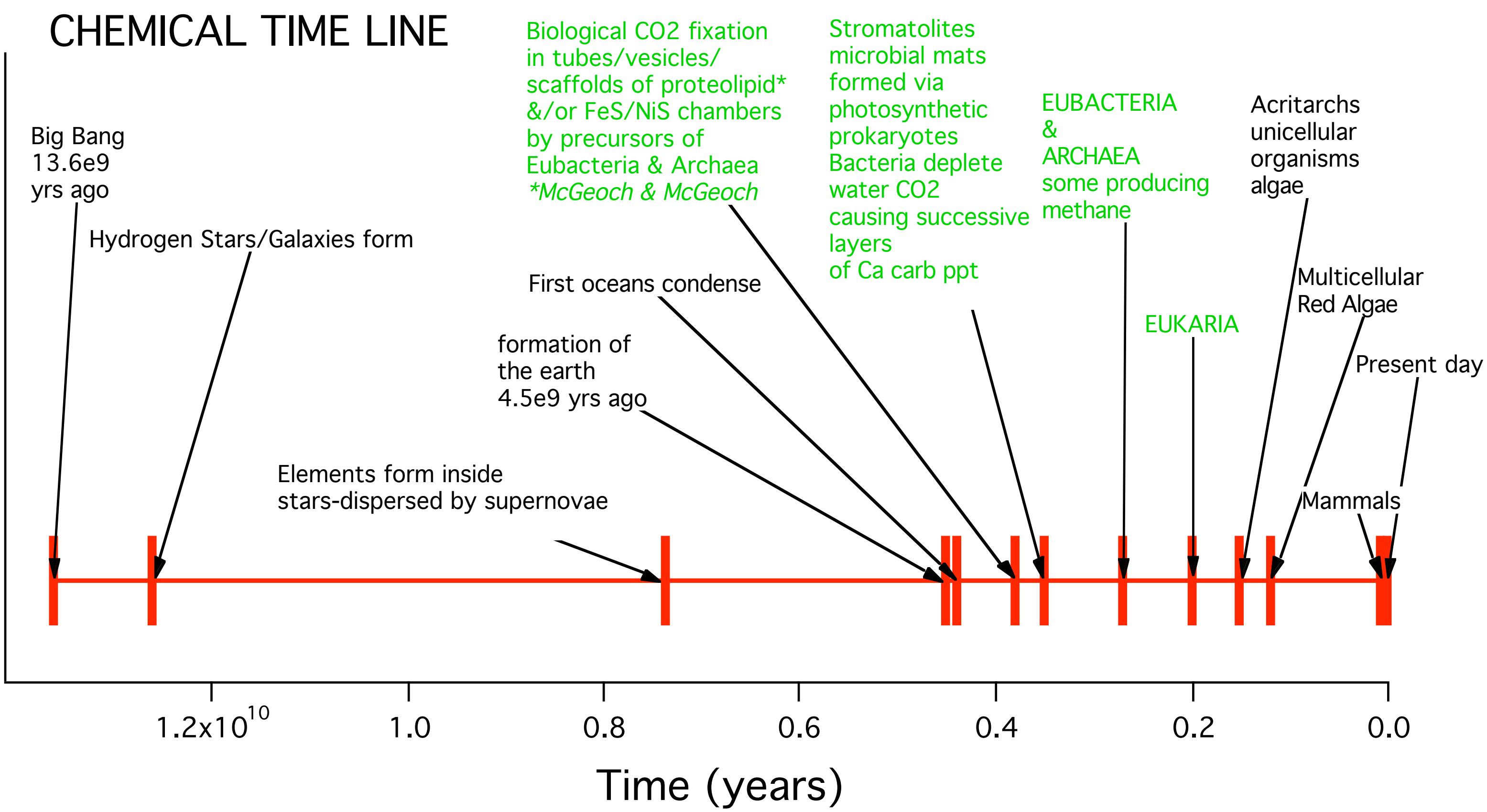
S1

Entrapment of water by subunit c of ATP synthase.

Julie E M McGeoch† & Malcolm W McGeoch*

† Department of Molecular and Cellular Biology, Harvard University, 7 Divinity Avenue, Cambridge, MA 02138, USA.* PLEX LLC, 275 Martine Street, Fall River, MA 02723, USA.

mcgeoch@fas.harvard.edu



1.36e10 years	Big Bang~formation of the universe
1.26e10 years	Hydrogen stars and Galaxies form
7.36e9 years	Elements formed inside stars-dispersed by supernovae
4.5e9 years	formation of the earth
4.4e9 years	First oceans condense
3.8e9 years	CO_2 fixation by precursors to Archaea and Eubacteria
3.5e9 years	Stromatolites
2.7e9 years	Archaea and Eubacteria
2e9 years	Eukaria
1.5e9 years	Acritarchs, unicellular algea
1.2e9 years	Multicellular red algea
6.8e7 years	Mammals
0 years	Present day

Time line dates derived from William Martin and Michael Russell Phil Trans R.Soc. Lond B (2003) 358, 59-85

Table 1 Comet & Meteorite chemicals

Enlarge to read the table

MISSION	SAMPLE SOURCE	AMINO ACIDS	LIPID	SUGAR	OTHER
	Murchison Carbonaceous chondrite Australia1969 Engel & Nagy 1982	70-90% aa with L bias Non-earth aa's with L-aa bias at incidence of 2-9%			
	Murchison Carbonaceous chondrite Australia1969 Deamer & Pashley 1989		Fractions (chloroform/methanol extraction) act like membranes		
	Murray Deamer & Pashley 1989		Fractions (ibid) act like membranes		
	Mighei Deamer & Pashley 1989		Fractions (ibid) act like membranes		
	Murchison Carbonaceous chondrite Australia1969 Mautner, Leonard & Deamer1995	glycine	Nonanoic acid-forms vesicles**		pyrene
	Deamer 1997 METIORITES: Murchison AntarcticALH84044 (origin through to be Mars-ejected from Mars 16 million yrs ago into Earth crossing orbit-landed in Antarctica 13,000 yrs ago) AntarcticLEW 8534		Many examples lipid from meteorite samples Very good vesicles		
	Tagish Lake Cananda Pizzarello et al 2001				Dicarboxylic acids Pyridine carboxylic acids Sulphonic acid Aliphatic and aromatic hydrocarbons The insoluble carbon has deuterium enrichment Fullerines containing planetary He and Ar
	Murchison Carbonaceous chondrite Australia1969 Cooper et al 2001			POLYOLS polyhydroxylated cpds sugars, sugar alcohols, sugar acids	
	Murray metiorite Cooper et al 2001			POLYOLS polyhydroxylated cpds sugars, sugar alcohols, sugar acids	
	Murchison Carbonaceous chondrite Australia1969 Shimoyama & Ogasawara 2002	Dipeptides: Gly-Gly 11pmo23/g Cyclo(Gly-Gly) 18pmol/g No L or LL stereoisomers of protein aa's Monomer glycine 3 orders of mag [higher] than dipeptides			
	Yamato-791198 Carbonaceous chondrite Shimoyama & Ogasawara 2002	Dipeptides: Gly-Gly 11pmol/g Cyclo(Gly-Gly) 18pmol/g No L or LL stereoisomers of protein aa's Monomer glycine 4 orders of mag [higher] than dipeptides			
	Murchison Carbonaceous chondrite Australia1969 Meierhenrich et al 2004	aa's and Di peptides with no chiral bias			
Rosetta					
Stardust					
Mars					
Voyager 1 to Titan					Thick pink haze surrounding Titan. Tholins Indicative of organic cpds
Voyager 1 to dark hemisphere of Saturus-satellite Inpetus					tholins
Voyager 1 to Centaur 5145 Pholus					tholins
	Comet 81P/wild2 Sandford S A 2006				Organics rich in oxygen and nitrogen compared to meteorites Deuterium and N15 content suggest interstellar heritage

Providing potential source of chemicals to earth from extraterrestrial in-fall

Table 1 References in the order that they appear in the table:

Engel & Nagy (1982) *Nature* **296**, 838.

Deamer & Pashley (1989) *Orig Life Evol Biosph* **19**, 21-38.

Mautner, Leonard & Deamer (1995) *Plan Space Sci* **43**, 139-147.

Deamer (1997) Microbiol *Mol Biol Rev* **61**, 239-261.

Pizzarello et al (2001) *Science* **293**, 2236-2239.

Cooper et al (2001) *Nature* **414**,879-883.

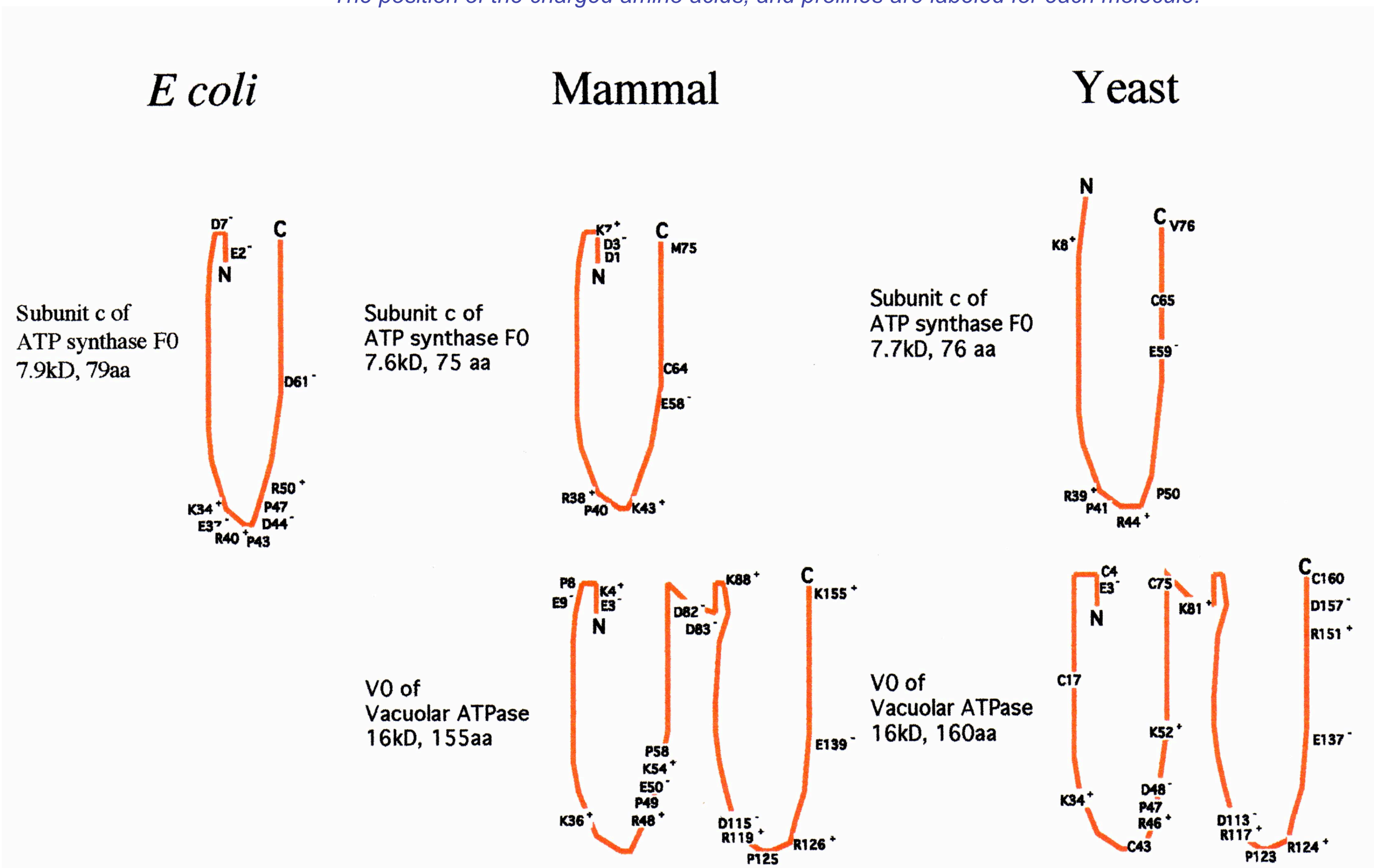
Shimoyama & Ogasawara (2002) *Orig Life Evol Biosph* **32**, 165-179.

Meierhenrich et al (2004) *PNAS* **101**,9182-9186.

Sandford et al (2006) *Meteor Plan Sci* **36**, 1117-1133.

Subunit c and its gene duplication, VO of Vacular ATPase in *E. coli*, Mammal and Yeast

The position of the charged amino acids, and prolines are labeled for each molecule.



MAMMALIAN SEQUENCE FOR SUBUNIT C OF ATP SYNTHASE

DIDTAAKFIG AGAATVGVAG SGAGIGTVFG SLIIGYARNP SLKQQLFSYA

ILGFALSEAM GLFCLMVAFL ILFAM

PROTEOLIPID SEQUENCES OF MAMMAL, YEAST & E. coli showing how the amino acids might distribute at a hydrophobic/hydrophilic interface - the mammal is seen to have the most alternating sequence, that goes above and below the interface every 2-3 amino acids and only at the C-terminus remains in the hydrophobic phase for 14 amino acids.

Red=hydrophobic amino acids
Blue/grey =hydrophilic amino acids

Mammalian subunit c **NP_788822 Bov**

DIDTAAKFIG AGAATVGVAG SGAGIGTVFG SLIIGYARNP SLKQQLFSYA ILGFALSEAM GLFCLMVAFL ILFAM

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40

I A A F I A A A V V A A I V F L I I Y A P

D D T K G G T G G S G G G T G S G R N

41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75

L L F Y A I L F A L A M L F C L M V A F L I L F A M

S K Q Q S G S E G

Yeast subunit c **NP_009319**

MQLVLAAKYI GAAIATIGLL GAGIGIAIVF AALINGTSRN PSLRNTLFPA ILGFALSEAT GLFCLMISFL LLYGV

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40

M L V L A A Y I A A I A I L L A I I A I V F A A L I

Q K G T G G G G N G T S R N

41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75

P L L F P A I L F A L A L F C L M I F L L L Y V

S R N T G S E T G S G

E.coli subunit c **AAC76760**

MENLNMDLLY MAAAVMMGLA AIGAAIGIGI LGGKFLEGAA RQPDLIPLLR TQFFIVMGLV DAIPMIAVGL GLYVMFAVA

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40

M L M L L Y A M A A V M M L A A I A A I I I L F L A A

E N N D G G G G G G K E G

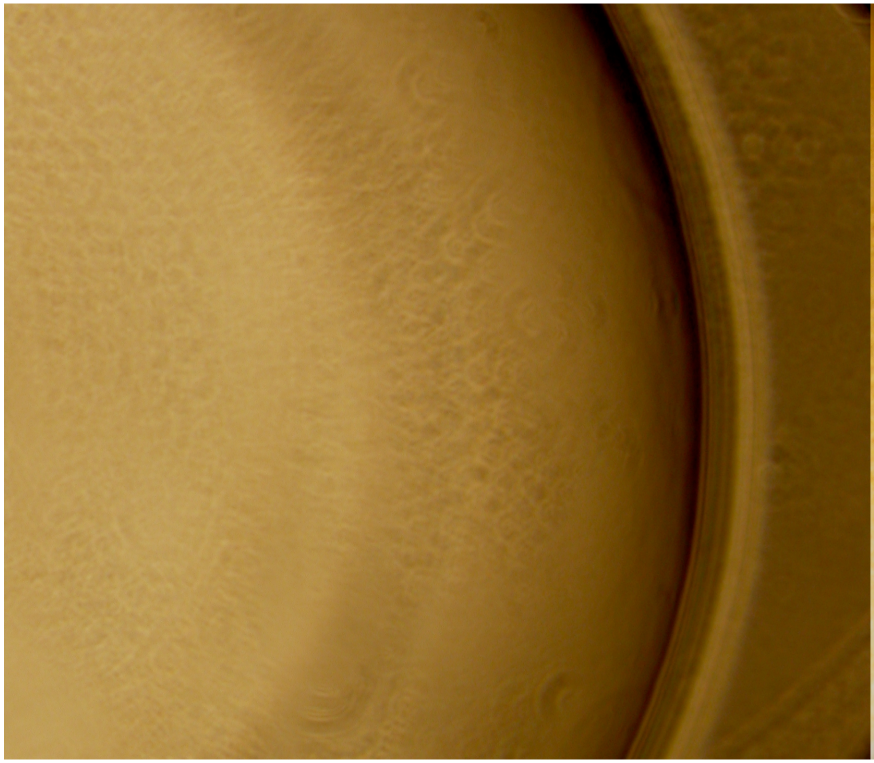
41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79

P L I P L L L F F I L V M L A I P M I A V L L Y V M F A V A

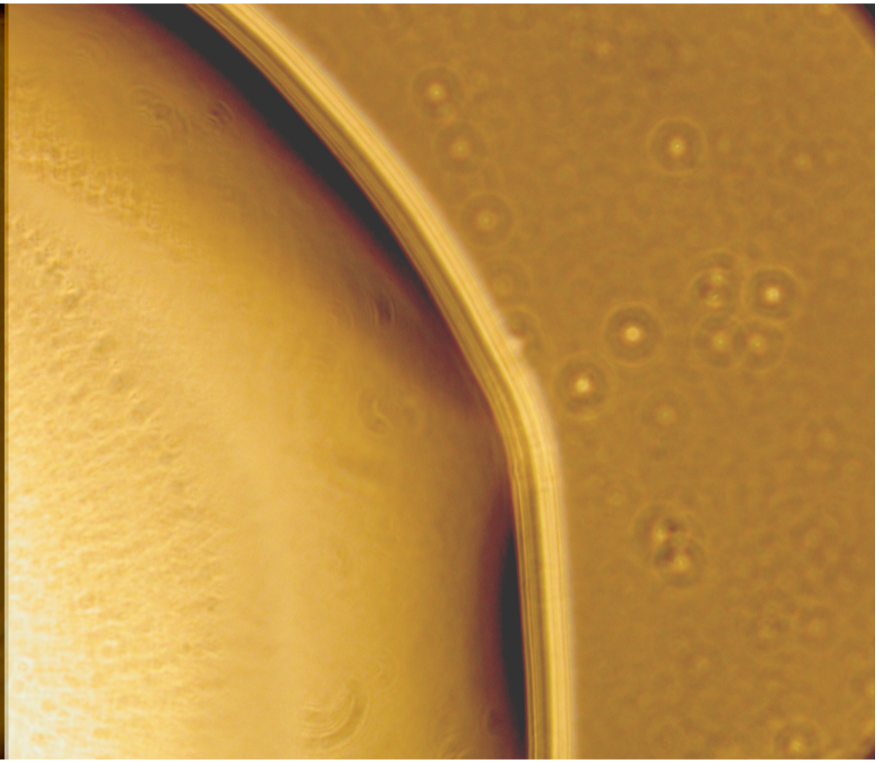
R Q D R T Q G D G G

Subunit c on the surface of water induces ordering of the surface

Glass slide with 1µl water



Same + 1ng subunit c. Note the edges of the droplet are becoming straight rather than circular due to the ordering via the protein



Light microscopy phase contrast image