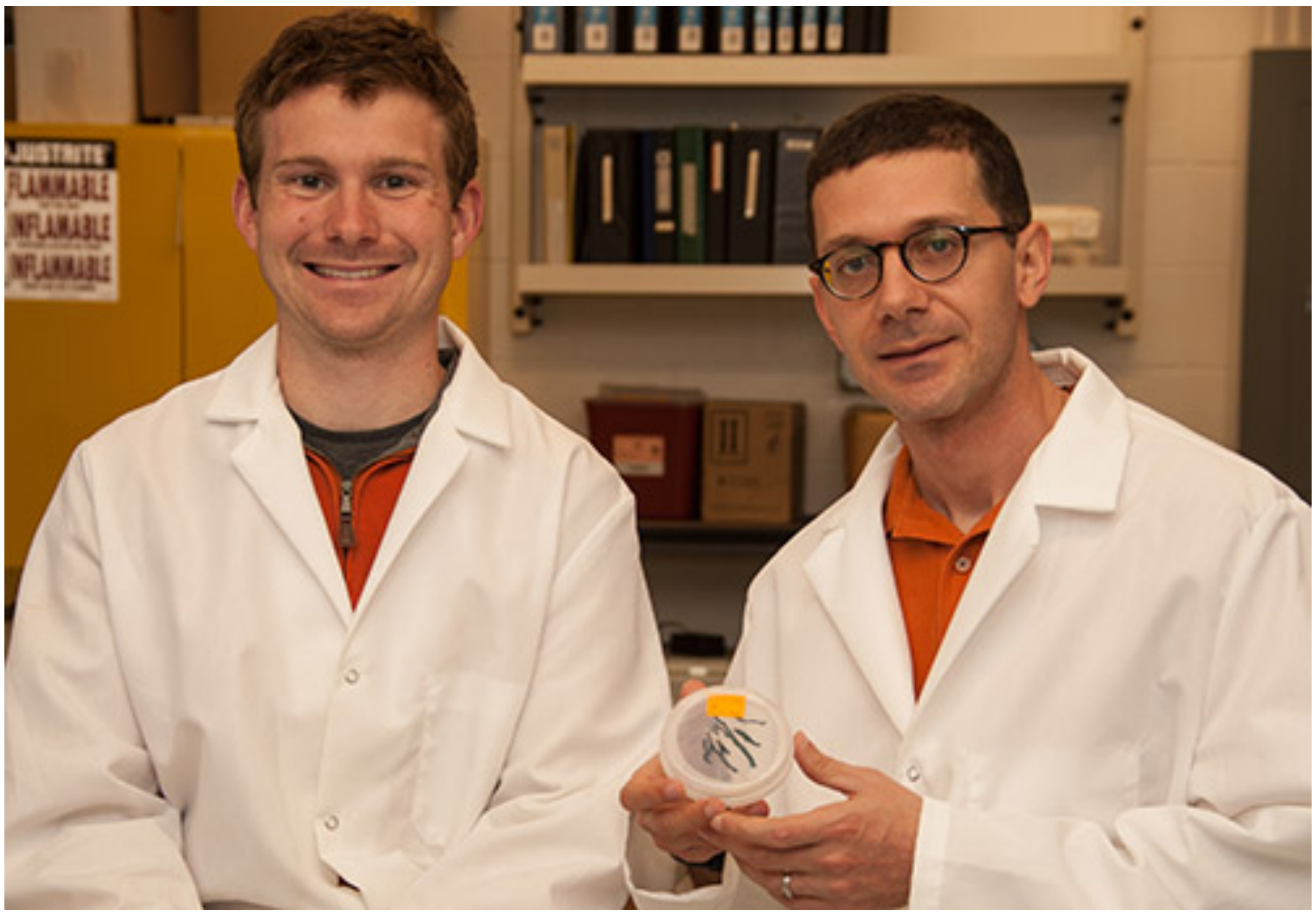
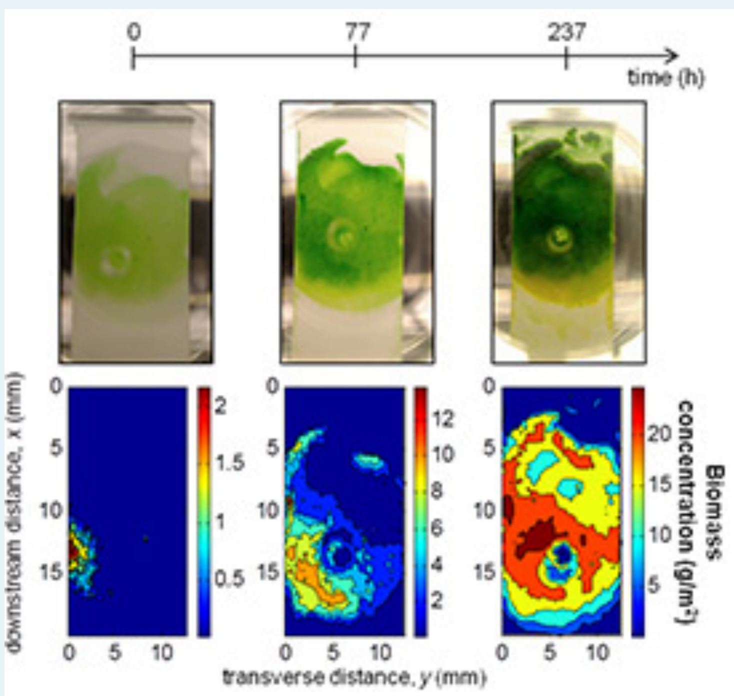
Designing Synthetic Trees: a Novel Approach for Producing Energy and Water Efficient Biofuels

AUSTIN, TEXAS—March 25, 2013



Ph.D. student Mr. Thomas Murphy (on the left) and Dr. Halil Berberoglu (on the right) in their laboratory with a sample of their algae they use for biofuel production.

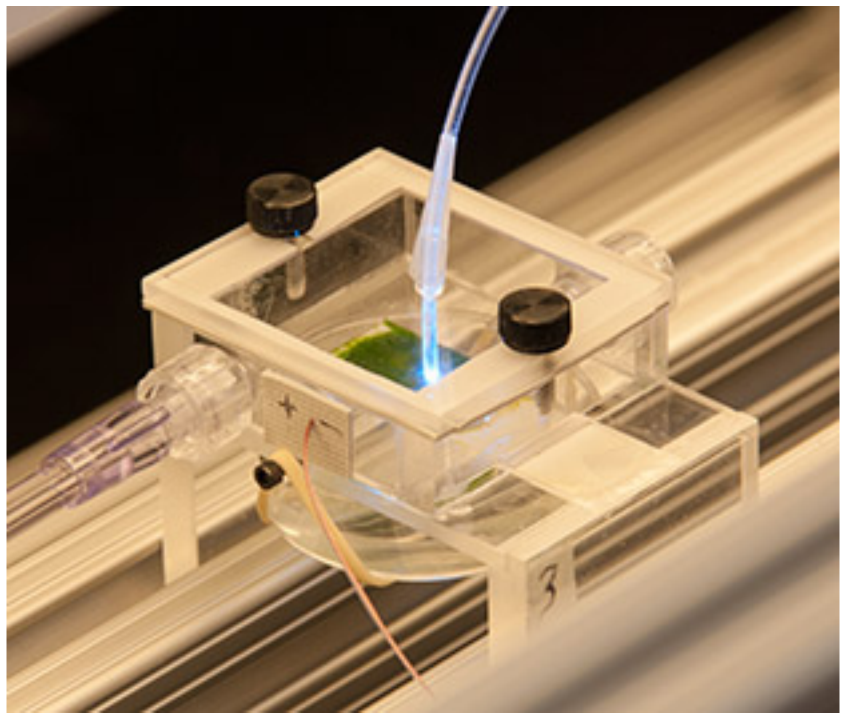
Assistant Professor Halil Berberoglu's First Five Years



Local productivity monitoring of biofilms with the multispectral imaging method developed at Dr. Berberoglu's Laboratory. ***Select photo or link for larger image.***

Dr. Halil Berberoglu, an assistant professor in the Cockrell School of Engineering at The University of Texas at Austin, joined the Department of Mechanical Engineering in 2008, working in the area of alternative energy. He has recently been the recipient of several prestigious awards and honors. In 2011, he received the **National Science Foundation's BRIGE award** for studying the interfacial and transport phenomena in photosynthetic biofilms for tailoring their applications in biotechnology.

In 2012, he was one of only 100 invited guests to attend the National Academy of Engineering's **U.S. Frontiers of**



The photosynthetic productivity of the biofilm is being measured with a pulse amplitude modulated (PAM) fluorometer.

Related Links

- Dr. Halil Berberoglu's Faculty profile
- Dr. Berberoglu's Research Web Site
- Norman Hackerman Award
- Frontiers of Science
- National Academy of Engineering
- Early Faculty CAREEER Development (CAREER Award)
- National Science Foundation (NSF)
- Ames Research Center at NASA

Learn More

- Synthetic Tree for Producing Biofuels, research video
- Wikipedia, Photosynthesis

Engineering symposium. If invited, most people only attend once in their lives, but he has been invited back to organize and co-chair a session on "Reducing Our Dependence on Fossil Fuels" for next year's symposium to be held at DuPont in Wilmington, Delaware in September 2013.

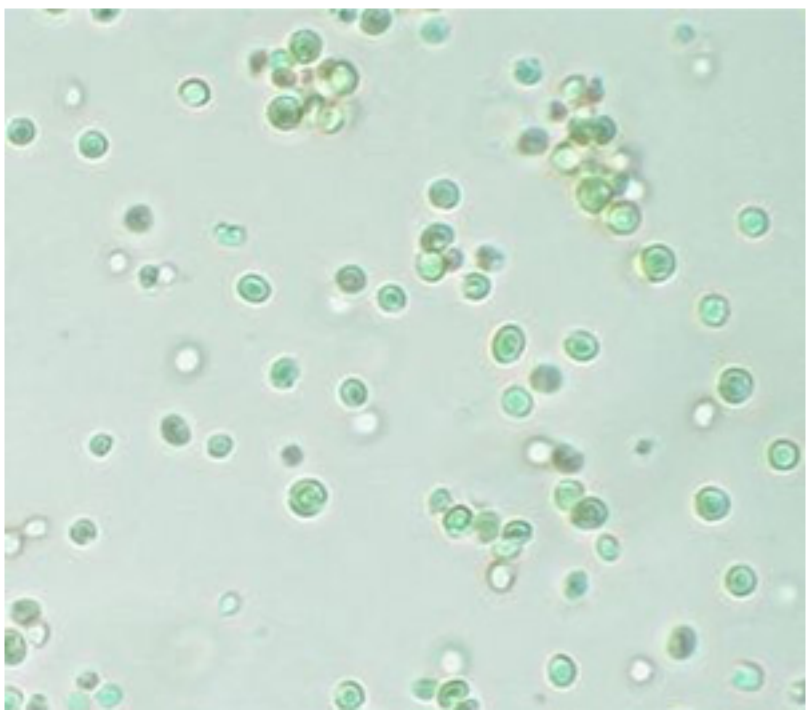
More recently, he was awarded the **Norman Hackerman Advanced Research Program Grant** from Texas Higher Education Coordinating Board to study the electric and magnetic field stimulation of cells. This monetary award goes to young scientists and engineers to support their early career research work. Just a few weeks ago, he received the **National Science Foundation's CAREER award** for developing novel algal cultivation methods for the production of energetically, economically, and environmentally sustainable biofuels.

Research Goal and Overview

The goal of Dr. Berberoglu's current research efforts is to produce renewable biofuel utilizing solar energy. Fundamental topics are the interaction of cells with each other and other surfaces, transport of mass, thermal energy, and light in biological and solar energy conversion systems, as well as more applied topics such as thermo-economic analysis and optimization of energy conversion systems. In this article, we will discuss his work to design a novel algae cultivation platform that uses algal biofilms as photosynthetic biocatalysts and mimics the way plants achieve transport of nutrients and bioproducts in their vascular systems.

View on YouTube*. *Video Description: *Dr. Berberoglu and Mr. Murphy are working with NASA to design synthetic trees using photosynthetic biofilms, which use much less water and energy than conventional photobioreactors for producing renewable fuels on earth and providing life support in space for astronauts.*

Algal Biofuel Production



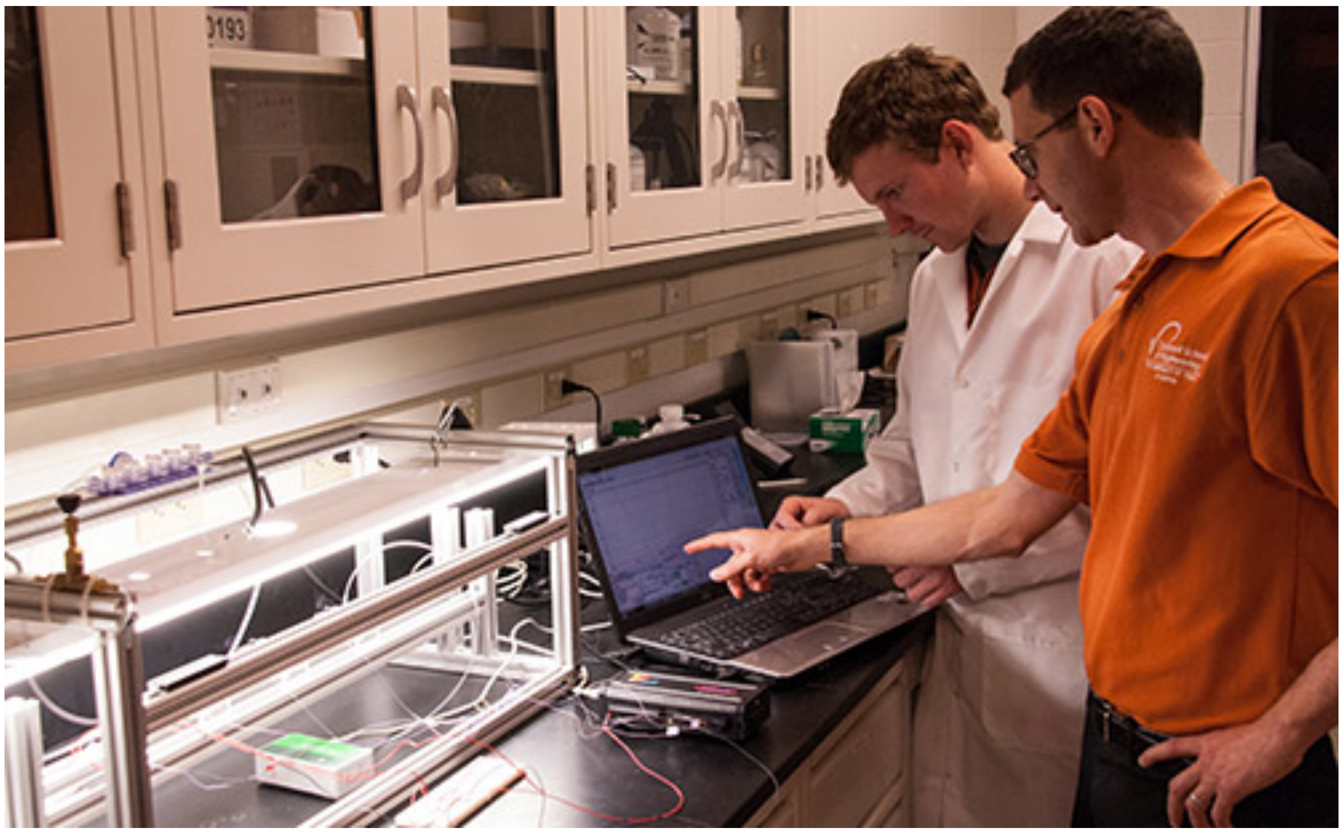
The microalgae Nannochloropsis sp., viewed under a light microscope. Image: Wikipedia, Commons license.

Microalgae (unicellular species) are a diverse group of photosynthetic cells which generally measure about 1/0th the diameter of a human hair. Just like plants, they are capable of using solar energy to fix (convert) carbon dioxide from the atmosphere into energy dense molecules such as sugars and oils. In this way they can serve as a feedstock material to be used in fuel production such as bioethanol and biodiesel. Compared to other photosynthetic systems, such as terrestrial plants, algae are the most efficient in converting solar energy into fuel precursors. Moreover, their cultivation does not require arable land or fresh water resources, providing the most promising option for producing domestic biofuels for our energy independence and security.

Challenges

There are energetic and economic challenges in viable implementation of algae-based biofuel production. These are mainly due to the high energy and water requirements of their cultivation and harvesting with the current technologies. A major problem with these current technologies, such as the raceway ponds (shallow artificial pond for growing algae) or the tubular/flat panel photobioreactors, is that algae are cultivated at fairly dilute concentrations. This manifests itself as the need for large volumes of water for cultivation, large amounts of energy for agitating and handling a large volume of cell suspension with low caloric value, and large energy requirements for separating and processing the cells. Moreover, only about a third of the biomass produced by algae is used in biofuel production, creating a waste of solar energy and a waste of valuable nutrients such as nitrogen and phosphorus during the process.

Algal Biofilm Cultivation and Synthetic Trees for Biofuel Production



Dr. Berberoglu and Mr. Murphy grow and evaluate the performance of algal biofilms in special chambers where they can control the environmental inputs. The detail photo on the right shows a close-up on one of the experimental chambers.

To address these challenges of conventional (natural) algal biofuel production, Dr. Berberoglu, together with his Ph.D. student Mr. Thomas Murphy, envisioned a novel system that mimics the way we obtain sap from a maple tree. In this case, instead of harvesting maple syrup, we would harvest biofuels from a synthetic tree.

In this concept, algae cells are grown as photosynthetic biofilms on porous surfaces that keep them hydrated and provide them with the nutrients they need for growing to maturity. Once the biofilm is matured, the supply of certain nutrients is stopped and the growth of cells is inhibited. At this point, the algae are provided with the necessary inputs to carry on photosynthesizing and secreting out energy dense molecules, such as free fatty acids. These are carried away from the cells in small channels mimicking the veins in plants and concentrated using evaporation-driven flows.

These concentrated energy-dense molecules can then be converted to a wide variety of biofuels. Once the algal biofilm reaches the end of its productive life over several months, it is removed, a new biofilm is grown to maturity, and the cycle continues. In this way, the available solar energy, water, and nutrients are directed more towards the production of fuel precursors and less towards growth, achieving a higher solar energy conversion and resource utilization efficiency. The movie above shows an animation of the operation of the synthetic tree concept.

Some of the initial work on developing algae biofilm cultivation was previously performed at Dr. Berberoglu's laboratory by **Dr. Altan Ozkan**, a former Ph.D. student of Dr. Berberoglu and now an assistant professor at Bahcesehir University in Istanbul, Turkey (video tour). Drs. Berberoglu and Ozkan cultivated algae as biofilms on impervious surfaces under surface flow of nutrients in the laboratory. They estimated as high as six times better energy return on investment in algal biofilm cultivation system with respect to that in open pond systems, albeit at a lower production rate. Moreover, they studied the fundamental aspects of algal cell attachment and formation of algal biofilms.

Green algae (on the left) and cyanobacteria (on the right) cultures being cultivated in the bottles use much more water than the algae grown as biofilms in the image above.

In the current work, Dr. Berberoglu and Mr. Murphy soon graduating with his Ph.D., are focusing on the transport of nutrients, metabolites, light and thermal energy in the photosynthetic biofilms. For this Mr. Murphy has been developing computer models that couple light and mass transport with cellular kinetics for understanding how these affect the productivity of the synthetic tree. Moreover, he is conducting experiments to verify his models and optimize his design. Finally, Mr. Murphy, along with Dr. Berberoglu and the undergraduate researcher **Mr. Keith Macon**, have developed a practical multispectral image analysis technique to non-invasively monitor the productivity of algal cultivation systems, including those of biofilms and ponds.

> "Non-invasive, rapid, and scalable productivity-monitoring technologies will be necessary for providing the process control feedback to enable efficient operation of large-scale cultivation systems."
> – Tom Murphy

Research Collaborators

To further this technology, Dr. Berberoglu is also collaborating with **Dr. Alexandre da Silva** (UT ME) studying evaporative-driven transport of nutrient solutions in porous media, with **Dr. Matt Posewitz** of Colorado School of Mines who is genetically engineering algal strains to secrete the desired bioproducts, and with **Drs. Lee** and **Brad Bebout** of NASA Ames who are ecological experts working on improving the diversity of species in the photosynthetic biofilms.

Synthetic Trees as Life Support Systems in Space

Another unique aspect of the synthetic tree concept is that it uses interfacial phenomena rather than inertial phenomena (gravity) to drive the transport of mass within the system. Together wi its significantly reduced water requirement and mass, this feature makes the synthetic tree a unique platform for cultivating cells in reduced gravity environments, i.e., space.

Last year, Dr. Berberoglu and his collaborators at the Exobiology branch at NASA Ames Research Center obtained a grant to develop a synthetic tree system they called **Surface Adhering Bioreactor (SABR)** for performing air regeneration (mitigation of carbon dioxide and generation of oxygen) using algal biofilms as a first step towards engineering a fully regenerative biological life support system for long duration manned space missions.

> "Earth is our spaceship where our ecosystem provides us with a fully regenerative biological life support. We want to understand how this ecosystem works, how we interact with it, and how we can engineer similar systems that will help us survive in space. We see SABR as one of many components of an artificial ecosystem we can engineer where different components can focus on recycling all our byproducts into resources again. I also believe that these ideas will have major implications on our terrestrial life as our technological impacts on Earth start becoming more significant at global scales."
> – Dr. Halil Berberoglu

Together with the NASA team, a joint patent application was filed for both the space and terrestrial applications of this technology. Currently, Dr. Berberoglu is leading an effort with teams of scientists and engineers from NASA Ames Research Center and Texas A&M University's Space Engineering Research Center to conduct experiments with SABR at the International Space Station (ISS).

Back to previous page

Last modified on May 30th, 2013

Cockrell School of Engineering | The University of Texas at Austin
Privacy Information | Resources for Accessibility
Comments: webmaster@me.utexas.edu

News Feed
Contact Information
Visitor Information
UTDirect Login