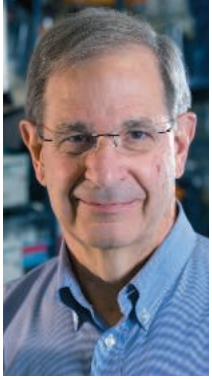

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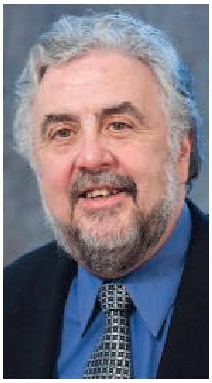

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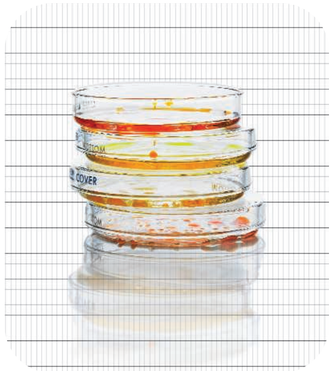
Microbes in the Energy Grid

THE CURRENT SURGE IN FOOD AND FUEL PRICES HAS SOUNDED AN ALARM SHOWING WHY providing a sustainable global energy supply and minimizing climate change are arguably two of the greatest challenges facing 21st-century society. With adequate research and proper implementation, the diverse and often unseen inhabitants of the microbial world—bacteria, yeasts, fungi, and archaea—can help address these challenges.

The incredible metabolic diversity of today's microbial world reflects the accumulated evolutionary response to diverse environments present over the 3.5 billion years that they have inhabited Earth. Over this time, extensive mutation, recombination, and lateral gene transfer have produced microbes that access most of the theoretically possible redox reactions, capture solar and other energy resources, and inhabit a wide range of environments. Some of these microbes—the extremophiles—exist at the current limits of life.

To harness microbial activities to address these challenges, much remains to be learned about the chemical space they occupy. Of the estimated 10^{30} microbes on Earth, the vast majority are still unknown. Unknown microbes live on and in us; some we encounter regularly in food, water, or air, and others live in often inhospitable places. Most microbes are beneficial, and their combined activities positively affect numerous aspects of the biosphere and its inhabitants.



For energy production, microbes offer efficient and sustainable ways to convert plants or other biomass into liquid fuels, hydrogen, methane, electricity, or chemical feedstocks currently derived from fossil fuels. But to realize this potential, society must invest in research programs to decouple bioenergy production from the food chain. Currently, microbial fermentation of sugars and starch from food crops is the main source of the ethanol blended with liquid transportation fuels. However, there is a large underutilized resource of cellulosic biomass from trees, grasses, and the nonedible parts of crops that could serve as a feedstock. To tap into this cellulose energy reserve, public and private sectors have begun research programs to use metagenomic, synthetic, and other approaches to identify microbes, enzymes, or microbial communities that release sugars from cellulose and convert them into ethanol or other fuels. Once efficient technologies are capable of achieving this, large-scale conversion of cellulosic biomass into ethanol and other biofuels, including hydrocarbons, will reduce the need to produce fuel from edible sugar and starch.

Microbial-plant relationships can improve the sustainability of biofuel production. Microbes surround plant roots; inhabit stems, roots, and leaves; and live on leaf and root surfaces. Individual microbial activities also provide plants with nitrogen (decreasing the need for fertilizer), help them access phosphorus, protect them from disease, recycle nutrients, and improve soil structure. These associations can improve crop production, especially on marginal lands, and benefit both food and fuel production, helping to abate the current food-versus-fuel debate and lessen the environmental footprint of agriculture.

Plants and autotrophic microbes might also help mitigate climate change because they sequester atmospheric carbon dioxide at a rate that dwarfs its flux into fossil fuels (120 versus 7.6 petagrams of carbon per year). It's the subsequent oxidation of soil and plant carbon by microbes that determines how much carbon will remain sequestered. Thus, managing the dynamics of the plant-microbe-soil ecosystem warrants further investigation, as it could improve the productivity and carbon neutrality of cellulose-to-liquid fuel systems, while helping us reshape how society generates a substantial fraction of its energy.

As Earth's master chemists, microbes can help address society's energy, environmental, and food challenges. To realize these goals, the scientific community must inform the public and policy-makers about the research needed to bring the chemical and catalytic power of microbes to bear on meeting our ever-growing energy needs. With proper research coordination and implementation, the genetic blueprints of microbes will provide a rich stockpile of building blocks to provide new energy sources while improving the health of the biosphere.

– James Tiedje and Timothy Donohue

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