

Epilogue

The ‘Life Force’

“My suspicion is that the Universe is not only queerer than we suppose, but queerer than we can suppose” J. B. S. Haldane.

Earth constitutes a unique planet in the Solar system and most likely far beyond. Drake and Dava (1992) estimate the frequency of technical civilizations in the Milky Way galaxy in terms of

$$N = R * fp * ne * fl * fi * fc * L.$$

N = the number of civilizations in our galaxy with which communication might be possible (i.e., which are on our current light cone); R = the average rate of star formation per year in our galaxy; fp = the fraction of those stars that have planets; ne = the average number of planets that can potentially support life per star that has planets; fl = the fraction of the above that actually go on to develop life at some point; fi = the fraction of the above that actually go on to develop intelligent life; fc = the fraction of civilizations that develop a technology that releases detectable signs of their existence into space; L = the length of time for which such civilizations release detectable signals into space. A critical parameter in this equation is “ L ”, the longevity of technological societies measured from the time radio telescopes are invented in an attempt to communicate with other planets. Estimates of “ L ” range between a minimum of 70 years and 10,000 years, but even for the more optimistic longevity scenario only 2.3 such planets would exist in the galaxy at the present time. Carl Sagan (1980) estimated L on the scale of only a couple of hundred years since a civilization discovered nuclear fission. It is another question whether an organism exists, in this, or any other galaxy, which has triggered a mass extinction of species.

The polarity between gradual biological evolution and mass extinction events parallels the polarity between uniformitarian views of terrestrial history (James Hutton: 1726–1797; Charles Lyell: 1797–1875) and the notion of catastrophism (Cuvier: 1769–1832). Following initial accretion of asteroid and cometary fragments and dust, including amino acid components (Chyba 1993; Chyba and Sagan 1996; Delsemme 2000) and oxygen ($^{18}\text{O}/^{16}\text{O}$) isotopic evidence from 4.4 Ga zircons suggests that granitic crust formed at that stage was in part cool enough

to allow liquid water near the surface (Wilde et al. 2001; Peck et al. 2001; Mojzsis et al. 2001). Cometary seeding of planetary atmospheres is capable of contributing extraterrestrial organic components, incinerated upon impact, possibly leading to shock synthesis of new organic molecules (Chyba and Sagan 1996). Cometary components of terrestrial sediments include aminoisobutyric acid (AIB), isovaline (Zhao and Bada 1989; Zahnle and Grinspoon 1990) and noble gases such as ^3H (Farley et al. 1998).

The transformation from organic molecules (amino acids, purine, pyrimidine), to complex information-rich biomolecules (peptide, nucleic acid, protein, enzyme) whose genetic information cannot be expressed by mathematical algorithms, has been estimated as a chance probability of $1:10^{120}$ (Davies 1998). Intrinsic to the question of the origin of early biomolecules is the nature of environmental settings of prebiotic molecules and early microorganisms. Earliest replicating cells at submarine hot springs probably required only twenty or so elements available and as many fundamental organic molecular components (Wald 1964; Eck and Dayhoff 1968). Original biomolecules could have been synthesized from amino acid of both terrestrial and cometary derivation. Panspermia theories, rather than offering an explanation for the origin of biomolecules, only defer the question further back in time and space, reflecting popular fads that advocate extraterrestrial origins of life.

Definitions of life in terms such as “matter that includes responsiveness, growth, metabolism, energy transformation, and reproduction” (Encyclopedia Britannica) and distinctions between animate and inanimate matter are complicated by the existence of intermediate entities, including DNA-free viruses and sub-micron nanobes (Uwins 1998) (Fig. Ep-1). Views of these entities vary, from “*organisms at the edge of life*” (Rybicki 1990) to fragments of DNA and larger cells. Once primordial biomolecules formed, natural selection accounts for their evolution trajectories in terms of mutations, adaptations and self-repair, all the way from microbes to brains. According to Ellis (2005) “*Ever higher levels of interaction and causality arose as complexity spontaneously increased in the expanding Universe, allowing life to emerge. Darwinian processes of selection guided the physical development of living systems, including the human brain*”. However, properties such as directionality and intentionality inherent in evolutionary chains, and the transfer of intelligence, constitute outstanding issues. The question arises, does intelligence constitute the property of organisms and species or, alternatively, does intelligence reside in unknown laws of nature, projected on all life forms. Such a rhetorical question would be in some respects analogous to a question such as “is gravity an inherent property of organisms or a feature inherent in the basic laws of nature?”

Inherent in the question are little-understood top-to-base causality processes (Ellis 2005), directionality and intentionality. Teilhard de Chardin hinted at the existence of laws of complexity giving rise to awareness and consciousness, stating: “... *the higher the degree of complexity in a living creature, the higher its consciousness, and vice versa. The two properties vary in parallel and simultaneously*” (1959, p. 111). The semi-autonomous existence of different

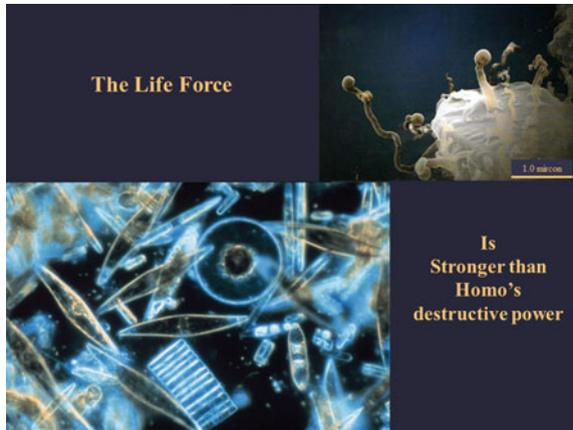


Fig. Ep-1 An epitaph: the life force is stronger than *H. sapiens*' power. **a** Nanobes, found living in deep fractures (courtesy of P.J.R. Uwins); **b** Diatoms seen through a microscope, encased within a silicate cell wall and living between crystals of annual sea ice in McMurdo Sound, Antarctica (NOAA Corps2365 Collection. Author. G. T. Taylor, Stony Brook University. Source: corp2365, NOAA Corps Collection; http://commons.wikimedia.org/wiki/File:Diatoms_through_the_microscope.jpg)

organizational levels within complex systems, including sub-atomic particles, atoms, molecules, biomolecules, nerves and brains, led Ellis (2005) to state: “although the laws of physics explain much of the world around us, we still do not have a realistic description of causality in truly complex hierarchical structures”.

Prior to the mastery of fire little difference existed between the behavior of Hominins and intelligent primate species. The mastery of fire and the expression by *Homo* through burial, art and eventually science, distinguishing the genus from all other creatures, remain to be explained. Acting as a mirror of the world around it, a product of millions of years of evolution, the apparent ability of the human brain to perceive the physical laws and their underlying mathematical logic requires that, embedded in the brain are the very codes it can perceive around it. Where science is based on empirical observations and mathematical calculations, the origin of intuitive and perceptive ideas remains unknown. It may be instructive to examine aspects of human behavior which appear to correlate with physical wave patterns, even if only as metaphors. In quantum mechanics, whereas the statistical behavior of collections of particles is defined by thermodynamic laws, it is not possible to predict the behavior of any single photon or quanta. By analogy, whereas the behavior of populations may follow statistical patterns, the behavior of individuals may be less or even unpredictable, giving rise to the concept of “free will”. If so, free will may display an analogy to solitons (solitary waves) formed through interference and amplification of wave patterns, propagating a powerful pulse.

The transition from organisms controlled purely by genetic and instinctive factors to organisms which develop thought processes and cultural traits remains undefined. The intelligent coordination of social systems intrinsic to termite nests, bee hives and modern cities where biological evolution is supplemented or superseded by cultural evolution—remains little understood. DNA and paleontological studies, documenting the molecular and physical evolution of species, are rarely if ever capable of elucidating the progress of intelligence — a little-defined faculty. Major questions remain. Two examples follow:

The resolution of the basic blocks of living organisms, a hierarchy ranging from basic atoms (C, O, H, N), to nucleic acids (adenine, cytosine, guanine, thymine, uracil), to DNA and RNA chains, genes, chromosomes, cell nuclei, multicellular organisms, constituting the hardware of life, leaves the question of the software of life open (Noble 2008). An analogy to the enigma would be discovery by an alien of a computer on a beach. Analyzing its components the alien would resolve its various building blocks, motherboard, electronic circuits, transistors, chips, vacuum tubes, gates—but would be unable to identify the mind which has designed the system. Nor has science to date decoded the natural laws that underlie the origin of the phenomenon of life. The evolutionary chain from DNA/RNA molecules, all the way to the brain, suggests an intelligence written into yet un-decoded laws of complexity and life.

Does the architectural evolution of myriad generations of termite nests represent an evolution of the inherent intelligence, of central “brains” of complex termite “cities”? Do animals and insects act by genetic controls, instincts or even by thought? For example, what is the role of thought where a bunch of termites construct a leaf shelter, each ant having its specific role in the process? Is it possible that humans apply an anthropocentric double standard when differentiating between such a group of ants and a group of people building a house? Is intelligence possessed by individual ants or humans, or does it reside in unknown natural laws? Is it possible that, far from being a unique property of any particular species, intelligence resides in un-decoded laws of nature?

In the absence of explanations, concepts such as that of a “*life force*” (Fig. Ep-1) may be invoked with reference to, for example, the survival of extremophile bacteria. On a larger scale, the Gaia Hypothesis, which views Earth as a single organism maintaining a homeostatic balance (Lovelock 1979), offers an attractive allegory combining both known and unknown elements of planetary evolution. These concepts transcend the boundary between science and philosophy, where the human brain remains in a realm of Flatland (Abbott 1884), blind but beginning, even if too late, to perceive dimensions it cannot comprehend.

We may never know.

Appendices

Tables A.1, A.2, D.1.

Table A.1 Geological stage boundaries, large asteroid impact events, large volcanic provinces and percent mass extinction of species (% mass extinctions after Keller, 2005)

Stage boundaries/ epochs	Large asteroid impacts	Large volcanic provinces	Percentage mass extinction of genera (%)
Mid-Miocene Langhian 15.97 Ma	Ries (24 km) 15.1 ± 1.0 Ma	Columbia Plateau Basalt 16.2 ± 1 Ma	6
Eocene–Oligocene boundary 33.9 ± 0.1 Ma	Popigai (100 km) 35.7 ± 0.2 Ma; Chesapeake Bay (85 km) 35.5 ± 0.3 Ma Mount Ashmore: E- O Boundary	Ethiopian Basalts 36.9 ± 0.9 Ma	10
KT boundary 65.5 ± 0.3 Ma	Chicxulub (170 km) 64.98 ± 0.05 Ma Boltsh (25 km) 65.17 ± 0.64 Ma	Deccan Plateau Basalts. 65.5 ± 0.7 Ma (pooled Ar Ages: 65.5 ± 2.5 Ma)	46
Cenomanian–Turonian 93.5 ± 0.8 Ma	Steen River (25 km) 95 ± 7 Ma	Madagascar Basalts 94.5 ± 1.2 Ma	17
Aptian (Early Cretaceous) 125–112 Ma	Carlswell (39 km) 115 ± 10 Ma; Tookoonooka (55 km; 125 ± 1 Ma); Talundilly (84 km; 125 ± 1 Ma); Mien (9 km) 121 ± 2.3 Ma; Rotmistrovka (2.7 km) 120 ± 10 Ma	Ontong-Java LIP 120 Ma Kerguelen LIP 120–112.7– 108.6 Ma Ramjalal Basalts, 11.7 ± 1	14

(continued)

Table A.1 (continued)

Stage boundaries/ epochs	Large asteroid impacts	Large volcanic provinces	Percentage mass extinction of genera (%)
End-Jurassic 145.5 ± 4 Ma	Morokweng (70 km) 145 ± 0.8 Gosses Bluff (24 km) 142.5 ± 0.8 Ma; Mjolnir (40 km) 143 ± 2.6 Ma	Dykes SW India 144 ± 6 Ma	20
End-Pliensbachian 183 ± 1.5 Ma		Peak Karoo volcanism Start 190 ± 5 Ma; Peaks 193, 178 Ma; Lesotho 182 ± 2 Ma	19
End-Triassic 199.6 ± 0.3 Ma		Central Atlantic Igneous Province: 203 ± 0.7–199 ± 2 Ma Newark Basalts 201 ± 1 Ma	18
Norian/Rhatian 216.5	Manicouagan (100 km) 214 ± 1 Ma; Rochechouart (23 km) 213 ± 8 Ma;		34
Permian–Triassic: 251 ± 0.4 Ma; 251.4 ± 0.3 to 250.7 ± 0.3 Ma	Araguinha (40 km) 252.7 ± 3.8 Ma	Siberian Norilsk 251.7 ± 0.4–251.1 ± 0.3 Ma	80
Late to end Devonian 374–359 Ma	Woodleigh (120 km) 359 ± 4 Ma; Siljan (52 km) 361 ± 1.1 Ma; Alamo breccia (~100 km) ~360 Ma; Charlevoix (54 km) 342 ± 15 Ma	Rifting and 364 Ma Pripyat– Dneiper–Donets volcanism	30 58
End-Ordovician 443.7 ± 1.5 Ma	Several small poorly dated impact craters		60
End-Early Cambrian 513 ± 2 Ma	Kalkarindji volcanic Province, northern Australia 507 ± 4 Ma		42

Table A.2 Comparison of mean global temperature rise rates during the Cenozoic, including the K-T impact events (Beerling et al. 2002), the 55.9 Ma PETM hyperthermal event (Zachos et al. 2008), end-Eocene freeze and formation of the Antarctic ice sheet (34–32 Ma) (Zachos et al. 2001), Oligocene (Zachos et al. 2001), Miocene (Kurschner et al. 2008) and end-Pliocene (Zachos et al. 2001; Beerling and Royer 2011) thermal rises, glacial terminations (Hansen et al. 2007) Dansgaard-Oeschger cycles (Ganopolski and Rahmstorf 2002; Jouzel 2007), 8.2 kyr event (Wagner et al. 2002) intra-Holocene events (IPCC 2007) and Anthropocene climate change (IPCC 2007)

Age	Interval	Mean global land and sea temp change (C)	Warming rate (C/year)	CO ₂ change (ppm)	CO ₂ change rate (ppm/year)	Reference	Proxy methods*
K-T impact 64.98 Ma	Instant to 10,000 years	Short freeze followed by ~+7.5C	~ 0.00075	~ 400–2,300	Instantaneous to 0.19 ppm/yr	Beerling et al. (2002)	Ginkgo stomata
PETM 55.9 Ma	~10,000 years	+5 – 9C	~ 0.0005	~ 1,800–4,000 ppm	~ 0.22 ppm/yr	Zeebe et al. (2009)	Deep sea carbonate dissolution
Eo-Ol freeze 34.2 – 34.0	~200,000 years	~ -5.4C	-0.000027	~ 1,120–560 ppm in 10 x 10 ⁶ years		Liu et al. (2009); Pollard and DeConto (2005)	TEX86; δ18O of benthic foraminifera; Boron and alkenones model
End-Oligocene ~24.7	~200,000 years	~+4C	0.00002	500–900 ppm	0.002	Pekar and Christenbleck (2007)	δ ¹³ C data from alkenones
Mid-Miocene 20 – 18 Ma	~200,000 years	~+1.5C	0.000007	~ 300 – 520 ppm	0.0011	Kurschner et al. (2008)	multiple-species stomatal frequency record
End-pliocene	4 – 3 Ma	~ +1C	0.000001	~ 250 – 400 ppm	0.00015	Zachos et al. (2001); Beerling and Royer (2011)	Stomata pores; δ ¹³ C plankton
Glacial terminations/ Eemian	11,000 years	+~5C	0.0004	+100 ppm	0.009	Hansen et al. (2007); Petit et al. (1999); EPICA (2004)	Ice cores
Dansgaard-Oeschger– 21 cycles of ~1,500 years each	~75 – 15 kyr	~ -3.5C	0.01 – 0.2	+20 ppm	0.2	Ganopolski and Rahmstorf (2002); Jouzel (2007)	Greenland ice cores

(continued)

Table A.2 (continued)

Age	Interval	Mean global land and sea temp change (C)	Warming rate (C/year)	CO ₂ change (ppm)	CO ₂ change rate (ppm/year)	Reference	Proxy methods*
Younger dryas	12.9 – 11.7 kyr	~ -15C in GISP2 ice core		-7 ppm			Greenland ice cores
Interglacial stadial							
8.2 kyr stadial	~100 years	-3.3C in the North Atlantic		-25 ppm in ~300 years	-0.08	Wagner et al. (2002)	Greenland ice cores
Medieval warm period (MWP)	~400 years	-0.4 – 0.5C	-0.001	5 ppm	~0.012	IPCC-(2007) Chapter 4	Ice cores, tree rings, cave deposits
Little ice age (LIA)	~60 years	~ -0.4C	~ -0.006	-5 ppm		IPCC-(2007) Chapter 4	Ice cores, tree rings, cave deposits
Post-1,750	263 years	+0.9C + 2.3C potential (with no aerosol masking)	-0.0034 ~ -0.008	280-400 ppm	~ 0.45	IPCC-(2007)	Instrumental
1975-2012	37 years	+0.6C	-0.016	330 – 394.28 ppm	~ 1.73	NASA/GISS IPCC-(2007)	Instrumental
March 2012-2013	1 year			2.89 ppm	2.89	NOAA (2013)	

Table D.1 Proposed solar mitigation and atmospheric carbon sequestration methods

Method	Supposed advantages	Problems
SO ₂ injections	Cheap and rapid application	Short multi-year atmospheric residence time; ocean acidification; retardation of precipitation and of monsoons
Space sunshades/minors	Rapid application. No direct effect on ocean chemistry	Limited space residence time. Uncertain positioning in space. Does not mitigate ongoing ocean acidification by carbon emissions
Ocean iron filings fertilization enhancing phytoplankton	CO ₂ sequestration	No evidence that dead phytoplankton would not release CO ₂ back to the ocean surface
Ocean pipe system for vertical circulation of cold water to enhance CO ₂ sequestration	CO ₂ sequestration	No evidence the cold water would not re-warm when pumped to the surface
“Sodium trees” NaOH liquid in pipe system sequestering CO ₂ to Na ₂ CO ₃ , separation and burial of CO ₂	CO ₂ sequestration, estimated by Hansen et al. (2008) at ~\$300 per ton CO ₂	Unproven efficiency: need for CO ₂ burial: \$trillions expense (though no more than current military expenses)
Soil carbon burial/biochar	Effective means of controlling the carbon cycle (plants + soil exchange more than 100 GtC/year with the atmosphere)	Requires a huge international effort by a workforce of millions of farmers
serpentine CO ₂ sequestration	CO ₂ sequestration	Possible scale unknown

About the Author



Andrew Glikson, an Earth and paleo-climate scientist, studied geology at the University of Jerusalem and graduated at the University of Western Australia in 1968. He conducted geological surveys of the oldest geological formations in Australia, South Africa, India and Canada, studied large asteroid impacts, including effects on the atmosphere and oceans mass extinction of species. Since 2005 he studied the relations between climate and human evolution. He was active in communicating nuclear issues and climate change evidence to the public and parliamentarians through papers, lectures and conferences.

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