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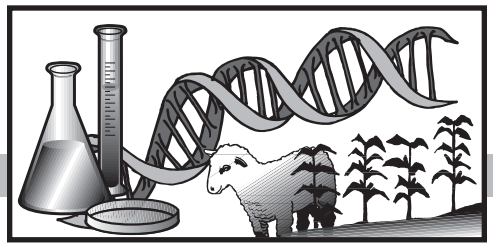


Biotechnology and Human Health

*Randy Vines**

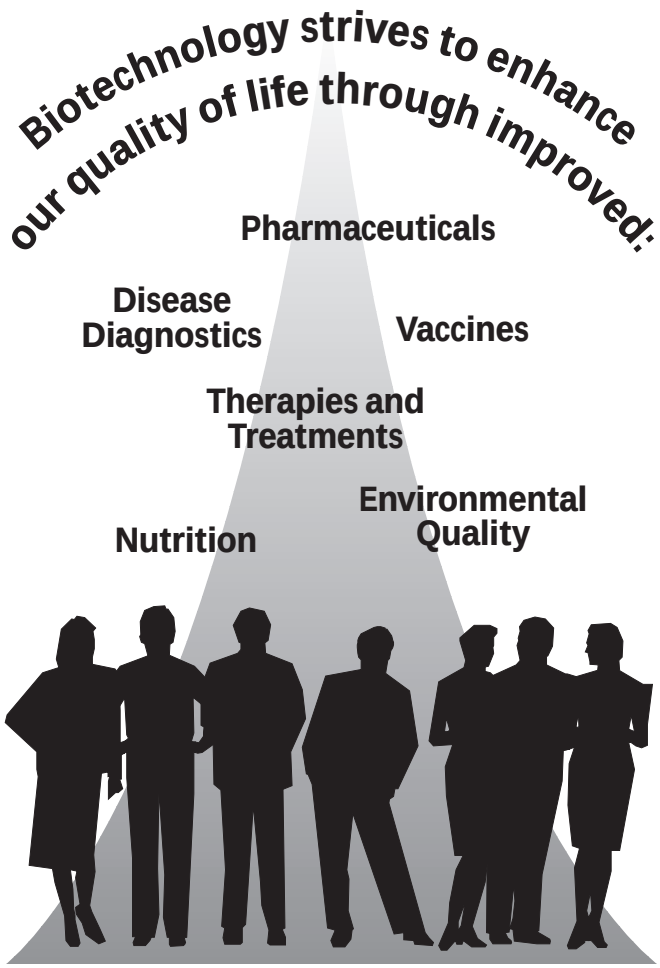
Modern day biotechnology is seeking new and better ways to enhance our quality of life through improvements in human health and nutrition. This publication will introduce you to new applications of biotechnology that are being explored to prevent, diagnose, and treat human health problems.

Direct Effects of Biotechnology on Human Health

Pharmaceuticals and Diagnostics

For centuries, biotechnology has contributed to the discovery of medicines and vaccines used to fight disease. Advances in scientific understanding and laboratory techniques during the last half of the twentieth century were significant and led to new medicines for diseases and conditions such as cancer, heart disease, stroke, diabetes, arthritis, obesity, and AIDS.

Using basic research and the tools of biotechnology, scientists better understand what causes certain diseases, giving them the ability to identify specific targets in the body for drug treatment. This results in more effective medicines that have fewer side effects. Additionally, as the underlying causes of diseases are revealed and diagnostic methods are improved, "personalized" disease diagnosis and treatment will become more prevalent and promises to change the way medicine is practiced.



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Partial List of Drugs that are Products of Modern Biotechnology

Drug	For Treatment Of /Use
Activase	Heart attack/stroke/ pulmonary embolism
AZT	HIV infection (one of 14 drugs for HIV)
BeneFix	Hemophilia B
Celebrex	Osteoarthritis and adult rheumatoid arthritis
Enbrel	Rheumatoid arthritis
Epogen	Anemia associated with kidney failure
Gleevec	Chronic myeloid leukemia
Herceptin	Certain type of breast cancer
Humulin	Diabetes
LYMErix	Lyme disease vaccine
Protropin	Growth hormone deficiency
Provigil	Narcolepsy
Recom-bivax-HB	Hepatitis B vaccine
Remicade	Crohn's disease and Rheumatoid arthritis
Rituxan	Certain non-Hodgkin's lymphoma (cancer)
Tamiflu	Flu infection
Xenical	Obesity
Zantac	Heartburn
Zenapax	Prevention of kidney transplant rejection
Zocor	High cholesterol levels

Sources:
The Biotechnology Industry Organization
United States Food and Drug Administration

For example, traditional treatments for breast cancer were surgery, radiation therapy, and chemotherapy. Recently, through basic cancer research, it was discovered that approximately 30% of breast cancers are associated with the overproduction of a protein called HER2. Combining this knowledge with modern techniques of biotechnology, scientists developed a drug that specifically targets HER2. Now, through better diagnostic methods, doctors can more specifically determine the type of breast cancer present, and if appropriate, use this new drug for more effective disease treatment.

Advances in biotechnology-driven diagnostic methods aid doctors in other ways. For example, it used to take 24 to 48 hours to conduct a throat culture test to determine if a patient with a sore throat had "Strep throat." Strep throat is caused by a bacterium and is treated with an antibiotic. A sore throat caused by a virus, such as cold or flu, will not respond to antibiotic treatment. Therefore, the doctor must know the cause of the sore throat before initiating treatment. Today, a "quick" Strep test can be performed in about 10 minutes, allowing the doctor to begin antibiotic treatment immediately if the test is positive.

Vaccines

In the late 18th century, Edward Jenner became the first person to systematically use cowpox to control the spread of smallpox in people, thus demonstrating the ability to prevent disease through vaccination. Since then, biotechnology has provided the means to produce over 15 vaccines that protect people from debilitating and potentially deadly diseases. In the United States, infants and children routinely receive 11 of these vaccinations.

Scientists continue to work on vaccines for diseases caused by bacteria, viruses, and protozoa. Diseases such as cholera, AIDS, and malaria are at the forefront of international vaccine research.

Currently, vaccines are expensive, must be refrigerated until used, and require sterile needles and specialized healthcare workers to be administered - each of which is a major barrier to immunizing people in developing countries. The tools of biotechnology are being used to design new methods of immunization that may alleviate these problems. One strategy is to genetically engineer plants to produce an "edible vaccine" in their fruits or leaves so that people could eat a fruit or drink a plant extract to be immunized. Scientists are also exploring the use of "patches," similar to the ones used to help overcome nicotine addiction, to deliver vaccines. Clinical trials are now in progress to see if these new vaccination methods result in adequate protection from disease.

Genes and Gene Therapy

Biotechnology allows scientists to study an organism's genes by sequencing its deoxyribonucleic acid (DNA). The goal of the Human Genome Project is to identify all of the genes present in humans (comprised of 3 billion bases of DNA) and make them available for

additional scientific studies that will ultimately improve human health. In February 2001, a "rough draft" of the human genome was published and it is expected that the final version will be available by 2003.

Current research, including work resulting from the Human Genome Project, suggests that flawed genes contribute to 4,000 human diseases. The goal of gene therapy is to repair a person's genetic defect and thereby cure or prevent the associated disease. Gene therapy holds great potential, howerver, the technology is still experimental and positive results from clinical trials involving gene therapy have been limited. Scientists are nonetheless optimistic that future advances in basic science and biotechnology will result in successful gene therapy techniques.

Organ Replacement Therapy

Because of improvements in medical science and an increase in available facilities, the number of successful organ transplants is rising each year. In the year 2000, over 22,000 operations to transplant organs such as heart, lung, kidney, liver, and pancreas were performed in the United States. However, nearly 6,000 people died while waiting for an available organ.

Xenotransplantation, which is the use of animal organs in humans, has been suggested as a possible solution to the problem of transplant organ shortage. The major scientific challenge to this approach is the strong rejection of the animal organ by the human immune system. Rejection is also encountered in human-to-human transplants, but, not surprisingly, is more problematic in xenotransplantation. To overcome this obstacle, researchers are genetically modifying pigs so that their organs will not be recognized as foreign by the human immune system. Work on this project is proceeding, but it is still far from being a viable option. Another problem in xenotransplantation is how to ensure that the animal organ is free from any viruses or other infectious agents that could cause disease in humans. Beyond the scientific issues, xenotransplantation raises moral and ethical concerns that will have to be addressed as well.

Indirect Effects of Biotechnology on Human Health

Nutrition

The goal of improving the health of people worldwide has driven scientists to produce genetically modified plants and animals that yield nutritionally enhanced foods (see sidebar on page 4 for listing). These products are in various stages of research and testing, but some may be commercially available in the near future.

Prevention of Food Contamination

In the United States, it is estimated that contamination of food with bacteria such as *Campylobacter, Eschericia coli, Listeria,* and *Salmonella* cause 3.8 million cases of human illness annually. Researchers are using biotechnology to design new ways to reduce and identify food contamination before tainted products reach the consumer.

Biotechnology and the Prevention of Tooth decay

Current evidence suggests that most dental disease is caused by the bacterium *Streptococcus mutans*. Once in the mouth, the bacterium binds to the surface of teeth where it builds up into a colony of bacteria that appears as plaque. An established colony of *S. mutans* feeds on sugars that are present in foods and secretes an acid that erodes the tooth and causes decay. Frequent brushing and flossing disrupts colony formation, thus preventing acid accumulation.

Once in the mouth, *S. mutans* can be thought of as a car looking for a space in a parking lot as it tries to attach to teeth. Researchers are using biotechnology to design new therapies that will either fill all of the available parking spaces in the mouth before *S. mutans* arrives or supply a protein that will stick onto *S. mutans* and block its ability to park in a space. These treatments may be in the form of a paste that would be applied to the teeth every few months, in a mouthwash, or be administered as a vaccine that would give lifelong protection. Some of these products have been tested in humans and found to be safe and effective at reducing *S. mutans* colonization in the mouth.

Foods, nutritionally enhanced through biotechnology, that may be used in the future:

- Cooking oils with healthier fats to lower cholesterol levels
- Tomatoes with more lycopene to help prevent cancer
- Potatoes that absorb less fat during frying to lower cholesterol levels
- Cereals and vegetables with increased protein content
- Foods that can protect people from chronic diseases - such as juices and cereals containing extra calcium to reduce osteoporosis
- Peanuts, milk, and wheat with allergenic proteins removed – allowing people with allergies to eat them
- Cow's milk that contains extra lysozyme – a natural anti-bacterial compound which could help prevent infection in infants and increase the shelf-life of milk
- Meats with less fat and better flavor

Some interesting developments include:

- Anti-bacterial compounds to be used for meat sterilization
- Vaccines to protect baby chicks from infection with *Salmonella*
- Field-based bacterial detection systems

Environmental Cleanup and Monitoring

As the world population increases, the environment is becoming increasingly contaminated with toxic metals, chemicals, and radioactive compounds. If these pollutants accumulate in soil and water, they can be ingested by animals and humans, potentially leading to many human health problems. Traditional methods of cleanup are costly and cause further destruction of the environment.

In a new approach to the problem, biotechnology is being used to genetically modify bacteria and plants so that they are able to efficiently sequester or detoxify these contaminants. Laboratory studies and limited field trials have demonstrated that this method is feasible and it has the added advantages of being relatively low-cost and non-destructive.

Genetically modified bacteria and plants that function as biological warning systems of environmental contaminants and hazards are also being produced. These "biosensors" may be used to monitor water and land near factories to provide a constant, low-maintenance way to make sure harmful compounds are not being released into the environment. There are concerns associated with releasing genetically modified organisms into the environment. Before they are used, their safety will have to be demonstrated.