Can microorganisms be a solution to the world's energy problems?

Microorganisms once reigned supreme on the Earth, thriving by filling every nook and cranny of the environment billions of years before humans first arrived on the scene. Now, this ability of microorganisms to grow from an almost infinite variety of food sources may play a significant role in bailing out society from its current energy crisis, according to the Biodesign Institute's Bruce Rittmann, Rosa Krajmalnik-Brown, and Rolf Halden.

In a new issue on "microbial ecology and sustainable energy" in the prestigious journal *Nature Reviews Microbiology*, the Biodesign researchers outline paths where bacteria are the best hope in producing renewable energy in large quantities without damaging the environment or competing with our food supply.

Two distinct, but complementary approaches will be needed. The first is to use microbes to convert biomass to useful energy. Different microorganisms can grow without oxygen to take this abundant organic matter and convert it to useful forms of energy such as methane, hydrogen, or even electricity. The second uses bacteria or algae that can capture sunlight to produce new biomass that can be turned into liquid fuels, like biodiesel, or converted by other microorganisms to useful energy. Both approaches currently are intensive areas of biofuel research at the Biodesign Institute, which has a joint project with petroleum giant BP to harvest photosynthetic bacteria to produce renewable liquid fuels, such as biodiesel.

What is it about bacteria that make them an attractive tool for a bioenergy researcher? Consider that one species of bacteria, the human gut bacterium *E. coli*, has become the workhorse of the multi-trillion dollar global biotech industry. Might other unearthed microbial treasures have the same potential in bioenergy applications?

The Biodesign team, in their Nature Review Microbiology perspective article, outlines the prospects for such applications. They believe the future of microbial bioenergy is brightened by recent advancements in genome technologies and other molecular-biology techniques.

Unlike the *E. coli* situation, using just one species may not work well for bioenergy, since, in nature, bacteria do not grow in isolation. In other words, no bacterium is an island. The very biodiversity that fills the Earth with bacteria and offers great bioenergy potential also presents a challenge for engineers. Even if one picks the ideal "bug," growing, maintaining, and optimizing conditions for its use in bioenergy applications remains a daunting challenge in terms of scalability and reliability.

"Microbial communities that are used to harvest energy must be resilient to fluctuations in environmental conditions, variations in nutrient and energy inputs and intrusion by microbial invaders that might consume the desired energy product," say the authors. The key to large-scale success in microbial bioenergy is managing the microbial community so that that the community delivers the desired bioenergy product reliably and at high rate.

In the absence of these molecular techniques, the authors state, our understanding of methanogenic communities progressed through slow, incremental advances over several decades. Today, society cannot wait decades for new bioenergy sources. Fortunately, an array of pre-genomic, genomic, and post-genomic tools is available to understand microorganisms involved in bioenergy production. Taking full advantage of these tools will greatly speed up scientific and technological advances, which is what society most needs.

Genomics provides the base sequence of the entire DNA in an organism, and the complete genome reveals all the possible biological reactions that a microorganism can carry out. In the past, complete genomes were only obtained for those microorganisms that could be isolated into pure culture, but it is now possible to sequence the genomes of uncultivated microorganisms using metagenomics.

To date, approximately 75 genomes are available from microorganisms that have a role in bioenergy production. These include 21 genomes from methane producing archaea, 24 genomes from bacteria that can produce hydrogen or electricity, and 30 genomes from cyanobacteria that are potential biodiesel producers. At least half of the completed microbial genomes that are relevant to bioenergy were released in the past 2 years, and more than 80 bioenergy-related genomes are currently being sequenced.

A great example is the Biodesign Institute's biofuel bacterium, Synechocystis sp. PCC 6803, the first bioenergy-relevant microorganism to be sequenced; its genome was released in 1995. This photosynthetic bacterium features membranes with high lipid (i.e., oil) content, which makes it an excellent biodiesel candidate.

The growing pool of genomic information provides molecular targets that support pre-genomic and post-genomic investigations, both of which provide essential information on what microorganisms are present in the community and what metabolic reactions they are carrying out. With genomics combined with high-throughput DNA sequencing and proteomics, our understanding of bioenergy-producing microorganisms should surge.

Because success with microbial bioenergy demands in-depth knowledge of the complex microbial communities that normally develop, a wide range of pre-genomic, genomic, and post-genomic tools is needed. The Biodesign team has unique expertise on using each kind of tool, and it's perspective article provides needed information about these tools and how they can be used to unravel the structures and functions of microbial communities involved in renewable bioenergy.

The authors conclude, "Information from these tools, when properly integrated with advanced engineering tools and material, should accelerate the rate at which microbial bioenergy processes can be converted from the realm of intriguing science to real world practice."

Source: Arizona State University