Harvard Origins of Life Initiative:

Building Blocks, Protocells & UV-driven Evolution

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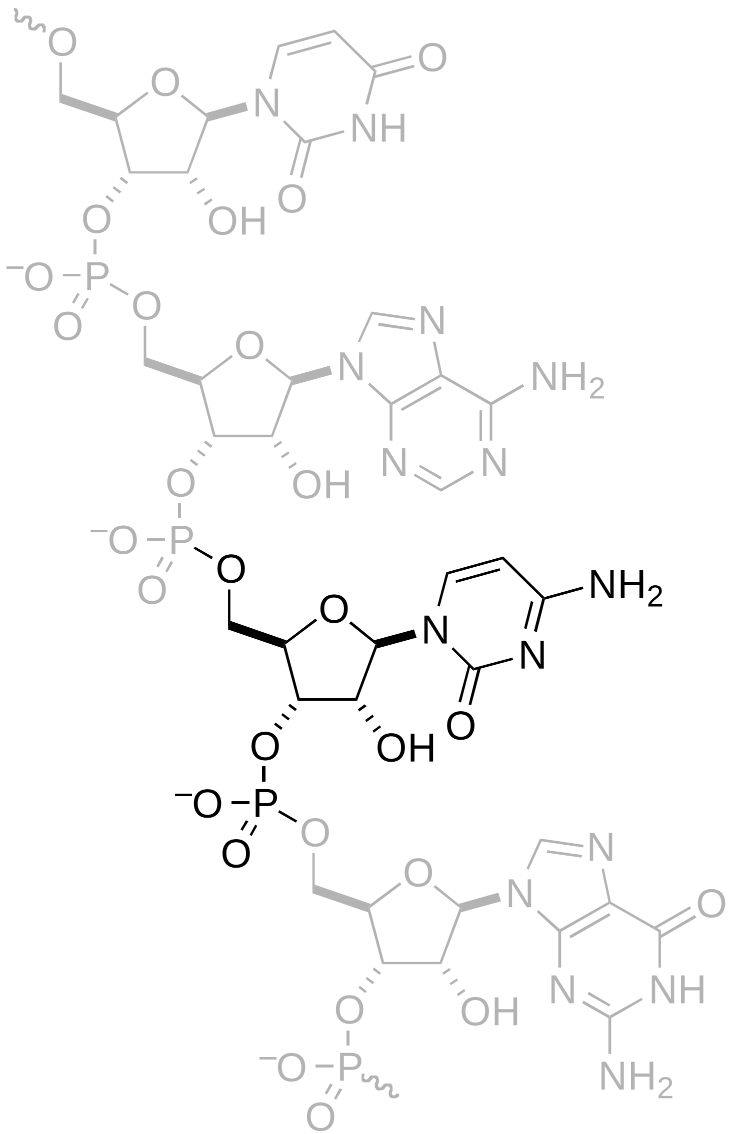
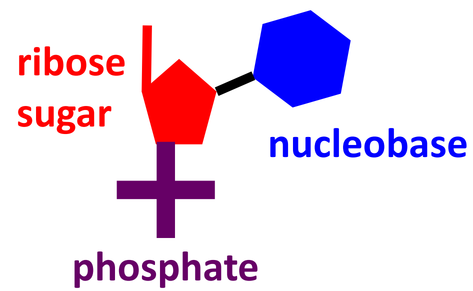
HARVARD
Origins of Life
INITIATIVE

The Harvard Origins of Life Initiative (HOLI)

HOLI Graduate Consortium astrobiology field trip to Iceland 2019

How do polynucleotide molecules, e.g. RNA, arise?

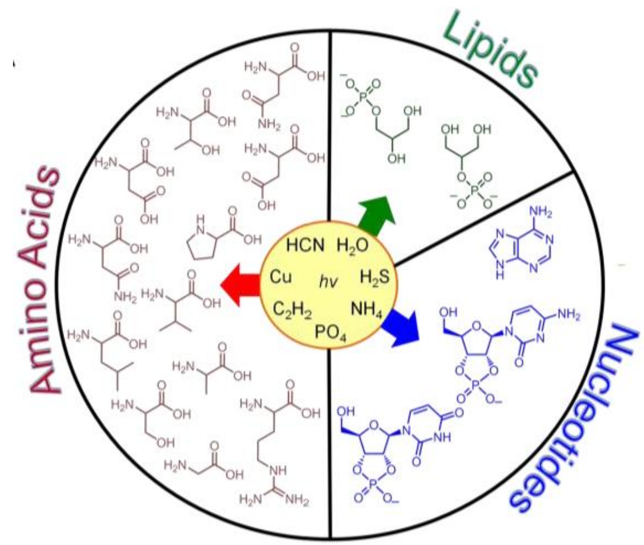




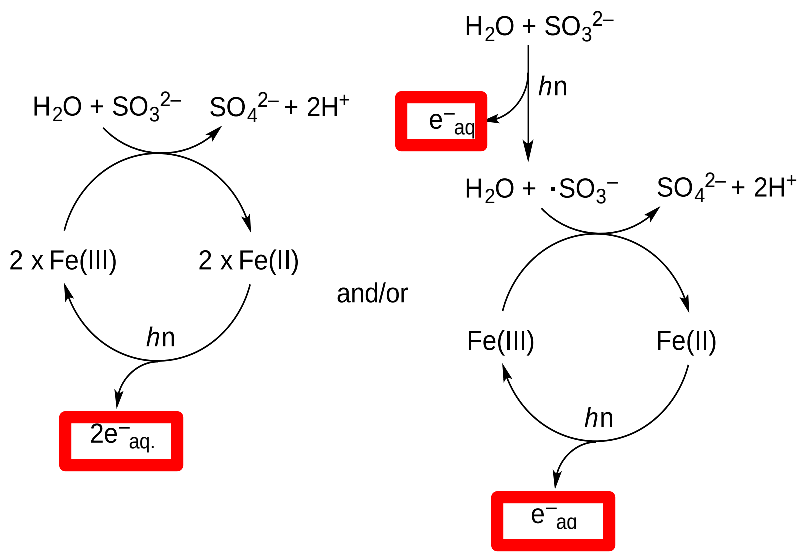
Sutherland Lab
Powner, Gerland & Sutherland (2009)

New Prebiotic Chemistry Paradigm

- *UV Light is central*



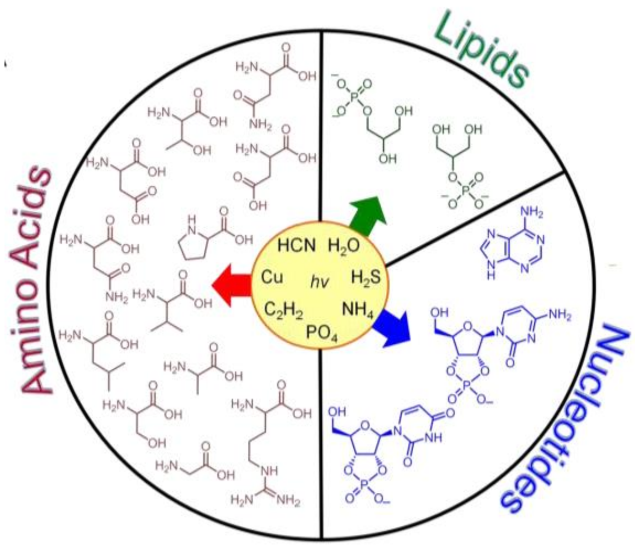
- *Cyano-sulfidic chemistry driven by hydrated electrons:*



Powner, Gerland & Sutherland (2009)
Ritson & Sutherland (2012)
Patel, Percivalle, Ritson & Sutherland (2015)
Xu, Ritson, Ranjan, Todd, Sasselov & Sutherland (2018)

New Prebiotic Chemistry Paradigm

- *UV Light is central*
  - Specific, mid-range UV light (*aka UVC from 200 – 300 nm*) *6 – 4 eV*
  - *Flux & Wavelength dependence*



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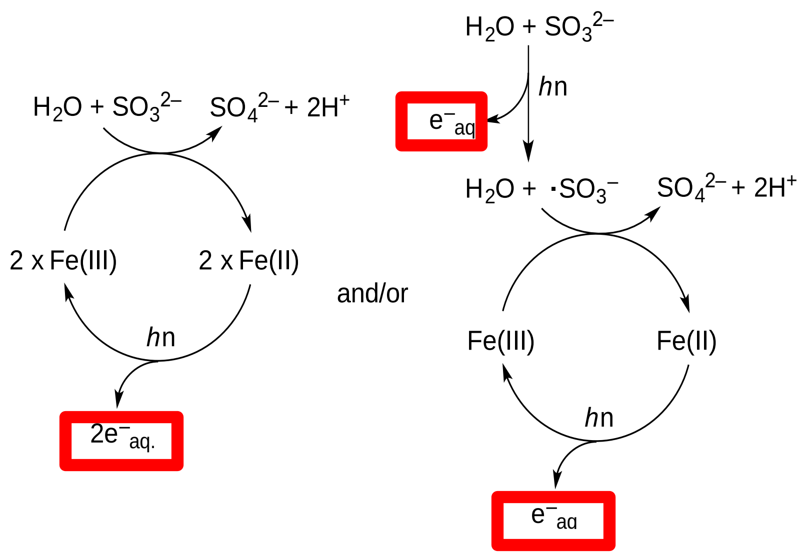
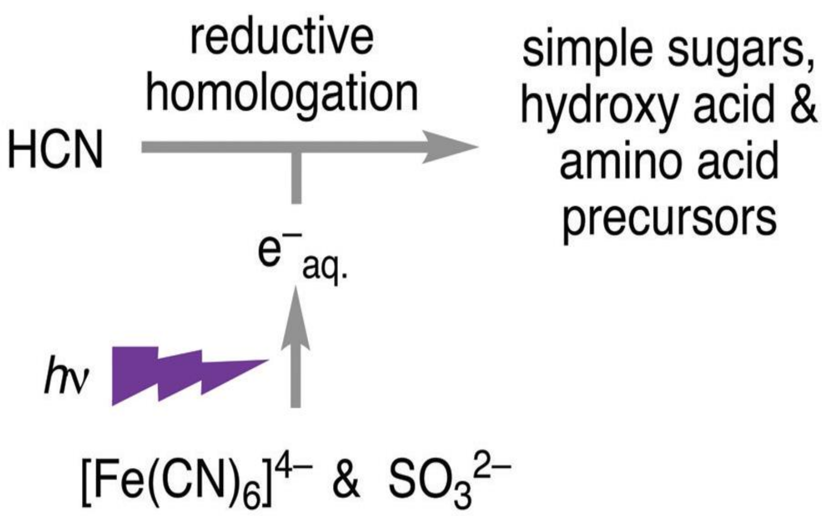
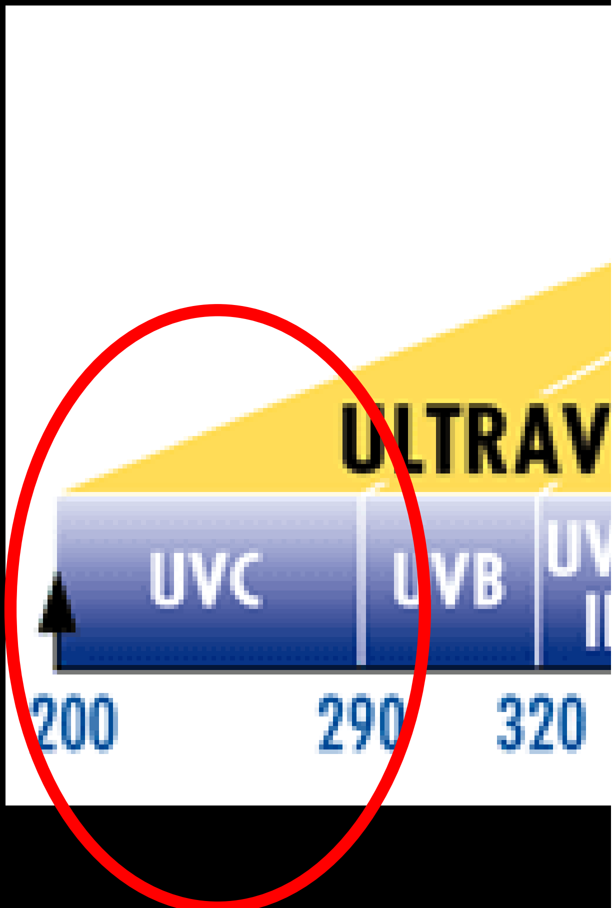
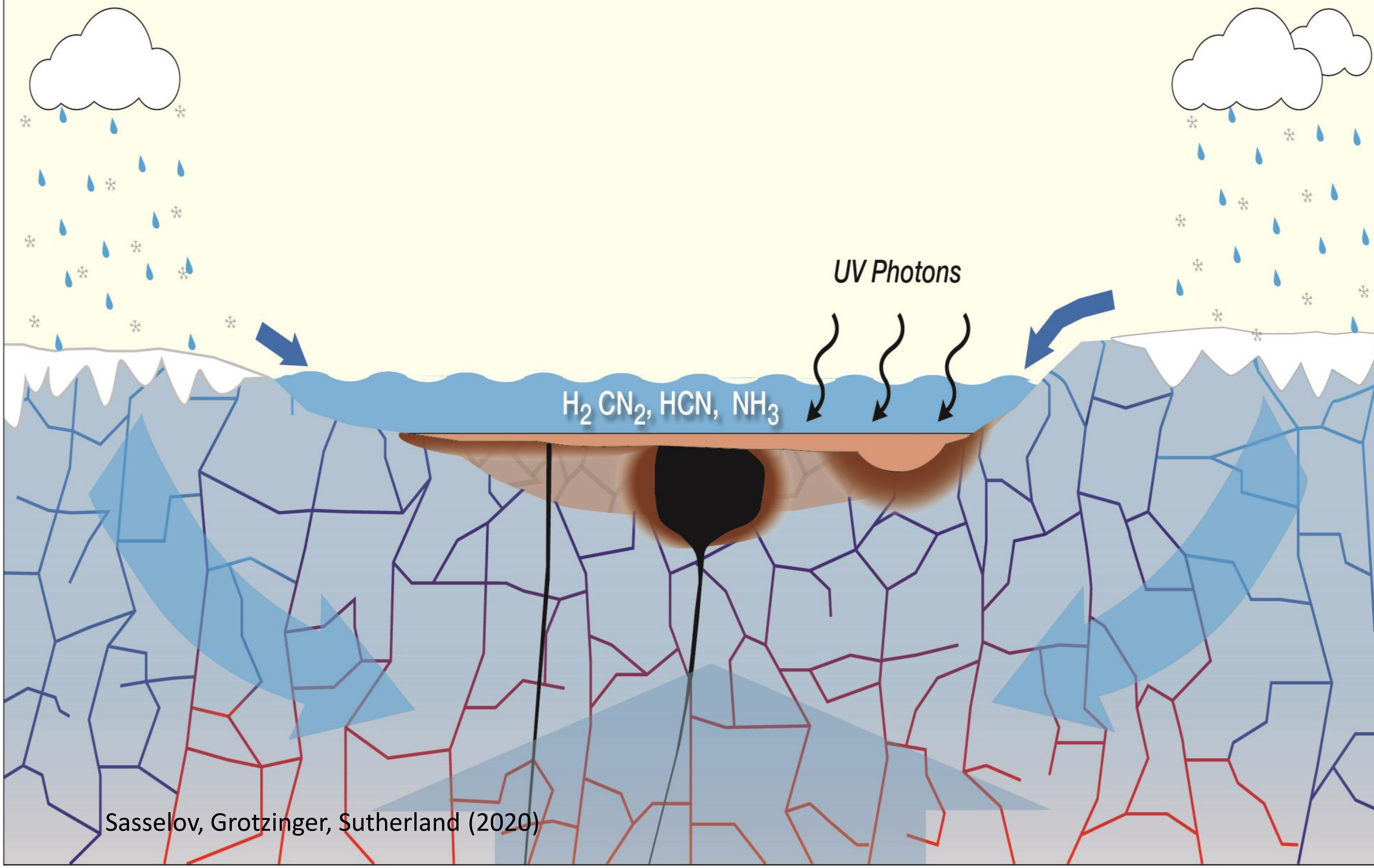




Know your UV light



UVC light reaches the surface of Early Earth, including through shallow water



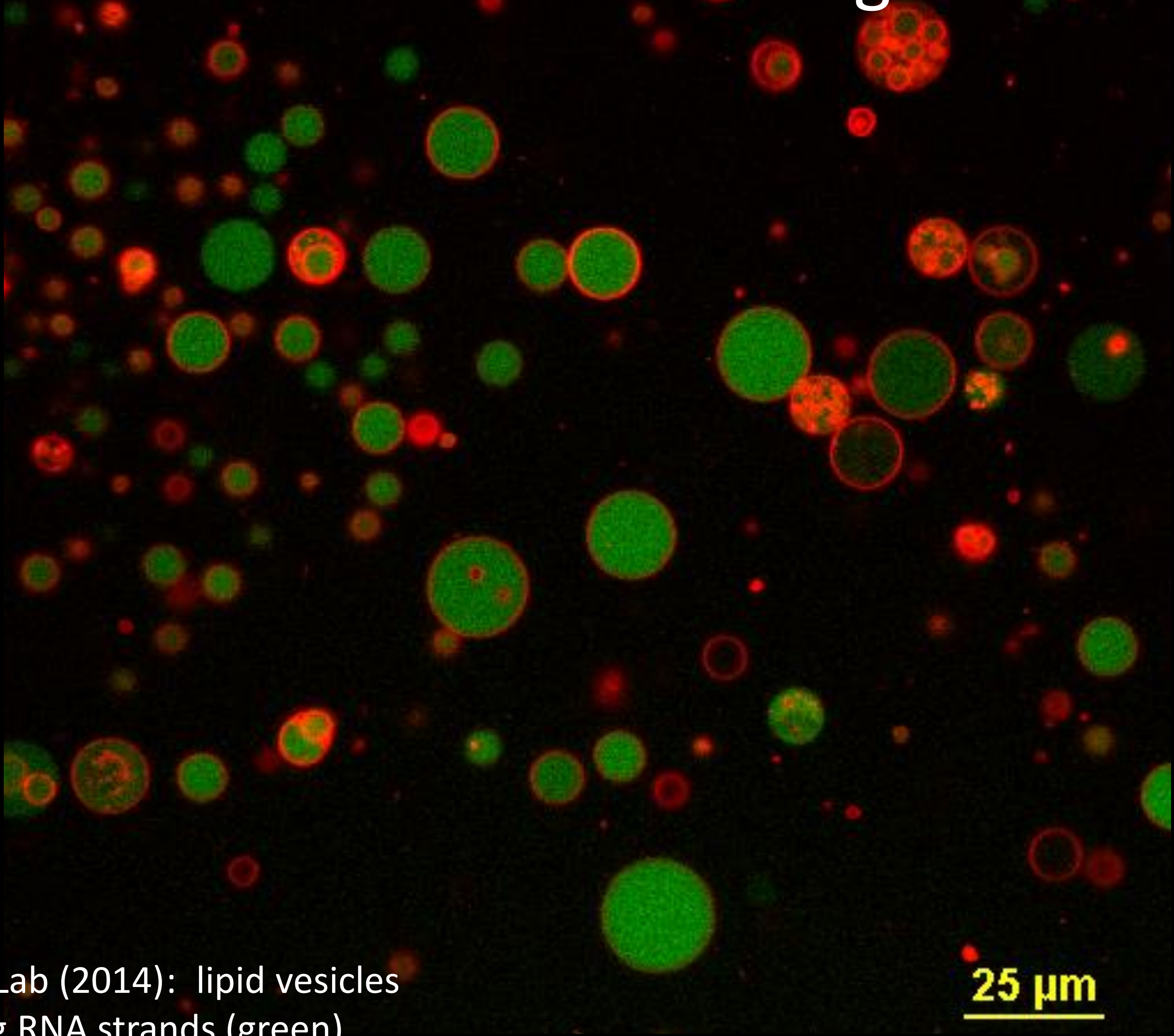
The 3 Roles of Sun's UVC Light

1. UV-driven synthesis: source of energy (*e.g.*, e^-_{aq})

2. UV-driven selection: source of high yields & function

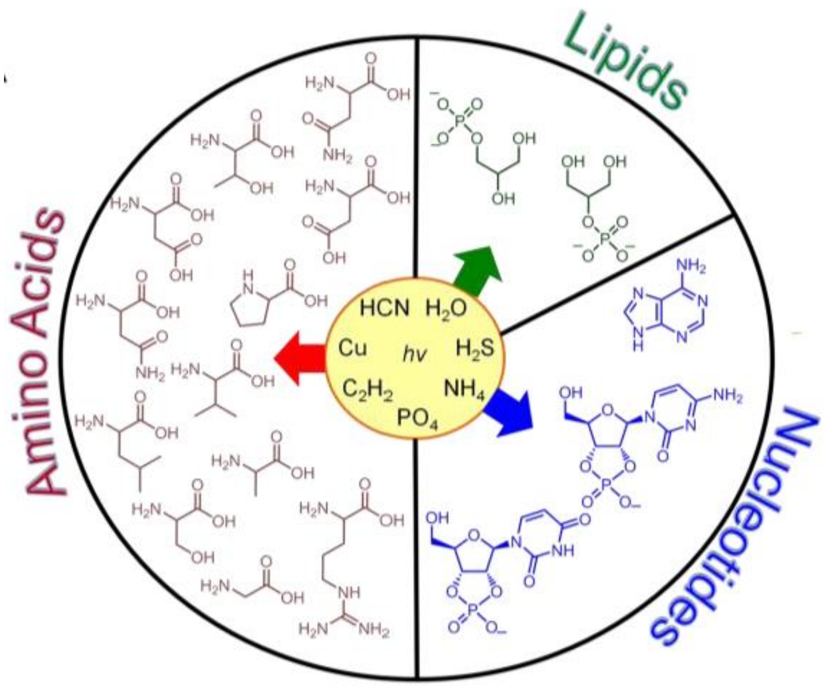
3. UV-induced self-repair: for polymers (*e.g.*, RNA, DNA), the transition from survival to biological function(?)

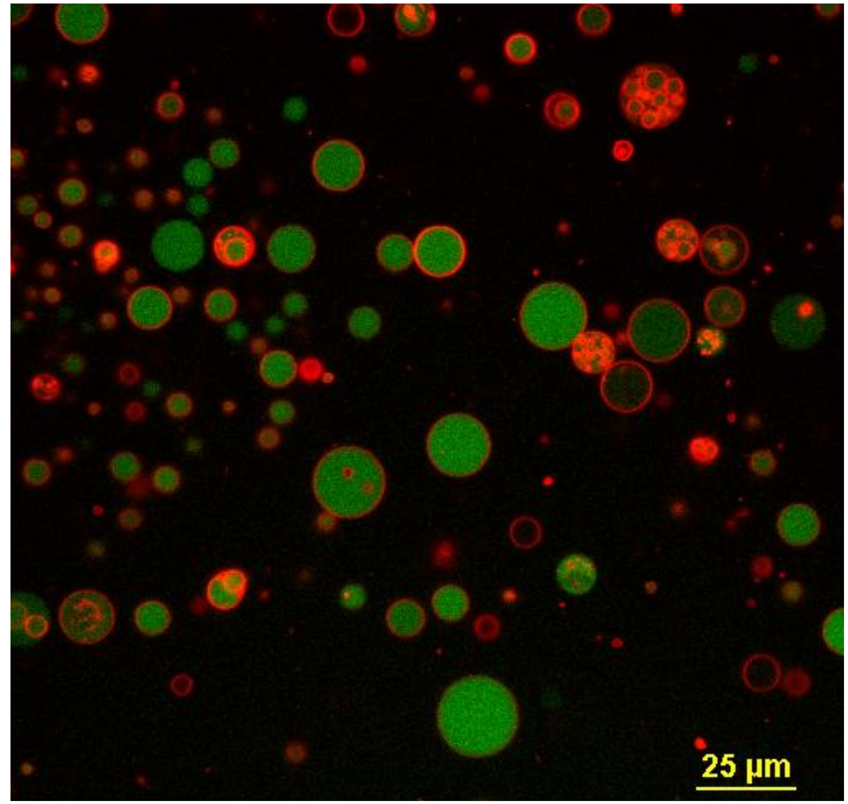
Protocells in the UV Light



Szostak Lab (2014): lipid vesicles
retaining RNA strands (green)

The balance between UV damage & UV self-repair

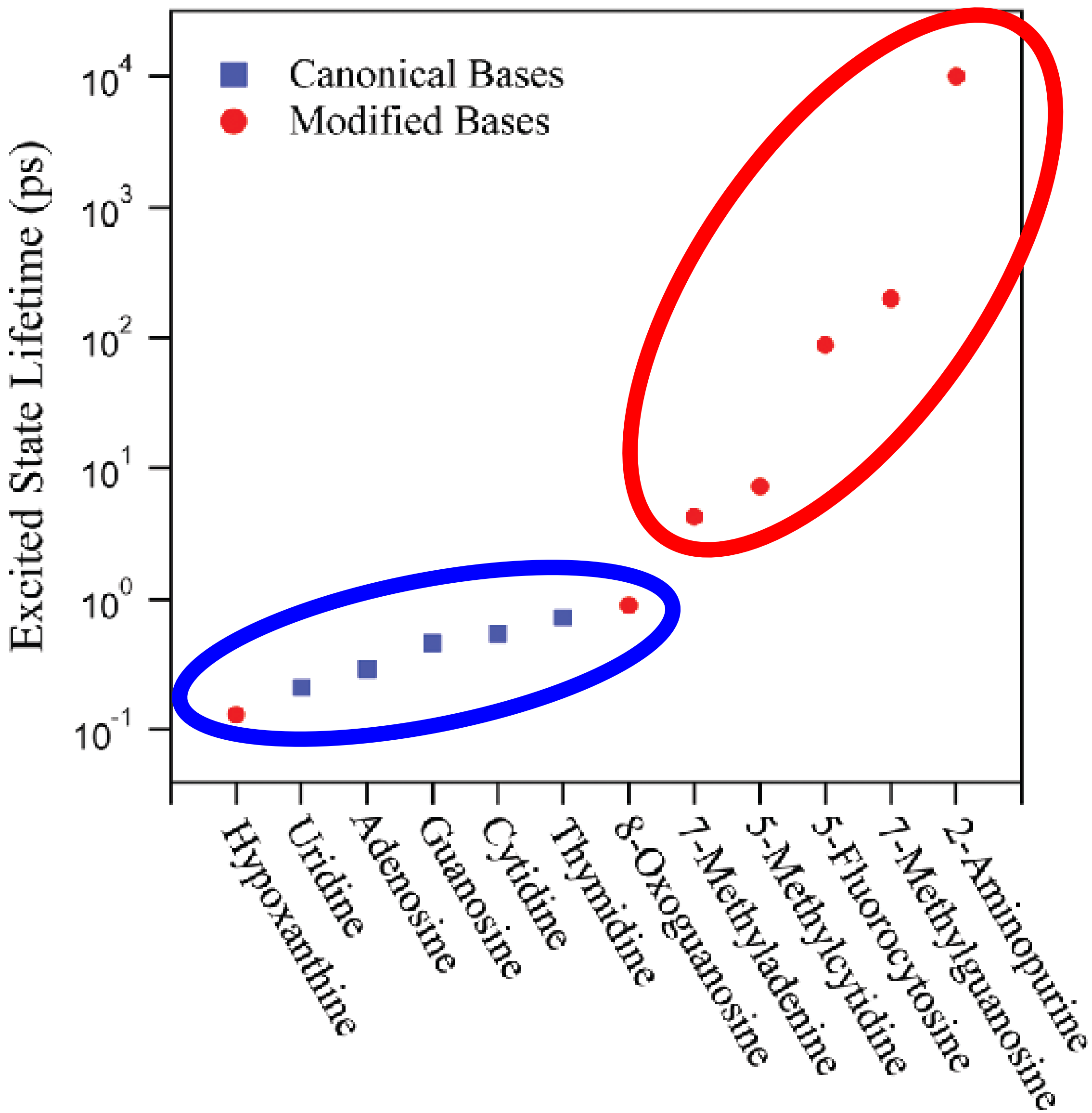




Protocells in a population enable RNA strands to "explore" sequence space.

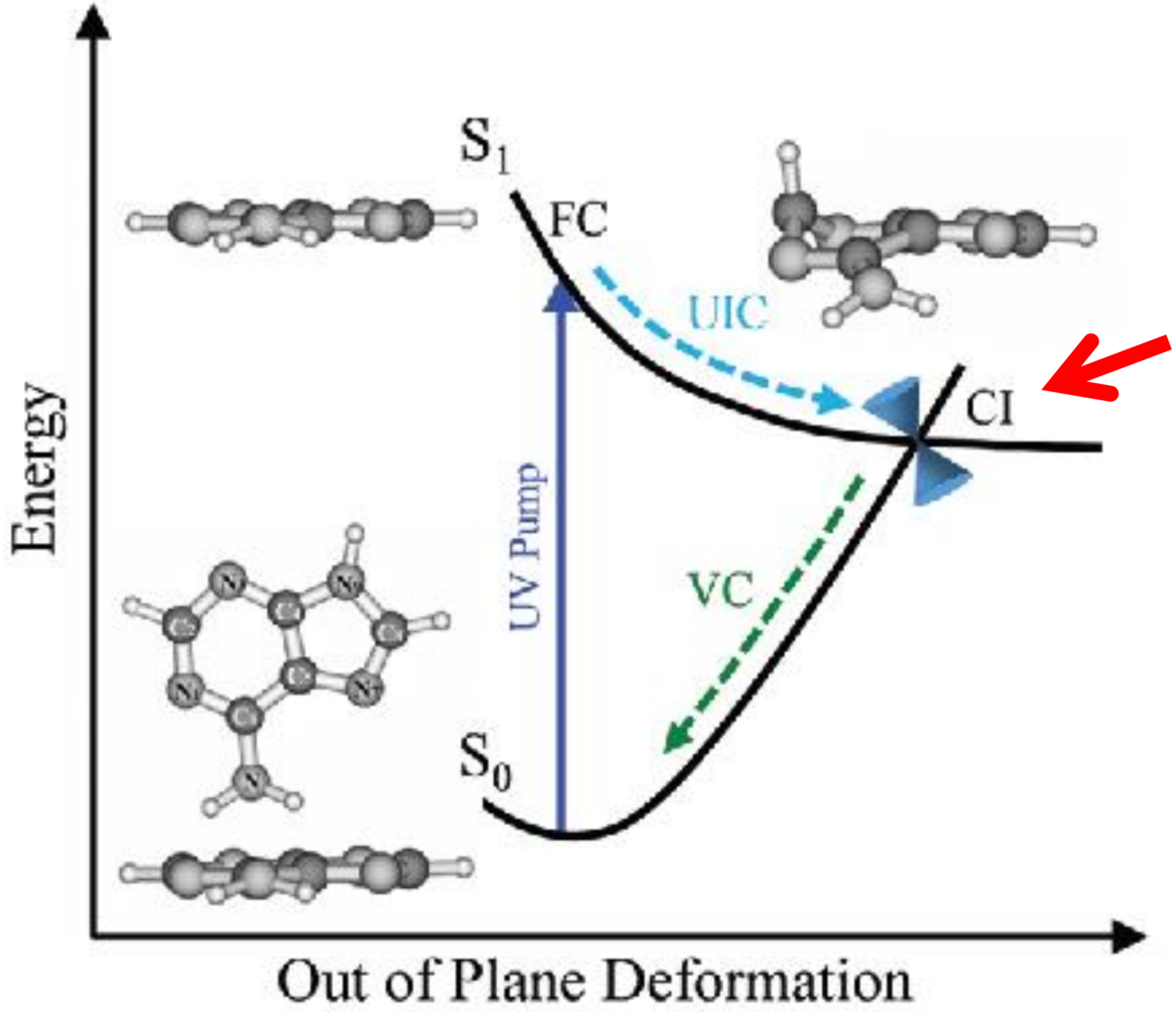
The protocells need to "live off the land", until becoming self-sufficient.

The canonical RNA/DNA bases are the most UV photostable isomers of the synthesis

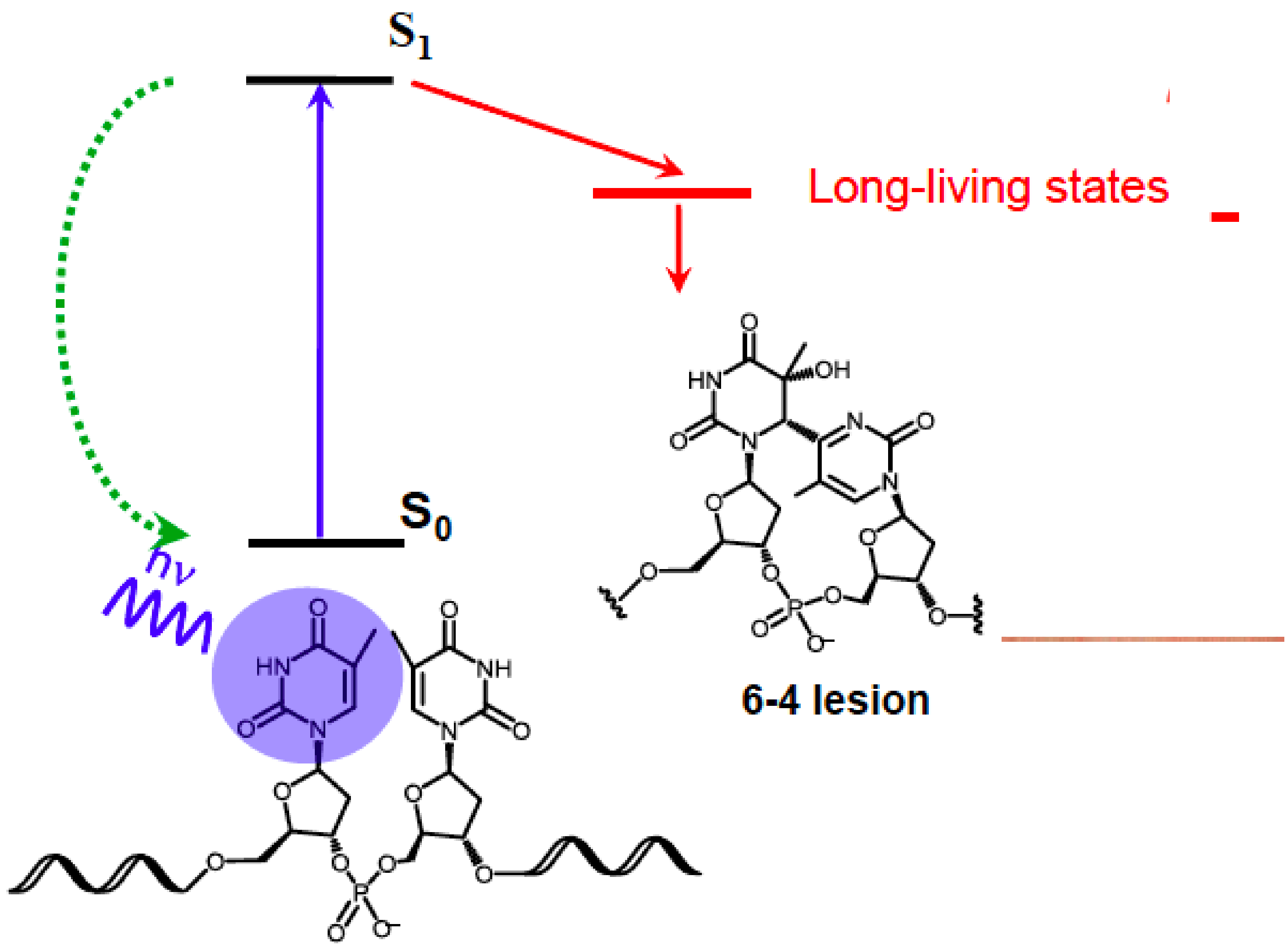


Beckstead et al. (2016)

The reason - Non-radiative deactivation:
ultrafast internal conversion
via a conical intersection



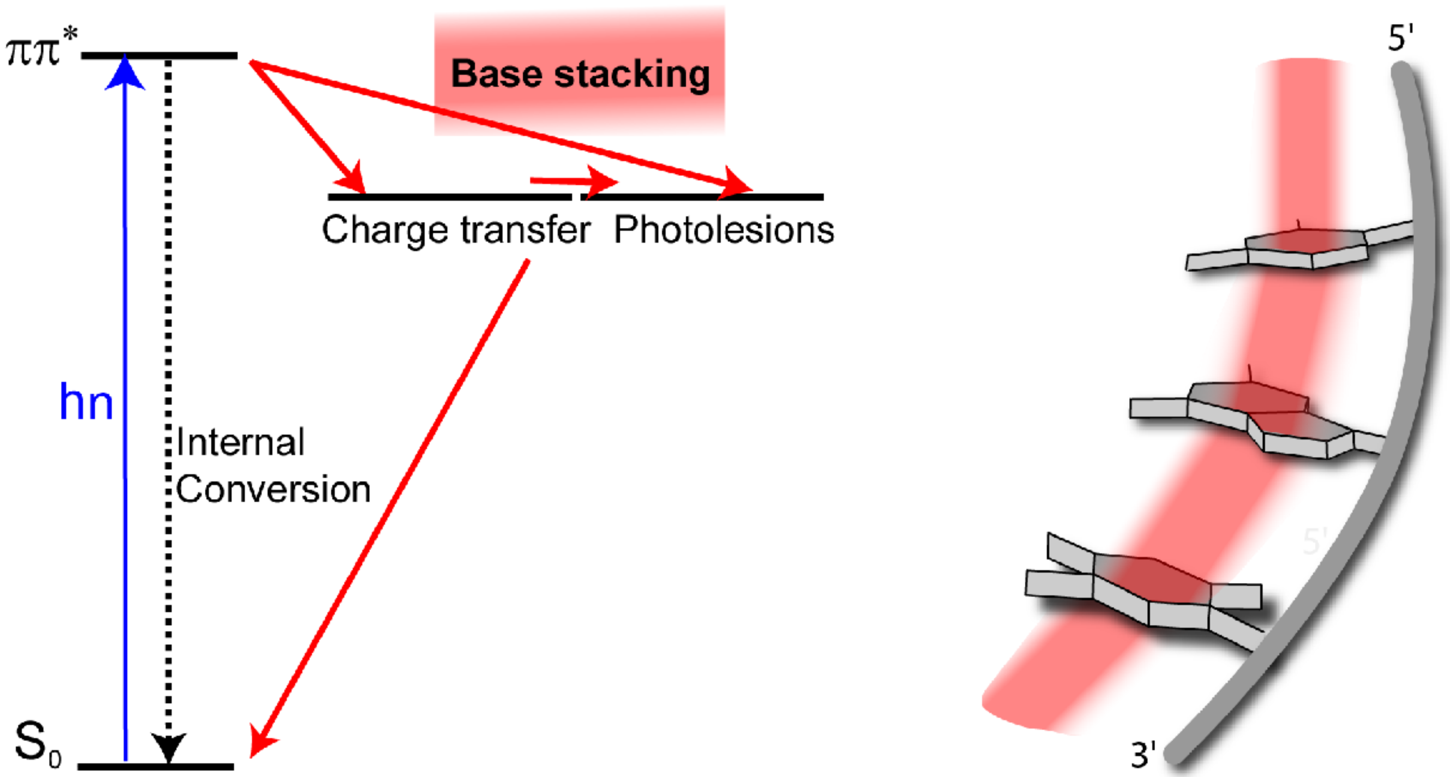
Beckstead et al. (2016)



Excited states of DNA strands decay to long-living damaging states!
e.g., cause for skin cancer.

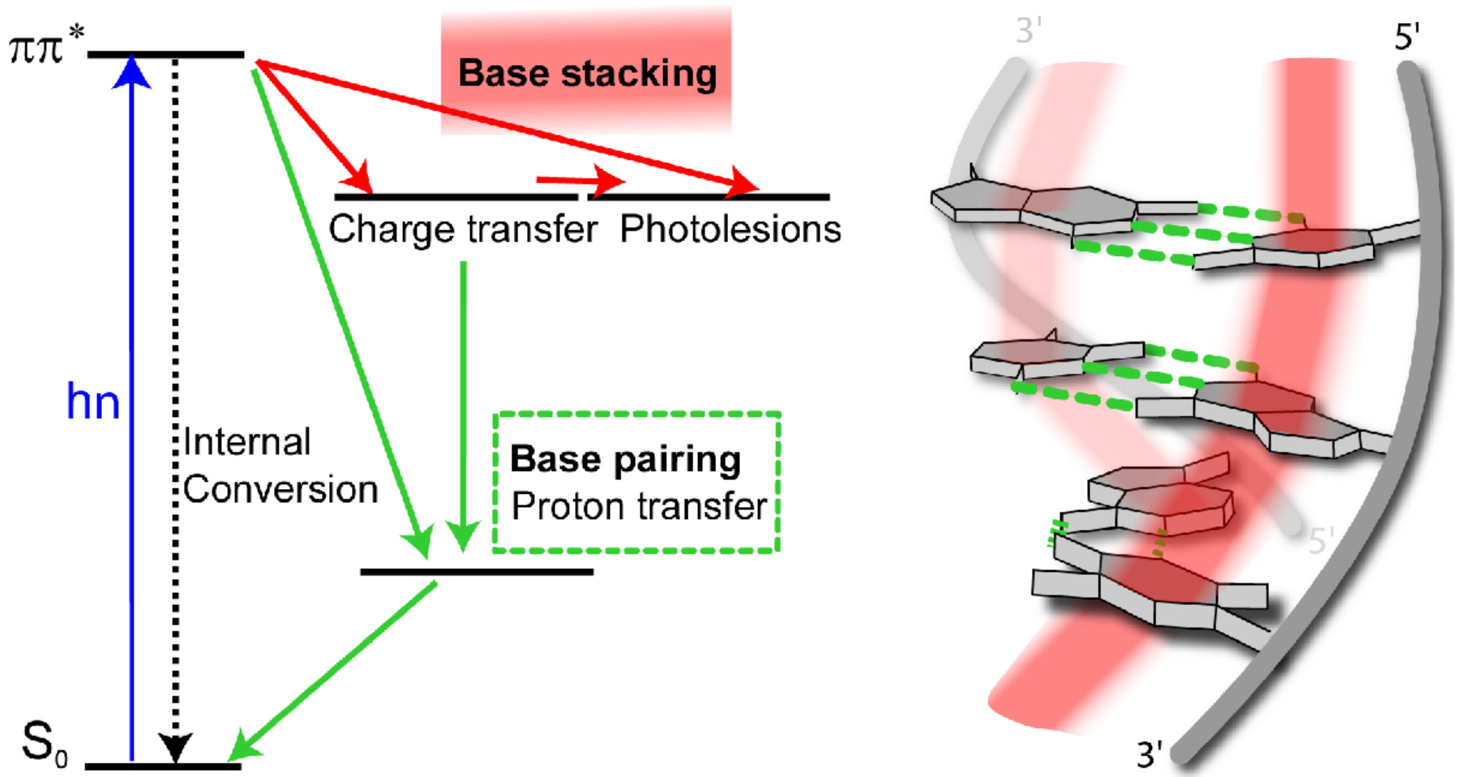
Bucher (2014)

Base-staking Enables Oligomer Damage



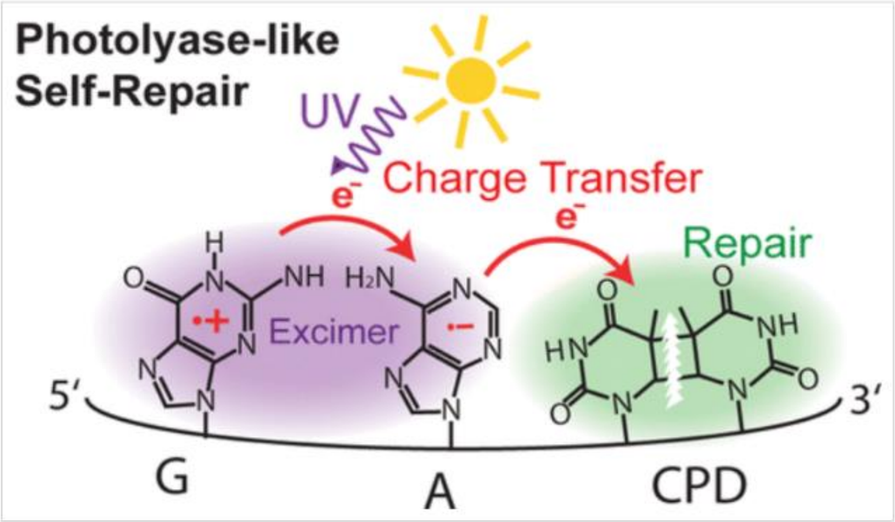
Bucher et al. (2014)

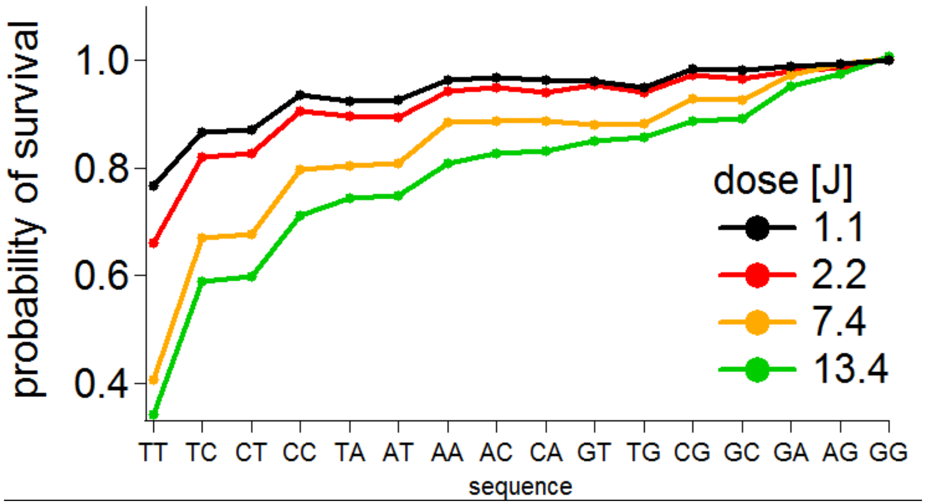
…but Base-*pairing* remedies that!



Bucher et al. (2014); Bucher, Kufner et al. (2016)

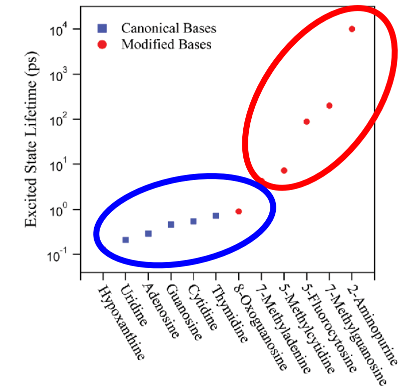
Certain sequences self-repair better & survive longer





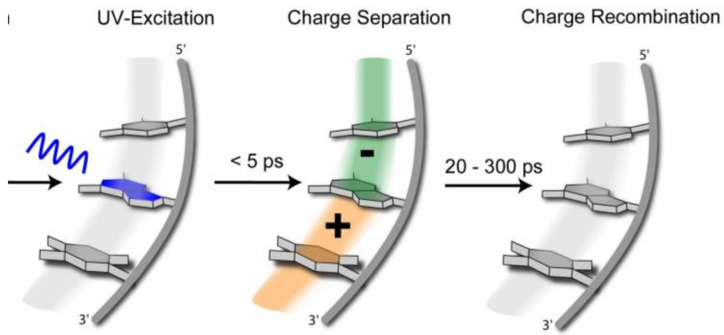
Kufner et al. (2020)

UV sculpts the molecular inventory ?



1) By selecting only UV-stable ones

- We can screen ~200 isomers & by-products of the cyanosulfidic prebiotic chemistry



2) By selecting oligomers with UV-induced self-repair properties

SUMMARY

1. Stellar UV light is commonly cut off at 204 nm on the surfaces of rocky planets (mainly by CO_2).

2. Planet surface UV fluxes in this 4 - 6 eV range are uniquely suited to enact **both** the *synthesis* & the *selectivity* of the nucleotides, and a few amino acids. The canonical monomers also happen to be the most UV photostable isomers.

3. The oligomers appear to be selected by their ability to **self-repair** UVC damage by UV excitation – a photolyase-like mechanism.

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