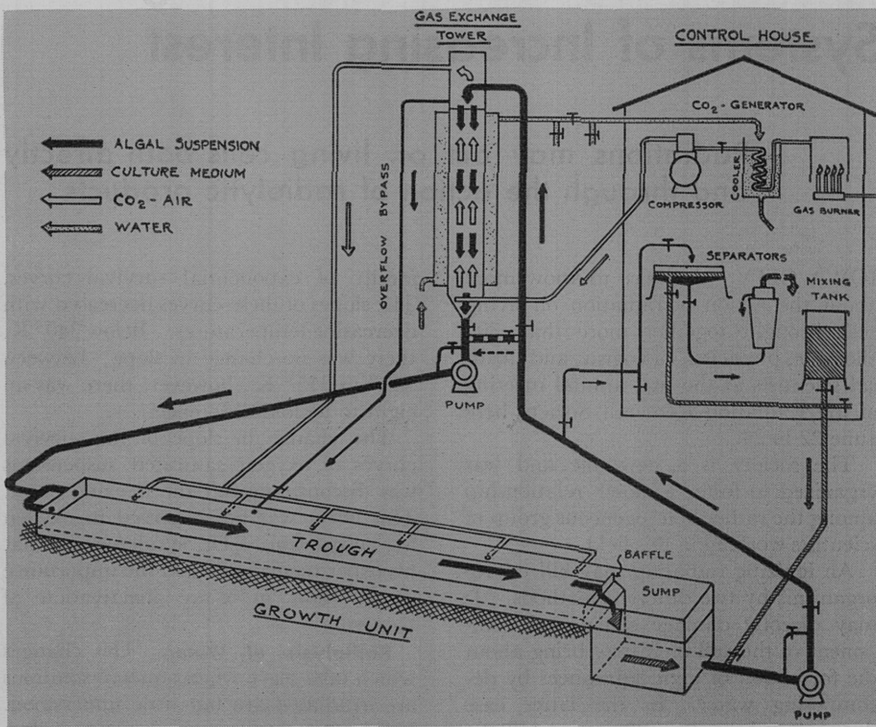


Schematic diagram of the Japanese pilot plant. The system yielded 52 grams of dried *Chlorella* per day. According to the report the plant is still in operation and the Japanese workers are attempting to improve some defects in the system

Mass Production Possibilities Seen for Algaculture

Carnegie Institution publication points way to algae as commercial source of food

ALGACULTURE, the commercial production of algae as a source of food protein and perhaps industrial raw materials, may not be an idle dream. The reports of pilot plants operated in various parts of the world for the cultivation of the algae *Chlorella* seem to indicate that the commercial culture of these unicellular plants may be a practical development in the not-too-distant future.

A monograph published this week by the Carnegie Institution of Washington entitled "Algal Culture from Laboratory to Pilot Plant" presents a survey of the development to date. The report discusses the progress made in pilot plants and semipilot plants toward the eventual large-scale production of algae as a commercial enterprise. Research principles of the operation and construction of these pilot plants as well as possible implications for the future are discussed by contributors to the monograph.

Much of the research responsibility of the institution is terminated now. As Vannevar Bush points out in the introduction to the monograph, basic research problems have been cleared to the point where construction of pilot plants and, eventually, production units is not impractical.

Algae Are Lowest Plants

The algae are classified in the lowest division of the plant kingdom, the *Thallophyta*, which includes the fungi, made up of molds and toadstools and other plants without chlorophyll and the algae which all contain chlorophyll of one form or another. The algae range in size from microscopic, single celled aquatic organisms like *Chlorella* to seaweeds and kelp growing several feet in length and found along the seashore.

The idea of algae as a food source is really not as improbable as it may sound at first. Various forms of kelp and seaweed are eaten in many regions of the earth. The use of the microscopic algae as a food, however, seems to be a relatively new idea. Before the pilot plants were set up there had never been an adequate supply of the material to conduct nutritional evaluation of *Chlorella*.

The Carnegie monograph reports on several nutritional investigations which indicate that the material is rich in available protein and has been used in animal feeding trials with good results.

In addition to the discussion of the investigation of the nutritional possibilities, the output from the pilot plants was studied as a possible source of raw materials. The dried product from the culture tanks was found to be rich in amino acids, vitamins, and fats.

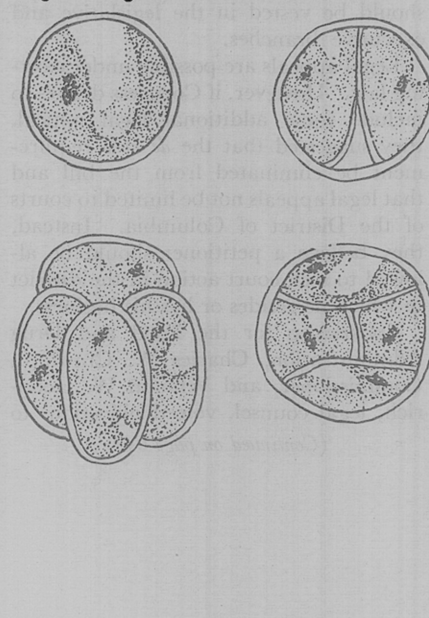
The Carnegie Institution's interest in mass culture of algae came as a result of basic research the institution had sponsored on photosynthesis. The unicellular algae *Chlorella pyrenoidosa* was the experimental plant for many of these studies, primarily because of the broad range of environmental conditions under which it could be grown.

During and after World War II H. A. Spoer and Harold Milner investigated the influence of environmental factors on the chemical composition of *Chlorella*. These environmental studies demonstrated that algae could be grown in a simple nonsterile medium consisting of nitrates and trace elements from technical grade chemicals, a 5% CO_2-air mixture, and a source of sunlight. Further it was not generally necessary to purify the water which was the base of the culture medium.

By 1947 with the general conditions for growth established, the idea of *Chlorella* as a source of food came up for serious consideration. Dr. Spoer and Dr. Milner prepared an analysis of the problem for the Carnegie Institution. They proposed a program of applied research and engineering which was subsequently approved and supported by the institution.

During the war a fairly dependable technique for the production of *Chlorella* in 5-gallon bottles was developed. However, sufficient information was not available on the effect of culture chamber

Chlorella pyrenoidosa as observed in a liquid culture—drawing of microscopic algae magnified about 3000 times



design on the yield and growth rate of the organisms; therefore, a number of prototype culture chambers of different designs were constructed.

The investigations were directed to finding the most efficient methods of exposing the organisms to sunlight and harvesting the yields from the culture chambers.

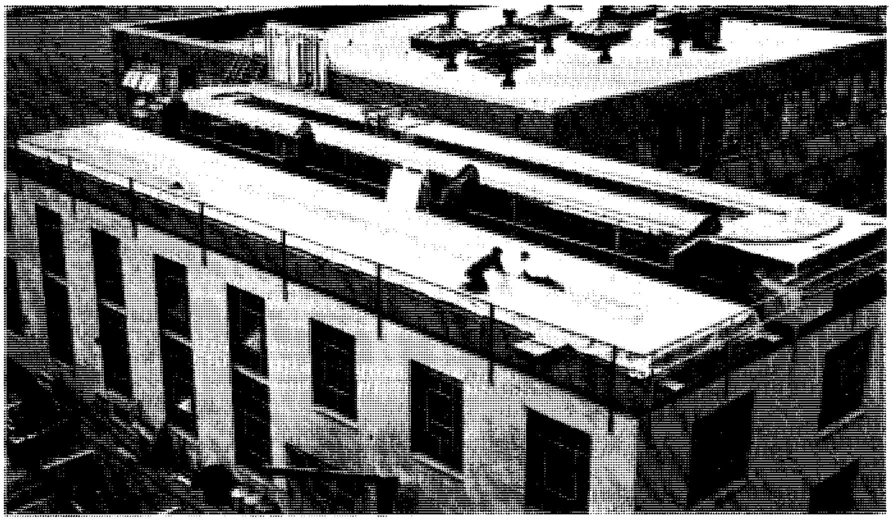
The most efficient photosynthetic utilization of solar energy takes place at low intensities of illumination. Since the intensity of the incident sunlight on the culture chamber could not be controlled, various methods were devised for modifying the intensity of illumination on the individual organisms. This was accomplished by cultivating dense cultures which would absorb all the incident solar energy in a shallow tank and agitating the medium so that each organism would be exposed to intermittent flashes of sunlight. The turbulence in the culture medium was accomplished by various pumping and baffle arrangements.

Gravitational settling and centrifugation techniques were used for separating the *Chlorella* from the culture medium. After separation the medium could be introduced back into the culture tank.

From these preliminary studies an engineering development program was initiated. Pilot plant studies were farmed out to the development groups of Arthur D. Little, Research Corp. of New York, and Stanford Research Institute.

At about this same time a British group, sponsored by Imperial Chemicals, Ltd., began semipilot plant studies at a research station in England and a Japanese group began construction of an operational pilot plant in Tokyo.

Perhaps the most interesting pilot plant was that set up by the group working in Tokyo. Here the production unit consisted of a concrete trough constructed in an open courtyard. The culture medium was pumped from the trough through a gas exchange tower containing CO_2 and air, then back through the trough. The Japanese unit was among the simplest production units developed, yet it gave adequate production yields. The results from the continuing Japanese work show that mass culture of algae is possible in Japan's climate; courtyard temperature ranged from 6° to 16° C. Implications of the Japanese work might prove important, for the Japanese with their low protein diet might be among the first to use algaculture as a food supply.



The pilot plant installation at Arthur D. Little. Two plastics ovals were constructed of parallel tubes about 70 feet long and 4 feet wide. The culture medium was circulated through the oval by a pump located within the building. Daily yields of 11 grams of dried *Chlorella* per square meter were obtained with this unit

The Future for Algaculture

Thus far there is no sound basis for estimating eventual cost of large scale commercial algaculture. Upper limits of yield per unit area have not been investigated. However, studies on the problem have, apparently, progressed to the point where continuing development of large scale cultures is not necessarily dependent in the hope for a cheap product.

The economic aspects of algaculture are, in some cases, dependent upon national policy. A case in point is Israel, where active work is approaching production stages with the hope of freeing Israelis from drains of their monetary reserves into other countries. Many active in the field seem to feel that large scale culture of *Chlorella* may offer a means of increasing the protein supply in areas where malnutrition and intensive overcropping have already reached a situation recalling Malthus' predictions.

Another fact for consideration is that the entire *Chlorella* organism is potentially edible; thus the energy converted from solar radiation is almost entirely available. With traditional crops much of the converted solar energy is wasted by the plant in the construction of supporting structures, leaves, stalk, and roots.

A total yield of 17.5 tons per acre is not considered an unreasonable expectation for *Chlorella* food production farms. Of this yield 50% would be protein, more than is found in the edible portion of any of the higher plants.

Extrapolation from the pilot studies led Dr. Burlew, editor of the Carnegie monograph, to predict that the total population of the world could be fed 30 grams of protein per person per day from the output of a million acres of algaculture. This area, slightly larger than Rhode Island, would, according to nutritional studies, supply a source of all 12 essential amino acids and of the major vitamins for the entire population of the world.

On The Cover

Livestock Feed Has Become the Major Use of Molasses

THE GRAPH LINES on the cover tell a story which has a technological basis. The manufacture of alcohol has consumed a large proportion of the supply of industrial molasses in years past. But development of a synthetic alcohol process based on petroleum products and increasing appreciation of the nutritional value of molasses for animal feeds have shifted the use pattern. The current trend indicates a further upward direction for feed use. The gains by synthetic alcohol and the high price molasses brings for feed combines to suggest that alcohol fermentation will continue to lose its position in the picture. The high price of corn has been a factor too. The latter reflects the increased attention farmers are giving to economics in their practices.

But as the feature article in this issue indicates, there is still much room for more of the hard-headed approach which calls for switching from the old traditional feed to one which does the job at a lower cost; the relationship of use of molasses to the saving involved still is out of balance. The future direction of the livestock feed curve on the cover may depend not only on prices, but on the spread of the application of economics to the business of farming.