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SciSpark

Igniting Ideas, Bridging Minds

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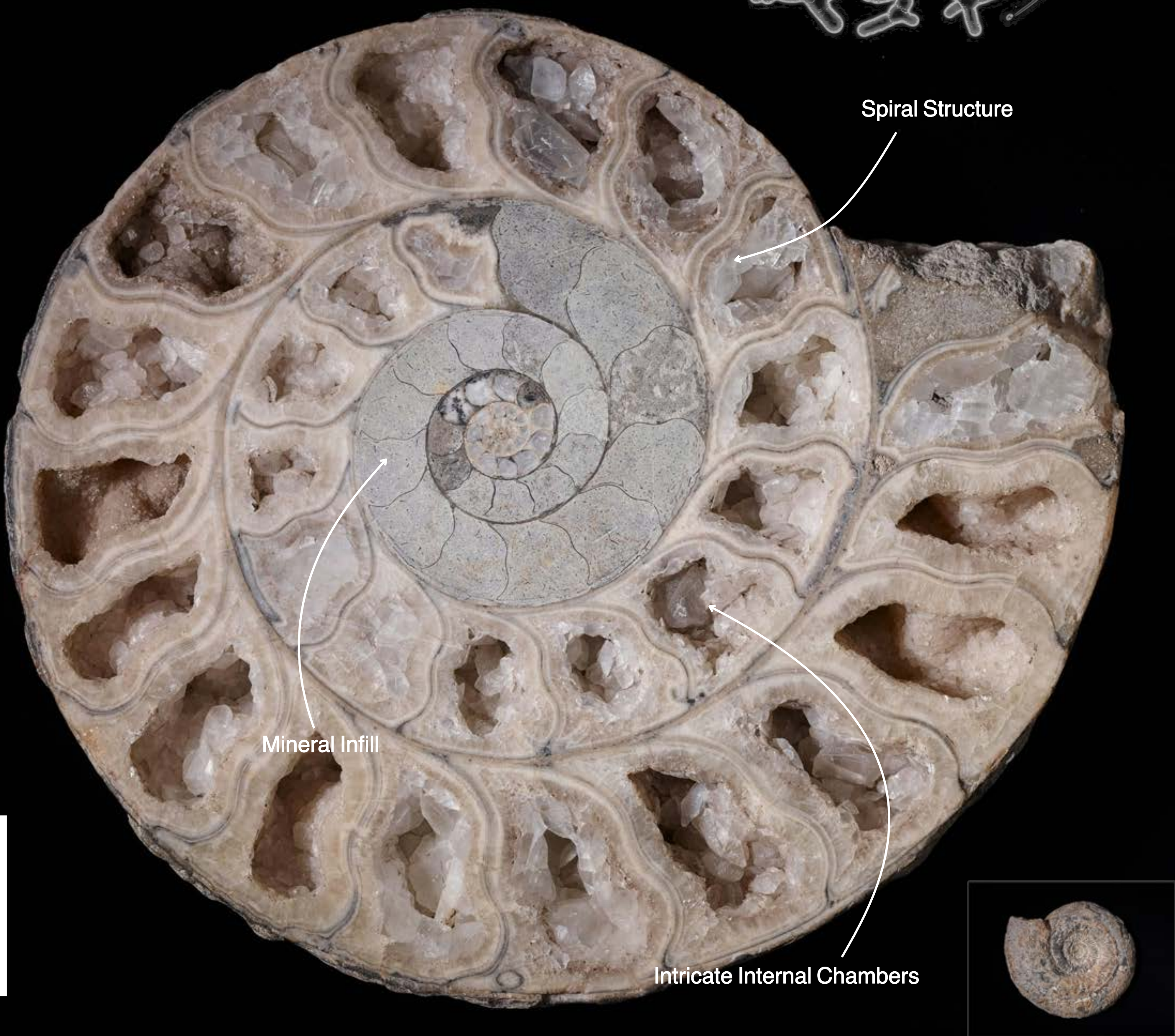

Sectioned Ammonite Fossils by Birmingham Museums Trust

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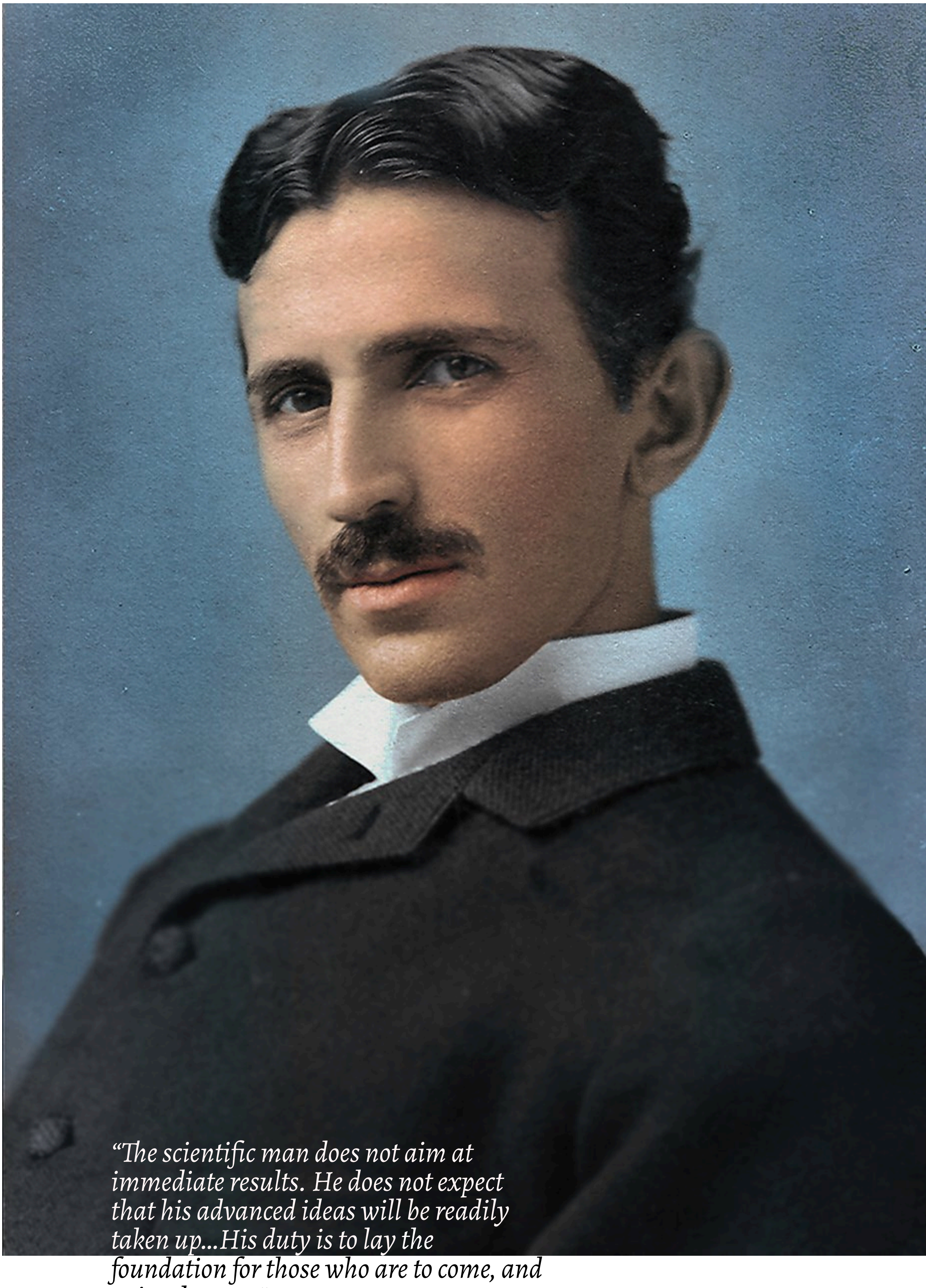
What fossils reveal about Evolution, Extinction, and Future

Ammonites, extinct marine mollusks from over 65 million years ago, leave behind intricately spiraled fossil shells that serve as a visual bridge between biology, geology, and time. Their chambered structures, often echoing the golden ratio, reveal nature's deep, mathematical patterns, uniting life, science, and the ancient Earth.



"The scientific man does not aim at immediate results. He does not expect that his advanced ideas will be readily taken up...His duty is to lay the foundation for those who are to come, and point the way."

-Nikola Tesla

EDITORIAL BOARD

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The National Institute of Fundamental Studies (NIFS) is the only research institute in Sri Lanka dedicated exclusively to fundamental research. It fosters interdisciplinary collaboration and actively supports the development of emerging scientists. The Microbial Biotechnology Research Program (MBRP) at NIFS investigates polymicrobial interactions and the underlying mechanisms of complex microbial biofilms. It also develops functional biofilms for diverse applications primarily in agriculture, ecosystems and environment, medicine, and planetary sciences, translating fundamental research into innovative, real-world solutions.

PREFACE

It is with great pride and enthusiasm that I introduce the inaugural edition of SciSpark, the official e-magazine of the Microbial Biotechnology Research Program (MBRP) at the National Institute of Fundamental Studies (NIFS). This publication embodies the spirit of scientific exploration, innovation, and teamwork within our department, with future issues set to include contributions beyond our immediate team.

SciSpark is more than a collection of articles, it is a reflection of curiosity, creativity, and commitment to making meaningful contributions to science and society. From student-led initiatives to pioneering research, every page of this magazine is a testament to the energy and excellence that drives our team.

I would like to extend my heartfelt appreciation to all the contributors, editorial team members, and supporters who made this issue possible. Your passion and dedication continue to illuminate the path forward for science and inspire the next generation of thinkers and innovators.

May this edition of SciSpark ignite new ideas, spark conversations, and remind us of the power of collaborative discoveries at a global level.

Professor Gamini Seneviratne
Advisor to SciSpark
Senior Research Professor &
Head, MBRP, NIFS, Sri Lanka.

EDITOR'S MESSAGE

It is with deep pride and excitement that I present the very first issue of SciSpark, the official magazine of the Microbial Biotechnology Research Program (MBRP) at the National Institute of Fundamental Studies (NIFS), Sri Lanka.

The idea for SciSpark grew from a simple but important need: to give our students and young scientists a platform to share their ideas, creativity, and research with a wider audience. At the same time, we wanted to bring attention to remarkable scientific work happening around the world; discoveries that deserve to be seen, discussed, and built upon.

This magazine brings together a unique mix of voices. Some articles are written by students who are taking their first steps in research. Others report on cutting-edge scientific findings by experienced researchers. Together, they reflect the energy, diversity, and depth of today's scientific landscape, and the importance of giving space to both emerging and established minds.

We hope SciSpark will grow into a global space for learning, dialogue, and inspiration. We welcome readers and contributors from around the world, because science thrives when it's shared openly, across borders and generations.

I want to thank everyone who made this issue possible, our students, authors, and editorial team. Your commitment and hard work have helped us light the first spark.

Let this be the start of something lasting, where science not only informs but also inspires; where it opens doors, connects people, and helps us care for each other and the planet we share.

Dr. Mahesh Premarathna
Editor-in-Chief of SciSpark
Research Fellow, MBRP, NIFS, Sri Lanka

CONTENT

Ammonites were marine mollusks that thrived in Earth's oceans for over 300 million years, from the Devonian to the end of the Cretaceous period. Related to modern squids and octopuses, they lived in coiled, chambered shells, using gas-filled compartments to control buoyancy and navigate ancient seas. Ammonites were incredibly diverse, occupying a wide range of ecological niches before becoming extinct around 65 million years ago, during the same mass extinction that wiped out the dinosaurs.

After their death, ammonite shells sank to the seabed, where sediment slowly buried them. Over millions of years, mineral-rich water seeped into the chambers, replacing the organic material with crystals like calcite or quartz, while preserving the shell's intricate internal structure. This natural process, called fossilization, transformed the once-living organism into stone.

The resulting fossil reveals a spiral shell divided into repeating chambers, forming a logarithmic spiral a near-perfect example of the golden ratio in nature. This proportion, common in plants, galaxies, and weather systems, reflects nature's mathematical efficiency and balance.

Ammonite fossils are not just relics of ancient life; they represent a bridge between biology, geology, and mathematics. Their structure encodes evolutionary innovation, natural symmetry, and the passage of deep time a hidden story written in stone, linking life's past to the language of science.

This same geometric principle echoes across scales, from the arrangement of sunflower seeds to the arms of galaxies, revealing a mathematical harmony woven into life's architecture. Beyond their scientific value, their spirals carry a philosophical resonance, symbols of continuity, transformation, and the interconnectedness of all things , reminding us that the patterns shaping a humble shell are the same that govern the cosmos

Inducing Natural Intelligence in Agriculture: Artificial Intelligence Alone is Not Sufficient

REVIVING ECOSYSTEM INTELLIGENCE FOR FUTURE FARMS

By Gamini Seneviratne, Sidath Ekanayaka and Mahesh Premarathna

Artificial Intelligence (AI) is revolutionizing agriculture by enabling precision farming, which optimizes resource use and increases yields[1]. By utilizing AI-driven sensors and drones, farmers are able to observe crop health, soil conditions, and livestock in real time, which facilitates more informed decision-making[2]. These innovations enable farmers to utilize resources more effectively, cut down on waste, and lessen labor by automating crucial processes such as planting, irrigation, harvesting, and distribution. However, in our pursuit of technological advancement, we often overlook a critical, time-tested component of sustainable ecosystems, Natural Intelligence (NI), particularly in the form of microbial life.

While AI-driven tools rely on a combination of factors, primarily data, algorithms, and connectivity of observable data, NI arises from millions of years of evolutionary adaptation and symbiotic relationships. In natural ecosystems like forests, complex microbial communities have thrived without human intervention, sustaining biodiversity, resilience, and balance[3]. These microorganisms, especially when organized in soil biofilms form a living, intelligent network that governs nutrient cycling, soil structure, and plant health[4]. Soil biofilms are structured microbial communities that adhere to surfaces and to one another, forming an integral part of the rhizosphere, the zone of soil influenced by plant roots[5].

While AI-driven tools rely on a combination of factors, primarily data, algorithms, and connectivity of observable data,...In natural ecosystems like forests, complex microbial communities have thrived without human intervention, sustaining biodiversity, resilience, and balance.

These microbial biofilms serve as nature's own version of a decentralized communication and resource-sharing network. Through biochemical signaling, they facilitate cooperation among microbes and between microbes and plants[6]. They help defend against pathogens, enhance nutrient uptake, and build healthy, structured soils. This form of NI is not just passive, it's active, dynamic, and foundational to long-term ecological health.

Unfortunately, numerous contemporary farming methods, including intensive tillage, monoculture cropping, and over-reliance on chemical fertilizers and pesticides, disturb these microbial networks. This disruption compromises soil health and threatens the core principles of sustainable agriculture[7]. If Smart Agriculture is to truly progress, it must look beyond AI and begin to integrate and mimic the principles of NI found in microbial ecosystems.

Harnessing the potential of microbial biofilms presents an opportunity to align technological innovation with ecological wisdom. Promoting and sustaining healthy microbial communities through practices like reduced tillage, crop diversification, and especially the use of biofilm-based biofertilizers, i.e., BFBFs, can restore soil vitality, increase crop resilience, and reduce reliance on synthetic fertilizers, particularly by concentrating carbon, nutrients, and moisture in the root zone[8,9,10]. Achieving this on a global scale across

millions of hectares is not feasible with any other technology. Therefore, this method not only promotes regenerative agriculture but also boosts the ecological intelligence of our farming systems.

The future of agriculture is not solely dependent on advanced machinery or more intelligent algorithms. Our capacity to harmonize these tools with the inherent intelligence of natural systems is essential. By connecting AI with NI, especially using a microbial biofilm approach, we can create a more resilient, productive, and sustainable future for agriculture.

Microbial Biotechnology Research Program, National Institute of Fundamental Studies, Kandy 20000, Sri Lanka.

Let Us Keep Our Loved Ones Forever

ECHOES BEYOND GOODBYE: MINDS THAT ENDURE WHISPERING WISDOM

By Sidath Ekanayake

Imagine a future where saying goodbye to a loved one no longer means permanent silence. We may soon record a person's inner life just as we record music, capturing not only their voice and stories but also the very patterns of their thoughts and feelings. Already, early experiments conducted at the University of Colorado (USC) in 2019 hint at this possibility: a grieving mother donned a VR headset and spent 10 minutes "reuniting" with an AI reconstruction of her late daughter, and a son turned his dying father's life story into an interactive "Dadbot" avatar[1,2]. These emotional reunions were more than gimmicks - neuroscientists now speak of "generative ghosts" (AI avatars built from a person's data) that can remember, plan and even evolve[1]. The vision is breathtaking: an AI-driven hologram of grandma telling stories to her grandchildren, offering comfort and wisdom long after she's gone.

In moments of doubt or grief, you'd converse with a digital avatar that understands you, offering tailored guidance and heartfelt comfort. Children of the future could meet their ancestors, asking about family lore or seeking perspectives on careers that didn't even exist in the last century. Knowledge, wisdom, and love would flow across generations, unbroken by the finality of death.

State of the Art Implant

The first step toward this digital afterlife is building better brain–computer interfaces (BCIs). In recent years, pioneering companies have begun implanting sensors into human brains and blood vessels to read neural signals. For example, Neuralink announced its first human implant in early 2024 (the "Telepathy" N1 chip)[3]. Paralysis patients with these implants can already move cursors and type by sheer thought. Other startups are racing ahead too. Synchron's Stentrode is a tiny electrode array threaded through the jugular vein into the motor cortex; trials show it can safely let paralyzed users send texts and control devices hands-free, with *no skull drilling required*[4]. Paradromics just completed the first human use of its high-bandwidth Connexus implant[5]. That device can record from hundreds of individual neurons at once and uses onboard AI to translate raw brain chatter into commands[5]. Meanwhile, Precision Neuroscience's hair-thin Layer 7 array (FDA-cleared for short-term use) packs an astounding 1,024 electrodes into a flexible strip thinner than a human hair[6]. With more electrodes and wireless links than ever, these devices are already turning thought-patterns into bits of information we can analyze or replay.

Listening to Emotions and Memories

Even non-invasive tools like EEG and fNIRS (functional near-infrared spectroscopy) are getting much smarter at decoding the mind's signals. Affective computing researchers have created public datasets (like DEAP and SEED) in which volunteers watch emotional videos or music clips while their EEG is recorded[7]. Machine-learning classifiers trained on this data can distinguish basic feelings – happy vs. sad, excited vs. calm - well above chance[7,8]. For instance, one study showed that a classifier could tell apart happy, sad, fearful or angry states from EEG with ~71% accuracy, and even fNIRS recordings (measuring blood flow) gave ~64% accuracy[8]. Other teams are pushing further: at UT Austin, researchers trained a transformer model (a GPT-like AI) on fMRI brain-scan data to decode full sentences from a subject listening to podcasts[9]. In tests, this "semantic decoder" often captured the gist of what a person heard: about half the time it produced text that matched the intended meaning of the speaker[9]. In short, the brain's electrical patterns do carry rich information about our thoughts and feelings, and modern AI can begin to untangle them.

"Keep" Our Loved Ones Forever

If we can record and interpret those neural patterns, the next step is reconstructing the mind. Neurologists are already experimenting with devices that repair memory pathways by mimicking our brain's code[10,11]. In USC labs, teams led by Ted Berger and Dong Song have built a hippocampal "prosthesis" that reads neural activity from one brain region and writes a restored signal to another. As Song explains, the implant uses a predictive model "to fix that broken part" of a damaged memory circuit, so that "the memory is all the patient's own memory"[10]. In trials, patients showed 35–37% improvements in recall when the device replayed their own[11]. Looking ahead, we can envision using similar methods to capture personal knowledge and decision-making styles. A full AI model could be trained on the unique neural data, combining with the loved ones' memories, language patterns and emotional quirks. Researchers envision people creating custom AI "agents" from exactly this kind of data[1]. These agents, the so-called generative ghosts, wouldn't just regurgitate old recordings. They could converse with you about events that occur after your loved ones' death, create new stories or advice in their own style, or share the wisdom they have gained in life[1]. It's not pure fantasy, several companies (and even grieving families) are already making prototype "afterlife" avatars by feeding an AI with a person's texts, voice clips and photos[1,2]. In future, the data could come straight from their brain, producing a holographic mentor who still feels like your loved one.

Once this neural archive is trained into an AI model, the possibilities become profound. No cumbersome robotics, no uncanny valley, just a gently glowing hologram and a voice that feels undeniably familiar. In moments of doubt or grief, you'd converse with a digital avatar that understands you, offering tailored guidance and heartfelt comfort. Children of the future could meet their ancestors, asking about family lore or seeking perspectives on careers that didn't even exist in the last century. Knowledge, wisdom, and love would flow across generations, unbroken by the finality of death. Beyond personal solace, this technology heralds a new era of collective memory and expertise. Imagine consulting the holographic projection of a beloved mentor in climate science, gleaning insights from decades of research long after their laboratory has closed. Cultural custodians could preserve the rhythms of vanished dialects, or elderly artists might continue teaching their craft through living digital workshops. Even therapists could integrate these compassionate presences into treatment, offering patients a tangible source of strength when human support feels out of reach.

Ethical Horizons

Of course, even as we edge toward this digital immortality, ethical issues loom large. Who owns the data of these minds, and who can say how it's used? Advocates warn that we must enshrine the "privacy of thought" and protect cognitive liberty, the right to control our own neural data, as neurotechnology evolves[12]. In addition, recreating a person's consciousness raises deep questions of identity and consent (after all, an AI grandma might comfort us, but is it really grandma?). Prominent ethicists note that AI avatars for the dead already spark tough debate about consent, grief and digital identity[1]. Ultimately, science may outpace our laws. However, if done thoughtfully, this technology could let us preserve the essence of someone, a voice or a mind, long after their body fades. In that sense, these mind-upload dreams might one day help the living feel that we are never truly alone, even in death.

Microbial Biotechnology Research Program, National Institute of Fundamental Studies, Kandy 20000, Sri Lanka.

Unseen but Alive: The Mystery of Viable but Non-Culturable Microbes

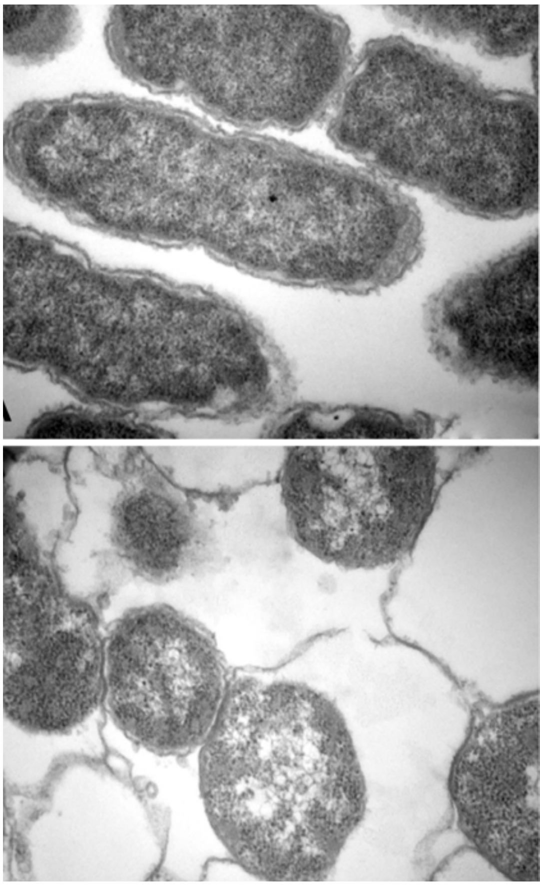
WHISPERS OF LIFE IN SILENCE, HIDDEN IN PLAIN SIGHT, NATURE'S QUIETEST SURVIVAL ARTISTS

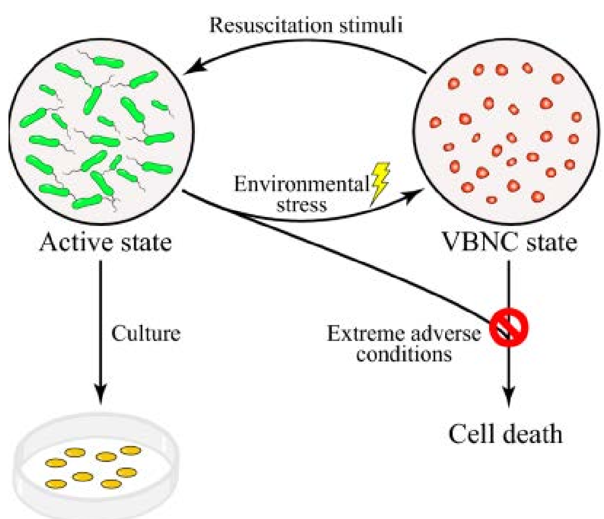
By Prashansani Jayasinghe

Imagine a scenario regarding microbes that are alive but show low levels of metabolic activity and, as a result of that, they are unable to culture under normal laboratory settings, which is known as a viable but non-culturable condition, commonly known as "VBNC". This state is similar to a hibernation or a medical coma condition that occurs due to starvation in humans. In such a condition, the entire biological workflow of the fascinating microbes gets disturbed. Their ATP production gets drastically reduced, respiratory processes as well as protein synthesis become very low during that state[1]. It's pathetic, isn't it? Its' strikingly parallel to the anemia condition in humans in case of nutrient deficiency. The condition may surprise you, because both the humans and microbes show similar behavior when they face starvation, but the underlying genetic mechanisms corresponding to both types may differ.

As their name suggests, these tiny microbes are unable to culture under normal laboratory conditions, but why? That's the mystery behind them. This wonderful condition was first reported in 1982[2]. It is currently recognized as a common survival mechanism used by microbes to tolerate environmental stresses during their survival[3]. Nature is marvelous that these invisible creatures have the ability to exist in soil, water, food, and even in clinical samples.

VBNC cells are live, but do not form colonies upon conventional culture media...Many pathogens retain infectivity and virulence in their VBNC state...This complicates food safety and public health surveillance,...Therefore, it is essential to understand the mystery behind VBNC microbes for the betterment of life on the earth.





Everything in this universe is not permanent, but these "VBNC" microbes can regain their culturability when the conditions become favorable, which is also known as "resuscitation". This is similar to the condition of humans, when they recover from illnesses after they receive proper treatment for their disease.

You might have the question regarding "What makes VBNC cells unique?". As I mentioned previously, the VBNC cells are live, but do not form colonies upon conventional culture media. They are different from persister cells because persister cells are dormant but culturable. The VBNC cells are capable of resuscitation when the conditions become favorable.

What Triggers the VBNC State?

The chemical and environmental stressors can lead bacteria into VBNC mode. They can be the disinfectants, shifts in temperature such as heat or cold shock, starvation of nutrients, osmotic pressure, and chemical exposure are mainly responsible for triggering VBNC state[4].

Inside the VBNC Cell: What Changes?

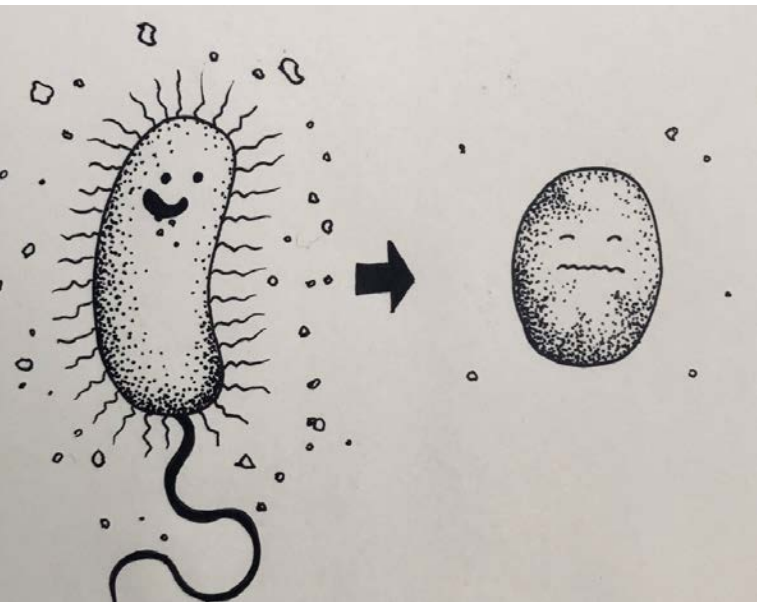
The VBNC bacteria undergo major transformations. During this stage, the microbes change their morphology by shrinkage and thickening the cell wall[5]. Not only that, it was observed that the microbes perform gene regulation by upregulating stress genes such as RpoS and EnvZ and altering their metabolism by reducing protein synthesis[6]. These mechanisms aid the bacteria to "hibernate" until the environment becomes favorable again.

The Hidden Danger: Virulence of VBNC Cells

Many pathogens retain infectivity and virulence in their VBNC state[4]. Once inside a host or a favorable niche, they can resuscitate and cause disease. This complicates food safety and public health surveillance, since standard detection techniques fail to identify them.

Detecting the Undetectable: Methods to Identify VBNC Bacteria

Everything in the universe has been generated because of a specific reason. Similarly, VBNC cells also formed to survive under stressful conditions. But how can we detect them? The question arises here. There should be alternative ways to detect these marvelous microbes. Yes, indeed, there are specific techniques. There are fluorescent staining methods and advanced molecular tools to detect cell differentiation and target VBNC cells, respectively[7].



Additionally, a new method using Raman Spectroscopy can be used to measure single-cell level metabolic activity[8]. The biomarker detection identifies VBNC bacteria using specific proteins or lipids[9].

Reviving the Invisible: Resuscitation

The VBNC cells can return to normal cells under favorable conditions. According to a study published in 2019 in the International Journal of Scientific Research and Reviews, it was suggested that, since these microbes are able to regain the culturability in the presence of favorable conditions, they can also be named as "viable but yet culturable microbes" too[10]. The nutrient addition, temperature upshift, Rpf proteins, and Quorum sensing (QS) molecules play a key role during the resuscitation process[11].

Real-world risks: Why VBNC microbes Matter

The VBNC pathogens in healthcare of patients can lead to false-negative diagnoses. In the food industry, the clean food may contain VBNC bacteria that resuscitate post-ingestion. Also, in the environment, the wastewater treatments might fail to kill VBNC cells, leading to contamination.

Therefore, it is essential to understand the mystery behind VBNC microbes for the betterment of life on Earth.

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Zombie Microbes and Mind-Control Parasites: When Microbes Turn Monster

INVISIBLE FORCES SHAPE ANIMAL BEHAVIOR

By Ravidu Pathirana

Imagine hiking in a tropical forest and spotting an ant locked in a death grip on the underside of a leaf. It's not movie magic; this is a real-life "zombie ant". A parasitic fungus (*Ophiocordyceps unilateralis*) has infected the ant and taken over its behavior[1]. As the infection advances, the ant is compelled to climb about 10 inches up vegetation, bite into a leaf vein, and die[1]. Days later, a spindly orange stalk of fungus erupts from the ant's head, broadcasting spores to infect other ants[1]. In effect, the fungus has turned the ant into its unwitting carrier; the ant's body becomes a living launchpad for fungal reproduction[1]. This eerie scene sounds like science fiction, but it's a cleverly evolved survival strategy of the fungus. Interestingly, *Ophiocordyceps unilateralis* shares an evolutionary lineage with the genus Cordyceps, to which it was once taxonomically assigned.

The Cordyceps story is only the opening act. Infected ants move almost normally at first a hidden incubation period, so their colony won't notice something's wrong[1]. Only when it's time to die does the fungus "flip the switch". Interestingly, researchers found that the fungus does not actually grow in the ant's brain.

Instead, it likely secretes mind-altering chemicals that hijack the ant's muscles and force the jaw to clamp shut in a "death grip"[1]. In short, Cordyceps "mind-control" doesn't involve brain invasion like in horror movies, but rather a biochemical takeover from within the ant's body. Only a few ants in a colony get infected at a time (keeping the ant population viable), so the fungus acts more like a chronic parasite than an army of zombies[1]. Scientists have now identified over 200 related Cordyceps species that infect many insects (and even spiders), each with its own grotesque manipulation tricks.

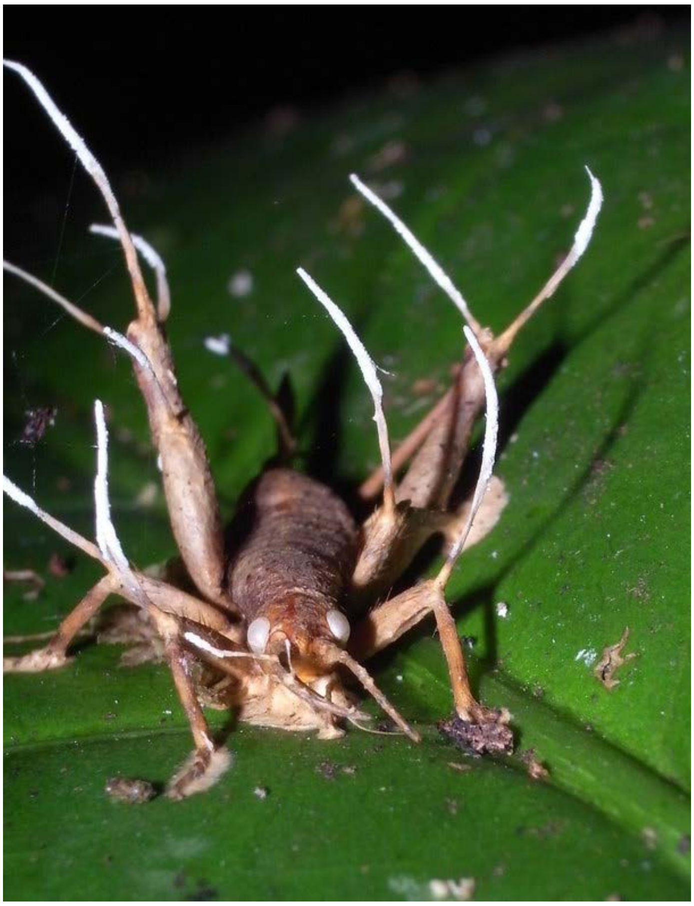
This phenomenon isn't limited to insects. A famous example in mammals is *Toxoplasma gondii*, a single-celled parasite carried by cats. *Toxoplasma* can infect rodents (and even humans), but it can only reproduce sexually in a cat's gut. To complete its life cycle, it helps if an infected mouse or rat gets eaten by a cat. Amazingly, *Toxoplasma* makes rodents lose their fear of cat smells[2,3]. Infected rats will even become attracted to cat urine instead of running from it[3]. In effect, the parasite knocks out the rodent's instinctive fear of cats. Researchers say this adaptive trick likely raises the chances that the mouse gets eaten by a cat, which is exactly where the parasite needs to be[2,3]. In fact, experiments have shown that mice infected with *Toxoplasma* no longer avoid cat urine long after the parasite has been cleared from their brains[2]. This is another example of a microbe acting like a puppeteer: by rewiring the mouse's brain, *Toxoplasma* drives behavior that benefits its own life cycle.

Many brain or behavior manipulating parasites produce powerful neurochemicals that mimic or alter their host's hormones and neurotransmitters. In some cases, they exploit normal behavioral circuits at the wrong time...As researchers say, it's a bio-neurological puzzle these parasites push their hosts to behave in ways that benefit the parasite, even if it means the host's death.

Across the animal kingdom, similar macabre strategies have evolved. For instance, the parasitic flatworm *Leucochloridium paradoxum* turns snails into flashing "bug lollipops". It grows inside a forest snail and inflates the snail's eyestalks into bright, wiggling green-and-black bands[4]. These pulsating bands mimic the appearance of caterpillars, tricking birds into thinking they're tasty prey. Infected snails are also driven to crawl into daylight, making their candy-colored, worm-filled eyestalks even more visible to hungry predators. When a bird pecks the snail and eats it (thinking it's a caterpillar), the worm jumps to the bird and continues its life cycle[4]. Other parasites use even more complex manipulation: one species of parasitic wasp lays an egg on a spider's abdomen, and when the wasp larva is ready to pupate, it manipulates the spider to spin an unusual "mummy web" optimized to hold the wasp's cocoon[4]. The spider, now zombie-like, builds a perfect chamber for the hungry wasp's pupa instead of its normal orb. Remarkably, even viruses can behave like tiny puppet masters: the rabies virus makes its mammalian hosts aggressive and froth at the mouth spreading the virus by biting and malaria parasites make infected people smell more attractive to mosquitoes, increasing the chances of transmission[4].

How Do They Do It?

Usually through biochemistry. Many brain or behavior manipulating parasites produce powerful neurochemicals that mimic or alter their host's hormones and neurotransmitters[4]. In some cases, they exploit normal behavioral circuits at the wrong time. As Harvard researcher David Hughes notes, parasites often "co-opt a preexisting behavior" in the host[4]. For example, ant mandible locking is a normal behavior, but Cordyceps makes it happen at death. Scientists have observed that fungal parasites like Cordyceps don't grow through the host brain, instead, they infiltrate muscles and likely secrete compounds that force specific actions[1]. Others have found parasite genes that produce dopamine or other signaling molecules, hinting at the chemical "language" of control[4]. Despite advances in genomics and neurobiology, we still know surprisingly little about the exact mechanisms of mind control. As researchers say, it's a bio-neurological puzzle these parasites push their hosts to behave in ways that benefit the parasite, even if it means the host's death[4].



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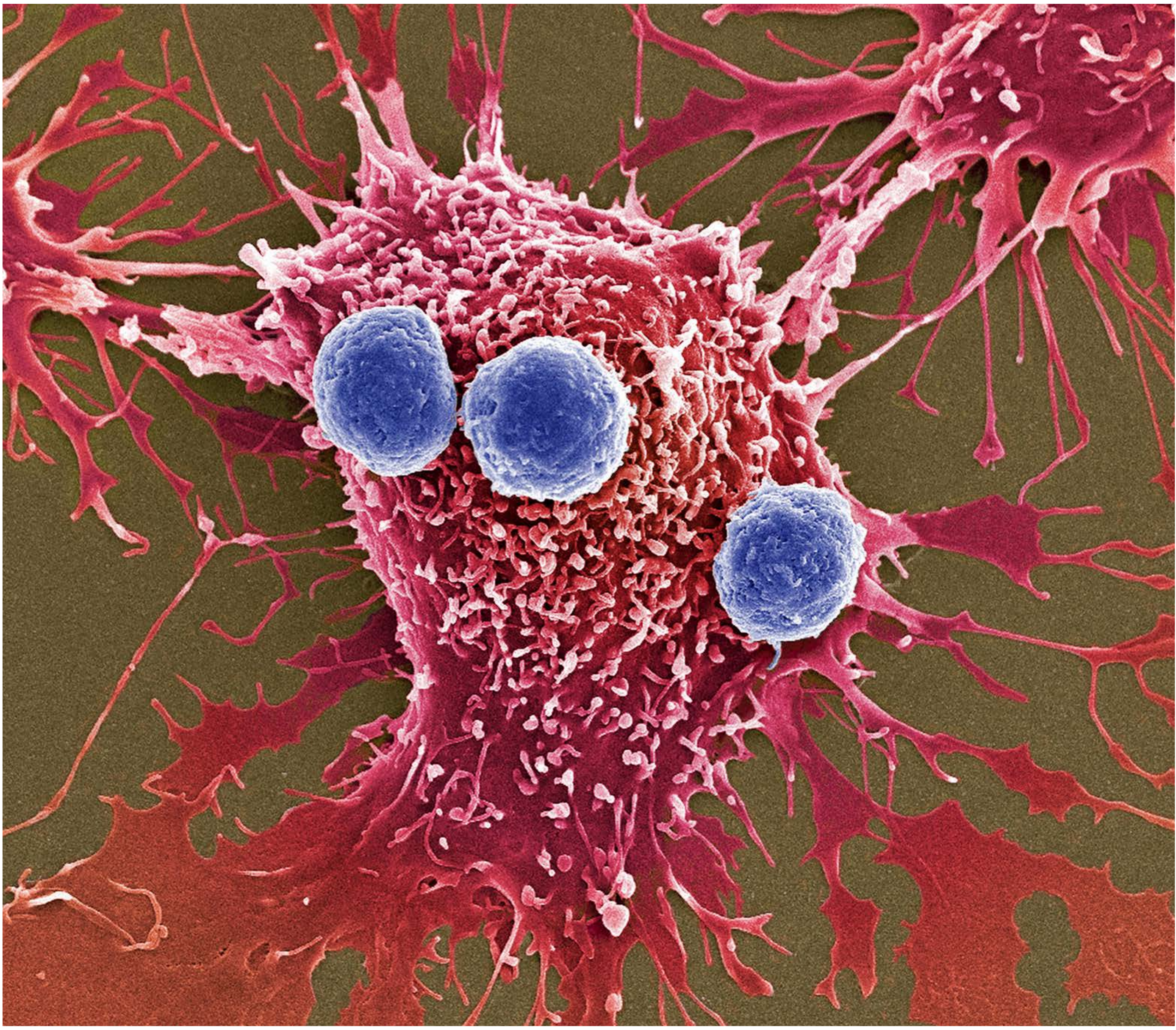
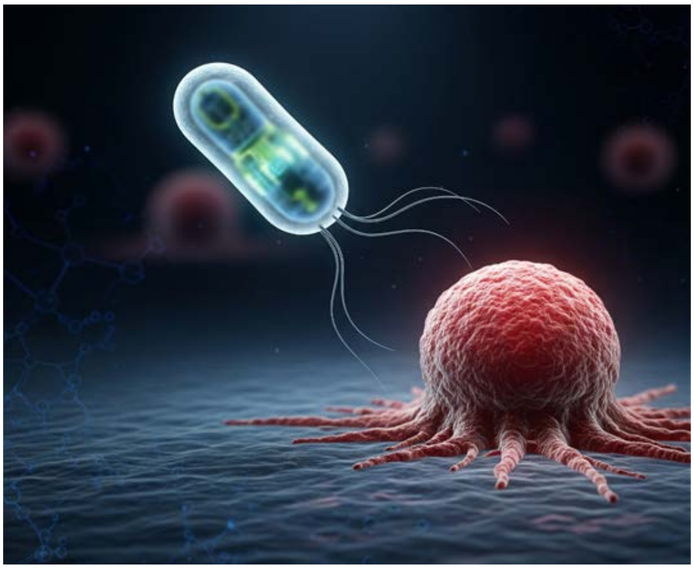


From Tumor Inducing Bacteria to Tumor Fighting Vectors: The Microbial Revolution in Cancer Therapy

FROM TUMOR CAUSERS TO CANCER KILLERS

By Umendra Jayasundara[1,2] & Mahesh Premarathna[1]

Picture a small soil bacterium that is capable of injecting a piece of its own DNA into a plant cell, taking over the cell machinery to form a tumor. Such is the activity of *Agrobacterium tumefaciens*, a plant pathogen that causes "crown gall disease" in numerous plants[1]. Yet, this bacterium's special talent for rewriting plant genetics once created agricultural problems, it's currently motivating researchers to consider how bacteria could be utilized to combat one of humanity's deadliest foes: cancer.



Nature's Genetic Engineer

Agrobacterium tumefaciens is often called nature's genetic engineer[2]. When a plant is wounded, the bacterium detects chemical signals and attaches itself to the damaged cells. It then transfers a specific segment of DNA, known as Transfer DNA (T-DNA), from its own plasmid directly into the plant's genome. This T-DNA encodes genes that trigger uncontrolled growth and production of plant hormones, causing tumors called crown galls. Remarkably, this trans-kingdom gene transfer, from bacteria to plants, has been harnessed for decades to create genetically modified crops.

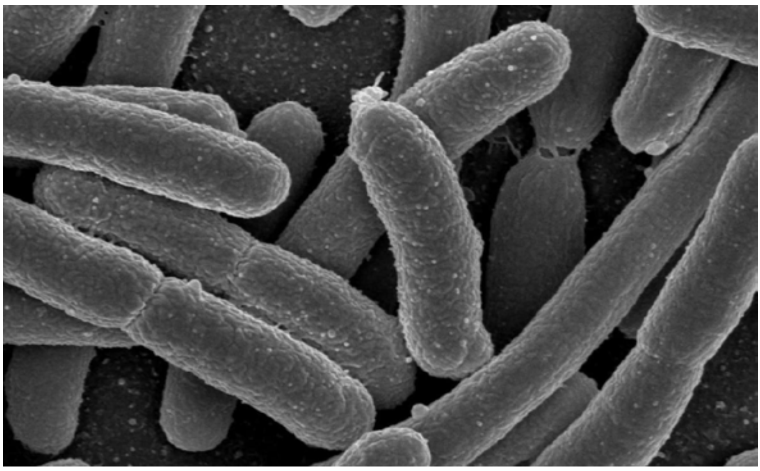
How bacteria could be utilized to combat one of humanity's deadliest foes: cancer…This strategy, often referred to as bactofection, which involves arming bacteria with mammalian-expression plasmids that carry therapeutic payloads…Bacteria, once feared as threats, may soon be among our most reliable allies in detecting, preventing, and curing human disease.

But could this remarkable natural mechanism teach us how to tackle tumors in animals and humans?

Bacteria as Vectors in Cancer Therapy: The Big Picture

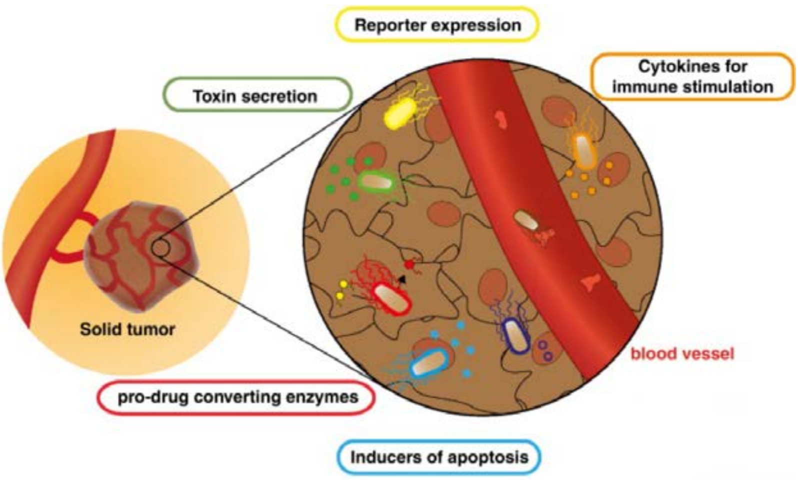
The idea that a bacterium like *Agrobacterium tumefaciens* can transfer its own DNA into another organism's genome isn't just a plant pathology marvel; it's a molecular gateway into the future of gene-based medicine. Though *Agrobacterium* is primarily a plant pathogen, there are multiple laboratory studies have demonstrated its ability to deliver genes into certain human and animal cells under specific conditions[3,4,5]. These kinds of experiments confirm that bacterial machinery can facilitate gene transfer across kingdoms. But the practical challenges, such as immune rejection, delivery inefficiency, and safety concerns, prevent the *Agrobacterium* from becoming a direct gene therapy vector in human medicine.

Nonetheless, *Agrobacterium's* DNA transfer system remains a powerful proof of concept, which shows that bacteria can serve as genetic couriers. This foundational idea has inspired researchers to explore how other bacteria, especially those more compatible with human biology, might be engineered to do what *Agrobacterium* does inside the



plants, by inserting therapeutic DNA to alter cell behavior. But, at this moment, the attention of tumors has moved on towards the organisms that have naturally localized tumors. These organisms, often thriving in low-oxygen environments where immune surveillance is weaker, are being reprogrammed as living vectors to deliver cancer fighting genes directly into tumor tissue.

This strategy, often referred to as **bactofection**, which involves arming bacteria with mammalian-expression plasmids that carry therapeutic payloads[6]. When these bacteria enter to the body, they travel to the tumor site, invade cancer cells, or die, then release their genetic material to uptake by host tissues. Among the pioneers in this space are attenuated strains of *Salmonella typhimurium*, which can home in on tumors and release immune-stimulating chemicals like cytokines or enzymes that activate prodrugs[6]. Similarly, *Listeria monocytogenes*, known for its ability to escape cellular compartments and spread intracellularly, has been re-engineered to deliver therapeutic DNA or cancer antigens[7]. Even the *Escherichia coli*, when equipped with invasion-promoting proteins and phagosomal escape tools like listeriolysin, has shown the capacity to deliver genes to human epithelial cells, with some systems being explored for oral delivery in gut-related conditions[8,9,10].



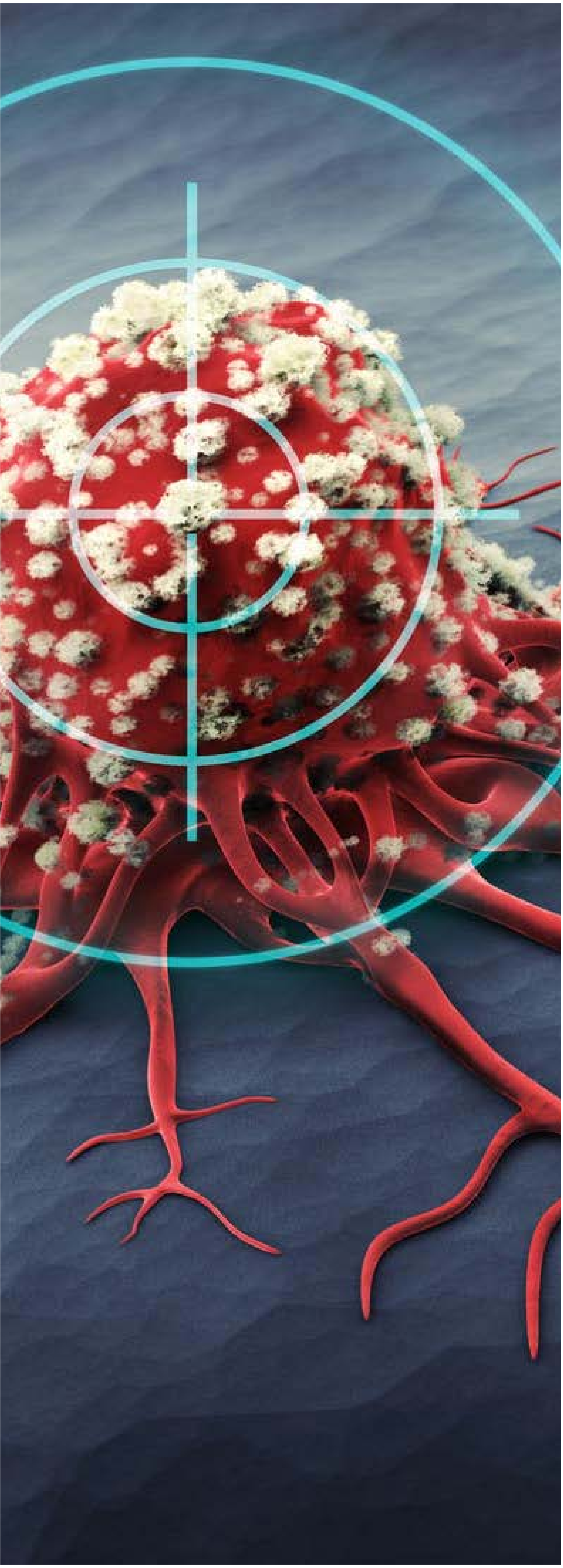
Meanwhile, the obligate anaerobes like *Clostridium novyi-NT* and *C. sporogenes* offer another promising route. These bacteria germinate exclusively within the necrotic centers of tumors, where they have been modified to express prodrug-converting enzymes and immune regulators, minimizing "off-target" effects[11]. In parallel, commensal anaerobes like *Bifidobacterium longum* have been shown to selectively colonize in tumors and they express therapeutic genes *in vivo*[12]. When the rise of synthetic biology, these kind of microbial systems can now be fine-tuned with genetic circuits, safety switches, and tumor-specific promoters to ensure that gene delivery is tightly controlled.

Bacterial Biosensors for Cancer Screening

In addition to therapy, researchers are now engineering bacteria as diagnostic tools. These microbial biosensors are capable of detecting tumor-specific DNA or metabolic markers and responding by producing detectable signals. One such system, involving *Acinetobacter baylyi*, was designed to detect mutant Kristen Murine Sarcoma Virus2 homolog (KRAS) DNA shed into the gut by colorectal tumors. Upon detecting the cancer-specific DNA, the bacteria activated a genetic switch to report the presence of a tumor. Such innovations suggest a future where a capsule of engineered bacteria could both diagnose and initiate treatment in a single pass through the digestive system[13].

Gene Delivery for Other Diseases

Not only for the cancer treatments, but also the potential of bacterial gene delivery extends well beyond oncology. In models of cystic fibrosis, modified strains of *Listeria* and *E. coli* have successfully delivered the Cystic Fibrosis Transmembrane Conductance Regulator (CFTR) gene to airway epithelial cells, showing promising restoration of function. For inflammatory bowel disease, the researchers engineered *E. coli* carrying plasmids for anti-inflammatory proteins like TGF-β1 have been administered orally to mice, reducing inflammation by acting directly on the gut mucosa. In parallel, there are some similar approaches under investigation for autoimmune disorders and metabolic diseases, where localized or systemic delivery of corrective genes could restore physiological balance[6,10].



The Challenges Ahead

But still, the bacterial vector treatments pose many challenges. Foremost is safety; injecting live bacteria into patients comes with the risk of infection or off-target immune responses. It is another challenge to make the bacteria target only tumors and not normal tissues. Finally, efficient delivery of genes and maintaining therapeutic effects over time without toxicity is a delicate balancing act.

Still, clinical trials are underway. For example, attenuated *Salmonella* strains have been tested in patients with advanced cancers[14,15], and spores of *Clostridium novyi* have shown tumor-shrinking effects[16,17]. While the results are preliminary, they offer hope that bacterial vectors could become powerful allies in the fight against cancer.

Looking Ahead: Microbial Symbiosis and Smart Therapies

The next frontier lies in transforming engineered microbes from mere delivery tools into intelligent, symbiotic agents. These future therapeutics may live inside us as part of our microbiome and be programmed to detect molecular signs of disease and respond instantly. Also, they could adjust therapeutic outputs based on local cues, provide long-term protection, or integrate with wearable health monitoring systems. From its origin as a tumor-inducing pathogen in plants, the concept of microbial gene transfer is being reimagined as a cornerstone of precision medicine. Bacteria, once feared as threats, may soon be among our most reliable allies in detecting, preventing, and curing human disease.

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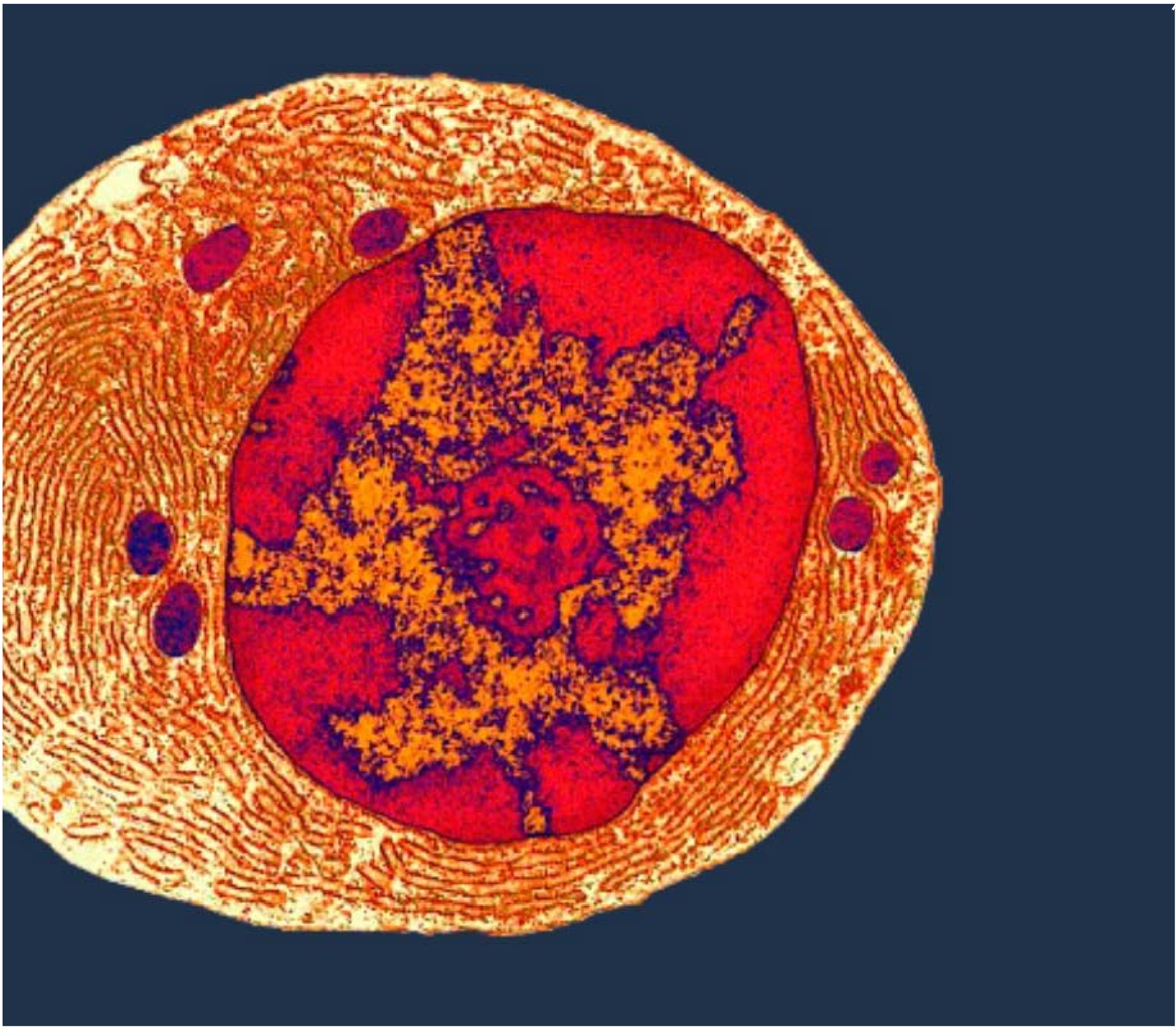


Evolution of Hemoglobin and Chlorophyll: A Molecular Journey from LUCA

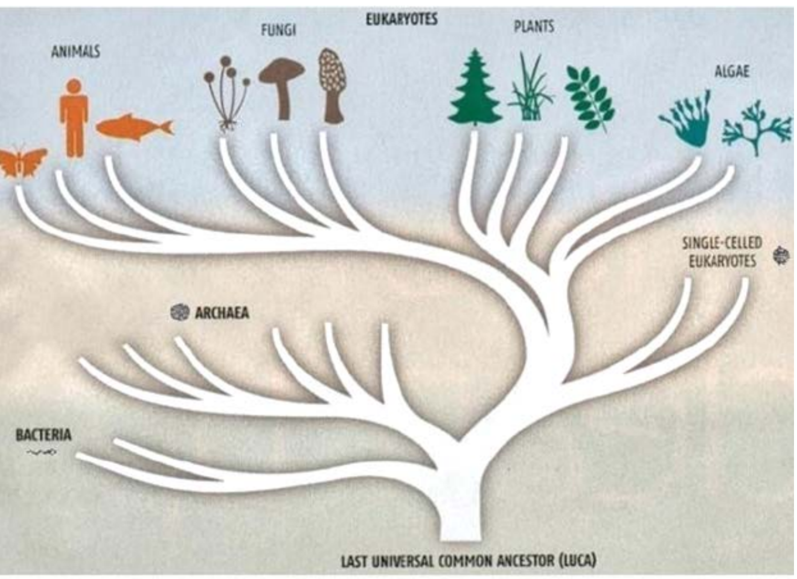
LUCA'S LEGACY: HOW A SINGLE PATHWAY GAVE RISE TO BLOOD AND GREEN

By Sajani Prathibha[1,2] & Mahesh Premarathna[1]

At first glance, hemoglobin and chlorophyll might seem like they belong to completely different worlds. Hemoglobin, a red protein containing iron, is found in animal blood and helps transport oxygen throughout the body, playing a key role in metabolism. On the other hand, chlorophyll is a green pigment in plants that captures sunlight and fuels the process of photosynthesis. Although hemoglobin and chlorophyll perform different functions in biology, they share a profound and age-old evolutionary bond in the form of a common ancestry, which is a molecular pathway that emerged right at the beginning of life on Earth.

To understand this connection, we must travel back more than 3.5 billion years to a time before plants, animals, or even complex cells existed. Life's earliest ancestor, known as the Last Universal Common Ancestor (LUCA), is believed to have been a simple organism. However, LUCA likely possessed a sophisticated set of metabolic tools, including the tetrapyrrole biosynthetic pathway. This pathway is fundamental to life today and forms the molecular foundation for the development of heme (a component of hemoglobin) and chlorophyll. The fact that this ancient biochemical machinery is still conserved across bacteria, plants, and animals speaks to its evolutionary significance[1].

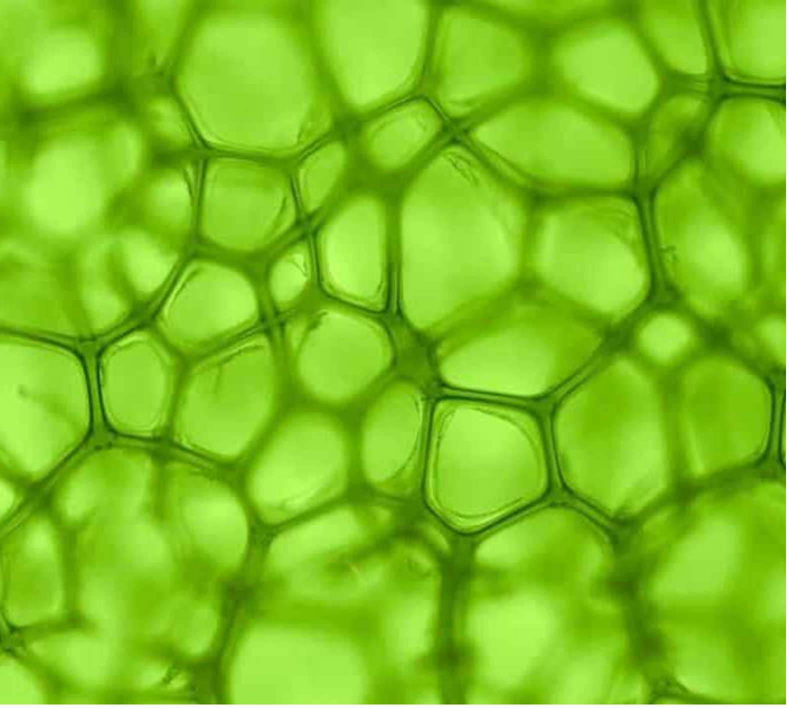
The evolutionary story of hemoglobin and chlorophyll spans billions of years...How did chlorophyll and hemoglobin evolve together? ...one carrying oxygen, the other capturing light, reflecting nature's adaptive versatility through evolution...However, both are constructed from a common tetrapyrrole ring and a shared biosynthetic pathway

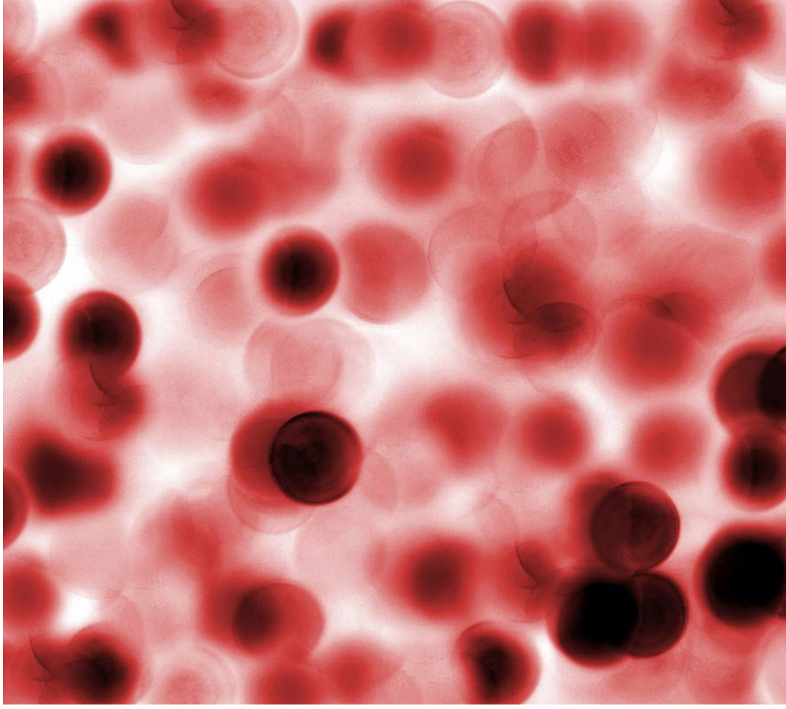


The central player in this shared evolutionary story is tetrapyrrole, a ring-shaped molecular scaffold composed of four interconnected pyrrole units. This scaffold is synthesized through a biosynthetic pathway that begins with 5-aminolevulinic acid (ALA)[2]. Through a series of enzymatic steps, ALA is converted into uroporphyrinogen III, which is then transformed into protoporphyrin IX. At this crucial branching point in evolution, the insertion of different metal ions determined two distinct biochemical destinies: the addition of iron (Fe) by the enzyme ferrochelatase led to the formation of heme, while the insertion of magnesium (Mg) via magnesium-chelatase produced chlorophyll. This single divergence, iron or magnesium, created molecules that enabled oxygen transport in animals and solar energy capture in plants, respectively[3].

The divergence at protoporphyrin IX marks one of nature's most efficient evolutionary decisions. Heme, the iron-containing product, became central to the function of hemoglobin, which emerged as an essential oxygen carrier in red blood cells. On the other hand, chlorophyll, with its magnesium core, became the main pigment driving photosynthesis, allowing autotrophs to convert light energy into chemical energy. These distinct pathways underscore how evolution can repurpose a common molecular ancestor to suit vastly different biological functions across species[4].

The evolutionary story of hemoglobin and chlorophyll spans billions of years. The earliest photosynthetic bacteria, appearing around 3.4 billion years ago, began utilizing primitive chlorophylls. Over time, cyanobacteria developed the ability to perform oxygenic photosynthesis, significantly altering Earth's atmosphere by producing free oxygen. Meanwhile, the incorporation of mitochondria and chloroplasts into eukaryotic cells allowed more complex organisms to harness both respiration and photosynthesis. The emergence of





multicellular animals, around 600 million years ago, brought hemoglobin into widespread use, especially in organisms that required efficient oxygen transport across their growing bodies. These parallel evolutionary paths, both grounded in tetrapyrrole chemistry, reflect nature's ability to adapt and innovate using shared molecular frameworks[5].

A New Scientific Vision: Converting Chlorophyll into Hemoglobin

In a daring and visionary step forward, researchers are now proposing something previously unthinkable: to reverse-engineer chlorophyll into hemoglobin not just metaphorically, but literally.

In 2024, a proposal by Israel A. Grillo (McPherson College), this idea is being brought to the laboratory bench. The goal was to synthesize functional hemoproteins like artificial hemoglobin by chemically transforming plant-based chlorophyll into a heme analog and binding it to globin proteins[6].

This isn't just an academic exercise. If successful, this transformation could redefine the boundaries of synthetic biology, paving the way for synthetic blood substitutes, bioengineered oxygen carriers, and sustainable heme production[6].

The conversion process follows a highly sophisticated path, merging organic chemistry, protein engineering, and biotechnology. To make chlorophyll more "heme-like," its phytol tail is removed and aldehyde groups are oxidized. Vinyl groups are introduced through Wittig reactions to match heme's structure. Chlorophyll's chlorin ring is oxidized into a fully conjugated porphyrin ring, mimicking the chemistry of heme using compounds.The magnesium at the center of chlorophyll is replaced with iron (Fe^{2+}) using metalation reactions thus converting it into a synthetic heme.

Globin proteins (alpha and beta chains) are expressed in *E. coli* using recombinant DNA technology. These proteins are then combined with the synthetic heme to create a functional hemoglobin analog. Spectroscopy (UV-Vis, NMR), oxygen-binding assays, and biological models are used to validate whether the new molecule truly behaves like native hemoglobin.

Implications: Synthetic Blood and Beyond

Should this groundbreaking process succeed, it could usher in an era of plant-based hemoproteins, offering solutions to medical crises such as: Blood shortages in emergency or remote situations, Synthetic oxygen carriers for high-altitude or deep-sea environments, Biocompatible heme for tissue engineering or drug delivery[6]. In addition, this approach provides an alternative, green, and sustainable method for the synthesis of intricate molecules that are usually obtained from animal or microbial sources.

"How did chlorophyll and hemoglobin evolve together?"

The case of hemoglobin and chlorophyll stands out in regard to molecular homology due to their evolutionary relationship they share, the concept that similar molecules may diverge to perform different and often unrelated functions - one carrying oxygen, the other capturing light, reflecting nature's adaptive versatility through evolution. Both molecules function in different biological contexts. However, both are constructed from a common tetrapyrrole ring and a shared biosynthetic pathway. This common lineage illustrates a fundamental idea in biology: evolution tends to adapt and modify what already exists rather than create something new. Understanding this unifying concept provides insight into the biochemical relationships that unite all beings on Earth, including the oxygen we breathe, the blood in our bodies, and the energy-rich food we consume.

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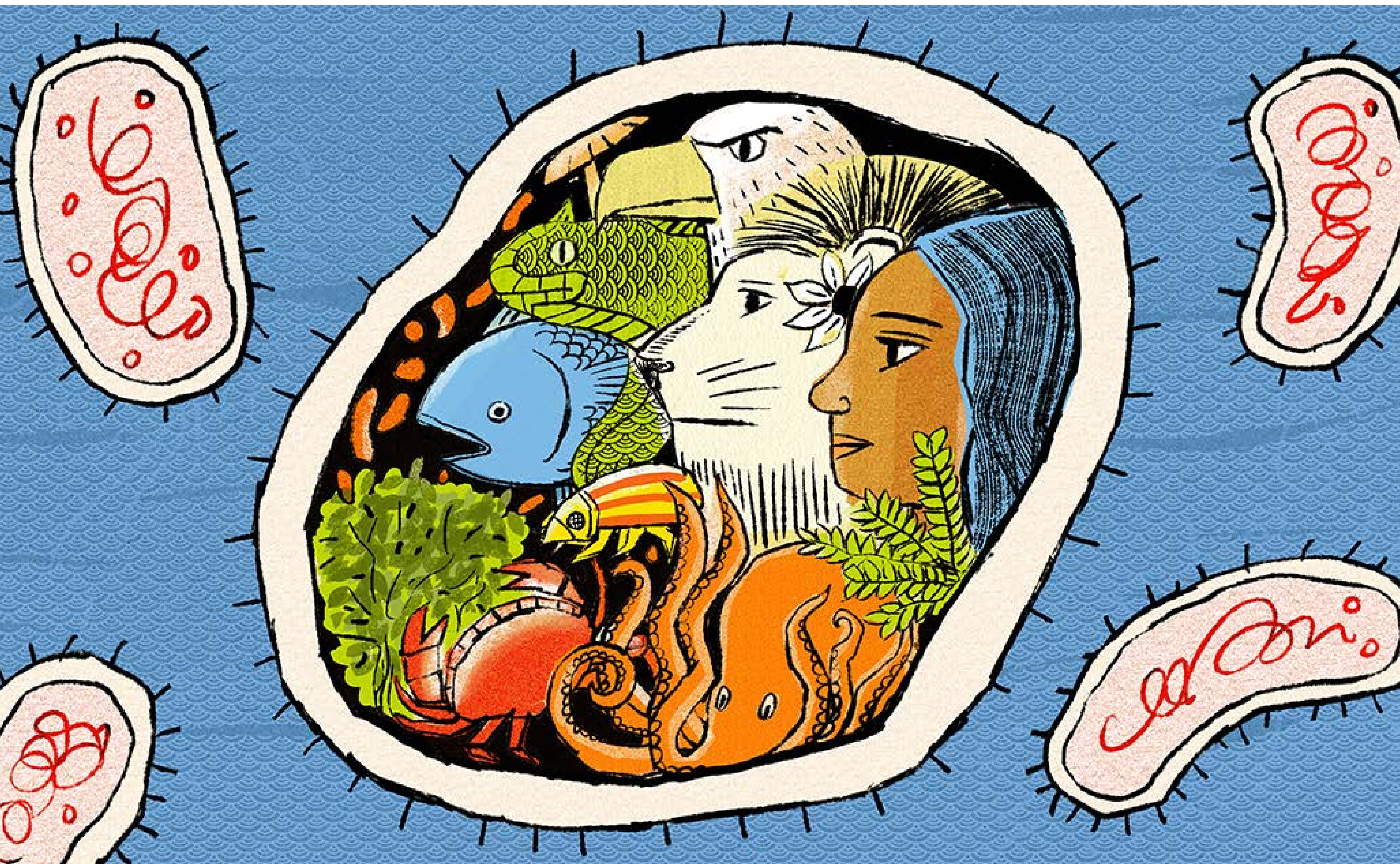
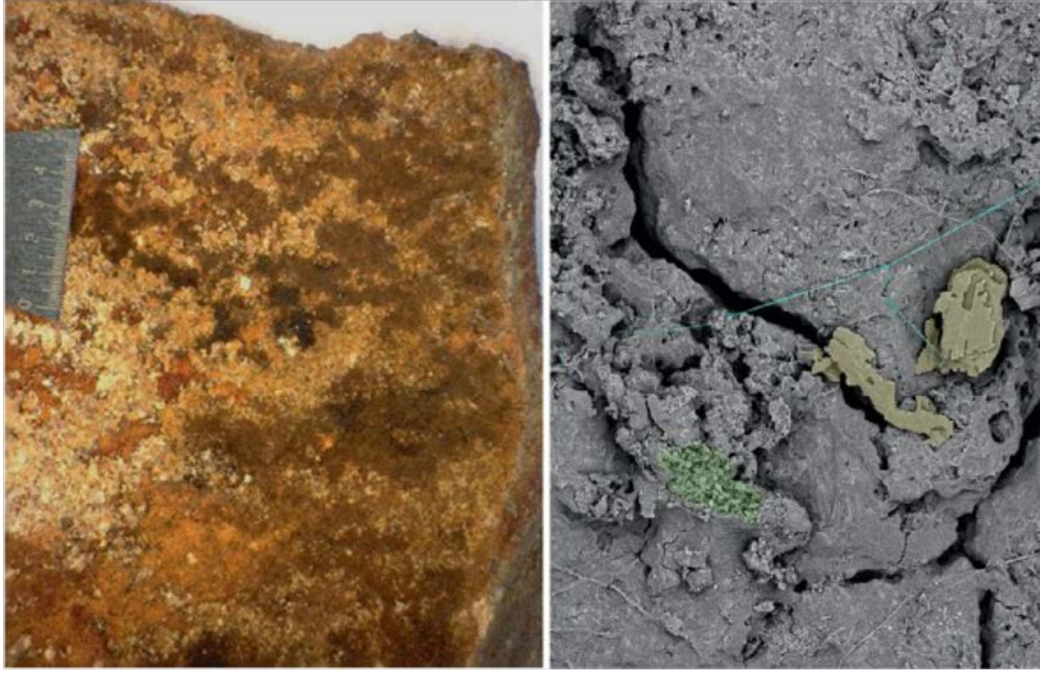


Alien Biofilms Beneath the Waves: Are Deep Sea Microbes the Key to New Antibiotics?

DEEP-SEA SECRETS: BIOFILMS IN THE FIGHT AGAINST ANTIBIOTIC RESISTANCE

By Dinithi Sathsarani



Beneath the crushing pressure and eternal darkness of the ocean floor, life doesn't just survive, it thrives in mind-blowing ways. In places where conditions would seem too harsh for anything to live, microbes have formed resilient, cooperative communities known as biofilms[1]. These microbial mats cling to rocks and withstanding extreme temperatures, intense salinity, and bone-crushing pressure. In my view, they deserve the name 'Alien biofilms' clinging to life in places so extreme, their very existence feels like science fiction made real.

These strange lifeforms are now capturing global attention as potential goldmines for new antibiotics and biotechnological innovations, especially in the fight against rising antibiotic resistance[2]. This article dives into the secrets of hidden world of deep-sea biofilms and their shaping the future of medicine.

Yet it is not just their resilience that makes these organisms truly unique, but their chemistry. In order to survive in such inhospitable environments, these microbes have developed the capacity to yield remarkable chemical compounds such as antibiotics, antivirals, antifungals. During an era when antibiotic resistance is on the increase, their biochemical compounds could potentially provide the medical advances that we so desperately require[3].

Antibiotic resistance is fast becoming one of the biggest challenges in contemporary medicine. As our normal methods for discovering new medicines are no longer proving very effective, scientists are turning to one of the last places one might expect to find solutions: the deep ocean[4].

Antibiotic resistance is fast becoming one of the biggest challenges in contemporary medicine…The deep ocean is one of the few remaining frontiers on Earth, and it may hold the secret to future medical advancements. ..The life-saving medications of tomorrow won't necessarily come from rainforests, but from the high-pressure, chilly environment far below the ocean's surface.

Certain microbes possess unique sets of genes, referred to as gene clusters, which allow them to produce novel molecules[5]. Though these genes tend to remain dormant in terrestrial organisms, they can be activated when subjected to the profound stress of the deep ocean. They've evolved to survive in extreme environments such as crushing pressure, high heat, and poisonous chemicals. In order to cope, they've evolved exceptionally stable and reactive compounds many of which are entirely unlike anything that we presently utilize.

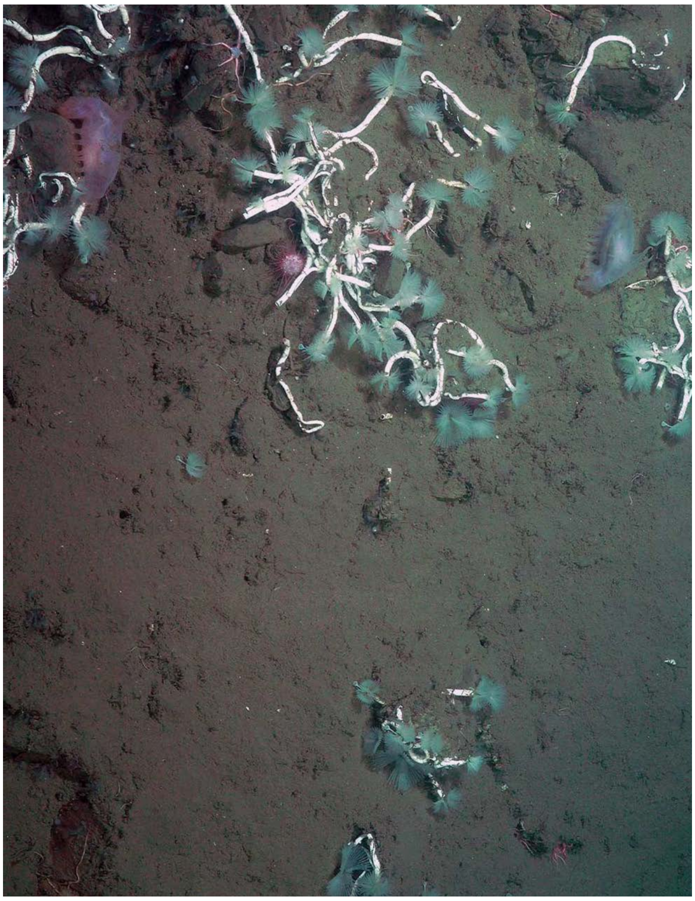
Even more intriguing, much of these microbes exist in intimate associations with deep-sea creatures, trading chemical signals that can also serve as antibiotics or immune system enhancers. Certain deep-sea bacteria, such as actinobacteria and proteobacteria, have already yielded molecules with antibacterial and anticancer potential[6]. Despite these incredible findings, however, the majority of this microbial underworld is still untapped, and we've barely scratched the surface of what it could provide.

The microbes within them exchange genes, assist in adapting to each other, and convey to each other through chemical signals. This microbe communication known as "quorum sensing" can even inform them when to produce beneficial compounds such as antibiotics[7]. Surprisingly, some of these beneficial compounds only manifest when microbes are stressed in their natural habitat, not when we cultivate them individually in a laboratory. Therefore, we could be lacking new medications due to the fact that we're not cultivating them the way they exist in nature.

Case Studies and Discoveries

Real discoveries are already proving the deep sea's potential. For example, a marine bacterium called ***Salinispora tropica*** found in ocean sediments produces **Salinosporamide A**, a powerful compound now being studied as an anticancer drug[8].

In the meantime, heat-loving microbes that inhabit the areas around hydrothermal vents produce super-stable enzymes that are utilized in applications such as PCR tests and industrial processes. And from the cold, dark areas referred to as cold seeps, researchers have discovered antibacterial peptides that are promising against resistant infections such as Methicillin-resistant Staphylococcus aureus (MRSA) and tuberculosis[9]. These advancements



are only the start, there's probably an immense reservoir of life-saving molecules lurking in deep-sea biofilms, waiting to be uncovered.

Challenges and the Way Forward

Investigating deep-sea biofilms is not straightforward that harnessing their promise involves genuine challenges. It is extremely challenging to collect samples from thousands of meters underwater and needs specialized equipment. Even if samples are gathered, it's hard to preserve the microbes alive, as they are accustomed to enormous pressure and near-freezing temperatures. Numerous of these microorganisms also refuse to grow under normal laboratory conditions, so they are challenging to investigate in the conventional manner[10].

Thanks to advances in metagenomics, however, researchers can now study DNA directly from sea samples, without having to culture the microbes. They can even take helpful genes from deep-sea microbes and insert them into easy-to-culture bacteria like *E. coli*, so that we can make valuable substances in the laboratory[11].

The deep ocean is one of the few remaining frontiers on Earth, and it may hold the secret to future medical advancements. In its darkest, most inhospitable regions, deep-sea microbes, particularly those that survive in biofilms have learned to thrive in ways we're only just beginning to appreciate. Having developed over millions of years in extreme environments, these microbes are already overturning what we thought we knew about biology and chemistry. With antibiotic resistance increasing, these unusual, deep-sea biofilms could be one of our best chances for discovering new, potent medicines. The life-saving medications of tomorrow won't necessarily come from rainforests, but from the high-pressure, chilly environment far below the ocean's surface.

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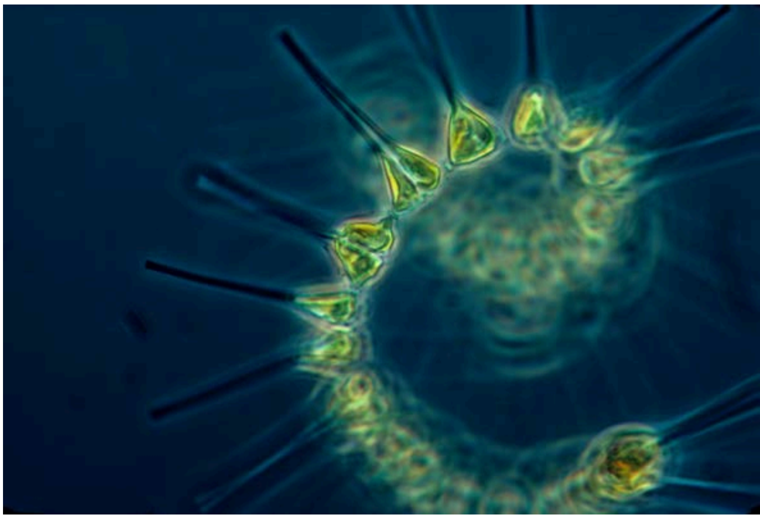
Sustainable Lifestyle is the Green Awakening of Intelligence: From Microbes to Philosophers

SUSTAIN TO EVOLVE: NATURE'S INTELLIGENCE BEGINS SMALL

By Madara Thilakarathne

Do I really need all this? This question sparked my journey into a more sustainable lifestyle. Surrounded by fast fashion, single-use plastics, and over-consumption, I chose to embrace a different path- living simply. Gradually, I started making mindful, conscious choices to minimize my environmental impact. This shift to living simply not only lessened my footprint on the Earth but also broadened my awareness, deepened my mindfulness, and led to meaningful realization. As a microbiology research student, I've come to the realization that microbes often live far more sustainably than we do. Their incredible decision-making, adaptive nature, and survival strategies are really fascinating to prove how life can thrive in harmony with nature.



So who are Microbes? Microbes, or microorganisms, are tiny living organisms that are invisible to the naked eye. They include bacteria, archaea, fungi, protozoa, algae, and viruses. These microscopic beings are deeply rooted in the Earth's ecosystem, and they continue to shape every aspect of liveliness. They live everywhere in soil, water, air, extreme environments like hot springs and glaciers, and even inside plants, animals, and humans.

Even before philosophy, microbes lived with mindful precision.Smartness didn't start with human it started with microbes...Transforming our lifestyles to be more sustainable echoes a growing realization in both science and philosophy: that living sustainably not only benefits the Earth but also nurtures intelligence in microbes and humans alike.

Microbes Live By Quiet Wisdom

Their connection to the planet is original and thoughtful because they think of natural principles of the earth more faithfully than by humans. Microbes have consistently followed sustainable practices, naturally adhering to a lifestyle that has enabled them to thrive and evolve over billions of years, demonstrating a timeless model of balanced living.

They only use what they need, when resources are scarce, soil bacteria or gut microbes simply slow down, form spores, and wait patiently. No overuse. No waste. They are master recyclers. Fungi gently break down fallen trees. Bacteria turn waste into nourishment. They thrive through connection. Rhizobium bacteria form bonds with legumes, fixing nitrogen to nourish their plant hosts. In our own bodies, gut microbes work silently, helping us digest food and even creating essential vitamins.

The Silent Wisdom of Microbes: Microbial Foresight

"Even before philosophy, microbes lived with mindful precision." "Smartness didn't start with human it started with microbes."

Microbes have a unique form of intelligence. In the world of microbes, intelligence isn't measured by neurons but by their survival strategy. "Believe it or not, microbes like *Escherichia coli* can predict the future."

Scientists once studied a, everyday bacterium, *Escherichia coli* to uncover just how intelligently it responds. What they found was remarkable: this tiny microbe could actually predict upcoming changes in its environment and prepare in advance, adapting not just to survive but to thrive. They switched on genes not for the current circumstances, but for what was likely to come next in future. This clever behavior is known as preparation-based intelligence: a quiet, natural wisdom that helps them stay one step ahead of future change. Here's the twist! Then *E. coli* were exposed to the same signal over and over again, generation after generation but eventually they stopped responding to it. This shows that their anticipatory intelligence. This behavior is dynamic. They learn, adapt, and even pass these wise behaviors down to the next generations[1]. Over time, *E. coli* "learn" and prepared. Simply predicting the future.

Biofilms: The Microbial Brain

Microbes have an amazing trick up their sleeves, they build biofilms, slimy little communities that cling to

things like rocks, water pipes, or even our teeth. At first, each microbe just hangs out quietly, but they're actually not just passively sitting, they're counting. They use a clever sensing system called quorum sensing to keep track of how many of them are around, as well as the size, length, width, and shape of their biofilm.

Once enough microbes gather together a moment called reaching quorum state comes. Then whole group suddenly switches on, acting together like a tiny brain together. The surface they cover becomes smart. Quorum sensing, guides the whole colony of bacteria to the production of factors that are only favorable at high population densities[2]. The microbes remain quiet, waiting patiently until their community grows big enough to wake up and work as one. They appreciate teamwork, share knowledge, and win together.

Microbial Intelligence and the Teachings of Philosophers in the Human History

This microbial intelligence reminded me of the greatest thinkers, intelligent people of all time and their simple lifestyle

Buddha and Jesus both of whom embraced sustainable simplicity.

Jesus: The greatest lover to humankind

Jesus often delivered his teaching through parables to the natural world the earth, animals, weather, and everyday farming life highlighting a way of living that was deeply sustainable and in tune with creation.

He referred to the lilies of the field that grow without effort yet are clothed more beautifully than kings (Matthew 6:28-29), Teaching us the profound value of beauty found in nature's perfect balance.

Buddha: The Mindful Pathfinder to Reality

After a life of royal luxury, Buddha renounced wealth to live mindfully. He meditated under trees, ate only what he needed, and taught that wisdom comes from reducing desire not from accumulating more. In the **Sigalovada Sutta**, Buddha emphasized the importance of ethical living, respecting the earth, practicing mindful consumption, and choosing the right livelihood, all fundamental aspects of a sustainable life. He recognized that true wisdom comes not from excess, but from harmony, with nature, others, and ourselves.

The most thoughtful way to live is, therefore, to adopt a sustainable lifestyle. Transforming our lifestyles to be more sustainable echoes a growing realization in both science and philosophy: that living sustainably not only benefits the Earth but also nurtures intelligence in microbes and humans alike. One last time, sustainable living isn’t just about bamboo brushes or tote bags. It’s not about going back to the Stone Age or holding onto outdated ways. It’s a smart, forward-thinking approach. Let’s embrace harmony with nature and inspire future generations to live mindfully and sustainably.

Dear next generations,

In the stillness of the Bodhi tree - In the cross of Calvary,
Beneath the microscope, Unseen truths swirls.
When the Philosophy wonders: "What is truth? What is self?"
It is the gentle knowing deep within - That your breath is shared, where we begin.
Your sorrow, your joy - they ripple wide - Your soul flows with the earth’s own tide.
From soil to trees, the sacred thread, Sustainable living - the path we’re led.
Not escape, but clear awakening - a life of mindful, green being.

Microbial Biotechnology Research Program, National Institute of Fundamental Studies, Kandy 20000, Sri Lanka.

Plastic-Eating Microorganisms: Nature's Cleanup Crew

NATURE'S ANSWER TO A GREENER FUTURE

By Sachini Jayasekara

Imagine our planet overwhelmed by waste. By 2025, global plastic waste is expected to reach 460 million tons annually, accumulating in oceans, landfills, and even entering the food we eat and the water we drink[1]. This unseen tide of synthetic debris gradually breaks down into microplastics, tiny particles that threaten ecosystems, wildlife, and human health. Traditional recycling efforts only go so far, and as plastic production continues to rise, there is a growing need for innovative biological solutions to address this challenge.

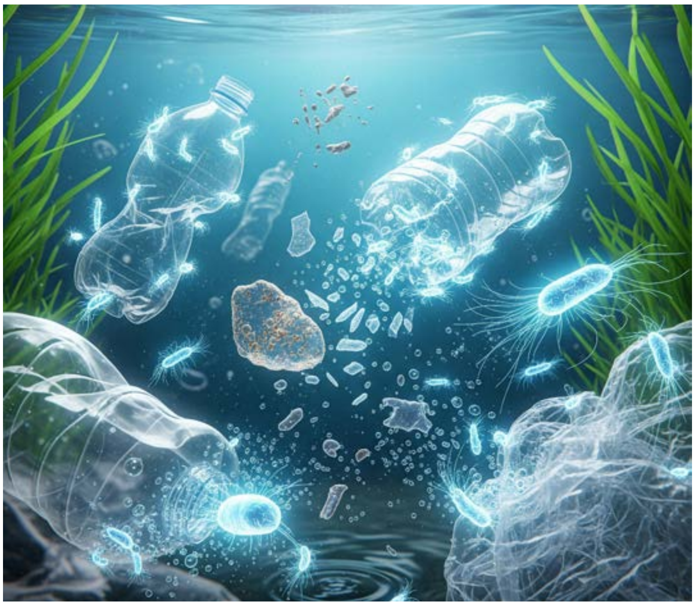
But imagine if the solution wasn't a bigger machine or a new invention by humans, but something tiny and incredible. What if the answer was a microscopic cleanup crew, patiently waiting to be discovered?

Plastivores: The Unseen Warriors Unleashed

In a remarkable twist of nature's creativity, scientists have identified a group of microorganisms, some bacteria and fungi called "plastivores", that actually consume plastic as food[2]. These microscopic warriors can digest stubborn plastics like polyethylene terephthalate (PET), low-density polyethylene (LDPE), and polyurethane, breaking them down into harmless byproducts[3,4,5].

Microscopic cleanup crew, patiently waiting to be discovered?...scientists have identified a group of microorganisms, some bacteria and fungi called "plastivores", that actually consume plastic as food...The next major breakthrough in sustainable science could come not from a machine, but from a microbe.

Species like *Ideonella sakaiensis* form biofilms on plastic surfaces and secrete enzymes, including Polyethylene Terephthalate Hydrolase (PETase) and mono (2hydroxyethyl) terephthalate hydrolase (MHETase) which degrade PET into smaller molecules that microbes can absorb and metabolize[6]. Additionally, a wide variety of other microbial species, including different bacteria and fungi also form biofilms and produce diverse plastic-degrading enzymes such as esterases, cutinases, and oxidases, which contribute to the breakdown of various plastics[11].



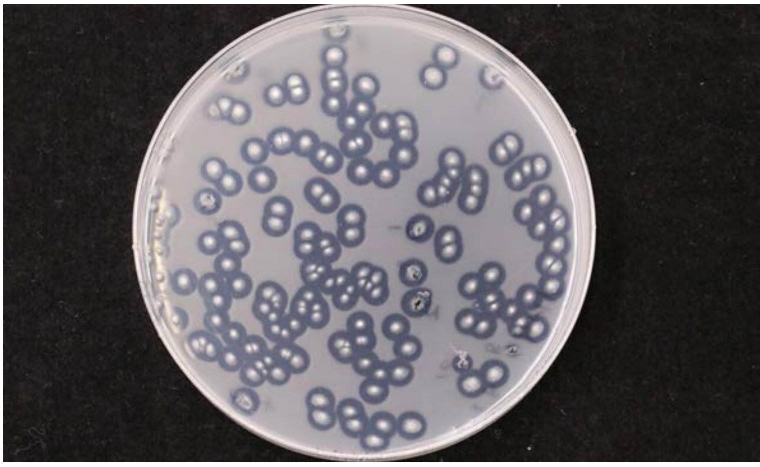
How do they do it?

Plastic eating microbes do not just stumble upon their meals; they follow a surprisingly elegant routine, almost like a well-rehearsed three-course meal. First comes Adhesion, the Sticky Landing. Our microscopic cleaners land on the plastic surface, creating a thin, gooey biofilm[6,7]. This is not just a casual visit; it is their way of setting up a localized chemical factory right on the plastic's surface, where all the magic begins. Once firmly anchored, the process advances to Depolymerization, the Molecular Mastication. At this stage, the microbes secrete powerful enzymes like PETase from *Ideonella sakaiensis*, which works tirelessly and precisely. These enzymes break down the long, stubborn plastic chains into smaller, more manageable fragments. Finally comes Assimilation; the Digestion and Disposal. The microbes absorb these newly freed molecules, metabolizing them to grow and reproduce. Just like any efficient biological system, they release harmless byproducts such as carbon dioxide, water, and microbial biomass back into the environment, completing the degradation cycle and turning plastic waste into natural end products[6,8,9].

From Petri Dish to the Planet: Unleashing Nature's Cleaners

This once-lab-bound curiosity is now a global scientific pursuit. Research teams around the world are exploring mixed microbial consortia, combinations of bacteria like *Bacillus* and *Pseudomonas*, alongside fungi such as *Aspergillus* and *Fusarium*, to accelerate plastic degradation[10,11]. These microbial teams work in synergy, breaking down plastic faster and more efficiently than individual strains.

For nations such as Sri Lanka, the potential in this domain is substantial. Our abundant and dynamic ecosystems are rich in microbial diversity, which remains largely unexamined. Although international research in this field is advancing rapidly, Sri Lanka remains in the initial phases, presenting a promising frontier for domestic scientists. The paucity of comprehensive local studies signifies that we are on the verge of significant discoveries, possessing the capacity to identify indigenous microbial solutions that are specifically adapted to our local environments.



Tiny Solutions, Monumental Impact

What once sounded like a scene from science fiction, organisms that devour plastic, is now an emerging scientific reality. And perhaps, the most transformative solutions to our global waste crisis won't come from futuristic machines, but from the tiniest life forms on Earth.

By embracing the plastic-degrading power of microbes, we're not just cleaning up landfills and oceans. We're redefining what waste means, rethinking materials from the molecular level up, and crafting a new path toward sustainability. As students, researchers, and innovators, especially here in Sri Lanka, we stand at the threshold of a powerful microbial revolution.

The next major breakthrough in sustainable science could come not from a machine, but from a microbe. And maybe, just maybe... from a **Petri dish in your own lab**.

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