Edited Book

Green Frontiers

Emerging Technologies for a Sustainable Future

Editors

Dr. Tanay Pramanik

Dr. Sayantan Sil

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Preface

In an age marked by rapid scientific progress and increasing global challenges, the integration of knowledge across disciplines has become essential for meaningful innovation and sustainable development. *Green Frontiers: Emerging Technologies for a Sustainable Future* is conceived as a comprehensive academic work that brings together diverse fields of study to present a unified perspective on contemporary scientific and technological advancements. The book seeks to highlight how evolving knowledge systems can address pressing environmental concerns, enhance technological capabilities, and contribute to the betterment of society.

The primary purpose of this volume is to provide a balanced understanding of both foundational concepts and emerging trends across multiple domains. It explores critical issues such as environmental degradation, renewable energy development, advanced materials, and intelligent systems, emphasizing their interconnected nature.

The scope of the book is intentionally broad, encompassing insights from environmental science, physics, engineering, biotechnology, and applied sciences. It reflects the growing need to move beyond isolated disciplinary frameworks and adopt integrated perspectives that foster innovation.

This volume is designed to serve as a valuable resource for students, researchers, and professionals alike. Students will find it particularly useful in building conceptual clarity and gaining exposure to emerging areas of study.

The relevance of *Green Frontiers: Emerging Technologies for a Sustainable Future* lies in its focus on the dynamic relationship between scientific advancement and societal needs. As the world faces challenges such as climate change, resource scarcity, and technological disruption, there is an increasing demand for knowledge that is both comprehensive and applicable. It is hoped that this work will encourage critical thinking, inspire innovation, and enable readers to contribute effectively to a sustainable and technologically advanced future.

— Editorial Board

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“Innovation and sustainability are not opposites—they are partners in shaping the future.”

— Paul Polman

Former CEO, Unilever; Sustainability Leader

CHAPTER 7

A BRIEF REVIEW ON BIOMIMICRY: GIANT CLAMS FOR NEXT-GENERATION CLEAN ENERGY SOLUTIONS

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Abstract:

Biomimicry is the way we humans draw inspirations from nature to solve real world problems. In this review article, we explored and researched about the giant clams and its adaptations to figure out its possible advancements to solar energy technology. These clams have developed a symbiotic relationship with zooxanthellae, a microscopic algae. Researches indicate that giant clams have a quantum efficiency of 42%, which can increase to 67% due to their specialized optimized geometry. In contrast, solar panels experience energy losses due to failure of absorbing photons and exhibits lower efficiency due to overheating and reflection of incident light. In this paper, we highlight the potential for innovations in renewable energy solutions for more sustainable and efficient solar technologies that mimicking the giant clams.

Keywords:

Biomimetics, Giant Clams, Clean energy, Solar panels

Introduction:

In a world of increasing demand for sustainable energy solutions, nature gifts us a marvel design; the giant clams. It is not only a stunning feature of coral reefs with its sparkly and vibrant colors but also capable of converting sunlight into energy with remarkable efficiency. In this article we delve into the fascinating world of giant clams, exploring their

biological mechanisms and an approach to advancements in clean energy technology, surpassing traditional methods like solar panels. These bioengineers complete this complex method by the help of the algae. Algae helps in performing photosynthesis and producing oxygen and sugar. But the twist is that the giant clamps have cracked the code of optimal solar harvesting. For comparison while our agricultural field capture a mere 3% of available solar energy, they have achieved efficiency as high as 67%. Their ability to thrive in nutrient-poor waters while maximizing light capture inspire further research between biologists, engineers and environmentalists.

The point of our article is to highlight insights from the giant clam's unique biology that could inspire new, advanced clean energy solutions through biomimicry.

Review of Literature:

Overview of Biomimicry:

Biomimicry can be defined as an approach to solving real life problems by mimicking or following the intricacies of nature's forms and ecosystem. It emphasizes on getting inspired and learning from nature rather than exploiting it. Nature has marinated over billions of years, steeping in experience and developing strategies that can inspire human inventions in numerous ways. Few instances of biomimicry: Infrastructure of turbine blades inspired by the movements of whale fins, manufacture of self-cleaning surfaces by emulating lotus leaves, aircrafts by mimicking flight mechanics of birds.

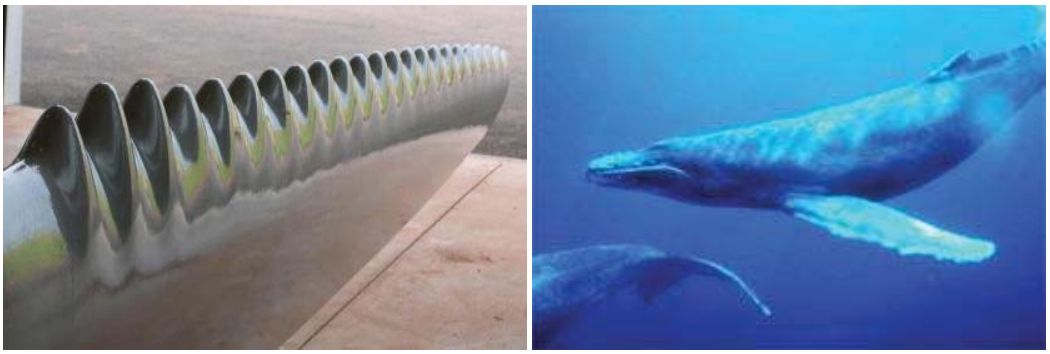

Figure 1: turbine blades inspired by whale fins [1]

Giant Clams as a Model Organism:

Giant clams are bivalve molluscs which belong to the family Tridacnidae with nine living species in two genera which are- Tridacna and Hippopus. They live in tropical waters and occur in association with coral reefs. Tridacna gigas, is the largest bivalve mollusks giant clamp that has ever existed. This clam was approximately up to 1.3 m long and weigh up to 500 kg. They are found in areas of Indian Ocean and the South Pacific Ocean, Coral Triangle, The Great Barrier Reef etc.

Figure 2: Giant clam - Tridacna maxima [2]

Biological Aspect:

Giant clams have a, thick, and heavy shell made of calcium carbonate which provides protection from predators and strong water currents. The mantle covering these giant clamps may or may not be colored, some clamps are brown in color reflecting the underlying tissues of zooxanthellae, and some are brightly colored due to the presence of pigments and iridocytes.

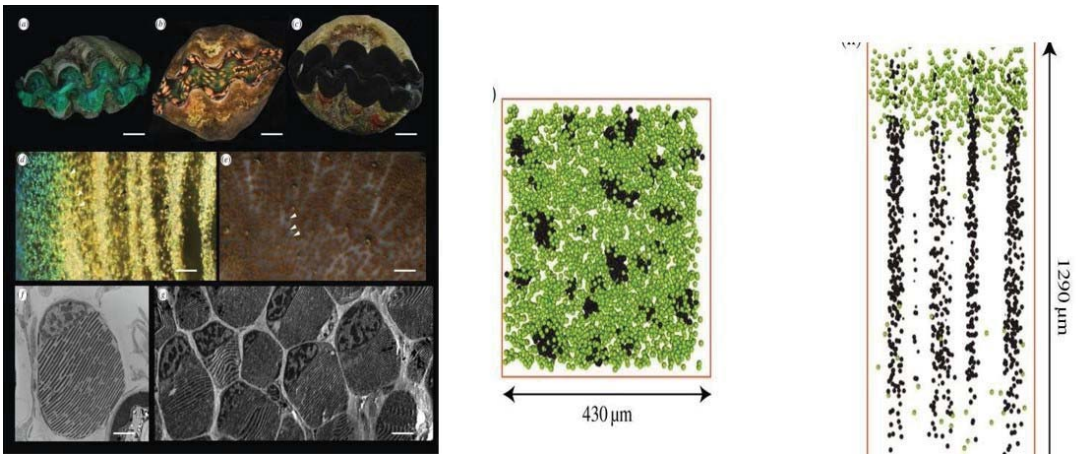

Figure 3: Overview of the giant clamp and its biology [4]

Symbiotic Relationship Between the Giant Clamp and the Algae:

These marine bivalves have a remarkable ability to convert energy from the sun into their own energy, much like plants do through photosynthesis. This is because giant clams share a symbiotic relationship with a type of microscopic algae known as zooxanthellae. These single celled photosynthetic receptors are organized in vertical cylinders within the clam's tissue which are again covered by the mantle which consists of a light scattering layer known as iridocytes.

Zooxanthellae use photosynthesis to make energy rich products like sugars and oxygen. These products are further shared with the giant clams for its growth and maintenance. In return, the giant clams provide a shelter to zooxanthellae within its tissue, protecting it from any kind of predators and providing a space for absorbing photons. The clams also provide nitrogenous waste materials which the algae use as additional resource to perform photosynthesis.

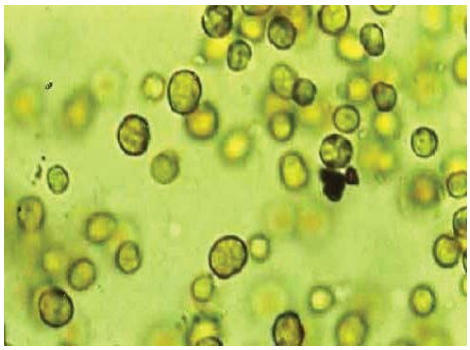

Figure 4: zooxanthellae [5]

Photosynthesis in Giant

Clams:

Iridocytes enhances photosynthesis by scattering and reflecting the incoming sunlight to deeper positioned zooxanthellae within the clam's tissue. With dilution, zooxanthellae living within the clams absorb sunlight and perform photosynthesis with the help of chlorophyll. The solar energy gets converted into chemical energy which gets stored in form of glucose. The clam then absorbs the glucose by ingesting the algae, this glucose gets further metabolized to release energy in form of ATP.

These clams have an optimized geometry; they are lined up in thin, tall columns. The clams rearrange themselves based on the availability of sunlight. When the sun is bright, the columns spread out to absorb more solar energy while in dim conditions, they move closer to maintain high efficiency. This inflating and deflating helps each algae cells to absorb equal proportion of sunlight.

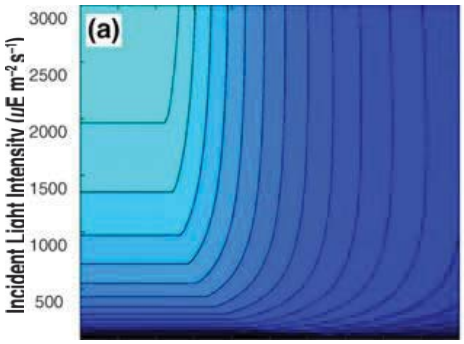

Figure 5: Productivity of a random layer of algae [4]

Superior Energy Solutions- Enhanced Solar Efficiency:

The natural architecture of these giant clams can lead to innovations in renewable energy production and more sustainable energy solutions.

In research done in Yale University, Sweeney and her team calculated the quantum efficiency of these clams (the process of converting incident photon particles into electrons) is 42% but due to their specialized optimal geometry it sprinted to 67% while the quantum efficiency in green plants is only 14%.

In solar cells, when the sunlight hits the layer of photovoltaic cell, photons that are not immediately absorbed are lost. Another drawback of solar cells is it loses its efficiency when it is exposed to excessive heat.

Figure 6: Photovoltaic cell [6]

Conclusion:

The Giants clams serves as one of nature's potential candidates for renewable clean energy solutions. One of the takeaways from this model is its adaptation to various environmental conditions, a factor that human solar technology still struggles with. With further research on these clams we can overcome current limitations in solar technology such an incompetent light absorption and inefficient heat management. Yale researcher Alison Sweeney said, "One could envision a new generation of solar panels that grow algae or inexpensive plastic solar panels that are made out of a stretchy material," To sum up, the clams open a range of doors, urging us to view solar technology through a lens of natural efficiency and ecological aspects.

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