It is hard to believe that a simple, single-celled organism better known as pond scum could be the key to saving our way of life. Nearly ubiquitous on the surface of the earth, algae are adapted to life in places as diverse as glaciers and desert soils. Algae can harness sunlight to convert water and carbon dioxide to biomass and are some of the world’s most widespread and productive organisms. They are photosynthetic energy powerhouses that account for approximately half of the world’s oceanic oxygen production. That humans should attempt to harness this resource is thus not only understandable but also practical. The return of algae to the spotlight has focused on its potential as an alternative fuel. While a futuristic world of cars and houses run on algae-based fuels seems remote, recent findings suggest algae are one of our most promising sources of biofuel and alternative energy.

Where don’t algae live?

Part of the scientific appeal of algae is their widespread abundance and biological diversity. Most algae live in the photic zone of the ocean, supporting much of our world’s marine life. For example, multi-cellular sea kelps serve as unique habitats for diverse organisms, like sheathbills, blennies, kelp hens and kelp crabs. While algae are commonly conceived of as sea creatures, several species thrive in terrestrial and freshwater environments.

In fact, algae can be found almost everywhere around the world. An occurrence known as snow algae is caused by algae that live where little else does, like glaciers and the Arctic pole. A decade ago, researchers were still discovering pockets of snow algae in the Sierra Nevada mountains and Afro-alpine environments. Surprisingly, the snow algae found in both locations strongly resembled previously discovered snow algae communities from other continents. While wind dispersal of spores is a possible explanation, researchers hypothesized Cenozoic era glaciations would have provided a continuous pathway for algae dispersal between current day Spain and Africa. Later geologic events may have separated populations originally in close proximity (1).

Ron Hoham, a researcher at Colgate University, studies how snow algae eke out an existence in a harsh and nutrient deficient environment. Co-editor of Snow Algae: A Unique World in a Cold Environment, Hoham has worked on the complex life cycles and adaptations of algae for over three decades (2). Snow algae come in shades of green, red and orange and support a minute ecosystem
of snow flies, bacteria, and ice worms. Adapted to tolerate high levels of ultraviolet radiation and acid, snow algae can serve as bioindicators of environmental health. One of Hoham’s studies has revealed a life cycle intricately tied to snow melt. Cells lie dormant through the winter while becoming active in the spring when the snow begins to melt. When most of the nutrients from the snow have been depleted, the algae enter a reproductive stage. The new cells enter dormancy and repeat the cycle. Hoham’s more recent work, published in *Arctic, Antarctic, and Alpine Research*, has focused on examining the optimal growth temperatures for *Chloromonas*, an algae native to Northeastern America. His team found that optimal temperature ranges interestingly depended on the phylogenetic history of algal strains rather than their habitat (3). While global warming may affect the temperatures of arctic environments, snow algae are uniquely adapted organisms. Snow algae absorb carbon dioxide at one-tenth the rate of plants (4). This minute existence effectively negates any possibility of using snow as a carbon sink, but the remarkable adaptability of algae to extreme environments is the key to its abundance on earth.

A staple of our way of life

From being a food source to an ingredient of industrial production, algae offer a spectrum of benefits. Seaweed, a form of multicellular algae, is touted for its nutritional value as a source of many vitamins. Green algae such as *Dunaliella bardawi* are cultivated for their production of beta-carotene. But perhaps the most promising application of algae is as a source of fuel for our energy demands. Algal biomass can be used to produce methane and to power heating or electrical needs. A project at the Massachusetts Institute of Technology snare the power of algae to reduce carbon emissions. An invention of Isaac Berzin, the founder of GreenFuel Technologies Corp., the system pumps waste carbon dioxide from MIT’s power plant through tubes of liquid algae. With the support of a grant from the MIT Entrepreneurship competition, Berzin tailored algae over three months to thrive on waste gases instead of air.

The algae convert the carbon dioxide to biomass, reducing CO₂ output by 82% on a sunny day. Optimally, algae farms would become economically favorable and operate on a commercial scale. Currently, a maximum production farm would consume approximately 40% of carbon dioxide emissions from a full time industrial facility while producing 25 kg of algae biomass per square meter every year (5). The algal biomass could eventually be used to produce oil, delipidated algal meal, and dried whole algae. At the end of the process, the oil can be sold to consumers and the latter two products can be used in livestock feed.

**From sunlight to fuel**

The limited availability of resources for energy demands is a major issue for the sustenance of current living conditions and future development around the globe. Alternative energy sources like wind and solar energy are expensive and insufficient to supply the gap created by depletion of fossil fuels. Green technology has turned to biofuels as a possible source of renewable energy. Corn-derived ethanol and biofuels from soybean and palm oil have received much attention and funding in the United States. However, cultivation of corn and soybean requires vast tracts of arable land in addition to competing with a staple food source. Furthermore, large scale production is impractical since soybean and palm oil produce oils in minuscule amounts: less than 5% of their biomass (6).

The production of biofuels from microalgae, on the other hand, offers a renewable energy source without risks of depleting the food supply. Microalgae need less water than land crops and can be grown on nonarable land. Furthermore, algae can be grown in brackish or salty water while possessing a higher oil content per dry weight of biomass than corn (7). Cultivation techniques include raceway ponds of algae that are cheap to maintain while highly productive. However, development of biofuels from algae entails the difficulties of extracting oil from microalgae and selection for algae that can be grown outdoors in variable conditions.
Boon or Bane?

The merits of algae as a potential biodiesel and carbon sink are numerous, but global warming along with industrial wastes released into freshwater lakes have caused algal blooms that negatively impact ecosystems. Warnings of red tides stem from the production of toxins by algae such as Karenia brevis that can cause illness after consumption or exposure. Toxins can even accumulate to fatal levels in fish and marine mammals. A case of algal toxins occurred in 2003 when 107 Florida bottlenose dolphins were found dead with high levels of brevetoxin, associated with the algae Karenia brevis (8). Algal blooms from increased nutrients in wastewater can also lead to oxygen depletion and the suffocation of aquatic organisms when the algae decay (9).

While not without danger, the versatility of algae has not gone unnoticed at the Culture Collection of Algae at the University of Texas at Austin. Harborin cultures of over 3,000 strains of living algae, the largest algal collection in the world sells samples to the public at $75 a culture. Uprising entrepreneurs hoping for the algae that will prove a wonder-fuel have the opportunity to order algae collected from far reaches of the globe. In an interview for the Wall Street Journal, Jerry Brand, the director of the Culture Collection, noted “Well I’m excited about it because algae have been on the back burner of most people’s minds…And those of us who studied algae for decades realize there’s a tremendous genetic potential there” (10). With such a biodiverse selection of algae, these entrepreneurs are hoping that somewhere there must be an algae perfectly suited for oil production. Academia and start-ups are not the only buyers knocking. With fossil fuels an increasingly limited resource, the world’s largest oil company Exxon Mobil has joined the field. While this venture into alternative fuels came rather late for ExxonMobil in comparison to its competitors, the company selected algae as the most promising investment after careful analysis of other biofuels. Last July, ExxonMobil announced a $300 million deal with Synthetic Genomics, a company selected algae as the most promising investment after careful analysis of other biofuels. Last July, ExxonMobil announced a $300 million deal with Synthetic Genomics, a company headed by biologist and entrepreneur Craig Venter. Their joint venture will aim to develop a viable algal biodiesel within the next few years. Instead of the more traditional methods of tweaking environmental conditions to encourage productivity in existing algal species, Venter hopes to genetically engineer a resistant strain of algae capable of commercial production (11). This would bypass many of the difficulties associated with the extraction of biofuels such as thick cell walls and unstable cultures. However, genetically modified algae may not survive in open cultivation ponds where competition with wild types could reduce productivity.

The efforts of scientists and entrepreneurs to learn more about algae have made the photosynthetic organism far from irrelevant. From engineering the rise of atmospheric oxygen to conquering the most inhospitable environments, algae have transformed much of the surface of the earth. Only a fraction of the world’s diverse algae are fully understood. Much remains to be done before production of algae-based biodiesel, but the sheer diversity and number of algae hints at their remarkable ability to adapt to a future.

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References