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COVER STORY

Dendrobium heterocarpum (Orchidaceae)
Primrose Orchid

Dendrobium heterocarpum is a native orchid species of Sri Lanka that grows epiphytically on the trunks of trees in wet evergreen forests and submontane forests above 1,200 m elevation. The species is also found in several Asian countries, including India, Myanmar, China, and Java.
According to the 2020 National Red List of Sri Lanka, *D. heterocarpum* is categorized as Endangered (EN) due to its high risk of extinction in the wild.

Photograph by Bhathiya Gopallawa
Postgraduate Institute of Science
University of Peradeniya
Sri Lanka

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PRESIDENT'S MESSAGE

It is my great pleasure to send this message to BIO-NEWS, the e-newsletter of the Institute of Biology, Sri Lanka (IOBSL).

We are living in a time when scientific innovation is central to addressing many of the pressing challenges facing our nation and the world, including food security, climate change, environmental degradation, emerging diseases, and the sustainable use of natural resources. In this context, biotechnology stands out as a transformative field with the power to improve lives, strengthen economies, and support sustainable development.

Reflecting this importance, the IOBSL has adopted "***Biotechnology Towards a Sustainable Future***" as its theme for the year. Biotechnology continues to reshape key sectors such as agriculture, healthcare, industry, environmental management, and biodiversity conservation, offering innovative and responsible solutions for a better future.

The IOBSL is privileged to have a diverse and highly skilled membership spanning the biological sciences. Through this collective strength, we aim to advance the application of biotechnology in addressing societal needs and contributing meaningfully to national development.

Through this collective strength, we aim to advance the application of biotechnology in addressing societal needs and contributing meaningfully to national development. Throughout the year, the Institute will continue to organize seminars, workshops, publications, and outreach activities that engage students, academics, professionals, policymakers, industry partners, and the wider community.

BIO-NEWS serves as an important platform to share the Institutes activities, highlight scientific achievements, and foster communication within our membership and beyond. I warmly invite all members and stakeholders to actively engage in our initiatives as we work together to promote innovation and sustainable solutions.

I wish you all a productive and successful year ahead and look forward to your continued support and active participation in the endeavors of the IOBSL.

Prof. H. D. D. Bandupriya
President (2025/2026)
Institute of Biology, Sri Lanka (IOBSL)

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IOBSL NEWS AND EVENTS

Sri Lankan Biology Olympiad 2026

An exciting opportunity awaits young biology enthusiasts!

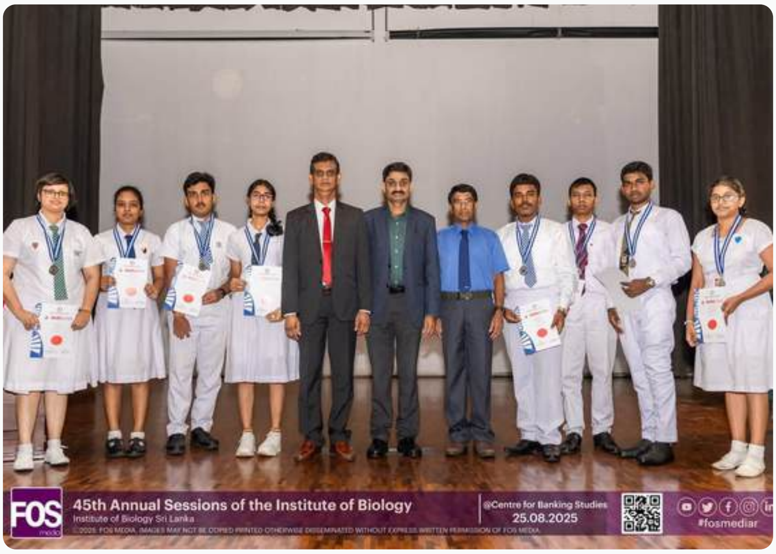
The Biology Olympiad provides a unique platform for students to challenge themselves, deepen their knowledge of biology, and interact with the country's brightest young minds in the life sciences.

Students sitting for the 2026 and 2027 G.C.E. Advanced Level Examination (Grade 12 and Grade 13) are invited to participate in the Sri Lankan Biology Olympiad 2026 and compete for prestigious medals and recognition.

The application deadline is on or before 10th July 2026.

Outstanding performers will have the opportunity to represent Sri Lanka on the international stage. Following a rigorous selection process, four students will be chosen to participate in the 38th International Biology Olympiad (IBO), scheduled to be held in Warsaw, Poland, from 18–26 July 2027.

For further information, please refer to the IOBSL official website.



Young Scientist Award 2026
Applications Now Open

The IOBSL is pleased to announce that applications are now open for the prestigious Young Scientist Award 2026. This award aims to recognize outstanding young biologists who have demonstrated excellence in research and made significant contributions to the advancement of Biology in Sri Lanka.

Eligible candidates are encouraged to apply and showcase their scientific achievements, innovation, and dedication to the biological sciences.

The award serves not only as a recognition of individual merit but also as a celebration of the potential and promise of the next generation of Sri Lankan biologists.

Applications are now open, and aspiring candidates are encouraged to submit their applications and be recognized for their contribution to the future of Biology.

For more information and application guidelines, please visit the official website of the IOBSL.

Prof. Anupama Daranagama
Recipient of the IOBSL Young Scientist Award 2025

Submit your research to

Sri Lankan Journal of Biology (SLJB)

SLJB provides high quality, comprehensive and broad coverage in all areas of Biology. The journal publishes original scientific research articles that describe significant research findings. SLJB encourages the submission of original contributions in all fields of basic and applied research involved in Biological Sciences.

Read the submission guidelines

Annual Sessions 2025

Moments from the IOBSL 45th Annual Sessions 2025, held on 22 September 2025 at the Centre for Banking Studies, Sri Jayewardenepura Mawatha, Kotte, bringing together members to discuss key activities, progress, and future initiatives of the IOBSL.


Agriculture in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Bacterial ClpP Protease System to Design Novel Antibiotics

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Globally, the emergence of antibiotic-resistant bacteria poses a serious threat to public health. Researchers are seeking alternative medical treatments since few new antibiotics are under development, and many old antibiotics are becoming increasingly ineffective. One promising approach is targeting bacterial proteases, which are necessary for protein homeostasis, cellular function, and stress adaptation. Among these, the caseinolytic protease P (ClpP) system has attracted particular interest due to its essential function in the control of protein turnover and cellular reactions to environmental stress.

In bacterial cells, the ClpP protease system is a complex that functions with caseinolytic protease subunit X (ClpX) or caseinolytic protease subunit A (ClpA) chaperones to break down/degrade misfolded or damaged proteins.

Comprising multiple subunits, the barrel-shaped ClpP protease operates under tightly regulated control. Disturbance of the ClpP system in bacteria results in the accumulation of damaged proteins, which causes cellular dysfunction, slowed growth, and finally, bacterial death. Because of its essential role in bacterial survival, ClpP is considered an attractive target for the development of novel antimicrobial drugs, particularly against multidrug-resistant diseases.

ClpP protease mechanism

The ClpP protease system has two primary components: an ATP-dependent chaperone partner (such as ClpX or ClpA) and the ClpP protease itself. The ClpP protease is a barrel-shaped structure made up of two stacked rings of heptameric subunits. ClpP performs best when triggered by a chaperone-like ClpX or ClpA, which helps to choose and unfold substrates before they are translocated into the ClpP protease chamber.

The ClpP protease aligns two heptameric rings longitudinally to form a tetradecameric cylinder. Each ring's axial pore, which has a diameter of about 10 Å, serves as the entry to the interior of the proteolytic chamber, which has a diameter of about 50 Å and contains 14 active catalytic sites. Depending on the species, each protomer has a C-terminus, an N-terminal loop, a handle, and a head domain, with a size ranging from 193-277 residues. The globular head domains make up the ring's main body when the tetradecamer is formed, and the barrel's interior contains the majority of its surface, including the active site.

As a chymotrypsin-like serine protease, ClpP's peptidase activity produces peptides with 7-8 residues that cut after non-polar residues. However, interaction with an unfoldase partner like ClpX or ClpA is required for the effective degradation of lengthy peptides and proteins. These chaperones serve as a cap for the ClpP cylinder and belong to the Hsp100 class of the AAA+ superfamily. Even though different organisms have different Clp ATPases, they all have a hexameric complex structure with a central pore that serves as a channel to move the substrates into the proteolytic chamber (Figure 1).

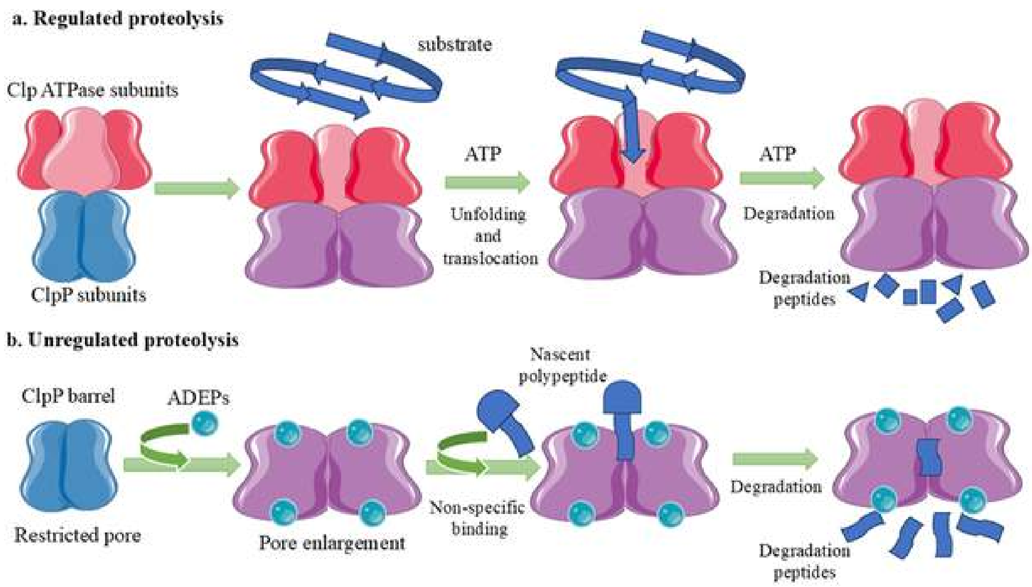

Figure 1 Regulation and unregulation of ClpP-mediated proteolysis. (a) Controlled proteolysis: hexameric Clp ATPases (red and pink) identify and unfold substrates. The unfolded substrates are translocated into the gated chamber of the ClpP peptidase (blue), where proteolysis occurs at the active sites on the inner surface of the barrel-shaped structure; (b) Unregulated proteolysis: binding of acyldepsipeptide (ADEP) to ClpP causes unregulated proteolysis. ADEP (green spheres) interacts with ClpP subunits (blue), opening the entrance pore of the ClpP barrel and causing uncontrolled degradation of nascent polypeptides and unfolded proteins.
Source: Frees, Brøndsted and Ingmer (2013)

ClpX and ClpA are AAA+ (ATPases associated with various cellular activities) chaperones that use energy from ATP hydrolysis to unfold and translocate substrates into the ClpP protease. Both ClpX and ClpA form hexameric rings containing inner ATPase domains. While ClpA is involved in a broader spectrum of activities, such as stress response and protease control, ClpX functions mostly with ClpP to eliminate damaged or misfolded proteins via regulated proteolysis. It is important to mention that caseinolytic protease subunit B (ClpB), which is also an AAA+ protein, does not associate with ClpP proteins, whereas ClpX and caseinolytic protease subunit (ClpY) consistently do. The chaperone proteins (ClpX/ ClpA) identify proteins intended for degradation, unfold them, and translocate them to the ClpP protease. The protease then breaks the substrates into smaller peptides, preventing the accumulation of damaged or misfolded proteins that could interfere with cellular functions (Figure 2).

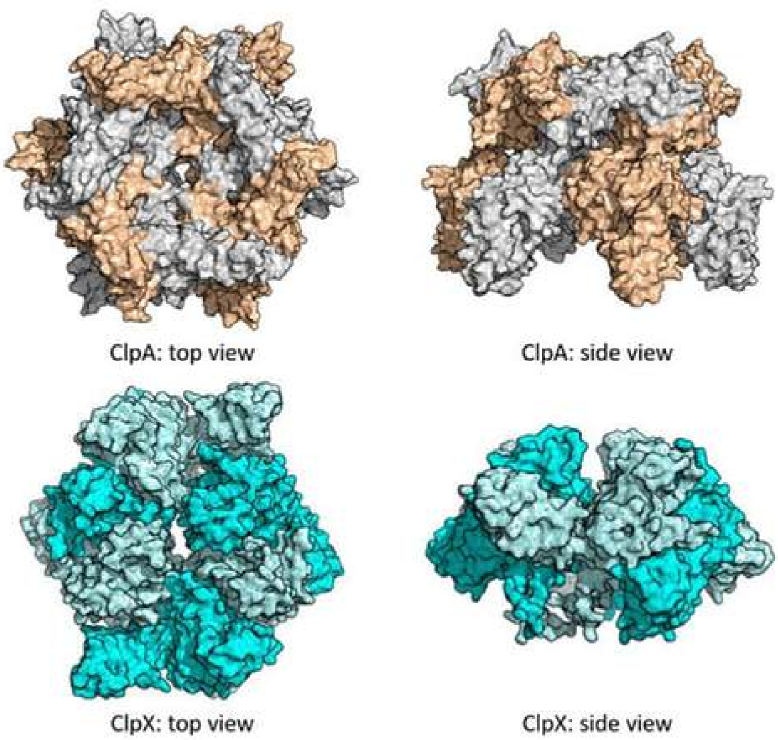

Figure 2 Top and side views of *Escherichia coli* caseinolytic protease subunit A (ClpA) and caseinolytic protease subunit X (ClpX) hexamers. The ClpA hexamer is shown in gray and wheat, while the ClpX hexamer is depicted in cyan and light cyan. Top views of ClpA and ClpX show the substrate's core channel.
Source: Malik and Brötz-Oesterhelt (2017)

The role of ClpP in responses to bacterial stress

Bacterial stress response mechanisms are linked to several stressors, including temperature stress, oxidative stress, and exposure to pharmacological substances. To maintain cellular integrity in response to these conditions, bacteria rely on stress response systems that depend on the ClpP protease system. ClpP regulates the breakdown/degradation of defective proteins, including those oxidised or misfolded from cellular stress. For example, during heat shock, protein denaturation leads to misfolding. The ClpP protease system helps alleviate stress by breaking down these misfolded proteins and thereby lowering harmful accumulation. Similarly, under oxidative stress, ClpP degrades oxidized proteins that might otherwise interfere with cellular functions. Apart from its role in stress responses, the ClpP system regulates the production of virulence factors, gene expression, and cellular division, thereby influencing both bacterial pathogenicity and survival.

Since bacterial survival depends critically on the ClpP, this system has become an attractive target for novel therapeutics. Reduced ClpP activity causes bacteria to lose their capacity to break down damaged proteins, leading to increased cellular stress, protein accumulation, and finally, cell death. Given that ClpP is somewhat conserved among bacterial species, targeting ClpP offers benefits over other antibiotics and holds promise for the development of broad-spectrum antibiotics. ClpP proteolytic systems are particularly important in several pathogenic bacteria, especially multidrug-resistant strains like *Staphylococcus aureus* and *Mycobacterium tuberculosis*.

Overcoming obstacles

The ClpP protease system functions independently of conventional antibiotic resistance pathways, making it a valuable target for restoring cellular homeostasis. ClpP inhibitors potentially provide a means to overcome existing resistance mechanisms and enhance the effectiveness of previously used antibiotics. These inhibitors can also act synergistically with present drugs, improving their efficacy, particularly against multidrug-resistant infections. By reducing the required doses of conventional antibiotics, such combination medications may minimize side effects and decrease the likelihood of further resistance development.

Current studies on ClpP inhibitors

Over the past decade, researchers have successfully identified and developed small compounds that inhibit the ClpP protease. For example, Trans-4-(3,4-dimethoxyphenyl-) 1,2-dihydro-3H-pyrrolo[3,4-b] has been shown to effectively ClpP in *Escherichia coli* and other bacterial species. These small molecules reduce ClpP's catalytic activity, thereby leading to the accumulation of damaged proteins and ultimately bacterial death. ClpP inhibitors have also been investigated using synthetic compounds, sometimes referred to as peptoids, which mimic peptides. These molecules are designed to bind specifically to the active site of the ClpP protease, preventing the enzyme from degrading its substrates.

In addition, potent ClpP inhibitors have been derived from natural substances, such as metabolites from myxobacteria. These compounds have demonstrated efficacy against several pathogenic bacteria by specifically targeting ClpP. Many studies have also investigated combining ClpP inhibitors with conventional antibiotics. This approach is particularly effective in treating multidrug-resistant infections, as it enhances the bactericidal activity of existing drugs.

Challenges and future directions

Despite their considerable potential as antibacterial agents, ClpP inhibitors are required to overcome several challenges. First, minimizing off-target effects and toxicity requires the development of selective inhibitors that specifically target bacterial ClpP while avoiding human proteases. Second, the pharmacokinetics and pharmacodynamics of ClpP inhibitors must be evaluated *in vivo* to determine optimal dose ranges. Furthermore, clinical trials are necessary to confirm the safety and efficacy of these inhibitors in humans, even if preclinical studies show promising results.

Combining drugs that target different bacterial systems, including ClpP, may offer a more effective and sustainable approach to overcoming antibiotic resistance.

The ClpP protease system remains a viable therapeutic target as it is essential for maintaining protein homeostasis, regulating stress responses, and supporting bacterial survival. Current research on ClpP inhibitors, particularly in combination with conventional antibiotics, provides promising novel approaches to address antibiotic-resistant infections.

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From Ocean to Medicine: The Untapped Potential of Marine Seaweeds in Combating Non-Communicable Diseases

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In the 21st century, the world faces an unprecedented health crisis not due to infectious outbreaks, but from the steady rise of non-communicable diseases (NCDs). Conditions such as cardiovascular diseases, type 2 diabetes, obesity, cancer, and chronic respiratory diseases have become the leading causes of mortality globally, accounting for over 70% of all deaths according to the World Health Organization (WHO). While these diseases are often linked to lifestyle and environmental factors, scientific research has been rapidly advancing toward preventive and therapeutic strategies derived from natural sources.

One such emerging and promising group of natural products comes not from the land, but from the sea. Marine seaweed, also known as macroalgae, has been consumed for centuries in coastal regions, particularly in East and Southeast Asia. Yet, their full potential in preventing and treating chronic diseases remains largely underexplored in most parts of the world, including South Asia. Seaweeds are not just edible marine plants; they are bioactive powerhouses that are now gaining recognition in modern medicine for their roles in nutrition, therapy, and disease prevention.

The diversity and composition of marine seaweeds

Marine seaweeds are broadly classified into three groups based on their pigmentation and taxonomic characteristics: brown algae (Phaeophyta) – *Laminaria*, *Fucus*, *Sargassum*, and *Undaria*; red algae (Rhodophyta) – *Gracilaria*, *Porphyra*, and *Kappaphycus*; and green algae (Chlorophyta) – *Ulva* and *Caulerpa*.

These seaweeds are rich in nutrients, including dietary fibers, essential amino acids, omega-3 fatty acids, vitamins (A, B, C, E, K), and minerals such as iodine, calcium, iron, and magnesium. What makes them particularly valuable in the fight against NCDs, however, is their abundance of bioactive compounds such as polyphenols, polysaccharides, carotenoids, sterols, and peptides that exhibit strong antioxidant, anti-inflammatory, anti-diabetic, lipid-lowering, and even anti-cancer properties.

Edible seaweeds: functional foods and beyond

In many Asian cultures, edible seaweeds have been a dietary staple for centuries. For example, nori (*Porphyra*), kombu (*Laminaria*), and wakame (*Undaria*) are commonly consumed in Japan and Korea, and are associated with longevity and a low incidence of NCDs in these populations.

Brown seaweeds are rich in fucoidans, alginates, and phlorotannins. These compounds have been shown to reduce cholesterol, regulate blood sugar, inhibit cancer cell growth, and support immune function. Red seaweeds contain carrageenans and agar, which act as prebiotics, supporting gut health and improving digestion. Their antioxidant activity helps in reducing oxidative stress, a primary trigger of chronic inflammation and NCDs. Green seaweeds are high in ulvans and chlorophylls, which have been studied for anti-hypertensive, antioxidant, and antimicrobial properties. Seaweeds are low in calories and high in satiety-inducing fibers, making them ideal for weight management and metabolic health.

Mechanisms of action of seaweeds against NCDs

Scientific investigations over the past two decades have begun to reveal the complex biochemical pathways through which seaweed-derived compounds exert their health benefits. Several key mechanisms have emerged as particularly promising. One major pathway involves the regulation of oxidative stress, which is driven by excessive production of reactive oxygen species (ROS) and is implicated in the pathogenesis of nearly all NCDs. Seaweeds are abundant in polyphenols such as phlorotannins, which scavenge free radicals and upregulate the body's endogenous antioxidant defenses like superoxide dismutase (SOD) and glutathione.

In addition to oxidative stress, chronic low-grade inflammation underlies diseases like arthritis, diabetes, and cardiovascular disorders. Bioactive compounds derived from seaweeds, particularly fucoidan and ulvan, have been shown to suppress pro-inflammatory cytokines such as tumor necrosis factor-α (TNF-α), interleukin-6 (IL-6), and cyclooxygenase-2 (COX-2).

Seaweeds also play a significant role in metabolic regulation, particularly in carbohydrate digestion and glucose homeostasis. Alginates and fucoidans inhibit key digestive enzymes such as alpha-amylase and alpha-glucosidase, thereby delaying glucose release into the bloodstream and reducing postprandial blood glucose levels. In addition, fucoxanthin derivatives isolated from the brown alga *Chnoospora minima* have demonstrated hypoglycemic activity by enhancing insulin sensitivity and modulating glucose metabolism (Figure 1).

High cholesterol and triglyceride levels are major risk factors for cardiovascular diseases. Seaweed-derived compounds have been shown to increase bile acid excretion and regulate hepatic lipid metabolism, leading to lower low-density lipoprotein (LDL) levels and improved high-density lipoprotein (HDL). Moreover, certain seaweed extracts have shown cytotoxicity against cancer cells without affecting normal cells. Bioactive molecules such as phlorotannins, fucoxanthin, and seaweed-derived peptides have been reported to induce apoptosis, inhibit metastasis, and suppress angiogenesis in various cancer models.

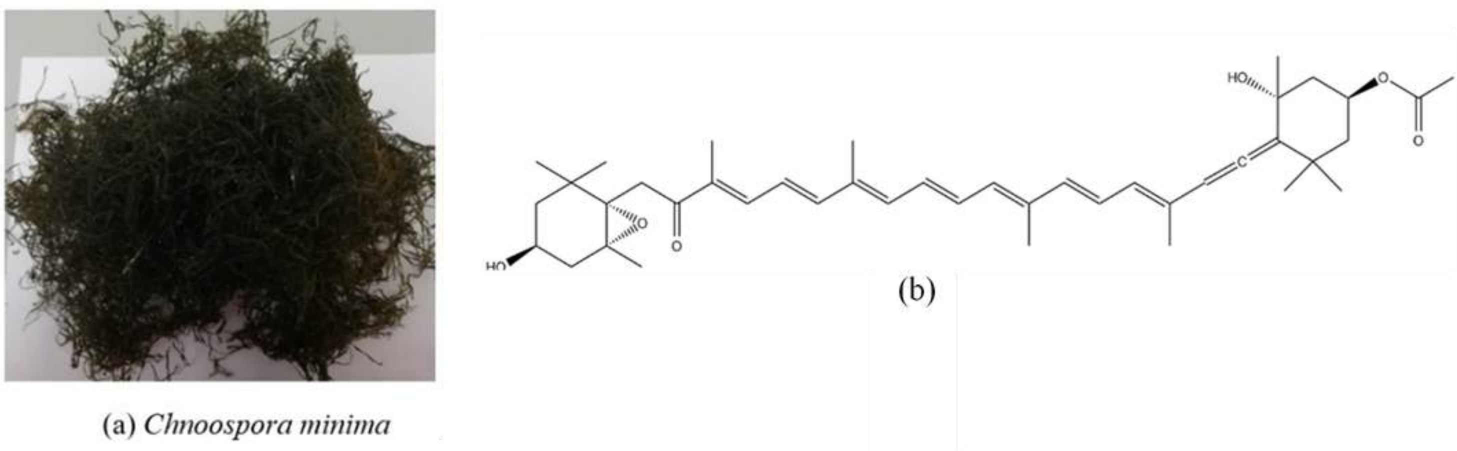

Figure 1 Fucoxanthin derivative isolated from the brown algae *Chnoospora minima*. (a) The brown alga *C. minima*; (b) Chemical structure of fucoxanthin, a bioactive compound derived from *C. minima*.
Source: Kumarasinghe and Gunathilaka (2025)

Seaweeds and gut health

Emerging research identifies the gut microbiome as a central player in chronic disease prevention. Seaweed polysaccharides function as prebiotics by selectively enhancing the growth of beneficial gut bacteria like *Bifidobacteria* and *Lactobacillus*. A healthy gut microbiota is linked with improved immunity, reduced inflammation, enhanced metabolic regulation, and even better mental well-being. In addition, seaweed-derived dietary fibers such as alginates, carrageenan, and agar increase fecal bulk and promote regular bowel movements, thereby reducing the risk of colorectal cancer and metabolic endotoxemia.

Sri Lanka's untapped seaweed potential

Sri Lanka, with its vast coastal belt and rich marine biodiversity, is home to numerous edible and medicinal seaweed species. Despite this natural abundance, the full potential of Sri Lankan seaweeds remains largely untapped. *Gracilaria edulis* (Figure 2), *Caulerpa racemosa*, and *Ulva lactuca* are among the native species with confirmed health benefits. Promoting the cultivation and consumption of seaweeds could not only support public health by reducing the burden of NCDs but also contribute to economic development through sustainable marine farming and the production of value-added products in the nutraceutical, cosmetic, and pharmaceutical sectors.

Figure 2 The red alga *Gracilaria edulis*
Source: Kumarasinghe and Gunathilaka (2025)

Challenges and the way forward

Despite their immense promise, the integration of seaweeds into modern health systems and diets faces several significant challenges. Consumer awareness remains low, especially in non-coastal and Western societies, where seaweeds are often perceived as exotic or unfamiliar. Standardization and quality control also present challenges, as the concentration of bioactive compounds in seaweeds can vary greatly depending on species, season, and environmental conditions.

This variability necessitates further research to establish consistent dosage, safety, and efficacy standards. Additionally, regulatory hurdles must be addressed, as seaweed-based functional foods and supplements are required to meet stringent food safety and health regulations before reaching the market. Overcoming these challenges will require interdisciplinary research, robust government policy support, and the development of public-private partnerships to scale up sustainable production, develop innovative seaweed-based products, and enhance community education and acceptance.

Current trends and innovations

In recent years, food scientists and biotechnologists have developed a range of value-added seaweed products, including seaweed noodles and pasta, nutrient-rich seaweed snacks, seaweed-infused bread, burgers, and beverages, as well as pharmaceutical-grade extracts targeting conditions such as diabetes and cancer. With growing interest in plant-based and sustainable foods, seaweed is gaining attention not just as a health supplement but also as a mainstream food ingredient in functional diets and medical nutrition therapy.

A global perspective: success stories

Japan and Korea provide real-world examples of how regular seaweed consumption correlates with reduced prevalence of NCDs. The traditional Japanese diet, which is rich in seaweed, fish, and fermented foods, is often cited as a model for longevity and healthy aging. In Europe and the United States, both large food companies and startups are investing in seaweed farming and product development. Countries such as Iceland and Ireland have already established seaweed industries that cater to both the health and cosmetic markets. Sri Lanka could adopt a similar model by utilizing indigenous species, encouraging academic-industry collaborations, and developing export-ready health products.

From coastal tides to clinical trials, the journey of marine seaweeds from food to medicine is just beginning. These oceanic superfoods represent a sustainable, accessible, and cost-effective solution to address some of the most pressing health issues of our time. With continued research, supportive policy intervention, and community engagement, seaweeds have the potential to transform not only our diets but also our healthcare systems. Marine seaweeds are not just aquatic plants; they are potent, nature-derived allies in the fight against chronic diseases. Their therapeutic compounds, combined with their nutritional richness, position seaweeds as a valuable tool for combating NCDs. Integrating seaweeds into daily diets and developing seaweed-based therapies may be one of the most impactful steps we can take toward a healthier and more sustainable future.

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From Cells to Organ-on-Chip: The Advancement of Animal Cell Culture

Animal cell culture is the process of culturing and maintaining animal, human, and insect cells *in vitro* under an artificially controlled environment. This technique was discovered in the late 19th century by scientists Wilhelm Roux and Ross Harrison, who successfully cultured embryonic chick cells and frog nerve cells, respectively. Then, in 1911, Lewis and Lewis discovered the first liquid culture medium, consisting of seawater, serum, embryo extract, salts, and peptones. Two years later, in 1913, Alexis Carrel introduced strict aseptic techniques that were essential for maintaining long-term cell cultures. However, the application of the animal cell culture technique remained limited until the mid-20th century. In the 1950s, the accidental discovery of immortalized HeLa cells by George Gey led to a significant breakthrough and marked the beginning of widespread use of this technique in life science research. Today, animal cell culture enables the growth of a wide variety of cells – from primary cells to established cell lines under controlled environmental conditions, and it is utilized in a diverse range of applications.

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Different types of animal cells

Primary cells, which are directly obtained from tissues, closely mimic their *in vivo* behavior. Embryonic stem cells and induced pluripotent stem cells are widely employed in cellular behavior studies and physiology. However, primary cells have a finite lifespan, are initially heterogeneous but later become dominated by fibroblasts, and are more susceptible to contamination. In addition, their maintenance requires skilled personnel, which restricts their broad applications. Despite those difficulties, scientists use these primary cells to study cellular behaviour and molecular mechanisms of cells.

To overcome the limitations associated with primary cells, continuous cell lines were established by integrating them with cancerous cells. This transformation occurs spontaneously or is induced by chemicals or viruses. Those transformed continuous cell lines show a fast growth rate with minimum nutrition requirements and less impact on their environment, making them more convenient for various applications. Therefore, these cell lines are extensively used in the medical field for toxicity testing, drug and vaccine development, biomanufacturing, and the investigation of novel therapeutic approaches. As examples, Caco-2, an immortalized cell line of human epithelial cells isolated from colon tissue derived from a 72-year-old, White, male with colorectal adenocarcinoma, is currently utilized as a model of the intestinal epithelial barrier. A cloned subline of the Neuroblastoma cell line SH-SY5Y is extensively applied in neurodegenerative diseases and neurotoxicity studies.

Simple, cost-effective two-dimensional (2D) monolayer cultures were heavily used in high-throughput screening purposes and other applications. But 2D cultures did not represent the *in vivo* environment, leading to altered cell-to-cell interactions and signalling. Therefore, scientists sought to optimise culture conditions and introduce various growth techniques to enhance cell-cell/cell-matrix interactions and broaden their applications. Figure 1 shows the evolution of animal cell culture techniques over time to expand their applications.

Three-dimensional culture models

Conventional 2D monolayer cultures were later advanced to three-dimensional (3D) models, such as spheroids and organoids, to better resemble the complexity of native tissues. As a result, 3D cell culture techniques provide more physiologically relevant results than traditional 2D cell models. Furthermore, co-culture systems combining 2D and 3D cells have been developed to study cellular interactions. These can mimic interactions between different cell types within an organ, allowing researchers to gain more precise insights into cellular cross-talk and its influence on cell behavior.

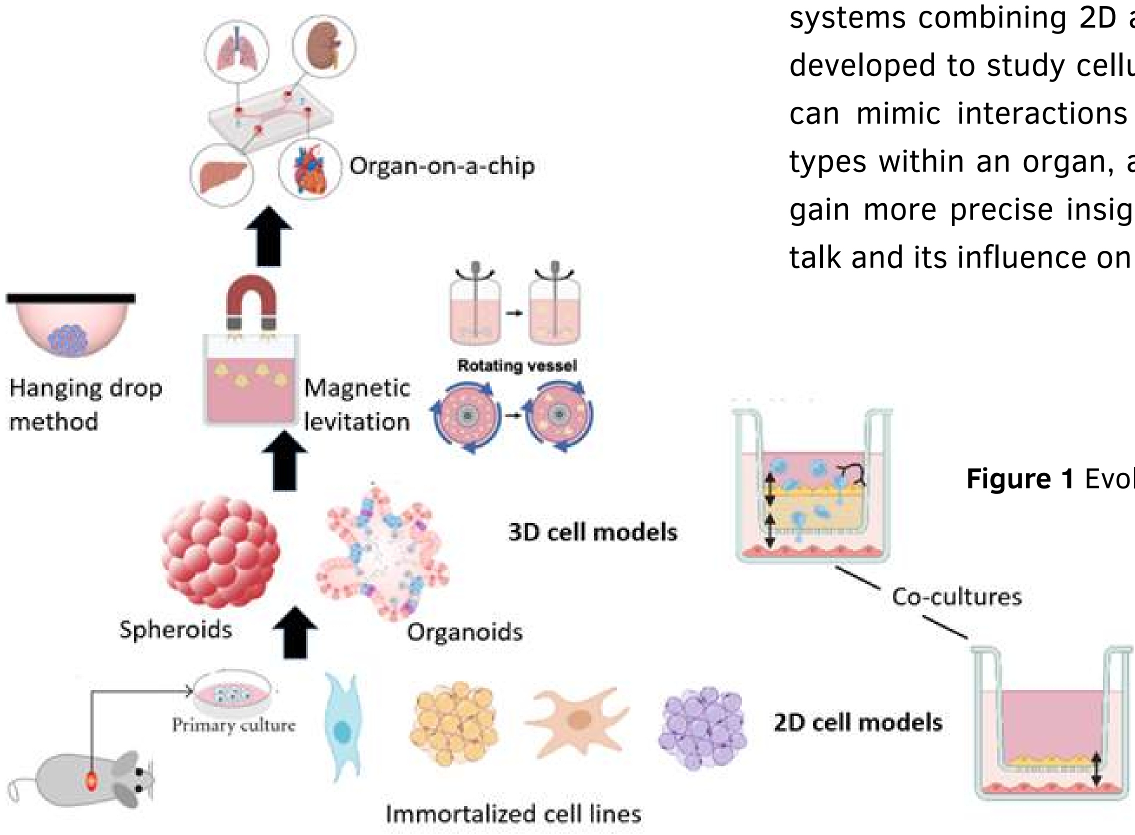

Figure 1 Evolution of animal cell culture

Depending on the research purpose, 3D cell models can be cultured in different scaffold/matrix materials, including biologically derived scaffold systems and synthetic materials. A few examples of commercially available biologically derived matrices are BD Matrigel™ basement membrane matrix (BD Sciences), Cultrex® basement membrane extract (BME; Trevigen), and hyaluronic acid and synthetic scaffolds materials are polyethylene glycol (PEG), polyvinyl alcohol (PVA), polylactide-co-glycolide (PLG), and polycaprolactone (PLA). All these cells can be cultured using various techniques, such as the hanging drop method, magnetic levitation, gel embedding, or by using rotors or spinners to rotate the cell culture. These techniques help to maintain uniform cell size and enhance the suitability of cultures for subsequent applications.

Even though 3D cultures are complex, expensive, and time-consuming to set up and maintain, they are utilised for disease modelling, especially in cancer studies, drug metabolism, and long-term studies such as biosensor development.

Microfluidic systems and organ-on-chip technology

At present, cells can also be grown in microchambers under microfluidic conditions. The pharmaceutical industry extensively utilizes this microfluidic culture technique in the drug development process since it is convenient for conducting drug target screening assays.

The latest advancement in animal cell culture technique involves combining 3D microfluidic cell cultures derived from multiple organs via interconnected channels on a circuit. In 2010, researchers at Harvard University developed the first lung-on-a-chip model. Then, organs such as the lung, brain, heart, liver, kidney, skin, and gut have been simulated in these organ-on-a-chip models. The organ-on-a-chip model aims to reproduce the necessary physiological attributes of human organs as accurately as possible. This high-throughput, sensitive, robust cellular design has significantly advanced the drug discovery process and transformed the field of personalized medicine. Moreover, organ-on-a-chip technology assists the investigation of disease mechanisms and inter-organ interactions with greater precision.

Modern trends in animal cell culture

Genetic engineering, particularly the use of the CRISPR-Cas system, has greatly advanced animal cell culture and tissue engineering technologies, enabling the mass production of cells and expanding their applications, especially in the healthcare sector. This precise genome editing tool will allow for making target DNA modifications (deletions, insertions, or replacements in the nucleotide sequence) in animal cells. Therefore, knock-out and knock-in cells produced from the CRISPR-Cas system are widely utilised as model systems in disease studies, and those findings will lead to effective therapeutic development.

All together, these developments: from basic cell culture to organ-on-a-chip systems facilitate the acquisition of crucial accurate information by reducing the use of animals in research, speeding up the study process, such as in the drug development process. In the past few years, scientists have discovered a diverse range of animal cells and developed different growth techniques, which have enabled them to be used as animal models. All these convenient cost-effective technologies significantly contribute to the advancements in the biological sciences specially in the medical sector. Currently, several industrial applications of animal cell cultures are dramatically increasing; however, scientists are still working to ensure reproducibility, high-throughput analysis, compatible readout techniques, and automation to enhance their application capacity.

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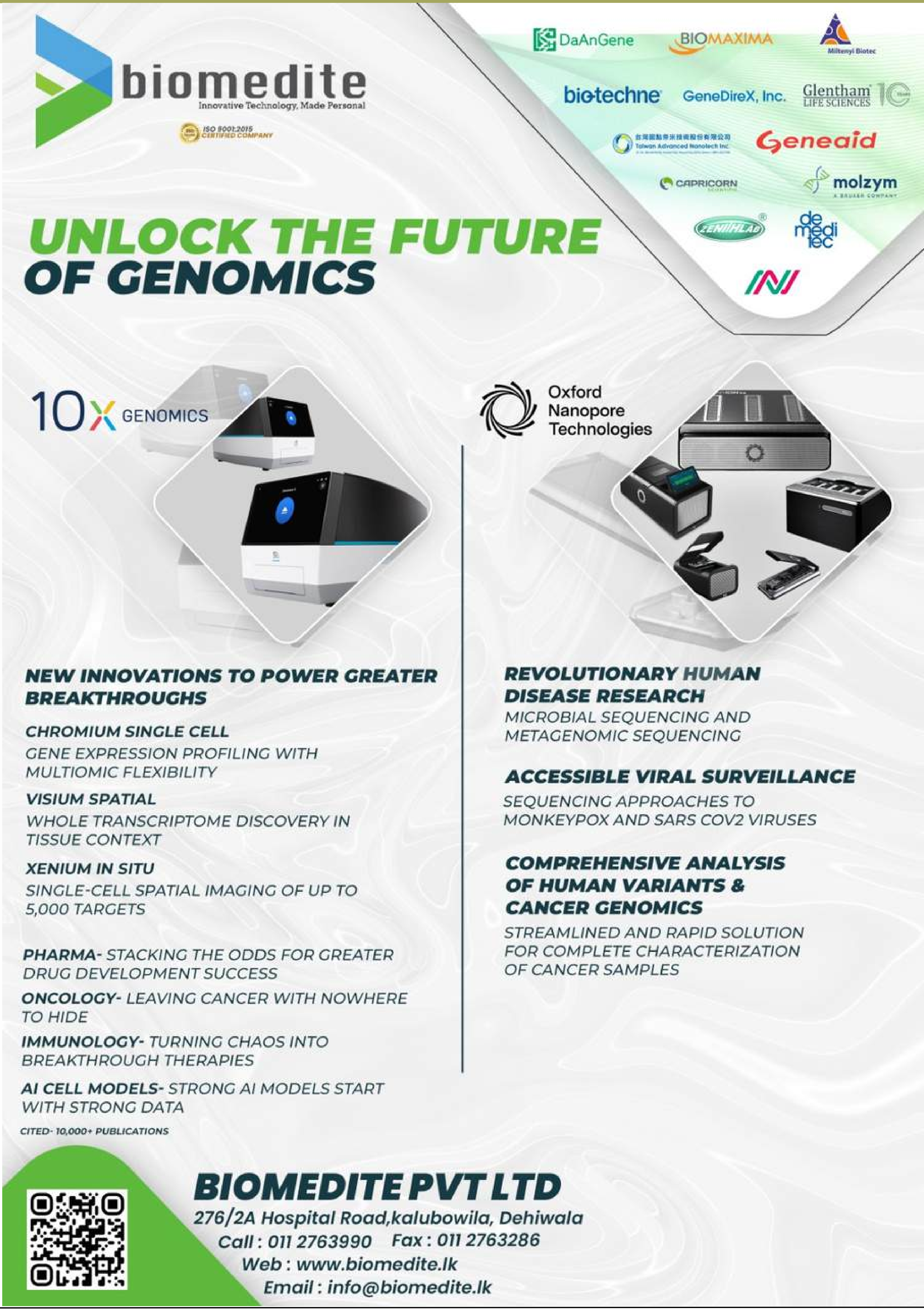
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Underutilized Fruit Crops to Tackle the Food, Nutrition, and Economic Security in Sri Lanka

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Sri Lanka, as a tropical country and biodiversity hotspot, provides conducive environments for diverse fruit crops. The presence of 46 agro-ecological zones in Sri Lanka supports the cultivation of a wide range of fruit crops, including underutilized varieties. The country is home to a large variety of fruit crops. This article explores the importance of underutilized fruits in addressing food, nutrition, and economic security challenges in Sri Lanka based on the ongoing research.

Underutilized fruit crops

The underutilized fruits are commonly known as fruit species whose potential have not been fully utilized. About 60 varieties were identified as underutilized fruit crops (UFCs), which are significant for their potential to enhance food security and nutrition.

Our study focused on underutilized fruits such as Nil veralu, Veralu, Sapodilla, Masan, Ugurassa, Ratagoraka, Kahata, Maran, Padagedi, Heendan, and Naminam (Table 1).

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Importance of underutilized fruit crops

Underutilized crops represent significant untapped resources that could enhance food security, health, income, and environmental benefits. These crops are vital for rural communities as they help improve livelihoods while promoting environmental sustainability. They decrease reliance on agricultural inputs like nitrogen fertilizers and enhance dietary diversity. Given their extensive genetic diversity, these crops can be valuable in future crop enhancement initiatives. Traditionally, underutilized crops have served as sources of food, fiber, medicinal products, fodder and oil. In Sri Lanka, neglected and underutilized fruit species are especially crucial for food and nutrient security as well as traditional medicine.

Distribution of underutilized fruit crops in Sri Lanka

Sri Lanka is an island that is particularly susceptible to the effects of climate change, which influences the distribution of species. In the country, the demand for commercially produced crop varieties has risen, while many traditional varieties have been largely neglected as underutilized crops (UCs). Approximately 60 varieties of underutilized fruit crops are cultivated, especially in less favorable environments throughout Sri Lanka. Although numerous underutilized crop species have been recognized in the country, only a handful are grown on a commercial scale. These plants thrive in all climatic zones nationwide, highlighting significant biodiversity.

Table 1 Underutilized fruit crop species in Sri Lanka

Common name	**Scientific name**	**Family**
Heendan	*Syzygium caryophyllatum*	Myrataceae
Padagedi	*Passiflora foetida*	Passifloraceae
Nilveralu	*Elaeocarpus angustifolius*	Elaeocarpaceae
Ugurassa	*Flacourtia indica*	Salicaceae
Veralu	*Elaeocarpus serratus*	Elaeocarpaceae
Naminam	*Cynometra cauliflora*	Fabaceae
Masan	*Ziziphus mauritiana*	Rhamnaceae
Sapodilla	*Manilkara zapota*	Sapotaceae
Kahata	*Careya arborea*	Lecythidaceae
Ratagoraka	*Garcinia xanthochymus*	Moraceae
Maran	*Syzygium zeylanicum*	Myrataceae

Value addition of underutilized fruit crops

The creation of value-added items like fruit jams, juices, dried snacks, jellies, beverages, fruit leathers, candies, cordials, syrups, and medicinal extracts can enhance the market worth of underused fruits and offer opportunities for local communities. By encouraging value addition, it fosters the empowerment of women in rural regions. Currently, there is a growing market demand for fruit pickles. Therefore, investigating innovative preservation methods can help prolong the shelf life of fruits and satisfy the rising demand for fruit pickles. Moreover, partnering with local farmers and cooperatives can booster the supply chain and promote sustainable economic development in rural areas. Furthermore, these fruits can be sustainably utilized for the production of nutraceuticals and pharmaceutical products. All of these initiatives aid in generating income within rural communities across the nation.

Underutilized fruit crops for promoting economic security

In Sri Lanka, the situation is further complicated by climate change, economic uncertainty, and the exhaustion of natural resources. Within these challenges, underutilized fruits often stand as significant unused assets in conventional agriculture and food systems, offering great potential for improving nutrition and economic stability.

Underutilized fruits symbolize an unexplored economic prospect for Sri Lanka. Their commercialization can create income streams for farmers and generate employment opportunities in processing.

Table 2 Value added products of underutilized fruits

Common name	Scientific name	Value added products
Heendan	*Syzygium caryophyllatum*	Wine
Padagedi	*Passiflora foetida*	Herbal tea, tablet, nutritional food powder
Nilveralu	*Elaeocarpus angustifolius*	Pickle,
Ugurassa	*Flacourtia indica*	Jam, Pickle, Jelly, Fruit leather
Veralu	*Elaeocarpus serratus*	Juice, Syrup, Nectar, Chutney, Pickle, Cordial, ice-cream, smoothie
Naminam	*Cynometra cauliflora*	Jam
Masan	*Ziziphus mauritiana*	Fruit powder
Sapodilla	*Manilkara zapota*	Fruit powder, Jam, Candy, Juice, Syrup, Nectar, Butter
Kahata	*Careya arborea*	Fruit powder
Ratagoraka	*Garcinia xanthochymus*	Jam, Dried fruit
Maran	*Syzygium zeylanicum*	Wine

Growing, adding value, and contributing to export revenues. Large-scale cultivation of these fruits offers numerous job opportunities, particularly as it aids in empowering women in rural communities.

During the fruit season, city dwellers often fill their containers with these fruits due to their nutritional value and health advantages. The weekly market acts as a hub where various underutilized fruits can be bought. Promoting a weekly marketplace with effective marketing strategies will facilitate the exchange of local goods and generate revenue for rural communities and wild gatherers. Different marketing strategies are employed by rural farmers to sell their local products, such as roadside stands, weekly markets in villages and cities, and establishing community collecting points.

During the fruit season, wild gatherers come to collect specific underutilized fruits. These groups aid in connecting rural farmers with urban markets, thus generating income. By supporting the transport and sale of these fruits, these organizations are vital in enhancing the economic sustainability of rural farming communities. Moreover, promoting sustainable harvesting methods guarantees the long-term availability of these precious resources. Underutilized fruits present an opportunity for farmers to diversify their income sources. These fruits require minimal resources and can thrive on less fertile lands, making them ideal for small farmers.

A steady supply of these fruits could reduce the need for fruit imports. Creating a fruit village is another strategy to promote these fruits and generate additional job opportunities. Furthermore, this can also benefit the country's tourism sector. Although most of these crops are seasonal and abundantly available at different times throughout the year, it is crucial to explore ways to ensure a continuous supply of these fruits to enhance processing and marketing strategies.

Numerous underappreciated fruits possess distinct flavors and nutritional advantages that resonate with international consumers. Establishing export-focused supply chains for these fruits has the potential to generate foreign earnings for Sri Lanka. By channeling resources into research and development to improve the quality and value of these fruits, Sri Lanka can position itself as a significant contender in the global health and wellness sector.

A major obstacle in promoting these fruits is the insufficient availability of planting material. Implementing comprehensive training programs, providing loan options, and disseminating knowledge to farmers can foster job creation through the production of superior planting material.

Additionally, investing in research and development to enhance farming practices and boost yields could also aid the expansion of the sector. By tackling these issues, Sri Lanka can further leverage the opportunities presented by its underutilized fruits for export.

Underutilized fruit crops for enhancing food security

Rising food insecurity can be attributed to several factors, including a growing population, climate change, and intensified pressure on traditional food systems. Consequently, it is vital to diversify agricultural resources. The effective utilization of underutilized fruits presents significant opportunities to address malnutrition and improve food security.

Fruits play a crucial role in our diet as they provide a wealth of macronutrients, micronutrients (such as vitamins and minerals), and antioxidants. The World Health Organization (WHO) recommends that adults consume at least 200 grams of fruits each day. Incorporating underutilized fruits into our diets can safeguard our bodies against various non-communicable diseases, including cancer, obesity, diabetes, and heart disease, while also combating malnutrition (Table 3).

Table 3 Health benefits of selected underutilized fruit

Common name	Scientific name	Value added products
Heendan	*Syzygium caryophyllatum*	Antidiabetic activity, anticancer activity, antioxidant activity, antimicrobial
Padagedi	*Passiflora foetida*	Anti-inflammatory, anti-epileptic, anti-hyperglycemic,
Nilveralu	*Elaeocarpus angustifolius*	Anti-inflammatory, antimicrobial, antihypertensive, antidepressant, analgesic, antioxidant activity
Ugurassa	*Flacourtia indica*	Leaves and roots are good for snake bites, good for diarrhea, and anti-inflammatory activities.
Veralu	*Elaeocarpus serratus*	Anti-inflammatory, anti-hyperglycemic, anti-diarrheal, anti-arthritic activity, good for analgesic activities
Naminam	*Cynometra cauliflora*	Good for high blood pressure and diabetes and for skin disease
Masan	*Ziziphus mauritiana*	Anti-obesity, anti-cancer, anti-inflammatory, anti-diarrheal, anti-diabetic, anti-steroidogenic activity, antioxidant activity, cholesterol lowering activity and anti-obesity activity
Sapodilla	*Manilkara zapota*	Reduce the risk of chronic diseases, anti-inflammatory properties, anti-diarrheal, antifungal, anti-arthritis, hemorrhage, pulmonary problems, muscle spasms and breast cancers
Kahata	*Careya arborea*	Astringent, demulcent, antipyretic, antipruritic, in cough, cold and eruptive fevers Smallpox Snake bite, antiobesity, antidiabetic, anticancer, wound healing activities
Ratagoraka	*Garcinia xanthochymus*	Good for fat burning, obesity, diabetes, antioxidant, anti-inflammatory activity
Maran	*Syzygium zeylanicum*	Anti-inflammatory activities, anticancer, anti-diarrheal, antidiabetic and antiobesity activity

Despite their high nutritional benefits and environmental advantages, underutilized fruits are often overlooked in favor of widely consumed fruits like bananas, apples, and oranges. Factors such as limited research, low awareness, and insufficient market access contribute to their lack of utilization.

Our investigation has shown that these fruits are rich in polyphenols and antioxidants. Furthermore, Kahata, Maran, Ratagoraka, and Heendan provide beneficial antidiabetic effects. Including these fruits in everyday diets can help combat nutrient deficiencies, especially in areas where malnutrition is widespread. Food security, which entails ensuring everyone has access to enough safe and nutritious food, is a pressing issue in Sri Lanka. Underutilized fruits could significantly help tackle this challenge. These lesser-known fruit crops are nutrient-rich, support health, and are resilient to climate impacts, thereby enhancing food security.

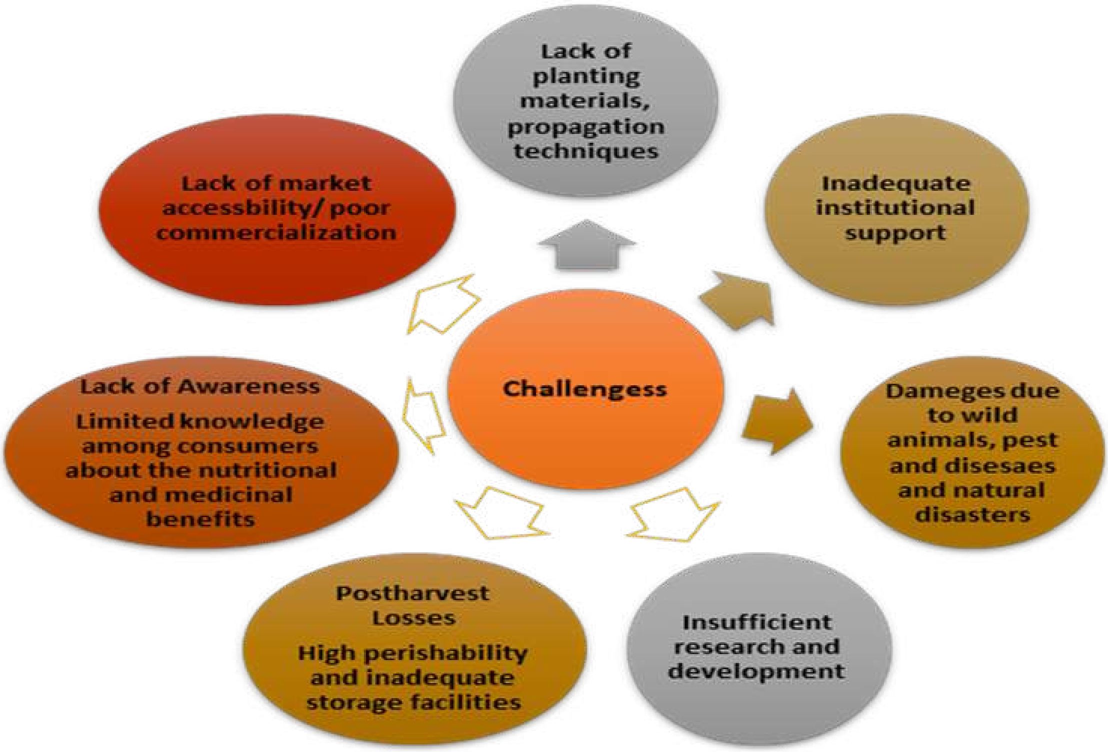
There is a heightened demand for these fruits during periods of fruit scarcity. These crops grow naturally with minimal input and do not rely on artificial methods to ripen, which makes them safer to eat than commercial varieties.

Underutilized fruit crops are well-suited to endure harsh environmental conditions, such as drought, high salinity, and poor soil quality. Their growth patterns establish them as dependable crops amidst climate change, thereby ensuring a consistent food supply even during challenging times.

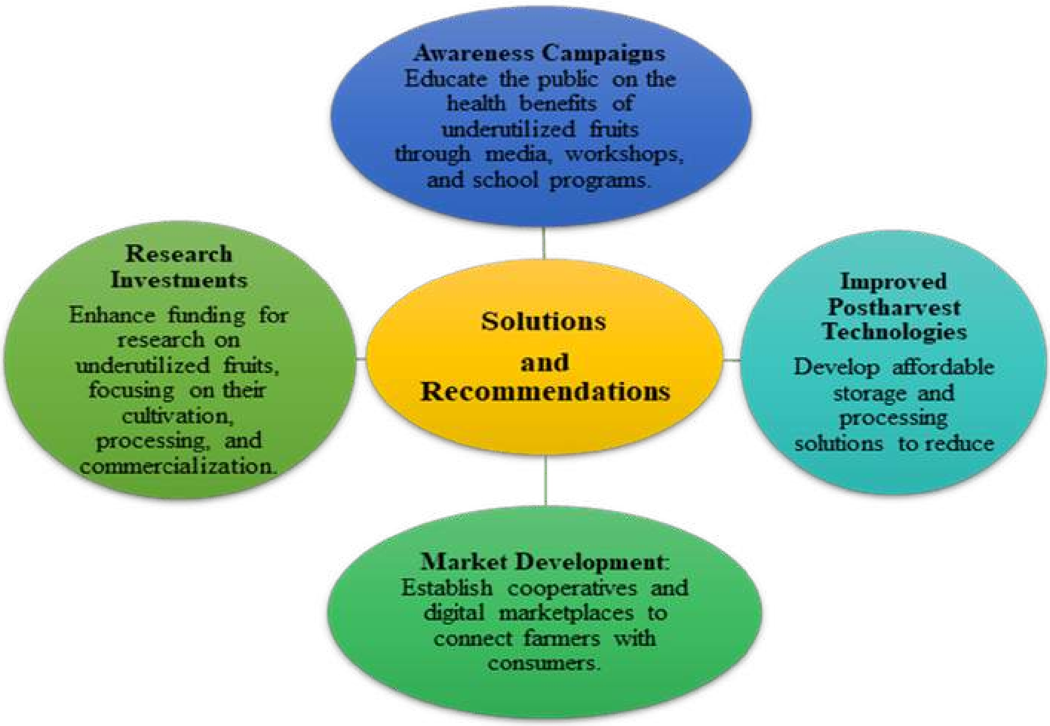
Encouraging the cultivation of these lesser-known crops enhances agricultural biodiversity, which is essential for maintaining ecosystem stability and resilience. Moreover, growing these fruits helps generate income and improves market access for rural communities.

Diverse cropping practices are less susceptible to pests, diseases, and extreme weather, guaranteeing sustainable food production.

Heavily depending on a small number of staple crops like rice, wheat, and maize exposes the food supply in Sri Lanka to potential risks. By incorporating underutilized fruits into diets, we can mitigate the vulnerabilities linked to monoculture and disruptions in the supply chain.



Challenges in promoting underutilized fruits



Solutions and Recommendations

The underutilized fruits in Sri Lanka serve as more than simply a food source; they are abundant in nutrients, essential for food security, and a driver for economic development. By integrating these fruits into mainstream farming and dietary practices, Sri Lanka can address critical challenges such as malnutrition, poverty, and environmental issues. Collaboration among policymakers, researchers, and communities is essential to fully harness the benefits of these fruits and ensure their potential is realized.

Through proactive initiatives, Sri Lanka has the opportunity to establish itself as a global frontrunner in the sustainable and responsible utilization of underutilized fruits, fostering a healthier, safer, and thriving future for everyone. It is crucial for Sri Lankan society to accept these exceptional fruits, not only for their distinctive characteristics but also for their promise to improve our health and well-being.

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Can Humans and Elephants Live Without Fear?
The Present and Future of Human-Elephant Conflict in Sri Lanka

This article is based on the panel discussion organized by the Institute of Biology Sri Lanka (IOBSL), Council 2024-2025. The panel discussion title was "*Finding Sustainable Solutions for Human-Wildlife Conflict in Sri Lanka*." The event was held at the Hector Kobbekaduwa Agrarian Research and Training Institute (HARTI), Wijerama Mawatha, Colombo, on 8th April 2025 at 2.00 p.m. onwards. The session's main objective was to understand the extent of human-wildlife conflict in Sri Lanka and find a sustainable solution with the collaboration of all stakeholders.

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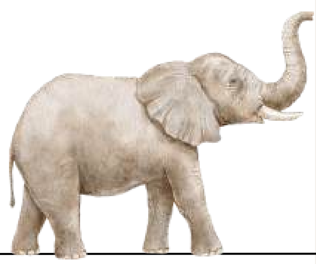
Why, and what is conflict?

In the current Anthropocene era, humans and animals constantly struggle to find food, water, and shelter. Wildlife and human habitats overlap and share common resources in many parts of the world, leading to regular human-wildlife encounters. The IUCN Species Survival Commission (SSC) defines the human-wildlife conflict as 'struggles that emerge when the presence or behaviour of wildlife poses an actual or perceived, direct and recurring threat to human interests or needs, leading to disagreements between groups of people and negative impacts on people and/or wildlife' (IUCN SSC, 2022). Human-wildlife conflict is becoming a burning problem in tropical areas due to human population dynamics, human resource requirements, land use change, extractive industries, linear infrastructure, perceptions of nature, market forces, policy effects, wildlife population dynamics, wildlife behaviour, and climate change. Some factors, such as habitat loss and fragmentation, disturbance of wildlife, blocking of wildlife corridors, extreme weather events, natural calamities, the effect of invasive species, economic hardship, attractants such as waste, human food, highly palatable crops, and livestock, may increase pressure, augmenting the human-wildlife conflict. In Sri Lanka, three major wildlife species are involved in HWC: elephants, monkeys, and crocodiles. The human elephant conflict (HEC) has become a unique and significant issue due to its economic, ecological, cultural, social, and political aspects.



Human-elephant conflict in Sri Lanka

In the past, humans elevated elephants into a divine state, making them part of their tradition and culture. Elephant domestication using traditional taming practices and traditional medicinal treatments revealed the closer relationships of humans and elephants in ancient human communities. Elephants are considered keystone species because their presence and activities disproportionately impact their ecosystems. Their ability to modify landscapes through feeding, uprooting trees, and trampling vegetation creates a mosaic of habitats, benefiting a wide range of species while contributing to seed dispersal, promoting the regeneration of different plant species across vast distances. Despite the elephants' cultural, ecological, and economic advantages, they have become among the most hated animals in the human-wildlife conflict scenario. How is this possible in a country like Sri Lanka, where most of the population is influenced by Buddhist cultural practices?

There are a few reasons emphasized during the panel discussion. Sri Lankan forest cover has been declining rapidly, and in 2019, it was only 21% of the total land area. Expansion of agricultural lands with the accelerated hydropower projects and irrigation has resulted in nearly 69.4% of the elephant ranges falling within human-prone areas. Dr Chathura K. De Silva mentioned that according to their research, 37% of the rural population lives in conflict-prone areas, and most of these lands are suitable for humans and elephants.

Most of the recent development projects in Sri Lanka have taken place in the dry zone, with the expansion of agricultural plantations and the resettlement of people, which have significant human elephant encounters and aggravate conflicts between wild elephants and people.

Conflicts between people and elephants and poaching are the leading causes of the decline in the wild elephant population, which has dropped from about 12,000 in the 19th century to about 4,000. Human-elephant conflict (HEC) poses a significant challenge to the destruction of both human and elephant lives in the past decade in Sri Lanka. According to wildlife reports, 380 elephant deaths and 154 human fatalities were recorded in 2024. Moreover, 2,111 human and 5,954 elephant fatalities were reported due to HEC within the last three decades in Sri Lanka.

According to the esteemed panelists, the HEC of Sri Lanka has become a complex, and each situation has unique ecological, cultural, social, economic, and political characteristics. Professor Sampath Seneviratne mentioned that different authorities and administrative personalities believed their opinions and suggestions were correct in relation to HEC. However, farmers struggling to maximize harvest for economic benefit, conservation activists trying to protect elephants, and administrative personnel bound to perform their duties struggle to solve this problem.

Possible mitigation strategies and future perspectives

Human-elephant conflict mitigation strategies have been suggested and reported by many international organizations such as the World Wildlife Fund (WWF), the International Union for Conservation of Nature (IUCN and the Food and Agriculture Organization (FAO) of the United Nations. The basic steps FAO (2021) suggested for HWC mitigation are as follows: (1) take into account social, political, and cultural root causes, (2) formulate case-specific policies and strategies, (3) develop an integrated land-use planning system, (4) empower affected local communities from the start, (5) build effective early-warning systems, (6) set up rigorous data collection systems, (7) create robust monitoring and reporting frameworks, (8) establish multi-sectoral partnerships from the outset. IOBSL also generated recommendations aligning with FAO suggestions.

HEC in Sri Lanka shows area-specific and crop-specific issues. Wild elephants have complex biology, population dynamics, migratory patterns, resource needs, and space requirements in different landscapes. Solving wildlife problems must consider the ecocentric perspective, keystone value, flagship value, and ecosystem services elephants provide. Dr Lakshman Peiris mentioned that human-elephant conflict should be addressed from a conservation perspective, while other human-related disputes should be addressed by considering conflict mitigation and disaster management strategies.

During the IOB panel discussion, Dr. Dulan Jayasekara emphasized the vital importance of data for conflict mitigation. Data deficiencies in some areas, behavior patterns of elephants, and land use patterns pose obstacles in tackling HEC. A broader research intervention must be implemented to generate data, and sufficient funding is needed to implement research activities wherever necessary. A collaborative multidisciplinary approach should be followed for successful data generation. Dr. Shamen Vidanage stated that, rather than moving towards conflict, empower people to value the ecosystem services through a people's willingness to pay (WTP) scheme, which can be used to compensate for the damage and manage the resources using a social-ecological system.

Dr. Shamen mentioned that, instead of clearing up more forest areas and changing natural habitats into agricultural systems, present agrarian lands can be enriched to gain more profit. As a concluding remark, Dr. Kalinga Padmal and Mr. Hemantha Warnakula emphasized that Sri Lanka has sufficient policies, laws, and management plans, but implementation and monitoring are not adequately done. If amendments are needed, they should be made based on the present knowledge and scenarios, and the government should consult the experts in the field of wildlife science and other related disciplines. Strong political support under the president's patronage will positively influence mitigating HEC in Sri Lanka.

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Photograph by Vimukthi R. Gunasekara
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UPDATES ON THE LATEST RESEARCH

Algae to Paper: How *Spirogyra* sp. Could Help Build a Greener Future for the Global Paper Industry

The modern paper industry is inseparable from forests. For centuries, wood-based cellulose has been the foundation of paper production, powering industries from printing and packaging to education and commerce. But this reliance comes at a significant environmental cost. Deforestation, energy-intensive pulping processes, and the release of toxic effluents continue to challenge the sustainability of conventional paper manufacturing. As global demand for paper products rises, driven in part by e-commerce and single-use packaging, the search for environmentally responsible alternatives has become more urgent than ever.

A growing body of research now points to an unexpected but promising solution: algae. Among these, *Spirogyra* sp., a familiar filamentous green alga often found in freshwater bodies (Figure 1a), is emerging as a potential raw material capable of reducing the industry's ecological footprint.

A recent study explores this idea in detail, evaluating *Spirogyra* sp. as a lignin-free, rapidly renewable alternative to wood in paper production.

Why *Spirogyra* sp.?

Spirogyra sp. is best known for its striking spiral chloroplasts (Figure 1b), but its deeper value lies in its biology. Unlike wood, *Spirogyra* sp. contains no lignin, the complex polymer that makes pulping wood so chemically demanding. Removing lignin from wood requires strong alkalis and bleaching agents. These processes are energy-intensive and often release harmful compounds into waterways. A lignin-free source like *Spirogyra* sp., therefore, offers the potential for cleaner processing, fewer chemicals, and lower environmental impact.

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Additionally, *Spirogyra* sp. grows rapidly and requires minimal inputs: sunlight, water, and simple nutrients. Many species thrive under conditions where agricultural crops are unable to cultivate without competing for arable land. This rapid productivity makes it an appealing candidate for biomass-based industries seeking renewable feedstocks.

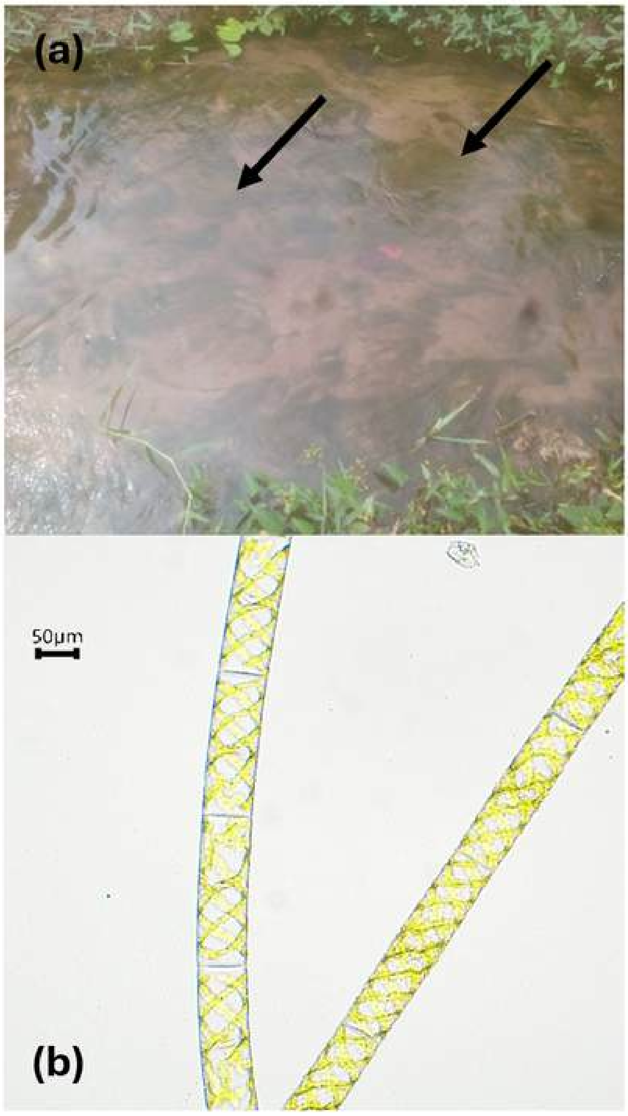


Figure 1 (a) Natural habitat where green alga, *Spirogyra* sp. has collected for the present study; (b) The cellular structure of *Spirogyra* sp. filaments under light microscope

Optimizing growth: from flask to scaled culture

The first step in assessing *Spirogyra* sp. as a viable fiber source is identifying optimal growth conditions. In the study, researchers cultivated the alga in three standard laboratory media, CHU 10, Bold's Basal Medium (BBM), and a triple-strength variation, 3N BBM, over six days. Starting with a modest inoculum of around 10 milligrams, they measured fresh biomass daily to determine which medium stimulated the greatest growth.

The results were decisive. Cultures grown in 3N BBM showed consistently higher biomass gains, increasing from 10.15 ± 0.06 mg to 12.73 ± 1.15 mg by day six. In contrast, those in CHU 10 experienced steady decline, dropping to 3.09 ± 0.98 mg, indicating that this medium is unsuitable for sustaining healthy *Spirogyra* sp. populations. A statistical comparison using ANOVA confirmed significant differences between treatments.

Taking these findings further, the researchers conducted a larger optimization trial using a 100 mg inoculum in 3N BBM (Figure 2). With 16 replicates, they tracked biomass over several days and found maximum accumulation occurring between 72 and 96 hours, with biomass peaking at 137.88 ± 4.90 mg before beginning to decline (Figure 3). This clearly defined the ideal harvest window, an essential parameter for anyone planning large-scale cultivation.

Scaling the culture from laboratory flasks to 500 mL vessels also proved successful, although dissolved oxygen emerged as a limiting factor. Maintaining oxygenation will therefore be important for future attempts to scale *Spirogyra* sp. biomass production to industrial volumes.

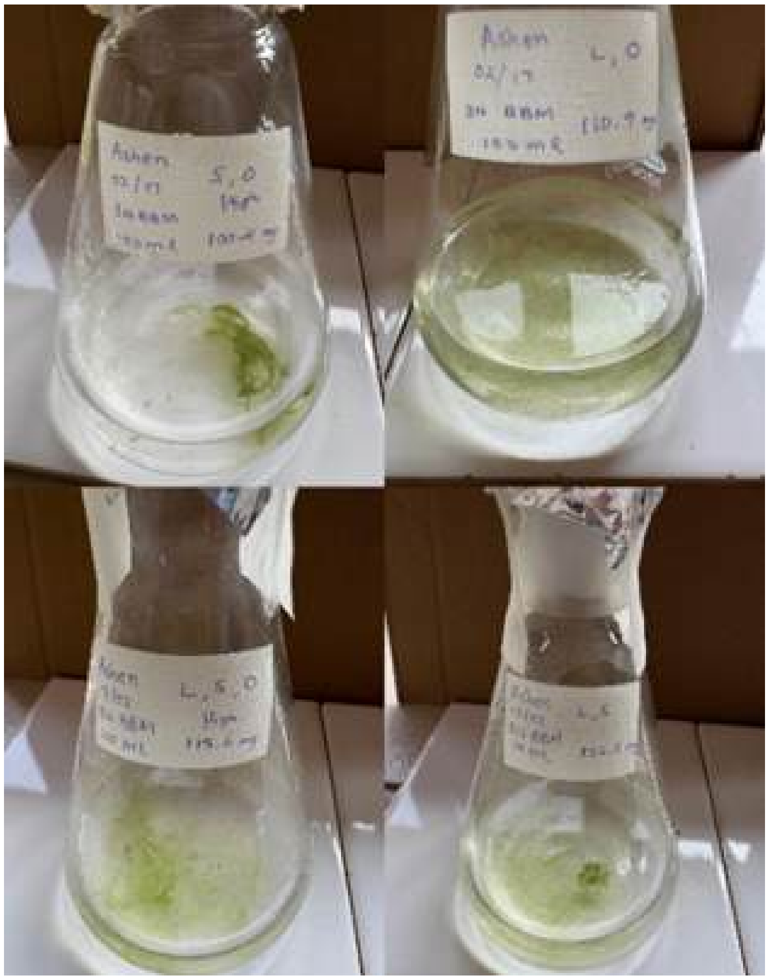


Figure 2 Culturing *Spirogyra* sp. in culture vessels

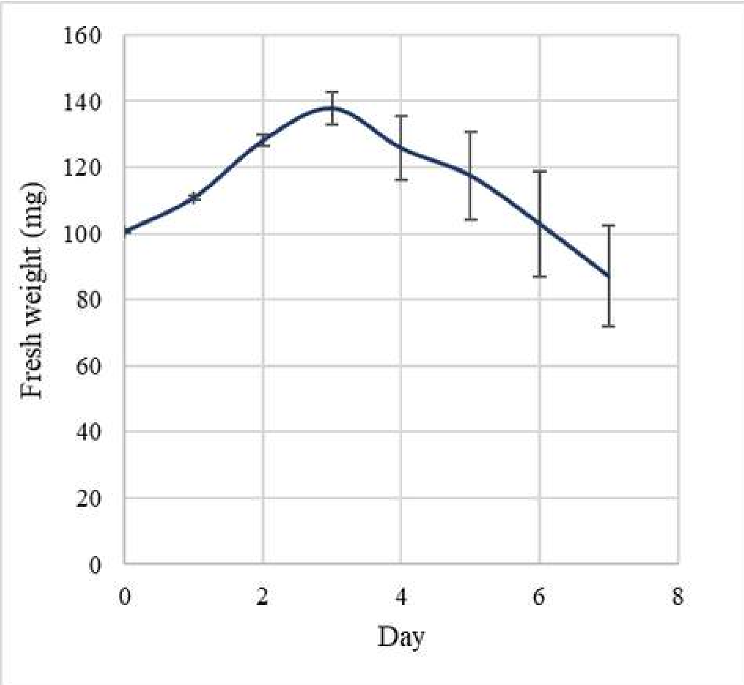


Figure 3 Growth curve of the *Spirogyra* sp. for the incubation period of 7 days

Green chemistry for green paper

Traditional paper processing depends on harsh chemicals for pigment removal and fiber separation. This study instead employed a green chemistry approach, prioritizing biodegradable and less damaging alternatives (Figure 4).

To remove pigments from the algal filaments, researchers used hot saturated salicylic acid, a mild, plant-derived compound that effectively bleaches green biomass without resorting to chlorine-based oxidants. This is a significant step toward reducing the environmental toxicity often associated with pulp bleaching operations.

Softening the filaments essential for forming uniform paper sheets was achieved using a dilute fabric softener solution. This gentle treatment loosened the natural mucilage and allowed fibers to disperse more evenly during sheet formation.

Using a classic deckle-and-mold (Figure 5a) method, the team then pressed and air-dried the resulting pulp, producing sheets of *Spirogyra* sp.-based paper (Figure 5b).

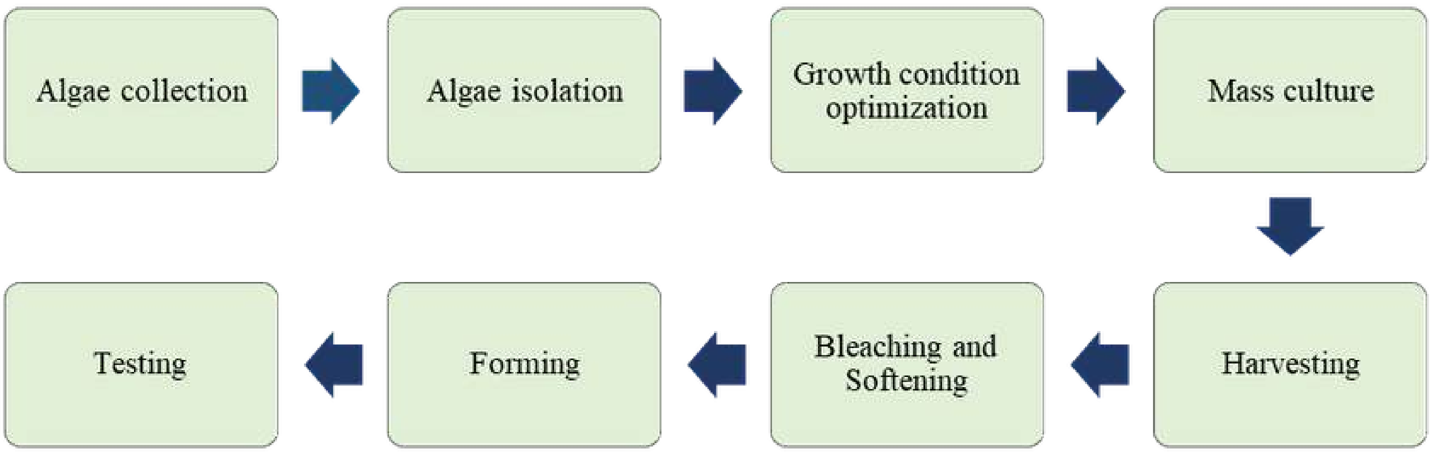


Figure 4 Overview of the experimental methodology

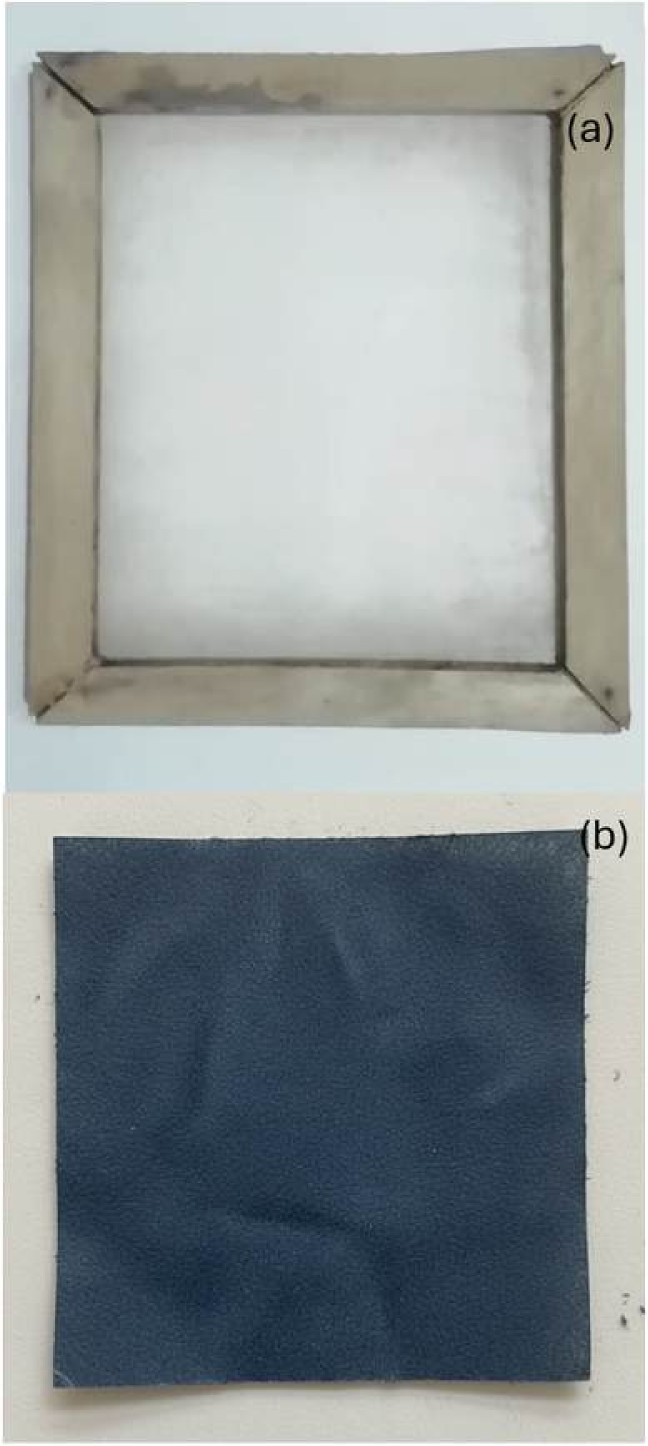


Figure 5 (a) Prepared deckle and mold for the paper production; (b) Prepared paper samples

What does algal paper look like?

The paper produced from *Spirogyra* sp. exhibited distinctive physical properties. The grammage (paper mass per unit area) was 182.42 ± 1.59 g/m^2, placing it in the heavyweight category. The sheets had a thickness of 0.32 ± 0.01 mm, a moisture content of 11.48 ± 0.47%, and a density of 0.563 g/cm^3. With a bulk value of 1.776 cm^3/g, this paper is relatively porous compared to standard wood-based papers.

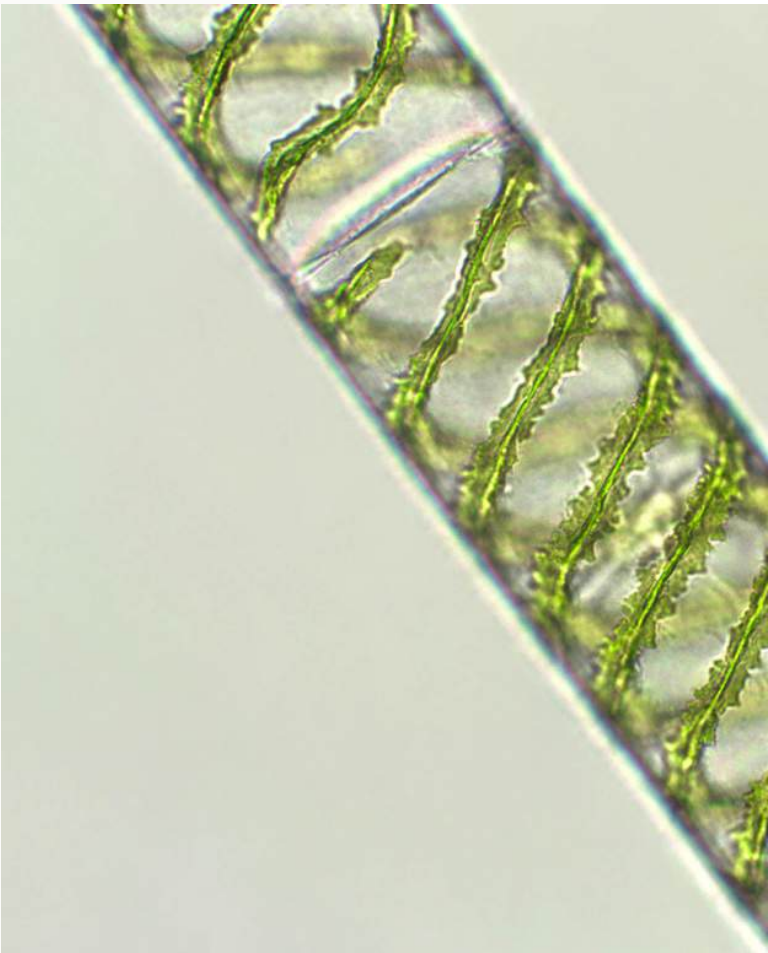
A defining feature of *Spirogyra* sp. is its long filaments, some up to 5 centimeters in length. While typical papermaking fibers are measured in millimeters, these long algal strands contributed significantly to the paper's high grammage and structural texture.

However, the material's tensile strength was low (0.4416 N or 29.44 N/m), making the sheets comparable to tissue-grade paper rather than writing or packaging paper. Yet this limitation is not insurmountable. When researchers blended *Spirogyra* sp. fibers with traditional softwood pulp, they observed clear improvements in mechanical strength, suggesting that algal biomass could serve as an effective supplementary fiber rather than a complete replacement.

Sustainable path forward

While *Spirogyra* sp. alone may not yet rival wood in producing high-strength paper, this study demonstrates its strong potential as a sustainable, lignin-free, rapidly renewable raw material. Used in combination with existing plant fibers or as the foundation for specialty papers, algal cellulose could significantly reduce environmental impacts in an industry seeking to reinvent itself.

As climate pressures intensify and industries transition toward circular, low-impact production systems, unconventional biological resources like *Spirogyra* sp. offer an exciting glimpse into the future. With further research, scaling, and technological refinement, the humble green filaments often seen floating in ponds may one day play a meaningful role in reshaping the global paper economy.



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CORNER FOR YOUNG BIOLOGISTS

Why Do We Dream? The Science Behind the Night Show

Dreams have inspired humans across nations and centuries, appearing in ancient religious writings, mythology, and philosophies as sources of guidance, prediction, and inspiration. "Why do we dream?" is still one of the most fascinating mysteries in biology and psychology, despite the development of modern neuroscience, Carl Jung's prototypes, and Sigmund Freud's psychoanalytic interpretations. Dreams are not random outcomes of sleep; rather, they reflect highly structured brain processes that may play roles in memory, emotion, creativity, and even survival. This article dives into the scientific basis of dreaming, including its neurological and chemical background, emotional and cultural relevance, and the exciting future potential of research regarding dreams.

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The neurobiology of sleep and dreaming

Sleep is not a single, consistent state but rather a series of stages, each with its own set of dreams. Sleep is typically classified into two types: rapid eye movement (REM) sleep and non-rapid eye movement (non-REM) sleep. Non-REM sleep accounts for 75-80% of total sleep and is divided into three stages. Stage 1 is light sleeping, which marks the transition from wakefulness to sleep.

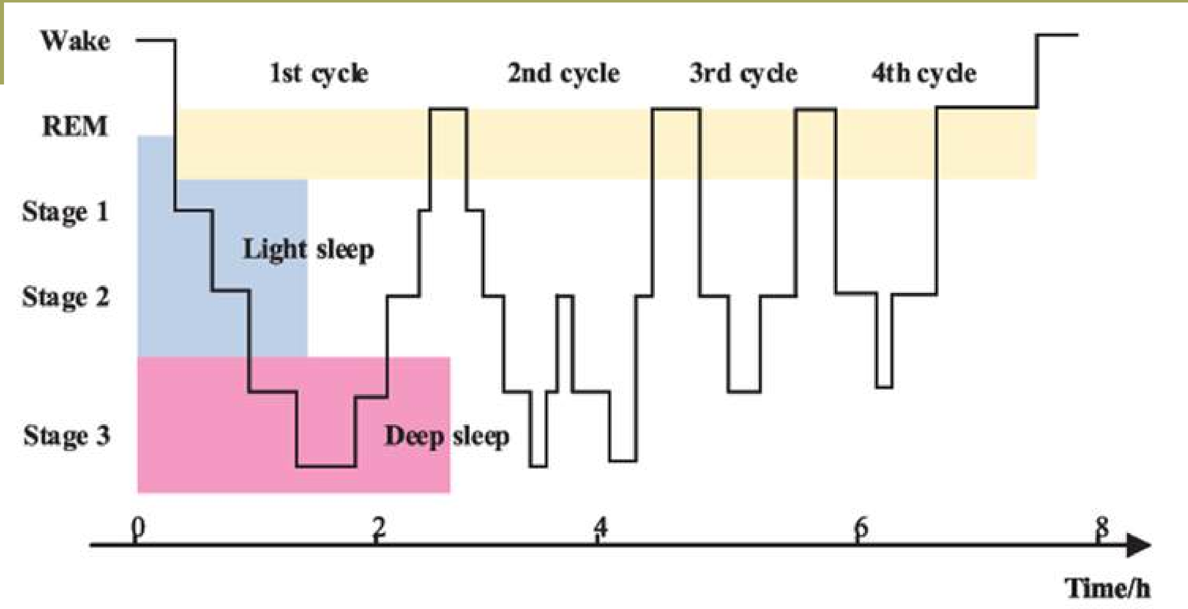

Figure 1 The general sleep transitions and sleep cycle
Source: https://www.researchgate.net/figure/The-general-sleep-transitions-and-sleep-cycles-Sleep-generally-transitions-from-the-wake_fig2_360908182

Stage 2 is slightly deeper, with slower breathing and heart rate and a lower body temperature. Stage 3, commonly known as slow-wave sleep, is the deepest and most restorative phase, necessary for tissue repair, immune function, and total physical recovery (Figure 1).

Dreams during REM sleep are typically vivid, emotional, and often odd, which most people associate with the dream state. In contrast, dreams occurring during non-REM sleep are less vivid and more thought-like, often reflecting everyday concerns. REM sleep can be identified by increased brain activity, fast eye movements, and muscle paralysis, indicating that the body is protected from acting out dreams. Importantly, humans experience 4–6 sleep cycles per night, with REM phases becoming longer toward the morning. Both REM and non-REM dreams appear to contribute uniquely to memory, psychological balance, and creativity, emphasizing the complexity of dreaming across the sleep cycle.

Modern neuroscience has discovered distinct brain areas that are activated during dreaming. The limbic system, which governs emotion, is extremely active during REM sleep, giving dreams their significant emotional nature (Figure 2). In contrast, the prefrontal cortex, which is responsible for logic and decision-making, is less active (Figure 3). This imbalance explains why dreams might feel emotionally powerful but irrational.

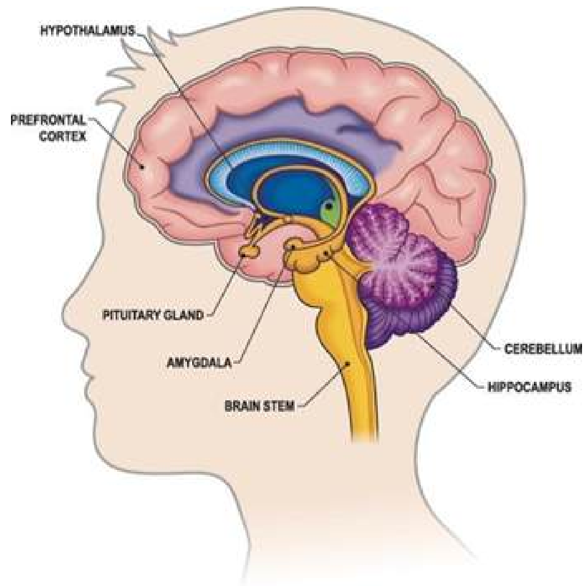

Figure 2 The limbic system
Source: https://qbi.uq.edu.au/brain/brain-anatomy/limbic-system

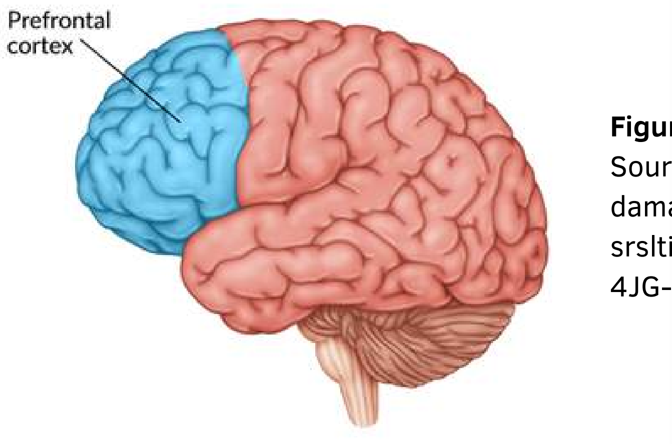

Figure 3 The prefrontal cortex of the brain
Source:https://www.flintrehab.com/prefrontal-cortex damage/?srsltid=AfmBOorQtEQNOPP8AteHbGp3D8cGhRGfapGcRpIUAY4JG-KzaZDksfxy

Another key system is the Default Mode Network (DMN), which consists of regions of the brain that are engaged during self-reflection and daydreaming (Figure 4). Its activity during dreaming indicates that our dreams have an unbreakable connection to our waking thoughts, concerns, and personal experiences.

The strangeness and intensity of dreams can be better understood by studying their neurochemical foundation. During REM sleep, acetylcholine levels rise, boosting brain activity and leading to vivid dreams. At the same time, serotonin and norepinephrine levels decrease, weakening rational thought and self-control, explaining the illogical and emotionally charged nature of many dreams. Dopamine, which relates to motivation and reward, remains active and may contribute to high emotional sensitivity. This fluctuating balance of neurotransmitters shows that dreams are influenced by a distinct neurochemical environment that differs significantly from both waking consciousness and deep non-REM sleep.

From an evolutionary aspect, the Threat Simulation Theory indicates that dreams once served as virtual training grounds for survival. For example, in ancestral environments, repeatedly simulating scenarios such as escaping from predators or navigating dangerous territories during dreams may have enhanced rapid threat recognition and defensive responses in day-to-day life. By rehearsing challenging scenarios, such as facing competition, our ancestors may have enhanced their capacity to respond to real-life threats. Many people still describe dreams about falling, being chased, or being in danger, indicating that this adaptive mechanism continues to shape dream content in modern times.

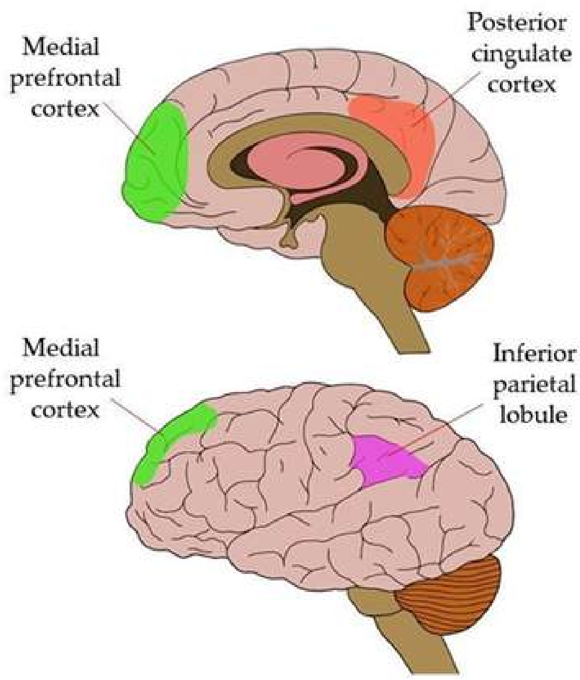

Figure 4 Regions of the default mode network (DMN)
Source:https://neuroscientificallychallenged.com/posts/know-your-brain-default-mode-network

Contribution of dreams to memory and emotions

One of the most accepted explanations for dreaming is that it helps with emotional control and memory consolidation. Dreams give a "safe space" for the brain to process emotions like fear, happiness, anxiety, and excitement, hence promoting psychological balance. Nightmares, while upsetting, are an extreme type of this process that frequently occurs in reaction to unresolved stress or trauma. Lowering daily stress has been shown to reduce their occurrence.

Dreams not only regulate emotions but also help to consolidate memories by converting short-term experiences into long-term storage. According to research, those who do not get enough REM sleep are extremely poor at memory-related activities, especially those requiring emotional material. Importantly, dreams rarely recreate events precisely as they occurred; instead, they combine fragments of experience to create new and frequently creative scenarios, for example, dreaming of studying in a classroom only to realize that it is on a beach. This combination of memory and imagination demonstrates how dreams help with emotional processing while also improving learning and adaptation.

Dreams reflect our daily lives

The continuity theory proposes that dreams reflect our waking lives. For example, students may dream about exams during stressful times, while sportsmen may dream about their sport during contests. This demonstrates that dreams are not just random, irrelevant, and illogical actions. Instead, they frequently refer to our thoughts, concerns, and daily activities. Dreams may thus serve as a personal diary, expressed in an unusual, creative manner.

Dreams are more than just about survival or memory; they can additionally inspire creativity. Because the dreaming brain connects in unusual ways, it can develop new, innovative thoughts. Many scientific and artistic accomplishments are associated with dreams. For example, Dmitri Mendeleev, who created the periodic table, believed the structure came to him in a dream. Modern research confirms that dreams can assist people in solving difficulties by mixing concepts in unexpected ways. This makes dreaming an attractive field of study in creativity and innovation.

Dreams and mental health

Dreaming is closely linked to psychological health. Individuals with depression, anxiety, or post-traumatic stress disorder (PTSD) frequently report altered dream content or disrupted REM sleep patterns. In PTSD, recurrent nightmares often reflect traumatic experiences, highlighting the strong connection between dreaming and emotional memory processing. This relationship has important clinical implications, as therapeutic approaches such as imagery rehearsal therapy, which involves modifying distressing dream content, and cognitive behavioral therapy for sleep disturbances have been shown to reduce nightmare frequency and emotional distress. Consequently, understanding the mechanisms of dreaming may contribute to the development of more effective treatments for mental health disorders, making it one of the most promising areas of research in neuroscience and psychology.

The future of dream research

Neuroimaging and brain-computer interface advancements have resulted in a new era of dream research. Researchers are using functional Magnetic Resonance Imaging (MRI) and electroencephalography (EEG) to analyze brain activity patterns, allowing them to reconstruct simple dream visualizations. Targeted memory reactivation (TMR), which uses sensory signals during sleeping to enhance certain memories, is being investigated as a tool for education and rehabilitation.

Lucid dreaming, in which the dreamer becomes aware of their dream state, provides unique therapeutic potential, particularly for lowering nightmares. Understanding dreams may change the way we think about cognition, creativity, and mental health as research continues.

Although the precise function of dreaming remains unresolved, evidence suggests that dreams arise from coordinated neural activity during sleep and support multiple adaptive processes. Research indicates that dreaming, particularly during REM sleep, contributes to memory consolidation, emotional regulation, and the simulation of threatening or socially relevant situations. These processes allow the brain to integrate past experiences with ongoing emotional concerns, thereby promoting behavioral flexibility and psychological resilience. Far from being a passive or meaningless phenomenon, dreaming reflects an active state of brain function that engages memory, emotion and perception networks during sleep. By linking neurobiological mechanisms with psychological and evolutionary perspectives, the study of dreams offers a valuable framework for understanding both normal cognitive function and the neural disruptions underlying mental health disorders. Continued research in this area may therefore inform future therapeutic strategies and deepen the understanding of the human brain.

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Cancer through an Evolutionary Lens at the Genomic Level: Clonal Evolution and Beyond

Cancer biology has been studied through various lenses over the years. However, one of the most discussed perspectives is cancer as an evolutionary system, which is influenced by changes in the genome. The gradual accumulation of genetic changes drives cancer as a dynamic and evolving system. Therefore, cancer is neither a single nor a static entity.

Due to genetic changes ranging from point mutations to chromosomal rearrangements, normal cellular functions are disrupted. As a result, affected cells gain abnormal growth advantages that enhance their survival. With the accumulation of genetic alterations, tumors become increasingly genetically diverse and create a complex microenvironment. This process is known as clonal evolution. Under selective pressures such as hypoxia, immune surveillance, or therapeutic intervention, some clones thrive while others are eliminated. Over time, the tumor genome reflects both the acquired mutations and the evolutionary history of which clones were favored and why.

When understanding cancer biology, the concept of cancer as an evolutionary system is central. This article explores how this idea originated as a theory decades ago and how it has been refined through genomic discoveries in the modern era. The biological importance of tumor evolution at the genomic level is emphasized throughout this article.

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Mapping tumor genomic evolution through clonal evolution

Clonal evolution was first proposed by Peter Nowell in 1976. According to this theory, cancer does not arise from a single genetic event; rather, it evolves through a series of successive mutations. Mutations that accumulate in progenitor cells are passed on to subsequent cell generations, forming a clone. The growth and survival of these clones are favored by certain mutations.

Nowell proposed that tumors are genetically diverse and that natural selection acting on genetic alterations results in a dynamic population of competing clones. A clone is defined as a population of cancer cells that shares a common set of somatic mutations inherited from a common ancestor. These mutations include point mutations in coding and regulatory genes, copy number alterations, structural variants, and genome-doubling events. Subclones with favorable mutations are continuously selected, adapt, and evolve. Consequently, cancers often become more aggressive and treatment-resistant over time.

Nowell's model shifted the perspective of cancer from a static disease characterized by uncontrolled proliferation to a genetically fluid system shaped by mutation and selection (Figure 1). Although conceptual at the time, the clonal evolution model laid the theoretical foundation for decades of future research, much of which has been validated through advances in cancer genomics.

In 2012, Gerlinger et al. identified dramatic genomic differences across different regions of renal carcinoma tumors. This study challenged the idea that tumors follow a simple linear path of progression and instead supported a branched evolutionary model. In this model, different clones emerge independently and coexist rather than sequentially replacing one another. This branching leads to intratumor heterogeneity, where different tumor regions harbor distinct subclonal mutations that respond differently to treatment and evolve resistance through separate paths. Due to this complexity, the full mutational landscape of a tumor cannot be captured by a single biopsy. Such heterogeneity is a hallmark of cancer and a major contributor to therapy failure and disease relapse.

The discovery of trunk mutations, which are common to all cancer cells, and branch mutations, which are restricted to subclones, validated the evolutionary framework of cancer genomes proposed by Nowell.

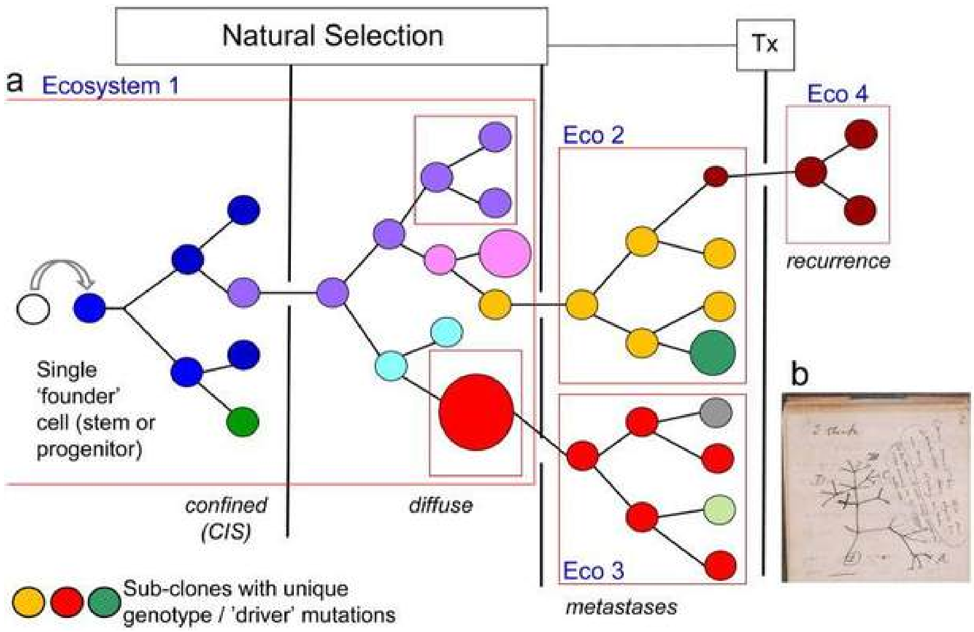

Figure 1 (a) The branching architecture of evolution in cancer; (b) Darwin's branching evolutionary tree of speciation from his notebook Source: Greaves and Maley (2012)

Classic driver mutations are often identified early in tumor development, whereas additional mutations arise later within specific clones. These findings demonstrate that tumors contain multiple coexisting genetic lineages that can compete within the same individual.

Tumor evolution can be mapped using phylogenetic reconstructions, in which early driver mutations form the trunk of the evolutionary tree and later subclonal events form the branches. Because clonal evolution is structured rather than random, it can be tracked, compared, and, to some extent, anticipated.

What clonal evolution teaches us about cancer behavior

Understanding clonal evolution is not merely an academic exercise; it fundamentally shapes how cancer is diagnosed, prognosed, and treated. It explains one of the most challenging aspects of oncology: cancer recurrence, and why recurrent tumors often differ genetically from the primary tumor.

Many defining hallmarks of cancer can be understood through the lens of clonal evolution. Tumors are not static; they become more aggressive over time due to selective pressures. Limited nutrients, immune surveillance, and therapeutic interventions, favor the expansion of the most fit clones. Genomic differences between subclones explain why different regions of the same tumor respond variably to treatment and why prognosis can differ among patients with the same diagnosis.

Subclones may also evolve independently through convergent mutations, whereby the same cancer-promoting pathway is activated through different genetic routes. This parallel evolution highlights the tumor's remarkable capacity to find multiple solutions to the same selective challenge. When cancer is treated, dominant clones may be eliminated by targeted therapies. However, minor clones with distinct genetic alterations can persist. Once competition from dominant clones is removed, these resistant subclones can expand. Over time, additional mutations may render them fully resistant to the original therapy.

Principles from ecology and population genetics have laid the foundation for evolutionary oncology, emphasizing cancer as an adaptive ecosystem. By understanding how clones emerge, adapt, and decline over time, treatment strategies can be designed to prevent or delay the emergence of resistant cancer cell populations. Incorporating clonal dynamics into cancer treatment offers a predictive approach—not only to understand how a tumor behaves currently, but also to anticipate how it is likely to change in the future.

Cancer genomic evolution beyond the Darwinian view

Beyond the traditional Darwinian framework, the Extended Evolutionary Synthesis (EES) is increasingly applied to explain cancer evolution. EES incorporates concepts such as phenotypic plasticity, niche construction, and epigenetics. It emphasizes that phenotypic changes may arise initially through plastic responses and later become genetically fixed through mutations—a process known as genetic accommodation or the Baldwin effect.

According to this model, cancer cells can rapidly adapt to new environmental conditions, promoting heterogeneity, macro-evolutionary shifts, and therapy resistance. Advances in epigenetic research and multi-omic single-cell technologies have further clarified the heritable diversity of cancer genomes. These insights help explain why genotype–phenotype correlations are difficult to establish in static cancer samples and underscore the importance of integrated approaches capable of capturing dynamic cellular states.

Cancer is best understood as a dynamic and adaptive process through the concept of clonal evolution. Tumors consist of diverse clones carrying distinct mutations that compete and adapt under selective pressures such as immune surveillance, nutrient limitation, and therapeutic intervention. This framework explains why cancers become more aggressive over time, relapse after treatment, and display regional heterogeneity within the same tumor.

Modern perspectives—including epigenetics, phenotypic plasticity, and multi-omic technologies—further illuminate cancer's ability to rapidly adapt and develop resistance. Viewing cancer through an evolutionary lens highlights both its biological complexity and the importance of adaptive therapeutic strategies designed to predict and counter future changes in tumor behavior.

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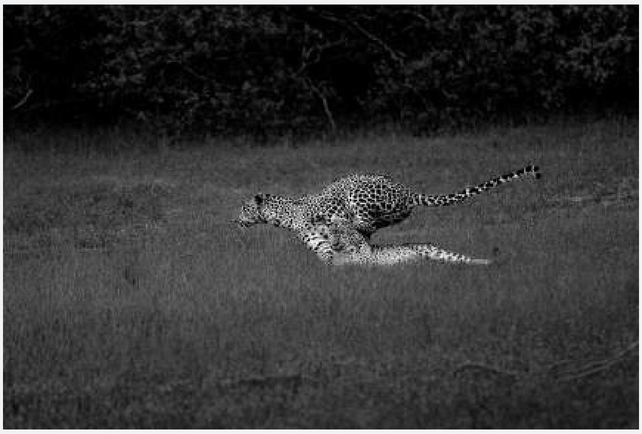

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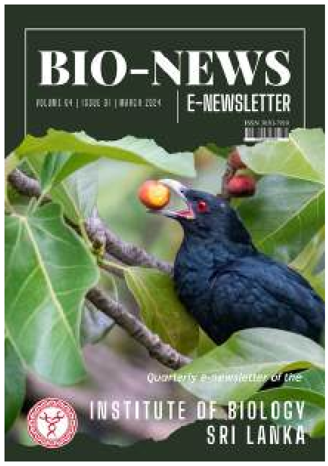

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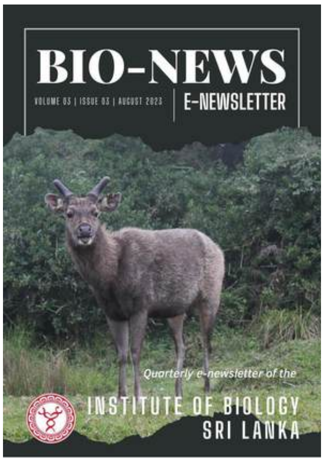

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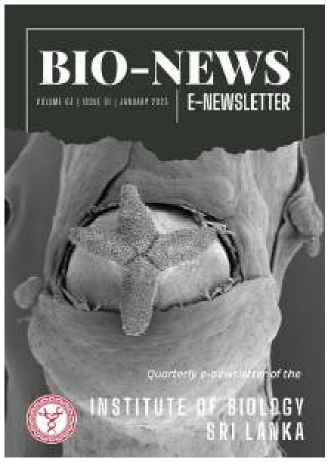

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