CITIES, HOMES, FACTORIES, cars, and trucks throughout the world are powered primarily by fossil fuels. Concerns about the availability of these fuels and the environmental impacts of producing and using them have led to a search for alternatives. One of these alternatives is a group of fuels called biofuels. Biofuels, including bioethanol and biodiesel, are compounds that are produced from renewable biological sources. Plants high in starch and sugar are made into ethanol, while vegetable oils and other fats are made into biodiesel. Both of these fuels may be burned in combustion engines in place of fossil fuels. Research on alternative fuels and the role of genetically modified organisms in producing them is rapidly expanding in the United States.

Scientists are currently working on ways to overcome several obstacles to the sustainable production of biofuels. They hope to improve the plants themselves to get high yields of fuel, and to improve the...
technology for extracting fuel from the plants. Much of the research focuses on the development of genetically modified microorganisms. Currently, most bioethanol is generated by fermenting corn or sugar cane with yeast or bacteria. Those crops, however, are also important food crops, and the starchy and sugary edible parts of these plants are the parts needed to make bioethanol. If too many farmers dedicate too much agricultural land to producing biofuel plants, supplies of basic foods will shrink. For this reason, scientists are trying to find efficient ways to make biofuels from the waste stalks and leaves of crops and from grasses that don’t require the high-quality soil that food crops need.

The difficulty in making fuel from grasses and inedible parts of crops is that they contain two substances—lignin and cellulose—that are very hard to break down. These substances add strength to the plants’ cell walls, but cause problems in the production of biofuels. The solution might be found in bacteria that live in such places as compost piles or in the digestive systems of termites and other organisms. Enzymes that break down wood and the tough parts of plants have been identified in these bacteria. A current approach scientists are pursuing is to insert genes from these bacteria into other bacteria that grow well on the large scale needed for producing commercial ethanol. One such bacterium is the very well understood E. coli. Scientists are working on a genetically modified E. coli that can break the lignin and cellulose into sugars that can then be converted to ethanol.

Another potential use of genetically modified microorganisms is to improve the quality of the fuel produced from sugars. Typically, yeast or bacteria break down sugars and starch to produce ethanol, a two-carbon fuel. Ethanol’s shortcomings, however, are that it doesn’t have a high energy content, it binds to water, and it corrodes metals, including those with which storage tanks and cars’ gas tanks are made. One research group has modified E. coli to produce fuels that have longer carbon chains and are similar to gasoline. These longer-chain alcohols store more energy than ethanol, are easier to separate from water, and perform better in engines.

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Currently, other types of microbes can produce these fuels, but the yield is low. The fuels can also be produced through breaking down the plant matter with chemicals, but this is expensive and requires a lot of energy. To harness *E. coli* to produce fuels scientists have deleted several genes in *E. coli* and replaced them with genes from other organisms. These efforts have been somewhat successful. The modified *E. coli* produces longer-chain alcohols, but not enough for commercial use. Some researchers are trying to determine how to balance each step of the reaction pathway in the *E. coli* to maximize production of the fuels. Other research is looking at performing a similar genetic modification in yeast and other microbes that are often used in converting plant material into other types of biofuel.

A third research group has genetically engineered *E. coli* that are able to both break down cellulose and turn that product into biodiesel and related compounds. They have done this by deleting two *E. coli* genes and adding genes from several other organisms. Although these modified *E. coli* produce less fuel than needed for commercial use, they produce enough that the results are promising.

Some scientists question the safety of modifying bacteria and other microbes to produce biofuel. They think there has not been enough safety testing done on genetically modified organisms, and suggest that there may be unintended consequences for human health or the environment. Although the *E. coli* needed to make biofuels would be grown only in laboratories, there might be problems if some were accidentally transferred to other environments.

Alternatives to developing genetically modified organisms for producing biofuels include:

- Improving the fuel quality of plants by selective breeding.
- Weakening plants’ cell walls through selective breeding.
- Improving the process of chemically breaking down plant matter.

Both scientific advances and policy decisions will play a role in decisions about pursuing these approaches to producing biofuels.
Analysis

1. Analyze your work in this activity and that of the other groups, according to your teacher’s instructions. Analysis should include a summary of the data collected and conclusions you and your group draw from the data about the bacteria on the plates. Explain possible sources of experimental error.

2. How would your results differ if you had not added ampicillin to any of the plates but kept all other variables the same?

3. What results would you expect if you had created a Luria–ampicillin plate containing *E. coli* that were not transformed?

4. What are the possible benefits and risks involved in developing genetically modified organisms to produce biofuels?

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<th>KEY VOCABULARY</th>
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<td><strong>biofuel</strong></td>
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These mosquito larvae have been genetically modified with GFP. Scientists hope to one day genetically modify mosquitoes so they cannot carry the protozoa that cause malaria. This could save millions of lives.