**ATMOSPHERES OF INVENTION, PASSAGES OF LIGHT**

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**Becoming thermodynamic**

Forget pre-impressionism. What the painter J.M.W. Turner was doing, insists philosopher Michel Serres, was realistically depicting the forces that were then transforming the material world. In early 19th century ways of life nudged along by wind, water and muscle were fast giving way to worlds propelled by steam. While the form of trains, boats and bridges may still be visible amidst an atmospheric vortex, what Turner’s landscapes actually show are the thermochemical reactions taking place *inside* the industrial heat engine.

“Turner no longer looks from the outside;” claims Serres, “[…] he enters into the boiler, the furnace, the firebox.”[[1]](#endnote-1) While the boiler envelops and harnesses the forces of the cosmos, so too does the whole universe begin to appear as the blazing energetic metamorphoses occurring within the steam engine: “the engine dissolves into the world that resembles it […] Heaven, sea, earth, and thunder are the interior of a boiler which bakes the material of the world […] Hotter and hotter, less and less confined by a boundary.”[[2]](#endnote-2)

The flash of brilliance may be as much Serres’ own. At the very moment of his depiction of Turner’s becoming thermodynamic, a scientific story of the human-induced heating of the earth was breaking. The heat engines of industrial modernity were indeed being turned inside out, their boundaries dissolving. All along, we discovered, the conflagration within the boiler, the steam turbine, the internal combustion engine had been gradually transforming the atmosphere of the whole earth.

Of course, the trick of turning the world outside in - and then remaking it from the inside out - had been learned long, long before the modern era. The very fact that there are fossil hydrocarbons for industrious humans to combust depends on the capacity of life itself to create a barrier, an envelope that enfolds a little of the sustaining world around it while at the same time dividing interior from exterior. All living beings are able to absorb and accumulate energy by way of this permeable membrane that is their interface with the world beyond.

Through a range of techniques, the organism seeks to regulate its own internal biochemical environment, working against a gradient to build up higher concentrations of energy and materials within its bounds than characterize the world at a large. It is this ability on the part of bacteria, algae, plants and animals to accumulate energy within their bodies which eventually produced the rich deposits of fossilized hydrocarbon that have fuelled the engines of the industrial age. At the same time, it is the emissions from organismic energy conversion – byproducts of photosynthesis – that raised atmospheric oxygen levels to the point where combustion could take place. From the outside in to the inside out: the solar becoming of myriads of living things gradually exhaling an atmosphere into being.

While some evolutionary theorists and their economist kin insist that all life is a squabble over scarce energy resources, other thinkers encourage us to see the diversity and exuberance of the living earth as symptomatic of a superfluity of available matter-energy. Taking the side of abundance, philosopher Henri Bergson observed that when it comes to the emergence and diversification of life: “Two things only are necessary: (1) a gradual accumulation of energy; (2) an elastic canalization of this energy in variable and indeterminable directions, at the end of which are free acts.”[[3]](#endnote-3) By working against the energy gradient, living beings accumulate more energy than they need for bare survival, energy that may then be expended in the more extravagant `free acts’ that interest Bergson and his successors; prolific reproduction, bodily diversification, a whole range of forms of display or self expression.

Intriguingly, at a time when the philosophical implications of Darwin’s evolutionary theory had barely been considered, Bergson went a step further. He wondered whether the capture, accumulation and setting to work of solar energy might yet take place in other ways, freed from the constraints and channels of the organismic body. “It can be conceived (although it can hardly be imagined)”, he wrote, “that energy might be saved up, and then expended on varying lines running across a matter not yet solidified.”[[4]](#endnote-4)

What might this look like? What forms could a creative evolution take if the expressive utilization of the sun’s superabundant energy were to extend beyond the limit of individuated bodies, or beyond biological being altogether? At the current juncture, in order to stave off catastrophic climate change, there is growing consensus that most subsurface non-renewable energy reserves must never see the light of day. At the same time, there is a frantic search for ways to return the byproducts of combusted hydrocarbon to the recesses of the earth. As if the best we can hope for is material-energetic inertness, re-sedimentation, the security of enduring substrata...

What if there was a way of working with, as well as railing against, the heat and turbulence we have added to the earth’s atmosphere; a way of turning around and reaching upwards, outwards in the direction of our energy emitting star? *Becoming Aerosolar*, in this sense, would mean lightening up, loosening the hold of heavy modernity, easing off from accumulation without end.

But is there more at stake than simply disavowing our fuming metal-clad engines in favor of lighter, cleaner machines? We now know only too well that the attempt to enclose fearsome thermochemical reactions inside formidable chambers – the quest for atmospheres of combustion at fingertip control – has had the unforeseen effect of transforming the atmosphere of the planet in its entirety. Though perhaps we have not yet dwelled fully on what it means to contain combustion, to manipulate atmospheres within an enclosed space, to use this power to transform matter-energy.

**Becoming pyrotechnic**

The first successful apparatus to use combusting fossil fuel to do mechanical work was built in the early 18th century to pump water out of mines. Itself the inheritor of many experimental devices, Thomas Newcomen’s `atmospheric engine’ used steam raised just above atmospheric pressure to push a piston upwards, then created a partial vacuum -producing a pressure differential - to push it down again.

Behind this technique was the understanding that the earth’s atmosphere itself had weight. Late in the 16th century, Galileo had figured out that an enclosed volume of air could be weighed. It was up to his pupil Evangelista Torricelli to work out that the entirety of the earth’s atmosphere pressed down upon our planet and all its inhabitants. In Torricelli’s awestruck words: “*Noi viviamo sommersi nel fondo d'un pelago d'aria*. We live submerged at the bottom of an ocean of air.”[[5]](#endnote-5)

The succession of ever more powerful `heat engines’ that propelled industrial production needed robust casings to handle differences in pressure between atmospheres within and without. More than this, they had to be able to contain the intense heat released by combusting the concentrated energy of fossilized hydrocarbons. If the modern heat engine is a furnace that has morphed into a prime mover, the metals that form its impermeable shell are themselves the product of furnaces. And the furnace itself, fire historian Stephen Pyne reminds us, belongs to a very long history of containing and controlling fire within purpose-built chambers.[[6]](#endnote-6)

Our human genus knew a lot about fire before they constructed the first permanent structures to enclose and focus its force. Over many millennia of cooking foodstuffs, our ancestors grasped the transformative effects of fire on other materials: that it hardened wood, cracked rock, baked clay.[[7]](#endnote-7) With the coming of the more settled climate of the early Holocene, agriculture and chambered fire rose in tandem. The ovens that rendered grains palatable also baked the earthenware used to store and serve food. More than just places where fire was housed and set to work, the towns that grew around agricultural sites were themselves composed of materials forged by fire. In the words of metallurgist J. E. Rehder:

The material fabrics of nearly all settled civilizations have by and large consisted of things that exist only because of pyrotechnology – the generation, control, and application of heat, which at sufficient temperatures can alter the properties and compositions of all materials.[[8]](#endnote-8)

From the lighter touch of nomadism – a life that swayed to the solar-powered ebb and flow of grasses, game and edible plants – agriculture and pyrotechnology conspired in the production of a weightier existence: dense, durable, solid-walled. But such a reading risks taking the productions of the pyrotechnical arts at face value. Deep within the ancient kiln, shielded from sight and touch, a modulation of atmospheres was taking place that contemporary observers still regard with awe.

The smelting of copper not only requires temperatures exceeding 1100 °C, but each firing requires the presence of a reducing agent – most often carbon monoxide - to trigger the chemical reaction that separates base metal from its ore. As is the case with all their smelting, metallurgists of antiquity had no way of divining the exact thermochemical transformations that were taking place in their kilns and furnaces. Collectively, over hundreds of generations, they developed tacit understandings of the best combination of fuel and air, the right mix of mineral ingredients, the effects of varying chemical concentrations of the gas atmosphere of each firing. And along the way, they produced some of the most beautiful objects the earth has ever seen

As it turned out, many ‘impurities’ of the materials that artisans were using served as catalysts or ingredients of the transmutations they sought to induce. Most momentously, by 1100 BC it had been discovered that the tensile strength of iron could be greatly improved by reheating it in a furnace with charcoal: carbon from the charcoal alloying itself with iron to produce steel. In this way, thousands of years before our own incidental addition of carbon to the earth’s atmosphere began to impact global climate, the presence of carbon in the microcosmic atmosphere of the kiln was already reshaping the physical world, object by object, firing by firing.

Pyrotechnical experimentation gradually ascended a ladder of heat, widening the range of elements that could be subjected to transformation, expanding the materials out of which social life was composed. But something vital is lost if we see the fusion of fire and earthy matter merely as a linear arc of advancing technics. When telling the story of their field, even the most empirically minded pyrotechnology scholars have a habit of interrupting their calculations and diagrams with reveries on the sheer joy of experimentation or the allure of the geological world itself.

Materials scientist Cyril Smith vouches that the vital impulse behind pyrotechnical development was not necessity but “a rich and varied sensual experience of the kind that comes directly from play with minerals, fire, and colors.”[[9]](#endnote-9) Clay figurines came before pots, ornaments and jewelry preceded metal implements and weaponry. “Nearly all the industrially useful properties of matter and ways of shaping materials”, Smith insists, “had their origin in the decorative arts.”[[10]](#endnote-10) Or in the words of pyrotechnical historian Theodore Wertime: “It was through working with bright, glittery metals that men came to have some scientific understanding of the physical forms of materials.”[[11]](#endnote-11)

In this way, we might view the heat engines of industrial modernity less as a technological rupture than as the inheritors of a long tradition of working with chambered fire and controlled atmospheres. But whereas the 10,000 year spree of pyrotechnical experimentation transmuted matter into all manner of new and unforeseen forms, the development of modern heat engines essentially reduced the transformative function of fire to the mechanical or kinetic functions of the `prime mover’. Power increased many times over, but in the process a generalized metamorphosis of earth materials gave way to the generation of brute force.

To return to our thoughts sparked by Serres’ reading of Turner: the cumulative effects of burning fossil fuels has effectively turned the modern heat engine inside out: the thermal transformation of atmosphere within the machine conspiring to transform the entire planetary atmosphere. But taking further cues from Serres, we might also view this the other way round. In the bigger picture of the pyrotechnical complex, the enclosure of fire might itself be seen as a turning outside in of the forces of the earth and cosmos.

The takeoff point of the pyrotechnical lineage comes not long after the exit from the last Pleistocene glacial episode. Not only a time rapid sea level rise, the receding of the ice caps has been linked to a marked increase in volcanic activity - the effect of changing ice volumes and meltwater loading on crustal stress. The earliest confirmed evidence of a furnace, dated around 9000 before the present, is in the excavated Neolithic settlement of Çatalhöyük in Anatolia. Just over a hundred kilometers northeast, is the volcano Hasan Dağı, which volcanologists recently confirmed erupted around 9000 years ago.

A causal link, however, is not the point. More importantly, kilns and furnaces themselves introduced temperatures into the everyday life of ancient settlements that were themselves `geologic’ in intensity. Over the course of ancient pyrotechnical experimentation, kilns were developed that could regularly reach the 1300 °C that geoscientists believe to be the maximum temperature of molten lava. Aside from a lightning strike, this is the highest naturally occurring temperature on the surface of the earth.

Effectively, what pioneering pyrotechnicians were doing was reproducing the igneous and metamorphic processes of the earth itself: they were reaching into the vast, inhuman forcefulness of the earth, and recreating it at a workable, human scale.

**Becoming aerosolar**

Philosopher Elizabeth Grosz suggests that we think about aesthetic expression more generally from the point of view of the earth itself. From this perspective, art – in the broadest sense – is an engagement with the dynamics and generativity of the earth and cosmos. It is a way of intervening in the world that draws upon the intrinsic ordering or self-organizing capacities of the physical world, while also responding to the power of the earth to overwhelm us. What art does, according to Grosz, is to: “temporarily and provisionally slow down chaos enough to extract from it something not so much useful as intensifying, a performance, a refrain, an organization of color or movement”.[[12]](#endnote-12)

Taking off from this idea, we might conceive of the pyrotechnician’s furnace as a means of confronting an earth that could be at once richly variable and frighteningly volatile: a kind of collective corralling of this diversity and dynamism. To borrow again from Grosz, it could be said that the oven, the kiln, the furnace allows the artisan: “to approach, to touch upon, harness, and live with chaos, to take a measured fragment of chaos”.[[13]](#endnote-13)

Avid readers of metallurgical texts, philosophers Giles Deleuze and Félix Guattari saw something in the pyrotechnic complex that offered a possible response to Bergson’s musings. By teasing out the multiple permutations of matter, by coaxing different materials over thresholds into new states, and by their own nomadic diffusion of knowledge, metallurgists could be seen to be exploring a kind of creative evolution beyond the confines of the organism.[[14]](#endnote-14) With their heat-induced elaboration on the forces of the earth – melting, forging, transmuting - were they not already on the way to an accumulation and intensification of forces “not yet solidified”?

Is too late to pick up where the pyrotechnical arts and thermo-industrial engineering left off? In an important sense, there is no going back. Surrounded by what was already an industrialized pyrotechnology, the residents of ancient Rome described their city’s smoky envelope as *gravioris caeli* : `heavy heaven’. Today the air in which we are submerged has been irreversibly heated and stirred by the addition of solar power from far-flung geologic eras. But if our distant ancestors, in the course of being propelled out of the last ice age, found it in themselves to corral a little geophysical chaos and to conjure creative miracles out of it, what are our own chances of carving novel atmospheres of invention out of an increasingly unruly ocean of air?

Neither linear development nor straight disavowal, *Becoming Aerosolar* inherits the generative atmospheres of pyrotechnic and thermodynamic complexes. It learns too from the bacteria who surf cloud droplets and the thermal-riding insects and arachnids: creatures whose skyward trajectories are enabled by the same fluid-filled membranes that once allowed them to leave the ocean. As in the case of its predecessors, aerosolar mobilization takes flight from an involution, an enfolding of forces too vast and volatile to grapple with on their own terms. Aspiring to sustainable envelopment, each aerosolar sculpture turns the planet’s great blanket of air outside in, engulfing air that is already the turning inside out of three hundred years of thermodynamic effluvia, 10,000 years of artisanal atmospheric modulation, and 3.7 billion years of biological exhalation.

An aesthetic elaboration on a dynamic solar-powered atmosphere, an aerosolar mission envelops a parcel of air that is inevitably infused with greenhouse gas emissions, volatile organic compounds and particulate matter. Each flight consigns itself to currents, thermals, levels of ultraviolet radiation that are partially of our own making. But if this is a step on the path to inhabiting the earth in all its volume and verticality- a diasporic probing outward and upward - it is perhaps as much a collective inhalation or in-spiring.

All along, the metal-encased thermo-industrial heat engines that shifted worlds and amassed fortunes were far more permeable - more `democratic’ - than most of us ever imagined: their most momentous product turning out to be a new atmosphere for every one of us to inhale and inhabit. This compromised atmosphere is the new global commons: a heaven weighing heaviest on those least culpable for its rising tumult. Any effective response too, must be collective, flowing over borders and between communities as earlier socio-technical complexes flowed through generations and across epochs.

A becoming, that is, in the manner of the solar energy that passes through membranes, across the boundaries of the organism, across all walls and borders. “These are contagions of energy, of movement, of warmth”, wrote Georges Bataille – that most presciently aerosolar of philosophers:

Life is never situated at a particular point: it passes rapidly from one point to another (or from multiple points to other points), like a current or like a sort of streaming of electricity […] The lasting vortex which constitutes you runs up against similar vortexes, with which it forms a vast figure, animated by measured agitation. Now to live signifies for you not only the flux and the fleeting play of light which are united in you, but the passage of warmth and light from one being to another …[[15]](#endnote-15)

*Becoming Aerosolar* is an accumulation and elastic canalization of energy that heads in indeterminable directions: a passage of warmth and light not only beyond the border of individual bodies or discrete communities, but beyond the surface of the earth. In each parceling of air, a segment of chaos, a measured agitation. The dream of innumerable vortexes joining forces, a multitude of small experiments and improvisations weaving themselves into a collective atmosphere of invention. From a long launching pad of heat-induced transformation of matter-energy, a new generation of artisans reaches into worlds of light and vapor...

1. Michel Serres, *Hermes: Literature, Science, Philosophy*, Baltimore, 1982, p. 56. [↑](#endnote-ref-1)
2. Serres 1982 (see note 1), p. 60. [↑](#endnote-ref-2)
3. Henri Bergson, *Creative Evolution*, Mineola, NY, 1998, p. 255. [↑](#endnote-ref-3)
4. Bergson 1998 (see note 3), p. 256. [↑](#endnote-ref-4)
5. Cited in Gabrielle Walker, *An Ocean of Air: A Natural History of the Atmosphere*, London, 2008, p. 17. [↑](#endnote-ref-5)
6. Stephen Pyne, *Fire: A Brief History*. Seattle, 2001, pp. 126-8. [↑](#endnote-ref-6)
7. Nigel Clark and Kathryn Yusoff, “Combustion and Society: A Fire-Centred History of Energy Use,”’ in: *Theory, Culture & Society,* issue31 (5), pp. 203-6. [↑](#endnote-ref-7)
8. J. E. Rehder, *The Mastery and Uses of Fire in Antiquity*, Montreal & Kingston, 2000, p. 3. [↑](#endnote-ref-8)
9. Cyril Stanley Smith, *A Search for Structure: Selected Essays on Science, Art, and History*, Cambridge, MA., 1981, p. 203. [↑](#endnote-ref-9)
10. Smith (see note 7), p 242. [↑](#endnote-ref-10)
11. Theodore Wertime, “Pyrotechnology: Man’s First Industrial Uses of Fire,” in: *American*

    *Scientist*, issue 61(6), 1973, pp. 670–82, p. 674. [↑](#endnote-ref-11)
12. Elizabeth Grosz, *Chaos, Territory, Art: Deleuze and the Framing of the Earth,* Durham, NC, 2008, pp. 3. [↑](#endnote-ref-12)
13. Grosz (see note 10), p. 27. [↑](#endnote-ref-13)
14. Gilles Deleuze and Félix Guattari, *A Thousand Plateaus: Capitalism and Schizophrenia*, Minneapolis, 1987, pp. 404–15. [↑](#endnote-ref-14)
15. Georges Bataille, *Inner Experience*, New York, 1988, p. 94. [↑](#endnote-ref-15)