Liquid Life
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Ironically, the idea that life requires an explanation is a relatively new one. To the ancients, life simply was; it was a given; a first principle, in terms of which other things were to be explained. Life vanished as an explanatory principle with the rise of mechanics, when Newton showed that the mysteries of the stars and planets yielded to a few simple rules in which life played no part, when Laplace could proudly say ‘Je n’ai pas besoin de cet hypothèse’; when the successive mysteries of nature seemed to yield to understanding based on inanimate nature alone: only then was it clear that life itself was something that had to be explained. — Robert Rosen (Rosen 1991, 11)

During the Enlightenment, the rise of secular atomism prompted investigators to provide a material explanation for the phenomenon of life. Through their rationalisation, the characteristics of living things needed to be accounted for by the properties of ‘brute’ (Bennett 2010b, 64) matter, without recourse to a vitalising agency. Although the concept of spontaneous generation was rejected, where non-living matter like dust could give rise to creatures like fleas, or dead flesh to maggots, Louis Pasteur demonstrated that life could not be accounted for by the forces of ‘brute’ matter alone. Concluding that vital agencies were involved in the making of living things, his experiments established a new rigour for the investigation of previously invisible forces (microbes) at work.

I took my drop of water from the immensity of creation, and I took it filled with that fecund jelly, that is, to use the language of science, full of the elements needed for the development of lower creatures. And then I waited, and I observed, and I asked questions of it, and I asked it to repeat the original act of creation for me; what a sight it
would be! But it is silent! It has been silent for several years, ever since I began these experiments. Yes! And it is because I have kept away from it, and am keeping away from it to this moment, the only thing that it has not been given to man to produce, I have kept away from it the germs that are floating in the air, I have kept away from it life, for life is the germ and the germ is life. — Louis Pasteur (quoted in Debré 1998, 169)

In the first part of the twentieth century, John Haldane conceived one of the most important scenarios about the origin of life on Earth, which offered a material explanation for chemical evolution that occurred in Earth’s early seas. Proposing that a hot dilute soup of inorganic substrates was capable of producing organic molecules, he freed the actions of matter from the need for vital forces (Tirard 2011).

Until about 150 years ago it was generally believed that living beings were constantly arising out of dead matter. Maggots were supposed to be generated spontaneously in decaying meat. In 1668 [Francesco] Redi showed that this did not happen provided insects* were carefully excluded. And in 1860 [Louis] Pasteur extended the proof to the bacteria which he had shown were the cause of putrefaction. It seemed fairly clear that all the living beings known to us originate from other living beings. At the same time [Charles] Darwin gave a new emotional interest to the problem. It had appeared unimportant that a few worms should originate from mud. But if man was descended from worms such spontaneous generation acquired a new significance. The origin of life on the earth would have been as casual an affair as the evolution of monkeys into man. Even if the latter stages of man’s history were due to natural causes,

* The reference to insects is on account of their propensity to lay tiny eggs in organic matter, which then hatch and may be interpreted as ‘proof’ of spontaneous generation.
pride clung to a supernatural, or at least surprising, mode of origin for his ultimate ancestors. So it was with a sigh of relief that a good many men, whom Darwin’s arguments had convinced, accepted the conclusion of Pasteur that life can originate only from life. It was possible either to suppose that life had been supernaturally created on earth some millions of years ago, or that it had been brought to earth by a meteorite or by micro-organisms floating through interstellar space. But a large number, perhaps the majority, of biologists, believed, in spite of Pasteur, that at some time in the remote past life had originated on earth from dead matter as the result of natural processes. — J.B.S. Haldane (Haldane 1929)

Contemporary explanations regarding how inert matter becomes animated, is framed by the discovery of deoxyribose nucleic acid (DNA), which provides organisational ‘information’. Situated within the nucleus of all cells, the processes of life governed by this polymer are equated with computing algorithms, which instruct the operations of machines. The rise of modern computers coincided with the rise of molecular biology, which consolidated a fundamentally mechanistic approach to the nature of life, and even shared many terms of reference such as virus, code and program. This is situated in a deterministic universe, thrives on the existence of stable things, and only generates change through random errors occurring spontaneously in cellular information.

In the beginning was simplicity … Darwin’s ‘survival of the fittest’ is really a special case of a more general law of survival of the stable. The universe is populated by stable things. A stable thing is a collection of atoms that is permanent enough, or common enough to deserve a name … — Richard Dawkins (Dawkins 2006, 15)

While mechanisms require self-similarity to perform their functions, molecular imaging techniques such as crystallography
demonstrated that the precision of the *code of life* was not perfect—or omnipotent—and naturally produced variety within the limits of the system, effectively establishing life’s operations were probabilistic, rather than deterministic.

5 All the work of the crystallographers serves only to demonstrate that there is only variety everywhere where they suppose uniformity … that in nature there is nothing absolute, nothing perfectly regular. — Georges-Louis Leclerc, Comte de Buffon (de Buffon 1783–1788, 433)

Increasingly, scientific investigation links living things to their environment that contextualises them in ways that exceed mechanistic explanation.

6 Living systems are units of interactions, they exist in an ambience. From a purely biological point of view they cannot be understood independently of that part of the ambience with which they interact: the niche; nor can the niche be defined independently of the living system that specifies it. — Humberto Maturana and Francisco Varela (Maturana and Varela 1928, 9)

Studies of gene expression reveal that the cell milieu does not slavishly carry out its programs but is actively enabled and modulated by a range of systems that include epigenetic processes and environmental contexts.

7 … life is defined as a material system that can acquire, store, process, and use information to organize its activities. In this broad view, the essence of life is information, but information is not synonymous with life. To be alive, a system must not only hold information but process and use it. It is the active use of information, and not the passive storage, that constitutes life. — Freeman Dyson (Dyson 2001)
Explanations for such fluid relationships are attributed to the properties of gelatinous matrixes such as protoplasm, nucleoplasm, cytoplasm and ectoplasm, which house ‘metabolic’ cellular systems capable of translating between internal imperatives and external circumstances.

8 Life is the mode of existence of albuminous bodies, and this mode of existence essentially consists in the constant self-renewal of the chemical constituents of these bodies. — Friedrich Engels (Engels 1947)

Expressions of living matter are thought to emerge from liquid environments, where a sophisticated and increasingly complex understanding of chemistry renders the synthesis of biological systems possible through a practice of synthetic biology.

9 The elementary phenomenon of life is the contact between an alimentary liquid and a cell. For the essential phenomenon of life is nutrition, and in order to be assimilated all the elements of an organism must be brought into a state of solution. Hence the study of life may be best begun by the study of those physico-chemical phenomena which result from the contact of two different liquids. Biology is thus but a branch of the physico-chemistry of liquids; it includes the study of electrolytic and colloidal solutions, and of the molecular forces brought into play by solution, osmosis, diffusion, cohesion and crystallisation. — Stéphane Leduc (Leduc 1911)

Accounts for the liveliness of matter, still cannot be completely resolved as a function of the individual properties and atoms and molecules by looking downward for answers. The continued pursuit of such an approach challenges the usefulness of the idea of ‘life’ at all.
Evolutionary biologists will sometimes suggest that origins is a subject different than the evolutionary history of life, but in so doing they reveal themselves as closet vitalists who assume that life is different than nonlife … origins is merely one stage of the grand history of replicators, which have elaborated themselves over time from simple strings of nucleic acids to complex strings of nucleic acids surrounded by the diversity of biological bags that we see today… as with all science, such questions should be bounded by naturalism, to avoid the temptation to slide into the supernatural just because the natural is often frustrating. — Andrew Ellington (Ellington 2012)

In reaching the limits of classical science, ensuing nihilism returns investigations into living systems back to a pre-Enlightenment context, where it seems pointless to even consider their nature.

Life has always been there; it has always propagated itself in the shape of living organisms, from cells and from individuals composed of cells. Man used to speculate on the origin of matter, but gave that up when experience taught him that matter is indestructible and can only be transformed. For similar reasons, we never inquire into the origin of the energy of motion. And we may become accustomed to the idea that life is eternal, and hence that it is useless to inquire into its origin. — Svante August Arrhenius (Arrenhius 1908, 218)

While the character of life cannot be explained through the collective action of individual molecules alone, an appreciation of the dynamic ecology of matter/energy relationships, generates new questions and modes of investigation that produce recognisably lifelike phenomena.
… we are literally inhabited by highly motile remnants of an ancient bacterial type that have become, in every sense, a part of ourselves. These thriving partial beings represent the physical basis of anima: soul, life, locomotion; an advocation of materialism in the crassest sense of the word. Put it this way: a purified chemical is prepared from brain and added to another purified chemical. These two chemicals — two different kinds of motile proteins — together crawl away, they locomote. They move all by themselves. Biochemists and cell biologists can show us the minimal common denominator of movement, locomotion. Anima. Soul. These moving proteins I interpret as the remains of the swimming bacteria incorporated by beings who became our ancestors as they became us. — Lynn Margulis (quoted in Brockman 2011)

Our capacity to manipulate and synthesise living agents from first principles and recruit them in a technological capacity increasingly relies on a better understanding of the flux of matter and context in which ‘beings’ exist. The Central Dogma whereby genetic codes alone, establish the fate of an organism, is giving way to alternative theories about how biological outcomes are shaped, specifically through the process of metabolism.

… by looking at the genes we should know everything in biology, and by just modifying them one could re-program the behaviour of living systems at our ease. It is like bacteria were computers making computers, and just by replacing the program one could make them do things that they normally do not do. The interpretative frame that places all emphasis on genes has dominated much of the biological research agenda of recent decades and has been recently boosted by the ease of cheap DNA sequencing. But is such a focus on genes and DNA the ultimate way to go? After many years of trying to genetically re-program environmental bacteria for release as agents of in situ bioremediation of toxic pollutants, my candid
answer is: no. And the one reason is that one cannot just play with DNA while ignoring chemistry and metabolism, let alone some principles of chemical engineering … This calls for a novel view (and possibly a fresh research agenda) in which metabolism has the leading role in the chain of biological command, opposite to the standard direction of the information flow in the canonical Central Dogma. — Victor de Lorenzo (de Lorenzo 2015)

Despite all that has been deduced and established through many advances in molecular science, and even with an in-depth knowledge of its ingredients, life still has not been built from scratch. Even the most sophisticated machines today are not autonomously self-producing agents, but workhorses for other agencies. The inability to recapitulate this aspect of life suggests that either assembling an organism from its components is unfeasibly hard, or that the ideas used to frame this process are fundamentally wrong.

… life on the Earth may be a miracle, or a freak, or an alien infection … in the fifties [it was anticipated that] … the answer to the origins of life would appear in some footnote to the answer to the question of how organisms work. Something much more will be needed. Something odd. — Alexander Graham Cairns-Smith (Cairns-Smith 1985, 8)