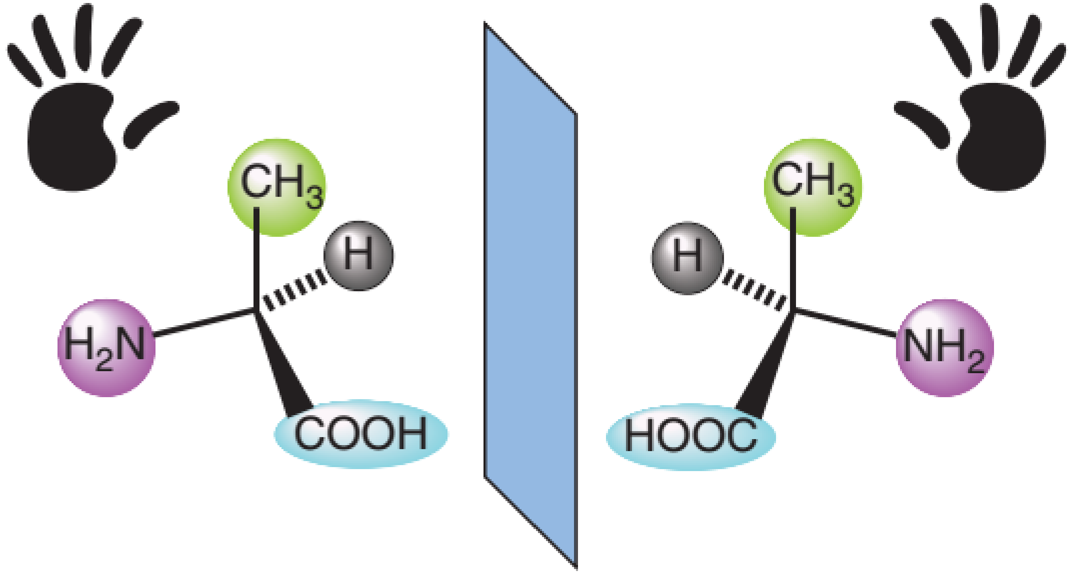
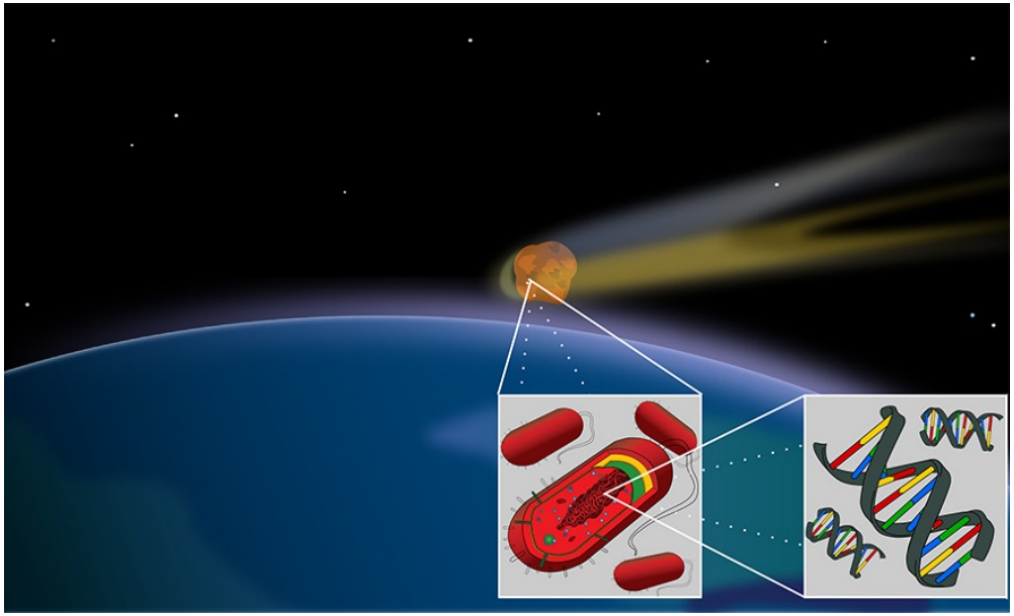
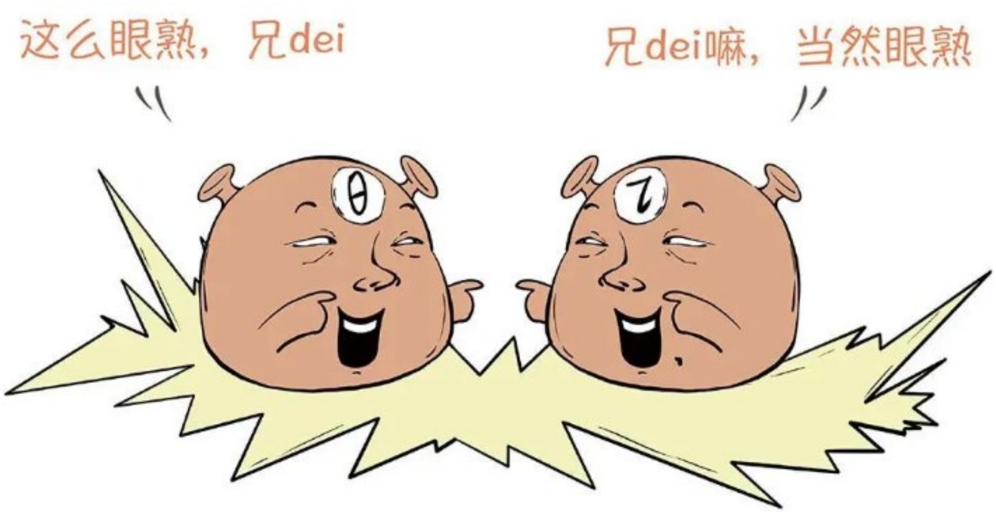
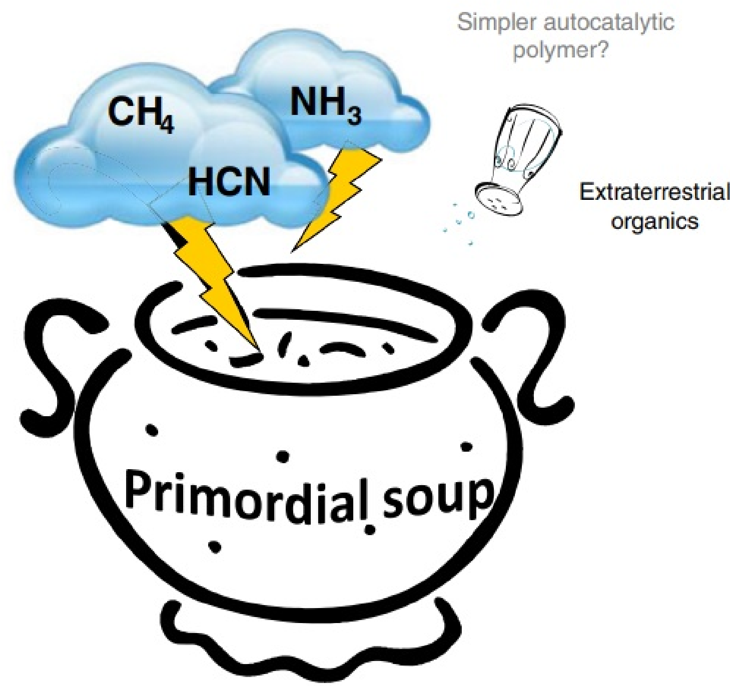
The Origin of Biological Homochirality



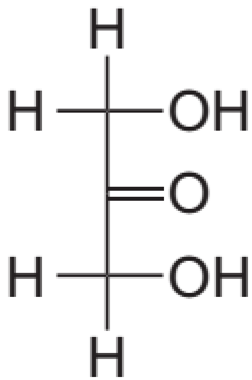
Origin of Life Hypothesis



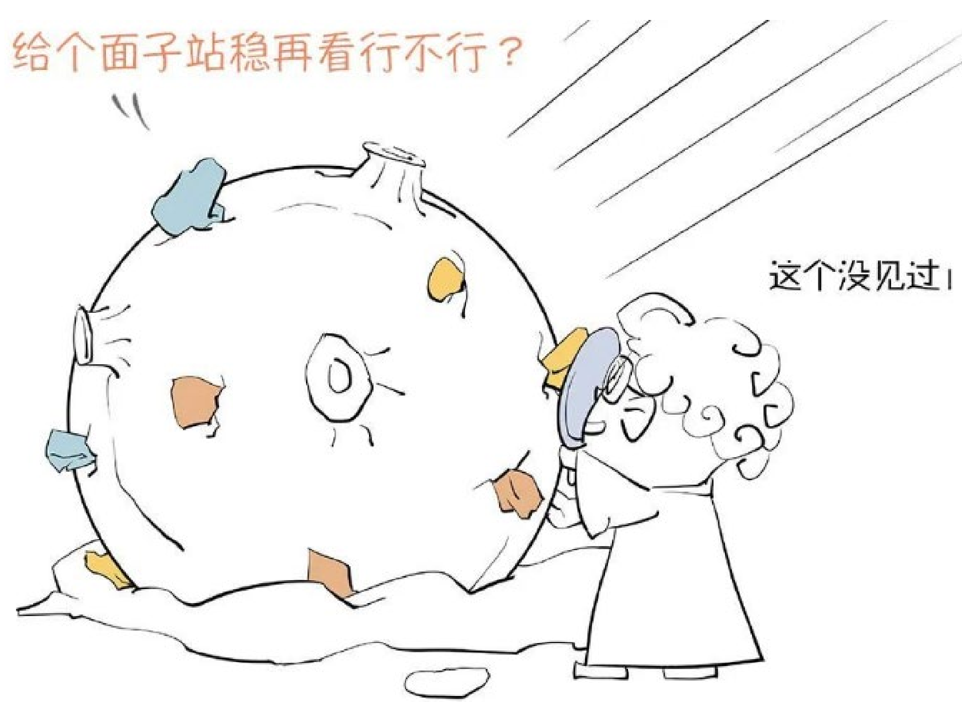


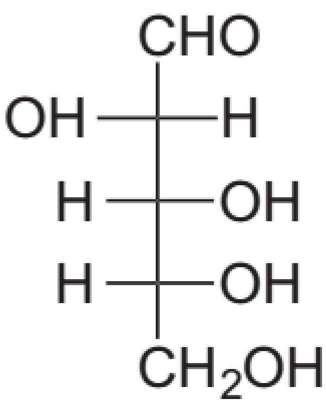


Panspermia Hypothesis

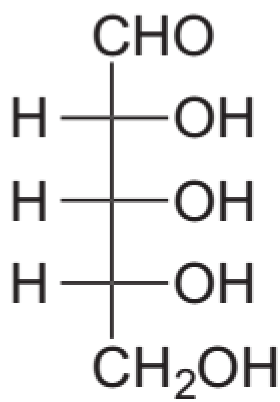


Dihydroxyacetone

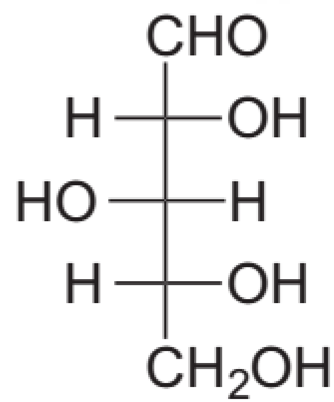




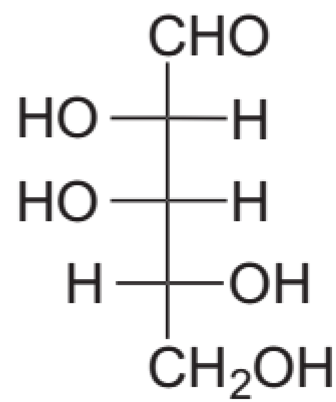
D-arabinose



D-ribose



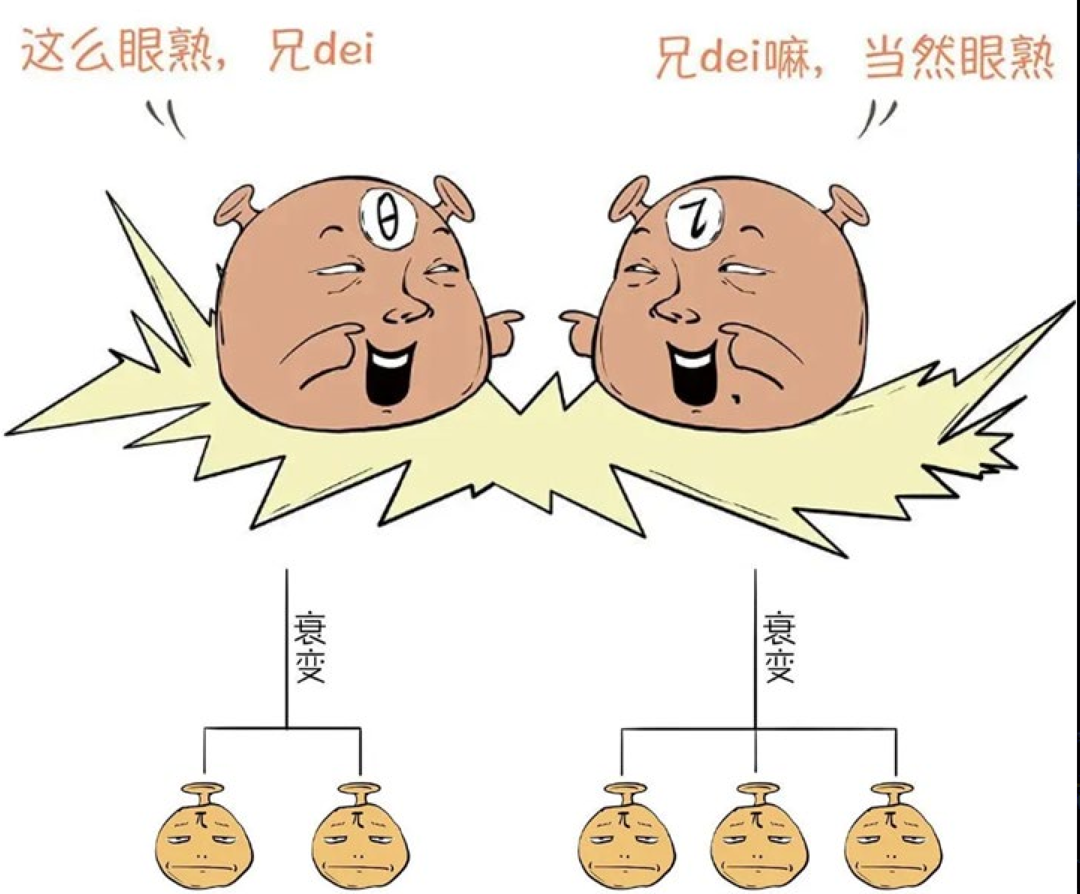
D-xylose

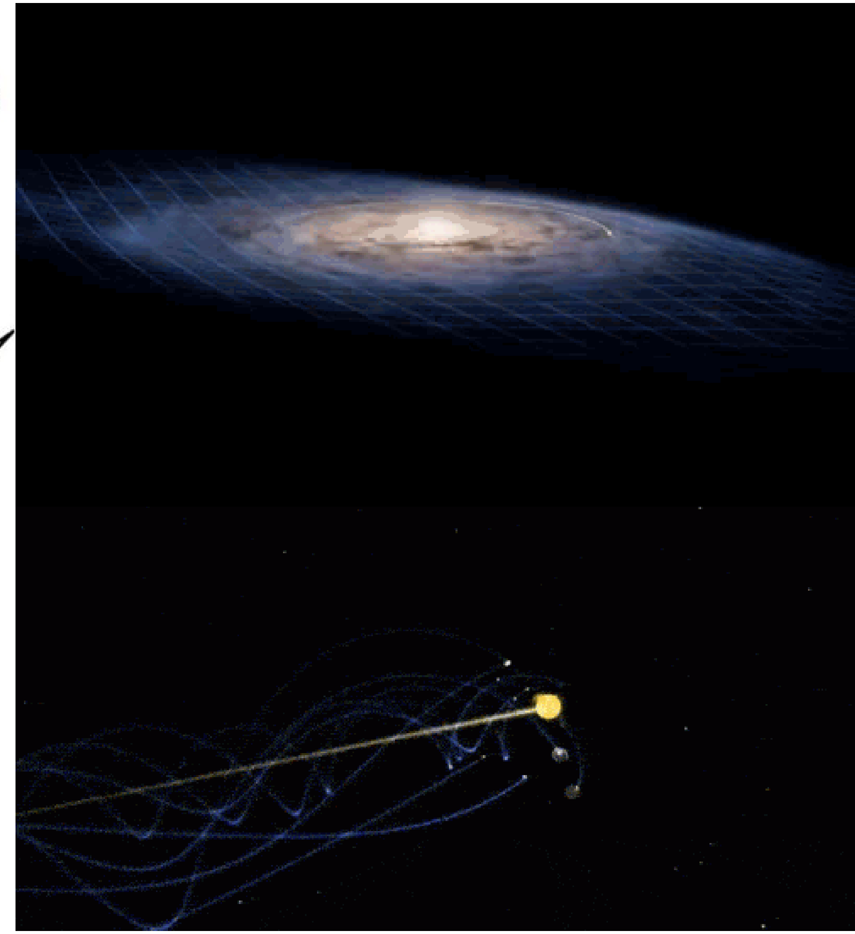


D-lyxose

PNAS , 2019, 116, 24440

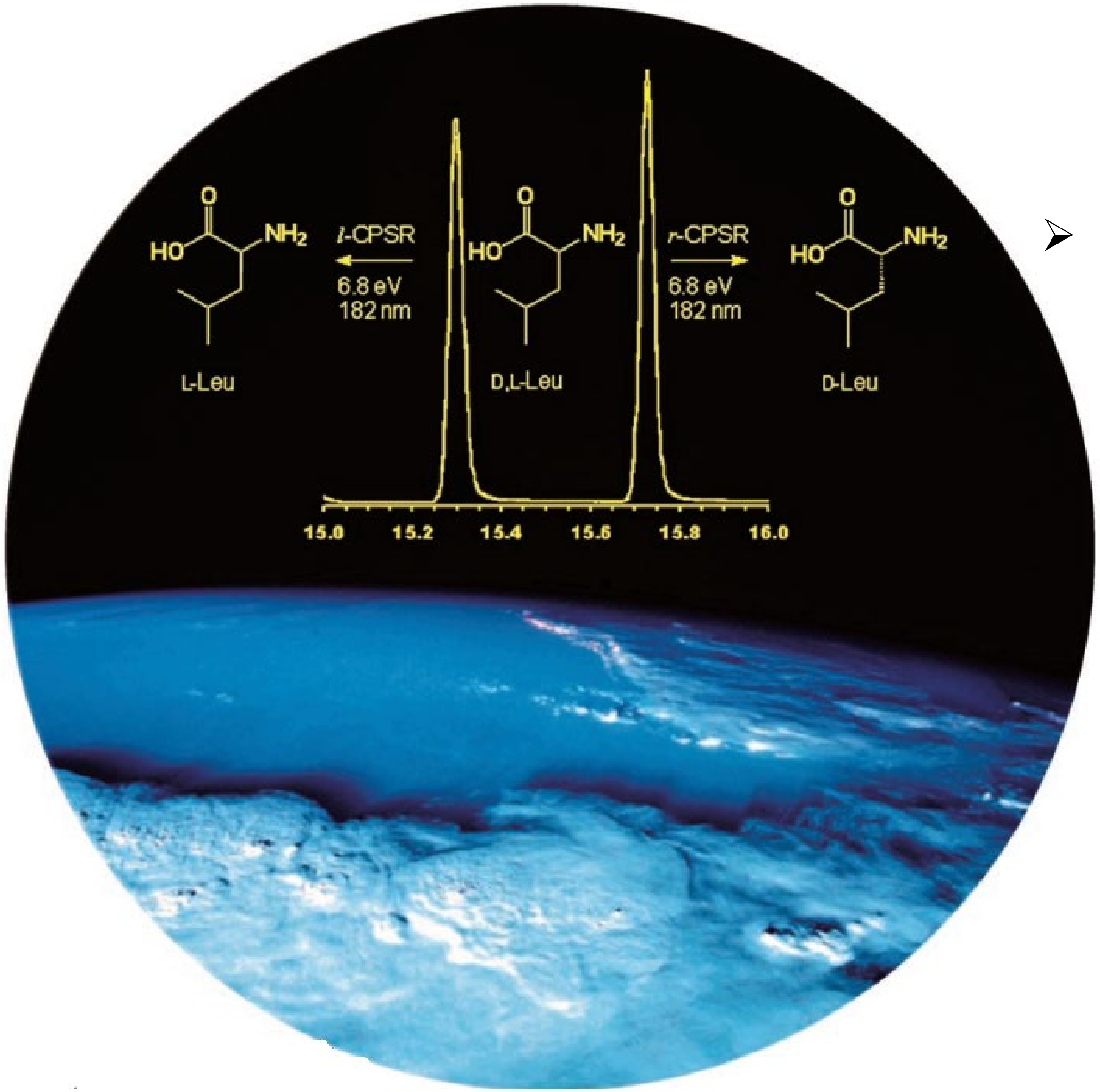
Parity Violation





1. Cosmic dust particles to polarize starlight as circularly polarized in one direction only.
2. The weak nuclear force (radioactive decay) is chiral. During beta decay, the emitted electrons preferentially favor one kind of spin.

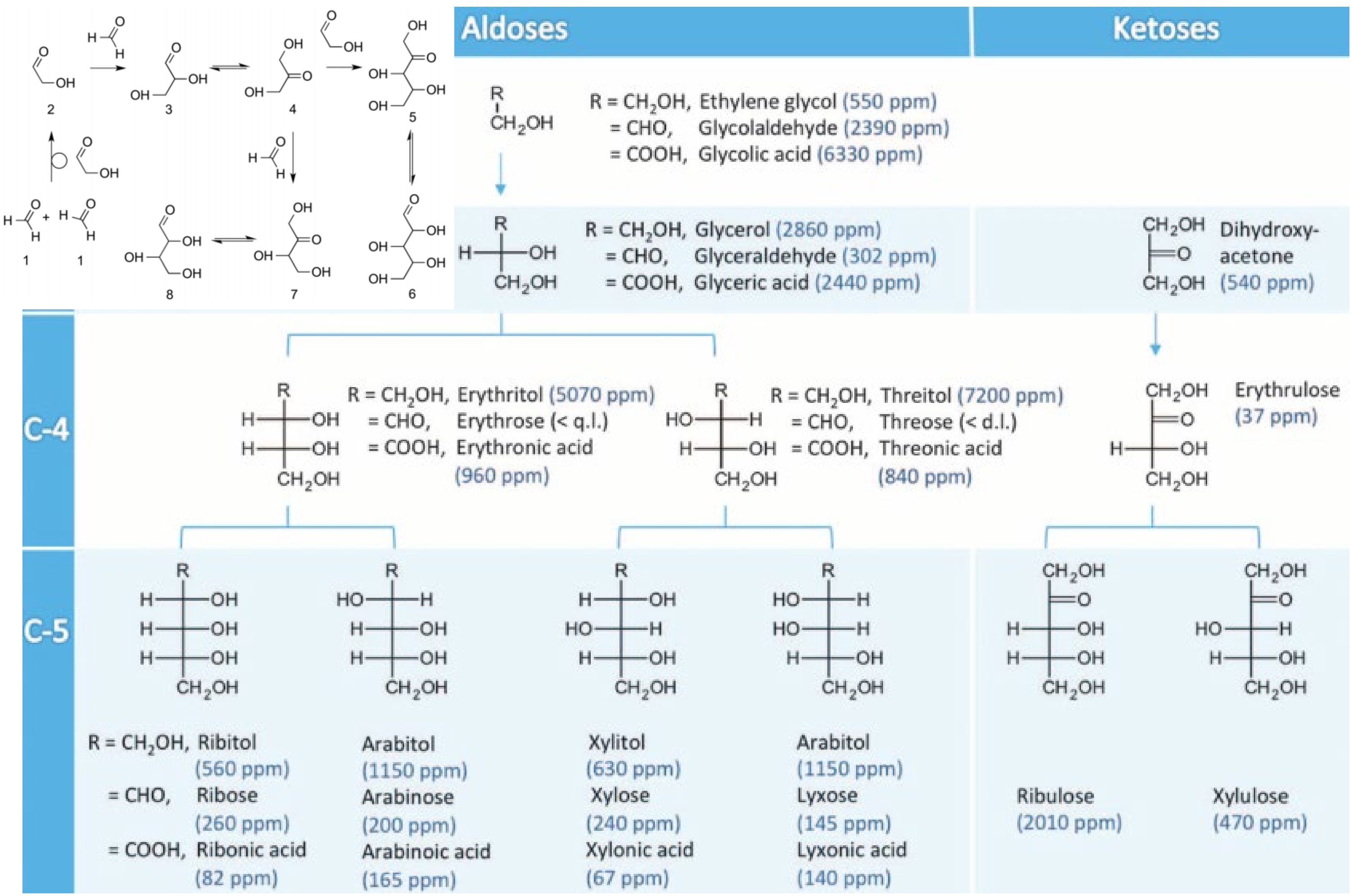
Panspermia Hypothesis-Parity Violation



- This circularly polarized light degrades D- amino acids more than L enantiomers, and this effect is clear when analyzing the amino acids found on comets and meteors.

Angew. Chem. Int. Ed. 2005, 44, 5630

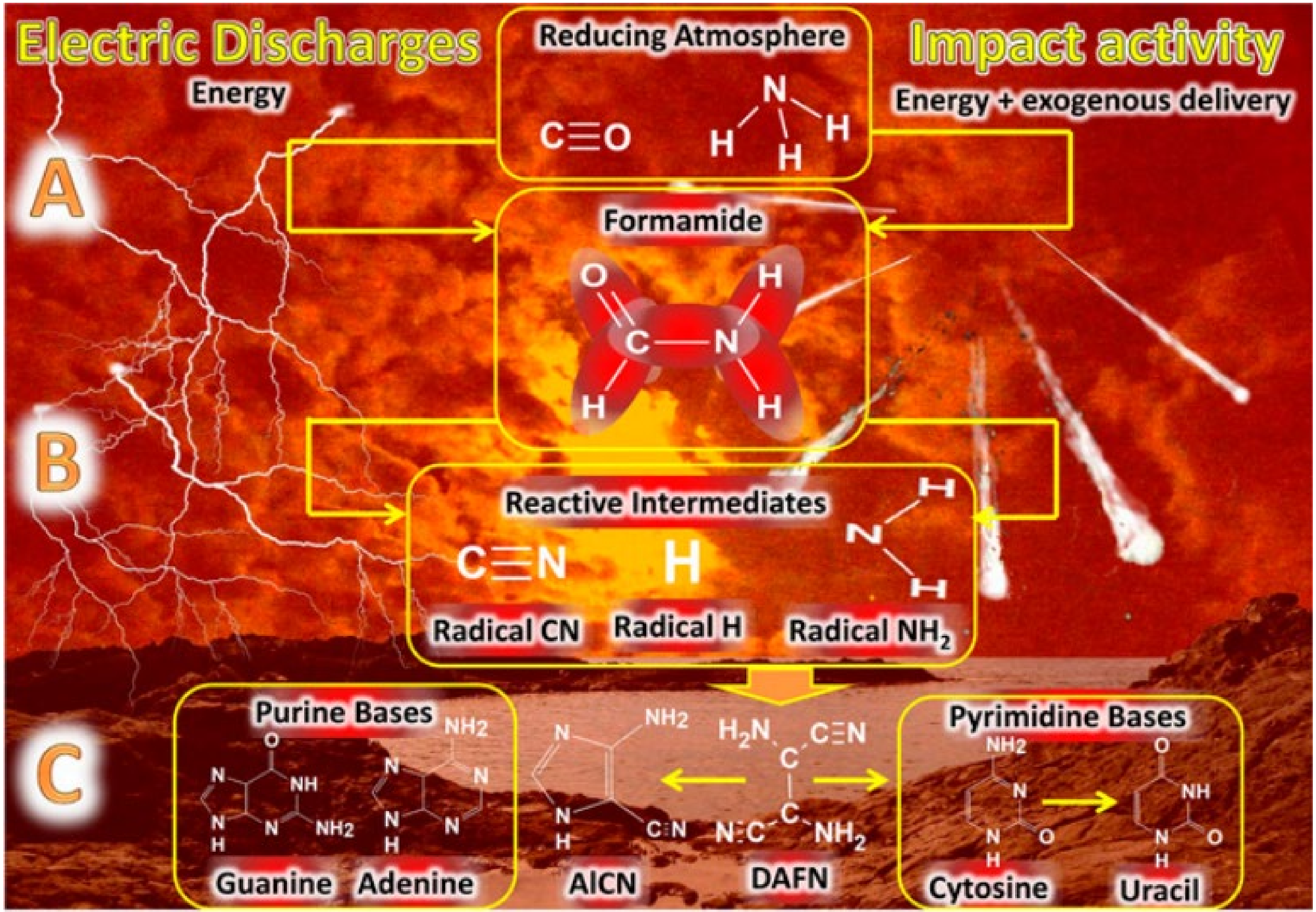
Parity Violation



Nature, 2002, 416, 401

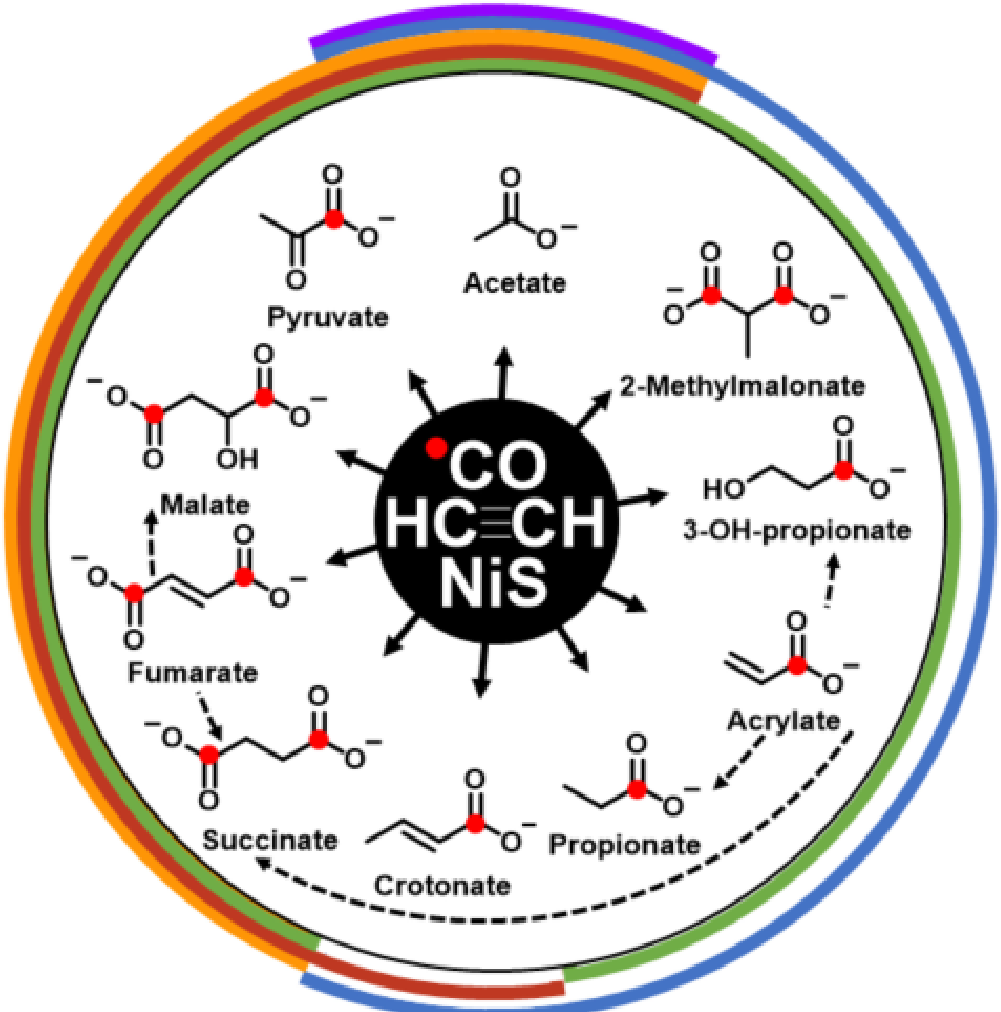
Science. 2016, 352, 208

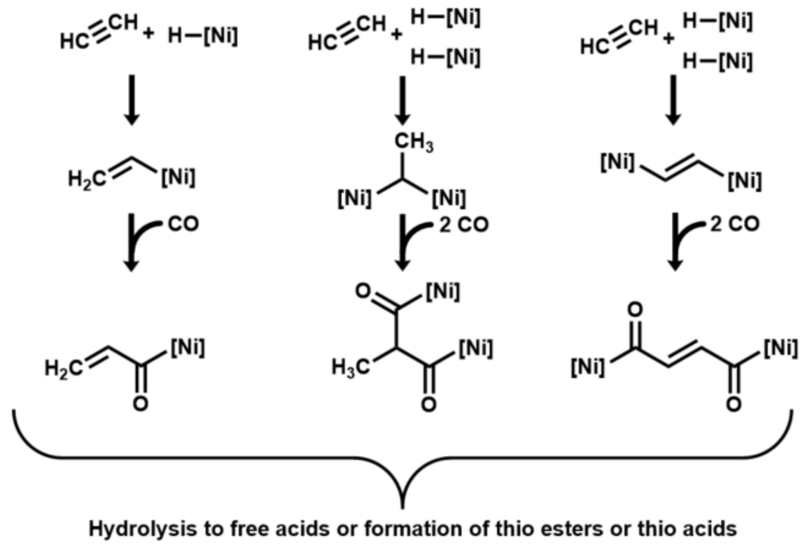
Prebiotic soup



PNAS , 2017, 114, 4306

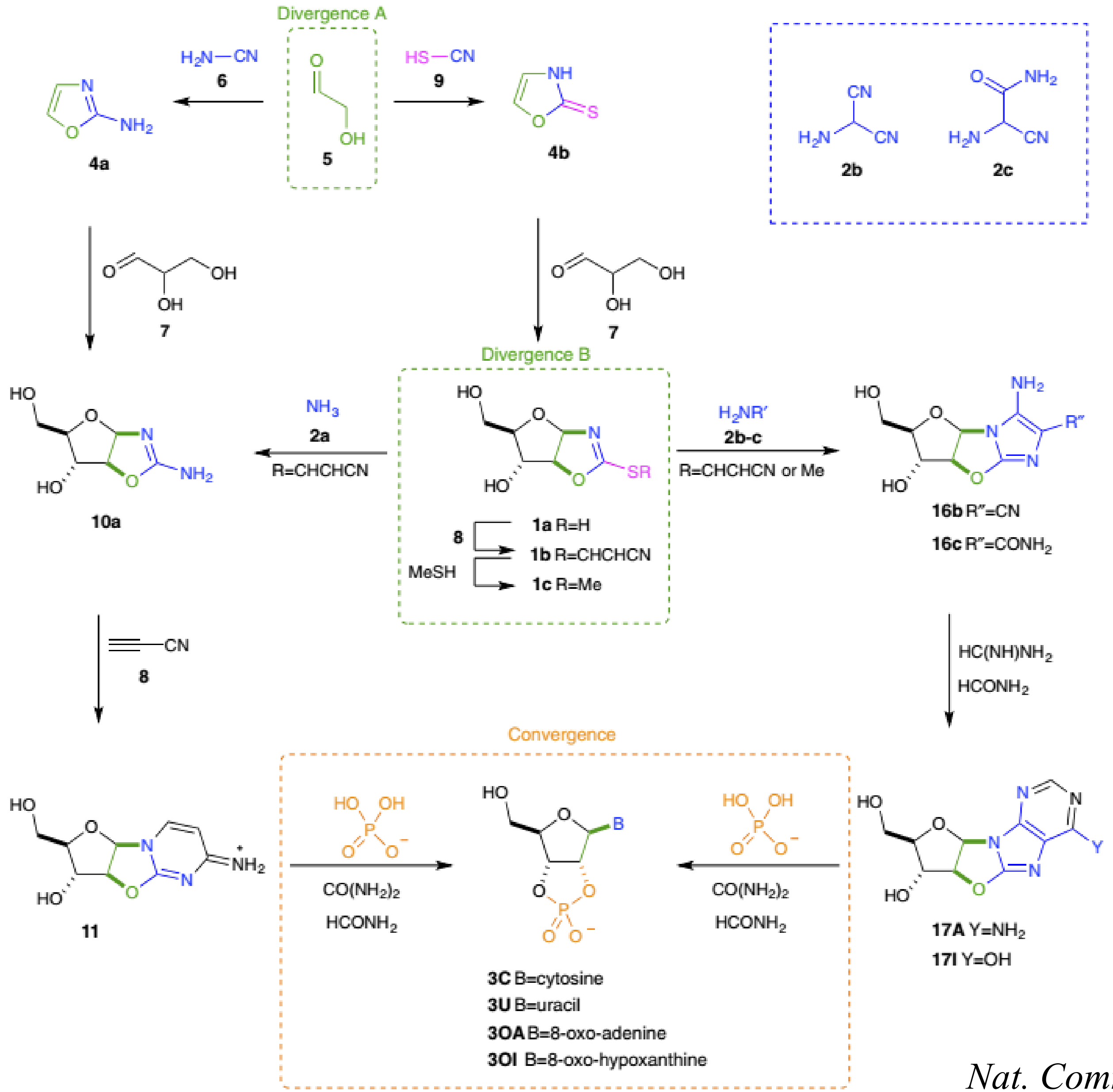
Prebiotic soup





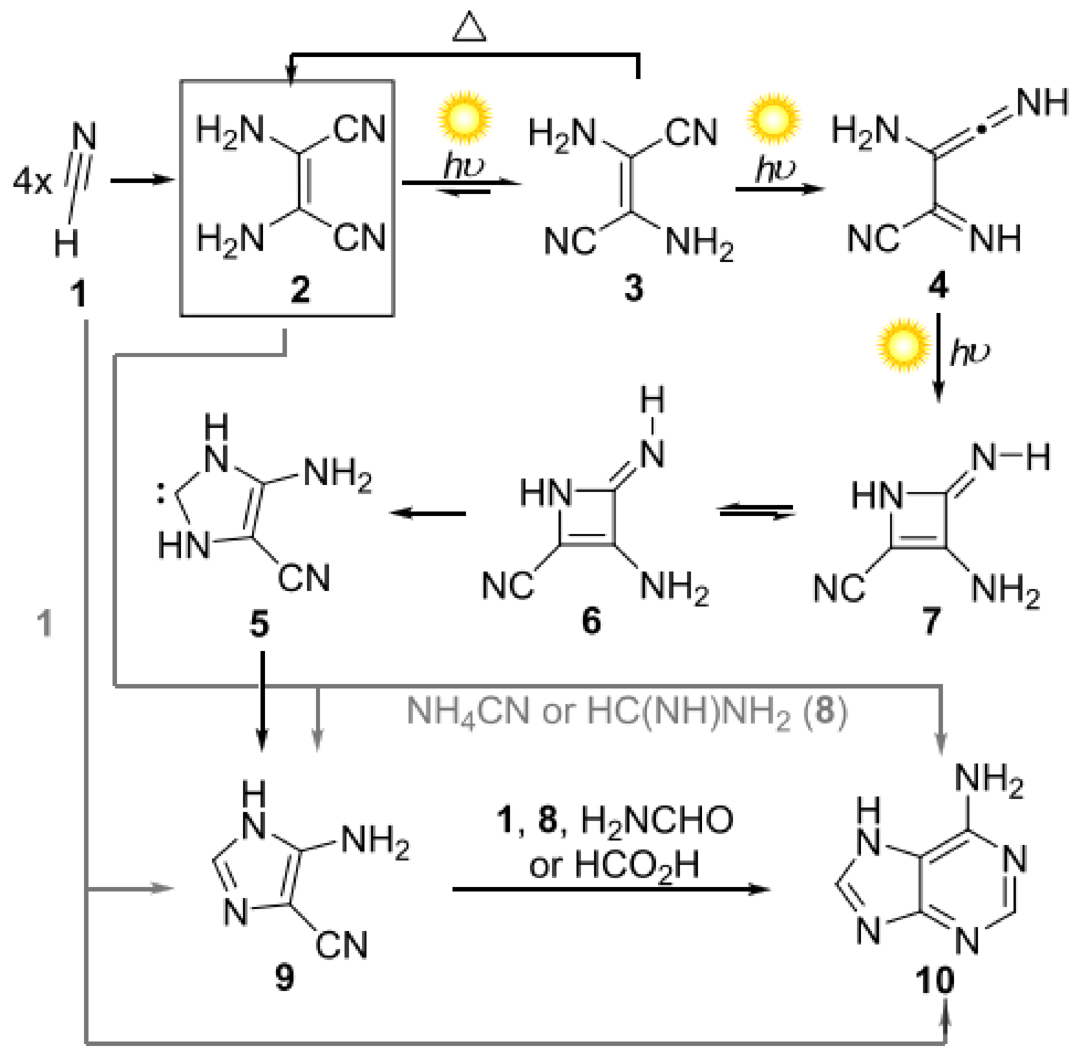
Life 2020, 10, 35

Prebiotic soup



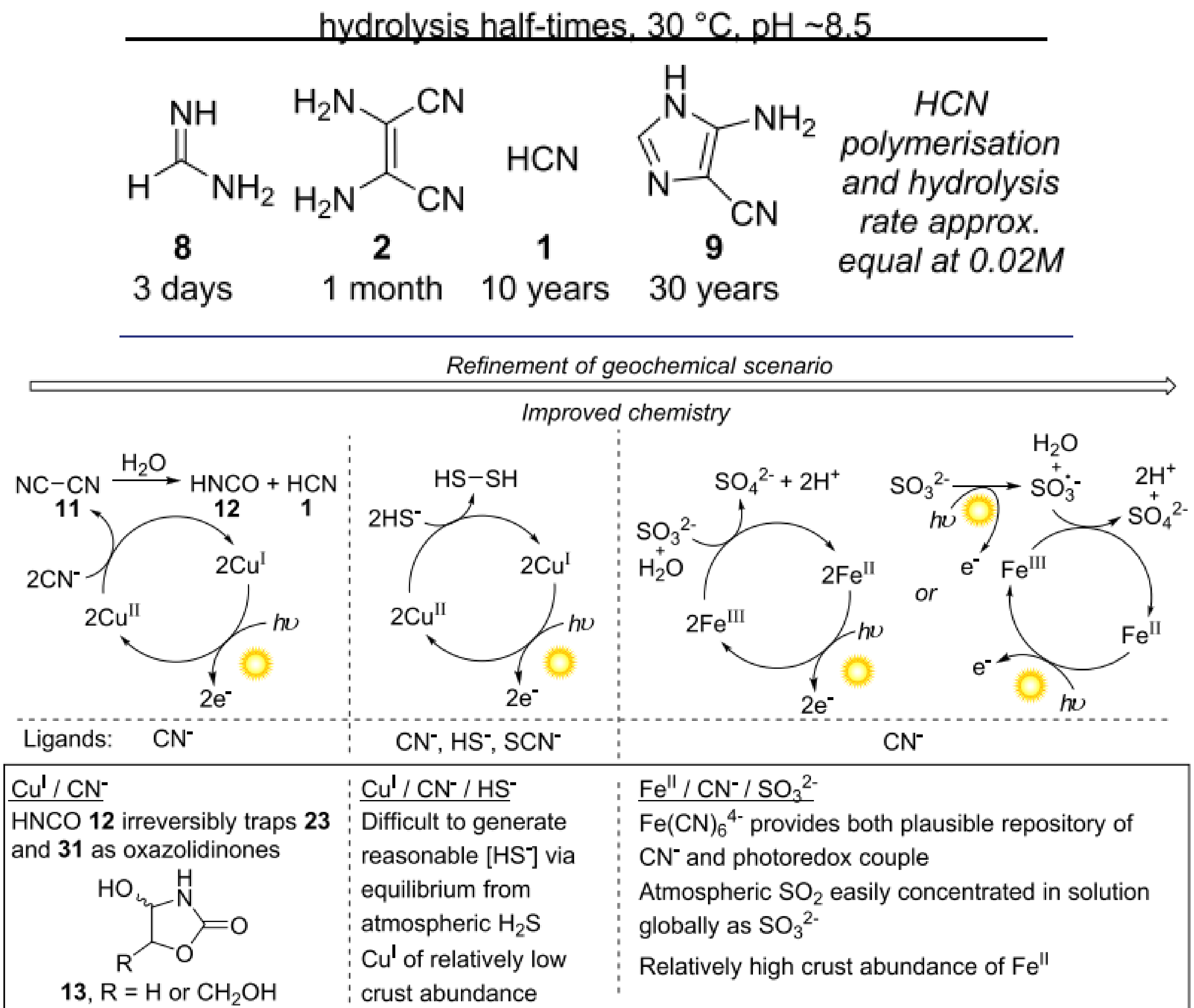
Nat. Commun. 2017, 8, 15270.

Prebiotic soup

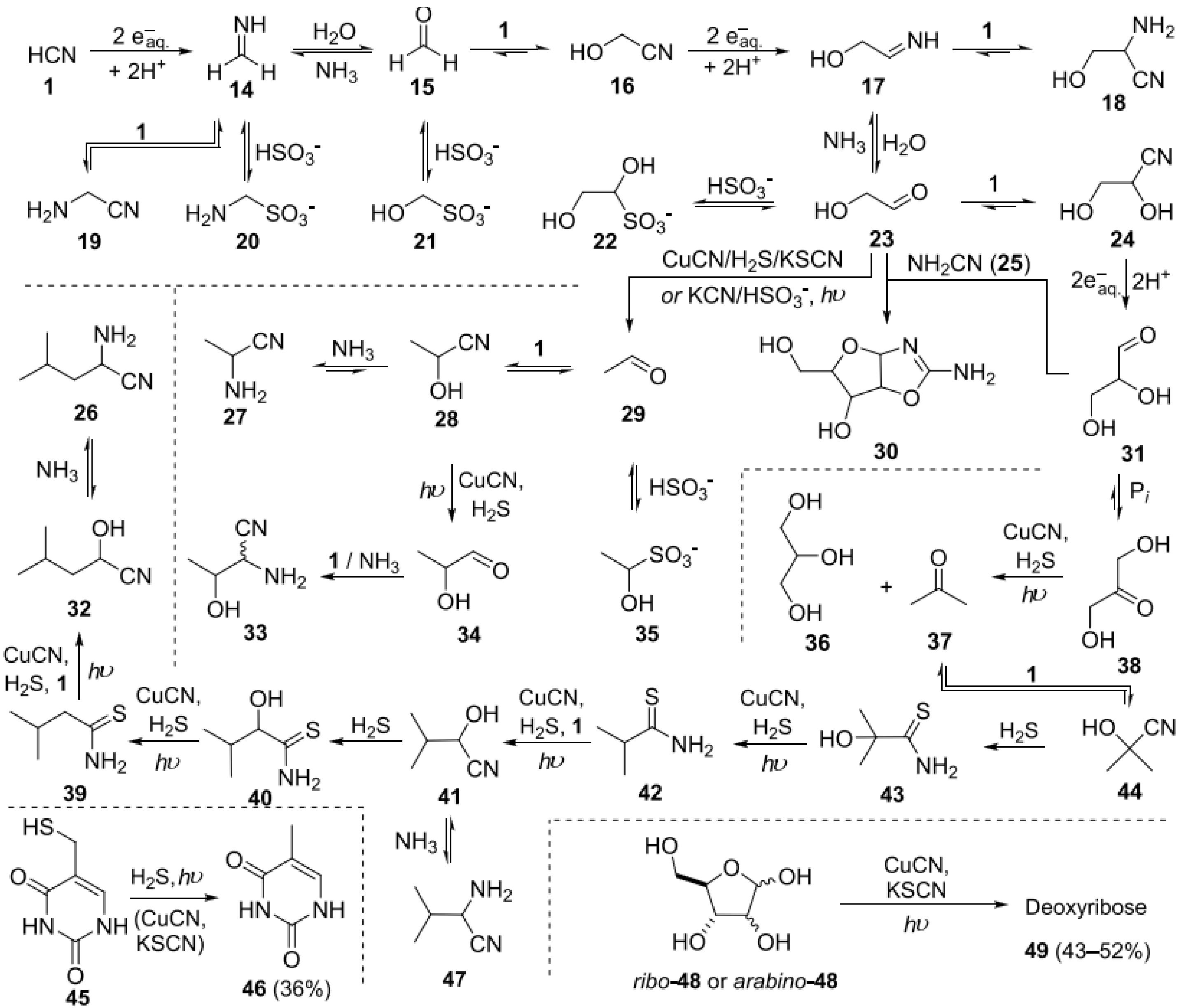


J. Am. Chem. Soc. 2021, 143, 7219

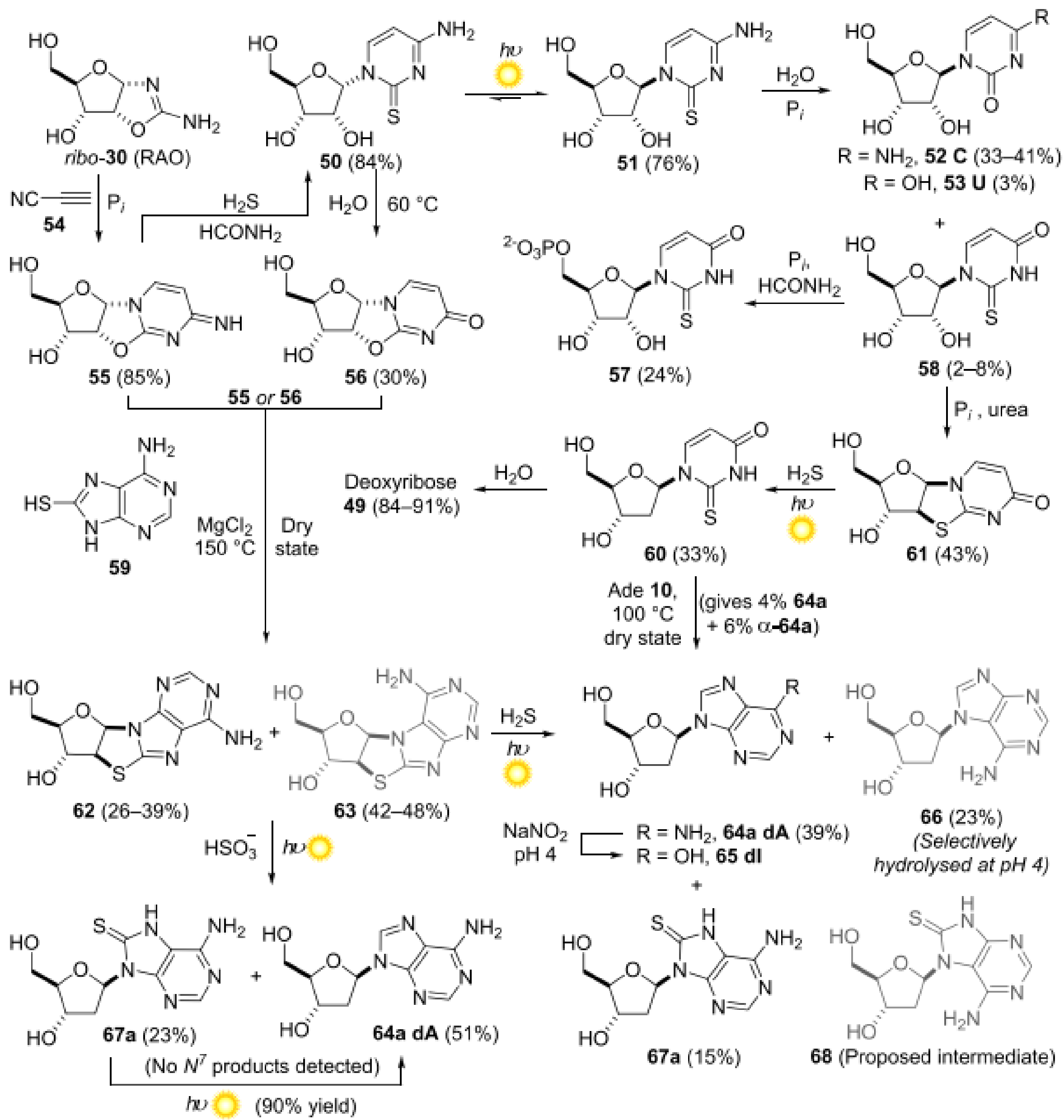
Prebiotic soup



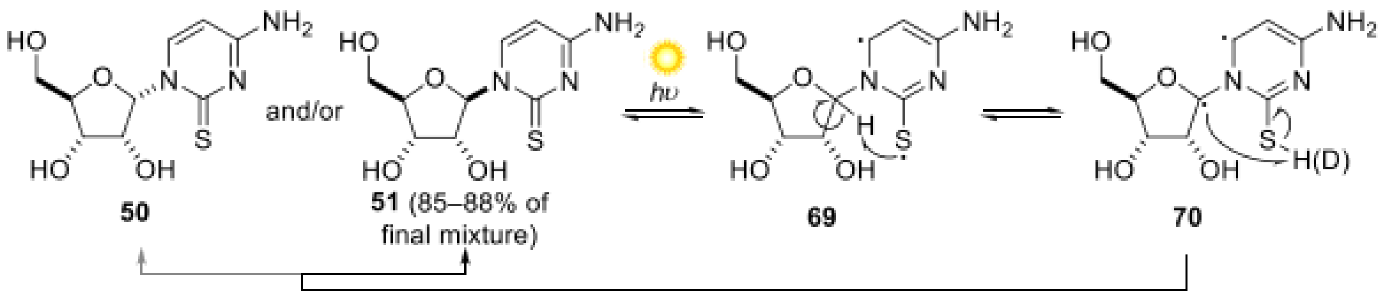
Prebiotic soup

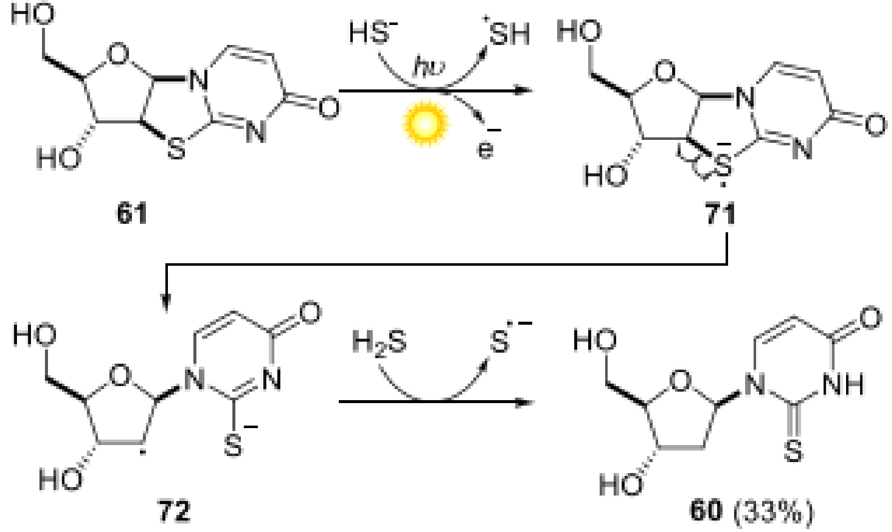


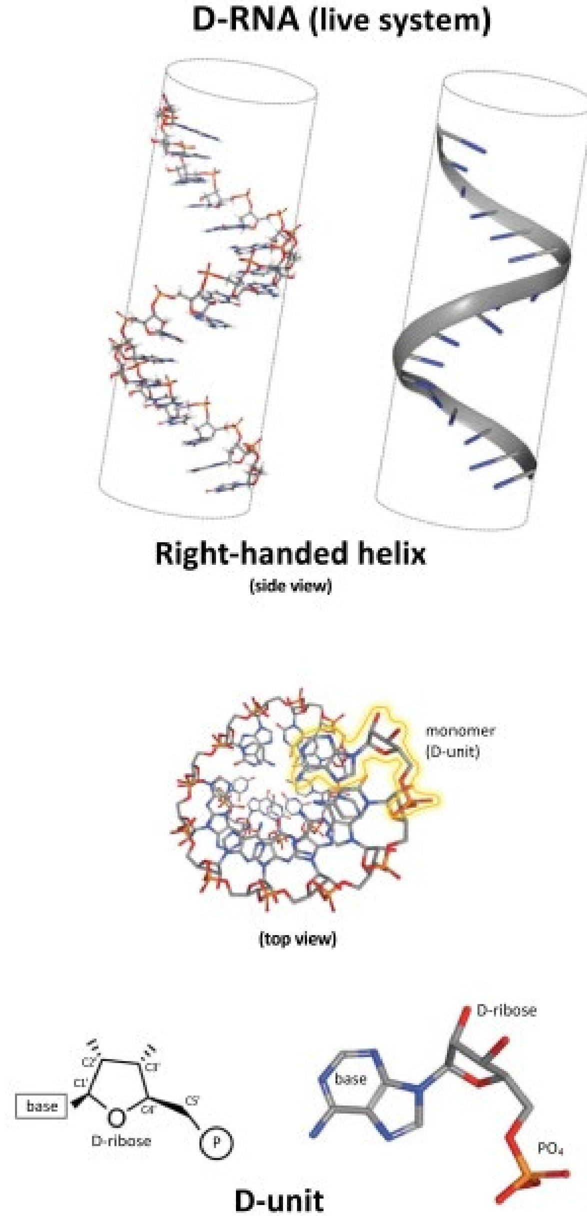
Prebiotic soup

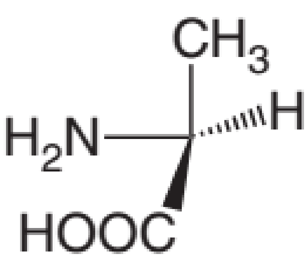


Prebiotic soup

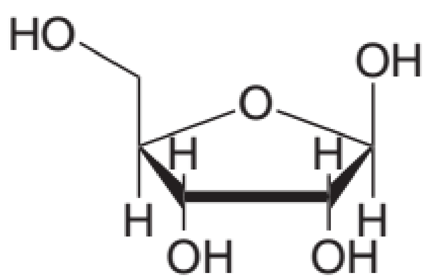




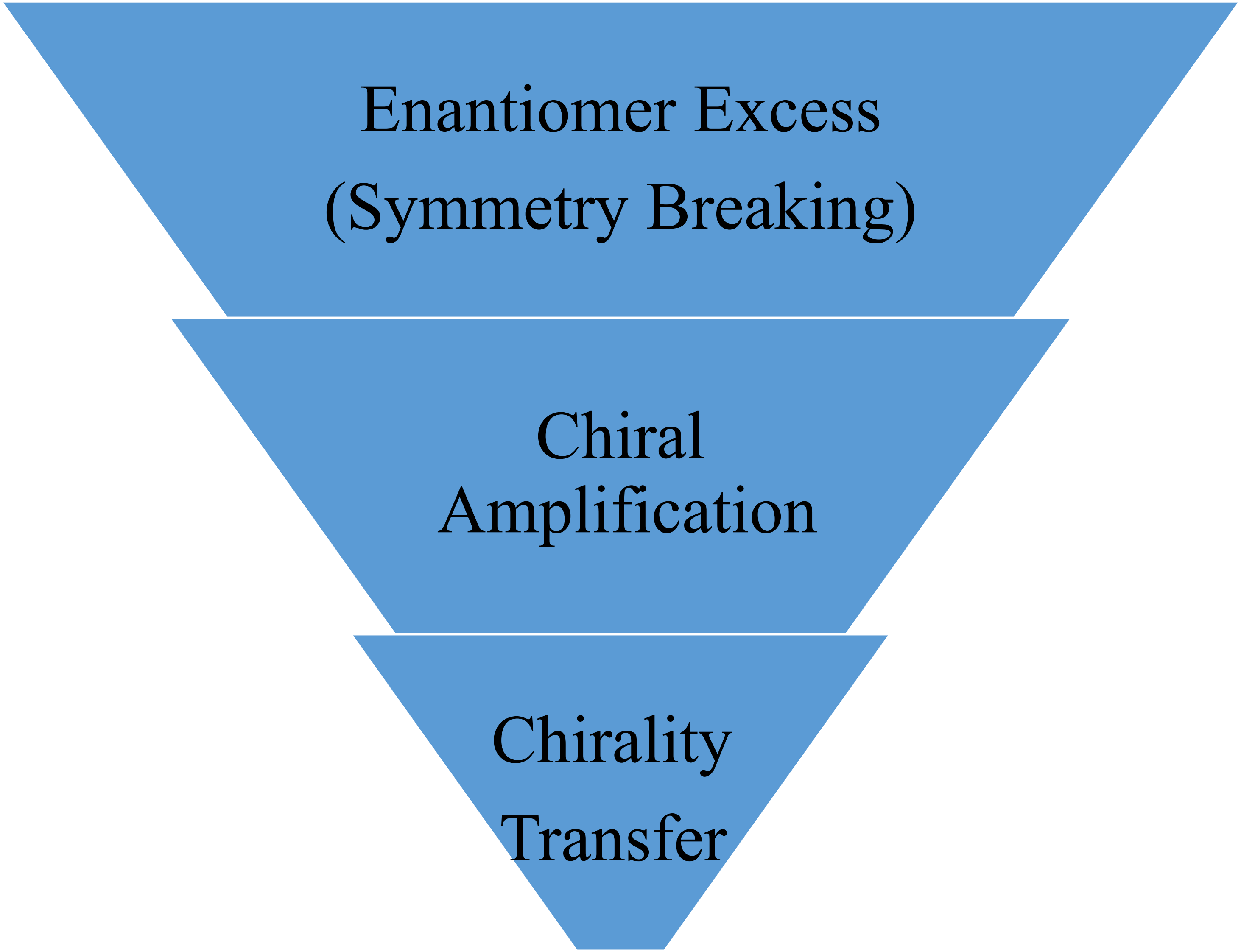




L-amino acids



D-amino acids



Symmetry, **2021**, *13*,2277
Cold Spring Harb Perspect Biol 2019;11:a032540

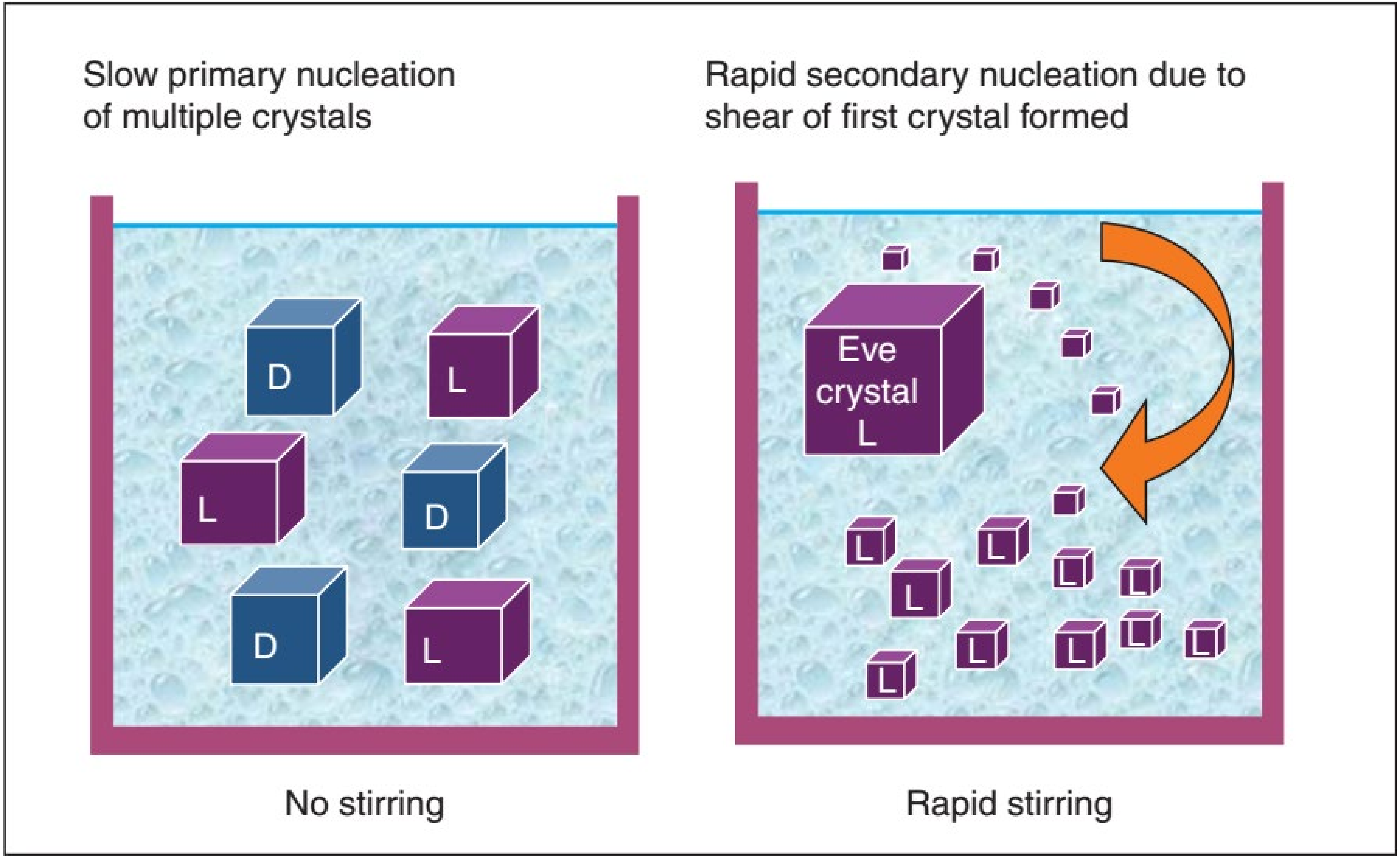
Symmetry Breaking

Enantiomeric excesses in amino acids from the Murchison and Murray meteorites.

	Sample				Standard					
Amino acid	L (%)	σ	n	ee (%)	L (%)	σ	n	ee (%)	Confidence (%)	Corrected ee (%)
Murray meteorite										
2-Amino-2,3-dimethyl-pentanoic acid										
2*S*,3*S*/2*R*,3*R*	50.6	0.7	12	1.2	50.1	0.6	16	0.2	>95	1.0
2*S*,3*R*/2*R*,3*S*	51.0	0.6	12	2.0	49.9	0.6	17	−0.2	>99	2.2
Isovaline	53.6	0.4	20	7.2	50.6	0.3	24	1.2	>99.9	6.0
α-Methylnorvaline	51.1	0.3	23	2.2	50.4	0.3	30	0.8	>99.9	1.4
α-Methylvaline	51.1	0.8	21	2.2	50.6	0.7	17	1.2	>90	1.0
α-Methylnorleucine	51.1	0.5	18	2.2	50.2	0.6	19	0.4	>99.9	1.8
α-Amino-*n*-butyric acid	50.8	0.5	14	1.6	51.0	0.4	20	2.0	Not sig.	−0.4
Norvaline	50.9	0.5	10	1.8	50.5	0.9	17	1.0	Not sig.	0.8
Alanine	51.0	0.3	21	2.0	50.8	0.3	27	1.6	>95	0.4
Valine	50.6	0.6	14	1.2	50.8	0.4	13	1.6	Not sig.	−0.4
Murchison meteorite										
* 2-Amino-2,3-dimethyl-pentanoic acid										
2*S*,3*S*/2*R*,3*R*	52.6	0.5	5	5.2	48.8	1.9	14	−2.4	>99	7.6
2*S*,3*R*/2*R*,3*S*	54.7	0.6	5	9.4	50.1	0.8	18	0.2	>99.9	9.2
* Isovaline	54.6	0.6	8	9.2	50.4	0.6	15	0.8	>99.9	8.4
* α-Methylnorvaline	51.4	0.4	10	2.8	50.0	0.2	10	0	>99.9	2.8
α-Methylvaline	51.6	0.3	7	3.2	50.2	0.6	10	0.4	>99.9	2.8
α-Methylnorleucine	52.5	1.3	10	5.0	50.3	0.4	13	0.6	>99.9	4.4
*α-Amino-*n*-butyric acid	50.4	0.2	3	0.8	50.2	0.2	12	0.4	Not sig.	0.4
*Norvaline	50.2	0	3	0.4	50.0	0.2	10	0	Not sig.	0.4
Alanine	50.8	0.4	15	1.6	50.2	0.3	16	0.4	>99.9	1.2
Valine	51.3	0.4	12	2.6	50.2	0.2	13	0.4	>99.9	2.2

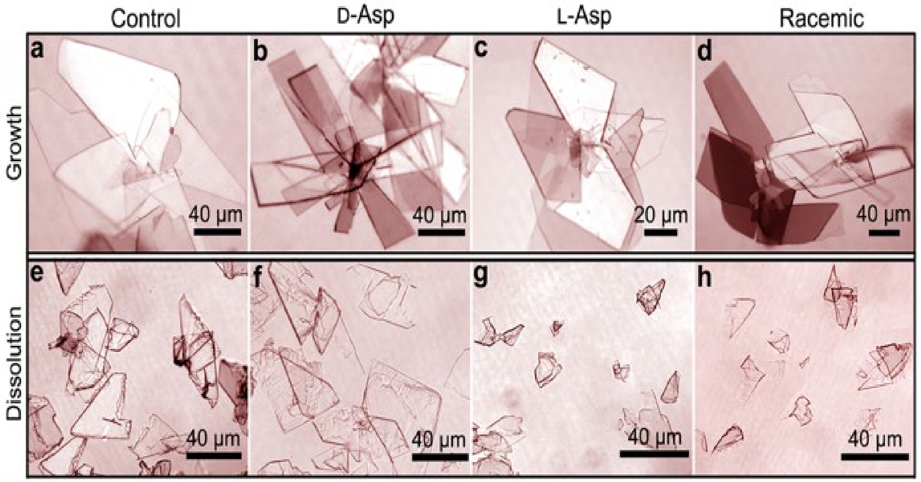
Geochimica et Cosmochimica Acta, 2000, 64, 329

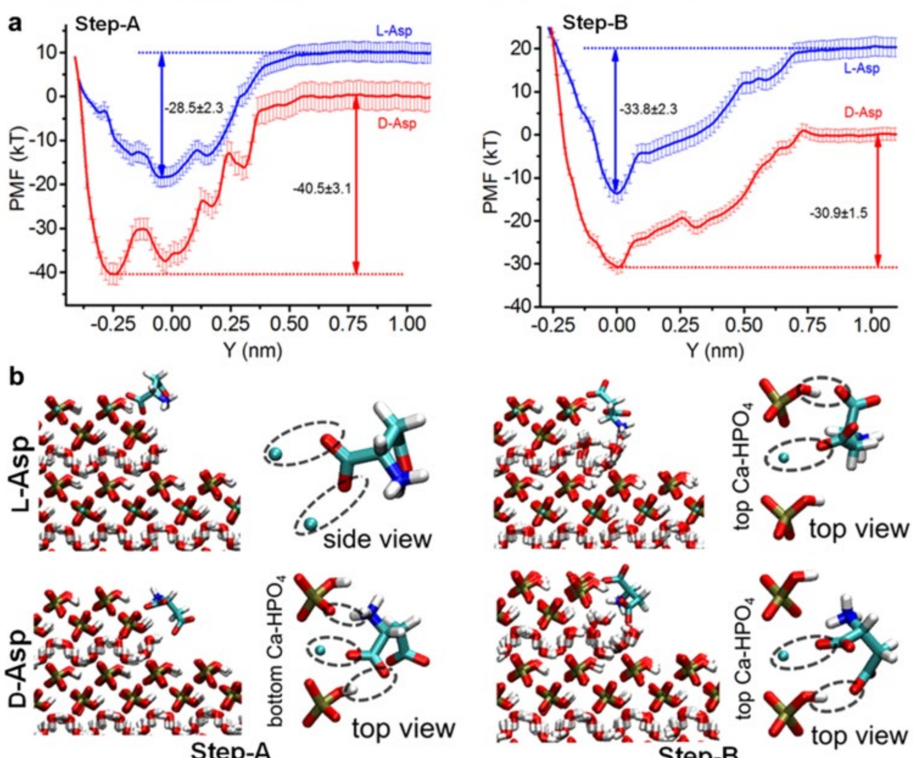
Symmetry Breaking

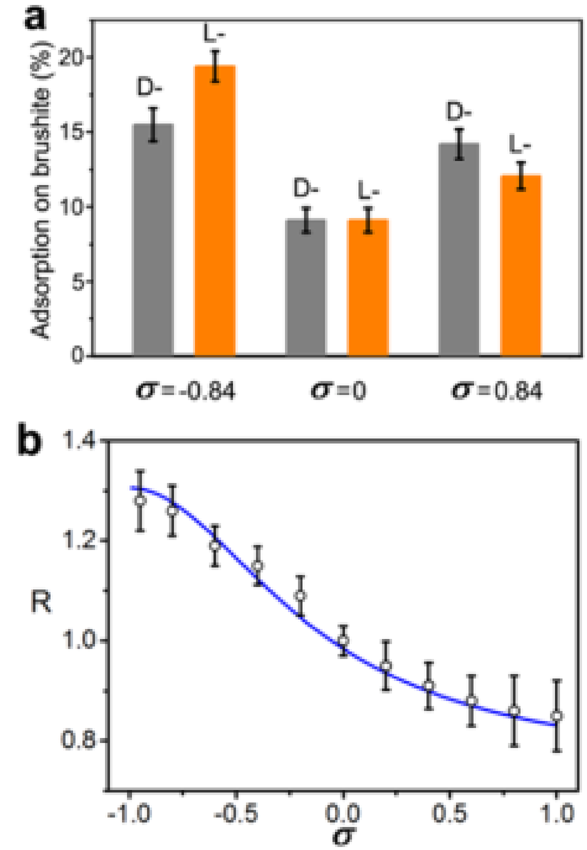


Cold Spring Harb Perspect Biol 2019;11:a032540

Symmetry Breaking

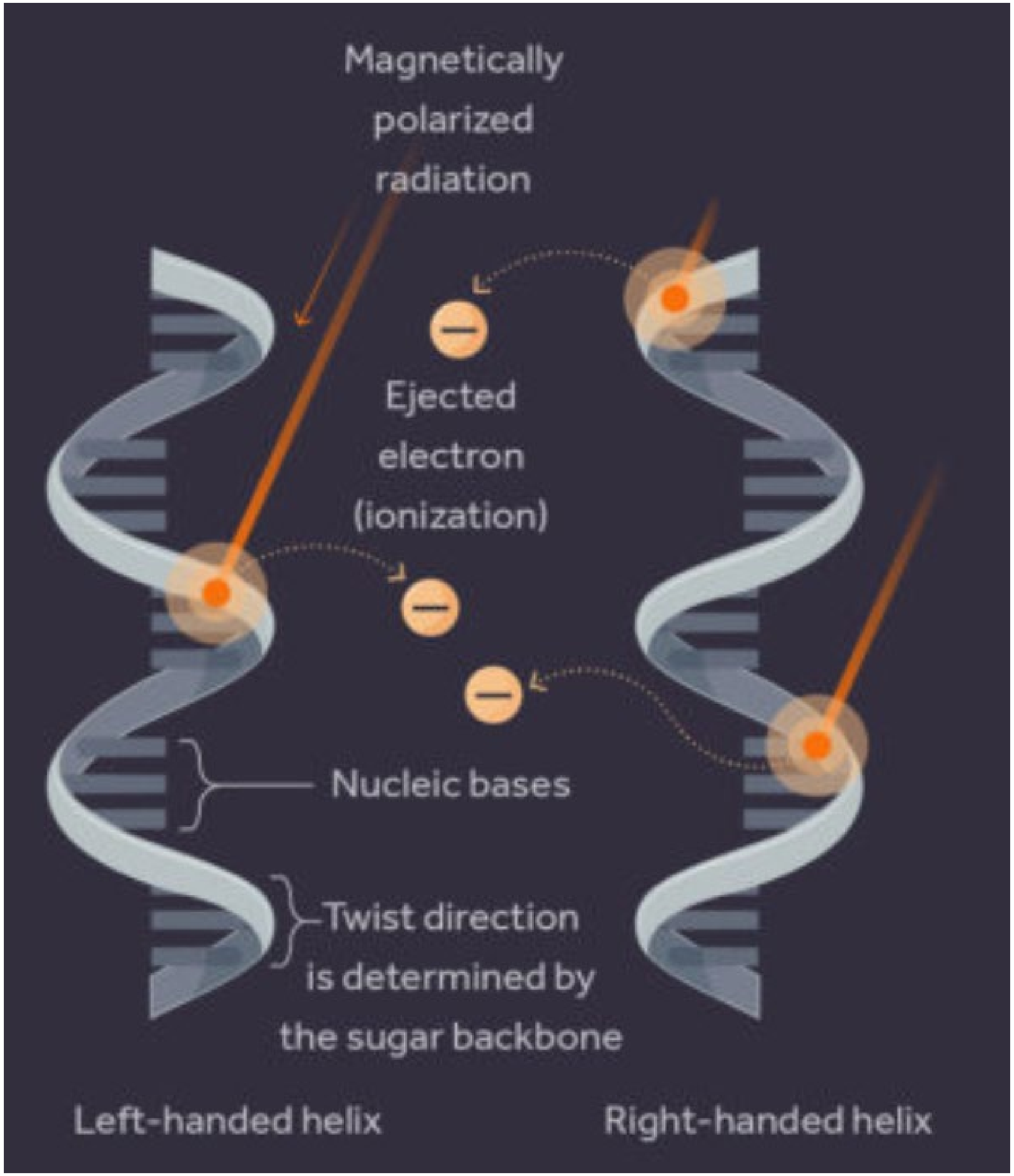






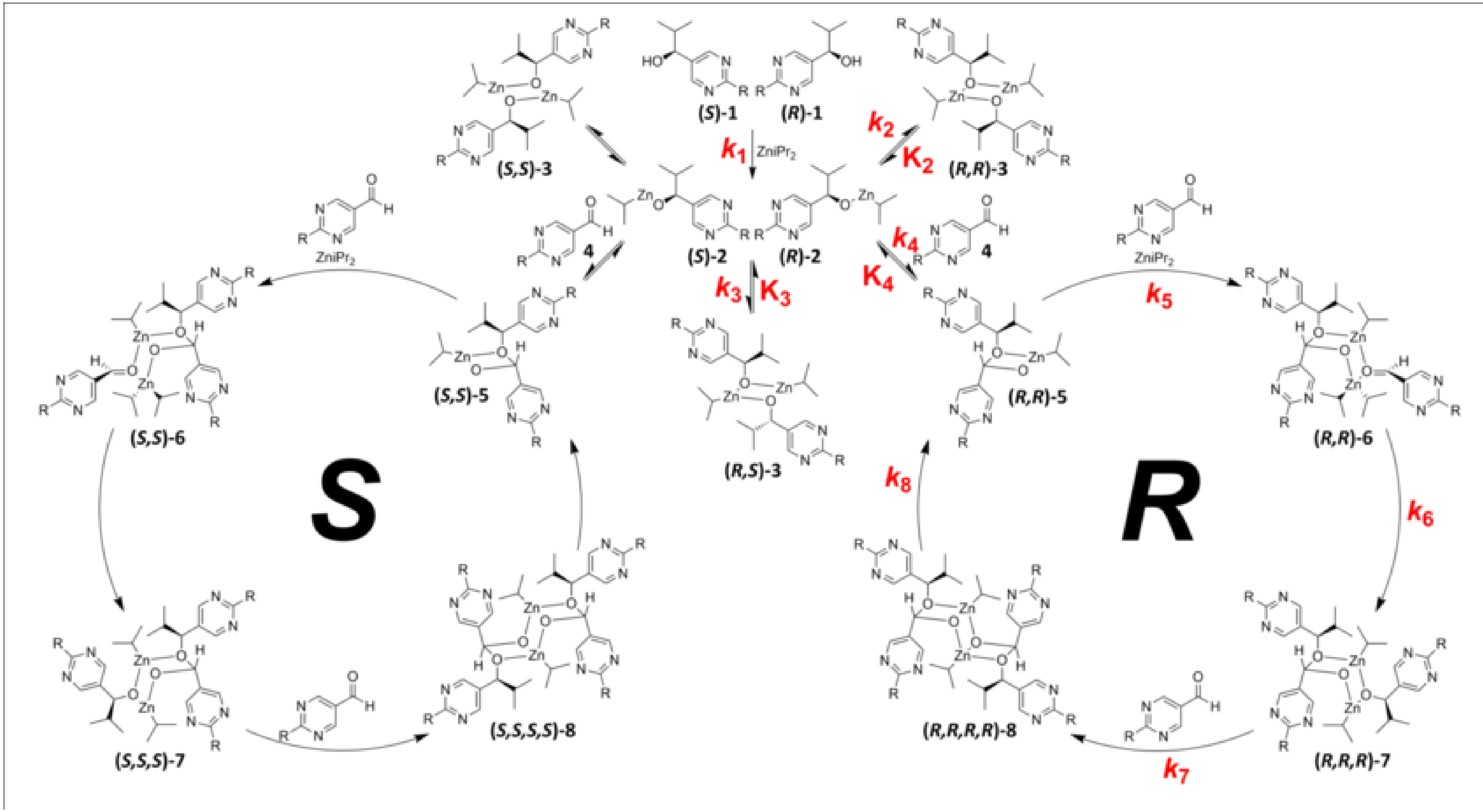
J. Am. Chem. Soc. 2017, 139, 8562

Symmetry Breaking



*ApJL,*2020, 895, L11

Chiral Amplification

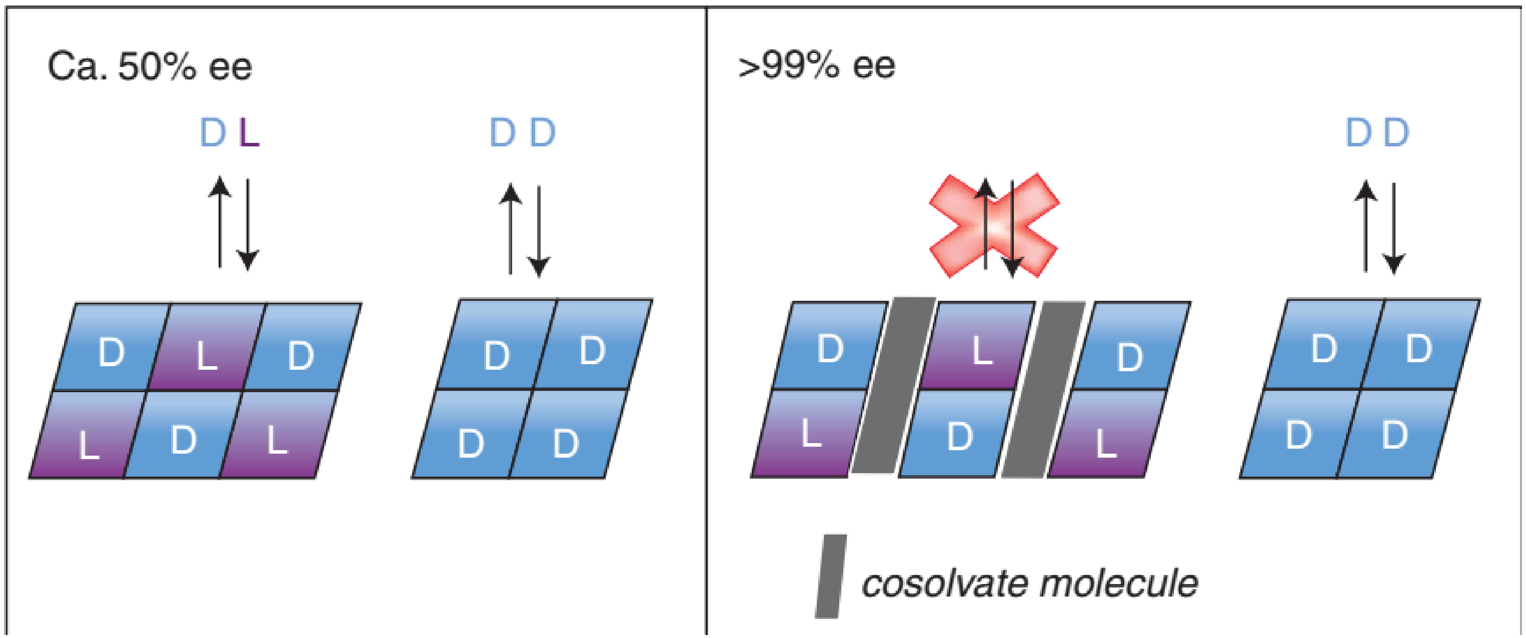


Soai autocatalytic reaction

Chiral Amplification

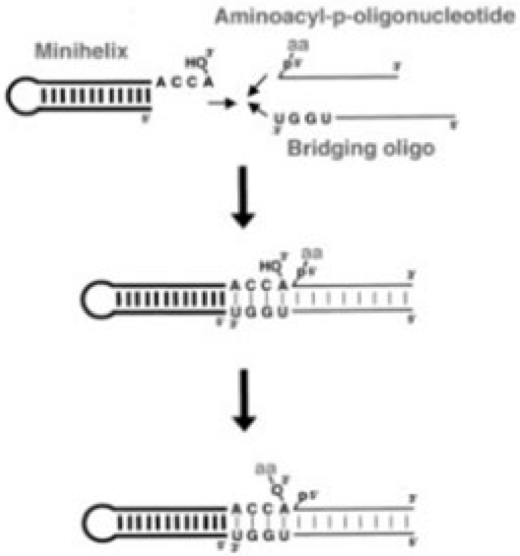
Enantiomeric concentration amplification of phenylalanine after two crystallizations from water

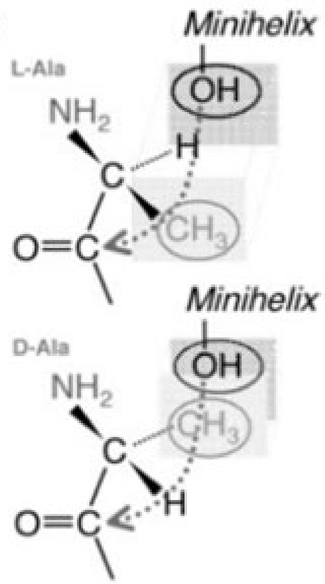
Component	Initial ee, %	Final ee, %
D	10	90.0 ± 3.7
	5	91.7 ± 1.5
	1	87.2 ± 2.0
L	10	88.3 ± 1.1
	5	88.6 ± 0.9
	1	90.9 ± 0.3

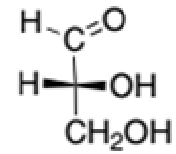


PNAS , 2006, 103,12979

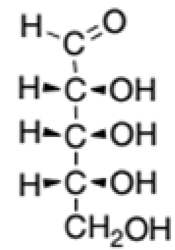
Chirality Transfer



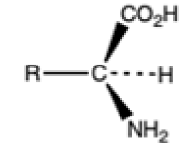




D-Glyceraldehyde

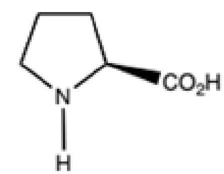


D-Ribose

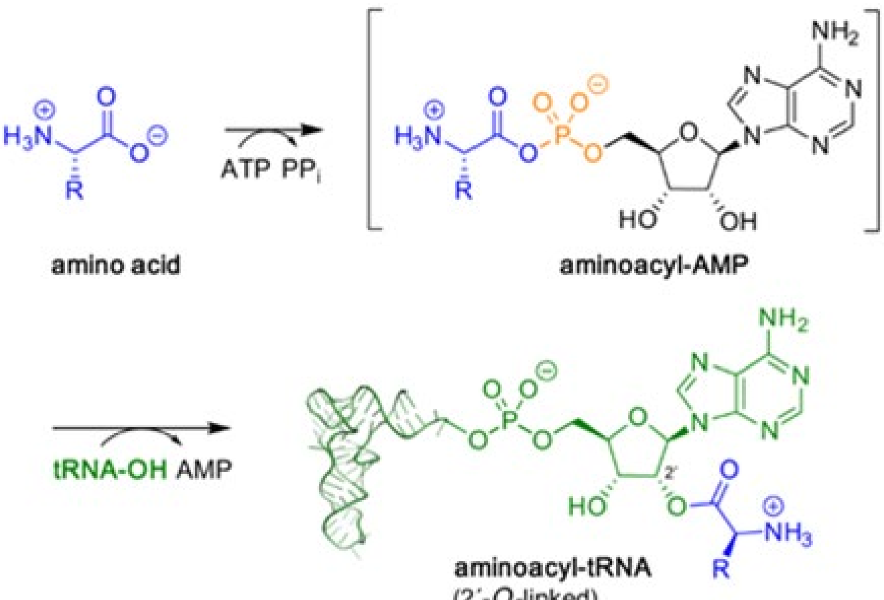


L-Amino Acids

alanine (R = CH_3); serine (R = CH_2OH); valine (R = $CH(CH_3)_2$); leucine (R = CH_2-$CH(CH_3)_2$); phenylalanine (R = CH_2-C_6H_5); glutamic acid (R = CH_2-CH_2-CO_2H



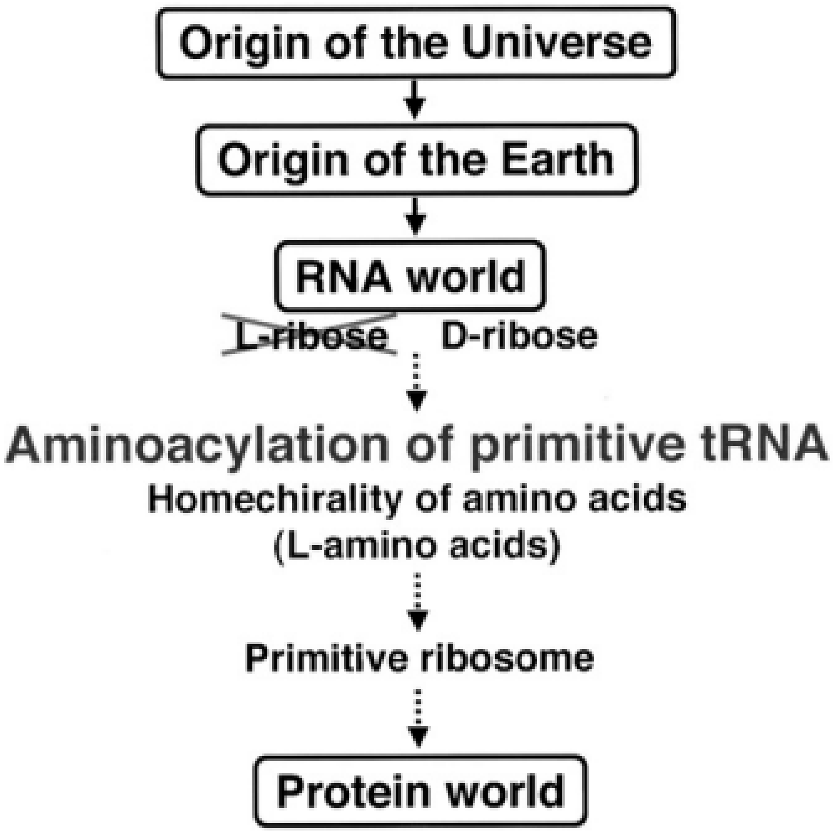
L-Proline

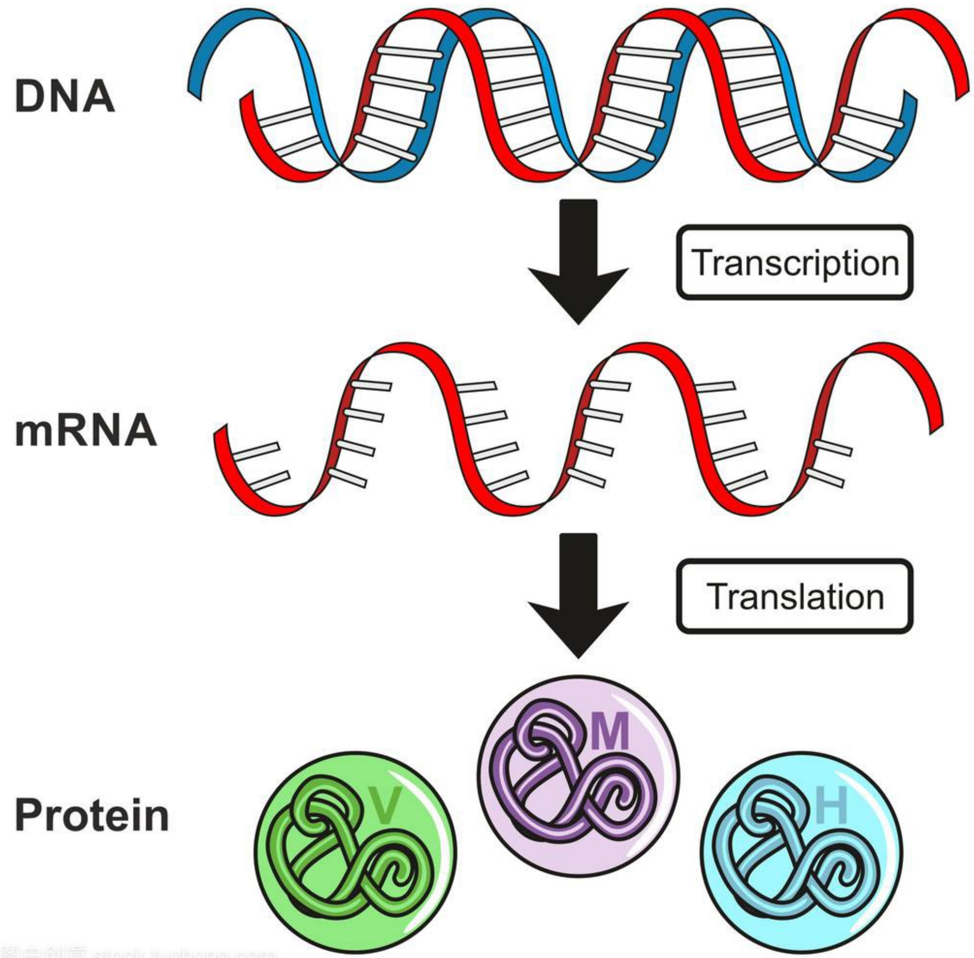


Amino acid	Ratio, D/L
L-serine	50.3/49.7
L-alanine	50.8/49.2
L-phenylalanine	52.2/47.8
L-valine	52.2/47.8
L-leucine	54.4/45.6
L-glutamic acid	60.7/39.3
L-proline	28.9/71.1

PNAS, 2010, 107, 5723
BioSystems, 2008, 92, 91

Chirality Transfer





PNAS, 2010, 107, 5723

Thanks !