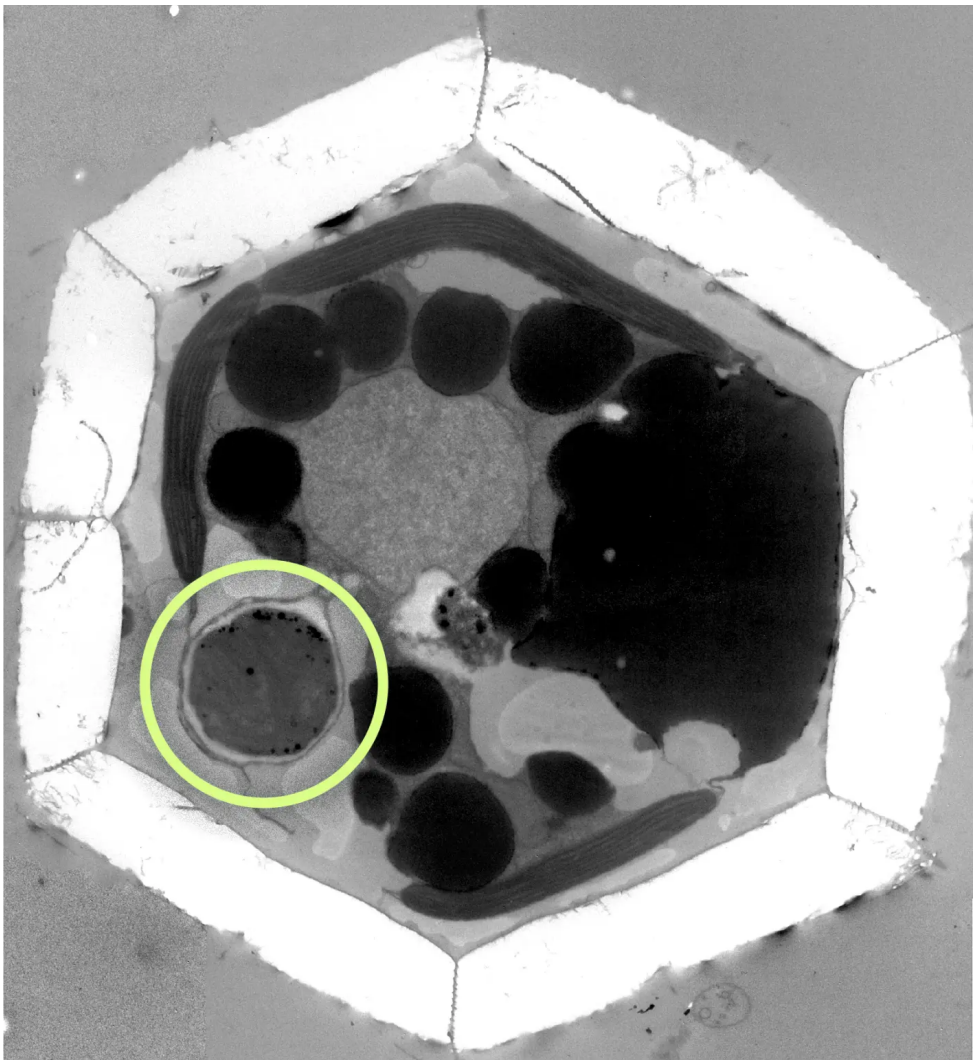


Figure 5. A transmission electron microscope image of a Bigelowii revealed a strange object. Courtesy of Kyoko Hagino.

After running a genetic test, Hagino confirmed her suspicions: the strange object was the nitrogen-fixing bacteria Zehr spent so long searching for. Together, Hagino and Zehr made a discovery that would question a fundamental rule of biology.

Findings

Across biology, scientists have observed numerous symbiotic relationships. A symbiotic relationship is a close, long-term interaction between two different species in which at least one organism benefits, and the other may benefit, be unaffected, or be harmed. A basic example of this is the relationship between a clownfish and an anemone, where organisms live inside other organisms. A step above this is when cells live inside other cells.

At a certain point, the relationship between two organisms becomes so close that they will be indistinguishable from each other. This is called endosymbiosis. The endosymbiotic theory explains that when one organism, typically a microbe, takes up residence within the cell

of another organism, over time, they form a close relationship that can be advantageous for both partners. The larger host cell provides a protected environment and essential nutrients. At the same time, the internalized microbe contributes its specialized functions, often becoming an organelle within the host cell. This line has been crossed only by a handful of organisms, one of the most famous being mitochondria. It started as an independent cell that, over time, got so close to its partner that it became an organelle.

Zehr and Hagino wanted to study the relationship between *Braarudosphaera bigelowii* and its mysterious nitrogen-fixing partner. However, their endeavours were complicated by the COVID lockdown. Despite this, Zehr's team made great progress in their research. Tyler Coale, a postdoctoral researcher in Zehr's team, ran tests and found that *Braarudosphaera bigelowii* was supplying the essential proteins that the bacterium was missing in its genome. This finding affirmed the fact that *Braarudosphaera bigelowii* and its partner crossed the line in symbiotic relationships. Zehr and his team decided to call the bacteria-turned-organelle Nitroplast.

This also means that, for the first time, *Braarudosphaera bigelowii* broke the fundamental rule of biology that only simple organisms can utilise nitrogen straight from the atmosphere. The algae is the first known complex organism that could pull nitrogen from the air because of the Nitroplast organelle.

Implications

While this journey is certainly an inspiring and intriguing one, what could it bring to the real world?

For starters, nitrogen is a major component of soil, as plants need it to grow. By enriching soil with nitrogen, crop yield will drastically increase. In the early 20th century, German scientists created synthetic fertiliser. However, the production of synthetic fertiliser requires massive amounts of energy, which is detrimental to the environment. Fertiliser overuse also pollutes the water, leading to "dead zones" (areas of the ocean with extremely low oxygen levels, where most marine life cannot survive) in the ocean. These problems have led scientists to consider self-fertilising plants, which was quashed by the aforementioned "rule".

While *Braarudosphaera bigelowii* is still in its early stages of research, it is said to have huge implication in industries like agriculture.

Coale makes a valid point when he said, “This organism has done what decades of biotech couldn’t do, right? It has engineered this capability into this cell. It’s natural to think that there might be lessons here that we could learn.”

“This experience has shown that we don’t know which research will be useful and when,” Hagino said.

“Some of the biggest, biggest advances might come from things that you didn’t expect,” Zehr remarked. “And this might be a case like that.”

Conclusion

This paper introduced *Braarudosphaera bigelowii*, its unique ability, and its discovery. Zehr, his team, and Hagino's investigation shows that, contrary to previous belief, complex organisms can also perform nitrogen-fixation through a special kind of symbiotic relationship.

Their experience has taught us a little bit more about how our incredible world works. In the future, when more research is conducted on *Braarudosphaera bigelowii*, more sustainable methods of enriching plants and crops can be found, impacting various industries such as agriculture and the environment.

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MICROGLIAL ACTIVATION IN NEURODEGRATION

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Introduction

Neurodegenerative diseases are disorders characterised by the progressive loss of function and death of neurones in the nervous system. Neurones have been at the center of these diseases, but emerging evidence suggests that other cells in the brain, in particular microglia, are important players in neurodegeneration. Microglia are specialised immune surveillance cells that reside in the central nervous system (CNS), within the brain and spinal cord. They are closely related to immune cells called macrophages that identify damaged or foreign material, consume unwanted substances and coordinate inflammatory responses. However, microglia are specifically adapted to the CNS and perform additional functions that are essential for maintaining brain health (Colonna & Butovsky, 2017).

Microglia monitor their surrounding environment and react when normal brain conditions are disrupted. Interestingly, they also support normal brain functions such as clearing cellular waste, supporting neurones and modulating synaptic connections (Colonna & Butovsky, 2017). Microglia can alter their shape, movement, gene expression and chemical signalling in response to damage, a process generally referred to as microglial activation. This response can initially protect the brain, but prolonged or dysregulated activation can contribute to chronic neuroinflammation and neuronal damage (Leng and Edison, 2021). Alzheimer's disease is an important example of this relationship, because microglia respond to the accumulation of abnormal proteins, especially amyloid-β (Aβ) while their prolonged activation can contribute to disease progression.

Explanation of Microglial Activation

Macrophages are part of the innate immune system and are responsible for the recognition and phagocytosis of damaged cells, pathogens and cellular debris. The phagocytosis process enables for a cell to engulf and surround unwanted material and then digest it inside. Macrophages can also secrete signalling molecules that communicate with surrounding cells to co-ordinate inflammation. Many of these same functions are carried out by microglia in the CNS, and they are thus considered resident macrophage-like immune cells of the brain (Colonna & Butovsky, 2017).

In a healthy brain, the microglia typically exhibit a ramified morphology. Morphology refers to the physical form and structure of a cell. Ramified microglia are characterised by a small central cell body (called 'soma') and numerous long, thin and highly branched processes extending into the surrounding tissue. These processes are constantly moving and surveying the brain, enabling microglia to detect changes in neuronal activity, damaged cells, and alterations in the chemical environment (Colonna & Butovsky, 2017).

Detection of damage can lead to dramatic changes in microglia morphology. Their processes may become shorter and fatter, and the soma may become larger. Under certain conditions, microglia take on a more rounded or amoeboid shape, which is associated with increased motility and phagocytic activity. This allows them to migrate to damaged regions and directly contact with abnormal material (Perry & Holmes, 2014). However, microglial

function is not entirely determined by morphology, as modern research has shown that microglia can exist in a variety of functional states depending on the signals that they receive.

A further important feature of microglial activation is the release of cytokines. Some cytokines are pro-inflammatory; others are regulatory or anti-inflammatory. Activated microglia release pro-inflammatory cytokines such as interleukin (IL)-1, IL-6 and tumour necrosis factor-alpha (TNF-α) (Mason et 2001). They can influence the cells around them, neurones included. While controlled cytokine release can help orchestrate a defensive response, prolonged production can lead to oxidative stress, impaired neuronal function and tissue damage (Leng & Edison, 2021).

Alzheimer's disease

Alzheimer's disease is one example of the complex relationship between microglia and neurodegeneration. The two main hallmarks of Alzheimer's disease are the accumulation of amyloid-β (Aβ) plaques and the abnormal tau protein. Amyloid-beta is a small piece of protein created when a larger protein, called amyloid precursor protein (APP), is broken apart. APP (amyloid precursor protein) is located within the membranes of neurones and other cells. The enzymes β- and γ-secretase cleave APP to generate amyloid-β peptides.

Initially, this response is protective as clearing Aβ can reduce the accumulation of Aβ in the brain (National Institute on Ageing, 2024). The microglial receptor TREM2 (triggering receptor expressed on myeloid cells 2) is particularly important in regulating microglial responses to pathological material. Mutations in TREM2 gene are linked to the higher risk of late-onset Alzheimer's disease, which highlights the significance of microglial function in the disease (Ulland & Colonna, 2018).

Microglia may be less efficient at clearing abnormal proteins, or less efficient at removing Aβ. Moreover, they can secrete inflammatory cytokines such as IL-1, IL-6 and TNF-α that contribute to persistent neuroinflammation (Leng & Edison, 2021). This can lead to a cycle where Aβ activates microglia, activated microglia contributes to inflammation, and inflammation contributes to further damage. Microglia also interact with abnormal tau protein. Tau usually stabilises the internal structure of neurones but in Alzheimer's disease it can be aberrantly modified and form neurofibrillary tangles.

Microglial inflammatory responses can modulate the progression of tau-related pathology, which suggests that microglia interact with several of the major pathological processes involved in Alzheimer's disease (Leng & Edison, 2021).

Microglia cannot simply be categorised

Microglia cannot be categorised as resting or activated or even wholly good or bad. Previous models have suggested that microglial activation is a binary switch between two states. Recent research has demonstrated that microglia are highly plastic cells that can change their morphology, gene expression and function depending on their environment. (Perry & Holmes, 2014).

For example, microglia surrounding Aβ plaques may develop distinct molecular and functional characteristics. These populations are sometimes referred to as disease-associated microglia (DAM) and may respond differently to neurodegenerative pathology (Ulland &

Colonna, 2018). The same microglial response may also be beneficial at one stage of Alzheimer's disease, but another is harmful. Early activation may promote the clearance of Aβ, whereas prolonged activation may be associated with reduced clearance and increased inflammatory signalling.

This is important, because completely blocking microglial activity may not be beneficial. Microglia are vital for normal brain maintenance and protective immune responses. Instead, insight into how their distinct functions can be regulated may enable beneficial activities such as Aβ clearance to be maintained, while limiting prolonged inflammatory responses (Leng & Edison, 2021).

Conclusion

Activation of microglia provides a complex example of the relationship between the immune system and neurodegeneration. Microglia are specialised immune cells that carry out macrophage-like functions, including the detection of damage, the removal of cellular debris and the coordination of inflammatory responses. Interestingly, they also aid in normal brain functions, such as clearing cellular waste, supporting neurones and regulating synaptic connections (Colonna & Butovsky, 2017). In Alzheimer's disease, microglia respond to the accumulation of amyloid-β, attempting to remove the abnormal protein by engulfing it. But chronic exposure to Aβ can alter microglial function, decreasing their ability to clear abnormal material while increasing inflammatory signalling. Chronic neuroinflammation and neuronal dysfunction are promoted by cytokines such as IL-1, IL-6 and TNF-α (Leng & Edison, 2021).

Microglia cannot be ultimately understood as just protective or harmful. Their effects depend on their functional state, on the signals present in the brain and the stage of Alzheimer's disease. It is important to get this balance right because future approaches to Alzheimer's disease may not be to completely suppress microglial activity, but to regulate it, so that their protective functions can continue along with limiting prolonged and damaging inflammation.

References

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Colonna & Butovsky (2017) — microglia, macrophages and normal brain function

Leng & Edison (2021) — microglial activation + neuroinflammation in Alzheimer's

Microglia and inflammation in Alzheimer's disease (2010) — cytokines + inflammatory response

Microglial Aβ Receptors in Alzheimer's Disease (2014) — Aβ recognition/receptors

National Institute on Aging — Alzheimer's pathology/background

Shi & Holtzman (2018) — innate immunity + APOE/TREM2

Ulland & Colonna (2018) — TREM2 + Aβ + disease-associated microglia

2023 Microglia in Alzheimer's disease review — phagocytosis and mechanisms

OPEN IDEAS LAB

A UK registered Non-Profit Organisation
www.openideaslab.org

We're delighted to announce a new collaboration between Open Ideas Lab, a UK non-profit, and the AIMERS Foundation.

Open Ideas Lab is an open and free platform for students aged 11+ to explore big questions, work on real-world challenges, develop their ideas, and learn from some of the world's leading scientific minds.

Through this partnership, we're excited to create an opportunity for student ideas and thinking to be published through the AIMERS Foundation's 'Make A Mark' journal - giving young people a platform to share their work and ideas with a wider audience.

We're especially excited about the longer-term possibility of these contributions becoming part of library and archival collections in Australia, creating a lasting record of young people's ideas and curiosity.

Open Ideas Lab is a not-for-profit organisation registered in England and Wales as a company limited by guarantee (No. 17091729).

Why was Open Ideas Lab created?

Open Ideas Lab was created after working closely with young people from diverse backgrounds and observing that:

- Many students have powerful ideas but lack early exposure and guidance,
- Real-world problems are rarely introduced in an age-appropriate way, and
- Access to mentorship often depends on privilege, geography, or resources.

We believe ideas can come from anywhere, and that every young mind deserves early access to inspiration, challenge, and thoughtful feedback regardless of socioeconomic background.

Welcome to the Open Ideas Lab!

Open Ideas Lab is a safe space for curious students to work on real-world challenges shared by scientists and experts. You don't need to be an expert — just be curious and willing to think. Your ideas will be reviewed respectfully, and select ideas will receive guidance from our mentors to help you learn and improve. This platform is free for students and focused on learning, not competition.

Open Ideas Lab is a not-for-profit global platform that helps young people aged 8–17 engage with real-world problems in science, technology, health, climate, mathematics, and society. Students explore problems shared by leading scientists, researchers, and experts, and develop their own ideas individually or collaboratively.

Our goal is to nurture curiosity-driven thinking, creativity, and problem-solving - well before students are forced into narrow academic or career paths.

Is Open Ideas Lab a school or tutoring platform?

Open Ideas Lab is not a school, coaching service, or tutoring platform.

It empowers curious students (ages 13+) to explore real-world challenges with guidance from experienced mentors. Here, students discover problems, test solutions, and receive constructive feedback — building confidence, creativity, and the skills to think beyond textbooks. Learning is driven by curiosity, not grades or competition.

Who can participate? Who is Open Ideas Lab for?

- Students aged 8–17 who are curious and want to explore ideas,
- Parents or guardians who wish to support their child's learning,
- Mentors and scientists who want to inspire the next generation, and
- Partner organizations working in science, health, environment, and social good.

Can students join directly?

No. For safety and legal reasons, all accounts must be created and managed by a parent or legal guardian. The contractual relationship is between Open Ideas Lab and the Parent/Guardian. Students participate as linked learners under the parent/guardian-developed account.

AIMERS Foundation is looking forward to creating a meaningful impact with **Open Ideas Lab**. We are delighted to have 2 articles from the students being published in the current issue of the "Make A Mark" journal.

ASTRA DOMUS - A CITY SETTLEMENT PROPOSAL DESIGN

*Sourced from **Open Ideas Lab***

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Summary

By 2100, the world may be almost entirely or entirely urbanised. This challenge asks students to critically examine whether traditional definitions of "cities" will still apply by then and how urban life, governance, infrastructure, and environmental systems might transform towards reaching a fully urban world. Historically, cities were dense settlements surrounded by rural areas, though urbanisation, digital connectivity, infrastructure expansion, and climate pressures are increasingly blurring these boundaries. If the entire world becomes urban, does the distinction between "urban" and "rural" still matter? How would food, water, and energy systems function? What happens to biodiversity and natural ecosystems? Would inequality increase or decrease? How would governance operate at a planetary urban scale? Students are asked to think critically about urban systems, not just bigger cities by considering economic, environmental, technological, and political dimensions.

Background

As per 2026 statistics, 45% of the world's populations live in cities, which is more than that of the 1950's. The United Nations DESA's World Urbanisation Prospects 2025 projects that around two-thirds of the global population will experience erupted growth in urban areas with rural populations peaking in 2040s and then declining thereafter. It is further suggested that by the year 2100, the global population will be overwhelmingly urban with much of that growth concentrated in rapidly expanding urban corridors present within Africa and South Asia such as Lagos, Nairobi and Delhi.

The expansion of "megacities" will continue. However, there will not be an abrupt or disruptive expansion. The current urban growth in the urban corridors is largely unplanned, caused by cities expanding through informal settlements alongside infrastructure expansions rather than using an integrated design which produces a predictable set of failures that are visible today. The transportation networks fail to keep up with the inferno of population increase, which has created a very distinguishable gap between outer rural settlements and urban centres and has led to an economic and physical destabilisation among the two regions. Water and sanitation systems that exist today are built reactively, leading to waterborne illnesses and resource stress that have already been documented in fast-growing African and South Asian cities. The healthcare, education and employment opportunities are concentrated only in the city settlements; this leaves the peri-urban and rural areas devoid of any sense of purpose or opportunity. This is a gap which is widening as cities grow; the very traditional urban-rural boundary is eroding without any solutions, which has led to rural-adjacent populations neither served by city infrastructure nor protected by historically rural self-sufficiency. Hence, if this trajectory is continued towards the year 2100, the world will entail geographic exclusion, transport poverty, healthcare deserts, employment concentration, and a

digital divide between core and periphery at an unprecedented scale which can lead to human extinction.

The proposed idea, Astra Domus, is a response to this problem. The proposal is an urban corridor settlement of 10 million inhabitants within a 900 km^2 city model that will enable every single settlement tier to have the same baseline of transport, healthcare, energy, water, and employment access. Consequently, the distinction between rural and urban is dissolved, as all essential amenities are being provided to all city levels.

Proposed Solution

The Astra Domus is a design solution to resolve urban inequality by the year 2100; instead of designing a city centre first and enabling other settlement types (including dense city core, suburb, town, village, etc.) to sprawl outwards unplanned. The Astra Domus has allocated every basic service to all settlement tiers such that one living in a rural-village zone can equivalently access a hospital or railway station or job as one living in a dense urban area. The ideology behind this is to crumble the very division between a city and a countryside functionality in the 22nd century to avoid such future societal inequalities.

The city is built as six concentric rings around a single core, each with a defined area, population, and density, including a 1% hyper dense urban core housing the biggest finance, tech, law, and political institutions, 15% urban hubs containing healthcare cities, science parks, and media districts, 35% suburban residential superblocks, 30% peri-urban manufacturing, data, and farming zones, 15% small towns; and 4% rural villages. Transport will be handled by the autonomous maglev pod network (Hermes) that connects every district internally and a 450 km h^{-1} vacuum tube hyperloop train that will directly link the rural outskirts to the urban core. Resources are closed-loop and will be AI-monitored. Water will run through the Aquanet autonomous system which will track the city-wide water quality and leak data. The power source will be from a Generation IV molten salt reactor supplemented by solar and hydrogen energy resources. Food will be produced locally in each sector via aeroponics, hydroponics and CRISPR technology. Governance is multi-tiered running from a metropolitan council to a neighbourhood community board with an AI control tower that is only restricted to monitoring and maintenance functions rather than making authoritative decisions.

In short, this project aims to create a functionally self-sufficient, equally connected and sustained environment that can structurally resolve present inequality.

Scope

The core logic of Astra Domus has been supported by precedents that are presently operating at smaller scales; hence, this proposed model is an extension of proven approaches rather than speculative approaches. The Maglev and hyperloop-style high speed transportations respectively exist presently in Shanghai and Japan, therefore supporting the feasibility of the Hermes network. Decentralised, AI-monitored water systems also exist in various, at least developing, cities, such as Nairobi. As such, scaling is more a matter of investment than feasibility. Even equal accessibility across settlement tiers has a logical advantage over the traditional single centre city models by removing various dependencies. While healthcare and water infrastructure exist in such cities, they are concentrated in the original city rather than in peri-urban and rural areas. The new and proven government systems inherent within Astra

Domus are such that federal systems and multi-tier urban governance are standard practices for many metropolitan areas. By restricting AI to a monitoring and optimization role rather than decision-making authority, the model captures efficiencies yet avoids a loss of democratic accountability.

Hence, all suggested solutions comprising life necessities of life have previously been tested and consequently removes any speculations nature of creating new systems.

Limitations

One barrier to developing this solution are the financing and budgeting. This proposal estimates total infrastructure as 541 billion USD. No government or coalition currently allocates capital at this scale for a single greenfield city, and the financing model for whichever party pays — national governments, private infrastructure consortia, international development funds — is presently undefined in the proposal. However, this is because the present stability of geopolitics and governance present is not guaranteed as stable in the 22nd century.

A second problem is that real urban growth occurs organically and chaotically. People move faster than infrastructures can be planned and built. Resultantly, a model that develops a fully built city does not necessarily explain how existing cities can transition or how a half-built Astra Domus can function during the decade-long construction periods where some rings would be developed and some not. A model that assumes uniform infrastructure will produce uniform settlement preference risks, hence treating rural identity as simply an access deficit to be engineered, rather than a genuine choice some populations would continue to develop even with full access to urban-tier services.

WHY EACH OF US SEES THE WORLD DIFFERENTLY

Sourced from ***Open Ideas Lab***

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Introduction

Most disagreements have been caused by people arguing over how something appears. The way one thinks about or understand someone, or something, is known as perception. This paper will explain why each of us sees or perceives things differently and why it is important to respect different views.

Causes of differences in perception

Neuroscientific research has led to the discovery that perception varies for each person due to many factors.

Attention plays a major role in the way one perceives something. Since the brain cannot focus on everything around us, it uses something known as selective attention, where it only filters the most important information. The most common example of this is the 'Invisible Gorilla experiment' where the audience is so engaged in counting the number of basketball passes that they fail to notice the gorilla behind the players. This shows us how the brain can manipulate one's sight to show us what is important currently.

How one can perceive something is broadly influenced by past experiences. The brain associates present experiences or objects with similar ones from the past, creating an 'average' of past and present images. An example of this is an experiment conducted by a psychologist in 1910, in which he showed a participant different-sized ball. They then visualized an 'average' of these balls. When asked the size of the smallest ball, the participants overestimated it, and when asked the size of the biggest ball, they underestimated it. This concludes that they were estimating based on a mental image formed from previous experience, which in this case is the 'average' of the balls.

Biology and perception are broadly related. While it might seem as though past experiences and attention are much bigger aspects of perception, if a person did not have the ability to remember or pay attention, then their perception would be considerably different. This is exactly how biology affects perception. The brain is the powerhouse of the body, where memory, movement, and emotional responses are processed. Even a small amount of damage in any part of the brain can affect human behaviour. For example, if the frontal lobe, which is responsible for thinking and conscious action, is damaged, it can cause challenges in judgement, movement, and speech.

How one feels upon experiencing or viewing something can make us focus on specific things or remember a detail vividly. This is how emotions influence perception. Upon feeling an emotion, the brain does not feel it in solitude but associates the emotion with the surroundings. For instance, upon being scared, the brain looks for possible threats in the surroundings, while more positive emotions like happiness and excitement can direct attention

to gestures that reflect empathy and kindness. This selective attention alters not only the present perception but also creates a long-lasting memory as events linked with strong emotions are remembered more vividly.

The culture in which people are are raised with impacts perception significantly. Culture can be defined as a shared set of values, beliefs, and practices that are followed by a group of people. It is a lens through which one can judge what is considered normal, acceptable, and appealing. As a result, culture greatly influences perception and the way one can organize and interpret day-to-day experiences. An excellent example of varied perception across cultures is a study using the 'fish tank experiment.' It revealed that participants of a western background focused on the fish (prominent objects), while East Asian participants paid more attention to the water and seaweed (background objects). This proves that each culture places importance on different qualities which are reflected in the people who follow it.

How varied perceptions can affect daily lives

Perception has many real-world applications across diverse fields. In psychology, it helps understand human behaviour and decision-making processes. In marketing, businesses use perception to advertise products based on customer preferences and reviews to influence their choices. In healthcare, it is used to diagnose conditions of patients by interpreting their symptoms and responses. In education, it can be especially useful in finding out the students' perceptions of school and enhancing learning methods accordingly. Similarly in technology, it can be leveraged to boost user experience. Each of these applications shapes how significant an impact perception has in everyday life.

While helping various fields, perception also significantly affects various aspects of life such as communication, relationships, and eyewitness testimonies in legal systems. In communication, differences in perception can easily cause misunderstanding. For example, in matters of time and priority, what someone means by urgent might be different from somebody else who is juggling multiple tasks. Cultural differences can also cause differences in perception. For example, while a thumbs-up might be understood as approval in one culture, it may be interpreted as a rude gesture in another culture. Another common misunderstanding in nonverbal communication is the lack of eye contact, which can signal respect to some people and disinterest to others. From these examples, it can be concluded that it is better to know the intention of a specific comment or action before making assumptions.

In legal procedures, perception may cause witnesses to interpret the same event differently. Some reasons may be environmental and situational filters such as lighting and distance. Because of low light, long distances or having seen the suspect briefly, the witness might not have seen the suspect's facial features clearly. Another reason is stress. For example, if a weapon was present, the witness may have focussed on it instead of the suspect. These examples suggest why the witness' statement is carefully verified.

Solution

To investigate the influence of expectation and attention on human perception, a controlled priming experiment is proposed using 'Rubin's Vase' (see below) as the primary stimulus. Rubin's Vase is a classic optical illusion featuring high-contrast symmetrical silhouettes that can be perceived as either a vase in the centre or two facial profiles looking at

each other on the sides. This experiment will recruit 20 participants between the ages 18-25 years by using a voluntary response recruitment method. This method will include distributing information flyers with details of the experiment in local communities, which will also help us confirm that this is a voluntary choice. To ensure against anomalies in the results, an exclusion criterion will be enforced: individuals who have already seen the image and know that there is more than one possibility will be excluded from participating. This will be implemented by adding it as part of the eligibility criteria in the flyers.



Figure 6. Perceptions of an image. Is the image displaying a vase or two human faces?

Once the participants have assembled at the designated location, they will be separated into groups of 10. The two groups will be named Group A and Group B. They will then be led to different places away from each other. The participants will be each given a computer to record what they see first. Group A will be shown a prime word 'vase' exactly 2,000 milliseconds (2 seconds), after which they will be shown the image. Meanwhile, Group B will be shown a blank screen for 2 seconds and then shown the image. If they see a vase first, they will press the 'V' key on the computer and if they see the faces first, they will press the 'F' key. When the participants click on the 'V' or 'F' keys, the reaction time of each participant can be accurately measured using Lab.js, which is a free platform which will measure to the exact millisecond.

The hypothesis for Group A is that majority of them will see a vase as the prime word prompts them to look for it. Attention is involved as people can only focus on one thing at a time and if they are told 'vase,' they will be guided towards the middle of the image instead of the sides. Expectation is involved as hearing the word 'vase' before looking at the image will cause them to anticipate a vase in the image. Meanwhile, the prediction for Group B is that their results will vary between a vase and two faces as their perception is not forced.

We can associate this hypothesis with how certain labels and descriptions in the news, photos and products in shops can change what people notice. Another thing one can associate with is how two people can experience the same thing differently because of the prior information given to them.

Scope

The preliminary data suggests that this experiment could provide clear evidence that attention and expectation significantly affect perception. In a previous experiment, 8 participants were divided into two groups. Group A was told the name 'Rubin's Vase' — which can be considered a prime word in this context — before they were shown the image, while group B was shown the image without a prime. Most of Group A saw a vase while the results of Group B results were varied. Two anomalies in the previous experiment were the broader age range and non-exclusion of participants who had seen the image before. These anomalies are corrected in the current solution to provide a fair test and accurate results.

Limitations

Due to biological differences, some participants may not be able to hear the instructions or comprehend the image, which can cause a major difference in the way they perceive the exercise. One more difficulty in the experiment might be that the participant processes the image in a certain order but answers in a different order. The prime word may not be strong enough and there might not be a large difference between the results of Group A and B.

Example of varied perception

A personal example of varied perceptions based on where we live is on the Pahalgam terror attack which occurred on 22nd April 2025. Since I live in India, I was affected significantly as it was closer to home and was a widely discussed topic. Some emotions I felt were fear, in case the conflict reached me, and sadness, because of all the lives that were lost. My uncle, although Indian, lives in the United States; he felt sad but did not share the same fear as the threat was much less immediate and he did not have the same information. My mother’s colleague, who is an American and lives in the United States, perceived that a war was unnecessary from a more international perspective. These three perspectives suggest that emotions, attention, culture, and environment, are major factors contributing to differences in perception.

Conclusion

In conclusion, perception plays a powerful role in the life of everyone. It affects decision-making, communication, and judgement. Perception is highly influenced by background, biology, attention, culture, and emotions. Ultimately, everyone might have a different view, but that does not necessarily mean it is wrong. Listening to different opinions is extremely important to learn and grow. Diverse perceptions are like pieces of a big puzzle, with each piece contributing to a collaborative understanding.

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STRUCTURE FOR THINKING SOLUTIONS: A LADDER, NOT A CAGE

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"Education is not the learning of facts, but the training of the mind to think." — Albert Einstein

Every meaningful solution begins with a thought. However, ideas can be disjointed. They bounce from one thought to another, sometimes taking us in the right direction, sometimes in the opposite direction. The key to turning thoughts into solutions is not just intelligence, it is the ability to organise thinking. That organisation is called structure.

The need for structure is apparent very early in life. A child is learning to write, and is first tracing dotted letters before writing independently. A learner on a bike starts using supporting wheels and then balances on two wheels. A musician practises scales for months before performing a concert. In both, structure offers stability in learning. It helps to develop confidence, discipline and readiness for further challenges. Structured guidance has long been advocated by educational psychologists as a way for learners to slowly build up their independent thinking skills instead of just memorising information [2,5].

Yet structure does not operate independently of the learner. A learner brings prior knowledge, foundational skills, experience, readiness, and individual ways of understanding to every learning situation. Structure becomes meaningful when it connects with these existing capabilities. Thus, the purpose of structure is not simply to impose an order on learning, but to provide a pathway through which learners can organise what they know, identify what they do not know, and gradually develop the ability to think independently.

Thinking and Learning: From Structure to Independence

1. The Beginning of Every Journey

One question is heard repeatedly in classrooms, laboratories, and workplaces: **"Where do I begin?"**

The difficulty is often not the problem itself. The real difficulty is finding the first step.

A student might be familiar with all the necessary formulas to solve a problem but not know the steps to get from the problem to the solution. However, structure does not operate independently of what the learner already knows. Prior knowledge and foundational skills provide the basis for interpreting a problem, recognizing relevant concepts, and connecting new information with existing understanding. Before asking "Where do I begin?", a learner may also need to ask: What do I already know? What information is given? Which concepts are related to this problem? What strategy have I used in a similar situation?

Structure becomes meaningful when it helps learners organize and apply existing knowledge rather than simply follow a predetermined sequence.

A young researcher can read hundreds of research papers and still not be sure how to formulate the research problem. An entrepreneur can have a great idea but not be able to make it into a viable product. In each of these cases, the challenge may not be a complete absence of knowledge, but difficulty in organizing knowledge and deciding how to proceed.

In all cases, structure can provide a beginning—a way to organise what the learner already knows and determine what to do next.

Structure is not the answer itself. Rather, it assists us in comprehending the issue. It helps us to distinguish between fact and assumption, determine what one knows and what one does not, and decide what to do next. After that, even a difficult problem can become more manageable.

Many educational approaches are built upon this principle. Learners are first introduced to structured problem-solving strategies and then gradually moved towards independent problem-solving. As confidence increases, more complex challenges are introduced and learners are encouraged to build their understanding rather than simply memorise answers [2,5].

However, the amount of structure required need not be the same for every learner. A beginner may need explicit modelling and step-by-step guidance, whereas an experienced learner may need only a question, a hint, or a reminder of a relevant principle. Effective structure must therefore respond to the learner rather than assume that all learners begin from the same point.

Learning is thus not simply a process of gathering answers. It is a process of connecting prior knowledge with new experiences and constructing increasingly useful structures for thinking. The progression from prior knowledge and structured guidance to independent thinking, questioning, and innovation is summarised in **Figure 7**.

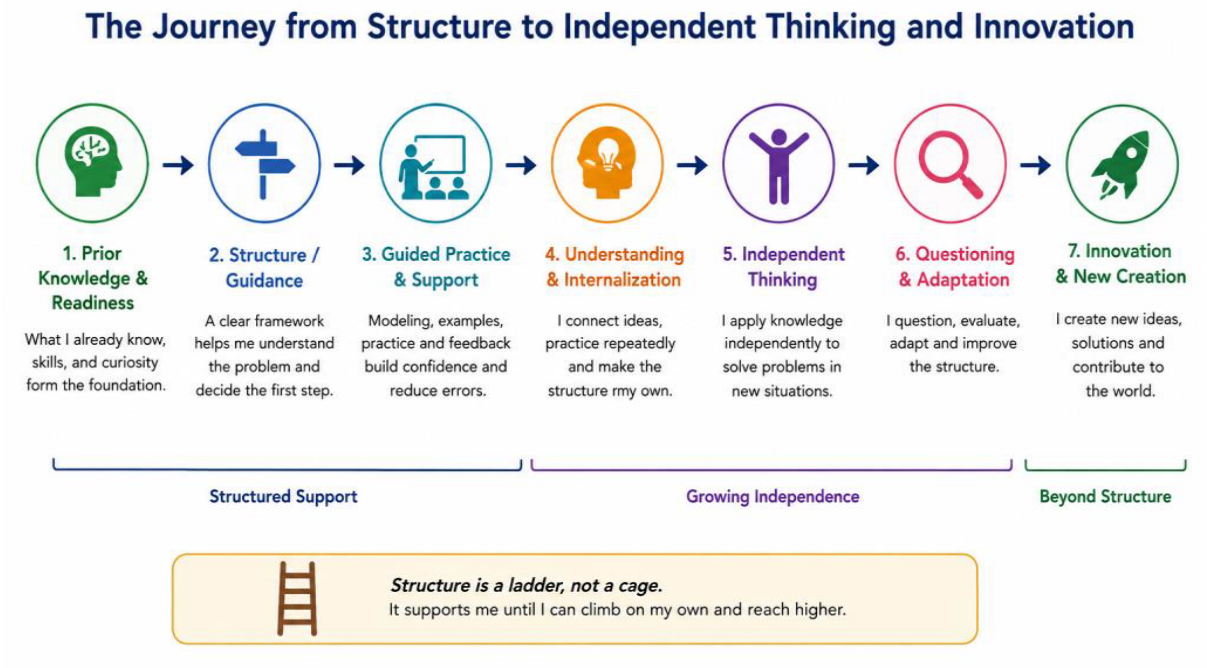


Figure 7. From structured guidance to independent thinking and innovation.

2. Structure Gives Shape to Thinking

Each discipline has its own organization, which has been built over a long period of learning and experience. The scientific method, which was greatly influenced by the work of Francis Bacon who stressed systematic observation and experimentation, shows how systematic inquiry can lead to reliable knowledge [1].

Scientists observe, question, experiment, analyse, and verify before reaching a conclusion. Engineers determine requirements, design, prototype, and test a solution before providing a solution. A doctor will check symptoms, review medical history, do investigations and make a diagnosis before recommending treatment. These jobs may seem distinct, but they all involve systematic reasoning to minimize uncertainty and enhance decision making.

Good decisions are not, therefore, random. They come from disciplined thinking.

There are many examples in everyday life. Consider planning a meal for visitors. Most people first choose the menu, lay out the ingredients, estimate the cooking time, and then cook the dishes. Very few begin cooking without any plan. The structure does not cook the meal; it organises the actions required to prepare it.

Another example is research. Most investigations begin with an understanding of what is already known. Researchers analyse previous research, determine what questions remain unanswered, develop a hypothesis, select a method, design an experiment, collect data, and interpret the results to arrive at a conclusion. This systematic process has developed because it turns curiosity into trustworthy knowledge and enables scientific results to be independently examined and confirmed [1,5].

Structure is thus a form of thinking. It transforms ideas into action and action into results.

But structure is useful only when the learner understands what the individual steps mean. Following a sequence mechanically may produce a correct answer in a familiar situation, but it may not prepare the learner for a different situation. Understanding therefore requires more than following a structure; it requires recognising the relationships among its components and knowing when and why they should be used.

This leads to a significant question: **Is it possible for a learning structure to become a constraint?**

3. Structure Also Makes Learning Possible

Educational thinkers have long emphasised the movement from guided learning towards independent thinking. John Dewey viewed education as a process of reflective thinking in which learners connect experience, inquiry, and action to understand new situations [5]. Similar ideas about guided learning and the gradual development of independent understanding can also be found in the work of Vygotsky and Bruner [2,6].

It is a fact that experienced teachers often observe that students do not fail because they cannot learn. Most frequently, they are unable to solve a problem because they don't know how to start. When they see a clear strategy, their confidence shifts drastically. They start to ask more questions, make more connections and slowly start to solve problems independently.

However, a strategy becomes effective only when it interacts with the learner's existing knowledge and abilities. A child learning to write does not become independent simply because dotted letters are placed on a page. In the earliest stages, the teacher may demonstrate the movement, physically guide the child's hand, provide correction, and encourage repeated practice. The dotted outline is therefore only one component of a larger structure that includes modelling, guided practice, feedback, repetition, and gradual release of support.

The same principle can be seen in learning to ride a bicycle. Training wheels provide external stability, but they do not independently produce the ability to ride. The learner must also possess or develop the physical readiness, coordination, observation, balance, and motor responses required for cycling. Practice allows these abilities to develop while the external support reduces the consequences of early errors.

These examples show that learning is a relationship between **external structure and internal development**. Structure can make learning possible by reducing unnecessary difficulty, but the learner's prior knowledge, abilities, experience, and engagement determine how that structure is interpreted and eventually internalised.

Structure is therefore not intended to produce dependence. Its purpose is to develop independence.

A map is useful when travelling through an unfamiliar area. A traveller who visits the same location repeatedly gradually develops an internal representation of the route and no longer relies solely on the map. The external structure has served its purpose because the knowledge it represented has become part of the traveller's experience.

Likewise, educational structures can guide learners until systematic thinking becomes increasingly internalised. With experience, guidance can gradually be replaced by independent thinking, enabling learners to use their knowledge confidently in new contexts [2,5].

Repetition is important in this process, but repetition alone is not sufficient. Repeating a procedure can build familiarity, yet genuine learning also requires understanding why the procedure works and opportunities to apply it in different situations. Otherwise, repetition may produce memorisation without transferable understanding.

The goal, therefore, is not simply to repeat a structured process until it becomes automatic. The goal is to understand the structure sufficiently to recognise when it applies, when it needs modification, and when another approach may be more appropriate.

4. When Structure Becomes Comfortable

Every successful structure carries a hidden risk. As a method becomes more successful, the more people are tempted to think that it is the only method.

History teaches us that change can start when things are taken for granted. For centuries, people thought that the Earth was the centre of the universe. This explanation was plausible because it was consistent with common experience. However, after careful observation and evidence, a new understanding of the cosmos emerged.

Science has changed in this way many times. According to Thomas Kuhn, scientific advances are not simply the result of gathering facts, but also of times when the prevailing

paradigm is challenged and replaced by a new one when it no longer fits the new facts [3]. Theories are accepted as valid because they account for what is already known but not taken for granted. All scientific theories are open to modification as new evidence emerges.

This is true not only in science. Many inventions that changed society were initially considered strange because they challenged established ways of thinking. New ideas can be uncomfortable precisely because they require people to reconsider structures that have become familiar.

The threat is therefore not structure itself. The risk lies in becoming so accustomed to a structure that it appears unnecessary to question it.

The same issue arises in education. A student who learns a particular method successfully may begin to assume that the method must always be followed. A researcher may continue using a familiar methodology even when the research problem requires a different approach. A professional may rely on an established procedure without reconsidering whether its assumptions still hold.

Learning must therefore include not only the ability to use structures but also the ability to examine them.

5. Learning to Shake Off the Structure

The term "*shake off the structure*" is not to be taken literally. It is not ignorance, it is not experience, and it is not discipline. Instead, it is about recognizing that every structure has a purpose, and every structure has a capacity.

Training wheels are helpful for learning to ride a bike.

These questions are a step from structure to understanding and evaluation.

The decision to decrease support should not be made based on time, age, or a specific exercise. It should be based on evidence of the learner's initial internalisation of the structure. Useful indicators are to explain why in their own words, to identify and correct errors without prompting, to choose an appropriate strategy without being prompted, to apply the concept to unfamiliar situations, and to justify conclusions with relevant evidence.

These indicators are significant because a learner can repeat a procedure successfully but still require a lot of external support. The meaning of independence is enhanced if the learner can apply the reasoning to a new context.

Support should be phased down and responsively. For some learners, detailed modelling may be needed for longer, and for others, they may be ready for independent exploration earlier. The goal is not to phase out support as soon as possible, but to phase out support when it is no longer needed to make meaningful progress.

The goal of a scaffold is to make it decreasingly necessary.

These are important questions to make a transition. The purpose is not to destroy a structure, but to learn enough about it to make it better.

There have been many discoveries that have emerged from such questioning. Innovation does not occur when people refuse to learn from what they already know. Instead,

it comes from a profound understanding of what is already known, which reveals new possibilities. The goal of learning is not to follow the structure but to grasp it well enough to improve it [6].

6. Thinking in the Age of Artificial Intelligence

AI has emerged as an extraordinary tool for analysing information, recognising patterns, generating content and supporting decisions. It can handle data that is beyond human capacity and can give amazing results in seconds. AI has come a long way from the theoretical question asked by Alan Turing, **"Can machines think?"** to a technology that has the potential to impact science, engineering, healthcare, education, and daily life [4].

But AI also gives us a reminder of something important about human thinking.

Artificial Intelligence is very good at learning patterns from existing data and applying learned structures. New structures are formed by human intelligence.

Machines can identify patterns.

Humans determine which patterns matter.

Machines can answer questions.

Humans choose which questions are worth asking.

This distinction becomes particularly important in education.

AI can be used as a **scaffold**, as it can facilitate the learner's thinking without taking over. It can explain a concept using a different approach, generate additional practice questions, provide examples, offer hints, provide feedback, or help a learner identify a possible error. In these instances, AI provides additional support to the learning structure.

When AI does the intellectual work that the learner is supposed to do, however, it can be a substitute. When a student asks AI to solve a problem, writes down the answer without understanding it, and submits the answer, the external structure has not developed independent thinking. The learner has merely transferred the thinking task to another system. This poses a new educational challenge. Pupils must be taught to question and assess the output of AI. They should be encouraged to check information, compare different explanations, look for possible mistakes, explain their reasoning in their own words and think about what they have learned.

It is particularly important to be able to ask effective questions. A learner with limited conceptual understanding might not know what information to give, what assumptions to challenge, or how to identify an incorrect answer. Therefore, AI literacy is inextricably linked with basic knowledge and critical thinking.

AI should therefore be viewed as another form of learning support rather than a replacement for learning itself.

A useful distinction is simple:

A scaffold helps the learner climb the ladder. A substitute climbs the ladder for the learner.

The future will then not be a choice between human intelligence and artificial intelligence, but a thoughtful interaction between the two. Machines can facilitate structured reasoning, while humans contribute imagination, judgement, ethics, creativity, contextual understanding, and the courage to challenge accepted wisdom. AI can enhance human thinking when it is used with human judgement and responsibility [4].

"The important thing is not to stop questioning. Curiosity has its own reason for existing." — Albert Einstein

7. Towards Better Structures

Structures are passed on from one generation to the next. Scientific methods, mathematical models, engineering principles, educational practices, and computational techniques have all been developed over many years of observation, experimentation, and refinement.

These buildings are deserving of respect because they have contributed to a great deal of progress. At the same time, there are new issues to be addressed for each generation, and new ideas are needed. Solutions from yesterday are not always sufficient to solve today's problems, such as climate change, sustainable development, healthcare, responsible Artificial Intelligence, cybersecurity, and many others.

The role of education goes beyond teaching known methods. It needs to train learners to think independently, to look closely at assumptions, and to enhance the structures they inherit. Dewey's philosophy of education is that it is reflective thinking, which means that the student can think intelligently in new situations without merely repeating what he or she has already learned [5].

This also implies acknowledging that learners are not all the same. Students come to the classroom with varying levels of prior knowledge, experience, confidence, language skills, learning abilities, and educational backgrounds. Therefore, the same structure might not be equally effective for all. Some learners might require extensive modelling and guided practice, whereas others might require a short cue to allow for more exploration.

Effective structure is not a formula. It is a flexible type of support that meets the learner's needs at the present time and maintains a suitable level of intellectual challenge. The teacher's job is then not just to provide a structure and then take it away. The teacher needs to watch for learner responses, uncover misconceptions, give feedback, modify the amount of support, and determine when the learner is ready to assume more responsibility for thinking.

The best thing a teacher can do is not to create students who can regurgitate the right answers, but to develop students who can ask the right questions with confidence and humility.

Structure should be thought of as a **ladder, not a cage**. It helps us climb towards understanding, but it should never prevent us from climbing higher.

A ladder is useful because it provides support at a particular stage of a journey. But reaching a higher step alters what the learner can see. Similarly, learning structures should expand what learners are able to understand and do. As learners develop knowledge, experience, judgement, and confidence, the structure should evolve with them.

Every discovery begins with learning an existing structure.

Every innovation begins with the courage to examine and improve it.

8. Summary

- Thinking gives birth to ideas.
- Prior knowledge and foundational skills give learners a basis for understanding new ideas.
- Structure gives direction to ideas and helps learners determine where to begin.
- Guided practice, feedback, and experience help learners internalise that structure.
- Independence develops when learners can apply their understanding without continuous external support.
- Questioning allows learners to examine, adapt, and improve existing structures.
- AI can support learning when it acts as a scaffold rather than a substitute for thinking.
- Curiosity gives learners the courage to challenge existing structures and create something new.

Structure should be a ladder, not a cage: it should help learners climb towards understanding without preventing them from climbing higher.

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THE FERMI PARADOX: WHERE IS EVERYONE?

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Abstract

The Fermi Paradox questions why, despite the substantial age and scale of the universe as well as the possibility of extraterrestrial life, no confirmed evidence of intelligent extraterrestrial civilisations has been detected. This article examines the factors that contribute to this paradox, including the scale of the universe, the discovery of exoplanets and the conditions that may allow life to exist. The Drake Equation is explored as a framework for considering the number of potentially detectable technological civilisations in the Milky Way, while recognising the uncertainty surrounding several of its factors. Possible explanations for the Fermi Paradox are also investigated, including the scarcity of intelligent life, the limited lifespan of technological civilisations, the difficulties of interstellar travel and limitations in current methods of detection. Finally, the role of SETI and the search for techno-signatures is examined. Overall, there is currently no definite explanation for the Fermi Paradox, leaving the question as to whether humanity is alone in the universe an unanswered scientific question.

Keywords: Fermi Paradox, Extraterrestrial Life, Intelligent Life, SETI, Drake Equation, Astronomy

Introduction

The universe is vast, containing a substantial number of stars and planets. In recent years, scientists have discovered many exoplanets and separate planetary systems, establishing potential environments in which life could exist [4,8]. The Fermi Paradox questions why, despite the potential for extraterrestrial life and intelligent civilizations, any evidence of their existence has yet to be uncovered [1,2]. The paradox arises from the contrast between the idea that given the age and enormous scale of the universe, it seems plausible that technological civilisations could have developed elsewhere with the observation of having no confirmed evidence of extraterrestrial technological civilisations [1,2].

This idea was first brought by the Italian-American physicist, Enrico Fermi [3]. The discussion that is known to have established this famous paradox occurred in 1950, in Los Alamos, during a lunchtime conversation among physicists Enrico Fermi, Edward Teller, Emil Konopinski, and Herbert York [1,2]. During this, Fermi brought up the question "Where is everybody?" Through this question, he reasoned that considering the age of the universe and the potential for interstellar travel, Earth should have been visited by extraterrestrial civilisations, from which he proceeded to propose reasons such as interstellar travel being impossible, alien civilizations choosing not to intervene, or technological civilizations being short-lived as possible explanations [1,2]. Today, the significance of this paradox is that it challenges expectations about how common and detectable technological civilisations should be, motivates investigation into possible explanations for the lack of evidence and reasons that the absence of evidence is not proof of absence, making continued scientific searches important [1,2]. This research will examine the scale of the universe, the possibility of extraterrestrial

life, the Drake Equation, possible explanations for the Fermi Paradox and how scientists are currently searching for extraterrestrial intelligence.

1. The Scale of the Universe

According to scientists, the universe is estimated to be 13.8 billion years old [4]. This number has been established by measuring the ages of the oldest stars, and the rate at which the universe is expanding [4]. Despite the universe being extremely vast, humans are only able to research and study the observable universe [5]. This refers to the region of space from which light or other detectable information has had enough time to reach Earth, allowing scientists to observe it using astronomical instruments [5]. Earth is at the centre of the observable universe because the latter is defined by what can currently be observed from the former [5]. The observable universe is approximately 93 billion light-years in diameter [5]. This is estimated from the age of the universe and observations of its expansion [4,5]. Although light from the most distant observable objects has travelled for approximately 13.8 billion years, the expansion of space means those objects are now approximately 46 billion light-years away [4,5]. Scientists estimate that the observable universe contains at least 2 trillion galaxies [6]. Earlier estimates suggested approximately 200 billion, but Hubble observations combined with mathematical modelling indicated that this was significantly underestimated [6]. Around 90% of the estimated galaxies are too faint or distant to be directly observed by current telescopes [6]. The Milky Way is estimated to contain approximately 100–400 billion stars [7]. Scientists cannot count the stars individually, so the number is estimated using observations of the galaxy's mass and models of stellar populations [7]. More than 6,200 exoplanets have been confirmed, with billions more estimated to exist within the Milky Way [8]. Thousands of additional exoplanet candidates are awaiting confirmation [8]. The discovery of exoplanets demonstrates that planets orbiting stars other than the Sun are common [8].

Therefore, this immense scale and age of the universe provide a basis for the Fermi Paradox. With the universe having billions of years available for civilisations to potentially develop, and an enormous number of galaxies, stars and planets providing possible environments for life, it seems reasonable to expect that technologically advanced civilisations could have developed elsewhere. However, despite this vast number of potential locations, no confirmed evidence of extraterrestrial technological civilisations has been detected [1,2]. This contrast between the enormous opportunities for life to develop and the lack of confirmed evidence contributes to the central question of the Fermi Paradox.

2. The Possibility of Extraterrestrial Life

Currently, Earth is the only known location in the universe where life exists, and no extraterrestrial life has been confirmed [8]. However, as established previously, the discovery of thousands of exoplanets provides many potential environments in which life could exist and further develop [8]. Scientists use what is known as the habitable zone to identify planets where conditions could allow liquid water to exist on their surfaces [8]. Despite this, a planet being located within a habitable zone does not immediately prove the existence of life, as factors such as planetary size, atmosphere, and the stability of the host star must also be considered [8]. NASA defines life as a self-sustaining chemical system capable of Darwinian evolution [8]. Scientists have only found one confirmed example of life, which is life on Earth, meaning that

one's understanding of the characteristics of life is based on terrestrial biology [8]. Therefore, extraterrestrial life may not necessarily have the same characteristics as life on Earth.

On Earth, extremophiles are organisms capable of surviving in environments that are extremely harsh for humans, including extreme temperatures, pressure, acidity, salinity, dryness and radiation [9]. They have been found in environments such as hydrothermal vents, glaciers, deep underground and desert rocks [9]. Their existence demonstrates the resilience and adaptability of life and helps scientists understand what environments beyond Earth could potentially support life [9]. However, the existence of life does not necessarily lead to intelligent or technological life. On Earth, life existed for billions of years before humans developed technological civilization. Scientists therefore do not know how likely the transition from simple life to intelligent and technological life is.

Scientists search for extraterrestrial life through biosignatures and techno-signatures [10]. Biosignatures are potential signs of biological life, while techno-signatures are detectable signs of technological activity [10]. Some examples of possible techno-signatures include radio or laser signals, artificial chemicals in planetary atmospheres, and large-scale structures or energy use [10]. However, no confirmed techno-signatures have been detected [10]. Despite this, the absence of detectable evidence does not necessarily mean that technological civilisations do not exist.

3. The Drake Equation

The Drake Equation is a mathematical formula used to estimate the number of technologically advanced or communicating extraterrestrial civilisations in the Milky Way galaxy [11,12]. This equation was developed by the astronomer Frank Drake in 1961 for a meeting in Green Bank, West Virginia [11,12]. It was created in relation to the possibility of searching for signals from extraterrestrial intelligence [11,12]. This equation provides a framework for studying and understanding extraterrestrial life and intelligence while guiding research in areas such as exoplanets, astrobiology and SETI [11,12]. This equation contains seven factors which are multiplied together to estimate **N**, which is the number of civilisations whose electromagnetic signals could be detected [11,12].

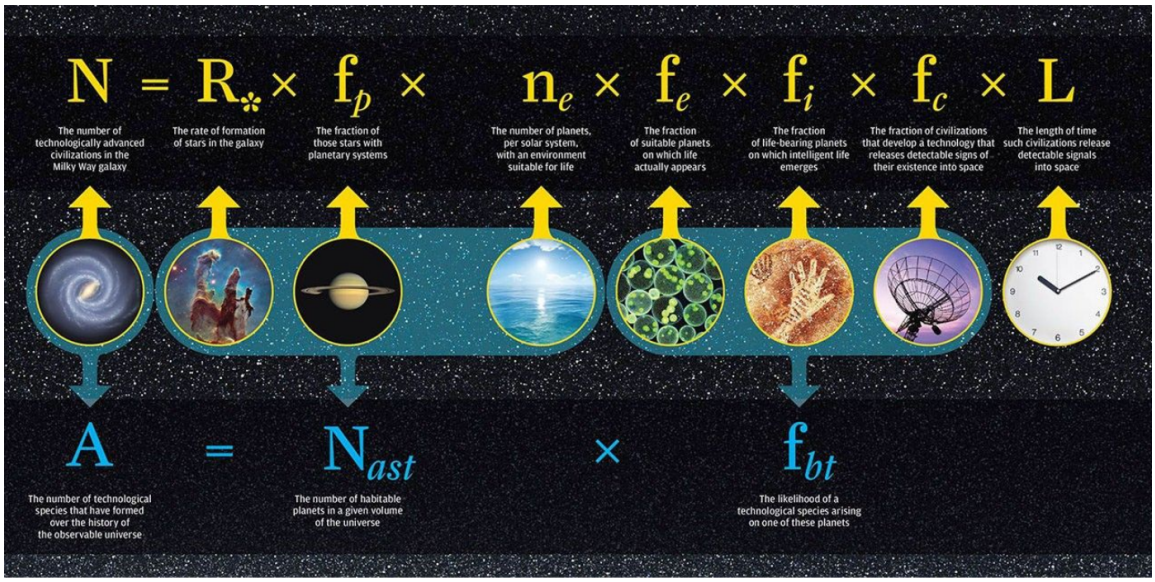


Figure 8. The Drake Equation. Source: NASA Science (2016).

The Seven Factors:

- R★ — the rate at which suitable stars form in the Milky Way [11,12].
- f□ — the fraction of those stars that have planets [11,12].
- n_e — the number of planets per system with environments suitable for life [11,12].
- f_l— the fraction of suitable planets where life develops [11,12].
- f_i — the fraction of life-bearing planets where intelligent life develops [11,12].
- fc — the fraction of intelligent civilisations that develop technology producing detectable signs of their existence [11,12].
- L — the average length of time those civilisations produce detectable signs [11,12].

This equation can be used to estimate how many detectable extraterrestrial civilisations may exist in the Milky Way [11,12]. Some of the factors are now better understood because of scientific discoveries, such as the discovery of thousands of exoplanets [11]. However, some factors within this equation remain uncertain, especially the likelihood that life develops intelligence and how long technological civilisations remain detectable [11,12]. As these factors are still not known, the Drake Equation is currently unable to give us an accurate exact number of extraterrestrial civilisations [11,12]. Instead, it provides a framework for thinking about and researching the possibility of extraterrestrial intelligence [11,12]. Overall, the Drake Equation suggests that there could be technologically advanced civilisations in the Milky Way, while the Fermi Paradox questions why evidence of any has not been detected, interconnecting both ideas [1,11,12].

4. Possible Explanations for the Fermi Paradox

4.1 The Great Filter

One proposed explanation for the Fermi Paradox is the Great Filter [13]. This explanation suggests that there is at least one extremely unlikely evolutionary step that prevents most life from developing into advanced, detectable civilisations [13]. Some of the stages could include the development of simple life into complex life, then into intelligent/technological life, and eventually galactic colonisation [13]. This filter could have been in the past, often known as the **Early Great Filter**, or in the future referred to as the **Late Great Filter** [13]. For Earth, this suggests that humanity has already passed through the difficult stage, or that the filter is ahead of us, yet to occur [13]. If the latter is to be true, it would mean humanity may face a difficult stage that prevents us from becoming a widespread spacefaring civilisation [13]. This could explain the Fermi Paradox because if most civilisations fail to pass the Great Filter, very few would survive long enough to become detectable [13].

4.2 Intelligent life is extremely rare

Another possible explanation for the Fermi Paradox is that intelligent life is extremely rare [1,2]. It is important to recognise, however, that there is a major distinction between

extraterrestrial life and intelligent extraterrestrial life. Extraterrestrial life refers to any form of life that exists beyond Earth, including simple or microbial organisms. In contrast, intelligent extraterrestrial life refers to life that has developed advanced intelligence and potentially possesses technological or communication abilities. Earth is currently the only confirmed example of technological intelligence [8,10]. Currently, scientists do not know how likely it is for life to develop intelligence. It is also important to recognise that humans can have an anthropocentric bias, meaning the tendency is to view the universe and other forms of life from a human-centred perspective. For example, one's understanding and definition of life have been established through what has been observed on Earth. NASA describes life as "a self-sustaining chemical system capable of Darwinian evolution" [8]. However, life on another planet could potentially have different characteristics because it may have evolved under different environmental conditions. Therefore, if intelligent life is extremely rare, there may be very few technologically advanced civilisations in the Milky Way, which could explain why evidence of extraterrestrial intelligence has not been detected.

4.3 Civilisations do not remain detectable for long

Another possible explanation for the Fermi Paradox is that technological civilisations may not remain detectable, or survive, for very long [11,12]. This idea arises from the fact that scientists do not have a clear estimate for how long technological civilisations survive, as Earth is the primary example [11,12]. Furthermore, as previously established, the universe is over 13 billion years old, meaning that other civilisations could have developed and disappeared millions or billions of years before humans came into existence [4]. This also entertains the possibility that civilisations could develop in the future. This potential explanation connects to the Drake Equation through its relation to the L factor from the equation [11,12]. This factor represents the average length of time a civilisation produces detectable signs of its existence [11,12]. A shorter value for L would mean that civilisations are harder to detect [11,12]. Therefore, if technological civilisations only remain detectable for a short period of time, their existence may not overlap with the relatively short period in which humans have been searching, meaning they might not be detected even if many have existed.

4.4 Interstellar travel is extremely difficult

Another possible explanation for the Fermi Paradox is that interstellar travel is significantly difficult or expensive for a civilisation to spread through the galaxy [1,2]. There are enormous distances between stars, with the nearest star system, Proxima Centauri, being about 4.2 light-years away. Travelling these great distances would require substantial amounts of energy and highly advanced technology, particularly for spacecraft designed to carry people and supplies. As a result of these high resource requirements, a potential civilisation may decide that long-distance interstellar travel or colonisation might not be worth the expense. This could also limit the spread of detectable evidence of a civilisation, as they may not have the ability or resources to send spacecraft across large distances. Therefore, extraterrestrial civilisations could exist but remain within their own star systems, meaning they may never reach or interact with Earth [1,2].

4.5 Others

While there are several major explanations for the Fermi Paradox, there are also other possibilities that should be considered [1,2]. This includes the possibility that humans have

been searching inadequately, as they mainly search for specific types of signals from extraterrestrial civilisations [10]. However, these may not be the right frequencies, and extraterrestrial technology could use communication methods that are beyond one's understanding or that they are unable to be detected [10]. Another includes that civilisations may deliberately avoid contact with Earth, as they know that humanity exists but choose not to contact us [1][2]. This comes from the zoo hypothesis that suggests that advanced civilisations might deliberately avoid interfering with less technologically developed civilisations [1,2]. Another possibility is that humans have not searched enough as the Milky Way contains hundreds of billions of stars, and SETI searches have only examined a tiny fraction of the galaxy [2]. Humans have only been thoroughly searching for technological signals for a relatively short period of time, and not detecting anything does not directly prove that nothing is there [2]. Others include that Earth may be unusually isolated, it may be misunderstood what detectable extraterrestrial intelligence would look like and signals from other civilisations may not reach Earth at the right time [1,2]. These are only some of the proposed explanations for the Fermi Paradox, with many other possibilities also being suggested.

5. Searching for Extraterrestrial Intelligence

One of the main scientific efforts to search for extraterrestrial intelligence is known as SETI, which stands for Search for Extraterrestrial Intelligence [2]. It is the general scientific effort to search for evidence that intelligent extraterrestrial civilisations exist [2]. Within this search for extraterrestrial civilisations, scientists look for techno-signatures, which are detectable signs of technology [10]. This means that scientists would detect the technology created by a civilisation, rather than the organism itself [10]. Scientists also search for radio signals or other electromagnetic waves that could indicate communication from other civilisations [2,10]. However, scientists are not limited to these methods, as they are also able to search for laser pulses, artificial chemicals in atmospheres, or large artificial structures [10]. Despite this, the potential signs would come from distant planets, making them difficult to observe, detect and interpret. Additionally, scientists do not know exactly what technology an extraterrestrial civilisation might use, making detection increasingly difficult. Nevertheless, scientists still actively search for techno-signatures, with no confirmed evidence of extraterrestrial intelligence so far [2,10].

6. Conclusion

In conclusion, the Fermi Paradox questions why, despite the enormous size and age of the universe and the possibility of extraterrestrial life, confirmed evidence of intelligent extraterrestrial civilisations has not been detected [1,2]. Throughout this research, it has been found that extraterrestrial life and intelligent extraterrestrial life are not the same and that scientists have evidence that planets capable of supporting life exist, but it is not known how likely intelligent technological life is [8,10]. The Drake Equation can provide a framework for estimating potentially detectable civilisations, but several factors remain highly uncertain, and others are gradually becoming better understood [11,12]. There are also several possible explanations for the Fermi Paradox, including the Great Filter, intelligent life being extremely rare, civilisations not remaining detectable for long and the difficulties of interstellar travel [1,2,13]. Other possibilities include humans searching in the wrong ways, civilisations deliberately avoiding contact and humanity simply not having searched enough [1,2,10]. In the end, scientists are continuing to investigate these possibilities through efforts such as SETI, but

no confirmed evidence of extraterrestrial intelligence has been found so far [2,10]. Therefore, there is currently no definite explanation for the Fermi Paradox, and whether humanity is alone in the universe remains an unanswered scientific question [1,2].

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2. CONCLUSION

Authors should synthesize an appropriate conclusion and inferences from their research. Future plans for the development of this study can also be added.

Acknowledgements

Acknowledgements of people, grants, funds, etc. should be placed in a separate section before the reference list. The names of funding organizations should be written in full. This section is optional.

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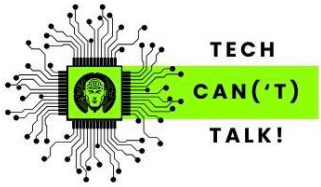
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