Liquid Life
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Part III

HYPERCOMPLEXITY
This chapter examines the physical and material properties of liquid at far-from-equilibrium states and the strange phenomena they emit. Developing these qualities through their protean materiality, the tangible yet extraordinary nature of the living realm is characterised.
Environment

Looking outward to the blackness of space, sprinkled with the glory of a universe of lights, I saw majesty — but no welcome. Below was a welcoming planet. There, contained in the thin, moving, incredibly fragile shell of the biosphere is everything that is dear to you, all the human drama and comedy. That’s where life is; that’s were all the good stuff is. (Botkin 2001, 192)

‘Controls’ were invented during the Enlightenment so that bodies could be understood as things-in-themselves without interference by their surroundings — wild flowers, Ice Age megafauna, mists, sunbeams, a scurrying beetle, gardens, cities, graffiti, spilt remains of a Friday evening takeaway on the pavement, guano, layers of pollution on brickwork, the volatile perfumes of summer flowers, clumsy wings flapping in branches dripping with leaves, traffic jams, plane trails, the sigh of a spider as it repairs threads on its web, thunder and lightning, or a runaway balloon. These classical scientific experiments factor out even the simplest substances like soil, air, and water, since their embodied hypercomplexity and unpredictability cannot be meaningfully engaged using mechanistic frameworks, which are dedicated to elucidating simple causes and effects. This has set the stage for the neglect of our vital surroundings, which became regarded as little more than decorative settings for their occupants. While prized as picturesque backdrops for resource-efficient metropolitan environments, these two-dimensional images are devoid of real value or presence beyond their bucolic aesthetic. While it may be simpler to empirically and aesthetically understand abstracted bodies in this way — rather than engaging with their true materiality — such perspectives prevent us from discovering sophisticated ways of inhabiting places whereby the environment flourishes alongside human development.
With the onset of increasingly turbulent environmental conditions that characterise climate change, the language of disaster is unleashed, as an ‘arms race’ between humans and nature begins. Colossal barriers like the MOSE gates in Venice, create defensive walls to keep out the high tides (Armstrong 2015), and geoengineering technologies like fertilizing phytoplankton with micronutrient iron on the ocean surface, seek to alter the flux of carbon to the deep ocean and mitigate global warming (Buesseler et. al 2004). Even R. Buckminster Fuller’s Manhattan-scale biosphere proposes to achieve full control of our environments, so their resources can be exploited more efficiently through the better design of machines in ‘The Good Anthropocene’ (Fuller 2016, 387).

People learned to create by the force of their own will, and called themselves gods. Now the world was filled with millions of gods. But their will was subordinate to impulse, and so chaos returned to the Sixth World. There was too much of everything, though something new was always coming into being. Time started gathering speed, and people started dying from the effort of trying to make something that did not yet exist. (Tokarczuk 2010, 204–5)

Implicit in this ‘struggle’ for survival is that we cannot dissociate ourselves from our habitats. Giving shape and meaning to the way we dwell in them, they generate value and a sense of belonging, so we can ‘feel at home’ in certain places, fall in love with a city, tend gardens, construct buildings, clean up beaches, or make a whole range of lifestyle choices. These specific material details are our interface with the world, which is so particular and peculiar to the places we encounter they possess unique meaning. Environment is exactly why what happens today still matters tomorrow and ways of working are urgently needed, so that the generative forces that enable the processes of living can continue their unbroken legacy.
Our planet may be blue from the inside out. Earth’s huge store of water might have originated via chemical reactions in the mantle, [as well as] arriving from space through collisions with ice-rich comets. (Coghlan 2017b)

A very small amount of water, comprising less than 0.1% of the Earth’s mass, confers our planet with a ‘pale blue’ appearance from space. Even at the time of the ‘cool early earth’, 4.4 billion years ago, when there were no tectonic plates to buckle and bow into landmasses and mountains, our world was covered with water.

For perhaps half a billion years, the place was too hot for life. Water remained as vapour in an atmosphere rich in carbon dioxide, formaldehyde, neon and cyanide. Then, as the Earth began to cool, it rained for perhaps twelve thousand years without stopping, helping to create the first seas. (Logan 2007, 10)

Miraculously, our water reserves have not evaporated into the atmosphere and out into space, partly due to Earth’s gravitational pull but also because most of it is not contained in its surface bodies. Only around a third of our water is freely available in the hydrosphere, which contains around $1.6 \times 10^{21}$ kilograms of water, while the rest of it is bound as hydrous minerals like clay and mica within Earth’s crust. Another 0.1 to 1.5 additional surface hydrospheres are anticipated to be bound to minerals within the bigger, lower mantle. While it is challenging to estimate the water content of the deeper layers, which may even be devoid of water (Mottl et al. 2007), it is equally possible that up to 100 hydrosphere equivalents exist in Earth’s core. Although the origins of Earth’s water are thought to have been acquired during the Late Heavy Bombardment when ice-containing asteroids and comets pulverised the world’s surface around 4.1 to 3.8 billion
years ago, it may also have been produced by a simple chemical reaction that takes place between silica and hydrogen in the upper mantle, which is around 4–400 kilometres below the surface. Here, the necessary extreme conditions at temperatures of 1400°C and at pressures greater than 20,000 atmospheres could be met (Burnham and Berry 2017). Under great pressure, this chemically produced reservoir may be responsible for triggering previously unexplained earthquakes (Futera et al. 2017), and it seems that Earth is probably ‘wet’ (i.e., contains water), in some sense, ‘all the way down to its core’ (Coghlan 2017b).

The actual mass of liquid water in Earth’s substance, however, does not account for its uniqueness. This arises from its ongoing, active circulation, and keen bioavailability through soils, liquid, and gas, which plays a critical role in establishing the conditions for liquid life.

People who are born where there’s a lot of water, in fertile lakelands or on the banks of great rivers, are different. Their bodies are soft, fragile and insensitive, their skin is darker, with an olive tinge, cool and damp with blue veins beneath it. (Tokarczuk 2003, 191)
Ocean

... the class of ‘bodies without surfaces,’ as Leonardo da Vinci was to put it, [are] bodies that have no precise form of extremities and whose limits interpenetrate with those of other[s]. (Damisch 2002, 124)

Oceans comprise 97% of Earth's surface water environments which exist between Earth's breathable atmosphere and the crust's solid ground. Recurrently reconfiguring the near-shore environment, the vastness and depth of oceans means they are opaque to our gaze, while their complex and changing behaviour provides a metaphor and linguistic trope for a world in flux (Steinberg and Peters 2015). Possessing recognisable configurations that escape formal human encoding, they are understood ambivalently as: voids with no persistent features, passive receptacles, givers of life, bringers of destruction (Patton 2006), or hypercomplex spaces that exceed our capacity to fully observe and analyse them, which is even more profound when entangled with globalisation's toxic effluents (Gordillo 2014). While oceans have facilitated human settlement and established power relations, they are not reducible to their social uses or simple categories. Indeed, oceans and synthetic platforms comprise 'an ideal spatial foundation ... [that] is indisputably voluminous, stubbornly material, and unmistakably undergoing continual reformation' (Steinberg and Peters 2015), which demands their own language, so their vastness and strangeness can be appreciated not only in their generalities, but also through their details.

Inspired by dynamic, contingent liquid relationships, oceanic ontologies are expressive apparatuses and agents of causal emergence, rather than descriptive tools. They can simultaneously process events across multi-scalar domains without resource to abstraction, reduction, or hierarchy. Matt Lee proposes these systems can be imaginatively explored like actors that improvise within a complex environment. A reading of the 'plot' can be made through their exchanges, which 'present us with ... a way
of learning … that isn’t subject centred but created through the movement of transformation’ (Lee 2011, 130), so their character becomes more visible and familiar.

The Drowned Man was always discovering his potential anew. At first he thought he was weak and defenceless, that he was something like a flurry of wind, a light haze or a puddle of water. Then he discovered that he could move faster than anyone could imagine, just be thought alone… He also discovered that the mist obeyed him, and that he could control it as he wished. He could take strength from it, or a shape, he could move entire clouds of it, block out the sun with it, blur the horizon and extend the night.

(Tokarczuk 2010, 79)
Throughout the ages, water has been understood as fundamental to life. Thales of Miletus considered water as the ‘prime’ matter — one of the fundamental elements of existence, or *archai* — that governed the growth of plants and animals. Continually rising, undulating, and falling within watery landscapes, liquid bodies are fundamentally lively. Simultaneously imbuing and infiltrated by their surroundings, neither our natural senses, nor concepts, fully convey their protean nature, which allies them with the realm of monsters — entities from unseen realms that evade categorisation by formal classification systems.

A classical approach to describing the motion of liquids is possible using Lagrangian fluid dynamics, where an observer follows a ‘fluid parcel’, which moves through space and time. Typically, these are constrained by considering very small amounts of liquids, which can be identified within a specific field and trajectory of flow. While the mass of a fluid parcel remains constant, its volume and shape may change due to distortion caused by its situatedness within the liquid field. Additionally, the properties of the fluid parcel may evolve during the trajectory as the result of simple physical laws acting upon it, like molecular diffusion.

In contrast, unconstrained fluid bodies are difficult to read beyond their surface qualities and are commonly regarded as bland, or featureless. Claude Lévi-Strauss regards the sea as uninspiring (Lévi-Strauss 1973, 338–39), while Roland Barthes views the ocean as a ‘non-signifying field [that] bears no message’ (Barthes 1972, 112) and Michel Serres embraces the details of liquid bodies specifically the subversive ‘nautical murmur’ of the sea, which he regards as a symptom of its disturbing pervasive vitality (Serres 1996, 13).

It is at the boundaries of physics, and physics is bathed in it, it lies under the cuttings of all phenomena, a proteus taking on any shape, the matter and flesh of manifestations.
The noise—intermittence and turbulence—quarrel and racket—this sea noise is the originating rumor and murmuring, the original hate. (Serres 1996, 14)

Liquid bodies are anything but banal. Their subversive unpredictability and unruly pluripotentiality resists control, componentisation—and, ultimately, mechanisation, so we are ill-equipped to quell their monstrous transformations, or impose order upon their undifferentiated expanses.

Lewis Carroll’s satirical poem, ‘The Hunting of the Snark’, encapsulates the absurdity of trying to rationalise the liquid realm through the tale of ten intrepid adventurers' that set out with the aid of a blank map to find a creature, which will make them invisible.

He had bought a large map representing the sea, Without the least vestige of land: And the crew were much pleased when they found it to be A map they could all understand. ‘What’s the good of Mercator’s North Poles and Equators, Tropics, Zones, and Meridian Lines?’ So the Bellman would cry: and the crew would reply ‘They are merely conventional signs! Other maps are such shapes, with their islands and capes! But we’ve got our brave Captain to thank: (So the crew would protest) that he’s bought us the best— A perfect and absolute blank!‘ (Carroll 1946, 6)

On entering the featureless terrain, each explorer conjures the encounters their preconceptions of the space and during the journey succumb to their individual neuroses. Just as the Baker thinks he has found the Snark, he vanishes, since the creature is

1 The band of ten intrepid explorers in search of the Snark are: Bellman, Boots, maker of Bonnets, Barrister, Broker, Billiard-maker, Banker, Butcher, Baker and Beaver.
2 From: Fit the second — the Bellman’s speech (Carroll 1946, 6, lines 5–16).
actually a Boojum — which is a highly dangerous version of the species (Carroll 1946, 50).

The unfathomable complexity of liquid expanses opens up a space for transgressions where the classical expectations of the material realm are disrupted. In this protean space, encounters between occupying bodies and their medium begin to develop structural relationships with each other. This primes their receptivity and capacity to respond to continually altering contexts, so they undergo many transformations, which enrich the living realm. Although the invisible forces shaping this dance are not fully fathomable, they are of consequence, since in an uncertain terrain it is possible to come across a Boojum when we are looking for a Snark. Instead of becoming selectively blind to oceanic ontologies with notions of ‘blandness’, we must instead become familiar with the complexity of liquid bodies, as well as the perils and delights of their enabling media (Armstrong et al. 2017).
The floating and the bottom-dwelling invertebrates of the seas are memorials to the earliest strategies for achieving [osmotic independence], but although they acquired a skin, they did not acquire the ability to move under their own power. In a sense, they were and have remained cells in the vast organism of the ocean, which moves them at will. (Logan 2012, 12)

The bodies of water that make up our deltas, rivers, and oceans have been studied by seafarers since ancient times. Today, real-time Global Positioning System (GPS) networks observe our liquid world from space, offering generalisations about how these immense expanses of fluids perform. Much less is known about their particularities and peculiarities, which ‘learned to contain the sea’ (Logan 2007, 11).

Contestably, life began in a liquid environment — freshwater lake, river, or stream, rather than in an oxygen-starved ocean (Byrne 2014). Darwin proposed that biogenesis occurred in the uterine environment of a ‘warm little pond’ (Brouwers 2012), while Alexander Oparin and J.B.S. Haldane give accounts of ‘primordial soups’ rich with organic materials (Shapiro 1987, 110). Deep seafarers imagine the rich yet isolated marine ecologies around the ‘black smokers’ of abyssal geothermal vents — naturally occurring chemical ‘pressure cookers’ — as the original site for life’s origins (Colín-García et al. 2016). Others propose Earth was seeded with life by asteroids carrying alien molecules that catalysed the initial reactions — a theory called panspermia (Arrenhius 1908).

Whatever the nature of the initiating event, and wherever the location of its original context, the chemical principles of

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3 While deep oceans are conventionally thought to hold life’s origins, recent research suggests that active volcanic landscapes may have been the site for biogenesis (van Kranendonk, Deamer and Djokic 2017).
its progression through biogenesis are outlined by two distinct postulates.

The command-and-control style information first hypothesis argues that biological codes arose before energy-producing bodies. The most popular theory is RNA World (Neveu, Kim and Benner 2013), which centres on the dual properties of a smart molecule, ribose nucleic acid (RNA), which can catalyse reactions and also replicate itself without the need of an existing cellular apparatus. Early forms of life, therefore, evolved from concentrations of these molecules that enabled them to conserve biological functions and catalyse chemical reactions, which gave rise to the major domains of life.

The Virus World theory also centres on an information-first event and is closely related to the RNA World theory, but differs in the evolutionary sequence of events, where viral ancestors evolved before cells (Arnold 2014). From an evolutionary perspective, viruses are far more diverse than cellular life, with many more ways of replicating possible that viruses either predated or coexisted alongside the last universal common ancestor (LUCA). Supporting evidence for this theory is provided by the discovery of giant viruses such as mimivirus, pithovirus, megavirus, and pandoravirus that were characterised in 2013. Typically, viruses are considered degenerate life forms and relative latecomers in the story of life that lost the capacity to self-replicate, and so developed ways of hijacking more sophisticated cell systems. Giant viruses challenge these assumptions since they are larger than certain bacteria and possess huge genomes, which may contain genes that are absent from the major domains of life that are sufficiently complex to perform complex autonomous functions, like protein synthesis and self-replication. Some viruses contain the enzyme reverse transcriptase, which is not present in cells, but allows the virus to write themselves into a cell’s genetic code by translating viral RNA into DNA sequences. The ancestors of giant viruses may have even provided the raw material for the development of cellular life and catalysed its biodiversity (Mølleg 2013).
The Metabolism First hypothesis suggests that self-sustaining biochemical systems did not initially require centrally-coordinated biological information to form its persistent, yet open ‘metabolisms’. While the sequence of biogenesis may have been initiated by traumatic events such as collapsing bubbles (Kaison, Furman and Zeiri 2017), repeated chemical exchanges within stable liquid environments could also have performed this function. Some theories propose that rich mineral rock surfaces provided such an environment (Wächtershäuser 2000), which are capable of catalysing fundamental reactions like carbon fixation and forming polymers. Within these protective niches, stable metabolisms could become more complex and organised, eventually becoming enclosed within selectively permeable membranes and integrating with biological information-carrying systems to give rise to primordial beings.

In practice, it is most likely that biogenesis was not a single process, but a range of entangled chemical strategies that contributed differently to loosely associating groups of agents, or protolife. Becoming more organised over time, at some point the first biological entity, or LUCA, evolved. This hypothetical creature may not have been a singularity, but a collaborating consortium of lively agents whose distributed tactics became integrated, then subsequently inseparable, over the course of evolution.

Ingenious material exchanges alone are not enough to precipitate vivogenesis — something unusual has to happen.
Life is a constant form of circulating matter. (Whewell 1840, 46)

Hippocrates, Plato, and Aristotle believed the body was governed by fluidic forces or ‘humours’ with melancholic, phlegmatic, choleric, and sanguine qualities. The humoral theory that governed these liquids proposed that imbalances in their proportions could cause disorder and provoke erratic conduct, so ‘treatments’ were choreographies of well-being that were titrated to the patient’s condition. Some were subtle, such as making alterations in dietary habits, exercise, and herbal medicines, while other therapies were aggressive. Most illnesses were attributed to excesses of the humours, which were purged from the body using a range of techniques, including laxatives, emetics, skin blistering, and bloodletting, which were thought to draw out toxins.

The constituents of the body — blood, phlegm, yellow bile and black bile — remain always the same according to both convention and nature. Phlegm is quite unlike blood, blood being quite unlike bile, bile being quite unlike phlegm. How could they be like one another when their colours appear not alive to the sight nor does their touch seem alike to the hand? For they are not equally warm, not cold, nor dry, not moist. If you give a man a medicine which withdraws phlegm, he will vomit you phlegm; if you give him one which withdraws bile, he will vomit you bile. Similarly, black bile is purged away if you give a medicine which withdraws black bile. And if you wound a man’s body so as to cause a wound, blood will flow from him. And you will find all these things happen on any day and on any night, both in winter and in summer, so long as the man can draw breath in and then breathe it out again, or until he is
deprived of one of the elements congenital with him. (Ray 1934, 120)

Although zoological observations during the scientific revolution were underpinned by the bête machine, the development of the field of physiology was described through liquid metaphors (Nicholson 2018, 13). Sanctorio Sanctorius was the first modern student of metabolism, who discovered the perspiratio insensibilis as the loss of an invisible body substance by measuring the quantities of his food, drink, urine, and faeces over a period of thirty years. This ‘insensible perspiration’ became an indicator of ongoing continuous exchanges and the premise for the physicochemical basis of life (Bing 1971).

… [a unicellular organism] is a perfect laboratory in itself, and it will act and react upon the water and the matters contained therein, converting them into new compounds resembling its own substance, and at the same time giving up portions of its own substance which have become effete. (Huxley 1897, 42)

Luigi Galvani’s (bio)electricity, or ‘animal electric fluid’, was also considered responsible for the vitalisation of tissues, until Alessandro Volta (re)interpreted these flows and demonstrated them within the context of (dry)electronic circuits, which repositioned this ‘vital’ force within the context of the bête machine.

… I eagerly inquired of my father the nature and origin of thunder and lightning. He replied, ‘Electricity;’ describing at the same time the various effects of that power. He constructed a small electrical machine, and exhibited a few experiments, he made also a kite, with a wire and string, which drew down that fluid from the clouds. (Shelley 2014, 57)

At the start of the twentieth century researchers delved more specifically into the particulars of life and fluids where increas-
ingly, the study of the bodily flows that made up a creature’s physiology were discussed in terms of metabolism. Alfred North Whitehead developed a ‘philosophy of organism’, while Edward Stuart Russell likened living processes to the persistent ripples that a stone makes in a stream (Russell 1924, 6) and Edmund Sinnott preferred to draw analogies between the living realm and the fluid form of waterfalls (Sinnott 1955, 117). Ludwig von Bertalanffy applied liquids as a conceptual framework for the manifestation of natural systems (von Bertalanffy 1968, 27), where biological structures arose from the flow of matter transformed by living processes. Lifelike structures within complex chemical phenomena could also be identified and used as experimental models to test these concepts, as in the Rayleigh–Bénard convection cell, an analogue system for exploring the principles of fluid cells. Life as a dynamic process was particularly embraced by the field of biochemistry (Gilbert 1982) being more broadly adopted into scientific investigation by Conrad Hal Waddington (1957, 2) and Carl Woese (2004).

Although the generalities of flow, change, and environmental responsiveness are encapsulated within a fluid metaphor of life, exactly how these properties are expressed through living systems remains elusive, since the dynamics and behaviour of liquids is extremely complex. The most powerful criticism of the ‘waterfall’ analogy for life was that it was incomplete, particularly with respect to its inability to produce ‘other whirlpools like itself’ (Thomson 1925, 123). Implicit in this difficulty was the question of ‘modification by descent’ (see section 04.2), where parents pass traits on to their offspring, which was at the heart of inheritance discourses during the nineteenth century. This concept was particularly resistant to liquid metaphors, as blending fluids leads to homogeneity, not diversity. Unlike the inert materials used to build machines, fluid dynamics must be considered under a range of different states, and while some liquids behave according to the classical laws of physics, others are non-linear and capable of changing phase, or state (gas, liquid, solid). Although the contemporary field of fluid dynamics is highly sophisticated, the range of possibilities is so vast and operate...
at such a range of scales — from microfluidics to oceans — that many questions about the capabilities of liquids remain partly, or completely unresolved.

In the early twentieth century, the liquid metaphor was adopted into the field of embryology by Jacques Loeb, who shifted the challenge of fertilisation from the realm of (protean) morphology to that of physical chemistry. This allowed descriptive and often speculative work, to be empirically evaluated (Allen 2018, 6). While evo-devo, the field of evolutionary developmental biology where organisms change over time, is compatible with notions of fluidity, the strategies for testing its liquid principles are elusive, even with an understanding of chemistry. At the time when evo-devo arose in the 1880s from the field of developmental biology, heredity was regarded ‘as identical to the problem of development’ (Morgan 1910), but this soon changed into a more atomistic narrative over the course of the twentieth century.

… biology … evolved two traditional approaches to characterise the physical basis of life. In each, the ‘natural order of rank’ is the reverse of the other. The first tradition [molecular biology/genetics] emphasises the phenomena of growth and replication as the major vital characteristics. Organisms are seen to increase in size and numbers and are thus akin to crystals. The second perspective [biochemistry/embryology] focuses on metabolism as life’s prime requisite, whereby an organism retains its form and individuality despite the constant changing of its component parts. In this respect, living beings resemble waves of whirlpools. These alternative crystalline and fluid models of organisms have interacted with each other for the past hundred years. (Gilbert 1982, 152)

During the mid-twentieth century, liquid and crystal substrates were forcibly separated as equal organising life-forces through ideas underpinning the developing field of genetics. By positioning genetics as the primary agent of heritability, Wilhelm Johannsen cleaved the study of (entangled) phenotype from
(distilled) genotype, privileging the study of genetics over embryology (Sapp 1983). While many biologists tried to reconcile the two fields, this proved theoretically and practically incompatible, as each discipline was now only able to give a partial account of the other (Waddington 1940, 3). The ensuing dichotomy between genetics and embryology was further augmented by ongoing debates in biochemistry and molecular biology, where more mechanistic perspectives ousted fluidic accounts, resulting in the Modern Synthesis (Rose and Oakley 2007; Laubichler and Maienschein 2007; Reid 2007). During the 1940s and 1950s the fields of genetics and molecular biology took a decidedly mechanistic turn. Max Delbrück, one of the founders of molecular biology, who studied gene transmission as a precise measurement of biological effects, felt that biochemists were misrepresenting the cell as ‘a sack full of enzymes acting on substrates, converting them through various intermediate stages either into cell substance of waste products’ (Gilbert 1982, 159–60). In his view, they had ‘stalled around a semi-descriptive manner without noticeably progressing towards a radical physical explanation’ (Gilbert 1982, 151). With a new emphasis on structured information, crystals—which had been identified as the most lifelike substances in the seventeenth and eighteenth centuries—were now considered ‘the nearest analogue to the formation of cells’ (Gilbert 1982, 154). Inspired by Delbrück, who regarded the gene as a crystal, Schrödinger’s 1944 essay What Is Life? exerted a powerful influence in validating the study of crystallinity as a state that could unify all matter, where ‘the most essential part of a living cell — the chromosome fibre — may suitably be called an aperiodic crystal’ (Gilbert 1982, 159). John Desmond Bernal, who pioneered the use of X-ray crystallography in molecular biology, also viewed crystals as components of cells and ‘proof’ of life (Gilbert 1982, 158), which consolidated the Modern Synthesis as the dominant worldview of life by the late twentieth century.

... by 1940 the lines were being drawn. Biochemistry, concerned with intermediary metabolism and the energy
that drives it, worked well within the tradition of flux and thermodynamics. However, the portion of the life sciences concerned with the transmission and expression of inherited characteristics rejected this view for the tradition of crystalline morphogenesis. Not only did the gene just not fit into the whirlpool model, but it looked as if functional genes (i.e. viruses) could even be crystallized. Whereas the principal characteristic of life for the biochemist was metabolism, life’s principal characteristic for the molecular biologists was replication. Furthermore, the primary unit of life for the biochemist was the result cell (metabolically active but not replicating), whereas the unit of life for the molecular biology was the virus — crystalline, nonmetabolising, and capable of enormous feats of replication. (Gilbert 1982, 159)

In 1937, Haldane predicted that classical biochemistry would be superseded by a new branch of biochemistry arising from the realm of genetics. During the second half of the twentieth century, liquid and mechanistic approaches were reconciled through the (re)approximation of molecular biology/genetics with biochemistry/embryology to conceive of networks of control (master) switches, capable of triggering developmental cascades. This more detailed understanding of the building blocks of life has been accomplished by new tools and techniques that are able map the appearance of creatures alongside their genetic material. New light is now being shed on one of the most surprising findings over the last 30 years in genetics — that there is remarkably little difference between the genes that are common to all known life forms. Although mice and humans are phenotypically very different, they share almost the same set of genes (Gunter and Dhand 2002), which were also present in ancient creatures. Alternative accounts of how such small numbers of critical genes can be differentially expressed over a broad range of contexts are emerging as a result of these new approaches. For example, cellular noise, which is non-linear and leads to symmetry breaking, seems to be extremely important in very
early embryo development and causes non-deterministic down-stream effects, which result in substantial differences between cells (Mohammed et al. 2017). The critical role of phenotypic ‘architecture’ is also being revealed in developmental processes, which includes factors such as epigenetic interactions, the chemophysical properties of developing cells and the influences of environmental parameters (Müller 2007).

While major challenges remain for evo-devo, its focus on peculiar, particular, non-deterministic and highly localised events provides a counterpoint to genetic theories, which deal with the averaging of large numbers of molecules that are observed in populations of organisms. Whether it is possible to reconcile these perspectives within a ‘unifying biological theory’ remains to be seen. Such a framework may be provided by new discourses that position metabolic networks as the dominant systems in regulating cell function. Víctor de Lorenzo likens the interplay of DNA and metabolism to that of politics and economy, where both systems regulate their own autonomous agendas, while influencing each other. Positioning metabolism as ‘the economy of living systems’, he observes that this ultimately determines the viability of any political moves, as it frames and eventually resolves whether any given genetic program will operate, or not (de Lorenzo 2015).

… both the metabolites and the biochemical fluxes behind any biological phenomenon are encrypted in the DNA sequence. Metabolism constrains and even changes the information flow when the DNA-encoded instructions conflict with the homeostasis of the biochemical network. Inspection of adaptive virulence programs and emergence of xenobiotic-biodegradation pathways in environmental bacteria suggest that their main evolutionary drive is the expansion of their metabolic networks towards new

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4 Challenges mainly relate to how evo-devo accounts for structural complexity, which is challenging to establish using empirical modes of testing, and its relationship to the population dynamics of classical evolutionary theory.
Since chemical landscapes radically increase the combinatorial potential of cell operations, Frederick Coolidge suggests a primordial platform for vivogenesis that approximates the RNA World hypothesis with metabolism’s first concepts. Proposing that early nuclear building blocks were made up of a larger range of primordial nucleotide chemical precursors than observed in RNA today,⁵ they could explore and exploit emerging chemical landscapes to evolve the relationship between ‘information storage’ systems and active metabolisms, which were also likely subjects for Darwinian natural selection (Coolidge 2017).

Liquid life’s challenge is not whether the fluidity of bodies is real but how its foundational ideas become demonstrable and testable, since few technological systems can visualise, model, and realise its protean character. In other words, we must learn how to build and experiment with liquids.

⁵ The nucleotides of RNA are: adenine, cytosine, guanine, and uracil.
Origins of Dissipative Propagation

Diderot was arguing against the mathematical mechanist conception of matter while today mathematical, physical and chemical physical references help to destabilise the blind watchmaker’s unilateral responsibility: chaotic systems, edge of chaos systems, dissipative structures, neural networks, all those objects have opened up new possibilities, new problems and new bridges. (Stengers 2000, 97)

While molecular interpretations of the bête machine attribute the character-specific properties of matter to crystalline states, liquids also confer unique order on systems. In liquid phases, molecules can freely associate and form transitional states of potentiality, as well as spatially orienting themselves in relationship to a site.

The primary operative agents of liquid life are not bounded cells instructed by central biological programs but are also derived from the broader spectrum of propagative agents at far-from-equilibrium states such as, dissipative structures (see sections 08.9). While these hubs of matter/energy are recognisable as singular entities, they can also link together to form massively distributed nuclei of activity across the surface of the planet, which not only form weather fronts but also form types of ‘metabolic weather’ (see sections 01.14 and 05.23). Such structures can be seen grinding away on the surface of Jupiter, which is pockmarked with a number of stable and violent storms. The most notorious of these is the Great Red Spot, which is twice as wide as the Earth and is potentially more than 150 years old. A lesser-known system is the String of Pearls, a caravan of eight storms rotating anti-clockwise on the southern hemisphere of the gas giant (Loria and Mosher 2016). Terrifyingly, the storms (Irma, Jose, Katia) that razed the Caribbean and Florida in September 2017 and also in 2014 (Charley, Ivan, Jeanne, Francis) bore remarkable similarity to this formation, raising the ques-
tion of whether an impending feature of climate change will be the onset of stable, effectively permanent storms. Such self-organising and persistent systems also constitute the low-level infrastructures of organisms. Becoming increasingly organised with time, they adapt, alter their surroundings, evolve, and contribute collectively to the active forces of nature.

Existing at many different scales, dissipative structures are more than background support for events. They are dynamic structuring systems whose interfaces provide sites for symmetry breaking and a range of specific spatial and material events. In fact, stability rather than change is a conundrum for liquid life, where permanence is an illusion orchestrated through highly persistent but mutable structures in constant motion. These paradoxical objects, which are simultaneously stable and unstable, confer integrity to dynamic bodies — not through stability, but through their repetitions and iterations of networked processes. Here, interiority and exteriority permeate each other through a constant choreography, which takes place between lively agents that shape developmental pathways. This tightly coupled system, which is a hallmark of dissipative structures, provides a highly robust, discursive platform for the synthesis of hyperlocal solutions, although it is also vulnerable to the potentially devastating effects of turbulence. Such configurations, however, possess many more degrees of freedom than are possible within the linear relationships and hierarchical ordering systems that typify classical machines, and can therefore mount creative resistance to external perturbations.

Liquid bodies persist when differential gradients are maintained across local micro-niches and environmental locales. Early life forms were likely leakier and more plastic than modern biological cells. Cradling dissipative bodies within them, molecular ‘skins’ provided quiet spaces for the accumulation of boundary-forming substances such as fatty molecules and set the scene for open niche construction. This enabled primitive

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6 This observation was made by Nathan Morrison, CTO of Sustainable Now Technologies, on Facebook on 7 September 2017.
bodies to respond to, and organise around, local metabolic opportunities. Before biogenesis, the first liquid bodies may have stabilised upon oily films, or within porous networks in hydrothermal vents (Priye et al. 2016). Pinched off by lipid films, chemical environments became ‘internalised’ and established matter/energy gradients. Mediated across leaky interfaces, the accumulation and diffusion of local molecular species enabled the first metabolisms to stabilise. With many iterations of exchanges, different kinds of gradients were established, setting the foundation for primitive bioenergetics, where important metabolic pathways that couple bioenergy and biomass were highly conserved, like pathways leading to acetyl CoA formation (Nitschke and Russell 2013).

Even without formal borders, the compartments of the earliest life forms were sufficiently deformable, and capable of internalising other structured spaces through endosymbiosis. This takes place when one body swallows another without wholly assimilating, or digesting, its contents. Biological cell organelles today such as the nucleus and the mitochondrion, give testimony to such remarkable mergers that took place early in eukaryotic life — perhaps when an archaeon engulfed a bacterium and the subsequent, symbiotic relationship became irreversibly and successfully intertwined. Formal cellular environments would have only been possible when membranes became sophisticated gatekeepers of internal metabolic conditions and were capable of regulating them in ways that enabled primordial cells to adapt to environmental changes.

In keeping with its far-from-equilibrium nature, liquid life’s influence on its surroundings extends beyond the limits of its physical boundaries. Innately agentised, its behaviours, metabolism, ‘liquid consciousness’ and soul substance — the winds that surround the cellular eye of the storm — produce tangible changes that can be encountered through their effects on other bodies like heat, vibration, and presence.7 Embracing all agentised

7 In this instance, ‘presence’ refers to the existence of being that, by virtue of its intangible (far-from-equilibrium state) emissions, generates effects
material epiphenomena (crystals, cells, bodies, ecosystems), it is expressed across geological and evolutionary scales, its ‘vital’ agency flowing through its constituent bodies: lively materials, metabolic networks, ecologies, and nurturing planetary systems, and constitutes an (effectively) immortal hyperbody.
Transitions

The inability of liquid life to stay still is not an error, which assumes an end goal, but an impeccably tuned system with countless tolerances and protean states.

Liquid life persists through its fundamental disobedience, in slingshots of thermodynamic resistance, where lively matter twists in corkscrewing iterations of molecular ingenuity away from the direct and efficient path towards thermodynamic equilibrium.

So far, liquid life has successfully persisted during the ever-changing and challenging contexts of the terrestrial realm, despite five major mass extinctions and many more annihilations during the Hadean epoch, when the Earth hissed and boiled.

This capacity to resist thermodynamic decay is embedded in the unfathomably strange and massless fundamental particles that constitute liquid life’s myriad bodies whose unfathomably peculiar fields enfold us within the strangest substance in the universe.
05.9
Mind as Substance

The hard problem of matter calls for non-structural properties, and consciousness is the one phenomenon we know that might meet this need. Consciousness is full of qualitative properties, from the redness of red and the discomfort of hunger to the phenomenology of thought. Such experiences, or ‘qualia,’ may have internal structure, but there is more to them than structure. We know something about what conscious experiences are like in and of themselves, not just how they function and relate to other properties. (Mørch 2017)

While Descartes justified human rationality through the soul, other views of consciousness couple it to matter (Dyson 1979; Armstrong 1993) and life (Shanta 2015). In Western cultures, various concepts—higher order theories, reflexive theories, representationalist theories, narrative interpretative theories, cognitive theories, information integration theory, neural theories, quantum theories, non-physical theories (van Gulick 2014)—give accounts of how awareness and capacity for self-observation are produced. Neither fully produced within the self, nor purely channelled into a body from elsewhere, David Chalmers describes consciousness as a ‘hard problem’ that inevitably exceeds our ability to provide a complete account of its effects. ‘Explaining’ the nature of consciousness is particularly challenging, as like the soul, it is not governed by the (scientific) laws of the bête machine. It is therefore impossible to provide a rational account through the laws of classical physics.

If the flesh came into being because of spirit, it is a wonder. But if spirit came into being because of the body, it is a wonder of wonders. Indeed, I am amazed at how this great wealth has made its home in this poverty. (Meyer and Bloom 1992, 37)
Drawing on alternative physical laws, Roger Penrose and Stuart Hameroff invoke the power of the quantum realm within nerve cell microtubules to offer ‘quantum consciousness’ as an alternative organisational model capable of offering a non-reductive explanation of consciousness, (Hameroff and Penrose 2014; Paulson 2017). In this book ‘liquid consciousness’ (see section 01.13) is presented as a way of discussing the receptive creativity and ‘wilful’ behaviour expressed by matter at far-from-equilibrium states, which is dynamically coupled with its structure.

Dissipative systems offer a significant advantage in providing an investigative platform for understanding notions of ‘consciousness’ from first principles in non-humans, as unlike quantum phenomena and ‘living’ biological brains, they can be directly observed and possess an apparent degree of ‘subjectivity’, which is governed by their extreme sensitivity to context. Each dissipative structure is an organising centre of information-gathering and action-making, like extremely primitive cells that can form coupled chains of activity (see chapter 09). This simple visualisation system provides a way of observing how a material structure can produce the phenomenological effects of a directly coupled sensor-effector system, in a testable, observable manner. Actuated by flow across interfaces, dissipative systems simultaneously alter themselves and their surroundings, by generating inhibitors (waste products), facilitators (catalysts) and physical obstacles (crystal skins). The decision-making capacities of these dynamic systems are located at the interface between oil and water, where they are amplified to produce observable, macroscale effects, through which they appear to make ‘sense’ of the world. As chemical activity is converted into kinetic energy, the droplet bodies are propelled forwards and move freely, encountering other active fields that maintain their liveliness. Contextualised and infiltrated by their surroundings, the material interfaces between active fields of chemical exchange, act as sensors, translators, and effectors of an (inner) materiality and an (outer) environment that may encode particular ideas, languages, images, and modes of expression. These can be read as a mode of ‘analogue pattern computing’, whose
emerging patterns correspond with primitive (material) forms of ‘decision making’ and constitute the emergence of a ‘dissipative mind’ (Medlock 2017).

... long before we were conscious, thinking beings, our cells were reading data from the environment and working together to mould us into robust, self-sustaining agents. What we take as intelligence, then, is not simply about using symbols to represent the world as it objectively is. Rather, we only have the world as it is revealed to us, which is rooted in our evolved, embodied needs as an organism. Nature ‘has built the apparatus of rationality not just on top of the apparatus of biological regulation, but also from it and with it,’ ... we think with our whole body, not just with the brain. (Medlock 2017)

The trails of transformation that emanate from these agentised bodies are expressions of ‘metabolic weather’ (see sections 01.14 and 05.23). Like thought processes, they generate unfathomably complex phenomena, which resist abstraction and simple causal explanations, but also leave behind physical residues that alter and complexify their surroundings. These spatially and temporally distributed substances may be read as a kind of ‘short-term physical memory’ that is not encoded within the body but is ‘remembered’, or understood, through ongoing encounters with its local metabolites. If the actions are repeated, then ‘long-term memory traces’ are consolidated as persistent structures, which constrain free movement within the active (cognitive) field/space. If these are not continually reinforced, they may be physically eroded by physical processes such as diffusion, or actively metabolised by other agents, which constitutes a kind of material ‘forgetting’. Beyond the prebiotic realm, colonies of single-celled organisms also chemically coordinate their behaviours to establish conditions for cohabitation like biofilms, slime moulds, and siphonophores (see section 07.4). Carrying the seeds of sensibility across many scales, these ‘dissipative minds’ are coupled with a whole range of embodiments (and evolving
memories) through a range of sensations, feelings, behaviours, and memories. The overall ongoing expression of these entanglements exemplifies ‘liquid consciousness’, which is always appropriate for the various forms of embodiment through which it is expressed, and neither aspires to be biological, nor ‘human’.
In-between

Where is she? Not there — not in heaven — not perished — where? Oh! You said you cared nothing for my sufferings! And I pray one prayer — I repeat it till my tongue stiffens — Catherine Earnshaw, may you not rest as long as I am living; you said I killed you — haunt me, then! The murdered do haunt their murderers, I believe. I know that ghosts have wandered on earth. Be with me always — take any form — drive me mad! Only do not leave me in this abyss, where I cannot find you! Oh God! It is unutterable! I cannot live without my life! I cannot live without my soul!
(Bronte 2009, 118)

When a body is intrinsically entangled with its ‘soul substance’ and leaves residues of its presence within a space, as in the case of dissipative structures, encounters with transitional presences and beings, that are neither fully material, nor agentised, become possible.

Throughout the ages, these angels, demons, spirits, and ghosts, are often encountered during heightened states and in places that are emotionally ‘charged’. A contemporary limbo is encapsulated by the paradox of Schrödinger’s cat, which shares Hamlet’s dilemma of being (to exist, or not), where such indeterminate beings are gateways between one state of existence and another. These are not purely imaginary situations but are based on actual experiences and have even been designed for since antiquity through tombs, where bodies were either preserved through mummification, or thoroughly rotted down, to ease their passage of their ‘soul’ into the afterworld.

When you think you’ve died, you haven’t actually died.
Death is a two-stage process, and where you woke up after your last breath is something of a Purgatory: you don’t feel dead, you don’t look dead, and in fact you are not dead. Yet.
(Eagleman 2010, 43)
From the moment that someone's heart stops beating, life's fluids no longer sustain the tissues and territory the body dies. Advances in modern medicine however, can artificially induce physiological holding-states, where vital organs such as the lungs and heart remain perfused and so, keep the brain 'alive'. These modes of life-suspension redefine the notion of 'death' and those that have been resuscitated during medical procedures report memories of these transitions, which vary from delightful to horrifying.

There were those who reported feeling afraid or suffering persecution, for example. ‘I had to get through a ceremony ... and the ceremony was to get burned,’ one patient recalled. ‘There were four men with me, and whichever lied would die ... I saw men in coffins being buried upright.’ Another remembered being ‘dragged through deep water’, and still another was ‘told I was going to die and the quickest way was to say the last short word I could remember’. (Nuwer 2015)

While such accounts may be little more than attempts to rationalise aberrant brain activity, studies of cardiac arrest survivors at New York University’s Langone School of Medicine revealed that many could recall conversations at the scene of their death, some even hearing they had been pronounced dead (Parker 2017).

They’ll describe watching doctors and nurses working; they’ll describe having awareness of full conversations, of visual things that were going on, that would otherwise not be known to them … (Parker 2017)

Empirical evidence also suggests that the body continues to ‘live’, even after certain technical criteria for death have been met. Animal experiments indicate that gene activity occurs for up to two days after death, which may be a natural response to tissue damage, and raises important genetic questions about the
definition of death (Williams 2016). Whether illusory or real, these intermediary expressions of ‘life’ are the cultural dominion of angels, where the mythological and material worlds mingle and establish the limits of what it means to be ‘alive’, ‘dead’ and acknowledge the existence of the liminal states in-between.

In this part of the afterlife, you imagine something analogous to your Earth life, and the thought is blissful: a life where episodes are split into tiny swallowable pieces, where moments do not endure, where one experiences the joy of jumping from one event to the next like a child hopping from spot to spot on the burning sand. (Eagleman 2010, 43)
Life did not crawl out of the sea onto the land; it oozed from the sea into the land, the organic acids of its excretions joining with the carbonic acid of the rainfall to create the first soft mantle of soil on the Earth. Maybe two billion years ago, the cyanobacteria began to use the sunlight to make sugars, excreting oxygen. They were green or brown, and their scum spread into lagoons, up rivers. The oxygen reacted with iron and for the first time there were orange, yellow, and brown colours in the earth. (Logan 2012, 12)

Soil is the living skin of the planet. There is not just one kind of soil, but many different types, which form giant bodies that are permeated with liquid life and are teeming with living systems and creatures. They reach down deep into the physics and chemistry of Earth's planetary system, occupying the interface between air, water, ground, biology, the land, and chemistry.

Soil is not unalive. It is a mixture of broken rock, pollen, fungal filaments, ciliate cysts, bacterial spores, nematodes and other microscopic animals and their parts. ‘Nature,’ Aristotle observed, ‘proceeds little by little from things lifeless to animal life in such a way that it is impossible to determine the exact line of demarcation.’ Independence is a political, not a scientific, term. (Margulis, and Sagan 1995, 19–20)

We walk and build upon these extraordinary hypercomplex, living fabrics as if they were inconsequential but within their substance, they forge the very webs of metabolic exchange upon which all life ultimately depends. A teaspoon of fertile earth houses more kinds of microbes than there are people on the planet and bacteria also colonise our bodies as symbiotic communities. Since the 1990s, this ‘microbiome’ is now recognised
as a distributed ‘organ’, which carries out a range of functions (Lederberg and McCray 2001).

Life is bacterial and those organisms that are not bacteria have evolved from organisms that were. … Gene exchanges were indispensable to those that would rid themselves of environmental toxins. … Replicating gene-carrying plasmids owned by the biosphere at large, when borrowed and returned by bacterial metabolic geniuses, alleviated most local environmental dangers, provided said plasmids could temporarily be incorporated into the cells of the threatened bacteria. The tiny bodies of the planetary patina spread to every reach, all microbes reproducing too rapidly for all offspring to survive in any finite universe. Undercover and unwitnessed, life back then was the prodigious progeny of bacteria. It still is. (Margulis and Sagan 1995, 111)

While soils are bringers of life, they are also intimately and creatively involved in the process of death. When a creature dies, its microbiome is no longer constrained by the host’s immune system and begins to consume the corpse, marking its transformation into the thanatobiome.

The microbiome goes on changing in response until death. Then the microbes will do their best to carry on elsewhere. First, though, they will consume the nutrients that leak from our dying cells. (Turney 2015, 132)

Working with the soil bacteria and a community of decomposers, the thanatobiome changes again to mingle with soil ecosystems to become the necrobiome. Returning organic matter and minerals into the life-bearing systems of soils, their webs of exchange are orchestrated by even more diverse communities of organisms than takes place within living bodies that are policed by their immune systems.
the dead trunk is as indispensable for the cycle of life in the forest as the live tree. For centuries, the tree sucked nutrients from the ground and stored them in its wood and bark. And now it is a precious resource for its children. But they don’t have direct access to the delicacies contained in their dead parents. To access them, the youngsters need the help of other organisms. As soon as the snapped trunk hits the ground, the tree and its root system becomes the site of a culinary relay race for thousands of species of fungi and insects. Each is specialised for a particular stage of the decomposition process and for a particular part of the tree. And this is why these species can never pose a danger to a living tree — it would be much too fresh for them. Soft, woody fibres and moist, mouldy calls — these are the things they find delicious. (Wohlleben 2016, 133)

The particle of gold falls to the bottom and rests — the particle of dead protein decomposes and disappears — it also rests: but the living protein mass neither tends to exhaustion of its forces not to any permanency of form, but it is essentially distinguished as a disturber of equilibrium so far as force is concerned — as undergoing continual metamorphosis and change, in point of form. (Huxley 1897, 43)

From active processes of this kind, where creatures engulf, partially digest, or fully digest others, the linking of life and death has maintained continuity since biogenesis. As strategies for persistence evolve, their limits and constraints have changed over the course of 3.5 billion years, but the active upcycling
of organic matter remains fundamental to life’s ongoingness and evolution on this planet.

I work in evolutionary biology, but with cells and microorganisms. Richard Dawkins, John Maynard Smith, George Williams, Richard Lewontin, Niles Eldredge, and Stephen Jay Gould all come out of the zoological tradition, which suggests to me that, in the words of our colleague Simon Robson, they deal with a data set some three billion years out of date. Eldredge and Gould and their many colleagues tend to codify an incredible ignorance of where the real action is in evolution, as they limit the domain of interest to animals — including, of course, people. All very interesting, but animals are very tardy on the evolutionary scene, and they give us little real insight into the major sources of evolution’s creativity … I refer in part to the fact that they miss four out of the five kingdoms of life. Animals are only one of these kingdoms. They miss bacteria, protoctista, fungi, and plants … Of what are they ignorant? Chemistry, primarily, because the language of evolutionary biology is the language of chemistry, and most of them ignore chemistry. (Brockman 2011)

While vertebrates are much more recent in evolutionary history than bacteria, they are used as the dominant ‘model’ in accounting for the lively potential of matter. In expanding our view of the capabilities of the living realm, much more robust, diverse, and unconventional models of ‘life’ are needed.
Hydrous Bodies

The sea was the proto-soil, where earth, air, water, and the solar fire met for the first time. It was an inverse soil, you might say, with the liquid element providing the matrix for the mineral salts and for dissolved gasses, a role that the mineral elements would later come to play. But from a certain point of view, all Earth’s later history is a consequence of that first mixing. (Logan 2007, 11)

Our bodies are 65% water by weight, which entangles us with the nature of other liquid bodies and their vastness. According to Giles Deleuze and Felix Guattari, the plane of ‘immanence’ (or birth) is a fluid substratum, or ‘body without organs’ (BwO) that is ‘permeated by unformed, unstable matters, by flows in all directions, by free intensities or nomadic singularities, by mad or transitory particles’ (Deleuze and Guattari 1987, 45). Such BwOs are ‘organism[s] without parts which operate[s] entirely by insufflation, respiration, evaporation, and fluid transmission’ (Deleuze 2015, 101). Such monstrous, exquisite, hyperobjects provoke awe and consternation — like encountering the night sky for the first time. Oscillating between the quantum and cosmic realms, these quasi-beings that are both inside and beyond us, question the classical view of reality and identity, where our concepts of finitude, the nature of objects, their relationship with time, our baselines of stability, locality, identity, scale, or human sanction, need to be restated.

It is wrong to say I think: one should say I am thought … I is an other. (Rimbaud 2004b, 288)

Hydrous bodies do not possess fragile egos. They are not alienated by the gargantuan, uncategorisable, or monstrous aspects

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In a letter to Georges Izambard, Charleville, May 1871.
of reality, and strike robust alliances with unknowns that enrich their portfolio of diversionary tactics in eluding entropy’s call.
Origins of Liquid Life

Liquid bodies were the first protolife that were sustained by iterative events within a flow of resources — light, reducing gases, crumbs of organic matter and mineral matrices, which set the stage for the theatre of terrestrial life. This section tells a story that conjures a pre-biological era at the origins of liquid life. It begins on the violent surface of our molten planet — a primordial landscape of liquid fire, choking gases, and searing radiation — where there is no competition for resources between bodies. Here, excitable fields of matter at far-from-equilibrium states start to overlap and produce undulating interfaces, where the weirding of Earth’s matter begins.

Wraiths of matter/energy fuelled by volcanic heat and cosmic radiation pass through each other. Sowing seeds of dissipative evolution they evade the planetary system’s march towards thermodynamic stability, or death. Imbibing the sunlight, greasy bodies pool on rocky surfaces, the cannibalise their surroundings and feed off each other’s turbulences.

These boiling seas are teeming with protolife.

Boundaries break and split, as tiny dissipative structures form dominant loci of activity. Little more than fluctuations with unregulated metabolisms, they reach into the tempestuous fields that roam these landscapes, exchanging structure for heat. Guided by passions and mischief, rebellious protolife searches for spandrels that promise opportunities for alternative modes of flourishing. Some bodies collapse and die, while those that resist the temptation of entropy, meander through varied pathways.

As proto-organism and mineral become inseparable, they form living rocks, which scar the world with their residues and inhibitors. Spewing monster after monster into the hostile surroundings, as kith, not offspring, lively surfaces spawn a host of liquid bodies. None are identical to their precursors, nor are they self-similar. Compulsively producing more oddities, each stranger than the last, the vortices of these vagrant droplets function like gizzards,
grinding matter into new configurations and assimilating their surroundings into their substance during this process.

Becoming more ordered with time, they begin to take on distinctive forms.

Over aeons, colonies of interacting bodies cooperate as aggregations and assemblages, while surreptitiously trying to digest them. There are no ‘pure’ organisms here, just lively collectives of material persistence that leak around their edges. Avoiding the direct pathway towards efficient chemical collapse, they dawdle through time in search of abundance, creativity, and subjective encounters, leaving footsteps of chemical transformation and rich soils in their wake. With the shock of reaching relative equilibrium, each generation of liquid bodies finds temporary rest and mingles with the accreting soils, when maybe tomorrow, or millions of years from now, their restless chemistry (re)enters the living realm.
Water is sometimes sharp and sometimes strong, sometimes acid and sometimes bitter, sometimes sweet and sometimes thick or thin, sometimes it is seen bringing hurt or pestilence, sometime health-giving, sometimes poisonous. It suffers change into as many natures as are the different places through which it passes. And as the mirror changes with the colour of its subject, so it alters with the nature of the place, becoming noisome, laxative, astringent, sulfurous, salty, incarnadined, mournful, raging, angry, red, yellow, green, black, blue, greasy, fat or slim. Sometimes it starts a conflagration, sometimes it extinguishes one; is warm and is cold, carries away or sets down, hollows out or builds up, tears or establishes, fills or empties, raises itself or burrows down, speeds or is still; is the cause at times of life or death, or increase or privation, nourishes at times and at others does the contrary; at times has a tang, at times is without savor, sometimes submerging the valleys with great floods. In time and with water, everything changes. (Deodhar 2009, 383)

Debates about the natural world and man’s ability to improve upon it during the Enlightenment led to experimental thinking, new apparatuses, specialised scientific practices and technologies capable of characterising the elements. Building upon the physical distillations and purifications that were established by alchemical practices, like Paracelsus and his mineral-based liquid medicines, modern science identified the molecular nature of substances through their atomic composition and structure, which enabled certain predictions to be made through their position on the periodic table of elements. With the advent of advanced imaging techniques such as atomic force microscopy, aided by artificial intelligence and automation (Extance 2018),
we are able to tell a whole lot more about the structure and character of molecules.

Consisting of two hydrogen atoms bonded to one oxygen atom ($H_2O$), the hydrogen side of the water molecule holds a slight positive charge and the oxygen side is negatively charged. Owing to this uneven distribution of electron density, water exhibits polarity and therefore acts as a powerful ‘universal’ solvent, being one of the most reactive and corrosive substances known. It also absorbs large amounts of heat energy before it warms up and cools down again since it has a high specific heat capacity, and large volumes of water can maintain a stable temperature, even when environmental temperatures are fluctuating wildly. In transitioning from liquid to solid phase, it occupies about 9% more volume and therefore floats. Other unique physical properties arise from the strong cohesion between water molecules, which exceed its affinity with the air, resulting in high surface tension. It also participates in finely tuned biochemical processes through its highly structured hydrogen-bonded network, which enables it to form organisational templates, assist molecular recognition, enable replication, and orchestrate protein folding. Integrated with the fundamental processes of life, it comprises 65% of our bodies by weight, with tissues such as the brain and the lung being nearly 80% water, and carries a constant flow of resources through our cells.

Despite our incredibly ability to observe and analyse it, not all aspects of water molecules are fully understood, and digital simulations are helping us better understand its unique and constantly surprising character. For example, classical theories predict that ‘supercooled’ water molecules should be frozen, but they continue moving in a liquid state below $0^\circ$C. Simulations suggest the reason is that the spatial distribution of water molecules in ice is uneven and pockets of water with differing characteristics exist and accounts for the way that ice can retain some of its liquid properties while in solid form. This means the properties of water are not merely a function of its global molecular characteristics but are also configured by local spatio-temporal relationships (De Marzio et al. 2017).
Water’s material richness, strangeness, and ability to interact, or associate with, so many substances has defined the nature of life on this planet. By allying with water and other liquids, we become semipermeable, protean beings that resist containment and can therefore adapt to changing circumstances.
Clay Code

Life’s inconstant and paradoxical relationship between inert structures and responsive flesh (whether plant or animal) invites a synthesis between mineral crystal (rigid) building blocks, which are the units of stable structures, and the wet, soft (flexible) environments of cells. Many ancient stories relate the emergence of life with the transformation of Earth’s soils such as the Sumerian myth of Marduk who created people by killing Qingu⁹ and mixing his blood with clay, or the golem—an earthen structure, shaped in human form and brought to life by God’s breath. Origin of life studies are now revealing the entanglements between life’s emergence and the evolution of our dirt.

There, on a clay bank, we measured out a man three cubits long, and we drew his face in the earth, and his arms and legs, the way a man lies on his back. Then all three of us stood at the feet of the reclining golem, with our faces to his face, and the rabbi commanded me to circle the golem seven times from the right side to the head, from the head to the left side, and then back to the feet, and he told me the formula to speak as I circle the golem seven times. And when I had done the rabbi’s biding, the golem turned as red as fire. Next, the rabbi commanded his pupil, Jacob Sassoon, to do the same as I had done, but he revealed different formulas to him. This time the fiery redness was extinguished, and a vapour arose from the supine figure, which had grown nails and hair. Now the rabbi walked around the golem seven times with the Torah scrolls, like the circular procession in a synagogue at New Year’s, and then, in conclusion, all three of us recited the verse, ‘And the Lord God formed man of the dust of the ground, and breathed into his nostrils the breath of life; and man became

⁹ Qingu also may be written ‘Kingu’.
a living soul.’ And now the golem opened his eyes and peered at us in amazement. (Neugroschel 2006, 13–14)

When ancient seawater is experimentally simulated and added to clay, it forms a hydrogel which soaks up fluids into its labyrinthine spaces. Here, complex biochemical reactions were able to catalyse the evolution of primordial chemistry towards the metabolisms of the living world, until membranes evolved that were capable of performing this function for wholly independent living cells (Young et al. 2011).

… use good smooth dirt that is free of sand, rocks and pebbles. In a small bucket mix the dirt with water. Using your hands to combine the dirt and water, continue to add small amounts of water until the mud is the consistency of bread dough. Knead the mud until the mud becomes firm enough not to lose shape when you roll it into a small ball. Mould the mud into pies by rolling the mud into balls and then flatten them down. You can make them as thick or as thin as you like. (Kidspot 2017)

John Desmond Bernal first suggested that clay played a key role in the origins of life through its ordered arrangement, high adsorption capacity, impedance to ultraviolet radiation and ability to form templates for polymerisation (Bernal 1949). A whole theory of life’s mineral origins was proposed by Alexander Graham Cairns-Smith, where simple crystal matrices, or ‘clay codes’, could offer physical structure, modes of synthesis, sites of catalysts and even programming information through ‘primitive geneographs’. All these systems existed within hydrated states of clay that were responsible for organising life’s building blocks and early metabolisms, until the more potent ‘genetic takeover’ took place, with a much-expanded molecular repertoire (Cairns-Smith 1965). While Cairns-Smith’s theory remains experimentally untested, inviting criticism that ‘no amount of vague talk about ‘clay organisms’ or ‘genetic clay’ [can] breathe life into such ideas as a substitute for a more tangible scientific
basis’ (Fox 1988), increasing evidence supports notions that life evolved along with its soils (Yang et al. 2013).

There are also people born on rocky ground, on sandstone or granite. Their skin is rough and hard, as are their muscles and bones. They have strong hair and teeth, and the skin on their palms and the soles of their feet is hard. On the surface they are tough and robust, because their bodies are like armour. They have a lot of empty space inside, so everything they see and hear echoes within them like a bell. (Tokarczuk 2003, 192)

In its most basic sense, clay creates a platform for prebiotic biochemistry and its ultimate assimilation into established metabolic networks. Although its vivogenetic properties have not been definitely proven, the clay montmorillonite has been shown to be catalytic in the assembly of RNA from simple nucleotides, and also accelerates the spontaneous conversion of fatty acid micelles into vesicles (Hanczyc, Fujikawa and Szostak 2003). Additionally, the role of hydrogels in the formation of ancient metabolic networks is being explored. Evidence supports the importance of localised concentration and protection of biomolecules in early life evolution, and also implicates a clay hydrogel environment for biochemical reactions during early life evolution (Yang et al. 2013). Working in combination with other substances, clay’s potency creates the possibility of new kinds of ‘agentised’ synthesis, which suggests that ceramic technologies may even enliven the living realm. Using genetically modified biofilms to produce a specific range of metabolites, the EU-funded Living Architecture project engages ceramic interfaces to investigate the formation of a ‘designed’ set of (bio)chemical transformations that are useful within urban living spaces, e.g., reclaiming phosphate from wastewater.10 A better

10 The Living Architecture project has received €3.2m funding from the European Union’s Horizon 2020 Research and Innovation Programme under Grant Agreement no. 686585. It is a collaboration of experts from the
understanding of how such molecular and metabolic processes may be shaped by clay as various forms of ceramics situated within technological systems, may contribute to our better understanding of living systems and how they relate to alternative models of organisation — such as liquid life.

Living Architecture is envisioned as a next-generation, selectively programmable bioreactor that uses techniques in biotechnology and synthetic biology to design communities of cooperating organisms that are capable of extracting valuable resources from sunlight, wastewater, and air and, in turn, generating oxygen, proteins, and biomass (Armstrong 2018b).
Colloids, Coacervates and Foam

... protoplasm has a definite structure and is not a homogeneous lump of slime. This structure holds the secret of life. Destroy it and there will remain in your hands a lifeless mixture of organic compounds. (Oparin 1953, 60)

Liquid and crystalline systems first began to mix in the ‘protoplasm’, which is a viscous, aqueous, clear, polyphasic colloid that provides a matrix for many kinds of material programs. In the nucleus, it is called ‘nucleoplasm’ and ‘cytoplasm’ in the cell body. Composed mainly of nucleic acids, proteins, lipids, carbohydrates, and inorganic salts, the cytoplasm provides supportive ‘skeletons’ and ‘muscle systems’ that generate cell structure. Selectively enabling molecules to move in and out of the cell’s highly choreographed environment, it regulates many vital processes such as energy production by the mitochondria, and protein synthesis in the granular ribosomes.

Prior to the discovery of DNA in the 1950s, cytoplasm was believed to be a complex substance capable of conferring cells with vital properties such as self-replication, the transmission of heritable particles (Hodges 1889), and even with immortality (Bogdanov 2002). This gel-like substance could choreograph the chemistry of life within cells, although without apparent form, it was not obvious how this was achieved.

It is not a question of straight lines and planes such as we meet in crystals, for here we have a whole network, a whole skein of fine threads which are interlaced, separating from one another and coming together again in a definite, complicated order. Sometimes these threads are very fine; on the other hand, sometimes they are thickened, fusing with one another to form small enclosed bubbles or alveoli. The structure of coagulates is strikingly reminiscent of that of protoplasm. Unfortunately, this structure has not yet been sufficiently well studied for us to be able to say anything.
conclusive about this resemblance. However, there can be no doubt that we are dealing with phenomena of the same order. There is no essential difference between the structure of coagula and that of protoplasm. It may be, however, that the difference between living and dead does not lie in the organization which, as we have seen, is present in both worlds, but in the other features which we mentioned, the ability of living organisms to metabolise, to reproduce themselves and to respond to stimuli. (Oparin 1953)

Alexander Oparin demonstrated that the anisotropy and non-linearity that existed at the interfaces between liquid media, spontaneously produced droplets, layers, and microscopic localised systems known as ‘protocells’ (Oparin 1953). Highlighting the way this self-assembling process could spontaneously structure protocellular spaces, he established a testable approach for his theories with an experimental platform that produced increasingly complex and more heterogeneous chemical assemblages (Sloterdijk 2011, 2014, 2016) capable of responding to a selection process.
Continuous Media: Ectoplasm

Things leak into each other according to a logic that does not belong to us and cannot be correlated to our chronological time. (Negarestani 2008, 49)

While quantum theory begins to close the ‘gap’ left between atomism’s objects, Descartes’ notion of ‘extended’ matter (see section 03.9) created the possibility of an atomic body that is permeated by its surroundings. Mutable like liquids, they no longer behave like geometrically discrete objects but fields (Dirac 1927), or strings (Smolin 2008), which draw both material and ephemeral forces into their substance.

The search for the interlocutors of the physical and immaterial realms coincided with the rise of spiritualism in the mid-nineteenth century, and was carried out by (mostly female) mediums. Regarded as hystericis, they reported leaking fluid-like substances out of their bodies during séances as a manifestation of spirit energy. Scientific luminaries like Charles Richet\(^\text{11}\) sought to discover the nature of this ‘ectoplasm’, considering it to be a ubiquitous protoplasmic \textit{prima materia} that arose from symptomatic vibrations of a ‘sixth’ sense that was capable of detecting ‘ectonic’ forces. The biological equivalent of the aether, it propagated the vibrations of life through the cellular substance of all beings, linking the ephemeral and material realms.

How can the vibration of reality bring about knowledge? … we are not prejudging the question as to whether these are vibrations of ether, or emissions of electrons … We know that there are around us, quite close to us, many vibrations which do not reach our normal senses, for instance those of attraction, of magnetism, of the Hertzian waves, etc. All

\(^\text{11}\) Charles Richet was a French physiologist at the Collège de France, who was known for his pioneering work in immunology and won the Nobel Prize for his work on anaphylaxis in 1913.
the same, it would be madness to suppose that there are not others. Therefore we have three orders of vibrations of reality: a) those which our senses perceive, b) those which our senses do not perceive but which are revealed to us by detectors, c) those that are unknown to us and which are revealed neither by our senses, nor by detectors ... When we have fathomed the history of these unknown vibrations emanating from reality — past reality, present reality, and even future reality — we shall doubtless have given them an unwonted degree of importance. The history of the Hertzian waves shows us the ubiquity of these vibrations in the external world, imperceptible to our senses ... when a new truth has invaded the world of humanity, even the most far-seeing individuals can never know to what conclusions it will lead. At times this truth entails unforeseen and unforeseeable consequences, and that even from the rigidly narrow point of view of our present material life. Who then could have foreseen when the great Hertz discovered the electric waves, that our practical daily life would be transformed and that all the ships sailing on the various oceans would be supplied with wireless? (Richet 2003)

Providing a legitimate scientific platform for his theories, Richet’s observations were more than a question of physics, or psychology, but situated at the cusp between psychical research and the nascent discipline of plasmogeny12 (Brain 2013). During the late nineteenth and early twentieth centuries, ectoplasm was ‘scientifically’ studied during paranormal theatre sessions, where spiritual mediums claimed to be able to link the psychic body with matter, making it possible to communicate with the dead. During a series of 87 séances led by 16-year-old Kathleen

12 The field of plasmogeny is concerned with the origin and study of protoplasm, but more broadly, also incorporates a study of the life-like behaviour of artefacts and is an early forerunner to the fields of synthetic biology and artificial life (Brain 2013).
Goligher, engineer William J. Crawford (‘the Lavoisier of teleplasty’) attempted to measure its appearances using a weighing scale large enough to hold the medium, while she was sitting in her chair. Noting a change in the distribution of mass in the subject’s body, Crawford attributed this to the manifestation of ‘psychic rods’ (Brain 2013). Other investigators, such as neurologist Jules Bernard Luys, observed that the ‘bodies of hystericis underwent a spasmodic consumption of energy and gave off a ‘radiating neural force’, taking the form of a luminous fluid that flooded out of the bodily orifices, especially the eyes and mouth’ (Brain 2013, 118). Albert Freiherr von Schrenck-Notzing, a German physician and psychiatrist at the University of Munich, corroborated these findings by reporting ‘the presence of fluid, white and luminous flakes of a size ranging from that of a pea to that of a five-franc piece’ (Brain 2013, 114) when mediums were in communication with the spirit world. Richet himself described different stages in the materialisation process:

[First,] a whitish steam, perhaps luminous, taking the shape of gauze or muslin, in which there develops a hand or an arm that gradually gains consistency. This ectoplasm makes personal movements. It creeps, rises from the ground, and puts forth tentacles like an amoeba. It is not always connected with the body of the medium but usually emanates from her, and is connected with her. (Richet 2010, 523)

While scientists had witnessed ectoplasm during séances in darkened rooms and by photographing its strange appearance, no actual samples that could be tested in a laboratory setting were provided (MacIsaac 2014). Spiritual mediums played on the vulnerability of their audiences using theatrical tricks to conjure the appearance of strange wools and fabrics from bodily orifices — particularly ears and mouths — as ‘evidence’ that bridging the realms of the living and the dead was possible. Medically trained Arthur Conan Doyle even became convinced of ectoplasm’s reality, describing it as a gelatinous substance
similar to body fluids and viscous liquids (Doyle 1930), but the non-scientist Harry Houdini was not so easy to deceive. Accompanied by an esteemed panel of scientists, he was invited to assess the psychic abilities of celebrity medium Mina Crandon, or ‘Margery’ — the Blonde Witch of Lime Street, New York and wife of a wealthy Boston surgeon and socialite, Dr Le Roi Goddard Crandon. Renowned for her nude séances délicité and assisted by her deceased brother Walter, many were convinced by her theatre of the dead. Tables knocked out messages, bells rung, and furniture shook with the fervour of the spirit world. She even conjured ectoplasm from her nose and ears and revealed an ‘ectomorphic hand’, from beneath a sheer kimono that bore a remarkable likeness to a string of entrails. While previous adjudicators had found no evidence of trickery, Houdini made a special instrument to detect the slightest movement in the darkened room. Binding his right knee so tightly that it was exquisitely sensitive to the subtlest movements, he could feel Margery play the séance table through a range of apparatuses that were operated by her head, legs, and ankles. Owing to her popularity in influential social circles, Houdini was, however, prevented from publicly debunking her techniques and instead, revealed the nature of her deceptions by exposing them in versions of his own performances (Love 2013).

Although ectoplasm was never proven to be a real substance, it was described in material terms by psychologists as composed of invisible rays, psychic forces, and ethereal vibrations, which could be conjured into actuality through a process of ‘ideoplasty’, or mental projection (Brain 2013, 116). Embryologist Hans Driesch took an assertively material view of ectoplasm as a medium for the union of matter and spirit. Regarding it as a special manifestation of protoplasm (Brain 2013), which contained a spirit force that could better explain the dynamic process of embryonic development in terms of the laws of physics and mathematics, he invoked Aristotle’s life force, or ‘entelechy’, as the organising force that conferred living matter with flexible principles. This new science of ‘supra-normal physiology’, or ‘super-normal biology’, made explicit the links between ectoplasm and
occult phenomena, where gelatinous bodies could also shape the course of prospective life. This groundbreaking scientific concept outlined a principle of malleable development, whereby undifferentiated organic tissue possessed pluripotentiality and inspired the emerging science of embryology.

Think of the little material body, called an egg, and think of the enormous and very complex material body, say, an elephant, that may come out of it: here you have a permanent stream of materializations before your eyes, all of them occurring in the way of assimilation, of a spreading entelechial control. (Driesch 1928, 173)
Aqua Vita

Of all the fluids that fill life’s interior spaces — vacuoles, coeloms, cavities, stomachs, ventricles, and vessels — none is conferred with more potency than blood.

Since ancient times, it has been considered as a life force, or *ichor*, and a very particular kind of plasm with mystical properties like Ambrosia\(^\text{13}\) that could be acquired in different ways, like the witch Medea who used it to transfuse ‘life’ into the dead, the old, and the dying (Tucker 2011):

Medea unsheathed her sword and drew a cut in the old man’s throat, so letting the blood drain out of his body. She then replaced it with juice from the pot. When Aeson had fully absorbed this, either by mouth or by way of the wound, his hair and his beard lost all of their whiteness and quickly returned to lustrous black. (Ovid 2004, 262)

The actual transfer of blood directly between individuals remained a magical notion until the Enlightenment. William Harvey’s rationalisation of blood flow as a theory of circulation in 1613 enabled the liquid to be empirically studied, but it did not quell belief in its rejuvenating powers, which remained the dominant motivation for developing the practice of blood transfusion. In 1666, Samuel Pepys referred to successful dog-to-dog blood transfusions in his diary, noting the potential medical implications and also the risks of the procedure:

The experiment of transfusing the blood of one dog into another was made before the Society by Mr. King and Mr. Thomas Coxe upon a little mastiff and a spaniel with very good success, the former bleeding to death, and the latter receiving the blood of the other, and emitting so much of his own, as to make him capable of receiving that of the

\(^{13}\) Ambrosia is the nectar of the gods that confers them with immortality.
Robert des Gabets claimed that transfusing blood between beings could not only transfer states of well-being, but also identity, which raised profound ethical questions for those who did not share Descartes’ view that the soul resided outside the body. Rumours spread that transfusing dogs with the blood from a sheep would give them the ability to grow wool, develop cloven hooves and sprout horns (Learoyd 2006). The first formal transfusion experiments are accredited to Christopher Wren who observed the levels of intoxication in dogs, after injecting them with wine and ale:

Some may conceive that liquors thus injected into veins without preparation and ingestion will make odd commotions in the blood, disturb nature and cause strange symptoms in the body, yet they have other thoughts of liquors that are prepared of such things that have passed the digestion of the stomach; for example, of spirit of urine, of blood, etc.; and they hope likewise that beside the medical uses that may be made of this invention, it may also serve for anatomical purposes by filling the vessels of an animal as full as they can hold, and by exceedingly distending them, discover new vessels … The reader may securely assume that this narrative is the naked real matter of fact, whereby it is clear as Noonday … that to Oxford, and in it, to Dr Christopher Wren, this invention is due. (Anon 1665–1666)

Despite a number of successful blood transfusions between animals and humans during the mid-seventeenth century, due to moral and ethical concerns the practice fell into general disrepute and was banned throughout most of Europe. Jean De nys conducted the first animal-to-human transfusions in 1667,
favouring the animal plasm for his experiments, as it was less likely ‘… to be rendered impure by passion or vice’. Although patchily successful owing to occasional haemolytic transfusion reactions, there were no further advances in blood transfusion for around 150 years (Learoyd 2006). This was a fortunate pause, since advances in antisepsis and immunology had not kept pace with this invasive practice.

In 1864, Paul Bert developed a new experimental technique in blood transfusion called ‘parabiosis’ whereby the skin of two mice were sewn together, and as the healing vessels fused, the animals shared a common circulatory system (Scudellari 2015). Significant scientific interest in blood transfusions was not however, rekindled until the second decade of the nineteenth century, when James Blundell used them to cure fatal haemorrhage in childbirth. Fatal haemolytic reactions arising from the mixing of incompatible blood types posed a significant risk to recipients until human blood groups A, B, and O were identified by Karl Landsteiner in 1901. Compatibility between donors and recipients could now be established before a transfusion took place and the practice of cross-matching was advocated as standard procedure by Reuben Ottenberg in 1907.

Despite these advances, the mystical potency of blood did not wane. The modern pioneer of blood transfusions, Alexander Bogdanov, regarded them as a replacement therapy that could cure sick and aged bodies. His grandiose approach to the powers of blood transfusion extended to claims it could reverse balding and improve eyesight. Ironically, he died following a poorly matched blood transfusion from a student suffering from malaria and tuberculosis, although the student recovered entirely following infusion with Bogdanov’s blood (Rosenthal 2002).

Further technical developments over the course of the twentieth century increased the safety of blood transfusions. Between 1914 and 1918, the advent of refrigeration techniques and anticoagulants such as sodium citrate prolonged the shelf life of the plasma, so that blood banks could be established. Throughout the 1920s and 1930s, voluntary blood donations for storage and use of blood became an acceptable social practice and during
World War II, transfusion was regarded as a reputable and life-saving treatment for wounded soldiers. Following this resounding success, it was adopted into mainstream medical practice and during the 1970s new technological developments in the manufacture of disposable PVC, transfusion practices became safer than ever before, although screening for viral antibodies did not occur until the 1980s following the HIV epidemic.

Blood transfusions bring biological benefits to recipients that cannot be accounted for by the expectations of replacement therapy alone. During the 1950s, Clive McCay revisited the practice of parabiosis to connect the vasculature of mice of different ages in pairs as a model system for studying the effects of old age. While some surgically ‘conjoined’ animals perished from a mysterious condition that became known as ‘parabiosis disease’, the old mice generally benefited from a range of rejuvenating effects, while the young mice aged prematurely. While animal research regulations established in the 1970s made it more challenging to conduct such experiments, the mystical rejuvenating powers of blood have not been assuaged. In 2014, researchers studying mice found that giving old animals blood from young ones could reverse some signs of ageing, which caused a rise in levels of a growth factor that had beneficial effects on the heart, skeletal muscle, and brain (Kaiser 2014). Recent experiments show that plasma proteins from human umbilical cord blood also have ‘rejuvenating’ effects on the memory of brain function in aged mice, with significant implications for treating degenerative brain diseases in humans (Castellano 2017).

Such promising scientific studies have attracted the attention of transhumanists, allegedly such as Peter Thiel, who stands ‘against confiscatory taxes, totalitarian collectives, and the ideology of the inevitability of the death of every individual’ and

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14 Disturbingly, if the rats were not adjusted to each other, then one would chew the other’s head until it perished (McCay et al. 1957).

15 ‘Parabiosis disease’ may have been a form of haemolytic reaction.

16 Such claims made by Gawker have been denied by Thiel at the 2018 New York Times Dealbook conference, who declared he was ‘not a vampire’ (Trotter 2017; Cuthberson 2018).
advocates the administration of a range of biological substances that may improve physical well-being — to the point where life spans can be radically increased. Thiel has already admitted to taking human growth hormone to maintain muscle mass and regards *transfusional parabiosis* as a pathway towards potentially infinite life extension (Kosoff 2016).

… infusions of young blood … [were sought after by] … aged billionaires. One, who flies around in a jet with his name emblazoned on the side … another correspondent wrote with a more disturbing offer … [to] … provide blood from children of whatever [the] age … required. (Sample 2015)

Young people are cloned in order to ‘harvest’ their organs, organ-by-organ until they die prematurely in Kazuo Ishiguro’s heartbreaking novel *Never Let Me Go*. While such an extreme scenario presently remains fiction, it raises relevant ethical questions about the Californian start-up *Ambrosia*, which meets the growing real-world market for plasma transfusions from young adults. Offering these as a rejuvenation therapy to tech circle clients, treatments promise to boost mood, the immune system, weight management, and much else. Unusually for an anti-ageing treatment, it appeals more to men than women (Haynes 2017).

As a business proposition, the transfusion of young blood raises all kinds of fears. It raises the spectre of a macabre black market, where teenagers bleed for the highest bidder, and young children go missing from the streets. Then there is the danger of unscrupulous dealers selling fake plasma, or plasma unsafe for human infusion. The fears are not unfounded: health has become one of the most lucrative sectors for criminals and con artists. (Sample 2015)

For now, claims that young blood, or plasma, can extend animal life spans are not supported by scientific data (Scudellari 2015)
and transfusional parabiosis undoubtedly carries unquantified risks, such as whether rejuvenating cells in ageing bodies carry a significant risk of cancer. Perhaps most intriguingly, despite our detailed understanding of medical treatments and advances in molecular biology, the crimson liquid that travels 96,000 kilometres along the arteries, veins, and capillaries of the circulatory system to carry more than 700 proteins and other substances around our bodies, remains mysteriously irreducible.

Blood might contain the fountain of youth after all. And it is within us all — that’s the crazy thing. It just loses its power as we age. (Thomson 2014)
Ghost of a Flea

The weightless, almost invisible, ubiquitous flea is a speck that challenges what a unit of life may be: a droplet masquerading as an object, a homunculus, a mini-monster, an ornate container for liquid, a self-propagating vector of pestilence, a parasite of sexual mingling, a host for a fluid drop of human life within an insect body, our blood-sucking enemy, and a curse that bites.

During the Renaissance, fleas were a humorous and risqué subject, which drew their many transgressions from the magical powers associated with blood. In a vision, William Blake saw the ghost of a flea that ‘told him that all fleas were inhabited by the souls of such men as were by nature blood-thirsty to excess, and were therefore providentially confined to the size and form of insects’ (Varley 1828, 54–55).

The development of the compound microscope catapulted the flea from the intangible to discernible realms, where — through his careful observation and detailing of their tiny armour plates — Robert Hooke demonstrated that the extreme performance of fleas far exceeded their fantastical status (Hooke 2007):

… as for the beauty of it, the Microscope manifests it to be all over adorn’d with a curiously polish’d suit of sable Armour, neatly jointed, and beset with multitudes of sharp pinns, shap’d almost like Porcupine’s Quills, or bright conical Steel-bodkins; the head is on either side beautify’d with a quick and round black eye … behind each of which also appears a small cavity … in which he seems to move to and fro a certain thin film beset with many small transparent hairs, which probably may be his ears; in the forepart of his head, between the two fore-leggs, he has two small long jointed feelers, or rather smellers … (Hooke 2007, 19)
Hooke’s drawings drew the attention of craftsmen, who began to demonstrate their technical prowess by depicting the flightless insects as tiny models of people, so that everyday life could be viewed as a corpuscular version of the human scale. In 1578, watchmaker Mark Scaliot built a lock and chain for a flea that was made up of 11 different microscopically crafted pieces of steel, iron, and brass, which weighed only one grain, plus the key belonging to it.

The same artist also constructed a chain of gold, containing forty-three links, which he fastened to the lock and key, and upon these being attached to the neck of a flea, the insect was able to draw them with ease. (Anon 1893, 187)

Other artisans followed suit, designing contraptions that ranged from landaus and chaises to cannons. During the 1820s fleas themselves, rather than the intricate objects associated with them, became the star attraction of shows. Louis Bertolotto’s insects pulled tiny carriages, danced to an orchestra, played tiny instruments and even (re)enacted the Battle of Waterloo wearing full battle regalia. In the 1900s, William Heckler claimed his troupe of fleas were ‘skilled professionals’, who juggled, raced, boxed, and even responded to voice commands. Gradually, flea circuses became part of carnival sideshows and were exhibited alongside circus ‘freaks’. They were also featured in magic routines, which resulted in the rise of the ‘humbug’ performance, where things appeared to happen — even in the absence of fleas.

The audience see a table or stand set out with all the fascinating gear and trappings of a miniature circus. An arched sign at the back, proclaims the name and merits of the show, lit up by small lights. The performers on this apparatus and in the air above it, are talented fleas — so the Ringmaster says. By the time the exciting and action-packed show is finished, many spectators are sure about the fleas, while others are doubtful, but nobody knows for sure! The entertainer never loses sight of his job for a
moment—which is to present a flea circus—a three ring show of performing fleas! (Palmer 1975)

While flea circuses are not prohibited, enthusiasm for them has dwindled—excepting the Munich Oktoberfest, which has upheld this tradition for over 150 years.

I had always thought that the flea circus was … an urban legend … Are there magnets under the table? Are there tiny wires attached to performers? I choose to believe … We watch the fleas play soccer. They pitch what looks to be pieces of styrofoam, 30 times their weight, into a tiny net … Then there was the chariot race. Pulling the chariot, said the ringmaster, was equivalent to a human pulling a locomotive. For all we know, the Pyramids could have been built employing trained fleas. Afterward, we got the opportunity to meet the actors … through a magnifying glass. (Johnson, n.d.)

Fleas are paradoxical creatures: simultaneously fluid and crystal, atom and fluid, seen and unseen. The not-quite-liquid-not-fully-droplet flea is a synonym for trickster, which personifies the outright contradictory aspects of liquid life.
Twenty-one Grams

... a cough came from the sacristy, then from the chancel, and finally died down, still coughing, behind the altar, behind the gymnast on the cross — where it quickly coughed up its soul. It is finished, coughed my cough; but nothing was finished. (Grass 2010, 342)

The idea of the soul as an ephemeral spirit entangled with a bodily identity is an ancient belief that is present in every civilisation and is thought to stem from our capacity for self-awareness. The narrative encapsulated in this dualism is highly compelling, since it offers transcendence from the insoluble difficulties of the material present and makes possible an unbounded world to be. The soul itself is generally considered an animating principle, whose presence is needed for the transformation between a living and dead state, even if, as Georg Ernst Stahl proposed, it is an agent that delays the decomposition of living things. The principles are so ingrained in our societies they are likely to have been communicated between early peoples at the dawn of cultural evolution around 200,000 years ago. Archaeologists from the Neubauer expedition of the Oriental Institute at the University of Chicago discovered a stone slab about a metre high and weighing about 350 kilograms at an Iron Age city called Sam'al in Turkey, which dated to around the eighth century BCE. Carved on its surface was a picture of a man, which was accompanied by an inscription that declared that his soul now resided within the stone slab (Small 2008).

There is something at work in my soul which I do not understand. (Shelley 2014, 11)

While religions offered laws about the nature of the soul, the Enlightenment brought ways of thinking and measuring that could potentially not only characterise, but also quantify it. Since, by definition cadaveric specimens did not have souls, it was hard
to establish an empirical method that could ascertain the relationship between body and spirit. In 1907, Duncan MacDougall sought to measure the loss of mass\textsuperscript{17} that he presumed occurred from a dying person when the soul parted from the body,\textsuperscript{18} which could be detected by a weighing scale that was sensitive to one-tenth of an ounce (3g). Implicit in this hypothesis was the assumption that the spirit was not immaterial like ‘mind’, but took the form of a physical substance, perhaps something like ectoplasm. MacDougall selected six patients with tuberculosis whose terminal symptoms could be clearly observed, so he and his colleagues would be able to identify the exact moment of death and quickly measure the differences in mass. His first subject, a ‘phlegmatic man, slow of thought and action, [whose] soul remained suspended in the body after death, during the minute that elapsed before it came to the consciousness of its freedom’, lost ‘three-fourths of an ounce’. This is around the mass of five sugar cubes and has since been popularised as ‘21 grams’. Three other cases, ‘including that of a woman’, lost between half an ounce (14g) and a full ounce (28g) in mass. Later, MacDougall repeated the experiment on 15 dogs, reporting the outcomes as ‘uniformly negative’, with no perceived change in mass at the time of death. This was interpreted as evidence that the ‘soul’ could be weighed, but dogs did not have ‘souls’. MacDougall also planned to take X-rays of the soul, but anticipated negative results, as he reasoned ‘in reality, the soul is a shadow picture’ (Snopes.com 2013). These controversial experiments were not only criticised for their speculative nature, but also the way the evidence was gathered. The sample size was considered too small to give significant results and other explanations for weight loss — for example, through evaporation — were poorly

\textsuperscript{17} It is worth observing that the idea of a loss of mass at the time of death is contrary to another (competitive) cultural trope, which suggests that, subjectively, the body appears to be heavier in death, leading to the idea of ‘dead weight’.

\textsuperscript{18} MacDougall assumes the moment of death is a precise event, rather than a complex sequence of events that include cellular death, brain death, cardiac death, etc. or that the soul is not trapped by or dissipates within the corpse.
controlled. Damningly, MacDougal’s results were heavily biased, as he only used findings that supported his initial hypothesis (Wiseman 2011, 42; Kruszelnicki 2004, 200–202).

Experiments conducted using even more sophisticated techniques, such as Magnetic Resonance Imaging (MRI), have been no more forthcoming about the transition between life and death, but raise significant ethical questions. Historically, the dead are used to study the natural of life as an intellectual inquiry. Joseph Paul Jernigan was a 38-year-old mechanic and murderer executed by lethal injection. Before his execution, a prison chaplain convinced him to donate his body to the Texas Anatomy Board. Alongside an anonymous female donor, a 59-year-old Maryland housewife, Jernigan’s body was selected by the committee to become the subject for the Visible Human Project, which was organised by the US National Library of Medicine and completed in 1994. The male cadaver was embalmed in gelatine and ‘cut’ in the axial plane at 1 mm intervals to produce a database of 1,871 slices, representing 15 gigabits of data. In 2000, the photos were rescanned at a higher resolution, yielding more than 65 gigabytes, while the female cadaver was sliced at 0.33 mm intervals, resulting in some 40 gigabytes of data. These datasets have been used to generate 3D anatomical models for medical research and train healthcare professionals.

Rather than comprehend the miracle of its genesis through its passions, it is much easier to understand life through its ‘lack’, which is how the phenomenon has largely been (scientifically) understood. The physiological deficits that result from physical subtractions of the body correspond with the criteria for liveliness. Let us remove the heart, the brain, the entrails, the head, the limbs, the eye, the genes and the soul and watch an exquisite choreography of unfathomably complex exchanges fall. There! Like a

19 In specimen preparation, the ‘cutting’ process actually involves grinding into the specimen. It is a destructive process and leaves no residual ‘slice’ of the cadaver.
mediaeval Trial by Ordeal, these insufficiencies are formal proof there was once a living thing. Since this essence can be isolated and obliterated, it is now understood. What beautiful poisons balance these theories, which ultimately conclude the nature of being is bounded by a fat ‘full stop’.

(Armstrong 2018b, 56)

The images acquired in the Human Visible Project are not only a neutral database that archives anatomical structures but ask searching questions about how the living realm is observed and valued. Cadaverous tissues, which are at relative thermodynamic equilibrium, are interpreted as the equivalents of dynamic systems at far-from-equilibrium, which begs the question — what new information is being revealed in this exercise? Moreover, the project’s association with human dissection as a data collection exercise is a morally dubious development within an already ethically questionable system of capital punishment and volunteer ‘coercion’ (Hildebrandt 2008).

At the trial the prisoner exhibited the utmost indifference to his fate, and appeared to entertain no fear for the consequences of his guilt. He maintained his firmness throughout a most feeling address of the learned judge, in which he was sentenced to death, but exhibited some emotion when he was informed that a part of the sentence was that his body should be given over to the surgeons to be dissected. (Anon, n.d.)
... aridity, dust and desert only elude water because they have already forged an alliance with a different species of wetness. Monster and alien vistas are indexed by climate and meteorology ... [where] the universe is ideated by elemental alignments in which air, fire and earth are paired with questionable liquidities which either possess deranged properties or share more than two properties at the same time with their neighbouring elements. In the case of the former, the derangement and confusion of primary and secondary properties — wetness and coldness — leads to the rediscovery of the elements earth and air as a New Earth and a Fresh Air. Miasma, putrefaction, unground, nigredo and so on refer to the alchemical dispositions or the cosmogenetic problems inherent to these revolutionized elements. Yet excessive properties of the moist element signal something more abysmal. If air and earth can afford water only through one property at a time — either wet or cold — then in considering these liquidities (wet alternatives to water) with more than two properties, we cannot help but submit ourselves to certain ire and troubling speculations ... the additional or so-called extraneous properties attest to missing links. In other words, these properties betoken other outsider elements to which the weird liquid species are coupled ... [and] impose the otherworldly building processes ... that ... are built upon meteorological taxonomies; for meteorology suggest the weather-harnessing power of these alien building processes ...

Dead seas bring rains and hails which are either crystals impregnated with sand of red and black particle, and sometimes even dead creatures. The desert is frequently haunted by pebble and sand rains, which not only being with themselves hordes of peculiar monsters, but also become teratological entities in themselves. The task of the desert and aridity is to invoke and to couple with alternate
fluids; but the task of foreign moistures is to smuggle in the outsider elements as familiar atmospheric phenomena in the form of weather anomalies or havocs. (Negarestani 2008, 98–99)

Liquids do not always behave according to our expectations of them. The double slit experiment, which experimentally established the wave/particle duality of quantum physics (Davisson and Germer 1928), is only part of the repertoire of this realm. When light particles condense in a state known as a Bose-Einstein condensate (the fifth state of matter), they can form liquid light. Like all superfluids, this condensate has zero friction and viscosity. Historically liquid light was only formed at temperatures close to absolute zero, existing for only fractions of a second, but using a Frankenstein mash-up of light and matter, it can now be formed at room temperature using light–matter particles called polaritons. Under these conditions, photons are so highly coordinated that they resist the characteristic disturbances produced by obstructions in their path to flow around objects and even corners (Lerario et al. 2017). Such extraordinary states challenge the classical notions of fluids, and solids, and point towards a stranger, quantum reality, which may be experienced in the everyday reality through encounters with monstrous materialities.
Making Ground

The cartography of oil as an omnipresent entity narrates the dynamics of planetary events. Oil is the undercurrent of all narrations, not only the political but also that of the ethics of life on earth. (Negarestani 2008, 19)

Dark liquids inhabit the ground beneath the soils. These dismal substances have lurked here for millions of years, metabolising slowly under pressure, as they turn like rancid milk. Possessing their own agency, they are changing our climate and global culture.

Historically, the ground is recognised as a generative and fertile matrix, but the source of this potency has been contested. Medieval accounts about the formation of land were based on Biblical accounts, which claim the world is between 6,000 and 12,000 years old.

As one penetrates from seam to seam, from stratum to stratum and discovers, under the quarries of Montmartre or in the schists of the Urals, those animals whose fossilized remains belong to antediluvian civilization, the mind is startled to catch a vista of the milliards of years and the millions of peoples which the feeble memory of man and an indestructible divine tradition have forgotten and whose ashes heaped on the surface of our globe, form the two feet of earth which furnish us with bread and flowers. (de Balzac 1977, 40–41)

The demand for metal purification practices that heralded the Industrial Revolution required an empirical analysis of ore-bearing ground. In *De Re Metallica*, ‘On the Nature of Metals’, Georgius Agricola created the foundations for a systematic study of the Earth’s rocks and established the founding principles for the scientific study of mining, metallurgy, and geology (Norman 2017). In 1666, intrigued by how one rock could
grow inside another, Nicolas Steno characterised the nature of fossils as snapshots of life at different moments in the planet's history, ensuring that his observations concurred with Biblical timelines and the advent of the Great Flood (Pennsylvania State University 2017).

... And on the seventeenth day of the seventh month the ark came to rest on the mountains of Ararat. (Gen 8:4)

Unlike Steno, Robert Plot recognised ‘the [giant] figure of the lowermost part of the thigh-bone of a Man or at least some other Animal’, in the ‘Formed Stones’ section of The Natural History of Oxfordshire of 1676. This stone was likened to the scrotum of a giant man by Richard Brookes in the eighteenth century, but it was not until 1970 that Beverley Halstead rediscovered these early accounts of fossils and recognised the drawings of ‘scrotum humanum’ as evidence of a theropod dinosaur (Carnall 2017). Increasingly, the scientific study of the ground was formalised through the study of mineralogy, which could not only reliably locate valuable ores but also contradicted Biblical accounts. James Hutton argued that geological timescales were much greater than Antediluvian accounts, which according to John Phillip were around 96 million years. However, there was discord even in secular accounts specifically between ‘Neptunists’ and ‘Vulcanists’, who differed in their view of the causes of extinction events that shaped the Earth. Neptunists argued they were the work of water, and Vulcanists, acts of fire. New names were invented to correspond with the recognition of particular epochs: the Carboniferous was associated with the formation of coal; Cretaceous with the deposition of chalk; and the Jurassic invoked the limestone Jura mountains.

During the late nineteenth and twentieth centuries, the ‘sudden’ cataclysmic theories of land formation were replaced by Louis Agassiz’s theory of Ice Ages, where huge amounts of earth moved across landscapes, prompting mass extinctions of

20 In Latin, *fossilis* refers to anything dug out of the ground.
mega flora and fauna. Around the late twentieth century, the ‘slow’ apocalypse was once again challenged by the possibility of a ‘sudden’ catastrophic event, where asteroids were the new agents of apocalypse, which saw the end of the dinosaurs. Once again, the Earth became a place where ‘powerful deluges, colossal landslides, gargantuan volcanic eruptions, supersonic impacts from extraterrestrial objects — played a role in shaping our world’ (Bjornerud 2015).

Contemporary geological debates centre on ‘sudden’ man-made geological impacts. While some, like rising global temperatures, may seem slow to us through the experience of lived time, from a geological perspective, they are taking place rapidly. Paul Crutzen and Eugene Stoermer argue that global human civilisation is generating irreversible planetary-scale impacts, which is irreversibly changing its character (Crutzen and Stoermer 2000). Although the impacts themselves are scientifically uncontroversial, their relationship to geological time remains hotly contested and whether we are presently in the Holocene, or Anthropocene, is still under consideration by the International Geological Congress (Carrington 2016).

The ‘Anthropocene’ is a term widely used … to denote the present time interval, in which many geologically significant conditions and processes are profoundly altered by human activities. These include changes in: erosion and sediment transport associated with a variety of anthropogenic processes, including colonisation, agriculture, urbanisation and global warming, the chemical composition of the atmosphere, oceans and soils, with significant anthropogenic perturbations of the cycles of elements such as carbon, nitrogen, phosphorus and various metals, environmental conditions generated by these perturbations; these include global warming, ocean acidification and spreading oceanic ‘dead zones’, the biosphere both on land and in the sea, as a result of habitat loss, predation, species invasions and the physical and chemical changes … (Subcommission on Quaternary Stratigraphy 2016)
As we bear witness to large-scale depletion of polar ice, a rise in ocean acidification, ‘new’ carbon dioxide released into the atmosphere from fossil fuels and toxic plastic deposits generating continent-scale islands in the ocean gyres, our current toolsets are not designed for practically addressing ongoing ecocide — particularly at such a speed, or scale, of multiple simultaneous events. Ironically, the industrial systems and modes of consumption that have produced them are the very same processes that we are focussing on as a way of combating this situation. Try as we might, without a distinct change in technological platform to underpin human development, we are *fiddling while our homes burn*. 
There is no other planet within twenty parsecs that has the like of it, and perhaps there is no other place anywhere at all that has such air. The air is the archetype of restless immanence. It is full of invisible movements and invisible contents. Through what is does and what is brings, it makes and unmakes the world it envelops. There is no actor more powerful on this earth, yet for the most part we studiedly ignore it … All the phenomena of weather and climate come from the restless motions of the air, the gyres, and all their permutations that bring rain, snow, fog, hail, sleet, black ice, tornadoes, hurricanes, the layers and the heaps of the clouds, the rising smoke of the chimneys. We can’t control the weather, but nevertheless the weather changes as we change the contents of the air. (Logan 2012, 19–20)

‘Metabolic weather’ arises from energy gradients, density currents, katabatic flows, vortices, dust clouds, pollution, and the myriad expressions of matter that detail our (earthy, liquid, gaseous) terrains, which sets the scene for the process of living, life-like events, and even life itself.

The potency of weather resides in its incessant flow, which is produced by the juxtaposition of gaseous and aqueous bodies at different temperatures, acting as the transport system for other agents. At the macroscale, ‘weather’ is a slow-moving field of enfolded dirts, water, and air; chemically, it is a highly active terrain where matter/energy is transformed into peculiar events, such as acidic rain, which excoriates alkaline surfaces like limestone. The field of termolecular chemical reactions describes the chemical processes that govern combustions, cloud formation, planetary atmospheres, and climate change (Caughill 2017). They are highly complex and uncommon, involving the simultaneous breaking and forming of chemical bonds between three molecules, ions, or atoms. Undergoing various transitional states that alter their reactivity, they can (re)combine in many
ways (Burke and Klippenstein 2017). Although these reactions were theorised during the 1920s, because of their complexity they could only recently be studied using state of the art computers, which ‘can provide a unique lens into harsh chemical environments ill-suited for experimental techniques for studying individual reaction dynamics’ (Bergan 2017). These modelling systems not only change the way complex chemistry is viewed, but also may have a broader impact on our study of chemical reactions, which offer insights into the planetary chemistry responsible for cloud formations, climate change, and evolution of pollutants (Burke and Klippenstein 2017). Importantly for metabolic weather, the sequence of reactions produces a plethora of turbulent structures, which are interconnected on a planetary scale and influence the conditions for terrestrial life. If we are to have any influence over these active fronts, their recognisable features must first be named.

… during the second world war when meteorologists forecasting weather ahead of battles began to draw cold fronts and warm fronts on maps… Jacob Bjerknes … discovered the different air masses around the world and the stormy weather that occurs on the edges of these air masses … [and] … likened them to the battle fronts across Europe, so he decided to call them fronts. (Meyers 2015)

Naming things so they may be controlled is an ancient practice that shapes how we make sense of our world. According to the book of Genesis, power resides in words where humans acquired power over animals by naming them. In finding the names for experiences, our thoughts become real, so we are no longer musing but acting, casting ‘spells’, or exerting influence, upon the world. Abracadabra, which is often used to announce a trick in magic shows, is Aramaic for ‘I create what I speak’. While the scientific Enlightenment changed naming into a practice of classifications, encyclopaedias, and taxonomies, the fundamental belief that finding the true names and nature of things increases our influence in the world, persists.
While it is relatively straightforward to describe and name objects with discrete boundaries—apple, chair, cat, saucer, bridge, sun—or particular actions and events—fall, buy, show, run, it is much more challenging to find specific names for things that we cannot observe in their totality, like the entire surface of the sea; abstractions, as in the objects associated with computer programming; or things that are constantly changing, like clouds.

… clouds have certain general forms which are not at all dependent upon chance but on a state of affairs which it would be useful to recognise and determine. (Hamblyn 2001, 103)

The visible patterns produced by weather fronts arise from a stream of transitions, so by interpreting these soft, dynamic structures as stable bodies, the chances of predicting their behaviour, or even controlling them, is increased. Jean-Baptiste Lamarck invented the first cloud classification system, while he was ill in bed. Staring out the window he noted basic typologies: *en voilé* (hazy), *attroupés* (massed), *pommelés* (dappled), *en balayures* (brooms) and *groupés* (grouped). Back then, before meteorologists could plot weather fronts and fields of equal atmospheric pressure, or isobars, the skies were read according to their cloud formations. Lamarck’s system did not catch on and was superseded by Luke Howard’s much more accessible Latin-based system, which used technical terminology and signs, namely: cirrus (curl of hair), cumulus (heap) and stratus (layer), terms that are now in common usage (Howard 1865). Considering these different cloud species as ‘good visible indications of the operation of [their] causes as [the equivalent of] the countenance of the state of a person’s mind or body’ (Zajonc 1984, 36), Johann Wolfgang von Goethe recognised a kindred spirit in Howard’s true typology of clouds. Popularising this gentle empiricism of the skies, he ensured the ‘open secrets’ of the natural world became accessible to all.
From all my strivings in science and art it must be clear how precious to me is this process, bestowing form on the formless and a system of ordered change on a boundless world. (Zajonc 1984, 38).

Even today, locally reading the details of actual clouds is a better predictor of events than a meteorological map. Despite our better understanding of its constituent events, the weather remains unpredictable as a global happening, sometimes astonishingly so. Many incidents of red rain have been described throughout the ages. In the *Iliad*, Homer described ‘bloody rain-drops on the earth’ (Homer 1987, 264), and although Pliny and Cicero also report such portents, Cicero suggests their causes are earthly, not supernatural, as arising ‘*ex aliqua contagione terrena*’ (Tatlock 1914). Ernst Chladni compiled a catalogue on widespread occurrences of red rain and snow since ancient times and attributed some of these to mineral causes such as dust, or biological agents like lichen (Chladni 1826, 202), while Christian Gottfried Ehrenberg observed the widespread occurrence of red rain and recreated it using a mixture of red dust and water (Wickramasinghe 2015, 160). More recently, in 2001, 50,000 kg of particular matter fell in the southern Indian state of Kerala (Louis and Kumar 2006) and an initial report from the Department of Meteorology suggested that this rainfall was chemical in origin. Studies commissioned by the Indian government analysed samples, which indicated that the red particles possessed capsules but no DNA and were thought to be spores of a lichen-forming alga belonging to the genus *Trentepohlia* (White, Cerveny and Balling 2012). Chandra Wickramasinghe contested these findings and suggested the recovered particles ‘represent an unknown microorganism of extraterrestrial origin’ (Wickramasinghe 2015, 161–67). Red rain was also reported

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21 The Latin translates as ‘from some earthly contagion’.
22 Ernst Chladni’s last catalogue entry dated 3 May 1821 reads: ‘Red rain at and near Giessen, during a calm, from a moderate-sized stratus … [that contained] … chromic acid, oxide of iron, silica, lime, a trace of magnesia, carbon, and several volatile substances, but no nickel.’
in 2013 over the Rakwana in the Kiwul-alla area, and then in mid-November 2015, across the Indikolapelessa and Moneralga district in Sri Lanka. On analysis, these samples confirmed the presence of *Trentepohlia* spores (Rajgopal 2015). Although many theories regarding the ontology of red rain exist, its formation remains perplexing and is likely to have various and highly contingent causes (Gat et al. 2017).

Outpourings of creatures falling from the sky have been reported since ancient times, which Pliny the Elder attributed to the natural but remarkable properties of water:

> Water engulfs lands, quenches flames, climbs aloft, and lays claim to even the sky, and by a covering of clouds chokes the life-giving spirit that forces out thunderbolts, as the world wages war with itself. What could be more amazing than water standing in the sky? But as though it were a mere trifle to reach such a great height, the water sucks up with itself shoals of fish and often stones as well, carrying more than its own weight aloft. (Pliny the Elder 1991, 272)

While transportation of a single species of creature from a stream of pond as a consequence of ‘weather’ may seem extreme, hurricanes and tornadoes are powerful enough to destroy buildings and may feasibly lift large particles in suspension into the atmosphere (Radford 2010; BBC News 2014). With the onset of climate change, the once seemingly recognisable patterns that Lamarck and Howard described are becoming increasingly unreliable. While showers of creatures are visible indicators that something in the natural cycles is unusual, the Anthropocene has introduced invisible agents into the atmosphere as *new carbon dioxide*. Having been quiescent for around 350 to 300 million years, this ancient source of carbon was first sequestered and buried on a massive scale by plants as biomass and turned into fossil fuels by subsequent geological events. With the advent of the Industrial Revolution which burned heavy oil to fuel powerful machines like the Hornsby–Akroyd engine, this recalcitrant carbon released by these dark ancient substances
is invading our skies and impacting on our weather systems as \textit{global storming}.

Metabolic weather is more than an atmospheric phenomenon, but also penetrates into all the terrains composed of atomic ‘dusts’ that are held to the Earth’s surface by gravity — air, water, and the soils. A generative platform for irrepressible synthesis, constant mutability, and evolutionary transgressions, it may one day precipitate the occurrence of new kinds of ‘life’. While the chances that this will happen are extremely small, that life has already occurred on this planet, significantly increases the likelihood of its recurrence.

… maybe life arose more than once at different locations on the early Earth. Those other organisms might have their own biochemistry and a separate evolutionary history … there may be some organisms hiding on Earth today that are based not on DNA and proteins but on a more primitive type of biochemistry … Even if [it] were living out in the open, the life detection tools that we have today would not find it … because they assume that all metabolisms must be similar to our own … There’s no reason in physics or chemistry why these different ways of building a life-form wouldn’t work … If life is easy to make and is widespread, then it should have happened many times on Earth … The best way to test for that is to look for it. (Zimmer 2007)