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Issue 07

Feature

Shine! Ultra Algae

When Algae and Humanity Unite, Our Earth's Future Will Shine Brighter.

Feature

To Protect Delicious Wakame: An Algae Adventure That Starts with Miso Soup

Did you know that wakame is now facing a crisis? Explore the world of algae through a curious and fascinating adventure story!

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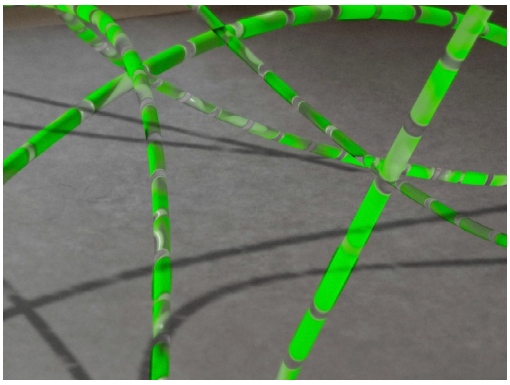

What Is Algae Biomass Energy, and How Can Wakame and Kombu Play a Role?

Algae biomass energy, anticipated as an alternative to petroleum, has been a focus of research for 50 years. Could it ultimately aim for world peace?

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To Protect Delicious Wakame: An Algae Adventure That Starts with Miso Soup

Wakame is a staple on the everyday dining tables of Japanese households. But this beloved ingredient is now facing an unexpected crisis. Could the changing global environment be to blame? Dive into this intriguing and slightly mysterious tale, where a humble bowl of miso soup sparks a deeper exploration into the world of algae.

Mayo

A spirited fifth-grader with a foodie streak. She adores the wakame her mom adds to miso soup. Once something catches her attention, she dives in headfirst and can't let it go.

Dr. Algae

An eccentric algae researcher with a passion for algae. He loves sharing his knowledge and often delves into intricate explanations, whether anyone asked for them or not.

Wakamen

A whimsical wakame fairy shrouded in mystery. Though their true identity remains unclear, their emotions seem different from those of humans.

Mayo has loved wakame for as long as she can remember. She's so obsessed with it that her summer vacation independent study is all about wakame!

Mayo What should I research about wakame? What even is wakame? A leaf? A jellyfish? Now that I think about it, there's so much I don't know!

Despite her enthusiasm, Mayo's research isn't going well. Wakame has even started showing up in her dreams, leaving her a little sleep-deprived.

Mayo I'll figure it out after I eat the wakame in my miso soup.

On one dinnertime evening, about halfway through summer vacation, Mayo sips her miso soup as usual when she suddenly hears a tiny voice coming out of nowhere.

Mysterious voice Mayo... Help...me...

Mayo What?!

She listens closely and realizes the voice is coming from inside the miso soup.

Mayo Who's that? What's going on?

Mayo looks into the bowl, and something even stranger happens—her body begins to shrink! She gets smaller and smaller until she's sucked right into the bowl!

Mayo Oh no! What's happening?!

Mayo gets sucked into the miso soup. When she comes to, she sees what looks like a human figure...

Mayo Where am I? And who are you...?!

Dr. Algae We're in the ocean. I'm Dr. Algae!

Wakamen I'm Wakamen. Thank you for coming, Mayo! Actually, we algae are in big trouble!

Dr. Algae Mayo, you can hear Wakamen's voice. Will you lend me your strength?

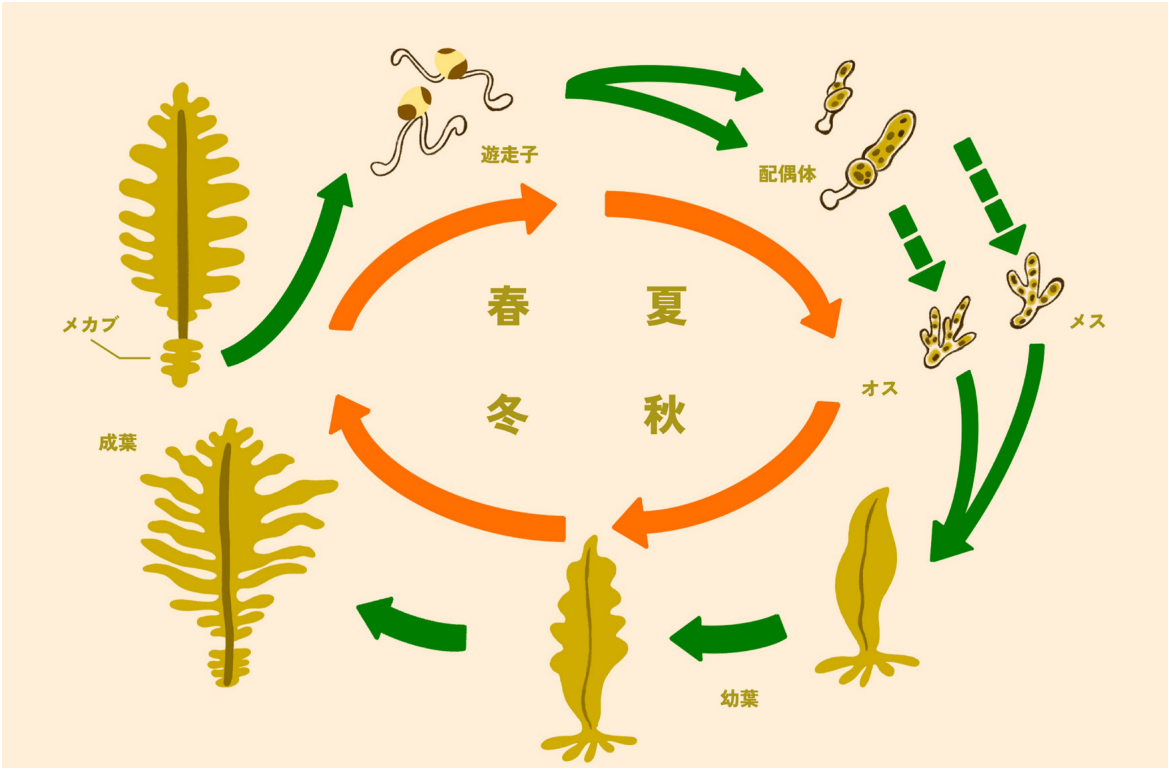
Mayo Of course!

Dr. Algae Here's a question for you. Do you know the connection between wakame and mekabu?

Mayo Are they like...distant relatives or something?

Dr. Algae Nice try, but the correct answer is that mekabu is actually part of wakame. The folds between the root and leaves of wakame are called mekabu.

Mayo Oh, I get it now!



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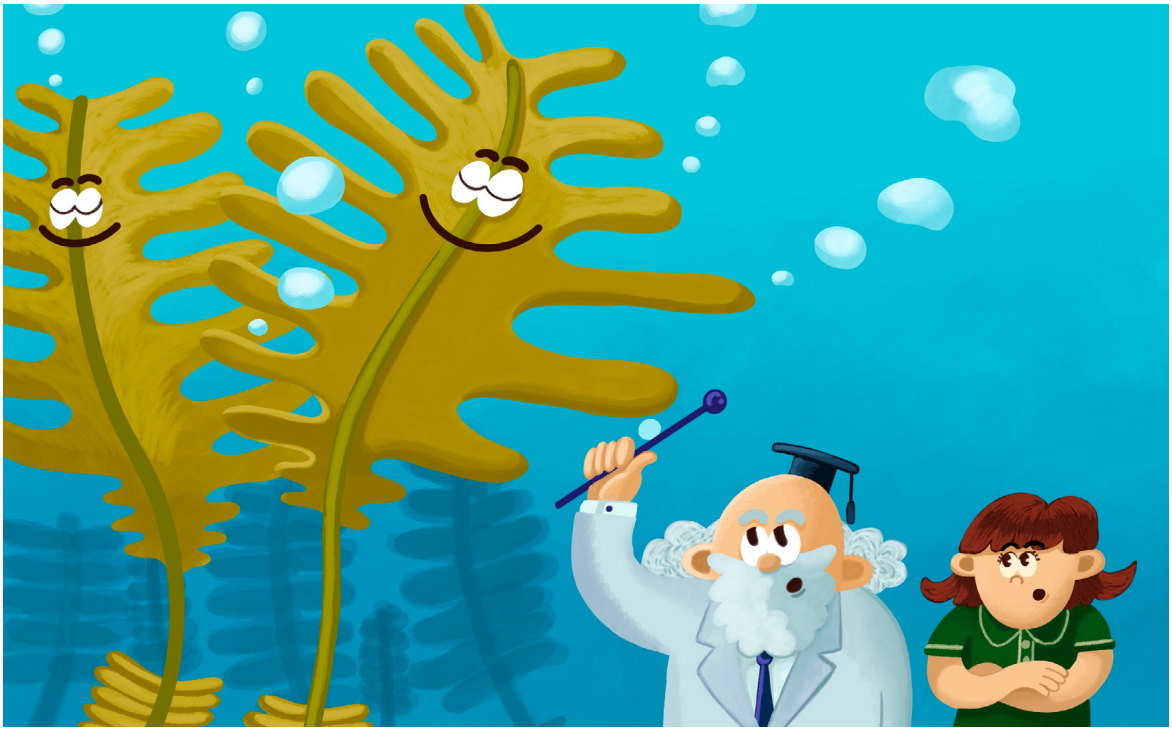
●Dr. Algae's Quick Facts on Algae

The folds between the roots and leaves of wakame, called mekabu, are packed with over 100 million zoospores—tiny spores with flagella that allow them to swim freely in the water. Just like playful children running around, wakame undergoes a phase where it swims through the sea. When these zoospores attach to rocks, they transform into tiny gametophytes that survive the high temperatures of summer and the creatures that munch on algae. As the water cools in winter, female gametophytes produce eggs, and male gametophytes release sperm. The fertilized eggs grow into new baby wakame! By spring, wakame starts growing again, releases more zoospores, and then dies off by early summer.

—

Mayo Oh, so that's the life cycle of wakame. But why does a single wakame produce 100 million spores when all they need to do is raise one little one with care?

Wakamen Well, we're vulnerable to high water temperatures, and since we're so tasty, sea urchins and fish love to eat us. In the end, only a few of our spores survive. That's why we produce so many.



Mayo I see... By the way, Wakamen, I heard someone say 'Help me!' What was that about?

Wakamen If things keep going like this, we might not be able to live in the sea at all...

Dr. Algae That's right. With the ocean warming up, sea urchins and fish are eating seaweed even in winter and spring, when the water's supposed to be cooler. The habitat of wakame, known as kelp forests, is disappearing. There are already seas where not a single piece of seaweed can be found—it's like a desert.

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●Dr. Algae's Quick Facts on Algae

The decline of kelp forests caused by herbivorous animals is known as isoyake, or rocky-shore denudation. During the process of isoyake, wakame may actually thrive for 10 to 15 years, creating the illusion that the kelp forests are recovering, but this is only temporary. It's a sign that the kelp forests are on the brink of disappearing, and eventually, the sea could become barren, with no seaweed left at all.

Seaweed, including wakame, plays a crucial role in purifying the water by absorbing carbon dioxide and producing oxygen. They also provide vital habitats for aquatic life, offering places for fish to spawn and hide, and forming the foundation of the food chain by serving as food for fish. If seaweed starts to decrease due to isoyake, it could signal a critical situation for all life on Earth.

—

Mayo Does this mean I won't be able to eat wakame anymore? I really don't want that to happen...

Dr. Algae It's not like that. First and foremost, I want people to learn more about wakame and other seaweeds. Protecting the environments where kelp forests thrive helps protect the global environment as a whole. It's important to take actions that benefit all living things, not just one species.

Wakamen Keep boiling us, eat us, cultivate us, and eat even more!

Mayo (I wonder what they's thinking...)

—

●Dr. Algae's Quick Facts on Algae

Pizza and ice cream made with suji-aonori seaweed, chocolate made with tosakanori seaweed, and even soy sauce and wine crafted from seaweed—these are just some of the innovative recipes by Chef Shui Ishizaka of Sea Vegetable. Sea Vegetable is a Japanese company dedicated to studying seaweed and promoting a seaweed-based food culture. Their efforts include marine surface cultivation, which protects seaweed from predators using protective cages, as well as introducing new ways to enjoy seaweed and selling it in high-end restaurants. They are committed to enhancing the value of seaweed while ensuring its protection in an environmentally and economically sustainable way.

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Mayo So seaweed isn't just for miso soup—you can even make delicious pizza with it!

Dr. Algae Exactly! Now, let me explain something interesting. This time, it's not about the sea, but the mountains.

Mayo The mountains? But...isn't seaweed from the ocean?

Dr. Algae Yes, but the sea, the mountains, and the rivers are all connected. Nature works as one big system.

—

●Dr. Algae's Quick Facts on Algae

Another factor contributing to the decline of kelp forests is sediment runoff from the mountains. When mud settles on the seabed, it prevents zoospores from attaching to rocks, making it difficult for seaweed to grow. However, in areas where freshwater springs emerge from the seabed, sediment doesn't accumulate, allowing seaweed to thrive. These freshwater springs carry nutrients and oxygen that originate from rainwater absorbed in the mountains. Thoughtful forest management, such as thinning trees to increase water retention, helps maintain healthy forests. This, in turn, supports thriving oceans.

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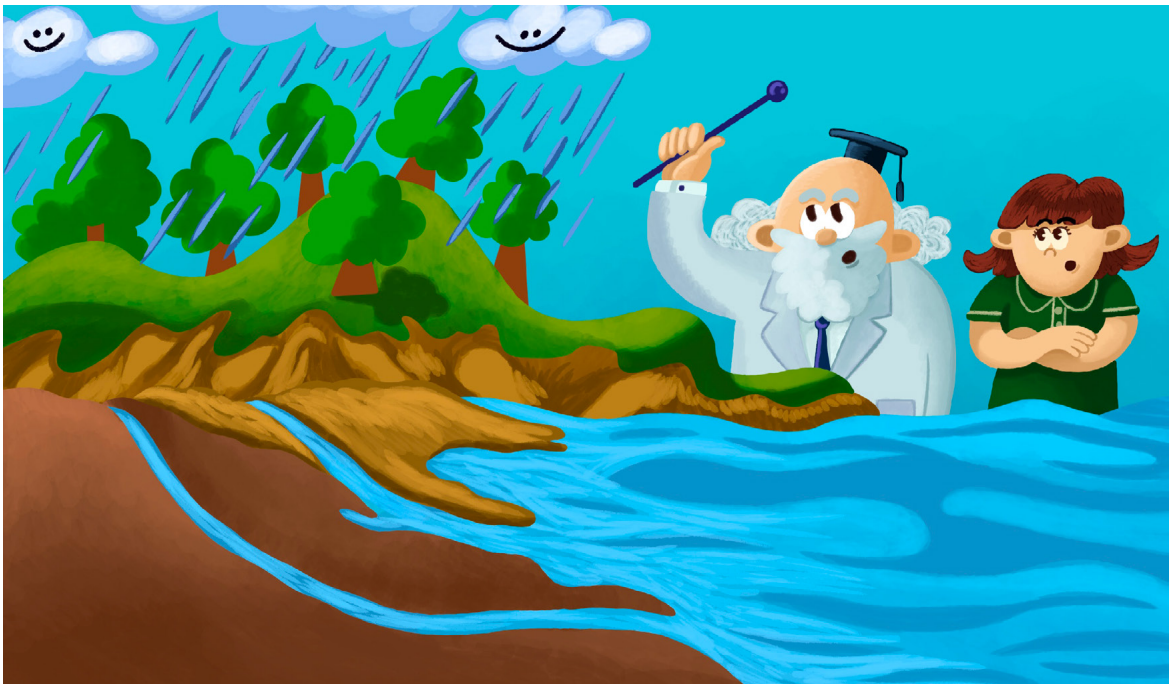


Wakamen We seaweed aren't just connected to the ocean—we're tied to the land and forests, too! That's the idea of circulation.

Mayo Whoa, that's...really deep.

Wakamen We're connected to humans as well. I believe if we work together, there's a way for both seaweed and people to thrive.

Mayo The sea, the mountains, the seaweed, mushrooms, bamboo shoots...they're all connected—and they all look so tasty... Oh, something smells really good...

"Mayo, dinner's ready! The wakame miso soup is getting cold. Don't doze off!"
She hears her mom calling from the kitchen.

Mayo Miso soup... Wakamen...?

When she opens her eyes, she's back at the dinner table, just like always. She must have been dreaming.

Mayo If I want to keep enjoying delicious wakame and protect the environment, I've got to tell everyone about algae! But first...I have to eat this miso soup!

"Help... Help..."

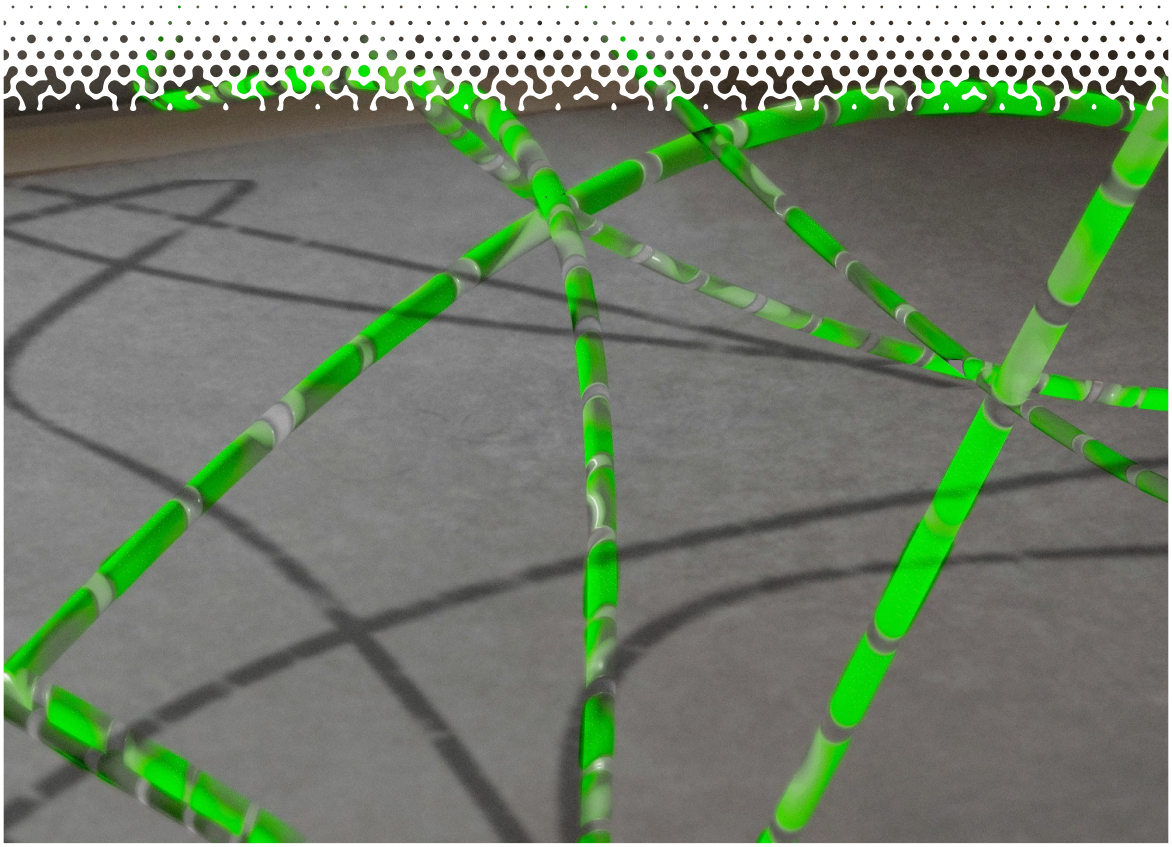
Mayo What?! Again?

Supervisor: Shogo Arai

Shogo Arai is the director of Kaiso Kenkyujo (Seaweed Research Institute Inc.), a leading expert in seaweed ecology at Sea Vegetable Company, and the chairman of the board for the Good Sea General Incorporated Association. His research focuses on isoyake caused by herbivore activity and the build-up of sediment. To address these challenges, he advocates for solutions such as expanding seaweed farming on the ocean surface and seabed, thinning forests to enhance seabed spring water flow, and creating rain gardens that individuals can implement in their own backyards.

Illustration: KAORU SATO

What Is Algae Biomass Energy, and How Can Wakame and Kombu Play a Role?



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Algae are water-dwelling organisms that perform photosynthesis. While they may seem humble, these organisms have played a significant role in Earth's history, contributing oxygen to the atmosphere over billions of years and serving as a foundation for life itself. In recent years, algae have also emerged as a promising resource in the development of biomass energy, thanks to the oils they contain.

Makoto Watanabe, a phycologist and chairman of the Algae Industry Creation Consortium, has been exploring the practical applications of algae biomass energy for over 20 years. The path has been far from easy, with numerous challenges to overcome. However, Watanabe remains steadfast in his belief in algae's potential. His ultimate goal? World peace. Let's take a look at the potential of algae.

In this article, we also showcase a 3D CGI animation by visual artist Takuma Nakata, featuring algae from around the globe. Perhaps the algae near you could one day play a vital role in advancing biomass energy.

What Are Algae Used for Biomass?

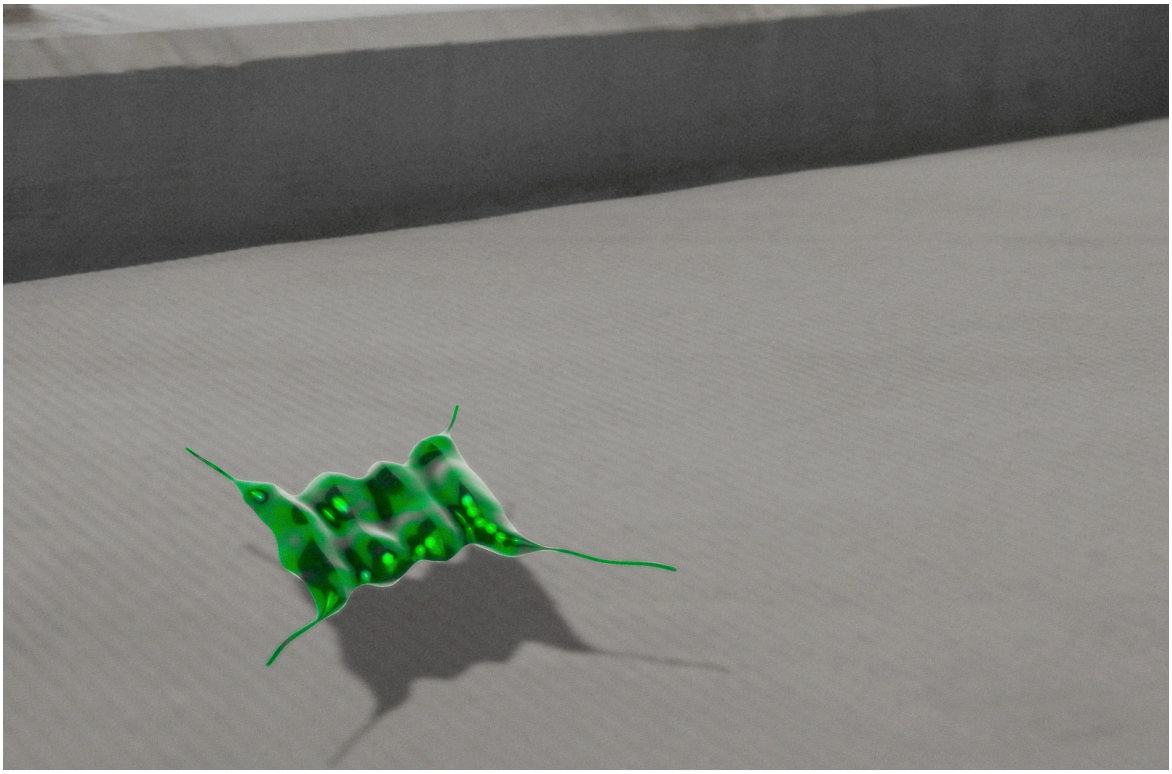
— First, could you explain what algae are?

Watanabe Broadly speaking, algae refer to organisms—other than terrestrial plants—that primarily live in water and perform photosynthesis. One unique feature of algae is that they lack the distinct structures found in plants, like roots, leaves, and stems.

Algae are all around us in daily life. Familiar examples include wakame seaweed and kombu kelp. These are considered macroalgae because they're relatively large. On the other hand, there are also very small types called microalgae. These range in size from just a few micrometers (μm) to a few hundred micrometers and can only be seen under a microscope.

What's fascinating about algae is that there are species that don't necessarily fit neatly into these definitions or characteristics. In fact, scientists estimate there are anywhere between 300,000 and 10 million species of algae in nature, yet only about 40,000 have been identified so far.

*1 μm is one-thousandth of a millimeter.



— Could you tell us about algae biomass energy and how it works?

Watanabe Algae biomass energy is a type of renewable energy that uses the oil, or bio-crude oil, found in algae cells. It's gaining global attention as a sustainable alternative to fossil fuels.

One of its key advantages is its carbon-neutral nature. Algae absorb carbon dioxide from the atmosphere and release oxygen during photosynthesis. So, even when algae biomass is burned for energy, the overall amount of carbon dioxide in the atmosphere doesn't increase significantly.

When people hear the term biomass, they often think of grain-based biomass made from crops such as corn. While grain biomass was popular for a time, it has a significant downside—it competes with the food supply. The more crops that are used for energy production, the less there is available as food, leading to potential price increases. Algae biomass, however, avoids this issue entirely.

In terms of productivity, algae biomass outperforms grain-based alternatives by a wide margin. For instance, a hectare of corn can produce about 172 liters of oil per year. In comparison, algae can yield approximately 136,900 liters of oil per year. While these numbers are just examples, they highlight the remarkable efficiency of algae for oil production. Our current project involves cultivating algae at a sewage treatment plant, eliminating the need to build new facilities. This approach not only reduces production costs but also makes the process more sustainable.

— Algae really does have incredible potential. What can the oil extracted from algae be used for?

Watanabe The possible applications are incredibly diverse. Algae oil can be used in cosmetics, plastics, resin products, and even animal feed. One of the most exciting recent developments, however, is its potential as a source for sustainable aviation fuel (SAF).

In fact, the Ministry of Economy, Trade and Industry has announced plans to mandate that 10% of the fuel used at Japanese airports must be SAF by 2030. This initiative is part of a broader effort to reduce carbon dioxide emissions, and it's keeping both airlines and oil wholesalers very busy. Algae biomass is emerging as a promising candidate to help meet these ambitious goals.

Algae Reveals the Origins of Life on Earth

— Why did you decide to study algal biomass, Mr. Watanabe?

Watanabe Let me explain step by step. My journey began with studying algae in general. I've been researching algae for nearly 50 years, and they're far more complex and fascinating than most people realize. They rarely get much attention, but without algae, life as we know it today wouldn't exist.

Here's why: algae played a crucial role in creating Earth's atmosphere. About 5 billion years ago, the atmosphere was mostly carbon dioxide. Then, roughly 3 billion years ago, photosynthetic algae—specifically cyanobacteria—appeared, and everything started to change. Through photosynthesis, cyanobacteria began releasing oxygen into the atmosphere. Over time, this oxygen accumulated, eventually forming the ozone layer. The ozone layer shielded the planet from harmful ultraviolet rays, making it possible for life to move from water onto land.

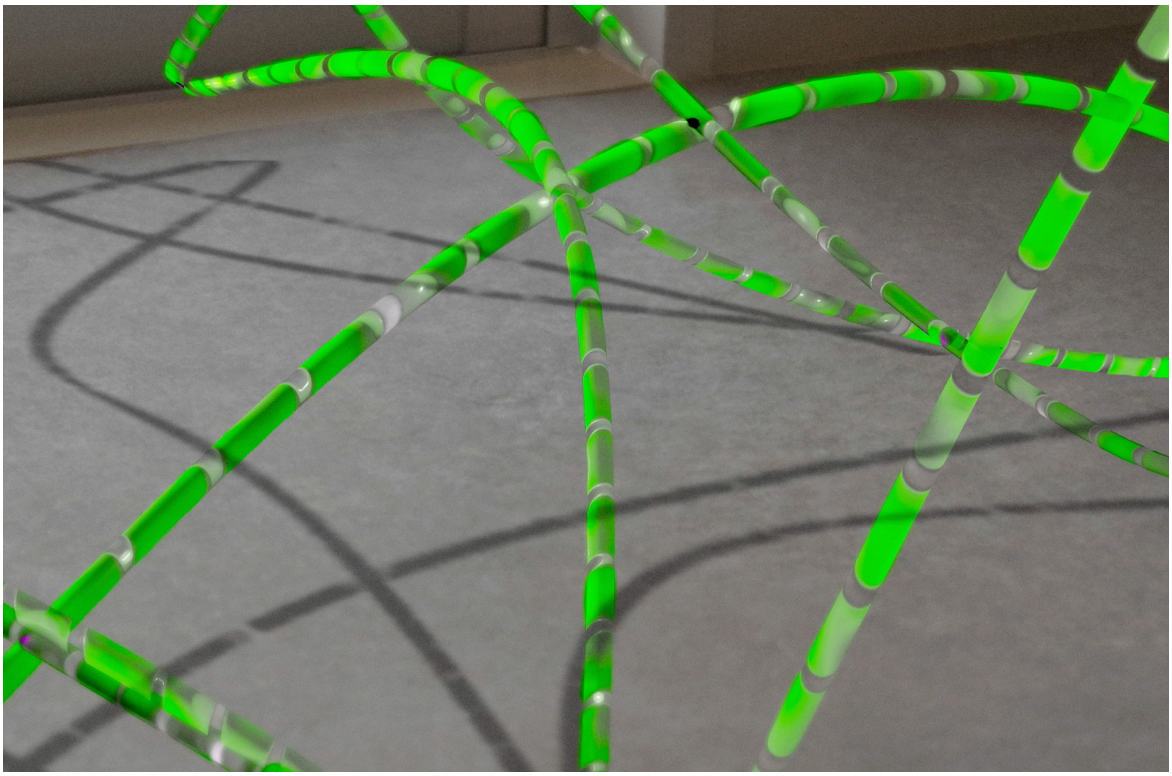
— Can studying algae really help us understand the origins of Earth?

Watanabe Exactly. I believe that without studying algae, we can't solve many of the pressing issues related to the global environment. In a way, algae hold the future of the Earth in their hands. Is there any research topic more compelling than this? It's hard to simply call it "romantic" (laughs).

We started researching algae biomass around 2005. At the time, oil prices had been rising since the previous year, and there were widespread concerns that oil resources are running out. To address this, people began looking into biomass alternatives made from corn and sugarcane. However, competition with food supplies became a significant drawback for grain biomass. As discussions about alternative materials took place globally, algae biomass emerged as the only viable option.

That said, this field was virtually unexplored in Japan. So, we decided to take

the lead, stepping into uncharted territory and launching our research in earnest.



— Research on algae biomass seems to be advancing overseas as well.

Watanabe The United States was actually the first to start researching algae biomass. After the first oil crisis in the 1970s, the US Department of Energy launched a project called the Aquatic Species Program.

The project lasted about 18 years, but eventually stalled as crude oil prices stabilized at lower levels. Even ExxonMobil, a major oil company, invested heavily in algae biomass research. However, in 2013, they publicly stated that it would take at least another 25 years before it could be commercially viable.

More recently, China has been ramping up its research efforts and expanding its presence in the field. But as with our project, the biggest challenge remains overcoming high production costs. Currently, crude oil costs around 80 yen per liter. To compete, algae-derived fuel would need to be priced at a similar level. If production costs were to reach 500 or 600 yen per liter, it would simply be too expensive for anyone to use.

Could Algae Replace All of Japan's Crude Oil Imports?

—— What kind of project are you working on, Mr. Watanabe?

Watanabe We're developing a system to produce algae oil using sewage treatment plants. Sewage contains large amounts of organic matter, nitrogen, and phosphorus—essentially the perfect "food" for algae. The algae consume these nutrients while performing photosynthesis, which not only helps them grow but also purifies the sewage in the process. This significantly lowers the cost of removing organic matter, nitrogen, and other waste.

In other words, it's a win-win system that combines large-scale algae cultivation with sewage treatment. The project is based on research from the University of California, Berkeley, which demonstrated that algae oil could be produced at a cost lower than that of crude oil.

Sewage treatment plants are, of course, critical infrastructure for daily life. Japan has more than 2,000 such facilities, and studies suggest that cultivating algae in just one-third of these could yield 136 million tons of oil annually—the same amount as Japan's yearly crude oil imports. Once the algae are cultivated, they're concentrated into pellets and converted into oil using high-temperature, high-pressure processing.

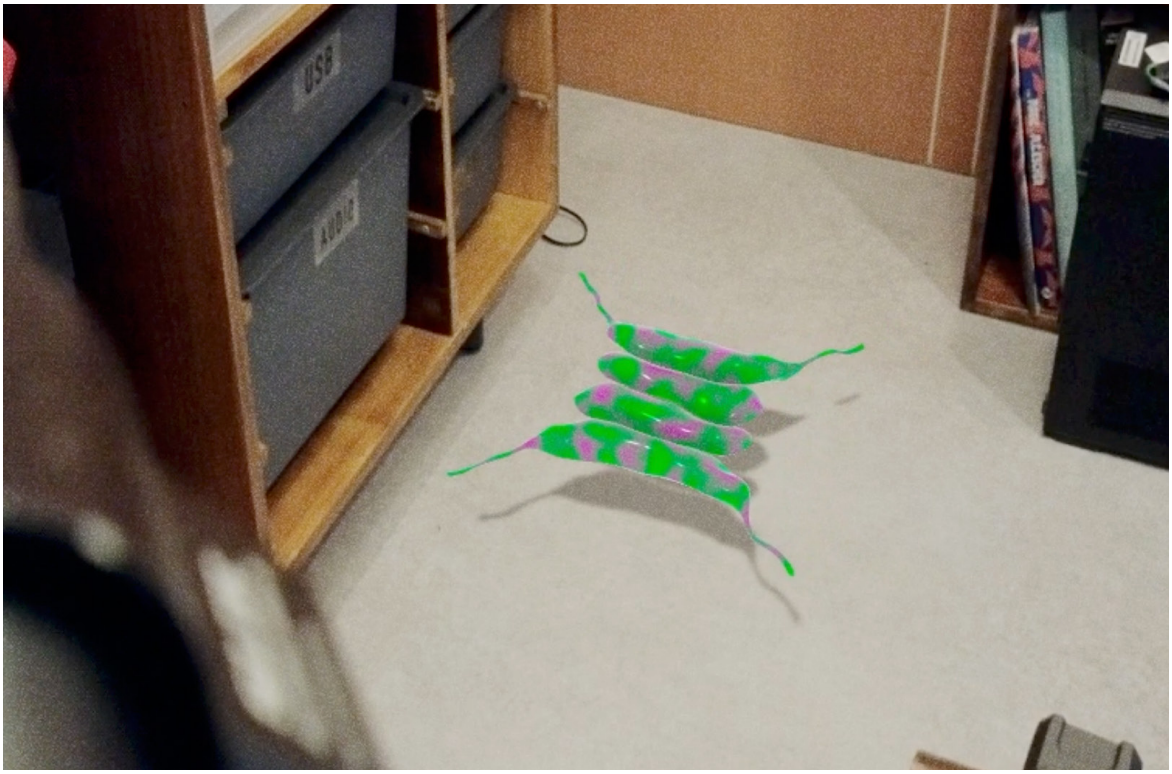
—— You mentioned earlier that 40,000 species of algae have been identified. What kind of algae are you using in your project?

Watanabe When we first started, we worked primarily with Botryococcus and Aurantiochytrium. Algae oil is generally similar to edible oil, but these two species produce a hydrocarbon oil, the main component of petroleum. The extracted oil is exceptional because it can be used as fuel almost directly. On top of that, they are easy to cultivate and have high oil productivity. In a sense, Botryococcus and Aurantiochytrium are the elite algae.

However, as the project progressed, we began to encounter their limitations. These elite algae are highly sensitive to environmental changes, with their growth rate dropping significantly in colder regions with low temperatures. Maintaining optimal conditions to cultivate them incurs additional running costs. While managing them in a controlled lab environment isn't an issue, scaling up to industrial production is not practical.

This led us to focus on indigenous algae—species naturally found around sewage treatment plants. Indigenous algae are well-adapted to the local climate and environment, which gave us the idea that they might be capable of year-round cultivation.

When we tested this hypothesis in a demonstration experiment, the results confirmed it: the indigenous algae grew steadily throughout the year. Since then, we've moved forward with a polyculture approach, combining elite algae with indigenous algae.



Could Algae Research Pave the Way to World Peace?

—— In 2022, your project was selected for the Ministry of Land, Infrastructure, Transport and Tourism's B-DASH (Breakthrough by Dynamic Approach in Sewage High Technology) Project.

Watanabe When that decision came through, I felt a sense of relief—finally, our efforts were recognized by the government. The funding we received was used to conduct a demonstration experiment at the Kokaigawa Tobu Wastewater Treatment Facility in Ibaraki Prefecture. The goal was to cultivate algae using primary treated sewage water, which has had most of the pollutants removed. We set up a 100-liter container and tested how well algae would grow under natural conditions. The experiment proved that algae can thrive even in water where sunlight struggles to penetrate deeply.

This project wouldn't be possible without collaboration. We're working alongside oil refining companies and sewage treatment plants, and as we look to scale up, we'll need to procure a significant amount of hydrothermal liquefaction equipment, which processes the algae under high-temperature and high-pressure conditions.

—— After dedicating nearly half a century to algae research, do you feel a strong attachment to them?

Watanabe Absolutely. After all these years, algae have become like a lifelong partner (laughs). Research has its challenges, but my passion for algae has kept me going.

Algae are everywhere on Earth, and sewage treatment plants are essential infrastructure worldwide. This means our project has the potential to be replicated not only across Japan but also globally. While we still face hurdles with production costs, if we can overcome them and make algae-based energy viable, the impact on global energy supply would be immense. By reducing competition for energy resources, we could also help prevent conflicts, making algae a potential contributor to world peace. It's a bold idea, but considering the potential algae hold, it's not far-fetched.

Phycologist/Chairman of the Algae Industry Creation Consortium

Makoto Watanabe

Born in Miyagi Prefecture in 1948. Graduated from the Department of Biology, Faculty of Science, Tohoku University, in 1971, and completed his doctoral studies at the Graduate School of Science, Hokkaido University. After serving as Director of the Biosphere Environment Department at the National Institute for Environmental Studies and as a Professor at the Institute of Life and Environmental Sciences, University of Tsukuba, he is now focused on researching algae-based biomass energy. In 2010, Watanabe co-founded the Algae Industry Creation Consortium with like-minded researchers and has been serving as its chairman ever since.

3DCG Animation: Takuma Nakata