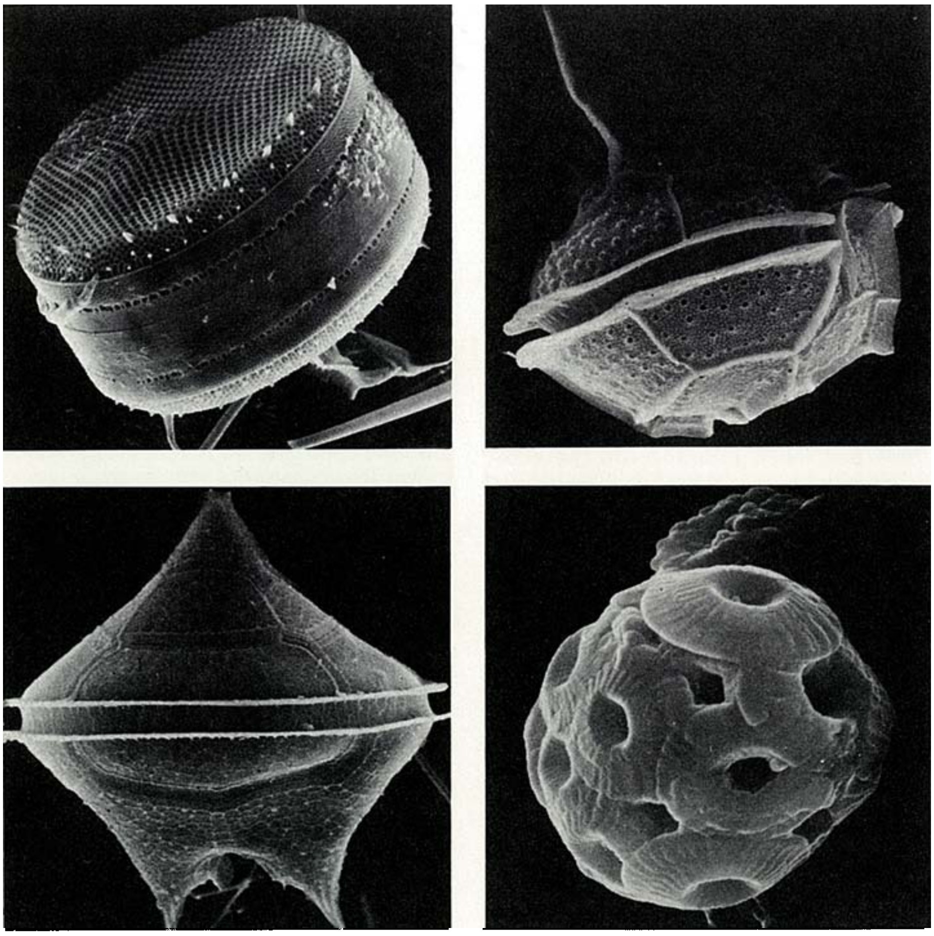


**Phytoplankton under the scanning electron microscope.**

# Cultivating tiny sea plants

When a sudden bloom of algae affects a nearby coastal inlet, most of us wish there were some way of getting rid of it (swimming is meant to be an enjoyable experience). But Dr Dennis Regan of the CSIRO Division of Chemical Technology would like to know how to perpetuate the growth and harvest the algae.

Actually Dr Regan doesn't wish to ruin our swimming — he suggests that the best place to grow algae would be our coastal arid land, good for no other commercial purpose.

Until now, most of the proposed schemes to bring desert areas into productive use have looked towards desalinating brackish water or sea water, or even towing icebergs from Antarctica. Yet the sea contains many tiny organisms — in particular, phytoplankton — adapted to a salt-water existence. If we could learn to cultivate them, many possibilities — for food, energy, chemicals, and medicine — would open up.

Phytoplankton are microscopic primitive plants (micro-algae) responsible for about half of the world's total photosynthesis. They vary in size from micrometres to millimetres, and their shape can be anything from a simple round outline to the intricately patterned forms of diatoms. Their larger relatives, seaweeds, are called macro-algae.

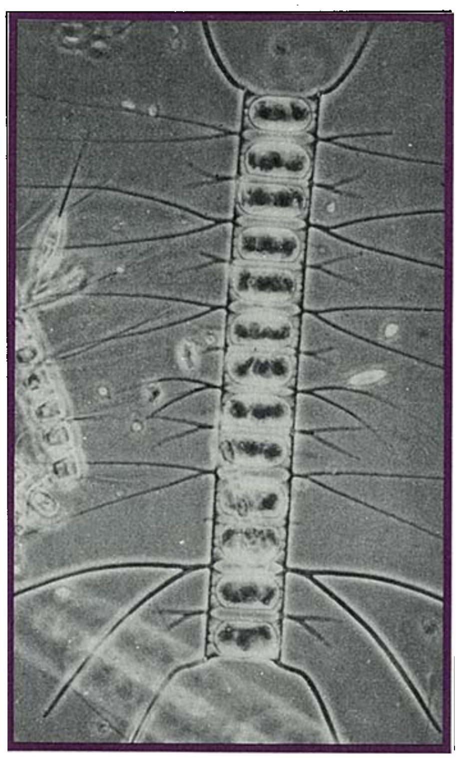
Just as grasses are the key plants for the pastoral industry, phytoplankton are the primary basis of the sea's productivity. They float in the surface layer, capturing the sun's energy and taking in carbon dioxide and nutrients from the sea water around them. Of course salt is not only tolerated, it is a necessary component of the system.

Hundreds of years ago the Aztecs used to harvest *Spirulina* — a fresh-water species of phytoplankton — from Lake Texcoco. Dried in the sun it made a nutritious food. Modern analysis shows that *Spirulina* contains more than 50% protein. In Mexico today the plant is cultivated in large ponds and the harvested product sold as a source of vitamins.

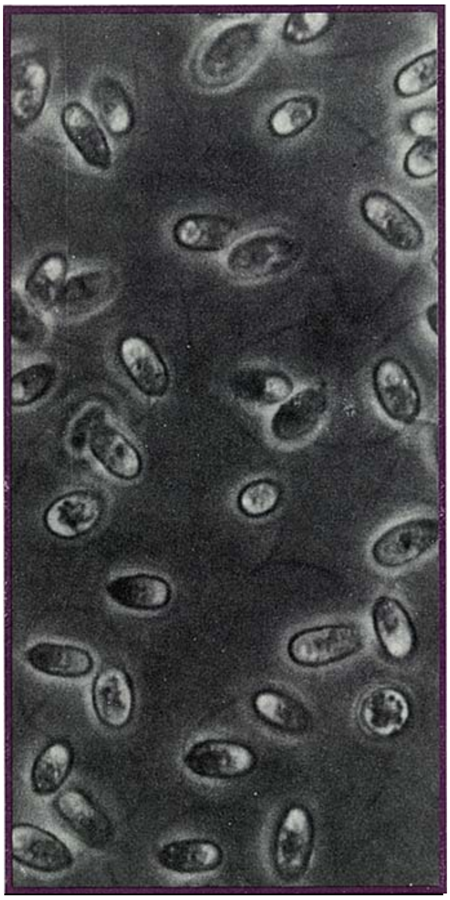
Dr Regan envisages that marine phytoplankton could be cultivated in a similar way along extensive sections of Australia's low-lying coastline where fresh water is scarce. Up to 12 million hectares of unused arid land could be used, an area about equal to that at present planted to cereal crops.

And the products could be remarkably diverse — not just food. The list could include antibiotics and other pharmaceutical products, natural dyes and flavours, fine chemicals, solvents, and waxes. Some phytoplankton accumulate metals in high concentrations from di-

*Dr Regan envisages that marine phytoplankton could be cultivated along Australia's coastline where fresh water is scarce.*



**The marine diatom *Chaetoceros*. Its spines enable it to float near the sea surface.**



**Sperm-shaped *Dunaliella*. This marine alga produces glycerol.**

lute solution and have potential for recovering metals from ores.

The cultivation of phytoplankton is the first step in many kinds of fish- and shellfish-farming.

Some phytoplankton store solar energy as fats and oils, and so have potential as a source of liquid fuels. (Indeed, on a geological time scale, many of our present oil and gas deposits originated this way.) Fuels could be made either by refining the natural oils or by fermenting the algae to make methane.

And in the very long term, hydrogen could be produced from water by the activity of blue-green algae. These contain specialized cells that release hydrogen under certain conditions.

### Adding nutrients to a desert

But how can such blooming soups be produced? Compared with the land, the sea is largely a biological desert, with low concentrations of nutrients and correspondingly low numbers of phytoplankton. However, when waters are enriched with nutrients, phytoplankton numbers multiply.

The answer, Dr Regan suggests, is to create huge shallow ponds near the sea, like the solar evaporation ponds used to yield salt, and to mix in nutrients. To make the most efficient use of sunlight, the ponds should not be more than about 30 cm deep.

Sewage is the most likely source of nutrients, although it does limit the range of species that can be grown. Growth media specially formulated for the species wanted would have distinct advantages.

Carbon dioxide is another substance needed in abundance for high growth rates. Dr Regan's experiments show that bubbling a 1% mixture of carbon dioxide in air through a culture tank can increase productivity more than four-fold. Waste carbon dioxide from power stations would make a good source, and the stations' cooling ponds could become culture ponds. A 1000-MW power station produces about 8 million tonnes of carbon dioxide per year, which, assuming a 50% efficiency in its use, could provide the carbon needed to grow 2 million tonnes of phytoplankton.

### The right conditions

A major problem is to maintain the pond as the exclusive home of the desired species. In traditional fermentation vats and cultures producing pharmaceutical products, stray organisms are kept at bay by using sterile conditions. In open outdoor phytoplankton cultures, growing conditions must be such as to favour the desired culture over others.

Dr Regan, with the help of Ms Neva Ivancic, is examining methods of maintaining desired species in open culture. The method that seems to work best is to create an extreme environment — tolerable to the desired organism but too extreme for its competitors. The extreme condition may be high temperature, high salinity, acidity, or high concentration of nutrients or carbon dioxide.

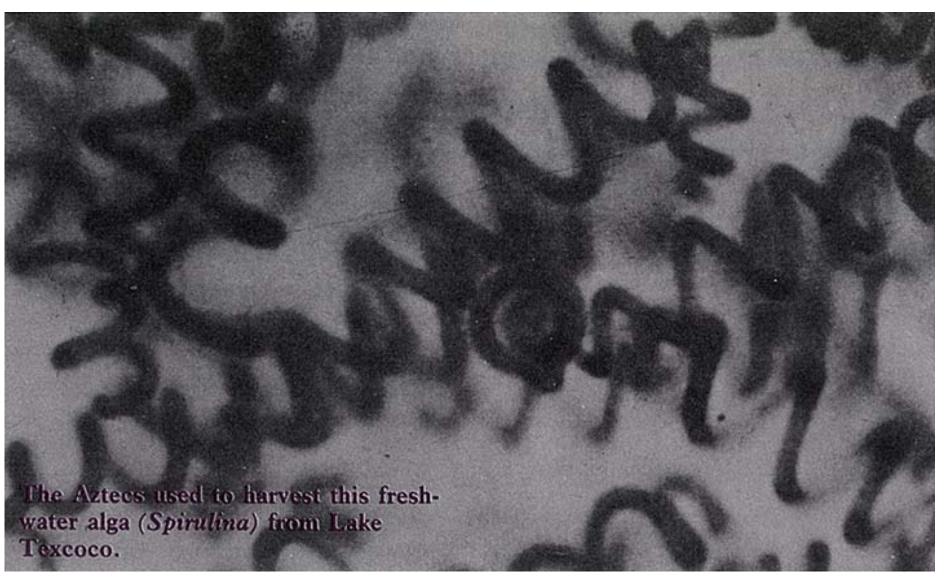
Dr Regan is working to establish the ecological relations involved to see what species are good candidates for culture on a large scale. So far he has found that *Dunaliella*, *Tetraselmis*, and three other species can be cultured to be dominant species. The first is a likely source of glycerol and carotene, and the second is a suitable food for oysters. Temperature and dilution are the most important factors affecting the success or otherwise of a species establishing itself as dominant, Dr Regan finds.

*A major problem is to maintain the pond as the exclusive home of the desired species.*

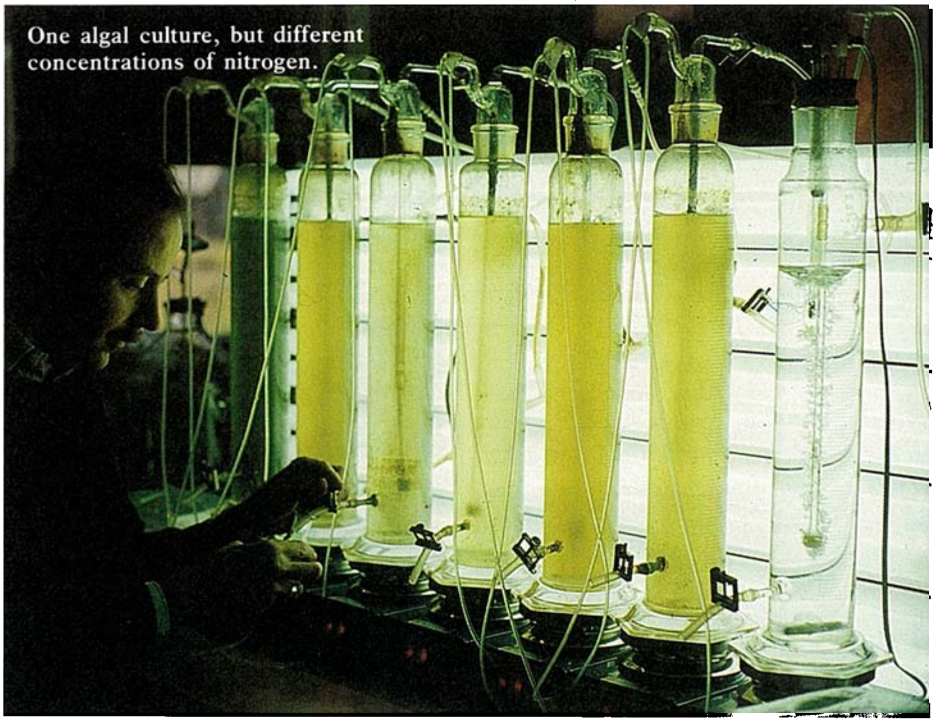
Which species eventually dominates in a culture also depends on the starting conditions. Depending principally on whether their numbers were high or low when the culture was begun, Dr Regan could induce either *Tetraselmis* or *Oscillatoria* to dominate under identical conditions later on.

Considerations of temperature led Dr Regan to begin seeking out marine species, not presently in culture collections, from rock pools. These inter-tidal organisms are adapted to temperatures much higher than those experienced by oceanic species, so they should grow better in shallow ponds in the arid zones, where temperatures near 35°C would be reached. Oceanic species grow well at 20°C, but very poorly at such elevated temperatures.

It is in the nature of animals to eat plants, and this is just as true on a



The Aztecs used to harvest this freshwater alga (*Spirulina*) from Lake Texcoco.



One algal culture, but different concentrations of nitrogen.

microscopic scale. In the oceans zooplankton eat phytoplankton; so when humans culture phytoplankton, a problem is that zooplankton appear and eat and proliferate.

Dr Regan has found that the predatory activities can be halted if aeration of the culture is stopped at night. The culture becomes starved of oxygen and the zooplankton suffocate.

### A packet of algae

The *Spirulina* species, noted earlier, is the first commercial success for algae culturing. It is grown in Mexico City in warm ponds with a high concentration of bicarbonate and salt. Twenty hectares of pond produce 2 tonnes (dry weight) of algae per day. The product is marketed as a source of vitamins, natural food dye, animal feed, and fish food.

*In Mexico City, 20 hectares of pond produce 2 tonnes (dry weight) of algae per day.*

Dr Regan has found that *Spirulina* can be maintained in sea water to which bicarbonate has been added. Whether it can be maintained as a dominant species he has yet to determine.

*Dunaliella*, one of the species that he has found can be so maintained, is being studied closely for commercial use in Israel. Scientists there are looking at the feasibility of producing glycerol from the organism. Glycerol is a viscous liquid used in making foods, cosmetics, soaps, drugs, explosives, and plastics.

The substance is produced directly by *Dunaliella* as a means of survival in salty water. The glycerol within its cell balances the high osmotic pressure due to high salt levels in the organism's surroundings. Raising the salt levels is a simple way of increasing glycerol yields.

Dr Regan believes it may be possible for each hectare of pond to yield 80 tonnes of *Dunaliella* each year, producing about 25 tonnes of glycerol worth perhaps $40 000.

*Dunaliella* also produces *beta*-carotene, a precursor of vitamin A and a natural colouring agent. At a price of $500–$750 a kilogram, the hectare of pond could perhaps return a tonne of the substance worth $600 000.

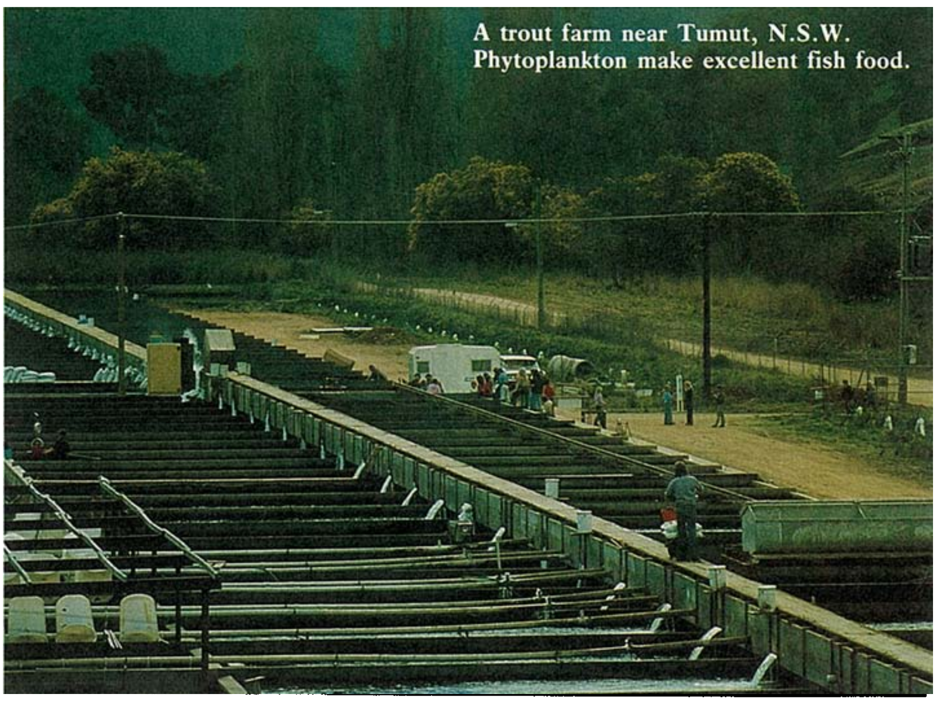
### No end of uses

Other possible uses for marine phytoplankton were mentioned earlier. Picking out some for elaboration will give a better idea of their potential.

PHARMACEUTICAL PRODUCTS. Certain marine environments create intense competition among micro-organisms, many of which produce chemicals that they use for self-protection. Among these, the list of pharmacologically active chemicals includes antibiotics, antifungals, anthelmintics, antivirals, anticoagulants, and antispasmodics. Others have potential as aggregation factors, growth regulators, neuroactive substances, cardioactive substances, and insecticides.

FISH-FARMING. Phytoplankton can be cultivated to serve as the primary food source for the farming of fish, prawns, and shellfish. The Food and Agricultural Organization of the United Nations has estimated that in 1975 fish-farming produced 9% of the total world fish catch, amounting to 6 million tonnes. The FAO has forecast that by the year 2000 fish-farming will expand to produce six to eight times more.

GUMS. Agar and alginates, derived from seaweeds (macro-algae), have been used for many years in the food, petroleum, and textile industries. They are used to increase the viscosity or gelling tendency of liquids. Recently, similar gums



A trout farm near Tumut, N.S.W. Phytoplankton make excellent fish food.

## Marine algae worth bottling

Bluish light illuminates marine phytoplankton cultures at the CSIRO Division of Fisheries.

Bright blue-green light illuminates rows of flasks on glass shelves. The light, resembling sunshine filtered through 10 metres of clean ocean water, comes from fluorescent tubes shining through sheets of Belgian stained glass. We are in one of the algae culture rooms at the CSIRO Division of Fisheries at Cronulla, N.S.W.

Dr Shirley Jeffrey has more than 100 species of marine algae in the controlled environment of the Algal Culture Laboratory. About half the species were collected in Australian waters, the others are strains from overseas collections. The main aim of Dr Jeffrey and her colleagues is to understand how algae survive the rigours of a life adrift in the oceans.

In order to study marine plants in detail, it is necessary to grow them in the laboratory. As Dr Jeffrey has found, that isn't all that easy. The growth medium is the tricky thing. Sea water is the basis, but each species needs the right nutrients. Some algae will survive on just nitrate and phosphate. Others demand soil extract and trace metals. Still others need vitamins, especially $B_{12}$, thiamine, and biotin.

Most of the several hundred species of marine algae held in culture around the world have been isolated from inshore and estuarine waters. These organisms tend to grow well in synthetic media.

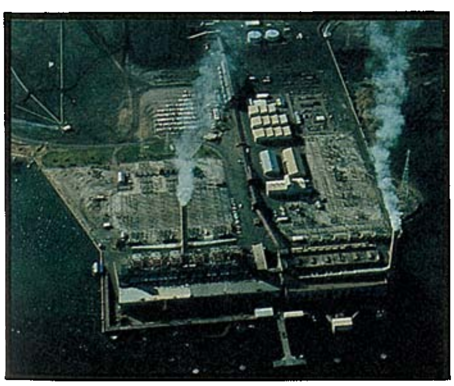
However, cultivating truly oceanic species as pure strains is still elusive. They seem to need associated bacteria, and in a culture collection this is an undesirable complication. Apparently, there are as-yet-undiscovered growth factors, which must be found, that can perform the bacteria's function.

At present, Dr Jeffrey and her group have succeeded in isolating and growing 20 types of algae in the collection under bacteria-free conditions. She finds it is still an art, and 'green fingers' are a necessity.

Dr Jeffrey has supplied dozens of cultures to universities, State departments, companies, and research institutions involved in fisheries or marine studies. Dr Regan's investigations are among those projects relying on CSIRO's Algal Culture Laboratory.

'Cultivating Uni-cellular Marine Plants.' S.W. Jeffrey. Reprinted from 'Annual Report 1977–79', CSIRO Division of Fisheries and Oceanography.

have been produced commercially from bacteria by fermentation. Micro-algae may be the next to be used. Injecting such gums, with water, into depleted oil wells is a technique already in use for recovering oil.



**The Thomas Playford power station at Port Augusta, S.A. — a good place to breed marine algae? Waste carbon dioxide could be used to promote growth in extensive shallow ponds.**

**Salt fields at Dampier, W.A. Similar ponds could be used for cultivating marine algae.**

METAL RECOVERY. Copper, iron, nickel, gold, and uranium can be recovered from sulfide ores by bacterial leaching. *Thiobacilli* oxidize the insoluble metal sulfide to a soluble sulfate, which is then washed out. The method can work on ore in the ground, mined ore, or mine waste heaps.

In the United States and Japan, copper is being recovered directly from the ground by percolating a fresh-water solution containing the bacteria through the ore body. If sea water and marine bacteria could be employed, microbial mining would be used more widely.

Dr Regan believes that marine biotechnology is set to become the next phase in our use of the earth's resources. The Aztecs' gatherings were but a taste of things to come.

*Andrew Bell*

### More about the topic

Marine biotechnology and the use of arid zones. D.L. Regan. *Search*, 1980, 11, 377–81.

'Phytoplankton Research: Current Perspectives, Problems and Future Prospects.' (Victorian Institute of Marine Sciences: Melbourne 1979.)