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TEACHING METHODS

Integrating biotechnology into a non-majors biology curriculum

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A general education biology course entitled 'Biotechnology Transforms Our World' has been developed to illustrate biological concepts with advances from biotechnology. The contributions of molecular biology to understanding human genetics, evolution, plant and animal (including human) biology and ecology are illustrated with specific case studies. *Journal of Industrial Microbiology & Biotechnology* (2000) **24,** 308–309.

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Introduction

A wide variety of areas within the science of biology have been advanced with the use of biotechnological techniques. An understanding of those methods, their power and limitations, and the knowledge that they have generated is critical for making informed decisions about the impact of biotechnology on our lives. In an attempt to introduce students to these methods and their applications, a general biology course for non-science majors entitled 'Biotechnology Transforms Our World' was developed. The course addresses major principles and basic concepts in biology, using biotechnology as a window for viewing the progress that has occurred in our understanding of the biological world.

Course content and delivery method

The course begins with a study of cell and molecular biology that provides background for understanding how DNA can be manipulated. The focus then shifts to a discussion of commonly used biotechnological methods. This foundation allows a survey of major areas of biology, highlighting a biotechnological application in each area (Table 1).

The biotechnological examples are presented in a case study format (Addendum 1). Students read the material provided and answer questions regarding the material (Addendum 2), usually in the context of group discussion in a cooperative learning exercise. The case study is written not only to elucidate the unique contribution of biotechnology to the area under consideration but also to provide connections to material learned previously. There are also questions involving prediction and/or application of the information. In the example presented in Addenda 1 and 2, the symbiotic relationships involved in nitrogen fixation are used to enhance understanding of ecological principles.

Table 1 Biotechnological applications for major topics in 'Biotechnology Transforms Our World'

Topic	Biotechnological application
Human genetics	Gene therapy for SCID Gene therapy for cystic fibrosis
Evolution	Studying evolutionary distance with mitochondrial DNA sequences
Reproductive system	Inheritance of breast cancer
Circulatory system	Production of recombinant tissue plasminogen activator
Nervous system	Pedigree analysis of Huntington's disease
Immune system	Detection of HIV with ELISA
Plant biology	New foods with genetic engineering
Animal biology	Transgenic animals
Ecology	Ice-minus bacteria Nitrogen fixation Monarch butterfly as a threatened species

The course also includes a laboratory where students experience methods for analyzing DNA including: DNA isolation from bacteria, agarose gel electrophoresis, simulations of paternity testing, and forensic analyses by Restriction Fragment Length Polymorphism (RFLP), and Polymerase Chain Reaction (PCR). An ELISA (Enzyme-Linked Immunosorbent Assay) protocol is used to illustrate protein analysis with specific antibodies. All of the exercises are carried out with commercially available kits. The laboratory is also used as a learning environment to debate controversial issues or to apply knowledge in medical case studies. Some useful references are listed in Addenda 1 and 2.

Conclusion

The practice of illustrating biological content areas with specific applications has allowed both a sufficient breadth of material to be covered and significant depth of understanding to be developed in unique areas of biology.

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Addendum 1 Case study on nitrogen fixation

Plants require nitrogen to produce proteins and nucleic acids. They are unable to use gaseous nitrogen from the atmosphere and must instead absorb nitrogen-containing compounds from the soil. In commercial agriculture, farmers use fertilizers to increase the content of nitrogen-rich compounds in the soil. There are bacteria, such as *Rhizobium*, which can take gaseous nitrogen and convert it to ammonia that the plants can use. This process, called nitrogen fixation, requires energy. In leguminous plants (eg beans, peas, clover), a symbiotic relationship has developed with *Rhizobium*. These bacteria enter the roots of the plants and collect in swellings called nodules. In addition to protection, the bacteria receive energy from the plant's photosynthetic products and the plant receives nitrogen-rich compounds from the bacterium [4]. If nitrogen fixation can be improved, perhaps the use of chemical fertilizers can be reduced.

Scientists are attempting to improve nitrogen fixation in muliple ways. They are studying the genes involved with nitrogen fixation to see if they can increase gene expression in *Rhizobium* [2]. They are breeding plants that can have a greater association with *Rhizobium*. They want to transfer nitrogen-fixing genes to bacteria that will associate with other agriculturally important crops such as corn, wheat and rice.

There are many challenges that face scientists in their task of optimizing nitrogen fixation. The most efficient nitrogen-fixing bacteria often cannot effectively compete with *Rhizobium* native to the soil. Other characteristics of the soil, including acidity or alkalinity, salinity, pollutants, and fertilizers can also have an adverse effect on nitrogen-fixing bacteria. Nitrogen-fixing bacteria can associate only with a narrow range of plant species so that this beneficial process cannot be widely applied to all plants. Additionally, nitrogen-fixing bacteria have high-energy needs that may not be met by some types of plants [1].

Recently recombinant bacteria have been developed that increase nitrogen fixation in soybean plants [5] and a gene for hypernodulation (increased number of nodules) in soybeans [3] has been discovered. A soybean plant that carries more nodules will carry more bacteria so that the rate of nitrogen fixation will be increased. While there is as yet no mechanism for associating nitrogen-fixing bacteria with corn, the increased nitrogen-containing compounds from hypernodulating soybeans can be released to the soil before planting corn in the same field. Scientists estimate that if hypernodulating soybeans could increase the amount of nitrogen-containing compounds two-fold over other soybean strains, they could provide about half of the nitrogen needed by most corn crops. This would reduce the need for fertilizer in growing corn.

Addendum 2 Discussion questions regarding nitrogen fixation

(1) What is the importance of nitrogen for the growth of plants?
(2) What types of improvements in nitrogen fixation are being attempted by biotechnologists?
(3) Predict which improvement is most likely to succeed. Give a reason for your prediction.
(4) What challenges face scientists who are attempting to provide adequate nitrogen for crops?
(5) What is the benefit that soybeans derive from *Rhizobium* bacteria?
(6) What is the benefit that *Rhizobium* bacteria derive from soybeans?
(7) What is the benefit that corn derives from soybeans?
(8) To increase nitrogen-containing compounds for corn, which type of symbiosis (parasitism, mutualism, or commensalism) is represented by the relationship between each of the following pairs:
    (a) Soybeans and *Rhizobium* bacteria?
    (b) Hypernodulating soybeans and corn?
    (c) *Rhizobium* bacteria and corn?

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