

CONTINUUM of LIVELINESS:

Viruses and the Boundary of Life

Essay for York University STS 6201

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I / INTRODUCTION: TROUBLING CONSENSUS (1)

IF THEY ARE HONEST, CONTEMPORARY scholars must - however ruefully - say of life what 1600 years ago Augustine, Bishop of Hippo, remarked of time: that all of us know what it is, so long as no one asks us (2). That being said, Time and Life do seem conceptually distinct. Both intuitively and mathematically, time seems like the Christian Trinity, which "was, is now, and ever shall be" puzzling (3); not so life. By contrast with time's unalleviated mystery, only recently has a consensual definition of life grown problematic; the academy's present befuddlement is barely two centuries old. Since about 1800, technoscience has drilled down into progressively tinier material subcomponents of living species, sparking new questions that still have no agreed-upon answers. Where is the boundary between life and lifelessness? Is that boundary adamantine or permeable? What is the lowest point, the smallest scale, at which living matter may no longer be considered living?

My thesis in this paper is that these koans are paradigmically crystallized in the entities called viruses. Technoscience's initial awareness of, and subsequent investigation into, these nanoscale atomic assemblages continue to challenge our core concepts of life.

For centuries, life was commonly (and commonsensically) held to display a unique set of defining characteristics. As seemed apparent to all, life was that (and only that) which -

- * Is conceived and born
- * Breathes and grows
- * Eats and excretes
- * Creates heat and reproduces
- * Exhibits reactive behaviour (and intentionality, at least in species defined as 'higher')
- * Inherits and transmits consistent traits, and -
- * Ultimately dies.

1. "Forewords are afterthoughts" (Rheinberger 11)

2. St Augustine of Hippo (*attributed*)

3. Church of England [Anglican Church in Canada], Book of Common Prayer liturgy, *passim*. One of the newest construals of time comes from quantum theory, which views time as a simple function of physical activity. If nothing happens, no time passes; if much happens, a correspondingly greater time interval has passed. One suspects this construal has yet to manifest its full power outside of physics. It may have its greatest influence in the biosciences, where (*e.g.*) the photosynthetic capture of light takes nanoseconds and the topological reconfiguration of a bioactive enzyme may be complete in a femtosecond (0.000 000 000 000 001 s; there are as many femtoseconds in an eyeblink [~25 ms] as there have been eyeblinks since the Big Bang). Given such data, it does not seem impossible that biotheoreticians may one day reconstrue evolution as something like the steadily increasing production of time.

These long-accepted assumptions were troubled when post-Enlightenment naturalists in Europe examined living species according to the dictates of systematic nontheistic reason (4), revealing previously unsuspected patterns. For example, it seemed that 'ontogeny recapitulates phylogeny' - *i.e.* that from conception to birth each fetus traces its species' collective anabasis from simple to complex form (5). Marine species such as sea urchins exhibited astonishing abilities to regenerate body parts, even entire individuals, from excised tissue. What then *was* life? At its foundation, of which material or immaterial essences might it consist?

After fifteen decades of technoscientific investigation, during which the term 'biology' became general, in 1953 came Franklin, Crick, and Watson: *et après leur la déluge*. An apparently universal structural code of bioheredity, already thought to lie within cellular nucleic acids (6), was conceptualized and physically modeled by the British team as a sequence of four simple nucleotide bases, stacked like rungs in a molecular ladder three nanometres across (7). Later investigations further decoded DNA to reveal how triplets of adjacent bases could order the synthesis of specific proteins within the cellular factories called ribosomes.

At once the essence of life became less mysterious and more material. Heredity (the transmission of traits) and metabolism (the consistent chemical operations that characterize and sustain life) were suddenly in sharper focus. Simultaneously, however, the *essence* of life became paradoxically more vague. Was life only a jostle of macromolecules, bench chemistry writ small? Were all life's reducible and 'emergent' properties (54) mere extensions of biophysics, following the iron rules of Wilsonian consilience (8)?

4. I use 'nontheistic' rather than 'atheistic' as the more value-neutral term; one may be a believer yet still address nature without constant reference to an existentially engaged deity. As well, polemicists such as Richard Dawkins and Christopher Hitchens have recently evidenced a quasi-religious atheism that is strident, intolerant, inflexible, doctrinaire, and at apparent odds with academic collegiality.

5. The dictum was pronounced by Ernst Haeckel and was subsequently drummed into countless biology students. Later it emerged that in his drawings of various species' embryos, Haeckel had taken illustrative liberties to buttress his theory. A recent student graffito noted with forgivable *schadenfreude* that *Haeckel ist ein Wanker*. (For a sound theoretical analysis of the development of scientific illustration, see Daston & Galison 1992 [in Bibliography])

6. The concept of nucleic acids as the master molecules of heredity was concretized, fittingly enough, through viral research. Only a year before Watson and Crick published, Hershey and Chase "used [bacterio]phage T2 [a virus infecting] . . . *E. coli* to provide strong evidence that genetic material is composed of DNA." (Carter & Saunders p.4)

7. Feminist STS scholars have since exposed the unconscionable exclusion of Watson's work in X-ray crystallography from formal peer recognition, including the Nobel Prize.

8. As neologized by E.O. Wilson, the term and concept of consilience holds that no technoscientific discipline may violate the findings of any more reductive discipline on which it rests. Chemistry cannot contradict physics, nor biology chemistry, nor sociology biology. [Source: *Sociobiology* Ch.2]

No better example exists of modern biology's epistemic and ontological concerns with life - they are literally vital - than the changing (one wants to say 'evolving') technoscientific consensus *in re* the tiny, quasi-living things called viruses. What was the virus seen to be in classical times? Or in 1890, 1935, 1953, 1955, and 1962? Each answer, or more accurately the succession of answers that forms a cinematographic depiction of experimental biology, illuminates how technoscience has wrestled with, and continues its attempts to characterize, the hub of life.

II / FEVER OF THE MARSH:

VIRAL CONCEPTUALIZATIONS BEFORE 1935 (9)

Societies' traditional understanding of life, as summarized in the table above, might have added a final item: Disease. Everything living, from bipeds and quadrupeds to fish and plants, is seen at some point to fall ill. Sometimes a stricken individual recovers; sometimes not. But what is the cause of a given debility? Over the centuries, illness has variously been assigned to the phases of the moon; to the "foul and pestilent congregation of vapours" (10) rising from decaying organic matter on battlefields or in swamps; to the evil eye of witches or shamans; or to jealous gods.

Here STS may offer EXPLANANDES. The human brain is skilled at recognizing patterns, including both the patterns of temporal sequence called succession and the subset of succession called causation (11). In fact the brain (12) appears to have so great a hunger for pattern that it

9. 'The green god . . . Whose blood is the Spring sap and the running streams, / Whose witchcraft is the fever of the marsh' [Benét p.50 *passim*]

10. *Hamlet* II.ii. Shakespeare, like some of his antecedents (*e.g.* Paracelsus) seems to have used M. Tarentivs Varro (d. 27 BCE) as an uncited authority: *In marshy places little animals multiply which the eye cannot see but they . . . enter the body through mouth and nose and may cause grave disease* [cited Gallo p.1]

11. Any event B which follows a prior event A is not necessarily caused by A, even partly (shared cause). Assuming $A \Rightarrow B$ because the two events or conditions occur nonsimultaneously is a logical fallacy identified by classical logicians as POST HOC ERGO PROPTER HOC ('after that, thus because of that'). In other words, a given event must not be assumed to have been caused by another event that came immediately before. But PHEPH is not necessarily a fallacy: valid causes are also inevitable precursors. Etymologically, the word 'consequence' means 'that which follows' - not only causatively but also temporally. A universally true statement might be POST HOC ERGO CAPAX PROPTER HOC - 'after that, thus *possibly* because of that.' To tease apparent cause from real cause (as grant proposals inevitably conclude) 'more research is needed.'

12. More properly not 'brain' but 'eye-brain system.' The optic nerves exhibit so high a data bandwidth (Baud rate) that they effectively operate as brain extensions: cortical pseudopods. They process and interpret visual data *in situ* and do not simply send it back to cognitive headquarters for review.

consistently links unrelated things into causation, inferring patterns where none exist (13). As a result *something*, traditional societies felt, must cause disease. The alternative - that pestilence and fever were unpredictable and unavoidable, and that by extension all existence lacked meaning - seemed, and still seems, insupportable to the human mind. Even the most brutal gods [*ἀρες* god of war, *ἀτὲ* goddess of strife] or fates [*ἀτροπός* life-cutter] could not be so fickle.

Given all this, what *were* the proximate or ultimate sources of disease? While prescientific societies generally erred in their identification of causative agents, their associative insights could be as acute as our own; causation might elude them, but correlation did not. People who frequented lowlying regions were indeed likely to contract yellow fever, the terrible *vomito negro*. In war, unburied corpses were linked with subsequent plagues. Thus if battlefields or swamps PER IPSOS were not the final agents of catastrophe, some vector still seemed to link miasma with death. Here, it seemed, lay the PRIMVM MOBILE of disease: in demotic metaphor, the smoking gun (14).

Two 19th-century innovations lifted technoscience's grasp of pathology and its subsequent command of public health to levels beyond the abysmal traditional norm. These innovations, as important to human welfare as steam or cybernetics, were germ theory and statistical geography.

Although A.P. van Leeuwenhoek announced his discovery of erythrocytes and spermatozoa in letters to the Royal Society of the United Kingdom as early as 1676 (15), the identification of similar-sized microorganisms (16) as potential pathogens took another two centuries to surface as a technoscientific hypothesis.

Scientists in several European countries contributed to this process. In 1854 England, the medical doctor John Snow painstakingly correlated outbreaks of the 'bloody flux' (cholera) with sub-areas of London. The micro-regions he analyzed were as small as 0.5 hectare and centred on

13. Hence the Rorschach test. Psychotherapists theorize that the images perceived (*i.e.* imagined) by human test subjects in symmetrical but random ink blots may give clues to those subjects' deep nonconscious cerebral activity. As well, the psychological relevance of dream images may proceed from attempts by the sleeping brain's higher processing functions to make sense of random neurological noise from the R-brain or basal ganglia. The brain's complex outer layers project upon the noise the images and incidents that are most meaningful to it.

14. This datum was brilliantly applied in Connie Willis's novel *Doomsday Book*, in which a crystallized mediaeval influenza virus unearthed at an archaeological dig emerges from hibernation and foments a plague c.2050.

15. The original Dutch was subsequently Englished as 'animalcules' or, my personal favourite, 'wee beasts.' van Leeuwenhoek probably self-sourced these monocytes, giving the phrase 'delights of scholarship' a new meaning.

16. Typical bacterium size is c.0.5 -5.0 μ (500 nm - 5.0 μ m) θ , although the smallest bacterium and the largest virus overlap at roughly c.0.7 μ (700 nm) θ . As a mean proportional, the parvovirus (c.20 nm θ) is to a child's balloon (c.30 cm) as the balloon is to the size of the Earth (Carter & Saunders pp.4-5)

Broad Street (17). The maps he produced, among the first and still among the most reliable instantiations of epidemiological geography, found a smoking gun by consistently correlating disease cases with communal water sources in poor neighbourhoods. While an agent for this high-mortality disease was as yet neither known nor posited, Snow adduced persuasive evidence that its pathogen was waterborne. In France, L. Pasteur engineered a consensus (occasionally, as in his experimental rivalry with Pouchet, by questionable means) that microorganisms were the causative agents of anthrax, cholera, tuberculosis, and other diseases of humans and non-humans (18). In a newly unified Germany, R. Koch formulated a set of four 'postulates', critical conditions that, once met, strengthened correlation into causation and identified microbial culprits (19) (11).

The contentions of Pasteur, Koch, and other 'microbe hunters' (20) received support from laboratory experiments showing that serum taken from infected animals and put through fine filters (16) could thereby lose its ability to infect healthy individuals. Such data were inconsistent, however, as some sera passed through the finest available filters with undiminished virulence. The filterability of the disease agent, and thus by inference its size, seemed a consistent function of the disease in question. Sera involving (*e.g.*) tuberculosis and cholera were rendered innocuous by

17. Later renamed Broadwick Street, possibly to help London Council avoid lasting epidemiological infamy. Snow is immortalized by the best means possible: a pub in Soho bears his name. See also Camus, A., *La Peste*, a novel whose hero is not the narrator but the epidemiological statistician who charts, and so helps contain, the plague. (Some suggest the plague depicted in the book is a metaphor for WWII France's Vichy régime, which collaborated with the Nazis after the fall of Paris 1940. No matter: Camus's exegesis is medically exact.)

18. *Source*: Durant, D., YU STS 2411 lecture, 2011 October 25. See Latour, B. *The Pasteurization of France*; also Farley, J., & Geison, G.L., *Science, Politics and Spontaneous Generation in Nineteenth-Century France: The Pasteur-Pouchet Debate* (Bulletin of the History of Medicine, 48(2), pp.161-198.

19. Koch's Postulates (formulated with Friederick Löffler in 1884), which follow below in their initial form, have been modified over the last 130 years. For example, Postulate 1 is now qualified in that a subclinically small quantity of various pathogens is now thought to exist in apparently healthy individuals at all times (Carter & Saunders 2-3). Here are the postulates in their original form (Gallo 274-80, 289-90):

1. *The microorganism must be found in abundance in all organisms suffering from the disease, but should not be found in healthy organisms;*
2. *The microorganism must be isolated from a diseased organism and grown in pure culture;*
3. *The cultured microorganism should cause disease when introduced into a healthy organism;*
4. *The microorganism must be reisolated from the inoculated, diseased experimental host and identified as being identical to the original specific causative agent.*

20. Whiggish science historians tout Koch and Pasteur as the heroes of a *Hygieneschenheldenkampf*, fighting on to victory without hope or pause. In doing so, runs the Whig narrative, the heroes of science transcend the gods; for (so Schiller) *Mit der Dummheit kämpfen Götter selbst vergebens*. So much the worse for those antiquated Olympians, than whom K&P proved more effective! Yet close examination of technoscience invariably brings up additional figures. Besides van Leeuwenhoek there emerge Cuvier, Haeckel, Lamarck, Darwin, Huxley, and even Pasteur's competitor Pouchet. "Nineteenth century biology was a ferment of competing ideas and their champions, rather than a discipline

dominated by a single overwhelming individual comparable to Newton or Einstein." [Sources: Elwick, J., YU STS 3740 lectures, 2011 February 03 & 10; de Kruif, Paul, *Microbe Hunters* (pub. 1926 and still in print)] filtration; sera involving (e.g.) yellow fever and poliomyelitis were not. Microbiologists reasoned that one of two conditions had to apply. Either the nonfilterable diseases were caused by some yet-to-be-characterized 'active principle' such as a chemical compound (21), or else the agents were microbial pathogens of a size hitherto unsuspected - too tiny to be filtered, too tiny to be imaged in (optical) microscopes. The culprits remained suspected but unseen.

III / THROUGH THE PORCELAIN GATE

On June 28, 1935, the *New York Times* carried a journalistic rarity: a front-page story on curiosity-driven laboratory research, by the U.S. biochemist W.M. Stanley. *Crystals Isolated at Princeton Believed [to be] Unseen Disease Virus*, read the *Times*'s headline. The subhead: *Plant Organisms So Tiny They Seep Through Porcelain and Defy Microscope Produced as Infection-Duplicating Protein by Dr. W. M. Stanley of Rockefeller Institute*. The body copy said this was "a crystalline protein which possess the properties of a virus and, by its action, is believed to be the virus itself [. It has been] made tangible (22) and visible for the first time. Viruses in turn are -

micro-organisms so small that even the most powerful microscope is incapable of seeing them. They pass through the pores of porcelain filters that arrest ordinary bacteria. Yet, small as they are, they are known to be the causes of some of the deadliest diseases of man, animal and plant including infantile paralysis [poliomyelitis], encephalitis, measles, yellow fever, smallpox, rabies . . . and even the common cold. Stanley has succeeded for the first time . . . in obtaining a ghost substance (23).

Despite the sensationalism here (moderate, of course: this was the august *Times*) the *Ur*-text of the announcement was less its content than its timing. The popularization came out on the same day that Stanley's article appeared in the peer-reviewed journal *Science*, then as now the official journal of the American Association for the Advancement of Science (24). Such concatenation was no coincidence: Stanley's findings were worldwide news partly because F.D. Roosevelt, newly elected president of the United States, was confined to a wheelchair following a youthful polio infection.

21. Surprising as it may sound to us today who accept these contentions as received wisdom (though epistemically speaking they remain, like Feynman's electrons, purely instrumentalistic), the word and concept 'molecule' had still not attained technoscientific consensus as late as 1920. Dalton had propounded the atomic theory little more than a century beforehand (1802) and Einstein had calculated the external diameter (θ) of a sucrose molecule only in his 1905 doctoral dissertation (which long remained the most cited paper from his *Wunderjahr*, surpassing citations of Special Relativity by a factor of three [see Carter & Saunders *passim* esp. pp.4ff])

22. *Sic*: of course no human can directly sense something the size of a virus by unmediated touch.

23. *New York Times*, New York NY: 1935.06.28 p.1 (cited Creager p.62)

24. *AAAS Science* is so unimpeachably eminent that it was once satirized in *Esquire* magazine as 'Founded A.D. 11'

Assuming that responsible journalism both popular and technoscientific must flag its speculations, the *Times's* article was undeniably sensationalistic. Yet ironically in terms of later technoscientific findings the *Times* had hit a bull's-eye (25). An ancient enemy, imagined since Varro but never yet directly seen, was hidden no more. This was literally front-page news.

Still, no *individual* virus had been imaged. The crystals displayed in Stanley's paper (and trumpeted simultaneously by the *Times*) were crystalline aggregations of extraordinarily large quantities of the tobacco mosaic virus (TMV) (26). The Stanley images were optical photomicrographs with diametric magnification <1000 (< 1 000 000 times area).

However, a much more perspicacious technoscientific imaging process was on the way. One of the arcane tenets of the quantum theory that arose in physics c.1890-1930 (27) was that subatomic entities might simultaneously behave as both particles and waves. Cathode-ray technology, already well developed in 1935 for the promising medium of television, was repurposed into new instruments that projected high-energy leptons (electrons) in wave mode. These TEMs (transmission electron microscopes) imaged not just the microcosm (\pm c.0.000 001 m = 1.0 μ m) but in some cases the nanocosm as well (\pm c. 0.000 000 001 m = 1.0 nm) (28).

Equipped with such technoscientific second sight, and aided by an advancing biochemistry, researchers both commercial and academic quickly characterized several pathogenic viruses well enough to permit antiviral vaccines that were both efficient in the laboratory and effective in the outside world. By 1955 a U.S. vaccine *blitzkrieg* let applied medicine safeguard large populations against measles, rubella (German measles), mumps, chicken pox, and polio (29).

25. A nice case of right conclusions from wrong reasons: *see also* note 26 below

26. The full TMV history *per se* is fascinating, though necessarily outside the scope of this STS/HPS review paper. TMV has long been a key subject of technoscientific investigation in both curiosity- and commercially-driven work, due not only to innate properties (*e.g.* it is large enough to be experimentally accessible) but also to its economic impact as a crop pathogen throughout the tobacco-farming regions of the U.S.A.

27. From the work of experimentalists and theoreticians such as Planck, Einstein, Rutherford, Heisenberg *et alia*

28. 1.0 angstrom (Å) = 10 nm. The word 'nanocosm' is my neologism (eponymous title 2003). For a detailed exploration of contemporary high-resolution TEMs see Atkinson (2003) pp.149-152.

29. The paradigm for this by-guess-and-by-God antiviral empiricism remains smallpox. Observing that milkmaids were renowned for their perfect skin because they rarely caught this disease, which disfigures even when it does not kill, the English physician Edmund Jenner (d.1823) correctly surmised that the milkmaids had contracted a less virulent agent (cowpox) that permanently forestalled later smallpox infection. (As an aside, denial of the effectiveness, safety, and public or private desirability of immunization is not limited to contemporary groups: resistance to vaccination began from the time that Jenner first advanced his hypotheses. The 19th-century German student song *Ich Bin Der Doktor Eisenbart* mocks a doctor so demented that he presumes to vaccinate his patients. *Sources*: Andrewes pp. 20, 32, 74, 119f, 204f; Carter & Saunders 307-14; Gallo 2, 26, 93). Finally, it is to my knowledge still not widely recognized that the accelerated rollout of the Sabin poliomyelitis vaccine, which cultivated live viruses in monkey kidneys, risked infecting millions of children with simian viruses whose very existence went long unrecognized.

FORTVNA IMPERATRIX MVNDI: While luck rules all, not all luck - luckily - is bad.

While these achievements were epochal, their triumph came through empiricism rather than from deep theoretical comprehension: technoscience had managed to thwart a group of pathogenic viruses about which it still knew very little (30). That was about to change.

IV / SVMMA MORIYAMAE: NO CIGAR

In 1955 Dr Hideo Moriyama, Director of the Shonan Institute in Kamakura, Japan, published *The Nature of Viruses and the Origin of Life*. In his 454-page SVMMA, Moriyama synopsized all current thought on the origin, nature, and effects of viral particles (31); and in doing so reviewed fifty years of what one might call a fertile technoscientific indeterminacy (32). *The Nature of Viruses* was an attempt by one of the world's most distinguished biochemical virologists to summarize the state of his art. Both Moriyama's synopses of experimental observations and his theoretical synopses of their underlying realities perfectly fit all known observations. In 1955, this was the best data and theory in existence. It had only one problem: it was almost entirely wrong.

In hindsight one sees Moriyama's conclusions as specious, *i.e.* initially believable but on later analysis erroneous. Yet only six decades ago Moriyama's monograph was entirely consistent with the state of the biomolecular art. As conceptualized by Moriyama, a virus was an escaped and undisciplined component of life, a fleck of cytoplasm that had jumped the fence and begun a life of crime. Intracellular mayhem occurred when these wayward fragments of intracellular stuff gummed up the cellular works.

In parallel with his theories of viral origin and function, Moriyama proposed a new theory of viral infection. To Moriyama a virus was (or at least functioned as) an enzyme, breaking down cytoplasm into subcomponents identical with itself, or at least the same size as itself. In Moriyama's conceptualization, a virus held nucleic acids within a tough protective coat of protein, which combined the benefits of a deep-sea diving suit with those of a bulletproof vest. Finally, the Moriyama virus could also function as a free gene (33).

30. Gallo 55; Strauss & Strauss p.319. Creager (p.153) cites a marginal note made by Basil O'Connor in 1944: "Let[']s have a *new* philosophy of *doing* things in medicine. Let *c* (*sic*) how *quickly* we can do it (intelligently) and not how long we can *study* it." Similar forces dominate bioscience today. (O'Connor, FDR's law partner and personal attorney, was instrumental in organizing, administering, and raising funds to investigate the polio that had crippled his friend.)

31. Moriyama *passim*

32. Moriyama *passim*. Cf. also Rheinberger (Chs. 1, 2, 11 & Epilogue)

33.

Moriyama

pp.

376-9

What strikes one in parsing Moriyama today is how nearly some of his tenets came to what would soon be called the Central Dogma of molecular biology. Again in the demotic, Moriyama's *weltanschauung* was 'close but no cigar.' Even allowing for the central tenets of STS - scientific data are never complete, theory is always underdetermined, data accumulate, ambient paradigms are continually qualified and ultimately overturned - Moriyama's tally of near-misses evokes a regretful respect. Here is a first-class mind "feeling out of sight / For the ends of Being and of Ideal Grace" (34) yet falling short in its heaven-storming ambition. (There are worse fates: it is better to have theorized and lost than never to have theorized at all (35)).

V / STANLEY *REDVX*: THE CENTRAL DOGMA IN 1962

To compare Moriyama's book with that of Burnet & Stanley 1959 (a scant four years later) or Stanley & Valens (1962, seven years) is virtually to contrast Paracelsus with Pasteur. Here at the start of the post-Moriyama aeon appears a radical but apparently viable new science from two Cambridges: one in England, the other in Massachusetts. Laboratories in these places combined to make Moriyama a footnote, not a pioneer: it was their famous double helix that 'got the cigar.'

The 1962 paradigm (36) construed the virus as containing a heritable core of nucleic acids, all of double-stranded deoxyribosenucleic acid (DNA). The 1962 model virus also had a self-assembling protein coat so tough and simple that it often took a straightforward shape such as an isohedron (37). Under environmental stress it could even crystallize, re-emerging after centuries of hibernation into a bioactive form (14). At last Stanley's crystals, macro-sized when compared to the few nanometres of their constituent individual TMVs, could be reductively explained (38).

34. Browning, E.B., *Sonnet 43* ll 3-4 (partial). Cf. poets.org/viewmedia.php/prmMID/15384

35. Cf. Tennyson, Alfred: *In Memoriam A.H.H.* (Canto 27 ll.3f)

36. Admittedly, Stanley's simplistic 1962 exegesis has in the last half-century been greatly modified and fleshed out: nature always proves more complex than technoscience thinks in the glow of every big discovery. Viruses have been experimentally found, and theoretically characterized, which contain either DNA or RNA, and in single- or double-strand forms. Further, the Central Dogma contention that information flows only one way (out of the nuclear genome and never into it) has been largely discredited, through discovery of processes such as methylation. Lamarck and even the much-scorned Lysenko have recently been at least partly vindicated: environments can indeed induce what are in effect heritable traits. Perhaps most surprisingly, only a small fraction of the genome (estimates are as low as 3%) seems to triplet-encode for proteins. Notwithstanding these and hundreds of other qualifications, the Stanley exegesis arguably still stands at (or at least closely adjacent to) the epistemological centre of modern biology. (*Source*: Stanley esp. 63-93; Strauss & Strauss *passim*. Epistemically, all comparisons involving knowledge systems from differing times also involve hindsight. New research inevitably reveals the misprisions of past conceptualizations, while necessarily ignoring its own inadequacies *vis-à-vis* later knowledge.)

37. Stanley 61 (including photos)

38. Strauss & Strauss 35-37; 342f

As imagined in 1962, the typical virus could not self-propagate except by parasitic incursion into a cell, whether prokaryotic (bacterial) or eukaryotic (all other cell forms including fungi). Once in contact with the outer boundary of a host cell - whose volume exceeded that of the virus by several orders of magnitude - the invading virus used an enzymatic crowbar to force apart the host's bilipid membrane and enter its cytoplasm. The virus then proceeded to the host's governing DNA, either in its nucleus or (less commonly) its mitochondria. There the virus seized control by inserting its own handful of genes, recently freed from their protein armor, into the reproductive machinery of the host (39).

At this point (so Stanley 1962) the parasitized cell was compelled to devote its free material and energy to churning out copies of its viral invader. Dissemination of the resultant viral clones - strictly speaking not intruders but daughter parasites synthesized IN CELLVLA - could take one of two forms. A virus whose virulence was attenuated (40) might limit its predation, holding clone production below the host cell's death. Clones of these less virulent viruses escaped their hosts by gently budding through the cell wall. Viruses that had not yet learned such enlightened self-interest spurned such biochemical restraint, forcing the host to work itself to death by converting its entire mass into viral clones. These literally exploded into the intercellular medium when the wall of the host cell was subjected to such intense internal pressure from the viral clones that it mechanically ruptured (41). Even at the molecular level, it seemed, nature was red in tooth and claw (42).

VI / ALIVE, ALIVE-O! (43)

A key question now arose within the pure-curiosity technoscientific community. Could these strange, unimaginably tiny things truly be considered living? Were they demonstrably alive, as animals and their constituent cells were? Or were they merely things that were produced by life yet had no real life of their own? As construed by Stanley - *Wunderkind* in 1935, grand old man a generation later in 1962 - a virus demonstrated neither respiration nor any means of replicating

39. Stanley 124-149

40. Presumably by adaptive evolution. A parasite's survival is often enhanced when it shows less brutality toward its host and acts more like a symbiont than a hangman.

41. *Celludämmerung*, as it were. (Carter & Saunders 43, 55-65, 83ff, 237-260; Creager 270-81)

42. Tennyson, Alfred: *In Memoriam A.H.H.* (Canto 56 l.3)

43. Folk song *Molly Malone* (trad. Irish): "Crying, 'Cockles! Mussels! Alive, Alive-O!'"

by itself. It ate nothing, unless one considered the cell that a virus invaded to be its food. It excreted nothing. It produced no heat. Nonetheless, a virus did seem to possess and transmit heritable traits, undeniably a key attribute of life. If viruses were not living things, they at least manifested some convincing mimicry (44).

Here there enters in what one might call componental reductionism, a concept I propose as a potentially fruitful subset of epistemic materiality. While one hesitates to argue from analogy (45), many parallels between organic life and mechanical artifact are undeniably striking. An automobile has motility as well as Latourian agency (if not intentionality, which requires conscious intelligence). Dissected into a pile of parts, however, a car has no such properties: a connecting rod is not an engine, nor yet an engine a working car (46). Similarly, a DNA molecule is not a cell: the cell merely provides a contextual surround, which molecules use to establish and perpetuate life as an entity that is responsive, and adaptable - literally 'viable.' Put another way: DNA is a *necessary* precondition for life, a SINE QVA NON; yet is *insufficient* for life. Life requires the cell; or (in the case of viruses) the protein coat and various cellular prey species.

May then the *whole* cell possess life while the governing molecules at its core do not? Is it the *system* that is alive, rather than any of its components? The answer depends on whether Dawkins is correct in contending that every gene is 'selfish' - *i.e.* that an individual phenotype is nothing but a vessel for gene transmission; that life is, strictly speaking, only a mob of competing molecular replicators (47). If this be true, then the entire cell, eukaryotic or prokaryotic, is of the same class of things as a viral protein coat: mere context, produced by an all-conquering genome to sustain and perpetuate itself.

44. I cannot resist an aria here. Seen in hindsight, the progress (in the Elizabethan sense of a leisurely royal tour) of viral conceptualization is an amazing tale. Once thought to be unseen causes; then invisible agents that *had* to exist to induce observable macro-effects such as nausea and fever in humans, or stunting and death in plants; then active but unfilterable principles; viruses have at last been individually imaged and theoretically understood. As Murray Gell-Mann said, science takes an otherwise sordid human existence and raises it to the grace of tragedy.

45. Usually with good reason. A is by definition distinct from B; if an identity existed, a single descriptor would suffice for the two terms even if they were initially considered separate. Still, otherwise distinct entities can still be identical in one way: function. While (*e.g.*) John is not Jane, both may be considered identical *PRO TEMPORE* if, for example, both vote the same ticket in the same election. (*Source*: Durant, D., & Atkinson, W., YU STS 2411 lecture, 2011 November 01 [a somewhat acerbic classroom interchange])

46. I acknowledge that car and driver are different in kind, if not in degree (although as Marx says, sufficient quantitative change is qualitative change). N.K. Hayles has nicely expressed this distinction as one of intentionality - in her precise terms, allopoietic *vs.* autopoietic. My aim here is simply to suggest that, Russellian set theory notwithstanding (the barber paradox), the whole not only *is* but also *does* more than the sum of its parts.

47.

Dawkins

15-20,

47f,

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Stanley himself wrestled with these points. In chapter titled *Dead or Alive?* (1962) he writes:

No one worried very much about what it meant to be "alive" before the viruses came along . . . [Then] the old philosophical question, "what is life?" gained new significance. And at second glance, it proved to be a profoundly difficult question to answer. (48)

Despite the difficulties that he adduces, Stanley immediately offers a fascinating suggestion:

Since the same basic materials, the same chemical elements, are found in both living and nonliving things, the secret of life must lie in the way in which these elements are *organized* [Italics mine - WIA.] . . . [Scientists] have gained a new perspective through the study of viruses: instead of seeing the objects in our world as divided into two distinct groups [*viz.* living or nonliving], we can now see a single, continuous sequence . . . through the simple molecule, the macromolecule, the virus, the bacterium, and the jellyfish, to man. (49)

Setting aside the issues of sexism and speciesism (no doubt invisible to Stanley and his contemporaries) Stanley may have a point: here he does not resolve the life/nonlife debate so much as he end-runs it. Is he successful? Is life not a binary but a continuum? To address these questions and conclude our debate, I will touch upon some key tenets in the philosophy of science.

VII / ARGUMENTS OF PHILOSOPHY

I open this penultimate section (50) by freely admitting my effrontery in condensing two and a half millennia of deep thought on the life/nonlife boundary to a few words. Libraries have been written on these issues, and it must seem glib or presumptuous of me to explain them away so quickly. Nonetheless I believe that technoscience, or more precisely the paradigm-altering technoscientist Wendell M. Stanley, has once and for all solved the ancient riddle.

Judging by behaviour, living matter unquestionably differs from nonliving. The former, unlike the latter, seems ineluctably more active, adaptable, robust, and varied. And yet - if such teleological questions be ontologically admissible - is there something specific that makes life *lively*? Some agency that animates the animal (51)? Some transforming force or field that spontaneously converts vast and complex aggregates of otherwise lifeless quarks and gauge bosons into

48. Stanley 33

49. Stanley 37f

50. This section incorporates part of a proposal submitted on 2014 February 26 to Dr. J. Steigerwald

51. Etymologically, an *animal* is simply a being that possesses an *anima*, *i.e.* an activating principle. Perhaps the

Augustan Romans were less speciesist than we

self-sustaining, self-replicating patterns that sing, swim, dream, and win Olympic medals? If the answer to all these questions is *No*, there exists nothing but matter and energy, from which all else follows epiphenomenally.

Though currently waged by academic soldiers wielding advanced conceptual weapons, the ancient *αγόν* persists - a contest between vitalism (animating essentialism) and biological-medical materialism (life is but matter, full stop). Certainly, biology has today discarded earlier notions of 'vital fluids', which like phlogiston, aether, and the quantum multiverse, purport to explain everything but have the terminally unscientific property of being untestable. Like Tolkein's Enemy, however, vitalism is everywhere defeated only to reappear in other forms. Jane Bennett considers matter 'vibrant', brimming with latent properties that emerge in, among other configurations, life: to Bennett even bedrock has a soul (52). Sonnenschein *et al.* envision a resurgent vitalism opposing "a sort of a naïve physicalism [i.e. biomedical materialism] that hinders the understanding of biological organization" (53). Malaterre proposes to revivify vitalism (in itself an arresting image) by stressing emergence, a concept that covers life's otherwise inexplicable properties with linguistic fairy dust (54). Cyberneticists, drunk on their discoveries like many technoscientific explorers, seek to reduce life to information, in the same way man was reduced to strings and levers c.1600 and to an electrical machine two centuries later (55). There are many additional examples. Yet for some deep reason, the life/nonlife distinction - what I call the Central Binary - troubles us still.

Here is my take. While recognizing that I risk Hideo Moriyama's fate of historical marginalization, my considered conclusion after engaging this philosophical *melée* is that Wendell Stanley's 1962 theoretical synopsis was and is correct. The Central Binary is not only an assumption: it is an unwarranted one. There *is* no life/nonlife boundary, and never has been. The entire thicket of philosophical speculation that has proceeded from the Central Binary over the last two dozen centuries, rests on air.

52. Bennett *passim*

53. Sonnenschein, Abstract

54. Malaterre, esp. Chs. 8 & 9. An 'emergent property' inevitably reduces to a material manifestation whose origins and causes cannot be explained. Something that wasn't there, is there now; one hangs the word 'emergence' on the mystery and calls it an EXPLANANS: problem solved! I find this logically disingenuous.

55. The identity of life and information, which arose from computer science after WWII, is now being troubled. Tom Theis (Head R&D, IBM) holds that life extracts far more information from its surround than it receives from any genome. (Private communication, San Diego CA, 2002 July 10. Cited in Atkinson [2003] pp. 106-115.)

Let me rephrase Stanley's axiom, which I think permanently answers these philosophical conundra: *Every bit of matter that exists, of whatever size, may be viewed as occupying a specific point along a biocontinuum, with quarks and leptons on the far left (56) and sentient beings on the far right (57).* A rightward movement adds life, or more accurately *liveliness*, via steadily increasing complexity of pattern. Atom begets crystal; crystal begets rock; rock begets primitive replicators; primitive replicators beget virus; *und so weiter*. Intricacy of pattern rules all.

To settle the question, then: Is a virus dead or alive? It is both and neither. It is an 'organule' or a 'molechism' (58), much as an electron is simultaneously both wave and particle - a 'wavicle.' At the level of the virus, almost arbitrarily - yet not *quite* arbitrarily, since we are dealing with that most technoscientifically unfashionable entity, a completely nonquantized continuum - life begins. At the level of the cell, perception and learning begin (59). At the level of the animal, affect begins. At the extreme limit of intelligence, consciousness begins - you and me. The Pennsylvanian biologist Loren Eiseley caught it perfectly: not just the emergence of *H.sapiens*, but the entire universe as well, is an 'immense journey' (60). In achieving life, the cosmos stirs in its sleep. In achieving intelligence, the cosmos makes weapons, agriculture, cities, watercraft, poems. And in achieving consciousness, the cosmos becomes self-aware (61). No matter how long our species figures in this process - one century, ten, a million - with or without us, the journey will go on. I say it with gladness: There is grandeur in this view (62).

56. And, in all likelihood, those subatomic particles' own sub-constituents occupy points even farther to the left. "Greater fleas have lesser fleas / Upon their backs to bite 'em / And lesser fleas yet lesser fleas/ And so AD INFINITVM." (trad. English)

57. Not necessarily a speciesist statement. Together with *H.sapiens* on the far right (who else publishes peer-reviewed technoscientific journals?) I would place our fellow pongids; all cetaceans; the larger corvids, particularly *C.corax*; parrots; and the elephants. Further, as the biocontinuum is infinitely extensible in both directions, I would with a nod to my late friend Joshua Lederer reserve additional rightward positions for the coming findings of exobiology. There is no reason to assume life requires DNA, RNA, carbon, or even water. As we mature beyond the Central Binary we shall be forever cured of bioethnocentricity, knowing there are more things in heaven and earth than are dreamt of in our current technoscience. There is no logical reason that we should not one day hold dialogue with a self-aware star.

58. Terms coined by Stanley's colleague Thomas Rivers (cited Stanley p.36)

59. Bray *in toto* (what a book!)

60. Eiseley, L., (*eponymous book*)

61. Consciousness being distinct from 'mere' intelligence, which is less lively. Cf. Julian Jaynes, *The Origin of Consciousness in the Breakdown of the Bicameral Mind* (1976)

62. From Darwin's closing paragraph in later editions (*i.e.* >1859) of *The Origin of Species by Natural Selection*

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