C5: Carbon Cycle, Chemistry and Climate Change

Jan H. van Maarseveen (Van ‘t Hoff Institute for Molecular Chemistry)

Institute for Advanced Study, Tuesday April 19

Honours course “Climate and Molecules” (Nov-Jan 2013-2014)

- *Drs. Marcel Crok (Science Journalist, author“de staat van het klimaat”)*
- Prof. Dr. Jaap Sinnighe Damsté (NIOZ, paleoclimatologist)
- Prof. Dr Luc Lourens (RU, paleoclimatologist)
- Prof. Dr. Bart van den Hurk (KNMI, climatologist)
- Dr. Caroline Katsman (KNMI, oceanologist)
- Prof. Dr. Hein de Baar (NIOZ, inorganic geochemist)
- Prof. Dr. Mike Jetten (RUN, microbiologist).
- *Dr. Bas van Geel (UvA, paleoecologist/paleoclimatologist)*
- Dr. Rob van Dorland (KNMI, climatologist, IPCC member)
- Drs. Elmar Veerman (VPRO, chief editor “Noorderlicht”)

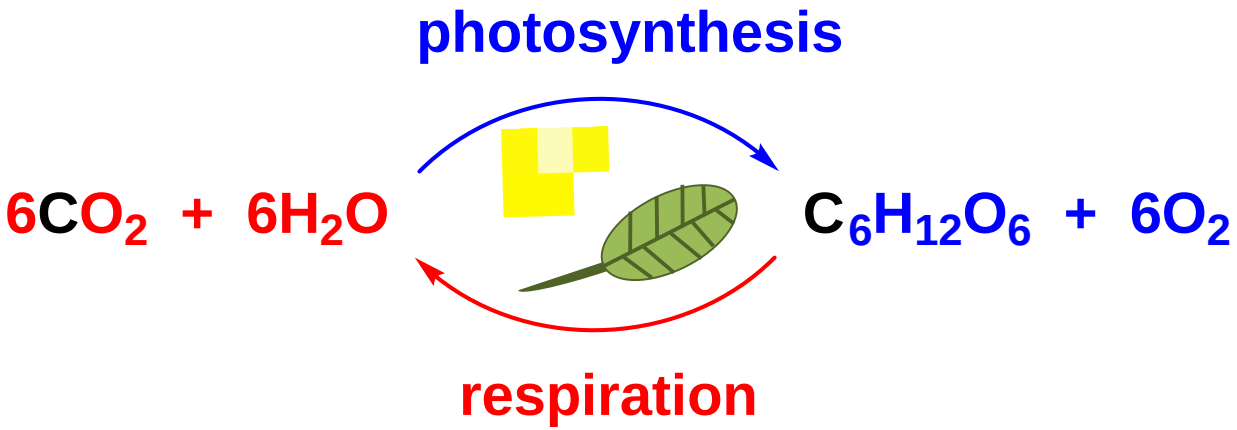
Site visit KNMI and NIOZ, presentation and essay.

Honours course “Sun, Energy & Materials” (2019, 2020, 2021)

- Chemical principles of the anthromorphic and natural carbon cycle (prof. J. H. van Maarseveen, UvA)
- The carbon cycle on earth (dr. B. Jansen, UvA)
- Carbon and climate in the past, current and future (prof. B. van der Zwaan, ECN/TNO and UvA)
- Current use of fossile resources for energy and materials (dr. A. van der Made, Shell)
- Can we do without carbon in 2050? (dr. R. Detz, ECN/TNO)
- Hydrogen (dr. M. Weeda, ECN/TNO)
- Materials in 2050 (prof. G.-J. Gruter, Avantium and UvA)
- Solar to fuel (prof. J. Reek, UvA)

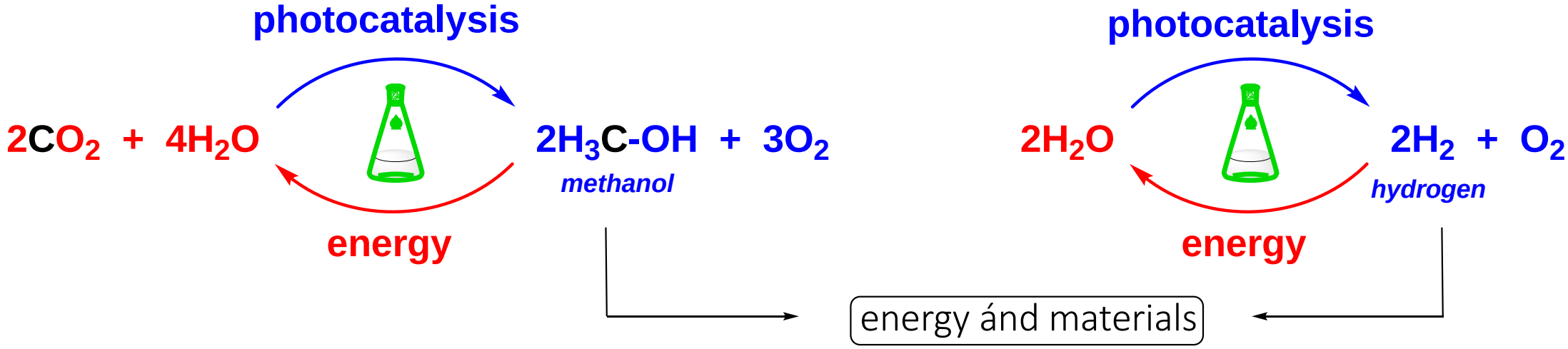
Presentation and writing research proposal

Carbon cycle: CO_2 and H_2O are also a solution for us





To be developed:



Background photosynthesis: reduction/oxidation (redox) chemistry

Iron is *oxidised* by molecular oxygen (O_2):

$$Fe \xrightarrow{\text{oxidation}} Fe^{3+} + 3\,e^-$$

$$O_2 + 4\,e^- \xrightarrow{\text{reduction}} 2\,O^{2-}$$

$$4\,Fe + 3\,O_2 \longrightarrow 2\,Fe_2O_3$$

(O_2 is an electron sponge)

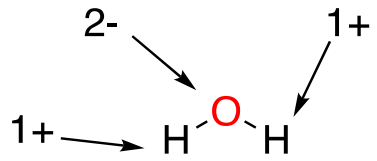
Water can also be oxidised:

$$H_2O \longrightarrow H^+ + HO^- \longrightarrow H^+ + O^{2-}$$

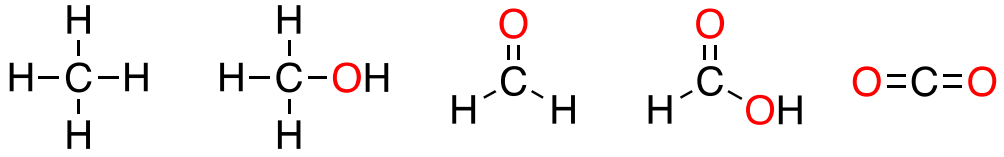
$$2\,O^{2-} \longrightarrow O_2 + 4\,e\text{- (electrons)}$$

..... However, water oxidation is extremely difficult

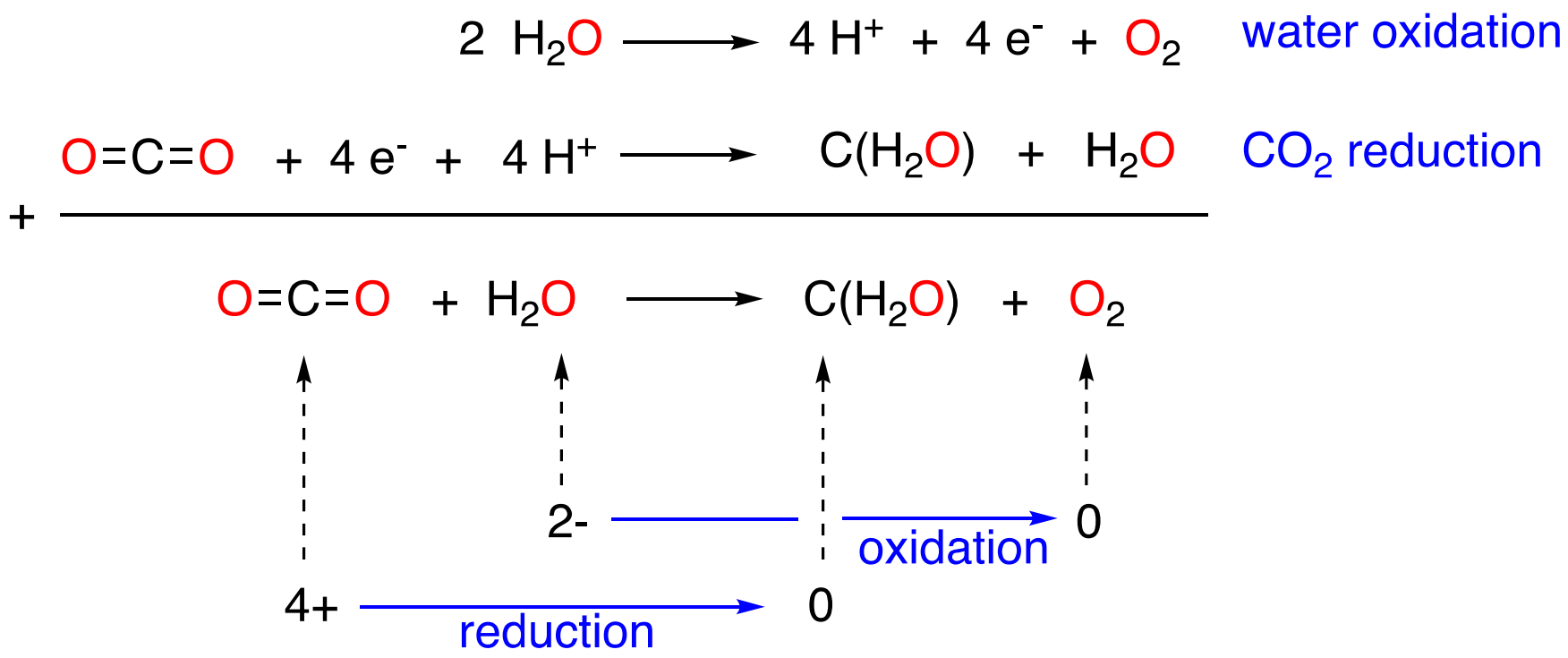
Oxidation numbers



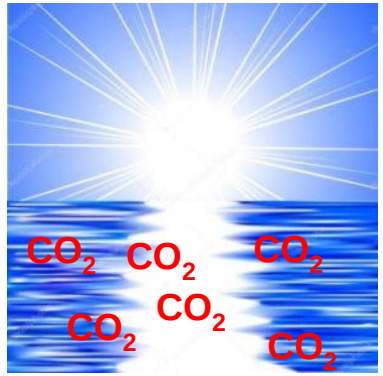
carbon

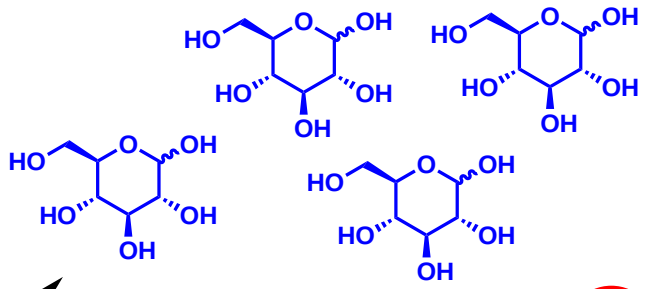


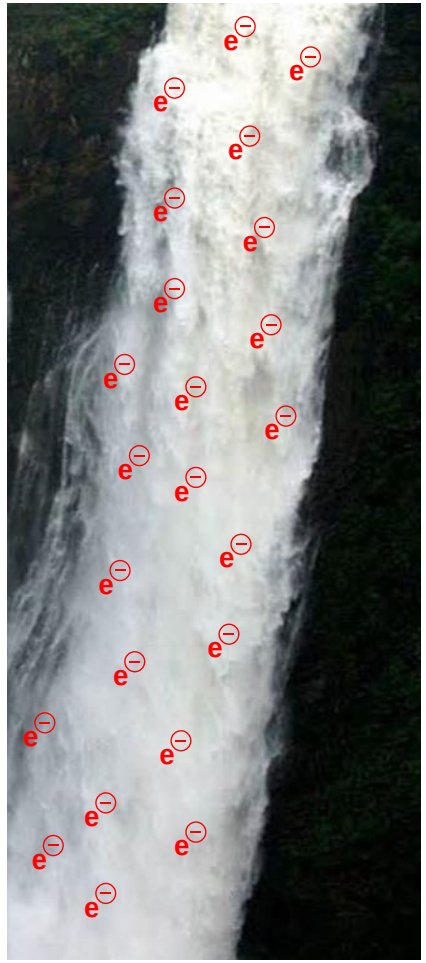
Redox principles of photosynthesis



Fundamentals of photosynthesis





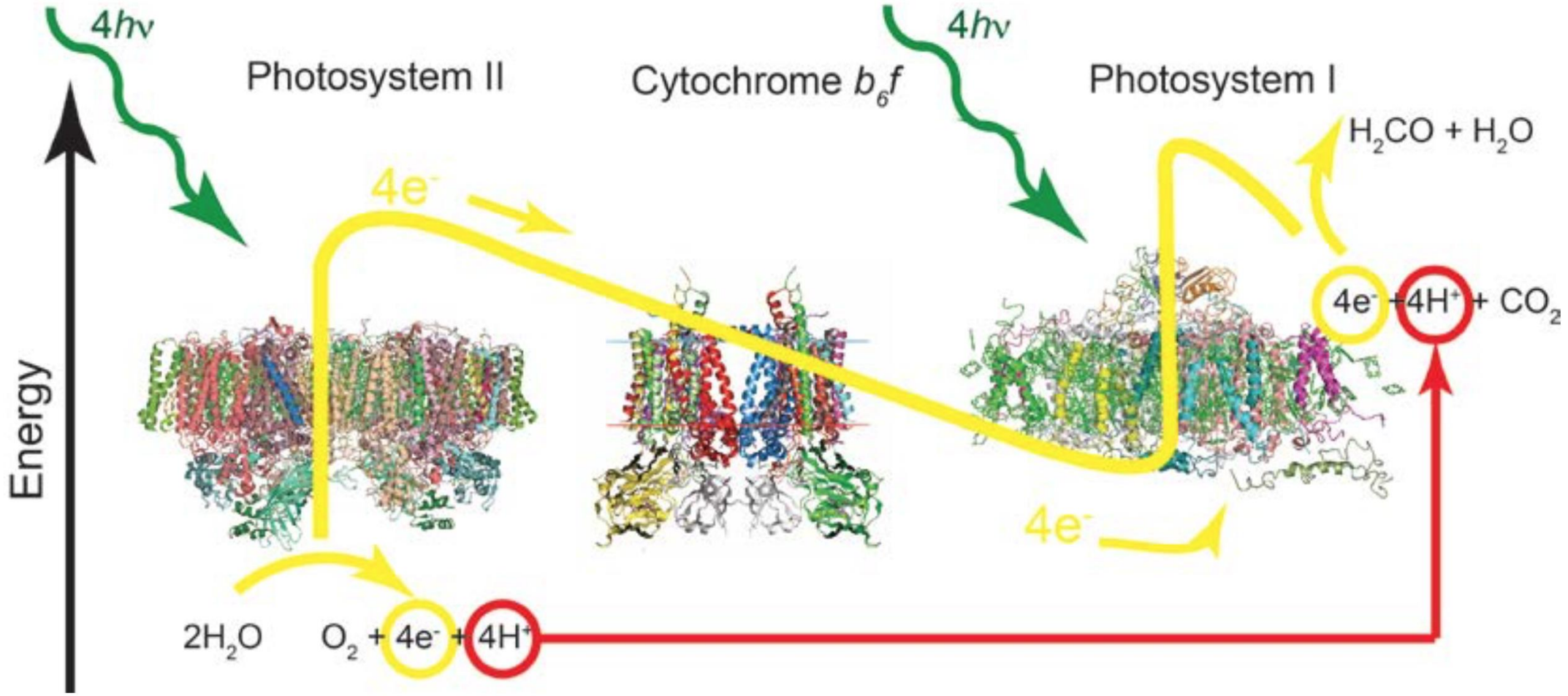






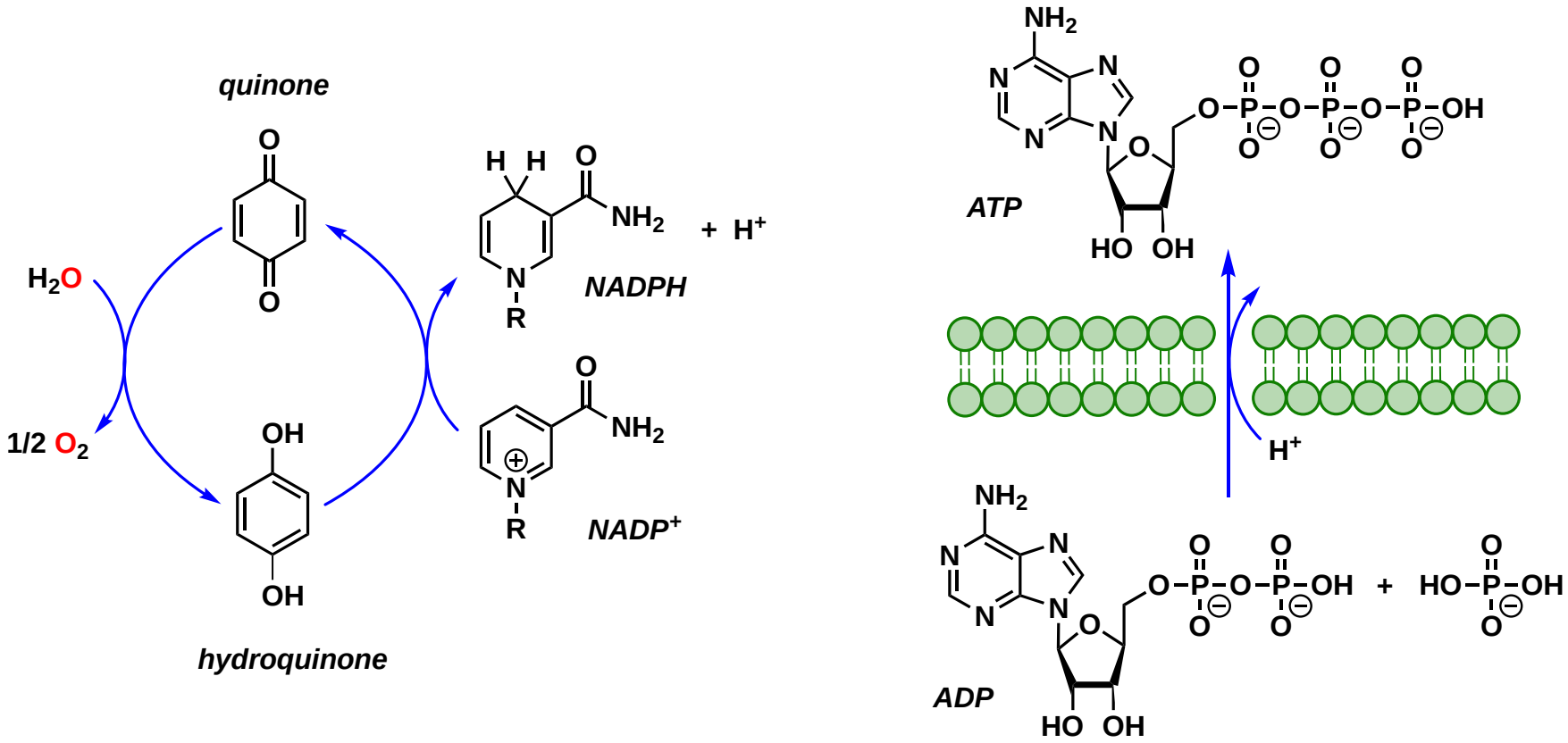
O_2 O_2 O_2 O_2 O_2 O_2 O_2

The photosynthetic biomachinery: it's all about liberating and transporting electrons



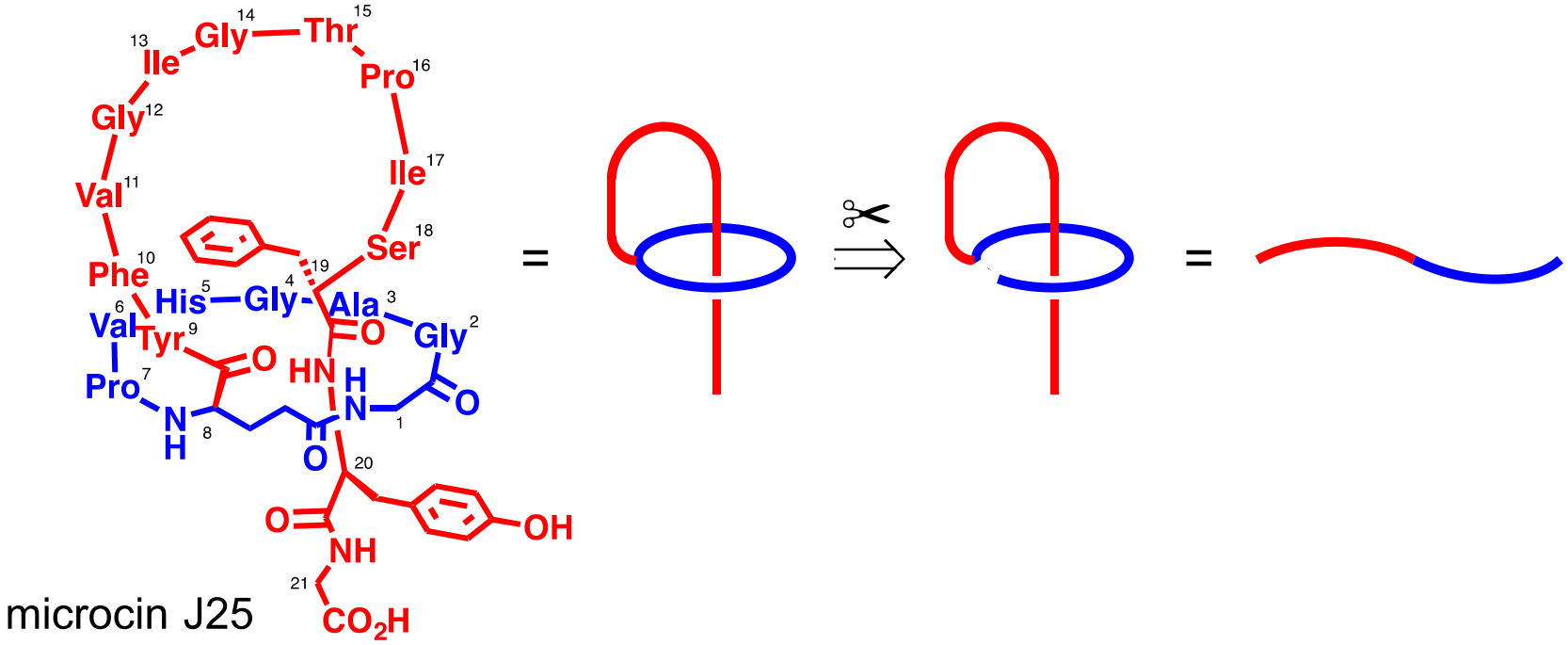
Picture from: Artificial photosynthesis for the conversion of sunlight to fuel, BioSolarCells, 2015

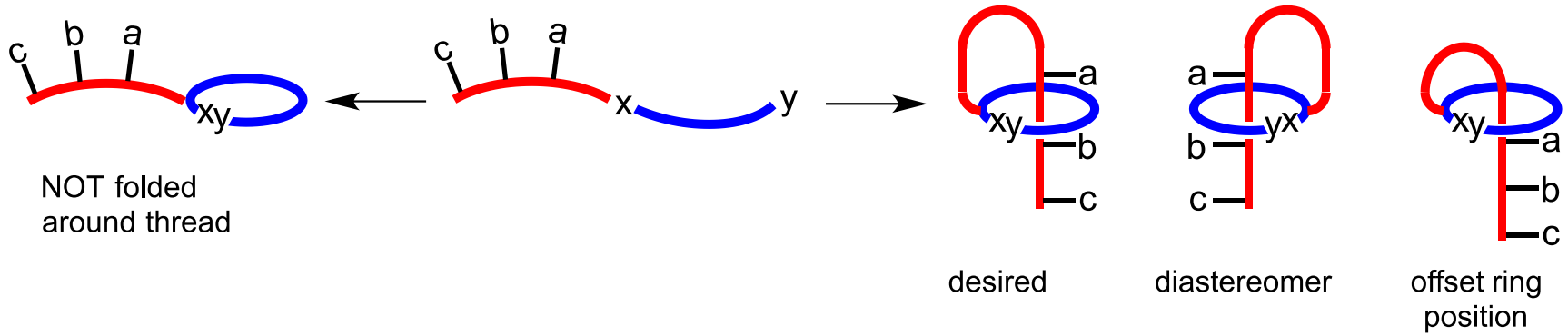
Organic molecules and photosynthesis



- Electrons derived from H_2O oxidation are used for NADPH and ATP synthesis
- Quinones function as electron transporters

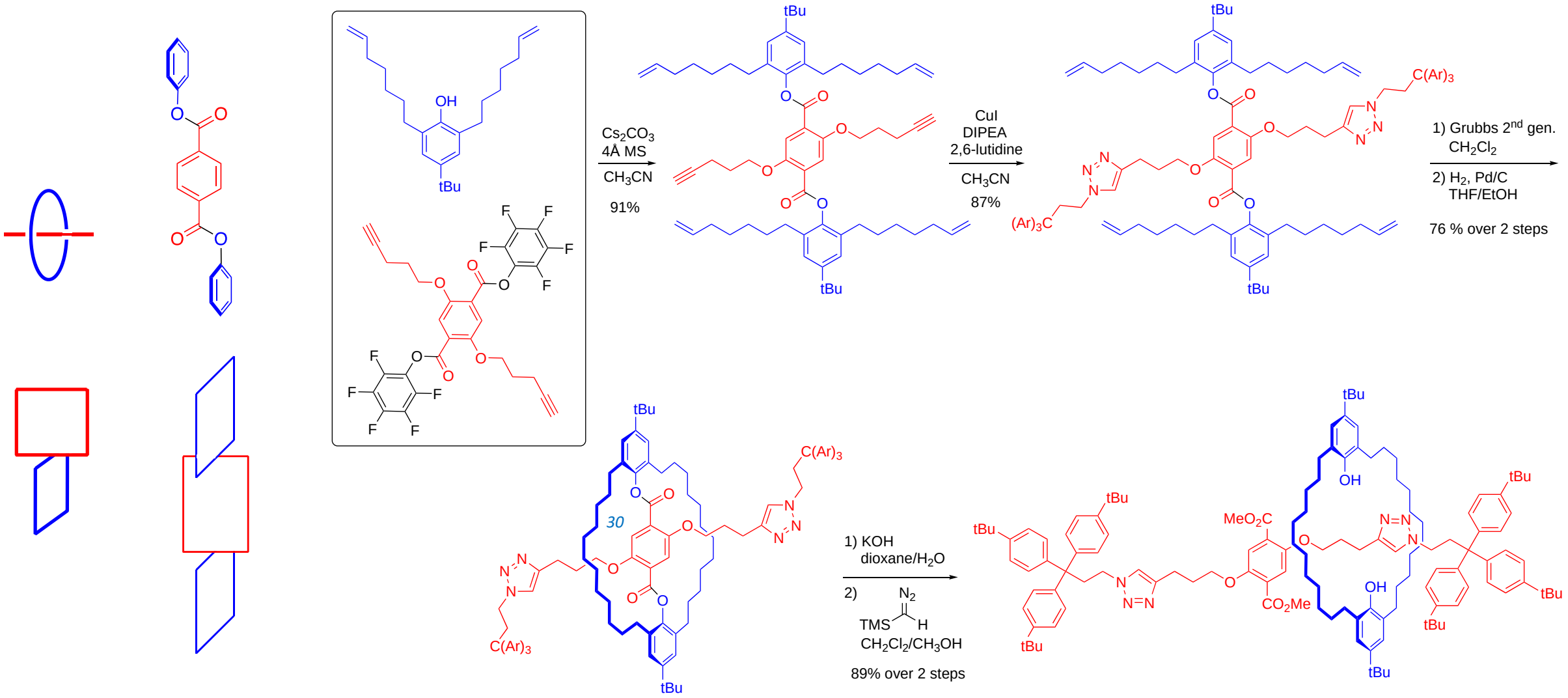
Lasso peptides: synthetic challenges





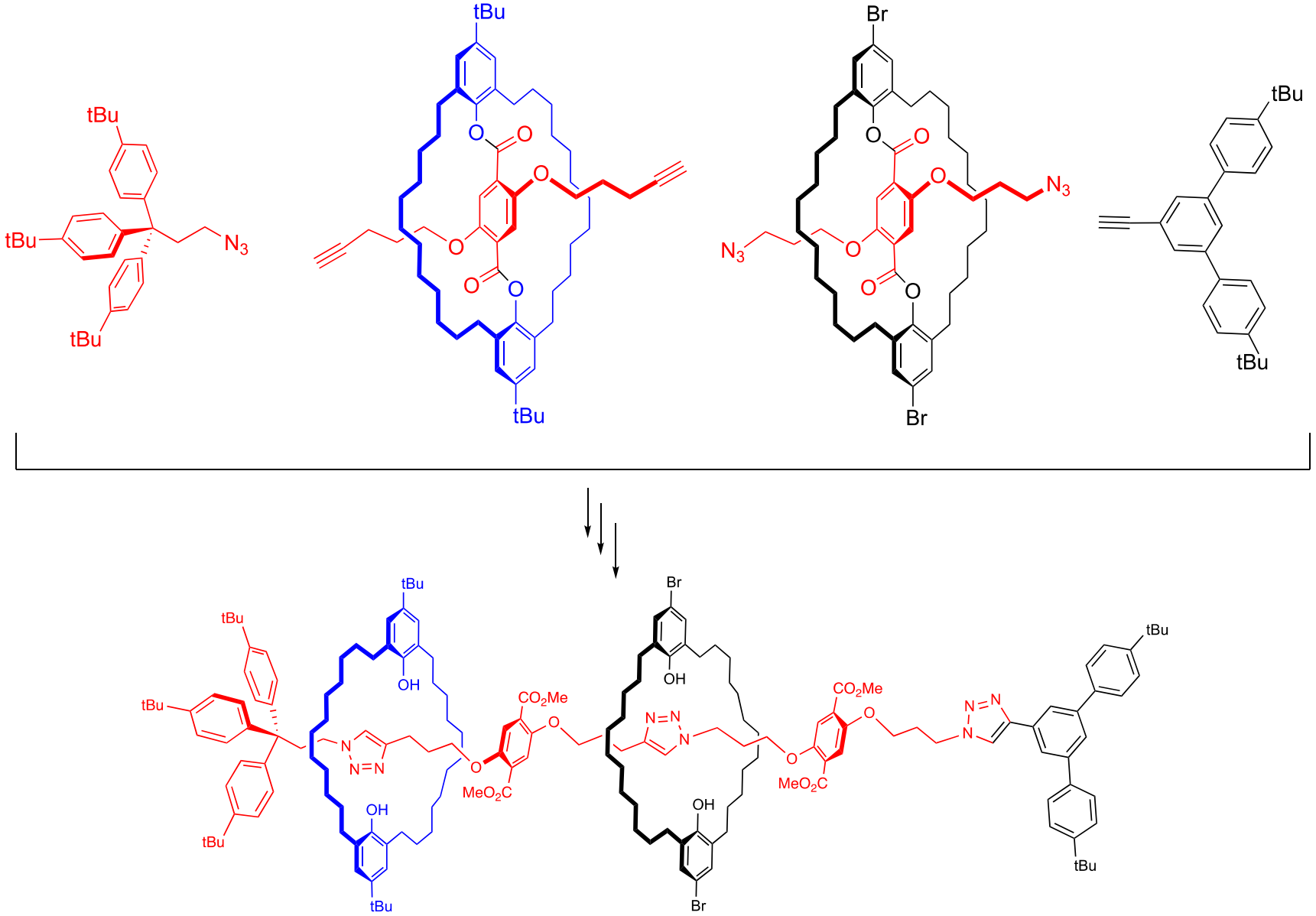
1. Van Maarseveen, J. H.. *Nature Chemistry.* ***2021,*** **13**, 822–823

[n]Rotaxane synthesis via perpendicular bisaryl terephthalates



Hetero [n]rotaxanes: the lego approach

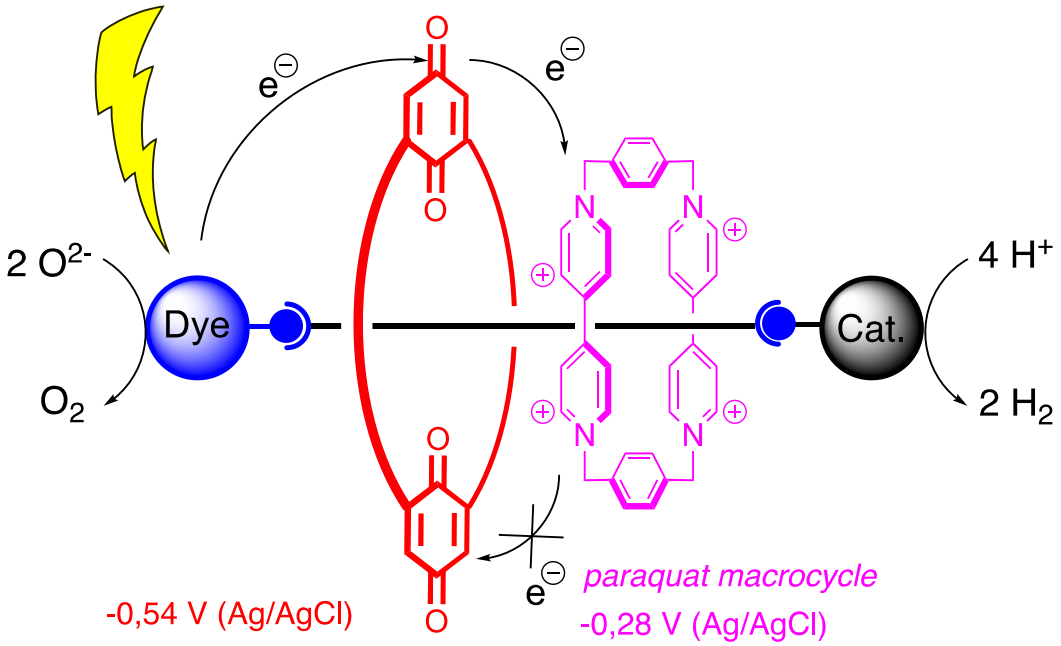


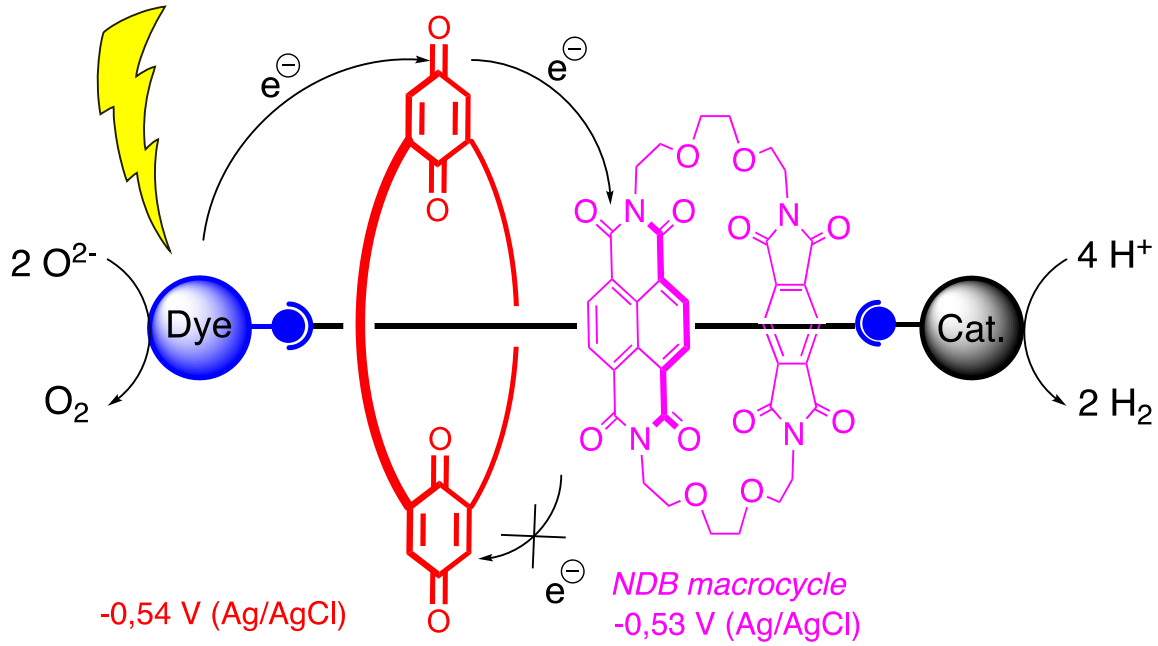


Simone Pilon, Milo Cornelissen, Steven Frölke, Luuk Steemers, Martin Wanner

J. Org. Chem. **2020**, *85*, 3146−3159

In progress: unidirectional electron transport





Nick Westerveld, Bram Verhoofstad

Climate change and fossil resources for energy and materials are molecular problems that require a molecular solution