ARIZONA STATE UNIVERSITY

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Dr. Vermaas's research program focuses on the molecular biology and cell physiology of prokaryotic photosynthetic systems, utilizing functional genomics and cutting-edge technologies and approaches.

His research team utilizes a cyanobacterium, *Synechocystis sp.* PCC 6803 (*Synechocystis for short*), in basic and applied research efforts.

Cyanobacteria are a group of very versatile and ancient organisms that can grow under a large range of conditions and that have many ways to make a living.

Synechocystis is particularly appealing because its photosynthetic system is essentially identical to that of plants; moreover – in contrast to most "real" plants – it is a molecular biologist's dream for several reasons:

1) its genome (some 3.6 million base pairs) has been sequenced in its entirety,

2) it is spontaneously transformable (i.e., it takes up DNA by itself),

3) it can integrate DNA into its genome by homologous recombination, and

4) it can grow in the absence of photosynthesis if it needs to.

The Vermaas team is currently involved in a transformative research effort to develop strains of *Synechocystis* that can produce and secrete products for use as renewable raw materials for the biofuels and chemical industries.

The organisms essentially become biocatalysts (mini-factories), producing and secreting feedstocks for harvest without themselves being consumed, much like a cow giving milk.

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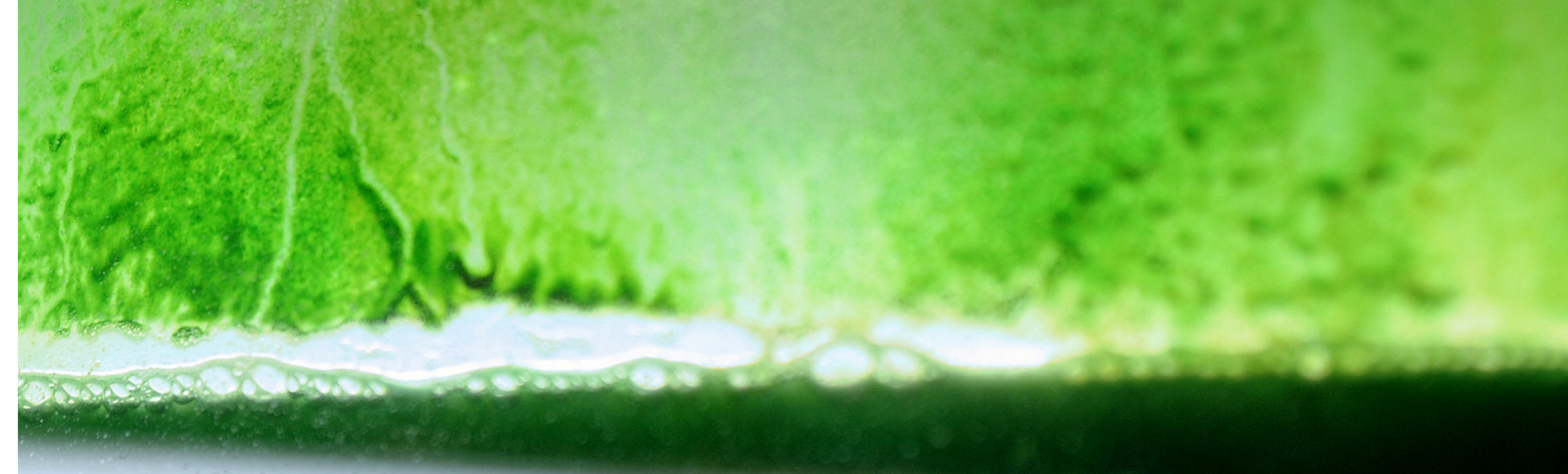
DIVERSIFIED ENERGY NC STATE UNIVERSITY BIOCEE



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Cyanobacteria

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Overview

The novel concept of this research program is to use photosynthetic microorganisms (cyanobacteria) as biocatalysts, i.e., mini factories, that use solar energy and carbon dioxide to produce and secrete fatty acids for the direct production of biofuel without major production of biomass **(Figure 1).**

Three major advantages:

1 The process is directly solar-powered utilizing CO2; no carbon-based feedstock is required.

2 Fixed CO2 is efficiently converted to fatty acids.

3 Solar energy is not lost to biomass production; more energy can be converted to a biofuel-compatible feedstock.

4 Cyanobacteria are grown in transparent enclosures called photobioreactors (PBRs) that can be located anywhere there is sunlight; no arable land or major inputs of fertilizer required thus no competition with food crops and depletion/contamination of soils.

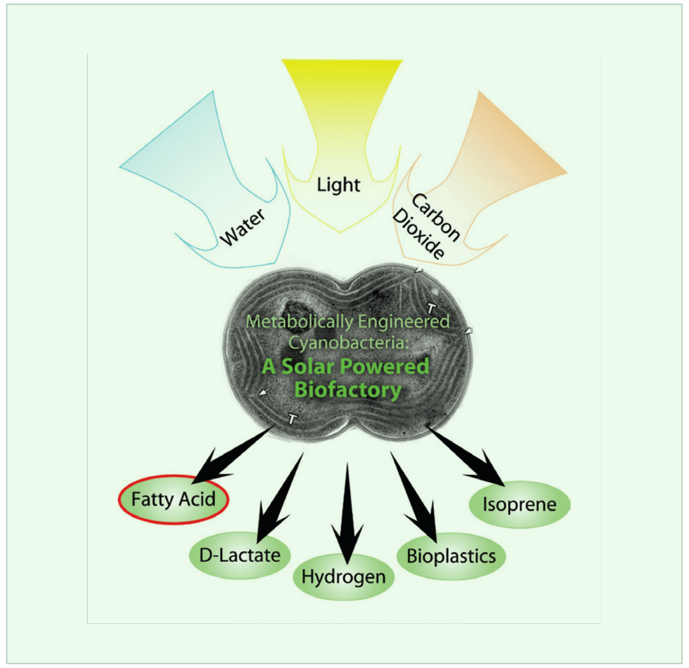
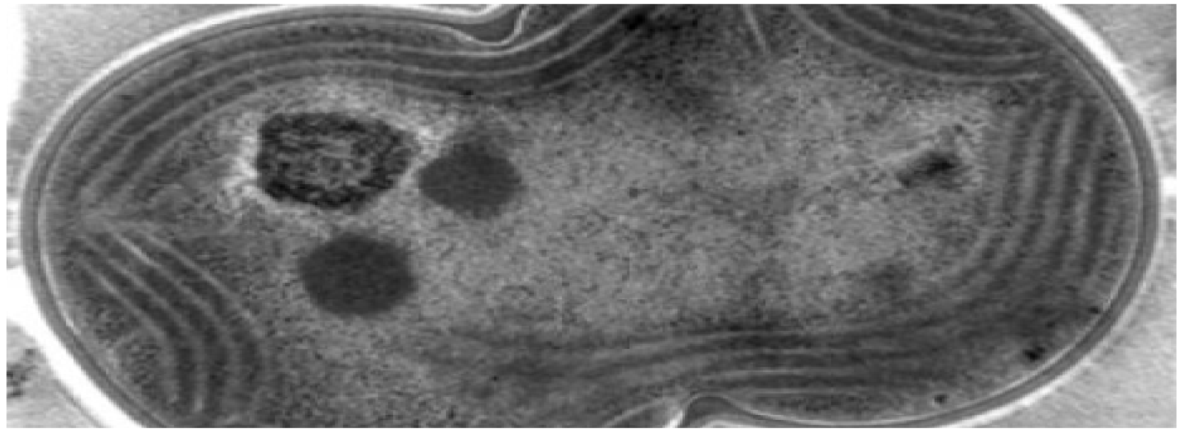


Figure 1: Use of genetically modified Synechocystis for efficient solar energy conversion to fatty acids and other useful products.



Synechocystis

viewed by transmission elecron microscopy.

Photo: Robert Roberson

Cyanobacteria as Mini-Factories

Features that make cyanobacteria excellent organisms for the production of carbon-neutral and sustainable biofuel:

1 Photosynthetic, rapid growth, and easy to manipulate genetically.

2 The cyanobacterium *Synechocystis* has been modified to produce and secrete fatty acids (Figure 2).

3 Robust in accommodating diverse environmental conditions; grows in a wide range of salt, fixed-nitrogen and CO_2 concentrations.

4 System requires minimal water consumption.

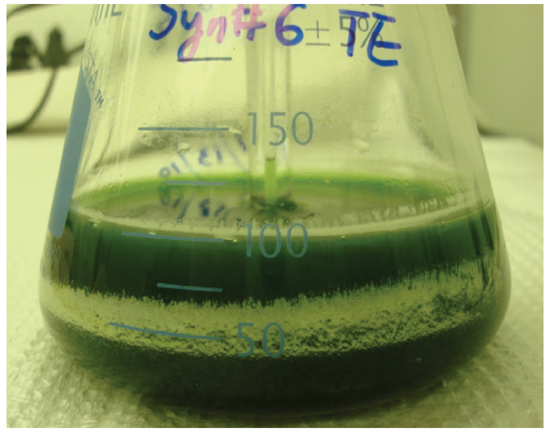


Figure 2: Culture of a fatty acid secreting strain of Synechocystis. Fatty acids can be seen as a ring on top of the culture and precipitated on the side of the flask.

Figure 3: Photobioreactors at Arizona State University.

Current Status

This system has been successfully used for the production of the fatty acid laurate, which is useful for the soap and cosmetics industry and can also be chemically decarboxylated to the alkane undecane, which is a precursor to fuels such as diesel, jet fuel, and gasoline. In the lab, laurate production is on the order of 0.15 mM per day, corresponding to an efficiency of light conversion to laurate formation that is >10% of the theoretically maximally attainable rate. Production has been successfully demonstrated at the 55-L scale in traditional PBRs (Figure 3) and harvested laurate has been successfully converted to biofuel via downstream catalytic processes (Figure 4).

Figure 4: Flask of cyanobacteria-derived biofuel produced after downstream processes.

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