FUELS TO FOOD FROM SUNLIGHT, AIR AND WATER

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Hybrid inorganic | biological constructs have been created to use sunlight, air and water to accomplish carbon fixation and nitrogen fixation, thus enabling distributed and renewable fuels and crop production. The carbon fixation cycle begins with the artificial leaf, which was invented to accomplish the solar fuels process of natural photosynthesis – the splitting of water to hydrogen and oxygen using sunlight – under ambient conditions. To create the artificial leaf, an oxygen evolving complex of Photosystem II was mimicked, the most important property of which was the self-healing nature of the catalyst. Self-healing permits water splitting to be accomplished under benign conditions. The ability to proceed with water splitting at neutral pH has the major benefit of allowing water splitting catalysis to be interfaced with bioorganisms. Using the tools of synthetic biology, a bio-engineered bacterium has been developed to convert carbon dioxide, along with the hydrogen produced from the catalysts of the artificial leaf, into biomass and liquid fuels, thus closing an entire artificial photosynthetic cycle. This hybrid microbial | artificial leaf system scrubs 180 grams of CO_2 from air, equivalent to 230,000 liters of air per 1 kWh of electricity. This hybrid device, called the bionic leaf, operates at unprecedented solar-to-biomass (10.7%) and solar-to-liquid fuels (6.2%) yields, greatly exceeding the 1% yield of natural photosynthesis. Extending our approach, we have discovered a renewable and distributed synthesis of ammonia at ambient conditions by coupling solar-based water splitting to a nitrogen fixing bioorganism in a single reactor. Nitrogen is fixed to ammonia by using the hydrogen produced from water splitting to power a nitrogenase installed in the bioorganism. The ammonia produced by the nitrogenase can be diverted from biomass formation to an extracellular product with the addition of an inhibitor. The nitrogen reduction reaction proceeds at a turnover number of 8×10^9 per cell and operates without the need for a carbon feedstock (which is provided by CO_2 from air). This approach can be powered by distributed renewable electricity, enabling sustainable crop production (as will be shown in the talk).