ISSN (O): 3083-2594

AIMERS
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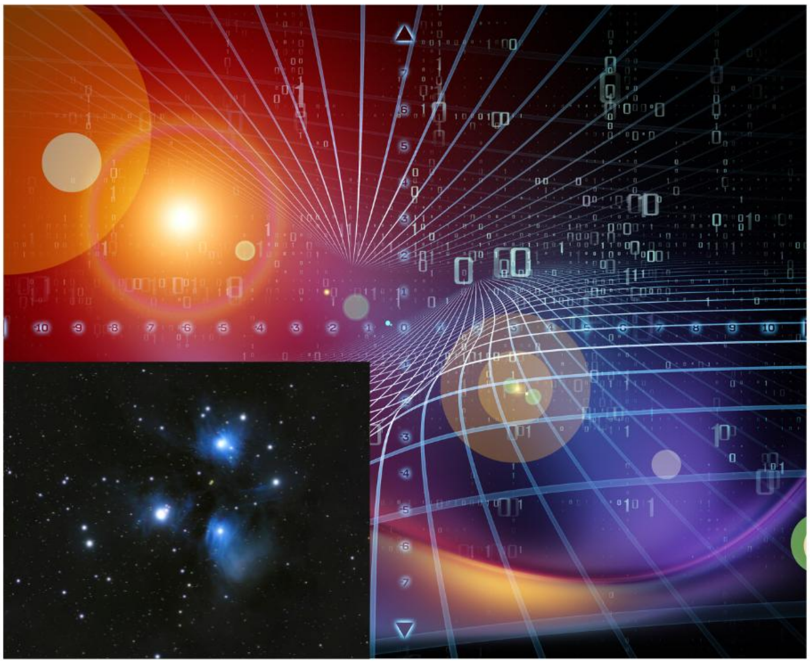
CREATING IMPACT
– FOR ALL – BY ALL

Make A Mark

Academic Journal for Students

Creating Confident Science Communicators



Volume 1 | Issue 3 | July 2026

Published By
AIMERS Foundation

Andrew Charlton MP
MEMBER FOR PARRAMATTA

May 2026

I am pleased to write in recognition of the work being undertaken by AIMERS Foundation, an Australian technology not-for-profit, in the area of space education and international collaboration.

It is encouraging to see an Australian organisation playing a meaningful role in Mission ShakthiSAT – an all-female-led lunar space mission that is providing 120 hours of free satellite-building training to 12,000 girls across 108 countries. AIMERS Foundation has been appointed to lead the Global Fundraiser for this mission, and I note that over 140 girls from Australia are currently participating in the program.

Mission ShakthiSAT is often recognised as the world's first all-female-led lunar space mission, providing young women with hands-on experience in real satellite development. This training is offered entirely free of charge, reflecting a genuine commitment to ensuring access to space education. Australia's participation in a mission of this scale is something worth recognising.

Beyond Mission ShakthiSAT, AIMERS Foundation runs a range of programs spanning space education, robotics, youth media, academic publishing, and STEM entrepreneurship. This breadth of activity works to create meaningful pathways for young Australians, particularly those from underrepresented communities, to engage with technology and innovation.

I wish AIMERS Foundation, Mission ShakthiSAT, and all the young women involved every success with this initiative and with the Foundation's broader goals of growing Australia's technology and innovation capability.

Sincerely,

Andrew Charlton

Dr Andrew Charlton MP
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Assistant Minister for Science, Technology and the Digital Economy
Federal Member for Parramatta

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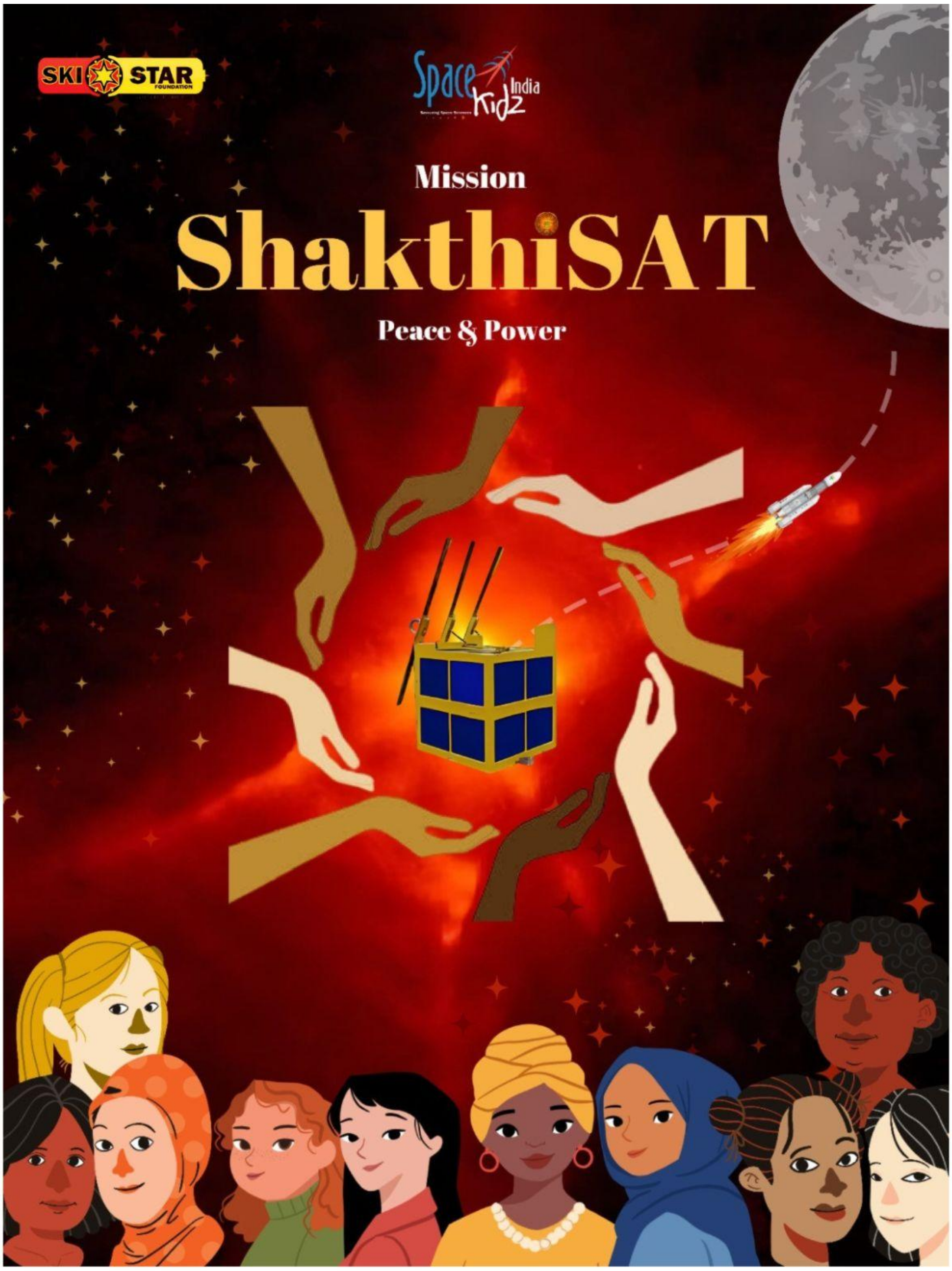

An all female led Lunar Space Mission Empowering 12,000 girls from 108 countries across the World with free 120 hours of training on Satellite building.

Publisher : **AIMERS Foundation**

Country of Publishing : **Australia**

Website : www.aimersfoundation.org

Email : mamjournal@aimersfoundation.org

ISSN(O): 3083-2594

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1 Think

Bertrand Russell wrote an opinion titled 'The Best Answer to Fanaticism – Liberalism' for 'The New York Times Magazine' published on December 16, 1951. Bertrand Russell was awarded the 1950 Nobel Prize in Literature, and he concluded this opinion as follows.

"The Ten Commandments that, as a teacher, I should wish to promulgate, might be set forth as follows:

1. Do not feel absolutely certain of anything.

2. Do not think it worthwhile to proceed by concealing evidence, for the evidence is sure to come to light.

3. Never try to discourage thinking for you are sure to succeed.

4. When you meet with opposition, even if it should be from your husband or your children, endeavor to overcome it by argument and not by authority, for a victory dependent upon authority is unreal and illusory.

5. Have no respect for the authority of others, for there are always contrary authorities to be found.

6. Do not use power to suppress opinions you think are pernicious, for if you do the opinions will suppress you.

7. Do not fear to be eccentric in opinion, for every opinion now accepted was once eccentric.

8. Find more pleasure in intelligent dissent than in passive agreement, for, if you value intelligence as you should, the former implies a deeper agreement than the latter.

9. Be scrupulously truthful, even if the truth is inconvenient, for it is more inconvenient when you try to conceal it.

10. Do not feel envious of the happiness of those who live in a fool's paradise, for only a fool will think that it is happiness."

The two words "think" and "thank" originate from the Proto-Indo-European root *teng- or *tong, meaning "to think, feel, or know"

"Science is a way of thinking much more than it is a body of knowledge." - Carl Edward Sagan, an American astronomer.

Mathematical thinking is a language that bridges pure logic and creative intuition. In science, it acts as a vital tool to build models, interpret data, and formalize theories.

“No human investigation can be called real science if it cannot be demonstrated mathematically." – Leonardo da Vinci, Italian Polymath

2 Positive Thinking

Positive thinking does not necessarily mean avoiding difficult situations. Instead, positive thinking means making the most of potential obstacles, trying to see the best in other people, and viewing yourself and your abilities in a positive light.

STEM fosters positive thinking by transforming challenges into exciting puzzles, building resilience through trial-and-error, and giving learners the confidence that they can create tangible solutions to real-world problems.

The STEM ways of thinking are:

Systems Thinking

Computational Thinking

Design Thinking

Mathematical Thinking

Scientific Thinking

Futures Thinking

STEAM adds the Arts into the STEM.

"Art completes what nature cannot bring to finish." – Aristotle, Father of Science

3 Computational Thinking

Computational thinking is a process used in computer science and everyday life. It is built on four core pillars given below.

Decomposition: Breaking down a complex, daunting problem or system into smaller, more manageable parts even for a team to solve

Pattern Recognition: Identifying similarities, trends, and regularities within or between problems

Abstraction: Filtering out unnecessary information and focusing only on the essential details needed to solve the problem. This is much like the way an artist accomplishes.

Algorithmic Thinking: Developing a step-by-step, ordered set of instructions or rules to solve the problem.

While the strengths of Computational Thinking are experienced at all levels of schooling, this process is weak in handling nuanced, emotional, and unpredictable real-world scenarios. In the form of a Machine the very first question that arises is “Can Machines Think?”. The more important question is putting Human and the machine together to solve the problems.

4 Thinking in Data

A reliable statistical estimate indicates that approximately 402.74 million terabytes of data are created each day. Any analysis today is too concerned with tools and techniques for cleansing, modelling, and visualizing datasets (both synthetic and real) and not concerned enough with asking the right questions.

Rather than relying on intuition or hunches, data emphasizes empirical evidence and continuous refinement to understand phenomena and make decisions. "Thinking in data" refers to the analytical process of structuring problems, exploring variables, and interpreting outcomes through the lens of data and metrics.

"I think, therefore I am"

Beliefs matter. Beliefs can comfort us, provide us with meaning, or tie us more closely to others However, belief in science differs fundamentally from religious faith; it is not based on unquestioning devotion, but on trust in empirical evidence, methodology, and the scientific community.

Reading this editorial is not the same as thinking about this editorial. Thinking enables the discovery of a belief that is *certain* and *irrefutable*.

"I think, therefore I am [*cogito ergo sum in Latin]*" – Rene Descartes, French Scientist

“Thunk” is an informal or humorous past tense of "Think". The word "thunk" is also a term in computer programming that means "a piece of code that does some delayed work or when needed". This is highly unique to computing.

Expressing scientific thought clearly requires combining rigorous methodology with imaginative articulation.

The governing maxim to facilitate the process begins with the ten commandments by Bertrand Russell that happen around the simple and single term “Think”.

Articles

Mission ShakthiSAT & AIMERS Students Update

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

The 20-month global journey of Mission ShakthiSAT is now reaching its defining milestone. For nearly two years, thousands of young women from 108 countries have embarked on an extraordinary mission to learn the science and engineering behind satellite technology. That journey now culminates in a historic gathering where one student from each participating country will travel to India to build, test and integrate a real satellite together.

Mission ShakthiSAT is the visionary initiative of Dr. Srimathy Kesan, Founder and Chief Executive Officer of SpaceKidz India, and is led in Australia by Sukruti Narayanan, Founder and President of AIMERS Foundation, Global Head of Partnerships for Mission ShakthiSAT, UNESCO Expert Reviewer for the 8th UNESCO Science Report, and Managing Editor of the Make-A-Mark Journal.

The final integration program will take place from 23 August to 1 September at Gautam Buddha University, with the initiative being hosted by Droupadi Murmu, President of the Republic of India, whose office serves as the constitutional Head of State of India. This is a remarkable recognition of one of the world's most ambitious STEM education initiatives for girls.Australia has proudly embraced this mission, with more than 250 girls aged 13–18 participating in the program. Every student receives 120 hours of world-class satellite engineering education, provided free of charge through the Zoho Learn platform.

Australian Federal Parliament in Canberra with the High Commissioner of India to Australia, Mr. Nagesh Singh to the left of Sukruti Narayanan, the Founder of AIMERS Foundation with the Asst Federal Minister of Science and Technology – Dr. Andrew Charlton to her right.

Mission ShakthiSAT has already achieved several significant milestones. Its official mascot was unveiled at the BRICS CCI WE Summit 2026 on 23 March 2026, in the presence of:

1.Meenakshi Lekhi – Former Minister of State for External Affairs, Government of India.

2.Ruby Sinha – President, BRICS Chamber of Commerce & Industry – Women Empowerment (BRICS CCI WE).

3.Ambassadors, senior government representatives and delegates from BRICS and partner nations.

The curriculum has been officially reviewed and approved by Indian National Space Promotion and Authorisation Centre (IN-SPACe), the Government of India's national space regulator and promoter of private sector participation in the space industry and is recognized by the National Council for Vocational Education and Training, under the Ministry of Skill Development and Entrepreneurship, Government of India, ensuring the program aligns with nationally recognised vocational education standards.

These engagements reflect the growing support from diplomatic leaders and Australian parliamentarians for international collaboration in STEM education, space technology and the empowerment of the next generation of women innovators.

In the picture above are (left) Sukruti Narayanan, Founder of AIMERS Foundation, (middle) Mr. Julian Leeser, Shadow Minister for Education and Shadow Minister for Indigenous Australians and (right) the High Commissioner of India to Australia, Mr. Nagesh Singh at the Federal Parliament House at Canberra.

Mission ShakthiSAT students at Victorian Parliament House

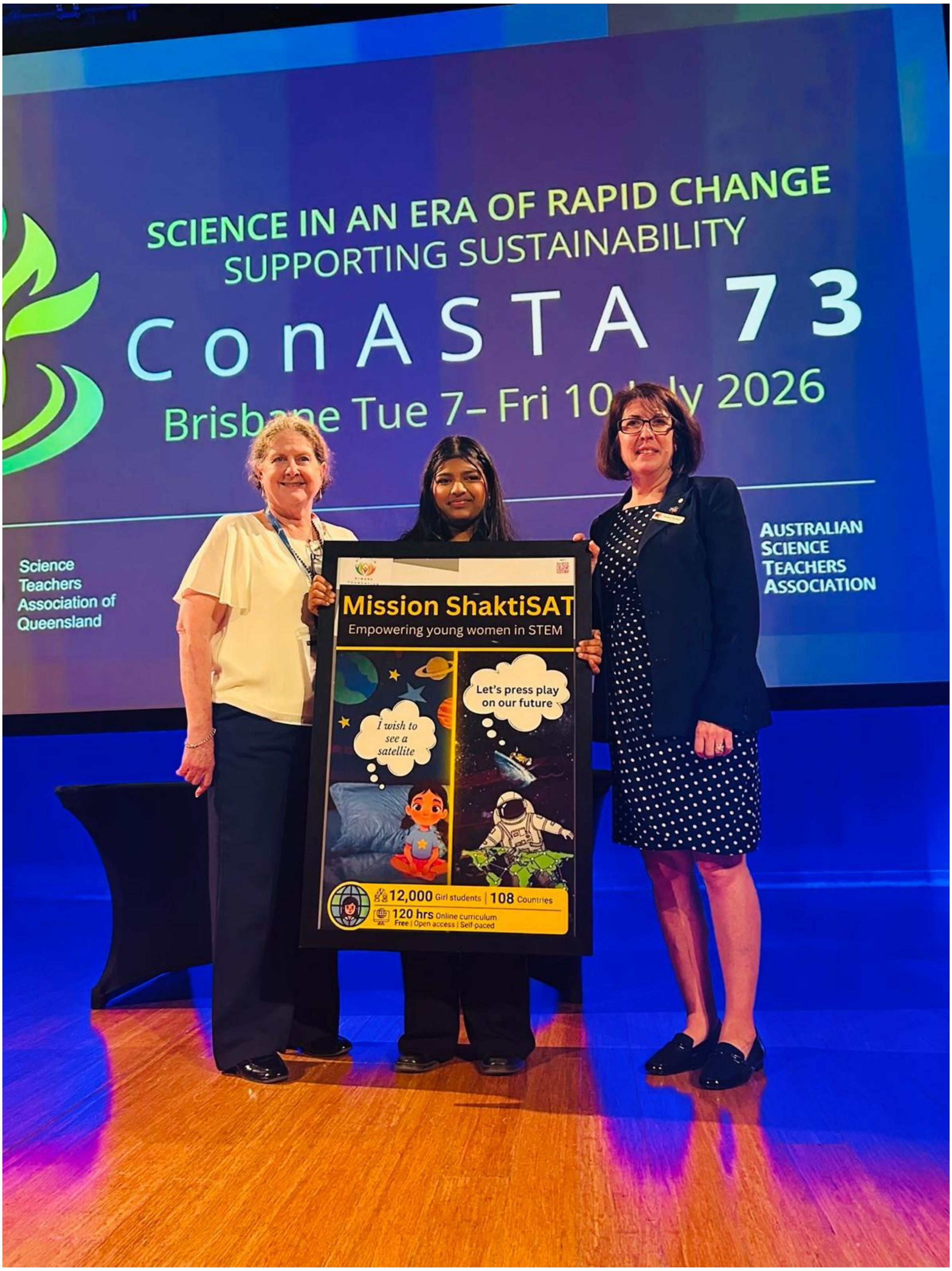
On 10 July 2026, the Parliament of Victoria welcomed an inspiring delegation of Mision ShakthiSAT students from New South Wales and Victoria, celebrating the next generation of Australia's STEM leaders. Led by Ms. Sohni Singh, State Director (Victoria) of AIMERS Foundation, the delegation was joined by Sukruti Narayanan, Founder of AIMERS Foundation, along with the Foundation's Student team – Gaavya Venkatesh- Victoria State Champion along with the Squads – Aanya Jain,

In a truly once-in-a-lifetime experience, the students addressed the **Legislative Assembly** within Parliament House, sharing their transformative journeys through **Mission ShakthiSAT**—a global initiative empowering young people to build, test and integrate a real satellite alongside peers from 108 countries.

Reflecting on the program's impact, **Aanya Jain's mother** shared: *"The opportunities provided by AIMERS Foundation have completely transformed my daughter's outlook on STEM. More importantly, they have taught her invaluable time management, confidence, discipline, and the belief that she can contribute to solving global challenges."*

The visit stood as a powerful testament to AIMERS Foundation's mission of nurturing future innovators, empowering young voices, and creating pathways for students to engage with science, technology and leadership at the highest levels.

Queensland State Champion – Dhanvi Deshpande presents Mission SakthiSAT at the ConASTA 73



In the photo, Margaret Sheperd(first left)- Vice president of ASTA, Dhanvi Deshpande(centre), Paula Taylor (right most) – President of ASTA

The Golden Ratio

Aarvi Chabra
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1. What is The Golden Ratio?

The Golden Ratio is a special mathematical proportion (approximately 1.618) that is believed to represent perfectly balanced, and aesthetically pleasing dimensions. In the real world, it has many names. It can be referred to as the golden mean, the golden section, divine proportion, phi (φ), the golden number, extreme and mean ratio, and the golden cut.

To explain a golden ratio, we can conduct a specific experiment (Mishra, 2026).

"Take any line segment. Cut it somewhere. You've made two pieces. Call the longer one a, the shorter one b. Now ask yourself: is there a cut so perfect that the ratio of the whole line to a equals the ratio of a to b? Same ratio, all the way down?

There is. Exactly one. And that ratio is approximately 1.618033988…

That's it. That's the golden ratio. That's φ (phi)." (Sikorski, 2024)

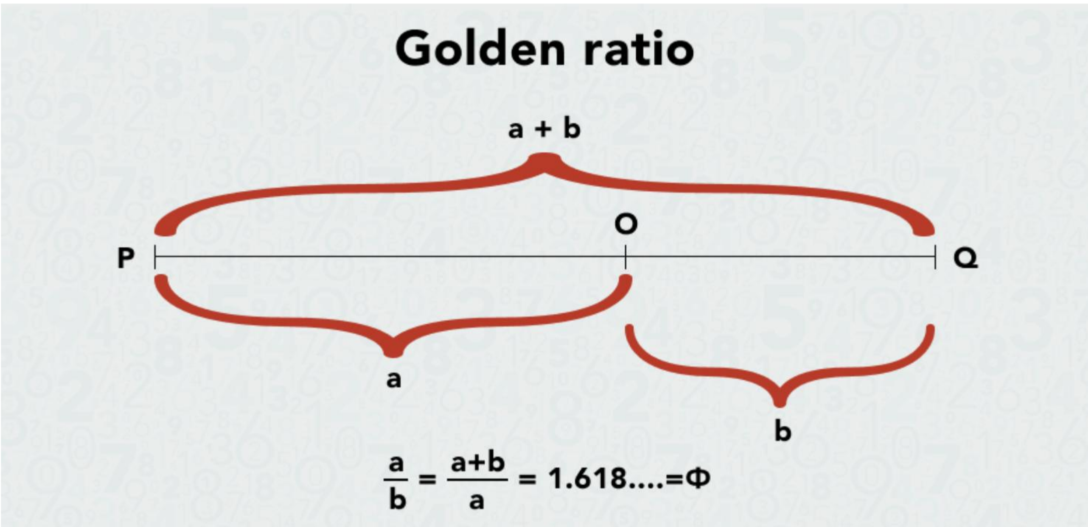

Figure 1: Golden ratio figure summary

Through this, we understand the Golden ratio is essentially a proportion, which can be represented by

$$\frac{a}{b} = \frac{(a+b)}{a}$$

Through simplification, if we let $\frac{a}{b} = \varphi$, then

$$\varphi = 1 + \left(\frac{1}{\varphi}\right)$$

$$\varphi^2 = \varphi + 1$$

Therefore,

$$\varphi^2 - \varphi - 1 = 0$$

Through this equation, two results are possible: +1.6180339887 and −0.6180339887.

Since standard physical calculations, lengths, sizes, etc. are typically positive, the first result ~~as~~ is the "golden ratio".

2. Its reputation as the most irrational number

In mathematics, the Golden Ratio is sometimes regarded as the most irrational number. Irrational numbers are numbers that cannot be represented in the form $\frac{p}{q}$, where p and q are integers and q is not equal to 0. Given their continued fractions, irrational numbers can be made into approximations. For example, the approximation of pi is $\frac{22}{7}$, derived from the continued fraction of pi as $\pi = 3 + \frac{1}{7+\frac{1}{15+\frac{1}{1+\frac{1}{292+-\cdots}}}}$.

However, the continued fraction for the Golden Ratio is quite different, where $\varphi = 1 + \frac{1}{1+\frac{1}{1+\frac{1}{\cdots}}}$.

The continued fraction for the Golden Ratio is merely a chain of ones, making it significantly harder to find approximations, paradoxically transforming the simplest mathematical approximation into the most irrational number.

This is because approximations are found by deriving fractions from the continued fraction of an irrational number. For these to be made with sufficient accuracy, large numbers within the fraction(s) provide big jumps, allowing the next fraction to land much closer to the true value. This is why numbers such as pi have famous approximations such as $\frac{22}{7}$, and even $\frac{355}{113}$. In contrast, with the Golden Ratio having only a chain of ones in its continued fraction and therefore no larger numbers, every approximation will grow at the slowest possible rate. Moreover, these numbers can be recognized as ratios of consecutive Fibonacci numbers ($\frac{1}{1}, \frac{2}{1}, \frac{3}{2}, \frac{5}{3}, \frac{8}{5}, \frac{13}{8}, \frac{21}{13}$, ...) with each adjacent fraction only modestly closer to the true value than the last. Hence, only after a long sequence of fractions will the true value be eventually reached.

3. Its connection to the Fibonacci sequence

The Fibonacci series is a sequence of numbers where each number is the sum of the two numbers preceding it. While the sequence originated in Indian mathematics, it was formally introduced to Western Europe by the Italian mathematician Leonardo of Pisa, who was commonly known as Fibonacci, in his 1202 book Liber Abaci (Book of Calculation). It was originally created to calculate the theoretical growth of an idealized rabbit population over a year. As mentioned earlier, the mathematical approximations of the Golden Ratio are ratios of consecutive Fibonacci sequence numbers. This also means that consecutive, increasing Fibonacci numbers approximates to the Golden Ratio.

As each Fibonacci number is the sum of the previous two, as they increase sequentially, the ratio between consecutive terms stabilises and approaches a constant value. Let this ratio be x. In deriving this, since every Fibonacci number (F) of position $(n+1)$ is the sum of the previous two positions $(n, n+1)$, the equation becomes:

$$F_{n+1} = F_n + F_{n-1}$$

$$\frac{F_{n+1}}{F_n} = 1 + \frac{F_{n-1}}{F_n}$$

As the sequence continues, both ratios approach the same limiting value x. A limiting value is the exact value to which functions or sequences approach as the input or term becomes closer to a specific value or to infinity. Therefore, by way of substitution,

$$x = 1 + \frac{1}{x}$$

this becomes the defining equation of the Golden Ratio, thereby confirming the connection and correlation.

4. Core concepts: Golden Rectangle and Golden Spiral

As an alternative visualization, the Golden Rectangle has side lengths which can also be represented by the Golden Ratio.

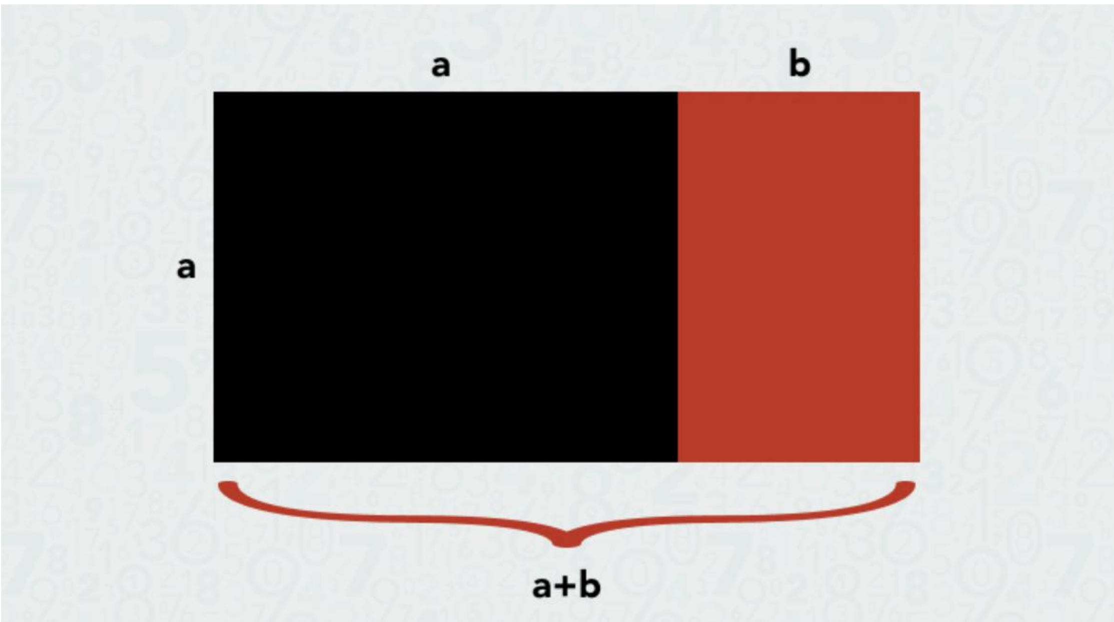

Figure 2: Golden Ratio expressed through rectangles

If a square is placed within a rectangle and has the same length as the shortest rectangle side, another rectangle is formed. If this process is continued infinitely, infinite rectangles are formed which follow the Golden Ratio. This is called self-similarity, which means that a shape contains smaller copies of itself.

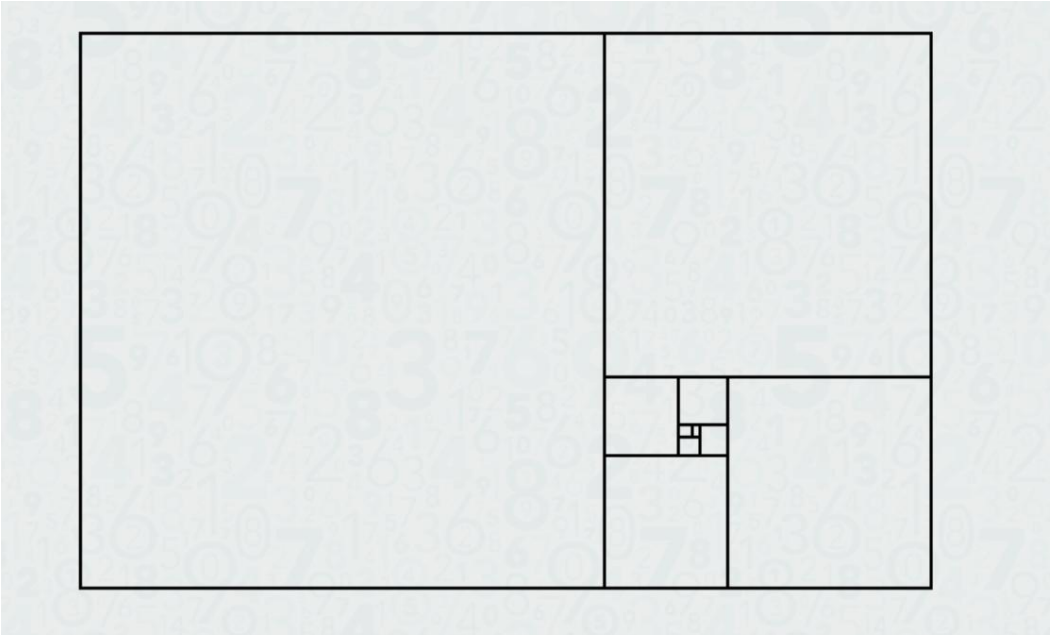

Figure 3: Self-similarity concept

If then drawing quarter-circles in each square, this results in the Golden Spiral. The Golden Spiral is a logarithmic spiral that widens by a factor of phi every quarter-turn. This beautifully captures the almost self-containing nature of the Golden Ratio, as it repeats itself through within.

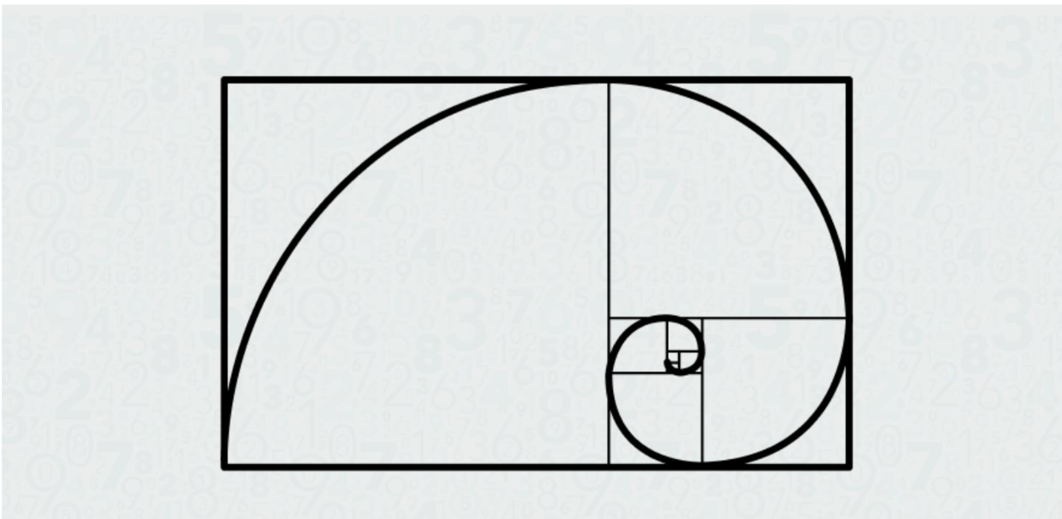

Figure 4: The Golden Spiral visualisation

5. Its connection with nature, and science

Now, for the fascinating part. The Golden Ratio can be seen very commonly around us.

Have you ever observed sunflowers? Maybe you have, but their pattern shows us something very spectacular. Sunflower seeds inside the center of the sunflower are arranged in spirals that follow Fibonacci numbers. When counting sunflower spirals, viewers can observe how they can count either 21 spirals clockwise, and 34 spirals anticlockwise, or 34 spirals clockwise, and 55 spirals anticlockwise. We can observe these as Fibonacci numbers approaching the Golden Ratio. This special arrangement helps sunflowers pack in as many seeds as possible and makes sure they have plenty of room to grow and reproduce.

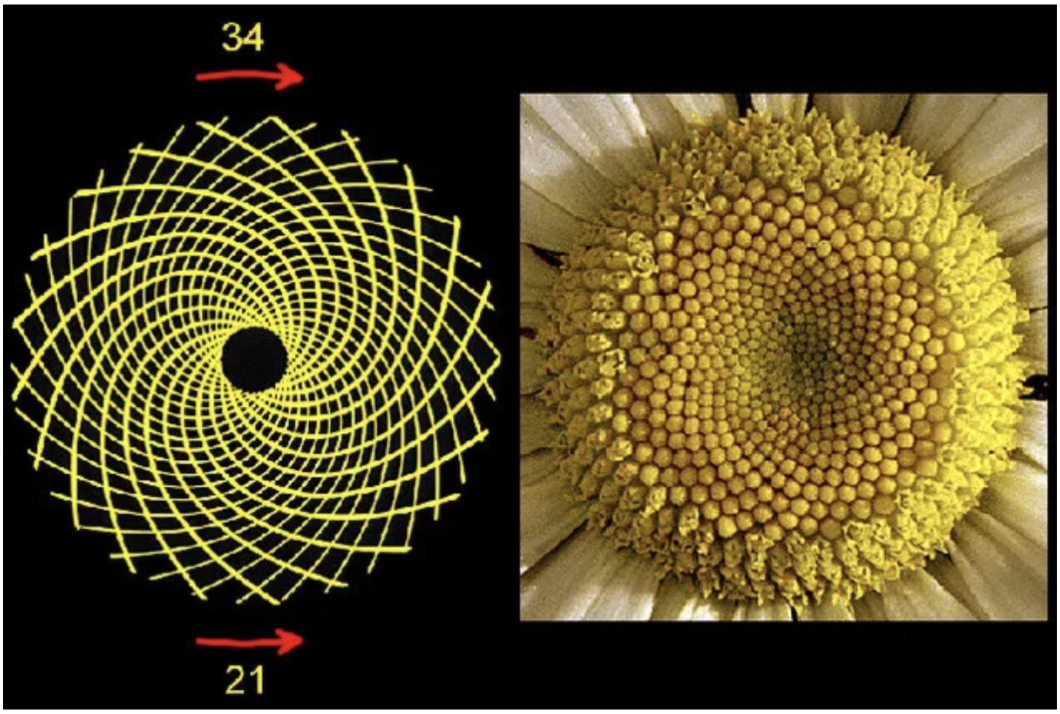

Figure 5: Nature's design: Sunflower seeds spiral in Fibonacci patterns. (Sikorski, 2024)

We can also observe this in pinecones. Each scale on a pinecone is arranged in a spiral pattern that follows the Fibonacci sequence. When counting the spirals, you might find, for example, five spirals travelling in one direction and eight in another, which again lead to the Golden Ratio.

The Golden Ratio can also be applied to several other scenarios and features, such as petals, shells, galaxies, weather patterns, and even facial features. In fact, at times, features closer in appearance to the Golden Ratio are described as 'aesthetic' and 'beautiful'.

6. Its intersection with theology and the source of its alias 'Divine Proportion'

The Golden Ratio has also been referred to as the Divine Proportion. The name was first coined in the late 15th century in a book, namely Divina Proportione, about geometry and architecture written by Italian mathematician and friar Luca Pacioli and illustrated by Leonardo da Vinci. In this book, the Golden Ratio and its geometric properties were explored, where Pacioli argued that it represented a 'perfect' and 'ideal' proportion. He believed that the ratio was 'divine' because it appeared so often in geometry and because it created shapes that were perfectly balanced and harmonious. At the time, many scholars believed that mathematical order reflected the structure of the universe; a number that produced such balanced proportions was seen as having a special, almost spiritual significance. The involvement of Leonardo da Vinci, who drew geometric solids based on it, helped spread the idea that the Golden Ratio represented ideal beauty and proportion in both mathematics and art

Figure 6: Pinecone spirals follow the Fibonacci numbers. (Sikorski, 2024)

7. Conclusion

The Golden Ratio, also known as Phi, or the Divine Proportion, is a special proportion which is closely related to the Fibonacci sequence. Spanning a lot of the natural world, they help understand and predict patterns of nature, such as sunflower seeds, flower petals, and much more! Its exciting history is truly a testament to its interesting nature and represents how STEM subjects are truly fascinating: not only to study, but to understand and explore the world around us.

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Assessing Recurrent Neural Network Accuracy and Interpretability in Breast Cancer Classification

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1. Abstract

Ribonucleic acid sequencing-based gene expression profiling enables molecular-level cancer diagnosis, yet most machine learning approaches lack the interpretability required for clinical adoption. This study trained a bidirectional long short-term memory recurrent neural network on The Cancer Genome Atlas Breast Cancer dataset (1,109 malignant; 109 normal samples) after reducing 20,530 genes to 5,000 genes. The model achieved 98.2% accuracy for malignancy classification (sensitivity 100%; specificity 70.6%) and 77.6% accuracy for molecular subtype classification. Explainability analysis via SHapley Additive exPlanations identified transferrin, adenosine diphosphate ribosylation factor interacting protein 2, and moesin as key genes, implicating iron metabolism and cytoskeletal regulation. These findings demonstrate that recurrent neural networks can achieve clinically applicable accuracy for transcriptomic breast cancer diagnosis while providing gene-level interpretability.

2. Introduction

Breast cancer is the most frequently diagnosed malignancy among women worldwide and a leading cause of cancer-related mortality, accounting for approximately 15% of female cancer deaths globally (Al-Khafaji & Islam, 2024). In Australia, annual diagnoses rose from approximately 13,500 cases in 2000 to over 20,000 in 2024 (Orrantia-Borunda, Anchondo-Nuñez, Acuña-Aguilar, Gómez-Valles & Ramírez-Valdespino, 2022). While the five-year survival rate in localised breast cancer cases is 99%, it drops to 32% in metastatic cases (Orrantia-Borunda et al., 2022), highlighting the critical need for earlier, molecular-level diagnostic strategies.

Current diagnostic methods rely on immunohistochemistry (IHC) to classify breast cancer into four principal molecular subtypes – Luminal A, Luminal B, HER2-enriched, and Basal-like – yet IHC oversimplifies tumour biology and fails to capture transcriptional heterogeneity (Orrantia-Borunda et al., 2022). Ribonucleic acid sequencing (RNA-seq) provides high-resolution transcriptomic profiling that surpasses microarrays in sensitivity and range and can reveal molecular distinctions preceding phenotypic change (Mantione, Kream, Kuzelova, Ptacek, Raboch, Samuel & Stefano, 2014). Despite this, clinical adoption in analysing patient RNA-seq data to diagnose breast cancer remains constrained by the computational challenges of the high-dimensionality of RNA-seq datasets Acedo-Terrades, Perera-Bel & Nonell, L, 2025).

Deep learning (DL) approaches, particularly recurrent neural networks (RNNs) incorporating Bidirectional Long Short-Term Memory (Bi-LSTM) units, are well-suited to modelling complex sequential dependencies and have demonstrated strong predictive performance in oncology (Dasgupta, Dutta, Halder, Khan, Saha & Pal, 2022). However, most existing RNN applications exclude transcriptomic inputs (Kim, Lee, You, Park, Lee, Kim, Lim, Kang, Nam, Park, An & Im, 2021), and many DL models lack the interpretability required for clinical trust and ethical deployment (Al-Khafaji et al., 2024). Explainable artificial intelligence (XAI) techniques such as SHapley Additive exPlanations (SHAP) enable gene-level attribution and contextualisation within biological frameworks (Lundberg & Lee, 2017). This study addresses these gaps by developing an interpretable Bi-LSTM RNN trained on RNA-seq data to classify breast cancer malignancy and molecular subtypes, hypothesising that integration of biologically informed preprocessing, recurrent architecture, and XAI would yield clinically relevant accuracy alongside meaningful gene-level insights.

3. Background

Breast cancer molecular subtypes exhibit distinct transcriptional signatures: elevated oestrogen receptor 1 (ESR1) and GATA3 in Luminal A; increased MKI67 in Luminal B; ERBB2 amplification in Human Epidermal Growth Receptor Factor 2 (HER2)-enriched disease; and TP53 mutations in Basal-like cancers (Orrantia-Borunda et al., 2022). These markers often precede morphological changes, positioning gene expression analysis as a tool for early detection. The Cancer Genome Atlas (TCGA) (TCGA, 2018) provides a large, well-annotated transcriptomic resource that facilitates robust model training (Alharbi & Vakanski, 2023).

Convolutional neural networks (CNNs) have achieved high diagnostic accuracy using medical imaging modalities but rely on late-stage morphological data and high-radiation techniques that limit suitability for early detection (Yu, Dong, Yang, Wang, Wang, & Ma, 2023). Conversely, Bi-LSTM RNNs capture long-range dependencies within sequential gene expression profiles. Recent transcriptomic studies have identified emerging biomarkers - including transferrin (TF), adenosine diphosphate ribosylation factor interacting protein 2 (ARFIP2), and moesin (MSN) - implicated in iron metabolism, cytoskeletal regulation, and hormonal treatment resistance, yet absent from standard clinical panels (Shi, Sheng, Fei, Wei, Zhang, Xia, Mao & Si, 2024; Alhaddad, Saifo & Alsayed, 2025). The integration of these signals into interpretable DL frameworks represents a key opportunity for advancing molecular oncology.

4. Results and Discussion

Gene expression data were obtained from the TCGA Breast Cancer (BRCA) cohort (n = 1,218; 1,109 primary tumours, 109 normal samples) sequenced via Illumina HiSeq. All analyses were conducted in Python 3.10 using TensorFlow, with model training performed in Google Colab. Batch effect assessment using t-distributed stochastic neighbour embedding (t-SNE) and principal component analysis (PCA) confirmed no systematic technical variation. 262 samples were removed following Mahalanobis outlier detection and low-information selective filtering. The sample filtering strategies (unfiltered, conservative, moderate, strict) were evaluated using clustering separation score, compactness, and their ratio (**Table 1**).

Table 1: Comparative analysis of dataset filtering strategies across four levels of stringency.

Dataset	Samples	Separation Score	Compactness	Quality Ratio	Sample Retention
Unfiltered	956	78.80	331.21	0.24	100%
Conservative	955	78.89	332.85	0.24	99.9%

Moderate	952	80.30	289.27	0.28	99.6%
Strict	932	83.29	271.81	0.31	97.5%

Moderate filtering was selected, retaining 99.6% of samples while substantially improving clustering quality. Feature selection reduced 20,530 genes to 5,000 using variance filtering, differential expression analysis (t-test, $p < 0.05$, $|\log_2 FC| > 0.585$), Pearson correlation filtering ($|r| > 0.85$), and ANOVA F-statistic ranking. Data were split into training (70%), validation (15%), and test (15%) sets. The Bi-LSTM model comprised two recurrent layers (128 and 64 units), dropout (0.30), a dense layer (32 units, ReLU), and dual output heads for binary (sigmoid) and subtype (softmax) classification, with L2 regularisation ($\lambda = 0.001$), trained using the Adam optimiser with early stopping.

Binary malignancy classification achieved 98.2% accuracy, with 100% sensitivity and 70.6% specificity and a weighted F1-score of 0.96. The absence of false negatives is clinically critical, as no malignant sample was misclassified as healthy. Molecular subtype classification achieved 77.6% accuracy, with Luminal A (recall 86.2%) and Basal-like (recall 86.4%) performing best, while HER2-enriched subtypes showed the lowest recall (30.0%), reflecting small sample size and transcriptional heterogeneity (**Table 2**). 61.3% of subtype errors occurred between Luminal A and Luminal B, consistent with their shared hormone-regulated pathways (Orrantia-Borunda et al., 2022).

Table 2: Classification performance metrics for malignancy detection (top) and molecular subtype classification (bottom).

Class / Subtype	Precision	Recall	F1-Score
Malignancy detection			
Healthy	1.00	0.71	0.83
Malignant	0.96	1.00	0.98
Weighted Average	0.97	0.97	0.96
Molecular subtype classification			
Luminal A	0.78	0.86	0.82
Luminal B	0.61	0.59	0.60
HER2-Enriched	0.50	0.30	0.38
Basal-Like	0.95	0.86	0.90

SHAP analysis revealed both shared and subtype-specific molecular drivers (**Table 3**). TF emerged as a consistently influential feature across subtypes, aligning with evidence linking iron metabolism dysregulation to tumour growth and therapeutic resistance (Alhaddad et al., 2025). ARFIP2 and MSN were identified in multiple subtype signatures and exclusively in HER2-enriched, respectively. Both genes have been associated with resistance to trastuzumab, a monoclonal antibody therapy targeting HER2-positive breast cancer, and poor prognosis (Shi et al., 2024). Subtype-exclusive genes - including CDH19 and HSD17B8 for Luminal A, SPINK4 for Luminal B, NEFL and MSN for HER2-enriched, and MEG3 and P2RX6 for Basal-like - extend established PAM50 panels with additional discriminatory markers.

Table 3: Top five SHAP-identified genes per molecular subtype.

Rank	Luminal A	Luminal B	HER2-Enriched	Basal-Like
1	TF	ARFIP2	TF	ACAT2
2	ARFIP2	HYMAI	BBS12	BBS12
3	BBS12	TF	ARFIP2	SSPN
4	HYMAI	BTRC	LHCGR	MEG3
5	LHCGR	ACAT2	HYMAI	PSENEN

Compared to imaging-based CNN approaches, the RNA-seq RNN model can detect malignancy prior to observable anatomical changes, positioning it as a molecular screening complement to existing workflows rather than a standalone diagnostic. Limitations include class imbalance (malignant vs. normal samples), subtype imbalance particularly for HER2-enriched tumours, and reliance on transcriptomic data alone, excluding clinical variables such as tumour stage and treatment history.

5. Future Trends

Future research should prioritise multi-cohort datasets with improved class balance to address specificity limitations and enhance cross-cancer generalisability. Integration of multimodal inputs – combining RNA-seq data with clinical variables, imaging features, and proteomic profiles – offers substantial potential to improve classification robustness. Longitudinal gene expression analysis could enable modelling of disease progression and treatment response, advancing the utility of transcriptomic AI beyond initial diagnosis.

The genes identified by SHAP, particularly TF, ARFIP2, and MSN, represent candidate biomarkers warranting prospective validation in independent clinical cohorts. Incorporation of such non-canonical biomarkers into expanded molecular panels could refine subtype discrimination beyond current PAM50 standards. As sequencing costs continue to decline and computational frameworks mature, RNA-seq-based DL models are poised to transition from research tools to integrated components of clinical oncology workflows, provided that explainability standards keep pace with regulatory and ethical requirements for medical AI adoption.

6. Conclusion

This study demonstrated that a multi-task Bi-LSTM recurrent neural network can accurately and interpretably classify breast cancer from RNA-seq gene expression data. The model achieved high diagnostic performance with perfect sensitivity for malignancy detection and reliable molecular subtype classification, with performance patterns reflecting known biological relationships. The preprocessing and feature selection strategy preserved clinically relevant biomarkers while improving dataset quality. SHAP-based explainability identified biologically meaningful gene signatures consistent with established and emerging breast cancer literature, supporting the hypothesis that deep interpretable learning can leverage transcriptomic data to deliver clinically relevant classification. These findings advance the case for transparent, molecular AI tools in oncology diagnostics.

7. Acknowledgements

The author thanks Ms Thompson for supervising this project and running the Science Extension course. The author also thanks Safaa Al Haj Hussein and Teah Goodhand for their mentorship, monthly feedback sessions, and careful review of drafts. The author acknowledges Ms Cartwright and Ms English for their constructive feedback on the first complete draft.

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STEM *vs.* S.T.E.M. – Part II

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"[E]ducation is ... that which is left after all that has been learned has been forgotten." (Conant, 1943)

4. Scientific Literacy

The NSW Department of Education and Training defines 'scientific thinking' as: "using evidence to establish cause and effect relationships", and also as "purposeful thinking that has the objective to enhance knowledge". [1]49 It also defines 'scientific literacy' as:

"The ability to use scientific knowledge, understanding, and inquiry skills to identify questions, acquire new knowledge, explain science phenomena, solve problems and draw evidence-based conclusions in making sense of the world, and to recognise how understandings of the nature, development, use and influence of science help us make responsible decisions and shape our interpretations of information." [2]

This is a longwinded way of saying that 'scientific literacy' is understanding the workings of Figure 3, namely:

4a: the ability to use STEM to perform S.T.E.M.;

4b: the ability to use the results of S.T.E.M. to update STEM; and

4c: the ability to put the whole process to good use.

In somewhat fewer words, it's knowing STEM, and knowing how to apply it. "Scientific literacy" is more than familiarity with the scientific method; it is a working knowledge of the conceptual foundations and logical structure of S.T.E.M. It is necessarily interdisciplinary – a "generalist specialization". Rather than the details of any one science or technology, it is concerned with the overall approach to S.T.E.M., and the relations and interactions between the different sciences and technologies.

5. Critical Thinking

STEM participates in the practice of S.T.E.M. in two ways: it provides a deeper understanding of how S.T.E.M. works; and it facilitates a more effective way of working with it. The first of these is scientific literacy (§4); the second is critical thinking. [3] Competent S.T.E.M. practitioners (and STEM educators) need both.

[1] https://education.nsw.gov.au/teaching-and-learning/curriculum/science/planning-programming-andassessing-science-k-6-2017/thinking-skills/scientific-thinking (Transcript).

[2] https://scientificliteracyforschools.weebly.com/what-is-scientific-literacy.html

[3] https://cvformat.io/blog/critical-thinking-skills-definition-benefits

Critical thinking is (a), ensuring that our understanding of S.T.E.M. is conceptually and contextually coherent; (b), understanding how and why we are confident that it is; (c), checking that our understanding accords with experience; and (d), looking for, anticipating, and fixing errors. It is believing nothing – taking nothing for granted – forever questioning assumptions, understanding, and expectations. It is remembering always to ask, “How do we know?”, and “How else might things be?”. Critical thinking is ‘rational [4] thinking’ on steroids.

The basic tools for rational thinking (and, indeed, for all ‘reasoning’) are semantics and formal logic. Their axioms and rules – for what our thoughts and ideas mean and how to manipulate them – set the gold standard for what it means for something to ‘make sense’.

Rational thinking does not come naturally to us, however. We are not born rational thinkers, we are born intuitive thinkers. Infants think with their feelings: they believe things and make judgements not according to what ‘makes sense’, but according to what ‘feels’ right. Rational thinking requires experience and memory, and toddlers show the first signs of it at around 15-18 months. [5] By age 4, they’re showing evidence of reinforcement learning. [6] Children learn fast, but how much and how fast depends on how varied and stimulating their environment is. [7] As adults, we continue to accumulate experiences and ‘wisdom’, but our rational thinking prowess starts to slow. (Sapolsky, 2017)

Some adults end up better rational thinkers than others, but never is anyone perfectly rational. And certainly not all the time: rational thinking requires more effort, so when we’re feeling tired, or lazy, or just not paying attention, we automatically revert to intuitive thinking. [8]

Critical thinking is also contingent upon a heightened acuity of observation:

“We need to train our powers of observation, to cultivate that attitude of mind of being constantly on the look-out for the unexpected and make a habit of examining every clue that chance presents. Discoveries are made by giving attention to the slightest clue.” (Beveridge, 1957, pg. 32)

For experienced critical thinkers, heightened acuity and rational thinking kicks in automatically as and when required. In ‘rational thinking mode’ they are acutely perceptive; forensically probing; rigorously logical; and annoyingly pedantic. They analyse every situation from every angle; they leave ‘no stone unturned’; and they often make themselves very unpopular! Yet we need them: we all want critical thinkers piloting our A380, and critical thinkers working on the Airbus design team. The benefits are obvious.

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[4] “rational”, adj. = logical, sensible, consistent with and/or based on sound reason and judgement. [L: ratio = reckoning].

[5] Alison Gopnik (TED, 2011): < https://www.youtube.com/watch?v=cplaWsiu7Yg >.

[6] Alison Gopnik (TED, 2011): < https://www.youtube.com/watch?v=cplaWsiu7Yg >.

[7] With respect to learning, “childhood” may extend to around age 25, after which adults learn more slowly and with more difficulty. (Consider how much more easily children learn a new language.)

[8] Most of us act on intuitive “type 1” thinking, most of the time. (Kahneman, 2011).

Critical thinking is essential for S.T.E.M.; but it also provides countless benefits in other areas, including in everyday life. (There is very little demand for uncritical thinking!)

"Appreciating the scientific process can be even more important than knowing scientific facts. People often encounter claims that something is scientifically known. If they understand how science generates and assesses evidence bearing on these claims, they possess analytical methods and critical thinking skills that are relevant to a wide variety of facts and concepts and can be used in a wide variety of contexts." (Office of the Chief Scientist, 2013, pg. 15).

Critical thinking is an acquired skill; and like learning to play the violin, it takes years of training. [9] To think rationally, we have literally to rewire our brains; we can't simply learn it out of a textbook. And like learning to play the violin, success is variable and not assured: some never quite master the instrument, some become competent orchestral players, and only a few become celebrated soloists.

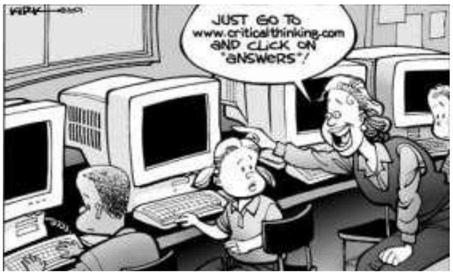

Figure 7: We need to think critically even about critical thinking. [10]

Once acquired – i.e., when our brain has undergone the requisite rewiring – critical thinking becomes 'automatic'. It kicks in and out seamlessly, just as multilingual speakers switch between languages. And this is what we recognise as proficiency in STEM.

6. STEM is not S.T.E.M.

As foreshadowed in §2, and contrary to the common view, this essay argues that STEM is not synonymous with S.T.E.M. By now the distinction should be clear: STEM is an adjunct to S.T.E.M. – it is about S.T.E.M., but it is not itself S.T.E.M.

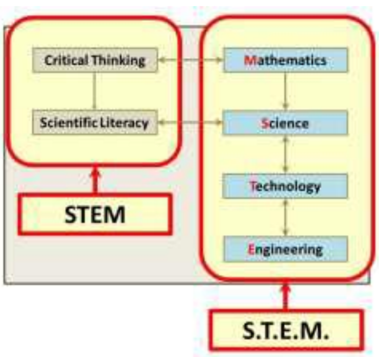

Figure 8: STEM is an adjunct to S.T.E.M.

[9] And it doesn't come easily! It is informative to watch university students struggle with learning Logic 101.

[10] Image credit: menace-theoriste.fr

In everyday parlance, however, STEM and S.T.E.M. are often conflated, as is evident in this paragraph from the Office of the Chief Scientist:

"STEM plays a critical role in our economy. But the value of our investment in STEM will be diminished if our practitioners operate without due regard for Australians, and their wants, needs, aspirations and concerns." (Office of the Chief Scientist, 2014, pg. 8).

It is S.T.E.M., not STEM, that "plays a critical role in our economy" – that is important to society for the material and economic benefits that it provides – and thus it is our S.T.E.M. practitioners who must operate with due regard for societal aspirations and concerns. (Office of the Chief Scientist, 2013, pg. 13).

The conflation is understandable. Governments see S.T.E.M. 'from the outside', so to speak, and do not draw the STEM/S.T.E.M. distinction. Their main interest lies in the contribution to the economy by S.T.E.M., and the cost to the economy of S.T.E.M. From their perspective, the STEM/S.T.E.M. distinction is a secondary consideration: the whole process is just a black box, into which investment is warranted by the expectation that it will deliver future social/economic benefits. By contrast, scientists see S.T.E.M. 'from the inside': their interest is mainly in the contribution that STEM makes to S.T.E.M.; and rely on the public desire for the outputs from S.T.E.M. to provide their funding. It is academics, teachers and educators who see S.T.E.M. from both sides, and readily distinguish between the practice and the theory: for while they're not actually doing S.T.E.M. themselves, they are the managers of the STEM expertise that makes S.T.E.M. possible.

"The value of STEM education extends beyond scientists, technologists, engineers, and mathematicians (who are essential contributors to the state's economic strength). STEM teaches and trains students to engage in critical thinking, inquiry, problem solving, and collaboration, which are a valuable skill set in an increasingly complex technological society." (CCST Newsroom, 2014, July 8)

7. The Art of Doing S.T.E.M.

In §1.5, we defined the Arts as everything that isn't S.T.E.M. and gathered the Arts under the rubric of "Humanities". Since STEM isn't S.T.E.M., it follows that STEM also resides in the Humanities. However, this does not mean that STEM and the other Humanities are somehow interconnected. While the Arts have a role as an aid to performing S.T.E.M. processes, shoehorning the Arts into STEM is unhelpful. (Jolly, 2014; Riley, 2013).

While sensitivity for human/social concerns (i.e., ethics) may direct us to the choice of which S.T.E.M. activities to pursue, it does not inform our scientific understanding or instruct us in critical thinking. It also does not dictate what STEM-based research can and cannot discover. [11] The Humanities may inform scientists about what activities are/are not currently socially acceptable (e.g., by selectively allocating/withholding public funding), but they cannot (or at least should not) tell scientists what research they may or may not conduct, and what they

[11] Ethics and dogma are not the same thing; and STEM is not answerable to dogma. Consider how, despite the best efforts of the Roman Catholic Church, it turns out not to be unethical to discover that the earth is not at the centre of the Universe. [Copernicus (1543)].

may or may not find. [12] There is nothing in STEM that qualifies as a candidate for ethical evaluation, human/social concerns are applicable only to S.T.E.M.

Further, the constraints imposed by social concerns are a general consideration applicable to all human endeavors, and do not have any particular application even to S.T.E.M. S.T.E.M. is just another ordinary human endeavour; like agriculture, or fishing. It is currently fashionable, but makes no sense, to blame science and technology for every human ill; these charges are aimed at the wrong target: for example, it wasn't the scientists or S.T.E.M. operators who wanted to bomb Hiroshima, or who drove people to consume five trillion plastic bags per year! [13]

Moreover, while STEM belongs in the Humanities, it is not one of the aesthetic 'Arts'; STEM is only an art in the sense of being a 'craft', or skill; i.e., in the sense of being "the Art of doing S.T.E.M.".

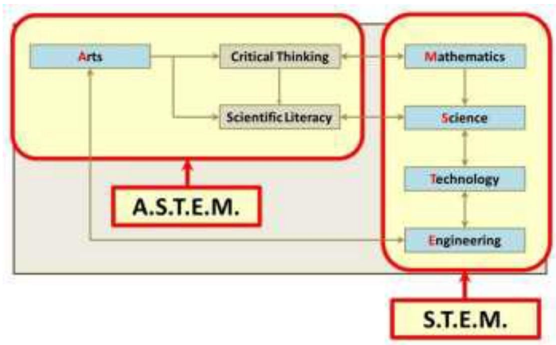

Figure 9: The Art of doing S.T.E.M.

"A.S.T.E.M." doesn't roll of the tongue quite as nicely as "STEAM", but at least its meaning is clear. STEM is also an art in other ways. It's conjuring up new ideas; (Beveridge, 1957, pg. 53) it's thinking "outside the square"; it's finding solutions to problems even before they arise ... It's everything that S.T.E.M. on its own does not and cannot do.

"... the great scientist must be regarded as a creative artist, and it is quite false to think of the scientist as a man who merely follows rules of logic and experiment." (Beveridge, 1957, pg. 71)

8. STEM Education

STEM education is difficult, and complicated. First, it involves teaching the basic sciences – physics, chemistry, biology, etc. Second, it involves teaching the relationships and

[12] Social influence can, and does, delay progress; but even the once all-powerful Catholic Church failed to stop humankind discovering that the Earth was not the centre of the Universe. After a mere 359 years, on November 1, 1992, the Vatican was forced to recant, admitting that it was permissible for Galileo to point his telescope to the stars. (No one can accuse the Church of acting in haste.) More recently, recall the furore in the United States over embryonic stem-cell research [Wolinsky (2010)]. Today, with the promise of advances in regenerative medicine, the research continues unabated.

[13] https://www.theworldcounts.com/challenges/waste/plastic-bags-used-per-year

interplay between these sciences – how biology supervenes on organic chemistry; how organic chemistry supervenes on molecular physics; and so on.

"Philosophy as a whole is like a tree; of which the roots are Metaphysics, the trunk is Physics, and the branches emerging from this trunk are all the other branches of knowledge." (Descartes, 1644), xxxiv) [14]

Third, it involves teaching basic mathematics – both pure and applied – and explaining how mathematics serves to describe the observed patterns and regularities in the structure and behavior of the physical world, as revealed by the various sciences. Students learn mathematics better when they know what it is for. [15] Fourth, teaching STEM involves engaging students in practical engineering projects, and introducing them to the associated enabling technologies.

And all this is just S.T.E.M. education! STEM education comes on top, with three additional aims: (a), to engender broad-spectrum scientific literacy; (b), to evoke proficiency in critical thinking; and (c), to develop acuteness of perception and sharpness of mind. Importantly, these aims are quite different: none can be achieved by teaching another, and none can be achieved by teaching S.T.E.M. alone.

Teaching 'scientific literacy' consists of familiarizing students with the content described in §3.1-§3.3. [16]74 On its own the material is abstract and theoretical; but presented alongside S.T.E.M. practice, it is meaningful and explanatory. And teaching 'scientific literacy' does not present any particular challenges – the only requirements being (a), teachers who are themselves scientifically literate; and (b), the extra time it takes to present and explain it. [17]

By contrast, teaching 'critical thinking' is a challenge. Unlike 'scientific literacy', 'critical thinking' is not content-based, and is not a subject that can be "presented" (alongside S.T.E.M. or otherwise). Nor can it be taught as a separate, free-standing subject: students can (and should) be taught some basic logic, but they can't be taught to '*think'*.

As shown in §5, 'critical thinking' is a skill – a particular 'way of thinking' – that can be acquired only through practice and experience; and the only way to train students to become proficient critical thinkers is to show/demonstrate/explain the basic principles of logic and inference and then guide them through many real-life situations that require them to apply these principles and practise thinking 'critically'. To be effective trainers, STEM teachers themselves need to be exemplars of critical thinking. Just as violin teachers need to be violinists, so STEM teachers need to be habitual critical thinkers: constantly provoking, questioning, showing, explaining, and guiding students towards assuming a critical stance – an acuteness of perception and sharpness of mind – in their inquiry into the workings of the S.T.E.M.

[14] Descartes was writing about "Philosophy", but recall that before around the mid- 19th century, Science was known as "natural philosophy". Philosophers today often refer to STEM as "philosophy of nature".

[15] The same applies to learning the sciences. Practical application/experience is easier to learn than abstract theory.

[16] As elaborated in numerous texts; see, for example: (de Regt, 2017).

[17] In practice, it seems both are in short supply. (Miller, 2016)

"We need to train our powers of observation, to cultivate that attitude of mind of being constantly on the look-out for the unexpected and make a habit of examining every clue that chance presents. Discoveries are made by giving attention to the slightest clue." (Beveridge, 1957, pg. 32)

In other words,

"In the fields of observation, chance favours only prepared minds." [18]

In §2.2, we described S.T.E.M. education as "guided accelerated fiddling". If students are encouraged to "fiddle", and their fiddling is well motivated, well guided, and well encouraged, then they will learn much more than just fiddling – they will learn STEM.

As STEM skills cannot be taught in the traditional way, 'teaching' STEM calls for trainers and coaches rather than traditional teachers. And here we encounter a problem: "hampered by an insufficient collective understanding of what is meant by integrated and engaging STEM teaching and learning", (Fraser et al., 2019, pg. 10) teachers – and even academics – feel ill-equipped to take on the task. [19] This is a pity; education is about much more than just teaching content.

When teachers are not adequately trained to engender critical thinking and STEM skills effectively, the ongoing decline is perhaps unsurprising. The problem trickles down from the very top: universities are not training their students – i.e., the teachers of the next generation – to become 'critical thinkers'; and those teachers, in turn, will be ill-equipped to train their students.

"We are approaching a darkness in the land. Boys and girls emerge from every level of school with certificates and degrees, but they can't read, write or calculate. We don't have academic honesty or intellectual rigor. Schools have abandoned integrity and rigor." (Faris, 1987) [20]

How often do we hear students say that they liked a subject at school, and even chose it as a career, primarily because they had an 'amazing' teacher! Students learn much more from their teachers than the subject matter for their exams – they also learn and adopt their teachers' views and attitudes to their subjects. Students mostly won't like a subject if their teacher doesn't; and they won't enjoy learning if their teacher doesn't enjoy teaching. Being an effective teacher consists in knowing how to teach; but being recognized by students as an

[18] "…dans les champs de l'observation le hasard ne favorise que les esprits préparés". (Pasteur, 1854).

[19] For example: Some years ago, the Head of a medical school at an Australian university proposed to his staff of professors and lecturers that they adopt a new approach to their teaching. Given that all their lectures and textbooks were available online, he said, they could: (a), distribute copies of the syllabus and lecture notes; (b), indicate clearly the range of material that will be examined; (c), direct students to all the necessary resources; and then (d), spend their valuable face-to-face time teaching their students what was presently not included in their lectures: additional background knowledge; analyses of real-world experiences; practical matters that can be learned only through 'bitter experience'; and so on. This 'meta-medical' experience (to borrow Aristotle's terminology) would serve as an invaluable enrichment of their students' understanding of the subject. To the Head's surprise and disappointment, the response from the lecturers was univocal: "We don't know how to do that, we only know how to teach content." [Recounted in personal conversation (2024). Name withheld by request.]

[20] Julius Sumner Miller, quoted by Gerald Faris in the L.A. Times, April 16, 1987.

‘amazing’ teacher requires fluency in the subject, confidence in its presentation, and genuine enthusiasm in its delivery. We live in an amazing world, and teaching STEM – i.e., filling students with a sense of wonder – calls for amazing teachers who are themselves amazed. [21]

“The mediocre teacher tells. The good teacher explains. The Superior teacher demonstrates. The great teacher inspires.” [22]

9. Conclusion

STEM is the ‘Art of doing S.T.E.M.’, and it is what the next generation needs if they are to thrive in a future that is ever more technological, digital, and artificial – an age where even intelligence is artificial!

It is widely held that students learn STEM by doing S.T.E.M., and that learning STEM is useful for a career in S.T.E.M. Each of these views is only half correct.

First, deriving the structure and content of STEM from the practice of S.T.E.M. is not straightforward, and it is neither easily taught, [23] nor easily learned. As shown in the previous section, students may (or may not) learn STEM while doing S.T.E.M., but they are unlikely to learn it by doing S.T.E.M.

And second, STEM has universal application: understanding how the world ‘works’ is beneficial for whatever activity one is pursuing, whether neurosurgery or gardening. Everything we do requires at least some rational thinking, and a deeper understanding of what we’re doing can never go astray. It is not possible to think too clearly, or to practice too much STEM!

This essay is not intended to be political, but it is a call to action. We need to lift STEM education at all levels: Educators of every stripe – teachers, academics, and policymakers – need to acquire better STEM skills and impart these skills to students and educators of the next generation. They’re going to need it...

“In the conditions of modern life, the rule is absolute, the race which does not value trained intelligence is doomed. Not all your heroism, not all your social charm, not all your wit, not all your victories on land or at sea, can move back the finger of fate. To-day we maintain ourselves. To-morrow science will have moved forward yet one more step, and there will be no appeal from the judgment which will then be pronounced on the uneducated.” (Whitehead, 1917), pg. 28)

As the old proverb almost says, “Give them a fish and they’ll eat for a day, teach them how to fish and they’ll eat for at least two days.”

Acknowledgements

Thanks to Peter Baume, Helen Georgiou, Margret Schuller and Sam Sharp for their helpful comments.

[21] The ‘amazingly’ enthusiastic physicist Julius Sumner Miller [1909-1987] was known to millions of children as “Professor Wonderful”. The acclamation was richly deserved: through his ABC TV series Why is it so? (1963- 86), he inspired countless children to pursue a career in Science.
[22] William Arthur Ward [1921-1994]
[23] Witness the school students who perform all the science experiments and then fail their exam.

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What is the gut-brain connection?

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Experiencing a gut feeling directly demonstrates this internal communication system. The gut-brain axis is a complex bidirectional communication network linking the emotional and cognitive centers of the brain with peripheral intestinal functions. It continually works to relay information, allowing the central nervous system (CNS) to influence gut function while allowing the gut to affect mood and behaviour. The gut-brain connection is not merely a physiological metaphor, but a complex physiological network driven by the vagus nerve, neurotransmitter production, and the gut microbiome, all of which directly influence both systemic health and emotional states.

The gut-to-brain axis links the gastrointestinal tract and the CNS by relying on three main structural and physiological pathways. Neural pathways, which contain the Enteric Nervous System (ENS), are responsible for controlling digestion. The ENS can also communicate directly with the CNS. The ENS has over 100 million nerve cells lining the gut. The ENS directly communicates with the CNS through the vagus nerve, directly linking the gut to the brainstem. Sensory fibres relay information about gut stretch, chemical states and microbial metabolites to the brain. Pelvic nerve pathways relay specific sensory information, including complex sensations like pain.

One of the most fascinating features of the gut-brain connection is that the gut does not simply digest food, it produces chemicals that influence how people think and feel. More than 90% of the body's serotonin (often called the feel-good neurotransmitter), is made in the gastrointestinal tract rather than the brain. That alone can completely change the way mental health is thought of. Gut bacteria can also produce short-chain fatty acids (SCFAs), which are able to cross the blood-brain barrier and affect the brain functions! When these chemical signals are balanced, this helps with the regulation of mood and emotional wellbeing, although when imbalanced, feelings such as anxiety and depression may emerge instead, thereby unveiling and highlighting a connection between gut health and brain chemistry. (N.B. poor gut health is merely one correlation affecting mental health).

The gut microbiome is composed of trillions of microorganisms. This is a common feature in both humans and animals and studies show that adjusting the balance of these microbiomes can also affect stress levels, behavior and mood. It is incredible to see how something so small can have such a massive impact on mental health. Rather than just helping with digestion, the microbiome acts like another organ, communicating with the brain through metabolic pathways and the immune system, thereby actively influencing emotional wellbeing.

Irritable Bowel Syndrome (IBS) is one of the clearest examples of how closely the gut and brain are connected. Stress and anxiety can trigger IBS symptoms such as pain and inflammation, while ongoing digestive problems can also worsen one's mental health, thereby creating a continuous cycle of potential health deterioration. Hence, the gut and brain cannot be treated as separate systems. Because of this two-way relationship, treatments like Cognitive Behavioral Therapy (CBT) are often used alongside medical care to help manage IBS, proving that both physical and psychological health play an important role in recovery. Please note that

CBT is a short-term talk therapy focused on how one's thoughts can affect one's feelings and behavior. It helps patients identify harmful, negative patterns and provides practical solutions to reframe these patterns, helping them better cope with anxiety and depression

In summary, the gut-brain axis demonstrates the close connection between physical and mental health and marks a significant paradigm shift in contemporary medicine. The physical foundation for immediate, two-way communication is provided by the Enteric Nervous System and the anatomical highway of the vagus nerve. Additionally, the metabolic activity of the microbiome and the production of vital neurotransmitters like serotonin in the digestive tract show that gut health directly affects central nervous system function. This truth is further supported by clinical models and conditions such as irritable bowel syndrome, which demonstrates that gastrointestinal discomfort and psychological suffering are mutually reinforcing. The human body is ultimately best understood as a single, cohesive ecosystem rather than as a collection of separate systems.

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Badaya Ngiyingayi Budyari Ganu! [24] Eat Your (Warrigal) Greens!

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1. Acknowledgement of Country

First Nations peoples have held and shared knowledge of native Australian foods since time immemorial. The Warrigal Greens used in this study were sourced from Dharug and Gundungurra Country in the Blue Mountains and from Guringai, Gaimarigal and Garigal Country on the Northern Beaches. I acknowledge the Traditional Owners of these lands and pay my deepest respects to Elders past and present. As an Aboriginal woman connected through my Paternal Grandmother to Ngadjuri Country, I am deeply grateful for the strength, resilience, and diversity of knowledge that continue to guide the communities and Countries across this diverse nation. This land was never ceded and always was, always will be Aboriginal land. As a Food Scientist who is Aboriginal, I am passionate about using Western Science and Traditional Knowledges to deepen respect, responsibility, community and connection to native ingredients.

Keywords: Warrigal Greens; Tetragonia tetragonioides; Australian native foods; First Nations; oxalates; microbial safety; food processing; wild-harvested foods.

2. Introduction

Having the opportunity to incorporate native ingredients is a privilege, particularly when their use is led by Aboriginal and Torres Strait Islander people who guide the oldest living cultures in the world (Cumpson, Fletcher et al., 2022; Lopes, de Saousa Alves Neri, et al., 2024). With Australian native foods existing in a highly trending and increasingly profitable environment, it is vital to understand how to support their sustainable use, respect cultural knowledge and meaningfully integrate these nutrient-dense foods into the modern diet (Janke,

[24] Dharug Language for "Eat Your Good Food (non-meat)" was gifted by Corina Norman and acknowledges Bayala Aboriginal Corporation.

2018). Supporting the research and revitalization of native foods is essential for decolonization and the assertion of First Nations' rights and self-determination, while the associated health benefits also extend to the wider population (Lopes, de Sousa Alves Neri et al., 2024). Equally, it is vital to remember that the importance of traditional foods is validated by their continued presence in the diets of the oldest living cultures in the world (Cumpston et al., 2022). Warrigal Greens have been used by our Elders and communities as a nutrient-rich leafy green, contributing high amounts of vitamin C, carotenoids, minerals, phytochemicals and antioxidant capacity (Kiloni et al., 2026).

Warrigal Greens (Tetragonia tetragonoides) hold cultural significance from a First Nations perspective, with a long history of use and recognized nutritional value. Respecting First Nations foods goes beyond consumption, it means supporting First Nations-led research, businesses and knowledge systems that have sustained the world's oldest food practices for over 120,000 years (Cumpston et al., 2022; Janke, 2018). Surprisingly, even with some of these most nutrient-dense foods present, Australian diets follow a highly colonized Western diet (Lopes, de Saousa Alves Neri et al., 2024). Western diets continue to fall short on the recommended fruit and vegetable intake, with only around 10% of Australians meeting the daily requirements (Utter, McRae et al., 2024). This gap highlights an opportunity for native ingredients, guided by First Nations leadership, to support both cultural sovereignty and population health (Cumpston et al., 2022; Lopes, de Sousa Alves Neri et al., 2024).

Past studies of Warrigal Greens suggest they are a superior leafy green but may present high anti-nutrients such as oxalates. However, this is not dissimilar to other leafy greens like spinach, chard, taro leaves and rhubarb (Chai and Liebman, 2005). Oxalates in high amounts can impact human health by reducing calcium absorption or contributing to kidney stone formation. This chemical is naturally present in many foods and assessments are needed to measure how much oxalates are in Warrigal Greens (Jaworska, 2005).

Currently, there are different recommendations for preparing Warrigal Greens, from blanching or boiling for varying time intervals, or consuming raw in small quantities so heat-sensitive vitamins are preserved. This project aimed to compare different processing techniques and see what is necessary for safe consumption, which will make public information available based on First Nations-led analytical testing for community protocols to be built upon wild harvesting (Lopes, de Sousa Alves Neri, et al., 2024).

This project had two key goals: To assess the microbial and chemical safety of Warrigal greens harvested from different environments. Then and to understand how common cooking methods influence the presence of oxalates. By comparing samples harvested from one Blue Mountains region (mountains environment) and two coastal beach regions (saline environments), this project explored whether location influences anti-nutrient composition (oxalates) and food safety (microbes).

3. Methods

Wild-harvested Warrigal Greens were collected aseptically by hand from three regions, WG-01 (Blue Mountains), WG-02 (Narrabeen), and WG-03 (Curl Curl). Samples were then subjected to different preparation techniques, including blanching, boiling, and frying at different time intervals for chemical (oxalate) testing and raw for microbial testing. These methods were chosen not only for their relevance to home cooking, but also because they reflect traditional and contemporary ways of preparing leafy greens such as spinach and chard (Chai and Liebman, 2005; Utter, McRae et al., 2024).

4. Results

Microbial presence in wild-harvested Warrigal Greens across three harvest locations.

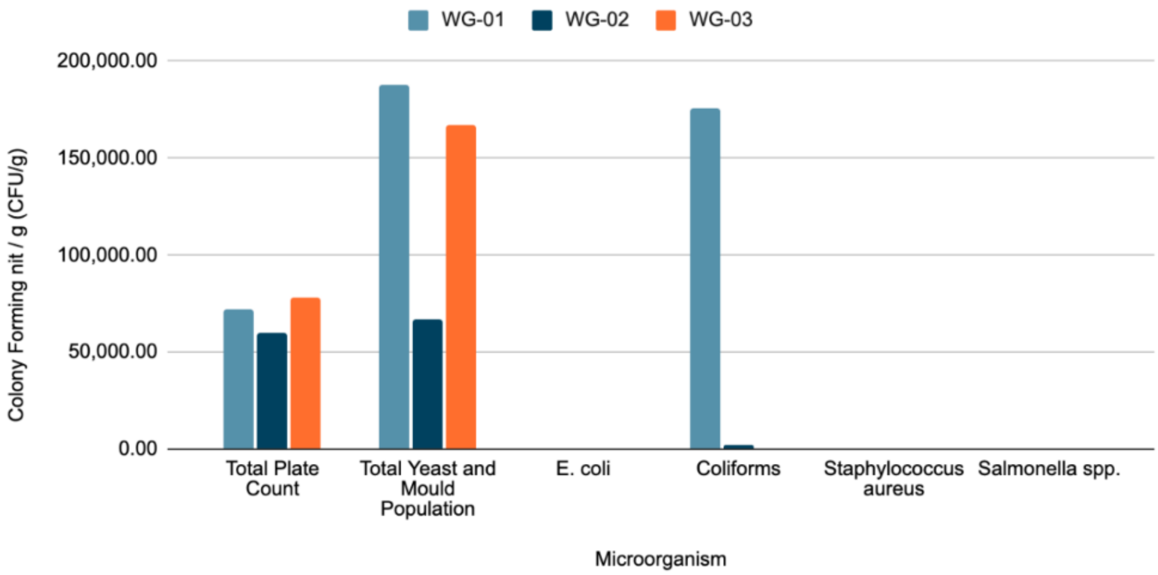

Figure 10: Microbial counts detected in wild-harvested Warrigal Greens collected from the Blue Mountains (WG-01), Narrabeen (WG-02), and Curl Curl (WG-03).

Microbial analysis demonstrated that microbial loads vary according to harvest location, highlighting the importance of appropriate handling and preparation prior to consumption (Carpena, Prieto et al., 2024). All results analyzed in this study were below the relevant guidelines by the New South Wales Food Authority (2009) and Food Standards Australia New Zealand (FSANZ) (2025) guidelines, despite being analyzed in their unwashed, wild-harvested state. Microbial loads would also be expected to decrease following washing and/or other cooking, although these comparisons were not conducted in this study. This means that all samples meet the standards for safe consumption.

Effect of processing methods on oxalate levels in Warrigal Greens.

Wet-heat processing methods (blanching or boiling) were associated with greater reductions in oxalate content compared to dry-heat methods (frying). However, these experimental values showed a much larger value of oxalates across all samples (between 23 mg/g to 54 mg/g) than what is in literature (5.6 mg/g) (Jaworska, 2005). These results are likely an overestimate as there were no preexisting methods for testing oxalates in Warrigal Greens via titration available. Difficulties were encountered in identifying an accurate endpoint due to color interference from other compounds present in the samples, emphasizing the need for further refinement of the method. Overall, boiling was shown to be the best at 120 seconds consistently across samples. Literature results for Oxalate content comparable greens like chard and spinach in raw form are 10.65-11.45 mg/g (Chai and Liebman, 2005). Due to the differences in experimental oxalate values and reported literature, this experiment was useful in seeing the general trends and decreases in oxalates only, as repetitions and improvements to the methods are needed for accuracy.

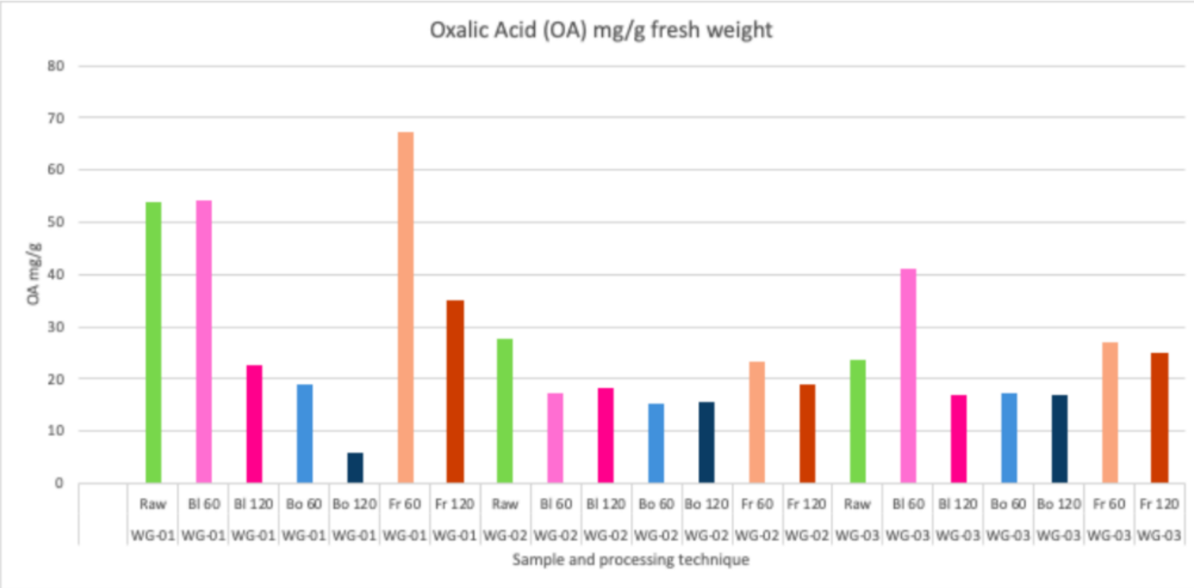

Figure 11: Changes in Oxalic Acid (OA) mg/g of Fresh Weight (FW) in Warrigal Greens samples (WG-01, WG-02 and WG-03) following blanching, steaming, and frying at varying time intervals. Raw was unprocessed form, Bl 60 was blanched for 60 seconds, Bl 120 was blanched for 120 seconds, Bo 60 was boiled for 60 seconds, Bo 120 was boiled for 120 seconds, Fr 60 was fried for 60 seconds, Fr 120 was fried for 120 seconds.

5. Discussions

This work highlights that native ingredients like Warrigal Greens should not be assessed through a Western scientific lens alone. First Nations peoples are the world's first scientists who have long understood when, where and how to harvest and prepare these foods safely (Lopes, de Sousa Alves Neri et al. 2024). Scientific testing can support and translate this knowledge for broader audiences, but it should never replace or override First Nations ways of knowing (Cumpston et al. 2022; Janke 2018).

Warrigal Greens harvested from different locations had different microbial loads and oxalate contents. Wet-heat methods were more effective at reducing oxalate content, while dry-heat methods like frying likely concentrated anti-nutrients due to moisture loss. These results suggested that environmental factors, such as harvest location, can influence both microbial load and chemical composition of Warrigal Greens.

The findings in **Figure** 10 highlight the need for washing and/or heat processing to remove microbial load from wild harvested plants (Carpena, Prieto et al., 2024). Additionally, **Figure 11** showed that heat preparation reduced oxalate content. Wet-heat methods such as steaming and boiling were effective at reducing oxalate levels and improving microbial safety (Chai and Liebman, 2005). This is likely due to most oxalates being water-soluble and, during boiling, water molecules surround the food and draw out oxalates into the water. To a slightly lesser extent, steaming removes fewer oxalates as there are fewer water molecules interacting with the food, so fewer oxalates are extracted.

Importantly, these results also suggested that environmental factors, such as harvest location, can influence both microbial load and chemical composition, reinforcing why blanket food preparation advice is not always appropriate for native foods and should be locally sourced and guided by Traditional Custodians[25] (Cumpston et al., 2022; Janke, 2018; Carpena, Prieto, et al., 2024).

6. Conclusion

This project represents a step toward helping modern science catch up with ancient knowledge systems to analytically reinforce what First Nations peoples have always known: that "plants of our Country are highly nutritionally valuable and are the perfect inclusion in the human diet to ensure health and vitality" (Cumpston et al., 2022). By grounding research in respect, community need and cultural leadership, native foods like Warrigal Greens can be meaningfully integrated into mainstream diets, benefiting both First Nations communities and the wider population. This project was a foundational move in a long journey of reincorporating Native Australian foods onto everyone's plate safely and sustainably.

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Where is the moon going?

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For our entire existence, humans have looked up to the stars and dreamt of reaching the Moon, but did we ever think the Moon might be trying to get away from us? Approximately 4.5 billion years ago, the Moon formed from what is believed to be debris from Theia colliding with earlier formations of Earth, and it has been drawn to the Earth ever since, orbiting from over 3 hundred thousand kilometers away. After finally landing on the moon in 1969, humans left reflectors on the surface that scientists have been shining lights towards to uncover valuable data about the Moon, its orbit, and its gravitational impact on Earth. With such data, astronomers made a shocking discovery: the Moon is moving away from the Earth at almost 4 cm per year.

1. What is the Moon?

The Moon is the Earth's natural satellite; the 1740-km radius sphere of rock orbits the Earth every month and has rooted itself in human dreams and myths. The moon likely formed approximately 4.5 billion years ago from the debris of a Mars-sized object called Theia crashing into Earth. The Moon completes an orbit around the Earth every 27.3 days; from the ground, we see different stages of its cycle. The Moon reflects the Sun's light towards the Earth, making it appear luminous even at night. The Earth casts shadows on the Moon, creating shapes seen as crescents, half-moon, and full moon that are observable from Earth, although Moon is seemingly invisible for three days of the cycle.

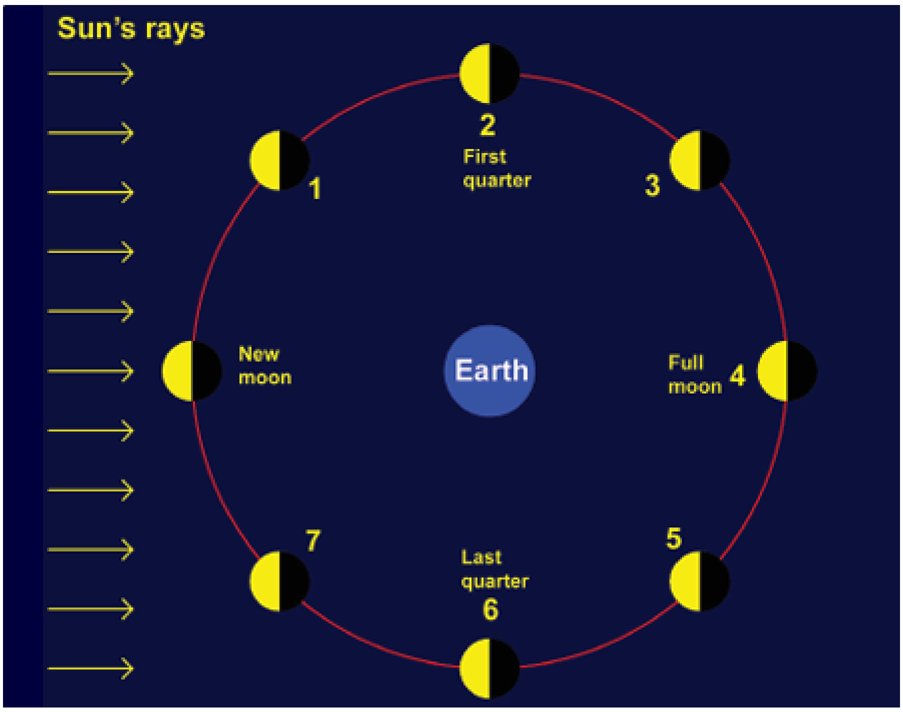

Figure 12: Moon cycle relative to the Earth's position and observation. The Launceston Planetarium Queen Victoria Museum

The Moon is covered in craters and plains, which from the Earth look like distinct shapes. In the Northern Heliosphere, a face can be seen, namely "The man in the moon", while other parts of the Earth would instead see shapes of a rabbit, a woman, or a frog. Like with constellations, different cultures, from Greek and Roman gods to people rising after three days, project images on the moon. As such, the Moon's orbit serves as a pivotal part of the sky and its disappearance is almost unimaginable.

2. What is the Moon's current orbit?

Our Moon orbits the Earth from approximately 384,000 kilometers away in an almost circular orbit. The orbit, however, is not circular but an ellipse with Earth being one of the foci (i.e., one of two points within an ellipse which defines its shape). Notably, the Moon's orbit is tilted at 5.1° compared to the plane of the Earth's orbit around the Sun. Due to the noncircular orbit, the Moon's distance from Earth is always changing throughout the month between the nearest distance (perigee) at about 356,400 kilometers away, and the farthest distance (apogee) at about 406,700 kilometers away. The changing distance of the Earth to the Moon causes variation of the tides on Earth. The Moon's gravitational pull on the Earth stabilizes its tilt of 23.5°**,** thereby influencing the Earth's seasons. On the Moon's orbital line, there are two nodes (ascending and descending) where the Moon's path intercepts the ecliptic plane (i.e., the plane of the Earth's orbit round the Sun). As such, when the Moon is at either node, eclipses occur.

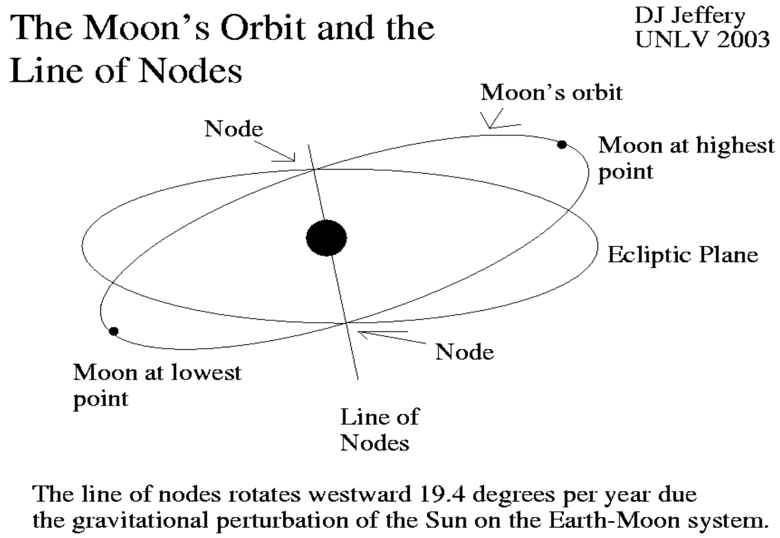

Figure 13: Moon's orbit. (University of Las Vegas Physics & Astronomy, 2003)

The Moon's path is always moving, causing the nodes, perigee and apogee to constantly change position as well. The Moon's pull on the Earth also slowly slows down our planet's rotation gradually increasing the length of a typical day on Earth; however, the lengthening of the day spans over millions of years and is negligible to our typical calendars.

The Moon's elliptical orbit causes noticeable changes in the ranges of tides across the Earth and creates visual differences in the Moon's size when positioned at the perigee and apogee. Astrophysicists have used Lunar Laser Ranging to determine the distance between Earth and the Moon. This has determined that as the Earth's rotation slows, the distance from the Moon increases.

3. So what are Lunar Ranging Measurements?

Lunar Laser Ranging (LLR) measures the distance from the Earth to the Moon. This is done by measuring the speed of laser pulses shot to retroreflectors on the Moon. The laser pulses are sent from Earth observatories. Observatories equipped to carry out the process include The McDonald Observatory in Texas, USA, the Apache Point Observatory, New Mexico, USA, and the Observatoire de la Côte d' Azur, France. The laser pulses are reflected by retroreflectors on the Moon which are reflective devices like mirrors designed to directly reflect light back to its source with little to no scattering. By measuring the time taken for the laser pulse to return, dividing it by two determines one-way travel time (T). By then incorporating the speed of light (S), the Earth-Moon distance (D) is measured by $D = S \times T$. LLR experiments can therefore uncover that the moon's orbit is elliptical and that the Earth-Moon distance increases at ~3.8 cm per year, as well as about the interior structure of the Moon, gravity effect variances, whether the equivalence principle is exact (that effects of gravity are indistinguishable from acceleration), and improve understanding of spacetime.

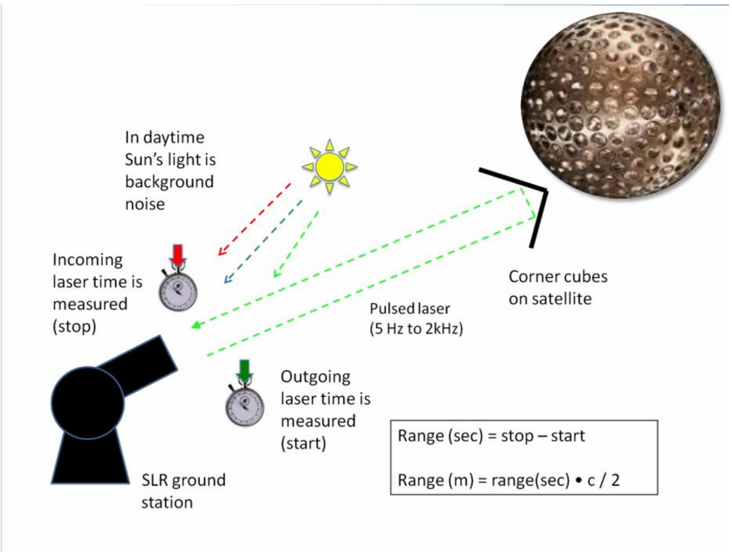

***Figure 14: Lunar Laser Ranging Artemis Era Presentation. Source:* ntrs.nasa.gov**

4. What causes the Moon's recession from the Earth?

How is the Moon getting further from the Earth each year? The Moon completes full rotation around the Earth every 27.3 days while the Earth rotates on its axis almost every 24 hours (much faster). The Moon's pull on the Earth's oceans creates tidal bulges and with the Earth rotating faster than the Moon's orbit, the tidal bulges and the object creating the bulges become misaligned which generates friction between the Earth and the Moon, slowing the Earth's rotation and pushing the Moon into a wider orbit of ~3.8 cm per year. Respectively, there are called Tidal Acceleration and Lunar Recession.

5. Who discovered the Lunar Recession?

The theories of Lunar Recession and Tidal Acceleration were developed by many astronomers over the last few hundred years. In 1786, Pierre-Simon Laplace crafted an analysis theorising the Moon's orbit would accelerate due to changes of the Earth's orbit around the

Sun, seemingly answering why the Moon's orbit changed over thousands of years, however in 1854, John Couch Adams discovered an error in Laplace's calculations, determining that the Moon's acceleration could not solely be attributed to the Earth's orbit. During the 1860s, C.E. Delaunay and William Ferrel suggested the slowing of the Earth's rotation made the Earth's days longer and caused Lunar Acceleration. This theory can be seen in our modern knowledge of Lunar Recession, but ultimately, the certainty of the Moon's recession and the Earth's rotation cannot be attributed to one person.

6. What happens when the Moon is gone?

If the moon were to disappear, the effects on the Earth would be astronomical. The Earth's tilt would fluctuate constantly, causing severe changes between the seasons; tides would decrease to a third of their regular size and would devastate beach and coastal ecosystems; such animals as turtles that leverage the moon for navigation after hatching would struggle to survive and such nocturnal animals as owls would not be able to see and would struggle hunting, causing drastic changes in animal ecosystems before they may die out.

But the Moon will not just vanish; as it slowly creeps away from the Earth, the friction on the Earth would decrease, causing the Moon to recess more slowly. Very slowly, the departing Moon weakens tides and allows fluctuations of the Earth's tilt over millions of years. The Moon would eventually cease its recession as the Earth would rotate at the same speed as the Moon's orbit. This would cause Earth to be tidally locked to the Moon, eliminating the positional transitions.

7. What is the risk to humans?

Currently, the Earth's orbit is slowing, and the Moon is moving away from Earth. This, however, is not as much of an issue as it may seem. The Earth's rotation slows by about 1.7 milliseconds per century, and the Moon is receding at ~3.8 cm per year. It will take 100,000 years for the Moon to recede by one kilometer and 200,000,000 years for a typical day on Earth to last 25 hours. The Moon will stop receding in about 15 billion years, but the Sun will start to become a red giant and die in about 5 billion years and life on Earth is likely to be eliminated by the Sun's evolution in merely 1.5 billion years. Conclusively, the Earth and Moon will be destroyed before the Earth could become tidally locked to the Moon.

8. Conclusion

Similarly, as Mount Everest climbers must work harder each year to reach the peak, astronauts must go further with each visit to the Moon. Although the moon is slowly moving away from the Earth, this is a natural process, resulting from the Moon's natural formation. The Moon plays a vital role in stabilising the Earth's tides and seasons and has influenced the Earth's properties for billions of years and will continue to shape Earth's history even as it distances itself. Nonetheless, life on Earth will be long gone before the Moon's influence from our Myths and Legends ever disappears.

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Osmosis, Plasmolysis, Turgidity in Red Onion Cells

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1. Introduction

Osmosis is a vital biological process that allows water molecules to move across a selectively permeable membrane from an area of high concentration to an area of low concentration (to maintain equilibrium). Plant cells rely on osmosis to maintain function and structure. Red onion epidermal cells are used in this practical due to the purple pigmentation that helps us detect the changes present in the cell. In this practical, solutions with various salt concentrations (0%, 5%, and 10%) either change the shape of the cell or make no change at all. Water moves into or out of the cells depending on the concentration gradient. In short, this investigation examines how distilled water and a concentrated salt solution affect red onion cells by causing turgidity or plasmolysis.

2. Turgidity & Isotonicity

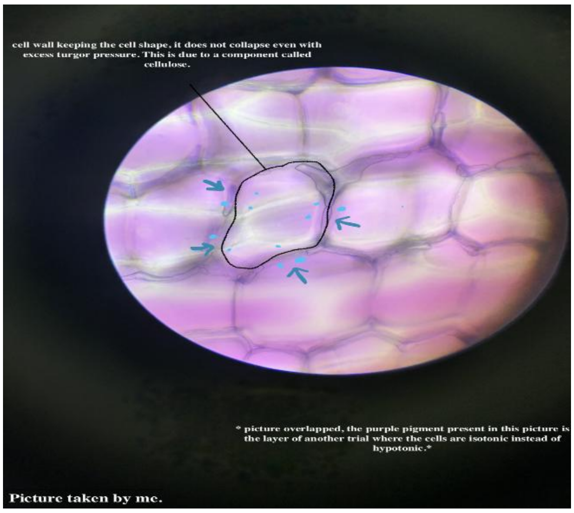
When red onion cells are placed in a solution with 0% salt concentration, the surrounding environment is hypotonic, meaning that the water molecules outside of the cell move into the cell via osmosis. This causes the cell to be more swollen and turgid. The purple vacuole inside the cell increases in size as water fills it. There is turgor pressure on the cell wall due to the increasing size of the central vacuole. The cell wall, made primarily from a component called cellulose, prevents the cell from bursting and collapsing. Under the microscope, cells appear larger in comparison to a normal red onion cell. When the salt concentration in solution increases to 5%, the protoplasm in the cell shrinks instead of expanding. The concentration of solutes outside the cell is greater than inside the cell, creating a water concentration gradient. Therefore, the water molecules move out of the cell via *osmosis* and maintain equilibrium. Due to a process called hydration, the dissolved sodium and chloride ions become surrounded by water molecules, reducing the amount of free water available outside the cell. This lowers the water potential of the solution, causing water to leave the cell by osmosis, leading to water loss inside of the cell, where the protoplasm shrinks as a response. The 5% salt solution creates a mildly hypertonic environment, causing only some water to leave the cells.

3. Plasmolysis

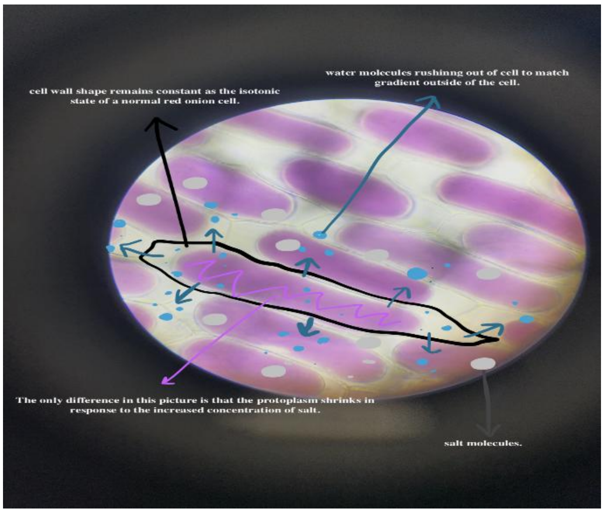
Plasmolysis describes a process involving a plant cell losing water content and therefore contracting and shrinking its cytoplasm and plasma membrane away from the inside of its cell wall. When the cells are exposed to an even more concentrated salt solution (10%), the external environment becomes hypertonic. Water moves out of the cells via osmosis because the water concentration outside the cell was lower than inside.

As water leaves the vacuole, it decreases in size and the cytoplasm contracts. Eventually, the plasma membrane pulls away from the cell wall, producing the condition of *plasmolysis*. The rigid cell wall retains its shape while the contents of the cell shrink inwards.

This observation clearly demonstrates the effect of water loss on plants and the importance of water balance through a red onion cell. As mentioned before, the dissolved sodium and chloride

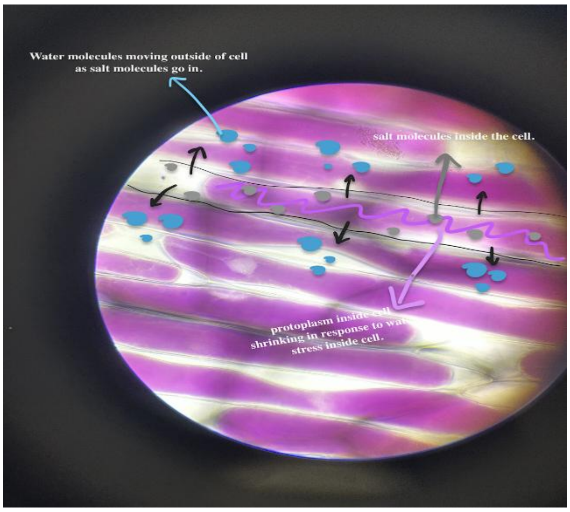


Hypotonicity (0%)



Slight-Hypertonic state (5%)

ions become surrounded by water molecules through hydration, reducing the amount of free water available outside the cell. This lowers the water potential of the solution, causing water to leave the cell by osmosis.



10% Salt Concentration, Hypertonic environment

4. Significance of the experiment

Through the investigation, it has been proved that osmosis is a beneficial process in ensuring plant survival. Turgid cells provide structural support towards stems and leaves, enabling plants to stand upright without the need for a skeletal structure. Plasmolysed cells lose water and become unable to maintain internal pressure, causing plant tissues to wilt if more cells in the plant are affected by a lack of water. Understanding that osmosis plays a key role in maintaining water balance in plants (as well as other organisms), it is essential both for crop production and for healthy plant growth. Looking at these processes within red onion cells provides a clear visual model of how water movement affects cell function.

5. Conclusion

The results show how water moves across selectively permeable membranes depending on differences in water concentration via osmosis. Red epidermal cells became turgid when placed in 0% salt concentration. As the concentration increased, cells became more plasmolysed in response to water stress in the cell. These observations confirm that osmosis is beneficial in maintaining structure, function, and survival of plant cells. To improve this practical further, an isotonic state should be observed within the cell by placing the red onion cell in the desired solution.

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Author 3 name
Author 3 affiliation, city, Country
Author 3 e-mail

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	Heading 1	**Heading 2**
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Two		
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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.

References

1. (book) A. Author, A. Author. "Book Title". City, Country: Publisher, Year.
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