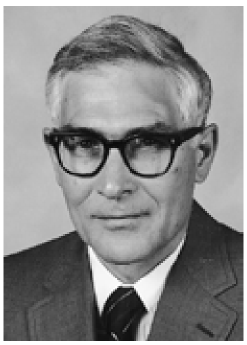
Hydroponics

In March 1999, my wife and I chaperoned our three oldest granddaughters on a trip to Walt Disney World Resort in Orlando, FL. This theme park is a great destination for children, but we grownups also had a fabulous time. For me, one of the high points of the visit was a special tour of "The Land" at Epcot Center. This facility contains extensive greenhouses devoted to hydroponics. During the tour, I discovered that hydroponics is the culture of plants without soil. The only requirements for plant growth are water, light, aeration, and nutrients.



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History of Hydroponics

Hydroponics is not a new concept (9,11). In fact, evidence exists that the Hanging Gardens of Babylon, which date back to 562 B.C., depended on hydroponic culture. Not until the nineteenth century, however, was a scientific basis developed for this practice. In 1860 a German botanist, Julius von Sachs, reported the results of his research on growing plants from nutrient solutions. von Sachs' work was followed by years of active research on plant nutrition and physiology, with many individuals contributing to a greater understanding of this science.

The first practical use of hydroponics was in 1936, when W. F. Gericke of the University of California applied the results of academic research to a commercial venture. He succeeded in growing root vegetables such as beets, radishes, carrots, and potatoes, as well as cereal crops, fruits, ornamentals, and flowers. Gericke was also responsible for naming this new enterprise "hydroponics," after the Greek words *hydro* (water) and *ponos* (labor). In retrospect, this new practice was a logical extension of growing plants in greenhouses. The major difference is that hydroponics is more efficient and provides greater yields than traditional horticulture.

Today hydroponics has grown to a sizable worldwide business. It fills a need for food production in nonarable regions and also has applications in diverse climatic zones, including northern lands with limited growing seasons. Holland, which has a shortage of land, has an estimated 10,000 acres (4,050 ha) dedicated to hydroponics. Outside Moscow, large greenhouses use soilless culture, and in arid regions such as the Middle East, hydroponic complexes combined with desalination units are being developed to meet local needs.

Hydroponics also is receiving attention in the United States. Not long ago, International Flavors & Fragrances Inc. broke ground on a hydroponic facility that will help the company develop new floral and fruit scents (6). The most dramatic application, however, for hydroponics lies in the future. We are on the verge of space travel, which will require new means of sustaining astronauts during missions. In case there is any doubt concerning the commitment of the United States, President Bush on January 14, 2004, unveiled a plan to develop a long-term manned base on the Moon and use it to prepare for landing a human on Mars (8).

Essentials of Hydroponics

Hydroponics represents the ultimate in a controlled environment—every variable is closely monitored. All parameters, including temperature, air, moisture, lighting, and nutrients, are controlled to provide optimal growing conditions. Nothing is left to chance.

Although the *Encyclopaedia Britannica* uses the term "soilless" culture, hydroponics usually incorporates a growing medium. Media may consist of materials such as perlite, gravel, shale, sand, or sawdust, which provide plant support and solution aeration. These media are all inert and should be sterilized before use to avoid infestation by insects and other pests.

Plants receive nourishment from nutrients dissolved in water that is circulated around the roots. Careful attention must be paid to the proper balance of both macro- and micronutrients. Macronutrients consist of nitrogen, potassium, calcium, phosphorus, magnesium, and sulfur. Smaller quantities of iron, chlorine, boron, manganese, zinc, copper, and molybdenum also are required. Notably absent is sodium, which most higher plants do not assimilate. The essential elements must be incorporated into soluble salts to make them available to the plant. The nutrient solution should be slightly acidic (pH 5.5–6.7).

Even with an extensive knowledge of plant nutrition, there is the possibility that a micronutrient may be overlooked. A practice called the Mittleider Method combines the features of hydroponics with soil cultivation using a specially prepared soil mix. Using the Mittleider Method, plant uptake of unidentified minerals may assist in plant development or be of use in human nutrition.

Where natural lighting is insufficient, it can be supplemented by artificial grow lights. Flowering plants, food crops, and seedlings need very bring light. Artificial grow lights must supply the full spectrum of sunlight to be effective; an ordinary incandescent bulb will not suffice. Fluorescent tubes designed for plants, metal halide high-pressure sodium lamps, and high-intensity discharge lamps are recommended.

Temperature and humidity also must be controlled. In general, optimal temperature and humidity depend on the plants under cultivation. Hydroponic conditions should reproduce their habitat. Because many agricultural crops have evolved from species found in tropical or semitropical locales, many crops grow best under such conditions, e.g., 72°F and 40% relative humidity. Night temperatures should be set about 10 degrees Fahrenheit lower than day temperatures.

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During the early years of development, hydroponics involved considerable capital investment for a commercial facility. Not only were there the construction costs for a greenhouse, but supplementary equipment, including pipes, pumps, valves, tanks, and controls, had to be purchased. In recent years, costs have dropped appreciably. The availability of modern construction materials, including plastics, has made a great difference.

Space Exploration

Space colonization will be the modern equivalent of the settling of North America by Europeans during the seventeenth century. Early immigrants to North America had to learn how to live off the land or perish because all ties with their homelands were severed. For better or worse, future astronauts will find themselves in a similar situation.

On future interplanetary missions, astronauts will not be supplied from Earth with freeze-dried concoctions and pureed foods squeezed from tubes. They will have to depend on hydroponics for their food supply (4), as well as supplemental food sources such as single-cell protein obtained from algae (1,2). NASA currently is funding research on growing red meat, chicken, and fish in laboratory cultures in anticipation of space travel (10). Food production by any of these means will require a closed system in which human waste and carbon dioxide are recycled to the organisms being grown. The only outside input to the system is energy.

When growing plants in space, a new variable is introduced to hydroponics. The effect of gravity, or lack thereof, must be taken into consideration. Experiments simulating microgravity have shown that some plants fare poorly under these conditions (5). Encouraging results, however, have been obtained by DuPont scientists, who succeeded in propagating soybeans aboard the International Space Station (3).

Astronauts who reach Mars will not find it to be nearly as inhospitable as it may seem from Earth. Future inhabitants will be protected from cosmic rays by the thin atmosphere, and the planet's gravity will alleviate problems associated with weightlessness (13). All the building blocks for proteins, fats, and carbohydrates are abundant on the planet. The atmosphere of Mars contains 95.3% carbon dioxide and 2.7% nitrogen (7), and ample supplies of water have been detected at the poles (12). In addition, deposits of sulfur, potassium, calcium, and magnesium have been found on the ground. Because of interference in the analytical method, phosphorus has not been detected but presumably is present. Using one of several chemical reactions, oxygen can be generated from carbon dioxide. Thus, all the elements for sustained life are present.

The plan to put people on Mars is ambitious, if not visionary. This undertaking will require the best efforts of many specialists, including food scientists, working together. Only a systems approach to quality assurance can guarantee success. Hydroponics must be integrated with other technologies into a seamless operation.

References

1. Angier, N. On this trip: One lifetime isn't enough. N.Y. Times, p. F1, Mar. 5, 2002.
2. Anonymous. NASA experiments with food for interplanetary travel. Food Technol. 52(6):12, 1998.
3. Anonymous. DuPont studies space soybeans. Chem. Eng. News 81(24): 10, 2003.
4. Brody, J. E. What to serve for dinner: When dinner is on Mars. N.Y. Times, p. F1, May 19, 1998.
5. Carlson, S. Geotropism: One last time. Sci. Am. 284(3):78, 2001.
6. Fisher, D. Fragrant prospects. Forbes, p. 102, Aug. 6, 2001.
7. Frankie, B. M., and Zubrin, R. Chemical engineering in extraterrestrial environments. Chem. Eng. Prog., p.45, February, 1999.
8. Kennedy, D., and Hanson, B. A time of opportunity. Science 303:589, 2004.
9. Nicholls, R. E. *Beginning Hydroponics*. Running Press, Philadelphia, 1977.
10. Port, O. Innovations. Bus. Week, p. 101, Jan. 27, 2003.
11. Resh, H. M. *Hydroponic Food Production*. 5th ed. Woodbridge Press Publishing Co., Santa Barbara, CA, 1998.
12. Titus, T. N. Water, water everywhere. Nature 428:610, 2004.
13. Zubrin, R. The Mars direct plan. Sci. Am., p. 52, March, 2000.