Projector Center

What is Biotechnology?

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Students hear that biotechnology holds great promise for human health and that biotechnology has become an enormous business. They need to know what biotechnology is. As citizens, our students will be asked to vote on biotechnology-related issues and serve as jurors in patent-dispute claims or product-defect liability claims. Some students will go on to be scientists, lawyers and other professionals directly involved in biotechnology.

We can put seemingly unrelated facts together for students with a discussion of biotechnology. Through classroom discussions or during an illness, children learn that antibiotics cure bacterial diseases. Most children like yogurt, cheese and bread—products of the biotechnology industry. In high school, students learn about genes and recombinant DNA technology. They read in newspapers that a recombinant vaccine for hepatitis B is available or that recombinant cells can produce human growth hormone. A biotechnology discussion can focus on the similar processes used in these technological advances.

Biotechnology is a way of making commercial products using living organisms. Foods, vaccines, antibiotics and vitamins have been produced by microbes for years. The process by which microbes produce these products is called fermentation. In the strict sense, fermentation is the release of energy from an organic molecule (e.g., sugars) without using oxygen or an electron transport system. Unlike respiration, fermentation uses an organic molecule as the final electron acceptor and does not use an electron transport chain. [Aerobic respiration uses molecular oxygen (O_2) as the final electron acceptor. Anaerobic respiration uses an inorganic chemical other than O_2.] In modern biotechnology, fermentation is also used to describe any process that produces ethyl alcohol or acids (e.g., the production of sauerkraut) or to refer to any large-scale microbial process occurring with or without air—such as the production of antibiotics.

Most antibiotics are made by bacteria in large, environmentally-controlled vats called fermenters. In 1928 Alexander Fleming discovered that the fungus *Penicillium* produced an antibacterial agent. Penicillin was purified and characterized in 1939 by Ernst Chain and Howard Florey. Actinomycetes (eubacteria), however, have been used to produce the vast majority of antibiotics since actinomycin and streptomycin were purified by Selman Waksman in the 1940s. Presently, three species of actinomycetes are used to produce more than 3000 different antibiotics. (Two other bacteria produce about 500 antibiotics and six species of fungi produce another 1000 antibiotics).

The menu accompanying this article is designed to illustrate some classical examples of fermentation. It may be reproduced as an overhead transparency and used to discuss biotechnology with a historical perspective. Some information to help start a class discussion from the menu is given below.

There are numerous ancient Chinese accounts of the production of fermented foods. Without refrigeration, selectively fermented foods would last longer than fresh food. For example, cheese and yogurt can be kept longer than milk because acid-intolerant bacteria cannot grow. Wine can be kept longer than fruit juice because of the antimicrobial action of ethyl alcohol. All of the menu items are real.

The starter cultures for sour breads such as sourdough and rye contain lactic acid bacteria (which produce the sour flavor) in addition to the traditional yeast (for leavening). Many microbial fermentations produce acidic end products. The practice of fermenting sausage probably prevented the growth of the acid-intolerant bacterium *Clostridium botulinum* (which can produce botulism toxin) in the ground meat. Microbial fermentation of sausage meats also produces the sausages' flavors.

Microbes may provide an alternative food source because they don't require large amounts of land (as grain crops do) or prime food sources (required by cattle). They can grow on cellulose and other biodegradable waste products. They can grow rapidly, sometimes doubling their weight in an hour. When used as a food, microbes are called single cell protein (SCP). The dried cells are 40 percent to 70 percent protein by weight. Three of the entrees on the menu illustrate SCP:

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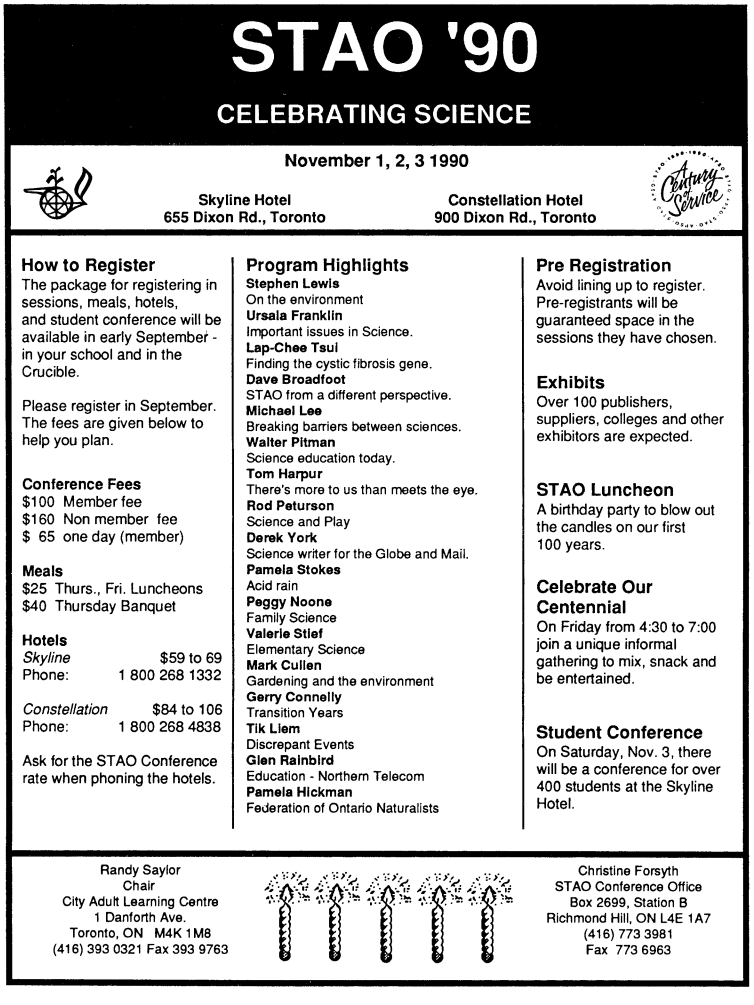
1. The cyanobacterium, *Spirulina*, is being grown for animal feed. Little is known about its possible use for human nutrition. It is used as a dietary supplement called dihé in the Chad area when animal protein is not available. Photosynthetic organisms are relatively inexpensive to grow because light is an inexhaustible energy source.
2. *Methylophilus* is grown on methyl alcohol to produce a food supplement for cattle in Europe.
3. Yeasts such as *Torulopsis* have been used as a human food supplement for many years.

The dessert menu is yogurt sweetened with dextran, a bacterial capsule used as a sweetener and source of glucose (dextrose).

Drinks on the menu include root beer which, prior to 1905, was a yeast oxidation of molasses and sassafras bark. (Sarsaparilla root was added for flavor.) This type of root beer contains approximately 0.03 percent alcohol. To make coffee and other drinks from plant products, pulpy material must be removed. This is accomplished by the bacterial enzyme pectinase. The enzyme hydrolyzes pectin to clarify juices.

In the 1980s the development that broadened biotechnology was the use of recombinant DNA. Changing the genetic make-up of a cell allows it to produce desirable macromolecules (e.g., an amino acid, a vitamin, or an antibiotic) in large quantities. The vaccine against hepatitis B is produced by a genetically-engineered yeast. A gene that codes for a viral coat protein is isolated from hepatitis B virus and inserted into baker's yeast (*Saccharomyces cerevisiae*). As the yeast grows, it makes the viral protein. To be used as a vaccine, this viral protein is purified by freeing it from yeast cells and culture medium. Unlike the smallpox and polio vaccines, this engineered hepatitis vaccine contains no live viruses, so there is no risk of developing hepatitis from the vaccine. Unlike the first hepatitis B vaccine, the newer engineered vaccine uses no human blood, so there is no risk of contamination by an undetected virus or bacterium in blood products.

The list of products and applications of biotechnology based on the techniques of recombinant DNA is long and expands almost daily. As these products come into use in medicine and in our homes, they will affect our lives.



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Student Activities

1. Find at least three supermarket products made by microorganisms. (The label will state the scientific name of the organism or include the word **culture**, **fermented**, or **brewed**.)
2. Look up recipes for yogurt, sauerkraut and bread. Find the steps indicating that the action of a microorganism is necessary.
3. Read the business/finance section of a newspaper and identify biotechnology companies and their new products.
4. Sauerkraut, yogurt and bread are easily made in the classroom. Students can learn about fermentation with these laboratory activities. We modify recipes to use metric measurements so students will gain experience with metrics and weighing. Kitchen measuring cups with metric volume measurements are sold in stores.
5. Discuss each of the following jobs in the biotechnology industry: molecular biologist, protein chemist, organic chemist, microbiologist, fermentation technician, quality control supervisor, geneticist.
6. Visit a winery, cheese factory, or biotechnology company.
7. Provide an argument either for or against the statement, "Genetically-engineered organisms are safe." Cite examples to substantiate your case.
8. How will advances in biotechnology (i.e., genetic engineering) improve the production of food and medicine?

References

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