Photobiological H_2 Production Systems

Creation of Designer Alga for Efficient and Robust Production of H_2 from Water

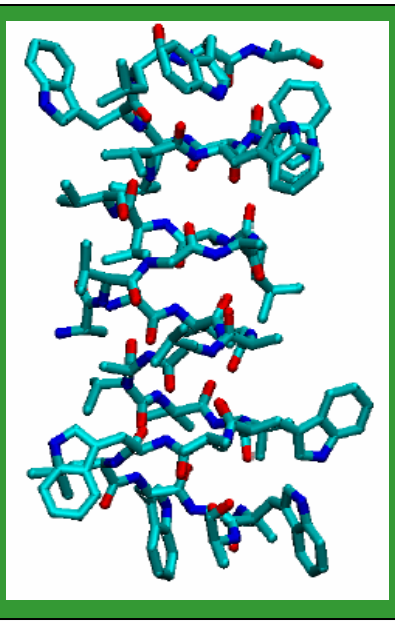
Background

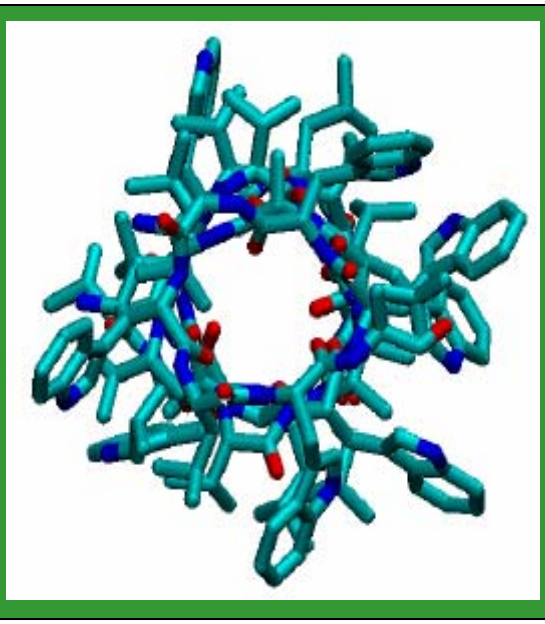
Algal photosynthetic hydrogen (H_2) production from water has tremendous potential as a clean and renewable energy resource. However, algal production of H_2 is currently limited by physiological obstacles related to proton gradient in wild algae and limit the absorbed light energy to hydrogen efficiency to less than 0.1%. Wild algae lack a proton channel, to release hydrogen. Development of such a channel would be a significant breakthrough in technology and would increase energy conversion by a factor of more than ten times.

Technology

This project aims to create an efficient, robust algal H_2 production system through a novel approach recently developed at Oak Ridge National Laboratory (ORNL). A "designer alga" will be created by genetic insertion of hydrogenase promoter-programmed polypeptide proton channels into algal thylakoid membranes. This approach solves the physiological problems related to proton gradient.

To develop designer algal cells that function as efficient and robust "green machines" the designer proton-channel gene must be expressed simultaneously with the induction of the hydrogenase enzyme under anaerobic conditions that can be achieved by removal of O_2 from the culture. In this application, an effective and safe H_2-O_2 gas separation system is required; and an O_2-tolerant hydrogenase would also be preferred. In a second application an envisioned designer proton-channel alga along with an O_2-consuming microbe could eliminate the needs of both an O_2-tolerant hydrogenase and a H_2-O_2 gas separation system. Finally, the designer proton-channel alga could be further upgraded with a switchable photosystem II (PSII) function so that the requirements of an O_2-tolerant hydrogenase and a H_2-O_2 gas separation system can be eliminated.





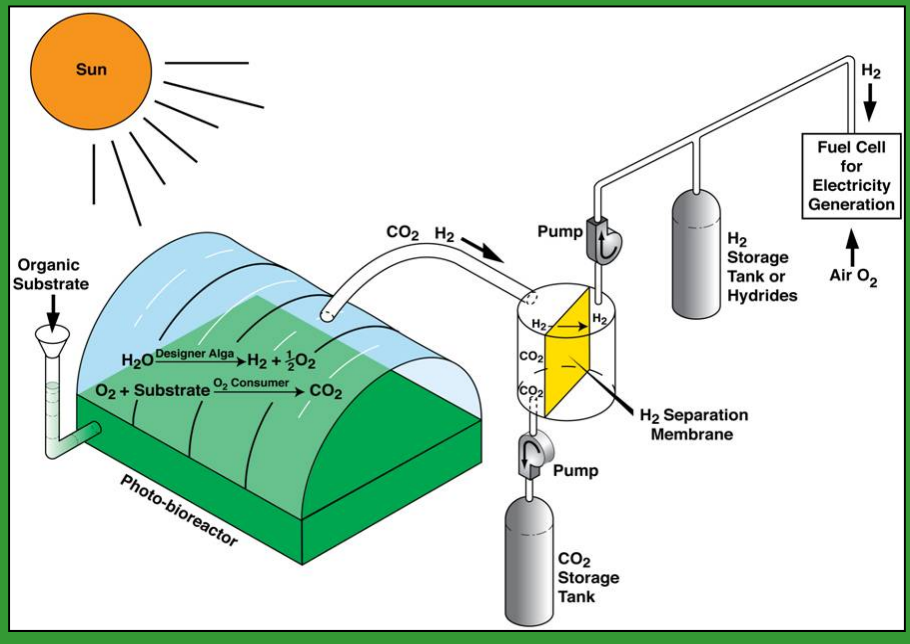
Side (Left) and Top (Right) views of computer DNA design to encode for proton channels in algal membranes

Accomplishments

The project has successfully completed tasks on designing and synthesizing for the first set of proton-channel genes. The design approach used computer simulation focused on the pore size (e.g. nm required for proton conductivity) and the molecular stability of the designer proton channel. Using this approach with the bioinformatics tools, enabled design the first set of genes (3 synthetic genes) that could encode the envisioned proton channels in algae.

In collaboration with GENEART USA and Bioclone Inc., this set of designer genes was recently synthesized . Subsequently, this set of designer proton-channel genes were successfully delivered into the host alga Chlamydomonas using the gene-transformation technique of electroporation at ORNL. Many transformants have now been generated. These transformants are expected to contain the envisioned proton-channel designer alga that could provide significant impact on technology development in the field of renewable photobiological H_2 production.

The novelty of the ORNL designer alga H_2-production R&D project has recently been recognized by the FuelCellSouth 2006 Crystal Flame Innovation Award.



How designer proton-channel alga may be used for photobiological production of H_2 without requiring any O_2-tolerant hydrogenase. construct.

Benefits

- The current hydrogen production rate from photosynthetic micro-organisms is far too low for commercial viability. The project has a potential to produce a breakthrough with an increase of solar-to-hydrogen energy conversion efficiency by a factor of more than 10 times

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