Metabolic Engineering of Hydrogen Production in Filamentous Cyanobacteria

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Objective:
Create and test the feasibility of new hydrogen production system based on photosynthetic filamentous cyanobacteria.

System Design:
An indirect photolysis of water (see left panel) will be created. In this scheme, oxygenic photosynthesis and hydrogen production occurs in separated compartments. Water molecules are split via photosynthesis in one compartment with the concomitant evolution of molecular oxygen. Protons and electrons extracted from water molecules are exported to a second compartment where hydrogen evolution occurs.

Potential Advantages over Existing Systems:
- Direct conversion of solar energy into chemical energy
- Renewable, carbon neutral
- Potentially higher efficiency than existing methods

Engineering Challenge:
Oxygenic photosynthesis produces molecular oxygen as a byproduct, while hydrogen production via hydrogenase is an anaerobic process. A functional system must therefore be configured in a way that the oxygen produced during photosynthesis does not interfere with hydrogen production.

Experimental Approach

Indirect (2-Stage) Photolysis of H\textsubscript{2}O

\textbf{Goal:} To create an indirect 2-stage photolysis system of H\textsubscript{2}O in filamentous cyanobacteria. In this system, photosynthesis and hydrogen production occurs in separate compartments (cell types).

Filamentous Cyanobacterial System

Indirect (2-Stage) Photolysis of H\textsubscript{2}O

\[ \text{2H}_2\text{O} \xrightarrow{\text{Light}} \text{H}_2 + 4\text{H}^+ + 4e^- \]

Compartments A and B

Filamentous cyanobacteria possess an unusual ability to fix dinitrogen while performing oxygenic photosynthesis simultaneously. Under nitrogen limited condition, specialized cells (heterocysts) are developed to fix dinitrogen. Nitrogenase, which reduces nitrogen to NH\textsubscript{3}, like hydrogenase requires low [O\textsubscript{2}] to function. This provides a ideal solution to the problem of incompatibility between oxygenic photosynthesis and hydrogenase.