Light-driven biotransformation using photosynthetic *Synechocystis* sp.

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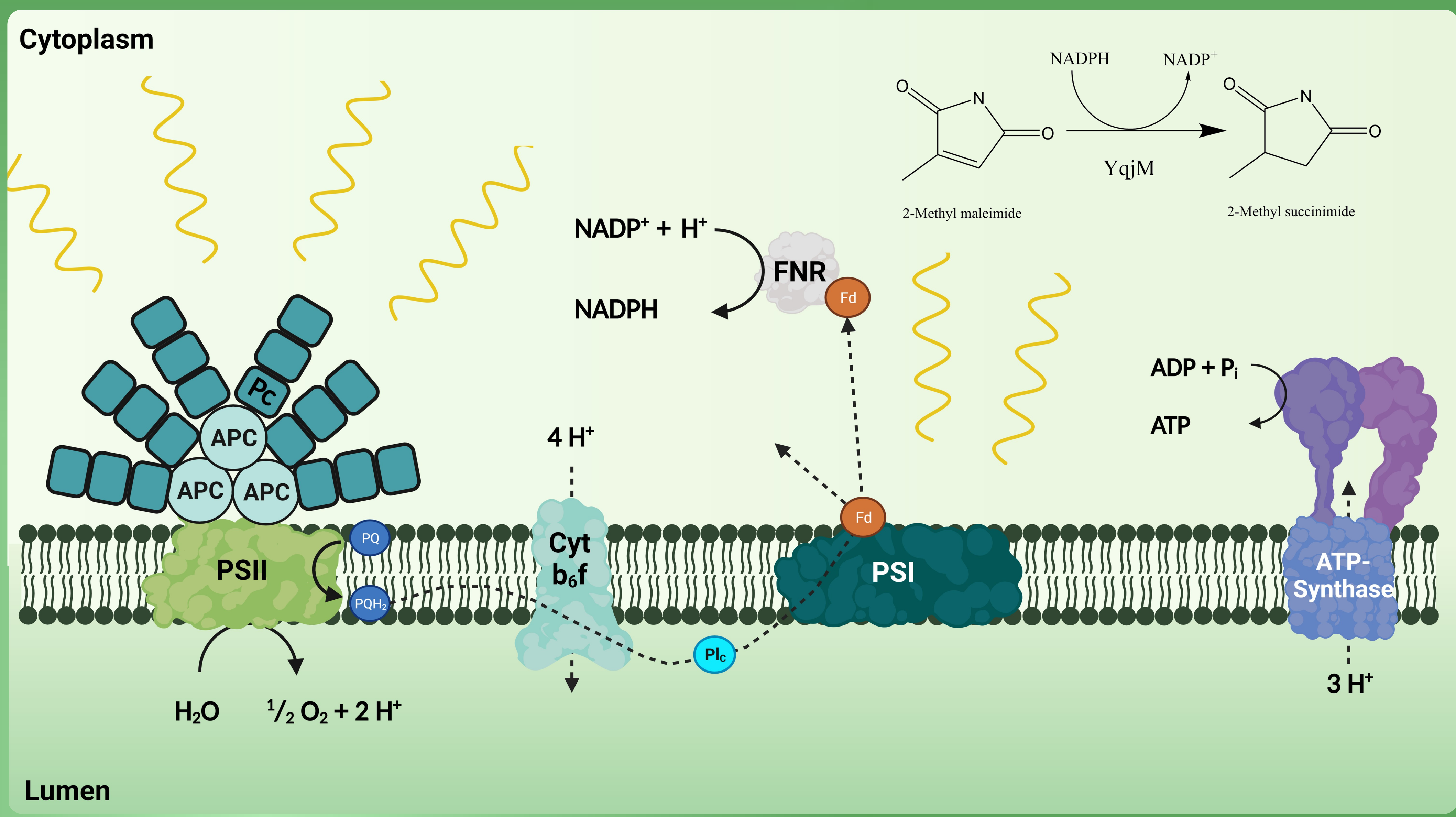
Background:

Biocatalysis uses a biological entity such as enzymes and whole-cells for chemical reactions in ambient temperature and pressure conditions. As a consequence, the use of hazardous metal catalysts and organic solvents can be reduced.

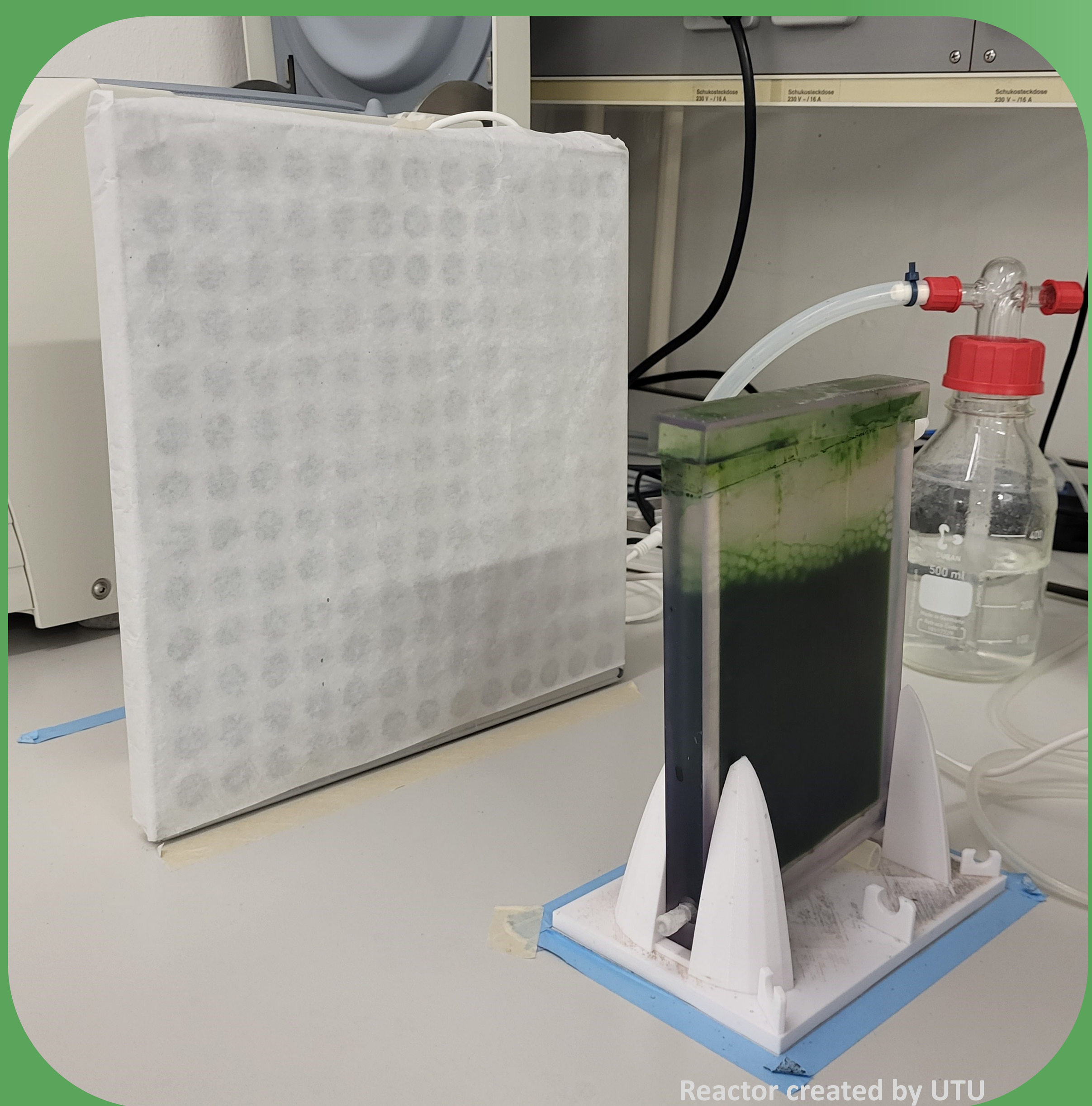
Employing oxidoreductases in industrial settings require addition of redox equivalent in the form of nicotinamide cofactor. Photosynthetic driven NADPH-recycling can offer a sustainable and cheaper process to facilitate redox reactions without the need of sacrificial substrates.

Important benchmarks for industrial application are the *productivity* which is obtained from the product concentration per unit of time and volume of media, the *efficiency* as the product formation rate dependent on cell mass and *product formation* obtained per unit of time. Depending on the purpose, the price needs to be in range of ~10 € $kg_{Product}^{-1}$ for low-priced products and higher than 1000 € $kg_{Product}^{-1}$ for higher-valued products. [1]

In the following, three different photo bioreactors are compared under optimal conditions in their potency of converting 2–methyl-maleimide to 2-methyl succinimide in whole-cells with integrated ene-reductase YqjM from *Bacillus subtilis*.



Flat Panel Bioreactor

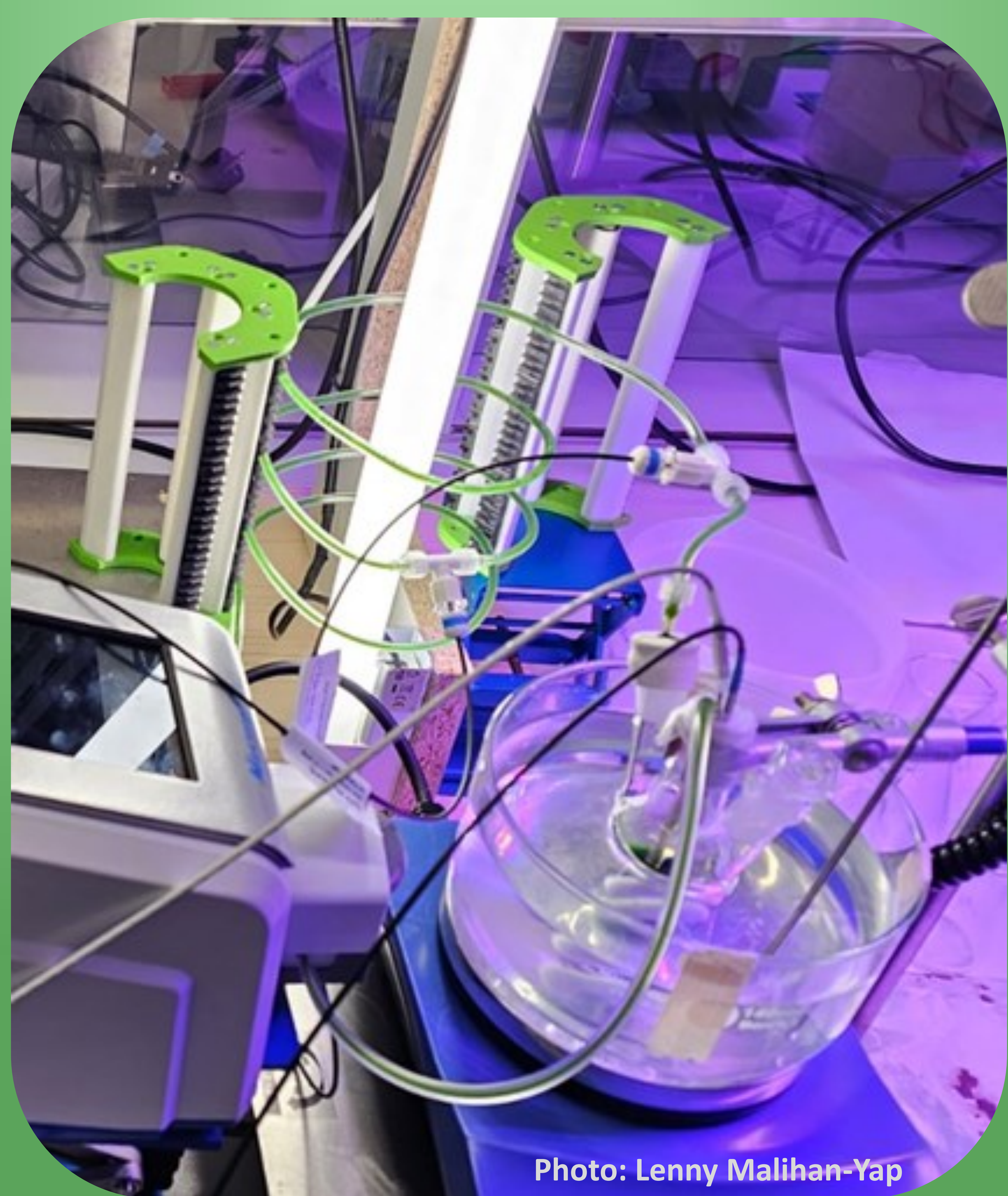


- Highest product formation
- Short light path & high volumes possible
- Highest efficiency (per biomass)

Efficiency	**112.8 U g_{CDW}^{-1}**
Productivity	0.91 g L^{-1} h^{-1}
Product formation	**0.14 g h^{-1}**

Conditions: cell density 1.2 g_{CDW} L^{-1}, 300 µmol photons m^{-2} s^{-1} ,0.5 L min^{-1} air bubbling, 150 mL

Continuous Coil Reactor[2]

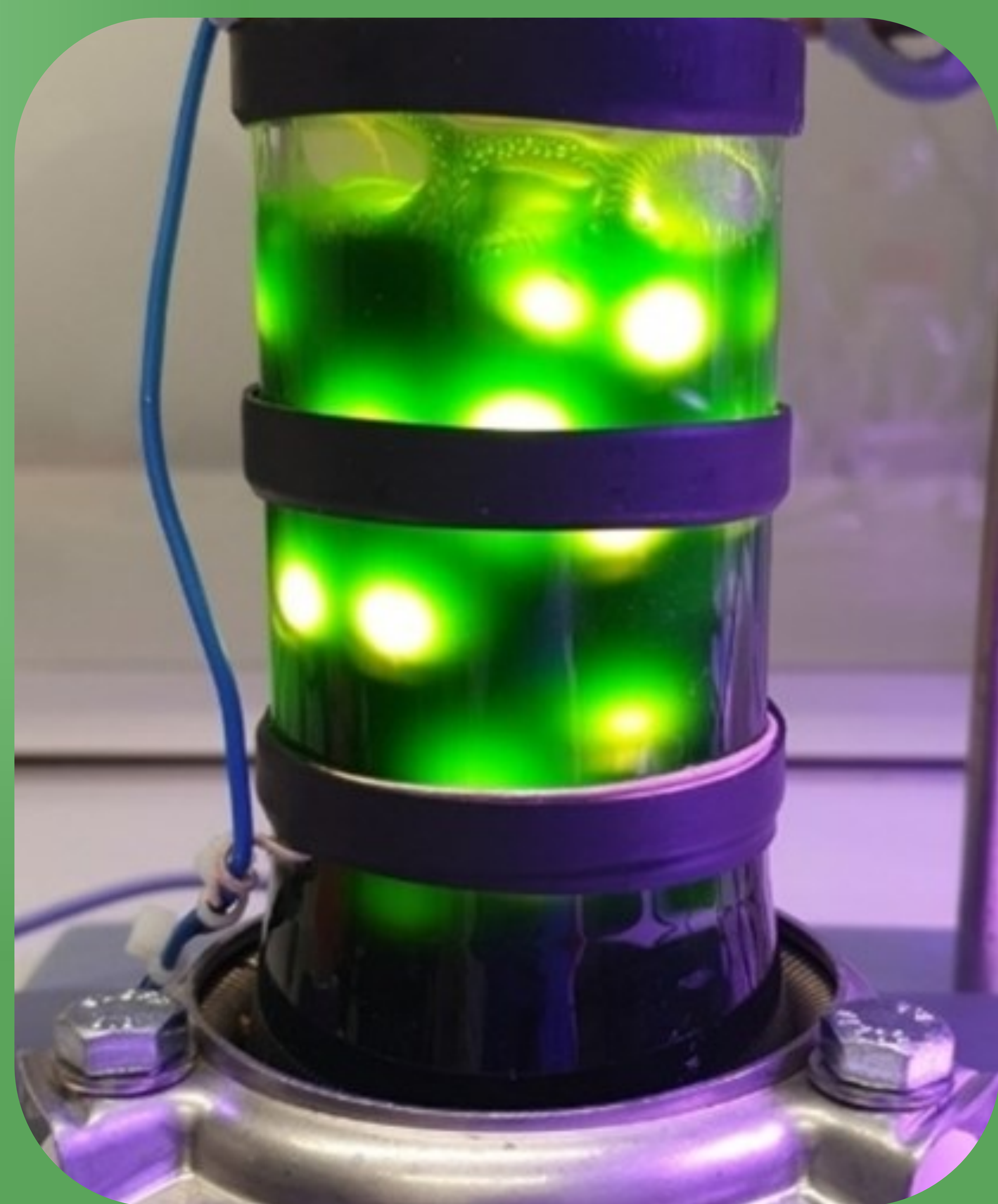


- Highest cell densities possible
- Very short light path
- Highest productivity

Efficiency	99.8 U g_{CDW}^{-1}
Productivity	**2.41 g L^{-1} h^{-1}**
Product formation	0.04 g h^{-1}

Conditions: cell density 3.6 g_{CDW} L^{-1}, 300 µmol photons m^{-2} s^{-1} , 30°C, 15 mL

Bubble Column Reactor[3]



- Dark zone formation with higher cell densities
- Higher volumes possible
- Increase in irradiance hardly advantageous

Efficiency	65.5 U g_{CDW}^{-1}
Productivity	0.40 g L^{-1} h^{-1}
Product formation	0.06 g h^{-1}

Conditions: cell density 1.2 g_{CDW} L^{-1}, 150 µmol photons m^{-2} s^{-1}, 0.5 L min^{-1} air bubbling, 150 mL

Conclusion:

- For the bubble column reactor, scaling-up is difficult due to the long diameter creating a long light path. Due to creation of dark zones, utilization of higher cell densities is restricted.
- Under optimal conditions the coil reactor shows the highest productivity. However, the investigated working volume (15 mL) is only a tenth compared to the other two reactors. Scaling-up the volume of the coil could lead to shorter light exposure and residence time. Reversely, increments in the tube length could lead to harmful oxygen accumulation through photosynthesis in the end. [4]
- The flat panel bioreactor offers a compromise between short light path and working volume. A wide surface area can be exposed to light, although higher cell densities still suffer from efficiency loss.

References:
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