

光合成都市, 2 何?

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太陽エネルギー化学研究センター

中西周次

Research Center for Solar Energy Conversion

太陽エネルギー化学研究センター

established in 1981.



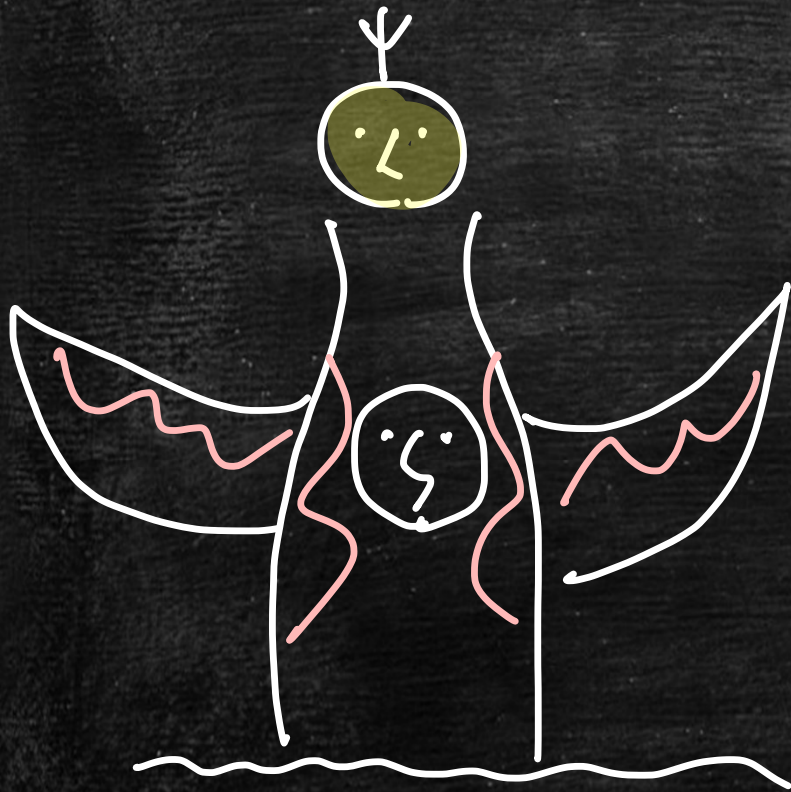
A step toward  
the Peace of the World.  
Melvin Calvin  
Dec 2, 1951

• Natural / Artificial Photosynthesis

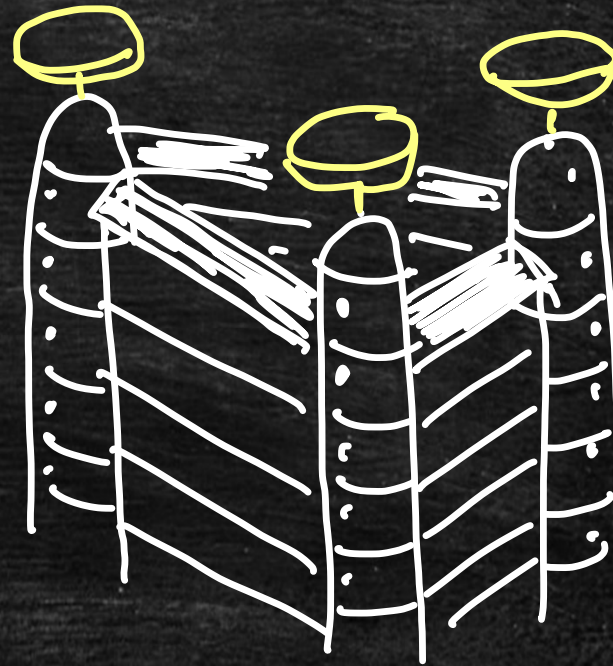
天然光合成 / 人工光合成



# 太陽の塔

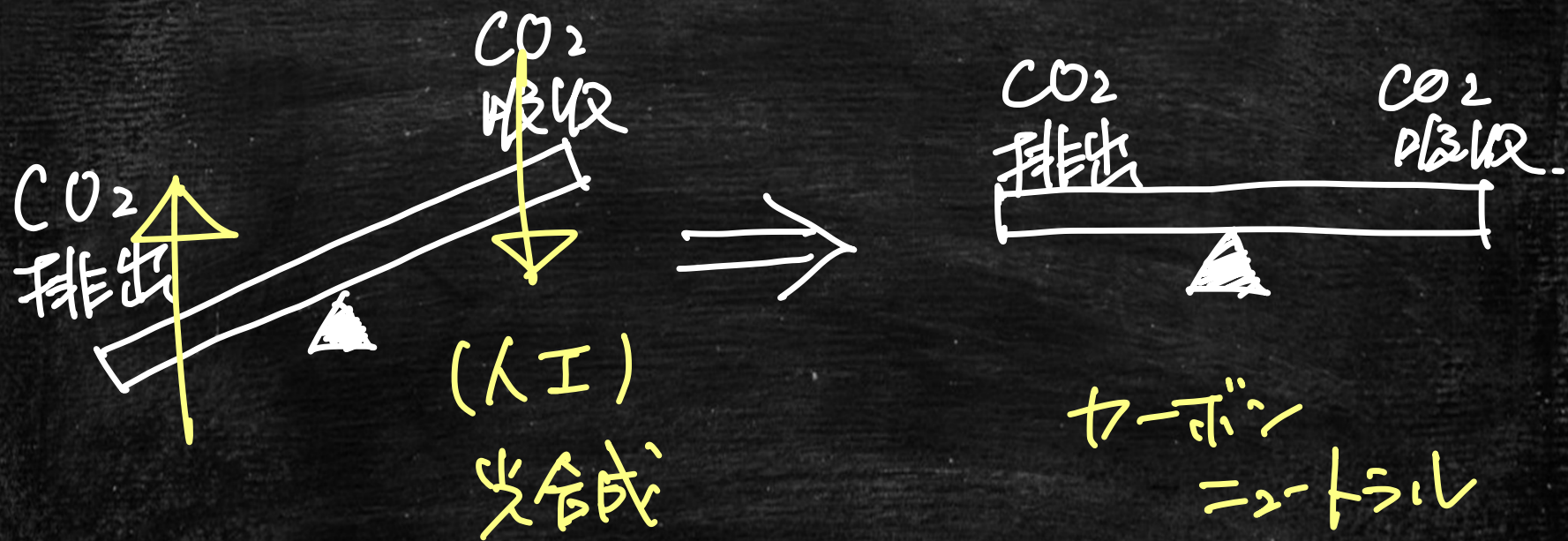


# 太陽塔 (未来少年エーノ)



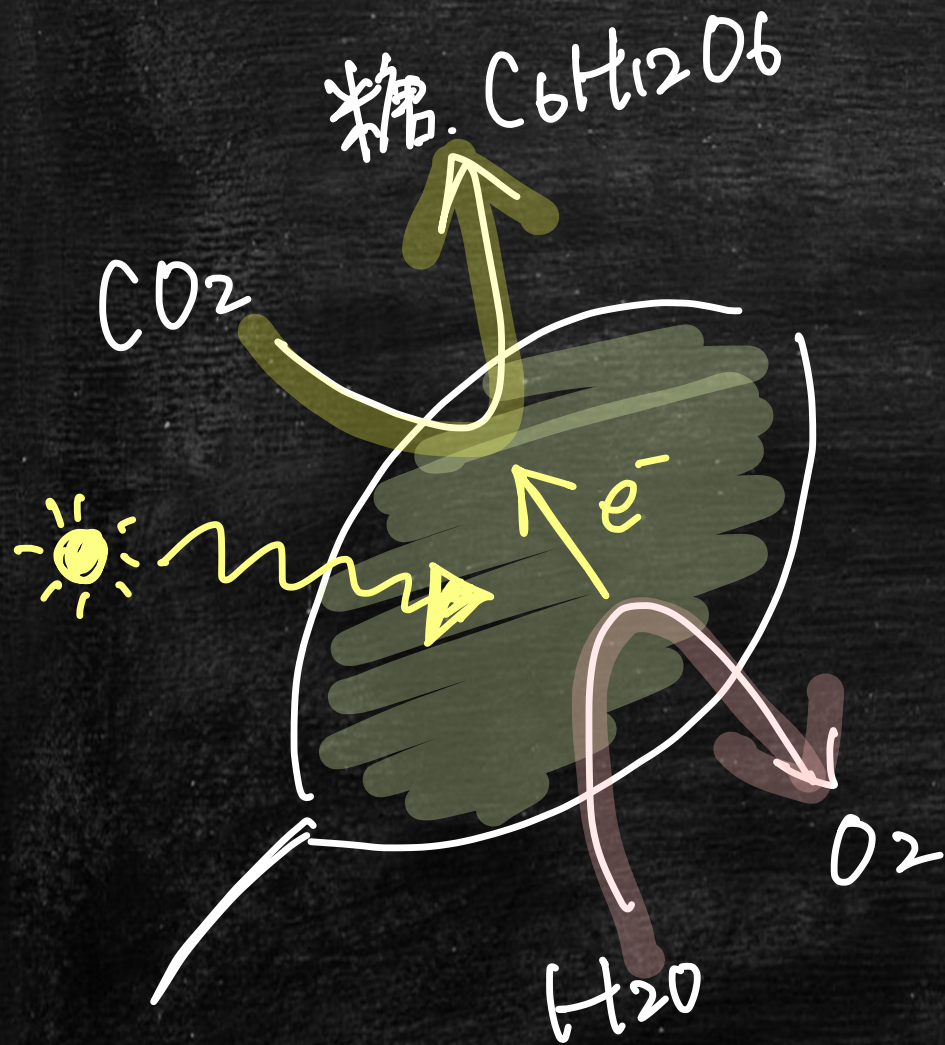
プラスチックから  
110ンを作っている。  
食料

# カーボンニュートラルと人工光合成

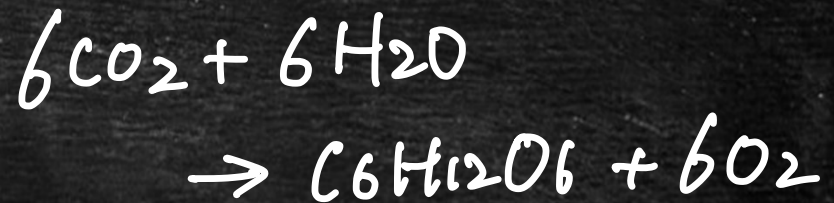




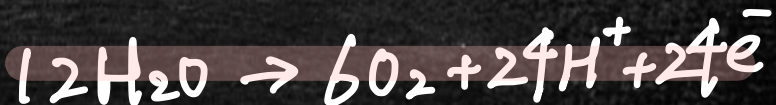
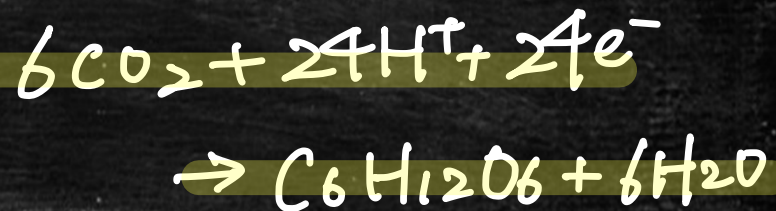
# 光合成の化学



全反応



↓ 半反応に分解





# 光合成の分子機構

## Photosynthesis

An important characteristic of plants is their ability to use sunlight and the carbon dioxide in the air to manufacture their own complex nutrients. This process, called photosynthesis, takes place in chloroplasts, cellular components that contain the necessary enzyme machinery to transform solar energy into chemical energy. Each plant cell can have between 20 and 100 oval-shaped chloroplasts. Chloroplasts can reproduce themselves, suggesting that they were once autonomous organisms that established a symbiosis, which produced the first plant cell.



### Why Green?

Leaves absorb energy from visible light, which consists of different colors. The leaves reflect only the green light.

### Leaves

are made of several types of plant tissues. Some serve as a support, and some serve as filler material.

### Algae

perform photosynthesis underwater. Together with water plants, they provide most of the atmosphere's oxygen.

**O<sub>2</sub>** IS RELEASED BY PLANTS INTO THE EARTH'S ATMOSPHERE

### Plant Cells

have three traits that differentiate them from animal cells: cell walls (which are made up of 40 percent cellulose), a large vacuole containing water and trace mineral elements, and chloroplasts containing chlorophyll. Like an animal cell, a plant cell has a nucleus.

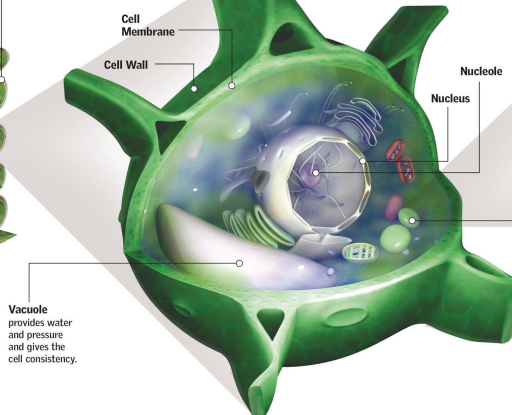
### Plant Tissues

The relative stiffness of plant cells is provided by cellulose, the polysaccharide formed by the plant's cell walls. This substance is made of thousands of glucose units, and it is very difficult to hydrolyze (break down in water).

**CARBON DIOXIDE** is absorbed by plant cells to form sugars by means of photosynthesis.

**OXYGEN** is a by-product of photosynthesis. It exits the surface of the leaves through their stoma (two-celled pores).

**WATER** Photosynthesis requires a constant supply of water, which reaches the leaves through the plant's roots and stem.

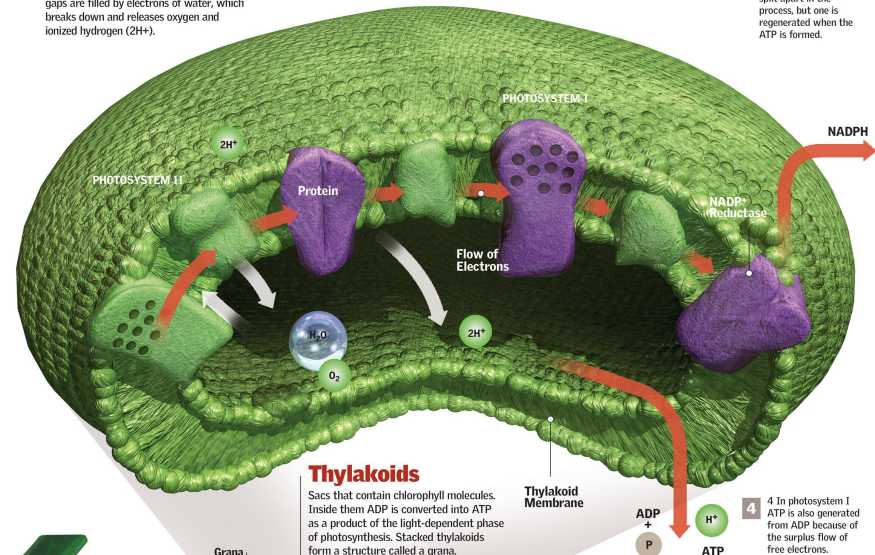


**Vacuole** provides water and pressure and gives the cell consistency.

### Stages of the Process

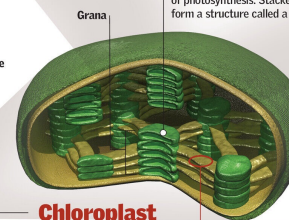
Photosynthesis takes place in two stages. The first, called photosystem II, depends directly on the amount of light received, which causes the chlorophyll to release electrons. The resulting gaps are filled by electrons of water, which breaks down and releases oxygen and ionized hydrogen (2H<sup>+</sup>).

- 1 ATP formation is powered by the movement of electrons into receptor molecules in a chain of oxidation and reduction reactions.
- 2 In photosystem I light energy is absorbed, sending electrons into other receptors and making NADPH out of NADP<sup>+</sup>.
- 3 The ATP and NADPH obtained are the net gain of the system, in addition to oxygen. Two water molecules are split apart in the process, but one is regenerated when the ATP is formed.



### Thylakoids

Sacs that contain chlorophyll molecules. Inside them ADP is converted into ATP as a product of the light-dependent phase of photosynthesis. Stacked thylakoids form a structure called a grana.

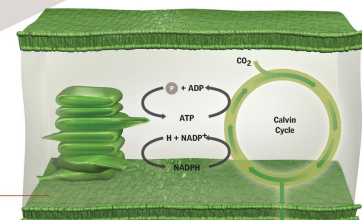


### Chloroplast

The part of the cell where both phases of photosynthesis take place. It also contains enzymes.

### Stroma

is the watery space inside the chloroplast.



### The Dark Phase

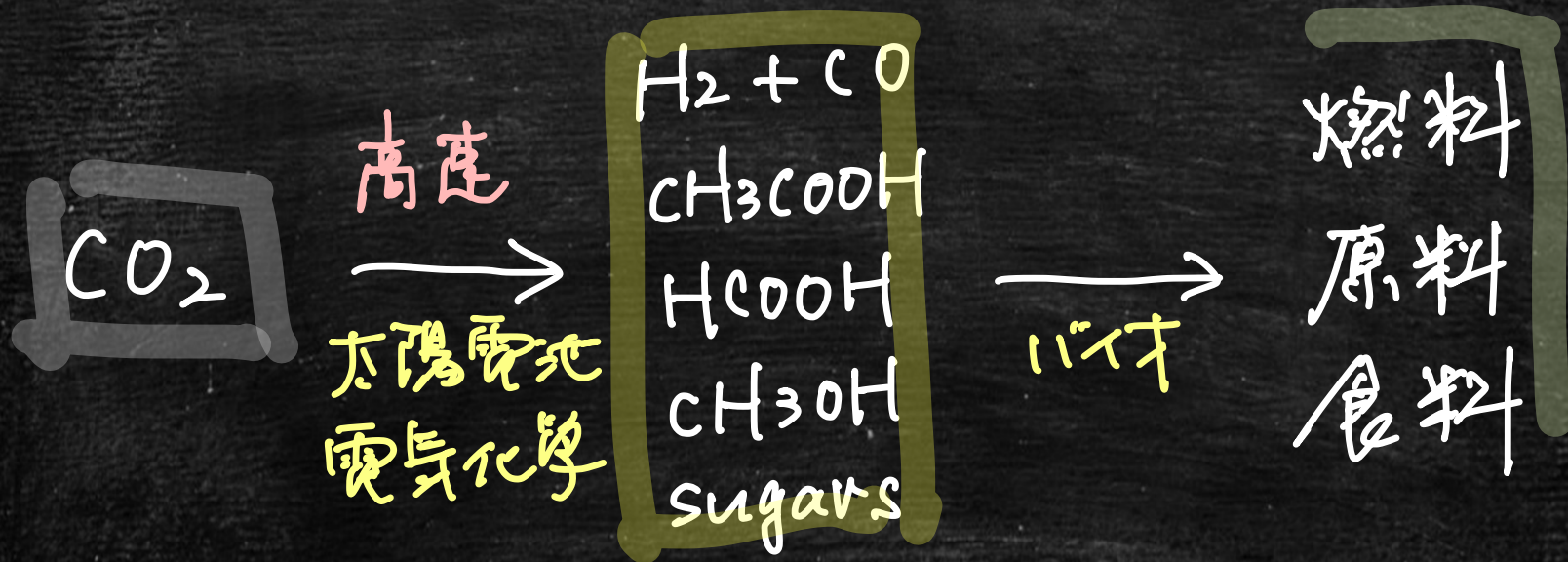
This phase, so called because it does not directly depend on light, takes place inside the stroma of the chloroplast. Energy in the form of ATP and NADPH, which was produced in the light-dependent phase, is used to fix carbon dioxide as organic carbon through a process called the Calvin cycle. This cycle consists of chemical reactions that produce phosphoglycerides, which the plant cell uses to synthesize nutrients.

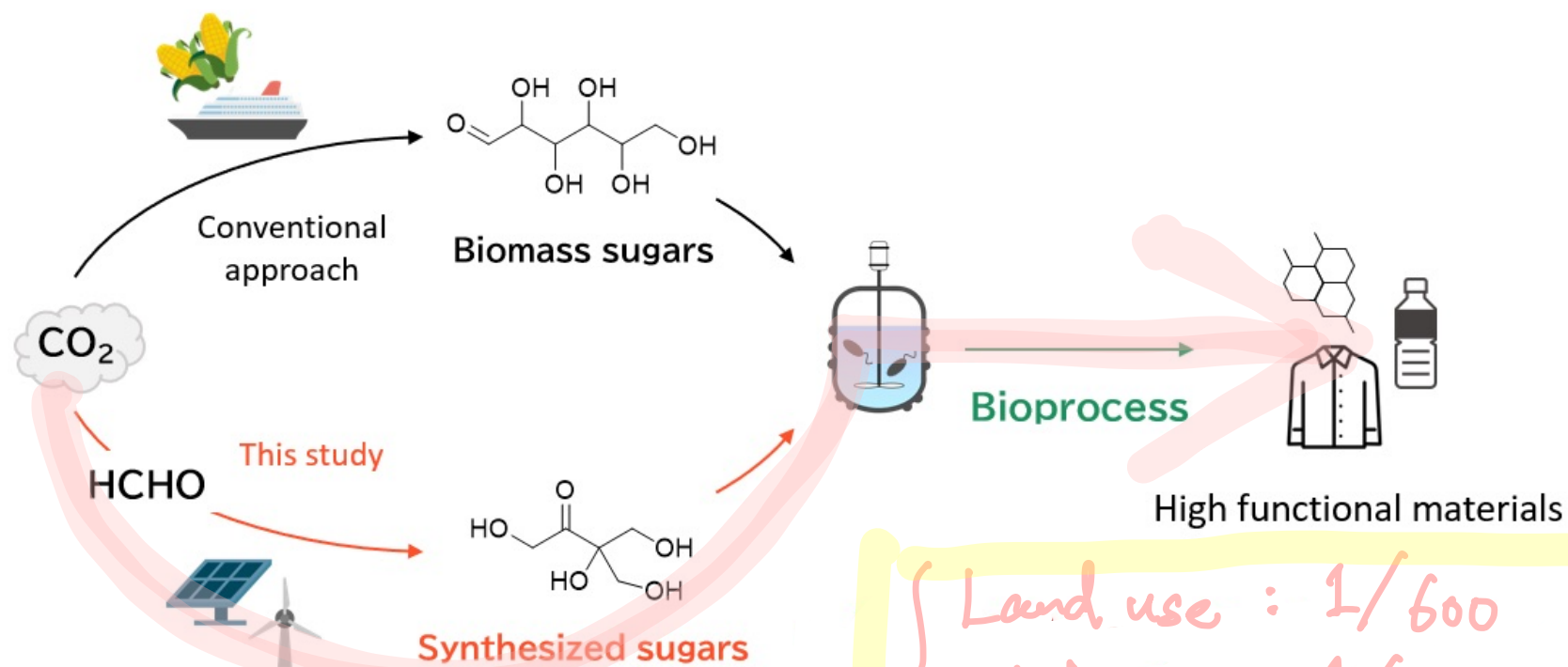
**END PRODUCTS** enable the plant to generate carbohydrates, fatty acids, and amino acids.

**Carbon**  
THE BUILDING BLOCK OF ORGANIC MATERIALS



# CO<sub>2</sub>の資源化 / 人工光合成





Land use : 1/600  
Water use : 1/1300  
No use of N & P

C. P. O'Brien, et al., ACS Energy Lett. 2022, 7, 10, 3509–3523

New pathway

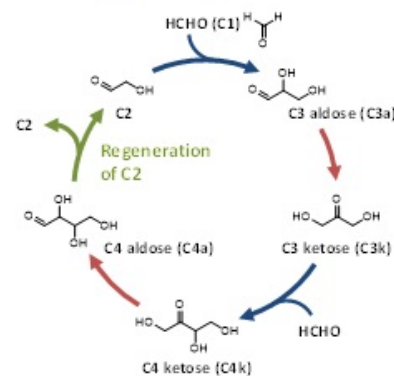


# 化学と生物の融合システム

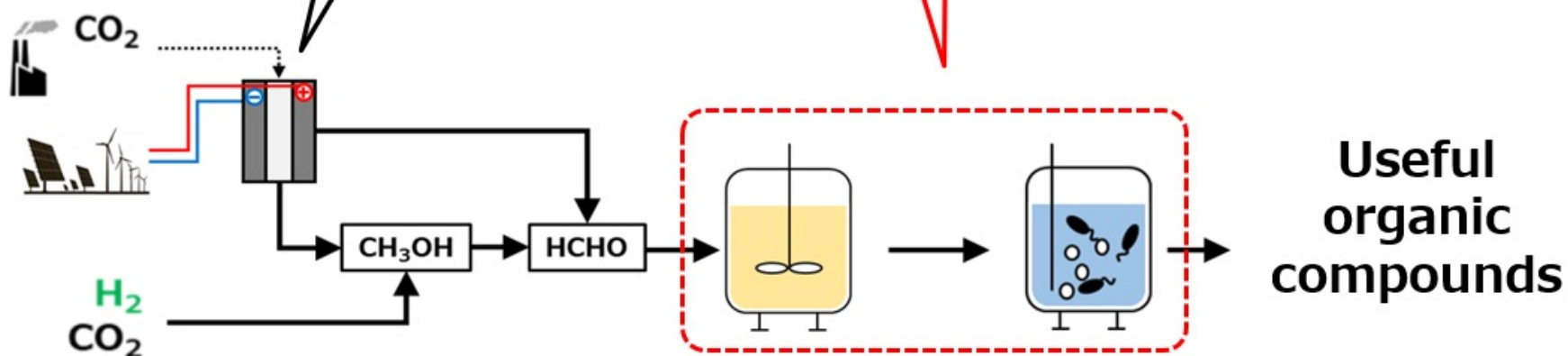
## Electrochemical CO<sub>2</sub> reduction



## non-enzymatic sugar synthesis



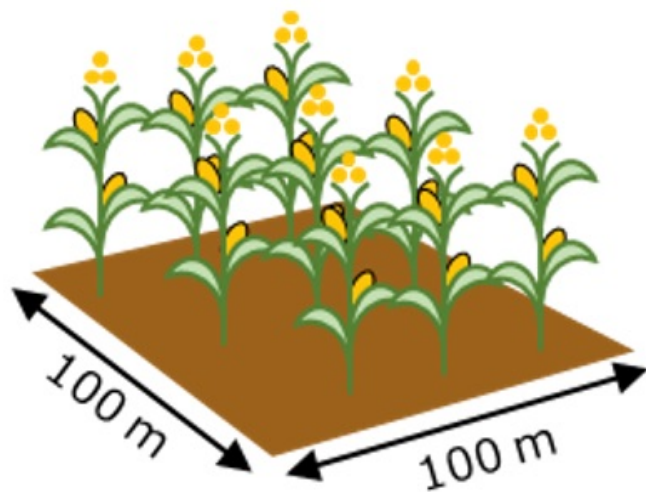
## Bio-process



NASA CO<sub>2</sub> conversion challenge  
Stefano Cestellos-Blanco, et al., *Joule*, **6**, 2304 (2022).

# 化学と生物の融合システム

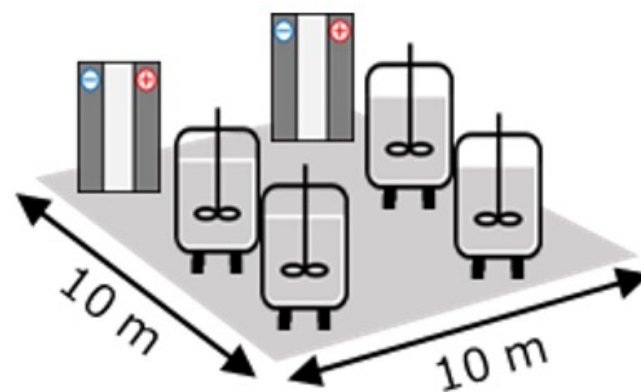
## ○天然光合成



1 tonのグルコース生産にかかる日数

$$\frac{365}{0.5 \times 11.4} = 64 \text{ [days/ha]}$$

## ○人工光合成（糖の電解合成）



$$\frac{5556 \text{ [mol]} \times 4 \times 6 \times 96500 \left[\frac{\text{C}}{\text{mol}}\right]}{0.2 \left[\frac{\text{Cs}}{\text{cm}^2}\right] \times 5.25 \times 10^6 \text{ [cm}^2\text{]} \times 60 \times 60 \times 24}$$
$$= 1.4 \times 10^{-1} \text{ [days/a]}$$

100分の1の面積で**450倍**の速度で糖の合成が可能に