

The Transcension Hypothesis: Sufficiently Advanced Civilizations Invariably Leave Our Universe, and Implications for METI and SETI.

[John M. Smart](#), 2011-2018. (v4.7).

President, [Acceleration Studies Foundation](#), Mountain View, CA USA

Lecturer, Naval Postgraduate School, Monterey, CA

Co-Founder, Evo Devo Universe Research Community, [EvoDevoUniverse.com](#)

Affiliate, [ECCO \(Evol. Complexity & Cognition\) Group](#), Center Leo Apostel, Free U. of Brussels, Belgium

Published as: Smart, John M. 2012. [The Transcension Hypothesis. *Acta Astronautica*, V78:55-68, doi:10.1016/j.actaastro.2011.11.006](#)

From presentation: *The Transcension Hypothesis*, 2nd IAA Symposium on Searching for Life Signatures, 6-8 Oct 2010, Kavli Royal Soc Internat'l Ctr, Buckinghamshire, UK ([Slides](#)).

For a longer treatment of the hypothesis: Smart, John M. 2008. [Evo Devo Universe? A Framework for Speculations on Cosmic Culture](#) In: *Cosmos & Culture*, S. Dick and M. Lupisella (Eds.), NASA Press, 2009

Highlights:

- Evolutionary developmental (evo devo) biology is used as a model for universal evolution and development.
- A developmental process is proposed that takes universal intelligence to black hole efficiency and density.
- Unique properties of black holes as attractors for advanced intelligence are reviewed.
- Testable implications of black hole transcension on exoplanet search, METI and SETI are proposed.
- Information theoretic and evo devo arguments for transcension as a solution to the Fermi paradox are proposed.

Abstract:

The emerging science of [evolutionary developmental \(“evo devo”\) biology](#) can aid us in thinking about our universe as both an evolutionary system, where most processes are unpredictable and creative, and a developmental system, where a special few processes are predictable and constrained to produce far-future-specific emergent order, just as we see in the common developmental processes in two stars of an identical population type, or in two genetically identical twins in biology. The transcension hypothesis proposes that a universal process of evolutionary development guides all sufficiently advanced civilizations into what may be called "inner space," a computationally optimal domain of increasingly dense, productive, miniaturized, and efficient scales of space, time, energy, and matter, and eventually, to a black-hole-like destination. Transcension as a developmental destiny might also contribute to the solution to the [Fermi paradox](#), the question of why we have not seen evidence of or received beacons from intelligent civilizations. A few potential evolutionary, developmental, and information theoretic reasons, mechanisms, and models for constrained transcension of advanced intelligence are briefly considered. In particular, we introduce arguments that black holes may be a developmental destiny and standard attractor for all higher intelligence, as they appear to some to be ideal computing, learning, forward time travel, energy harvesting, civilization merger, natural selection, and universe replication devices. In the transcension hypothesis, simpler civilizations that succeed in resisting transcension by staying in outer (normal) space would be developmental failures, which are statistically very rare late in the life cycle of any biological developing system. If transcension is a developmental process, we may expect brief broadcasts or subtle forms of galactic engineering to occur in small portions of a few galaxies, the handiwork of young and immature civilizations, but constrained transcension should be by far the norm for all mature civilizations.

The transcension hypothesis has significant and testable implications for our current and future METI and SETI agendas. If all universal intelligence eventually transcends to black-hole-like environments, after which some form of merger and selection occurs, and if two-way messaging (a send-receive cycle) is severely limited by the great distances between neighboring and rapidly transcending civilizations, then communication with feedback may be very rare, an event restricted to nearest-neighbor stars for a very brief period prior to transcension. The only kind of communication that might be common enough to be easily detectable by us would be the sending of one-way METI or probes throughout the galaxy. But simple one-way messaging or probes may be not worth the cost to send, and advanced messaging or probes may provably reduce the evolutionary diversity in all civilizations receiving them, as they would condemn the receiver to transcending in a manner similar to that of the sender. If

each civilization in our universe is quite limited in what they can learn given their finite computational resources, and if many civilizations evolve in parallel and in isolation in our universe for this reason, then a powerful ethical injunction against one-way messaging or probes might emerge in the morality and sustainability systems of all sufficiently advanced civilizations, an argument known as the [Zoo hypothesis](#) in Fermi paradox literature. In any such environment, the evolutionary value of sending any interstellar message or probe may simply not be worth the cost, if transcension and post-transcension merger are elements of an inevitable, accelerative, and testable developmental process, one that eventually will be discovered and quantitatively described by future physics.

Fortunately, transcension processes may be measurable today even without good physical theory, and radio and optical SETI may each provide empirical tests. If transcension is a universal developmental constraint, then without exception all early and low-power electromagnetic leakage signals (radar, radio, television), and later, optical evidence of the exoplanets and their atmospheres should reliably cease as each civilization enters its own technological singularities (emergence of postbiological intelligence and life forms) and recognizes they are on an optimal and accelerating path to a black-hole-like environment. Furthermore, optical SETI may soon allow us to map an expanding area of the galactic habitable zone we may call the galactic transcension zone, an inner ring that contains older transcended civilizations, and a missing planets problem as we discover that planets with life signatures occur at a much lower frequencies in this inner ring than in the remainder of the habitable zone.

Keywords:

Acceleration Studies; Astrosociology; Barrow Scale; Black Holes; Black Hole Accretion; Black Hole Time Dilation; Complexity; Computronium; Cosmological Natural Selection; Developmental Immunity; Doppler Spectroscopy; Evolutionary Development; Evo Devo Biology; Evo Devo Universe; Exoplanets; Fermi Paradox; Focal Sphere; Fundamental Parameters; Performance Capability Metrics; Galactic Habitable Zone; Galactic Transcension Zone; Gravitational Lensing; Information Theory; Inner Space; Intelligence Principle; Kardashev Scale; METI; Locality; Log Normal Distribution; Low Mass X-Ray Binary Systems; Moore's Law Limit; Morality; Missing Planets Problem; Polarimetry; Postbiological Life; Optical SETI; Order From Noise; Radio SETI; Square Kilometer Array; Star Lifting; STEM Compression; STEM Density; STEM Efficiency; Stochasticity; Superexponential Growth; Technological Singularity; Teleology; Transcension Hypothesis; Two-Way Messaging Limit; Universe Development; Universe Evolution; Zoo Hypothesis

Sections:

- 1. Universe Evolution and Development**
- 2. The Transcension Hypothesis**
- 3. Measuring Transcension**
- 4. Black Holes I**
- 5. Black Holes II**
- 6. METI Implications**
- 7. SETI Implications**
- 8. Resisting Transcension**
- 9. Acknowledgments**
- 10. References**

1. Universe Evolution and Development: A Biological Model for Cosmic Culture

The emerging science of evolutionary developmental (“evo devo”) biology (Carroll 2005, Kirschner and Gerhart 2005) can aid us in thinking about our universe as both an evolutionary system, where most processes are unpredictable and creative, and a developmental system, where a special few processes are predictable and constrained to produce far-future-specific emergent order, as seen in the developmental processes guiding the emergent similarities among two genetically identical twins.

In discriminating between evolution and development in living systems, one of the most important insights is that the vast majority of biological change that we observe in the emergence or control of complexity is evolutionary. By this we mean it is unpredictable, stochastic, experimenting, creative, locally-driven, a bottom-up, two-way (communication and feedback) process of complexity creation and variation. Only a special subset of biological change, perhaps something less than 5% at the genetic level, to a first approximation, is what we call developmental. By this we mean it is predictable, cyclic, randomness-reducing, convergent, conservative, globally-

driven, a top-down, one-way process of complexity conservation and constraint. The “developmental genetic toolkit” is a set of special genes that have been highly conserved in all higher life, from nematodes to humans. To a rough order it involves 2-5% of genes in complex organisms (e.g., perhaps 2-3% of the *Dictyostelium* genome of 13,000 genes, Iranfar et al., 2003). These genes constrain and direct developmental change, and change very slowly over time. Evolutionary processes range across the entire remainder (95-98%) of the genome, and produce phenotypic variety. The genes involved in evolutionary processes change much faster over time.

Gould (2002) has argued that the only broadly predictable feature of evolutionary processes is that their variety increases over time. Viewed over geologic time, the “tree of life” gains ever more branches, species, and specializations across all life-permitting environments. At the same time, all biological systems engage in developmental processes, which cause them to be born, grow, mature, replicate, grow old, and die. Such perennial developmental life cycles are the conserved and constraining framework upon which all evolutionary processes occur. If one has the appropriate physical knowledge, such as the ability to computationally model development, or if one has historical experience with prior cycles of a developing system, developmental processes become predictable.

As Smart (2008, 2010), Vidal (2008, 2010a,b), and others in the [Evo Devo Universe research community](#) have proposed, evolution and development may work the same way in the universe as a system. If our universe is a system presently engaged in a life cycle (“Big Bang” birth, growth, maturity, replication, senescence, and eventual thermodynamic or other death), we may ask, which of its features are evolutionary, and which are developmental, and which mechanisms it uses to pass on its evolutionary intelligence in the next developmental life cycle. We can observe many physical processes in our universe that seem perennially creative, exploratory, and unpredictable (quantum mechanics, chaos, nonlinear dynamics, non-equilibrium thermodynamics), and a special subset of processes that seem highly conservative, constraining, and predictable (conservation laws, entropy, classical mechanics, stellar lifecycles, spacetime acceleration). Both evolutionary and developmental attractors, or systemic teleologies, appear to operate in this complex system.

If universal change is analogous to the evolutionary development of two genetically identical twins, two parametrically identical universes (possessing identical fundamental physical parameters at the Big Bang) would exhibit unpredictably separate and unique internal evolutionary variation over their lifespan (unpredictable differences in specific types of species, technologies, and knowledge among civilizations), and at the same time, a broad set of predictable and irreversible developmental milestones and shared structure and function between them (broad and deep commonalities in the developmental processes, body plans, and archetypes of life, culture and technology among all intelligent civilizations). This question is thus relevant to astrophysics, astrobiology and astrosociology. One potential developmental process that, if validated, would have great impact on the future of civilizations will now be proposed.

2. The Transcension Hypothesis: Sufficiently Advanced Civilizations Invariably Leave Our Universe

The *expansion hypothesis* (Kardashev 1964, and many others since) predicts that some fraction of advanced civilizations in our galaxy and universe must become beacon builders and spacefarers, spreading their knowledge and culture far and wide. Expansion is the standard expectation of those engaged in SETI (search for extraterrestrial intelligence) and METI (messaging to extraterrestrial intelligence) today. Expansion scenarios typically assume ETI messaging to be bounded by the speed of light, and space travel to occur at some significant fraction of the speed of light.

By contrast, the *transcension hypothesis*, also known as the developmental singularity hypothesis (Smart 2000, 2008, 2010) proposes that a universal process of evolutionary development guides all sufficiently advanced civilizations increasingly into inner space, the domain of very small scales of space, time, energy and matter (STEM), and eventually, to a black-hole-like destination, censored from our observation. Vinge (1986), Banks (1988), Brin (1998a) and others have explored variations of this idea in science fiction. If constrained transcension operates on all advanced civilizations as they develop, and if this process leads them, with rare exception, to enter inner space or black-hole-like domains, this would explain Enrico Fermi's curious paradox, the question of why we have not seen signs of intelligence in our own galaxy, even though Earth has likely developed intelligent life one to

three billion years later than other Earth-like environments closer to our galactic core (Lineweaver et. al. 2004). This impressively long period of prior evolutionary development provides plenty of time for messages, automated probes, or other signs of galactic intelligence to have arrived from any *single* advanced civilization that chooses an expansionist program. Explaining the Fermi paradox is a particularly great scientific challenge if ours is a biofelicitous (life friendly) universe, as recent astrobiological evidence suggests it to be (Davies 2004, 2007).

Proving the existence and exclusivity of the transcension hypothesis with today's science may be impossible. Nevertheless, several early lines of evidence, and corresponding SETI tests, can be offered in support of the idea. If we grossly define "complexity" as the number of unique combinations of structure and function expressed in a physical system, we can propose that the leading edge of structural complexity over universal history has occupied ever more spatially-restricted universal domains than its antecedents, a phenomenon we may call the increasing "locality" (or perhaps, "multi-locality") of complexity. A familiar history of physical complexity begins with universally distributed early matter, leading next to superclusters and large scale structure, then to the first galaxies, then to metal-rich replicating stars within special galaxies, then to stellar habitable zones, then to prokaryotic life existing on and around single planets in those zones (miles deep in our crust, miles in the air, and evolved in situ or as planetary ejecta on meteorites in near space), then to eukaryotic life inhabiting a far more restricted domain of the special planet's surface, then to human civilizations living in yet more localized domains, then to humans (each with 100 trillion unique synaptic connections) in industrial cities emerging as the leading edge in those civilizations, and perhaps soon, to intelligent, self-aware technology, which will have even more unique connectivity, and inhabit, at least initially, a vastly more local subset of Earth's city space. Self-aware computers may themselves be able to enter far more miniaturized and local nanocomputational domains. Thus, to a first approximation, the increasing spatiotemporal locality of leading edge substrate emergence looks like universal complexity heading toward transcension as it develops (Smart 2008).

Now complex systems do expand regularly into neighboring, or "next adjacent" spatial realms during their evolutionary development, and during such brief expansions, locality decreases briefly for the system under observation. Supernovas reach distant domains of space, ocean life colonized land, humans colonized much of the surface of Earth, intelligent robots will soon colonize our solar system. But note that this type of expansion is always quite limited. Systems at any fixed level of complexity do not expand continuously, or at an accelerating rate. They expand until they reach their own systemic or local environmental limits, or have produced the next level of complexity development. Over universal history the increasing locality of the spatial domain of the leading edge of complex systems is a far more prevalent trend than the periodic next-adjacent spatial expansion in these systems, and on first inspection, increasing locality seems a good candidate to be a process of universal development.

3. Measuring Transcension: Accelerating STEM Density, Efficiency, and Computational Capability Trends

A few evolutionary, physical, and information theoretic reasons, mechanisms, and models for constrained transcension have been proposed, and a few will now be briefly examined. Smart (2000, 2002b, 2010), Chaisson (2001, 2003) and others have noted that a special subset of our most recently evolved complex systems display accelerating growth in both their computational capabilities and the efficiencies and densities of their physical resource (Space, Time, Energy and Matter, or STEM) inputs to computation. Accelerating STEM efficiency and density growth at the leading edge of complexity can be called STEM compression, the phenomenon of increasing spatial, temporal, energetic, and material density and efficiency per computation in leading edge systems over time. Aspects of this phenomenon have been described in the literature as dematerialization (Ausubel et. al. 1996), ephemeralization (Fuller 1938,1979,1981), time-space compression (Harvey 1989), miniaturization (Gilbert 1961), densification (Leskovec et al. 2005), virtualization (Levy 1998, Blascovich and Bailenson 2011), digitization (Negroponte 1996, Polastron 2009), and simulation (NSF 2006). To date, no comprehensive theory of this process has been advanced, yet we can observe and measure it from each of these and other perspectives.

We have already noted the increasing spatial locality (space density and efficiency) in leading complex systems over universal history, and this phenomenon continues to accelerate in human civilization today. As Glaeser (2010) notes, 243 million Americans, 79% of us, voluntarily crowd together in just the 3% of our nation's space that is urban. Bettencourt et. al. (2010) document the greatly superior per capita wealth generation, innovation, and

sustainability features of highest density megacities, and their ability to solve problems of pollution, crime, and gridlock that periodically block further densification. Yet while the world continues to urbanize, cities may no longer be the leading edge of complexity per computation or information generated per unit of space, time, energy, or matter. Some argue that corporations outperform cities on information generation and computation per resource, and certainly our new electronic devices and networks are even more STEM dense and efficient per computation than anything so far seen on Earth, as we will see below.

Returning to a macroevolutionary perspective and moving on from space to *time*, we can measure the increasingly rapid temporal succession of significant complexity emergences in cosmic, biological, and human history, the closer we approach the present day. Adams (1909) and many successors have observed this accelerating emergence pattern, popularized in the metaphor of the Cosmic Calendar (Sagan 1977). Meyer (1947,54) and successors (Nottale et al. 2000a,b, Johansen and Sornette 2001, Kurzweil 2005, Korotayev 2006) have built simple empirical mathematical models of log-periodic emergence acceleration in the history of life and human culture.

Energy flow density acceleration at the leading edge of complex systems has been estimated by Chaisson (2001,2003). He calls energy flow density a measure of the dynamic complexity of the system being studied. The more complex the system, the more this energy flow, or metabolism in living systems, may be a proxy for the intrinsic rate of computation and learning occurring in the system. Per Chaisson, a modern computer chip exhibits roughly ten million times more energy rate density (energy flow per unit mass or volume) than a human brain. It communicates and generates systemic information roughly ten million times faster too (the speed of electricity versus the speed of neural action potentials). While today's computers still lack our structural or connectionist complexity, their vastly superior rate of learning suggests that in the foreseeable future they will attain and exceed our structural complexity as well. Energy efficiency acceleration has also been shown to be smoothly logarithmic for at least the last few hundred years, across a broad variety of lighting, power, computation, and communications technologies and nanotechnologies (Richards & Shaw 2004, Koh & Magee 2006, 2008). Note also that the higher the energy flow density of any system, the closer the system approaches the universal density limit—a black hole.

Matter density and efficiency are also growing rapidly with time in leading edge systems. Consider the growth in matter efficiency and density of computation that was needed to produce biological cells. We think pre-life chemistry was far less materially efficient and dense than the first cell (Orgel 1973). DNA packing and unfolding machinery (histones, nucleosomes, etc.) in every eukaryotic cell allows a massive increase in material efficiency and density of genetic computation vs. earlier prokaryotic cells, which contain far more primitive compression technology. Human and material flow efficiency and density in a modern city is far greater than in pre-technologic cultures. Material efficiency and density in ICT computing also grows rapidly, and is increasingly led by mass- and energy-efficient Green ICT initiatives (OECD 2009)

Computational performance capabilities, as measured by information production, instructions per second/energy/mass/volume, perception, action, and other measures, appears to grow exponentially or greater at the leading edge of complex systems (Nagy et. al. 2010). From a theoretical perspective, whenever STEM compression of inputs to computing systems governs the rate of local complexity development, we may expect accelerating STEM compression to be accompanied by accelerating computational outputs in leading complex systems. Computational acceleration measures are plentiful. Bohn and Short (2009) and others have measured exponential growth in information production in technological society. Nagy et al. have measured exponential or greater growth in the computational outputs of market-leading technological systems. Swenson and Turvey (1991) and others in ecological psychology have measured long-term exponential growth in perception and action variables in leading-edge living systems. Zotin (1984) has charted exponential growth in respiration intensity (both an energetic and an action variable) in higher organisms as a function of geologic time. Scholars of functional performance capability metrics (Sahal 1979, Dutton and Thomas 1984, Koh & Magee 2006, Nemet 2006, Yeh & Rubin 2007, McNerney et. al. 2009) chart the accelerating capability of human-technological systems to produce products with power-law declining resource inputs, yielding accelerating increases in services or information output per resource input. While the performance capability curve of each specific technology is often logistic (Modis 2002), successive functional substitution of ever more STEM efficient, miniaturized, and dense technologies yields an exponential or greater second order trend. For an obvious example, while human transportation through physical space has been in logistic saturation for decades, computational complexity itself is

subject to no such limits. It continually jumps to more STEM efficient, dense, and virtual substrates (e.g., telepresence vs. physical commuting).

Based partly on these trends, the arrival of generally human-surpassing machine intelligence, an event called the technological singularity, is expected by some as an imminent development (Vinge 1993, Sandberg 2010). Science fiction authors such as Stapledon (1937) and Asimov (1956), and philosopher scientists such as Teilhard (1955) and Tipler (1997) have contemplated the idea of accelerating complexification as a universal developmental process, and universal intelligence's eventual arrival at an "omega point," representing the maximum complexity allowed by our universe's particular physics. What is needed now is to update and further constrain such ideas within a model of universal evolutionary development, a model that contrasts a small subset of statistically predictable developmental processes with the apparently much larger set of unpredictable evolutionary experiments occurring within the universe, and perhaps, an understanding of our universe as a finite system engaged in a developmental cycle within a multiversal environment (Smolin 1994).

Expansion-oriented scholars frequently refer to the Kardashev scale (1964,1997), which first proposed that growth in a civilization's total energy use (using first a planet, then a sun, then a galaxy, then the universe's energy budget) is a reasonable metric for development. But if transcension is the fate of all advanced civilizations, total energy use would only be a proxy for early civilization development, and a would be a misleading indicator late in development. Total energy use cannot grow exponentially beyond the energy budget of the civilization's star, *unless* such civilizations enter black holes (inner space) and undergo extreme time dilation, a topic we will discuss shortly. In normal (outer) space, we can expect a civilization's energy use to grow logarithmically to the limit of local energy resources, due to the vast distances between stars. Barrow (1998) has proposed an anti-Kardashev scale, where the key metric is instead the miniaturization (spatial localization) of a civilization's engineering, perhaps terminating at the Planck scale. Due to STEM compression, intelligent civilizations can presumably continue to develop exponentially more localized, miniaturized, dense, efficient and complex structures and energy flows to generate greater computational and adaptive capacity, right up to the black hole limit and presumably even beyond, as black hole event horizons in stellar mass and supermassive black holes are still well above the apparent Planck-scale limits of universal structure. Thus, if the hypothesis is correct, the Barrow scale, and more generally, STEM efficiency, STEM density, and computational growth scales would be much more appropriate measures of civilization development.

Because of the superior adaptive and innovative capabilities of systems at the leading edge of universal complexity, and because the special physics of our universe appears to support computing and physical transformation at ever-denser, more miniaturized, and more STEM efficient (sustainable, virtual) scales, our civilization's present acceleration toward the black hole limit seems likely to continue. So far, as each particular computing system has saturated in its capabilities, new ones with ever greater miniaturization, energy flow density, and efficiency have continually emerged. Visionary engineers propose that future computation and future intelligence may use single electron transistors, photonics, spintronics, etc. As Nagy et. al. (2010) and others note, our technology capability performance metrics related to computing, communications, and nanotechnologies have always been on gently superexponential, perhaps even hyperbolic curves. Astonishingly, if current trends continue, a physical limit to computational acceleration must arrive just centuries, not millennia, from now. Quantum physicist Seth Lloyd (2000a, 2001) proposed that we will arrive at the Planck scale of computational miniaturization within the next 250-600 years, if acceleration continues at historical rates. Krauss and Starkman (2004) make similar calculations arriving at a 600 year limit to the continued acceleration of Moore's law. Subjectively the transition might feel much longer, to the hyperaccelerated intelligences of the postbiological Earth. Yet to an observer in "normal" spacetime, transcension would occur over an amazingly short period in astronomical time, a shortness with major implications for SETI, as we will discuss.

4. Black Holes I: Ultimate Computing, Forward Time Travel, Learning, and Energy Harvesting Devices

With respect to their internal computational capacities, Lloyd has theorized that black holes are the "ultimate" computing environment, as only at black hole energy densities does the "memory wall" of modern computing disappear (2000a,b). In all classical computing, there is a time cost to sending information from the processor to the memory register and back again. At the black hole limit of STEM density, computers attain the Bekenstein

bound for the energy cost of information transfer (Bekenstein 1981), and the time it takes to compute, or flip a bit (t_{flip}) at any position, is the same as the time it takes to communicate (t_{com}) from any point in the system to any other around the event horizon. Communication and computation have become a convergently unified process in black holes, making them a maximally STEM efficient learning system.

Local intelligence would very likely need to be able to enter a black hole without losing any of its structural complexity. Hawking (1987) has speculated we might do just this, if advanced intelligence is built out of some form of femtotechnology (structures below the atom in size). There are twenty five orders of magnitude of “undiscovered country” in scale between atoms (10^{-10} m) and the Planck length (10^{-35} m) for the possible future creation of intelligent systems. Inner space engineering may one day occur within this vast range, which is almost as broad as the thirty orders of scale presently inhabited by biological life.

Just as curiously, due to the nonintuitive properties of general relativity, black holes are near-instantaneous one-way information collection (to the hole, almost exclusively) and potential time travel (to the future only) devices. Because of the gravitational time dilation, nonlocal time flows slower for all objects experiencing any gravitational field, and it flows *vastly* slower externally the closer you approach a black hole. Thus a highly dense, miniaturized, and intelligent civilization sitting just above the event horizon of a black hole would *merge nearly instantaneously*, from their unique time-dilated reference frame, with all other black holes that are in their local gravity wells in the universe (Thorne 1994). Recall the college physics example of the astronaut falling into a black hole, who, the closer he gets to the hole, seems to slow down, from our reference frame. Eventually his image is frozen at the event horizon, staying for a near-eternity, to external observers. From the astronaut's reference frame, time goes no faster in his local vicinity, but everything in the external universe speeds up incredibly the closer he gets to the horizon, eventually going near-instantaneously fast (Taylor and Wheeler 2000). He sees remaining universal dynamics play out almost immediately. While the physics of black holes themselves is a strange and still-unsettled topic (Susskind 2008), it seems reasonable to this author that given time dilation as we *approach* black holes under standard relativity theory, black-hole-dense objects themselves should also experience instantaneous (or near-instantaneous, as infinities don't make sense in physical systems) forward time travel with respect to the universe.

For non-rotating Schwarzschild black holes, the radius of the last stable orbit (LSO) in general relativity is $6GM/c^2$, three times further out than its event horizon. But such black holes may only be mathematical idealizations. Some astrophysicists think that all black holes rotate at least a little, making them all Kerr or Kerr-Newman black holes, and most should rotate extremely fast, due to conservation of angular momentum. For maximally rotating Kerr or Kerr-Newman black holes, the last stable orbit (LSO) occurs at half of the Schwarzschild radius R_s . For such black holes, $R_s/2$ is also where the event horizon occurs. Direct and indirect measurements have estimated that several known supermassive black holes, resident at galactic centers, natively rotate at very close to the speed of light (86 to 99%, by various measurements, see Reich 2013). So for the extreme case of a maximally rotating black hole at least, $EH = LSO = R_s/2$, we can imagine an engineered object capable of acting as an instantaneous forward time travel device, under standard interpretations of general relativity.

It is also possible that advanced civilizations rather than "entering" a local black hole, rather embed themselves, like flies to flypaper, as "information structures" on its computationally optimal surface. One leading version of the current information theory of black holes proposes that a complete description of all information that enters any black hole must be contained on its surface, in the 2D information structure of its event horizon. The most general version of this postulate is known as the holographic principle in string theory (Bousso 2002). It proposes that all 3D physical activity in the universe can also be represented as a 2D information structure embedded in the universe's cosmological horizon (outer accessible boundary), and on the surface of black holes. It is too early to know if all universal information and physics are related in this conceptually simple and elegant way, yet it is promising avenue of research. In short, as there is much about both stellar and supermassive black holes that we still do not understand, including the informational and physical nature of their surfaces and interior, the possibilities of black hole forward time travel remains guesswork today. Much more theoretical, observational (via gravity waves), and perhaps one day, empirical work may be required.

Using current measurements of dark energy acceleration in between galaxies, a repulsive effect that appears to be subdividing our universe into informationally-disconnected islands, but which is also overwhelmed by gravitational attraction between local galactic clusters, Nagamine and Loeb 2003 tell us that our Milky Way galaxy

will merge with the Andromeda galaxy in just tens to a few hundred billions of years, and all black holes, and black hole associated civilizations within each galaxy, including those which may exist near or within the supermassives at the core of each galaxy, will merge in a few hundred billion years thereafter. But if black holes can be used for extreme gravitational time dilation/compression as I have described, these civilization mergers should occur near-instantaneously to all observers in the reference frame of their local black hole time. Prior to merger, all such civilizations may also be able to maximize their information collection with respect to the external universe, as we will next describe. Whether these results can occur inside the event horizon of a black hole, as well as at or near the event horizon itself, is not settled yet, as far as I can tell. But what is clear is that all the matter in all galaxies will end up inside merged black holes (Lehners et. al. 2009).

A black hole is the last place you want to be if you are still trying to create (evolve) in the universe, but this seems exactly where you want to be if you have reached the asymptote of complexity development in outer (normal) space, have employed all local STEM resources to create the most dense and efficient non-relativistic computational substrate possible, a substrate some science fiction authors refer to as “computronium” (Amato 1991), and are now finding the observable universe to be an increasingly ergodic (repetitive, uninformative) and senescent or saturated learning environment, relative to you. In other words, the more computationally closed local computing and discovery become, and the more complex you become relative to the nondense regions of the universe, the faster you want the nonlocal universe to run to transfer the last bits of useful nonlocal information to yourself in the shortest amount of local time. Black holes are also a way to change the topology of the universe to allow you to rapidly merge with all its most complex regions (other universal intelligences), a topic we will discuss in the next section.

Furthermore, as Eshleman (1979, 1991), Maccone (1992, 1998) and others propose, massive objects like our sun are great telescopes for gravitational lensing, for collecting nonlocal information about the universe. Sensors in orbit at a stellar focal distance of 550 AU from our sun would have very high quality nonlocal information streaming into them. Maccone has estimated that such a telescope would allow us to observe planets across our galaxy as if they were in our own solar system, and detect and analyze the faintest EM signals. But as Vidal (2010b) has noted, the resources of our parent star, if absorbed into a black hole instead, would allow an even better telescope to be produced, one with a focal distance only a *few kilometers* away from the hole (Maccone 2010), and thus the ability to field a far higher density of sensors. Should an intelligent civilization, prior to its final formation as a black hole, construct a focal sphere of tiny orbiting sensors at the appropriate focal distance in normal space, the sensors would stream the ultimate high resolution movie of all future universal activity into it as it instantaneously headed to its gravitationally-determined merger point. Thus we may call the black hole focal sphere an “ultimate learning device,” as it would capture as much remaining nonlocal information as may be theoretically possible, in the shortest local time possible, allowing all black hole civilizations to record remaining universal reality as fast as possible, then update their perennially imperfect and incomplete models as best as possible at the merger.

Finally, very slow accretion of matter into a supermassive black hole, such as occurs in now-quietest supermassives like Sagittarius A* at our galactic center, is perhaps the most efficient energy harvesting process presently known in our universe (Frank et. al. 2000). The thin class of accretion disks observed around some stellar-mass black holes are also the most efficient presently known local harvesters, as much as 50 times as efficient as stellar nuclear fusion (Narayan and Quataert 2005). If an intelligent civilization desired to maximize the STEM efficiency of its remaining pre-merger computations in the process of black hole formation, as seems likely, slow accretion of the gases of the parent star would seem to be an ideal developmental path. As Vidal (2010b) proposes, high-efficiency or other unusual routes of black hole formation, if otherwise unexpected and observed only in a special class of black holes, may be evidence of intelligent rather than classical processes of formation.

5. Black Holes II: Ultimate Civilization Merger, Natural Selection, and Universe Replication Devices

Now imagine you are an advanced future civilization in our solar system. You have rearranged your solar system's matter and energy into exponentially more STEM efficient, dense, and adaptive types of computing substrates over time. You have transitioned from postbiological life emerging at a singular point on Earth (Vinge 1993), to an

integrated global brain (Bloom 2000, Heylighen 2007), and perhaps next to a Jupiter brain (Clarke 1982; Sandberg 1999), exponentially harvesting the matter of your local gas giants (Jupiter and Saturn for us) and other planets, via some form of self-replicating nanomachinery, and turning it all into computronium. You might spare your home world briefly prior to uploading it (Broderick 2002), but in the long run, you would likely collect all easily accessible nonsolar matter and convert it to a multi-planet mass entity with a very high density, one that still allows you to enter normal space. You would probably be something like an artificial neutron star (Forward 1980), with a metabolism and brain operating at femtosecond speeds. Once you have reached this near physical limit of computational miniaturization and easy access to new mass, your long history of superexponential acceleration must stop, due to the speed of light barrier and the astronomical distances between you and other resources. At this unique point in evolutionary development, the only way your civilization can continue to accelerate is to compress itself further, all the way to a black hole, perhaps leaving a small shell of normal matter around yourself to create a focal sphere, to relay high-quality observations of the universe as it progressively merges and dies.

If, after black hole accretion, stellar fusion is the highest yield energy production process intelligence can control in our universe, as some have suggested (Harris 2008), then there seems to be no value to "[star lifting](#)", the repurposing of a star's matter-energy for intelligent uses (Criswell 1985), other than by passive accretion into the hole. Intelligences could be expected to slowly accrete the mass of their parent star, rather than lifting or collapsing that mass and then inefficiently recreating fusion within the black hole (if the laws of physics even allow the latter, which they may not). In other words, you might absorb your star in a passive and gravitationally-driven process that would look a lot like a low mass X-ray binary (LMXRB) system to external observers, but in which the black hole companion begins as a planet mass black hole on the order of 1000 times less massive than the star companion, which should be a main-sequence star, likely with a spectral class G, like our Sun.

Approximately 100 LMXRBs have been discovered in our galaxy to date, and about 13 of these have been found in the globular clusters, areas at the rim of our galaxy that may not harbor intelligence. They have also been found in many distant galaxies, again often in globular clusters. Few have involved G class stars, and none have yet been discovered with the very high, 1,000:1 mass ratio the hypothesis appears to predict. This may simply be a problem of detection. XRBs emit X-rays only when they are "eating" their companion sun, a transient phenomenon. *Chandra*, our best X-ray observatory, may also not have the sensitivity or persistence needed to detect very high mass ratio LMXRBs, or those that absorb their star's matter very infrequently or in very small doses. More research and theory is needed in this area.

Returning to your perspective as a newly created intelligent black hole, one of extreme gravitationally induced time-dilation, you would near-immediately absorb your star's mass-energy, and then rapidly and passively merge with all the other intelligent black holes in your vicinity (Andromeda and Milky Way galaxies, for us). If each of these civilizations is computationally unique and incomplete, this would appear to be an ideal universal mechanism to allow further competition, cooperation, and natural selection at the merger point. Black hole creation and passive merger can thus be seen as an attractive and potentially developmentally-constrained destination for all sufficiently advanced intelligences in universes with our physics.

Black holes may not only be ideal attractors of advanced complexity, there is also early evidence that they may be ideal *seeds* or replicators of universes within an environmental structure called the multiverse. Lee Smolin's hypothesis of [Cosmological Natural Selection](#) (1992, 1994, 1997, 2006) makes this claim. In the 1980's, theorists in quantum gravity began postulating that our universe might give birth to new universes via fluctuations in spacetime over very short distances (Baum 1983; Strominger 1984; Hawking 1987, 1988, 1993; Coleman 1988). Some (Hawking 1987; Frolov 1989) proposed that new universe creation might be particularly likely at the central "singularity" inside black holes. The singularity is a region where our equations of relativity fail to hold, depicting energy and space at improbably "infinite" densities. In Smolin's model, what occurs there is a "bounce" that produces a new daughter universe, one with fundamental parameters that are stochastically different from the parent universe.

Furthermore, Smolin (1997) noticed that fundamental parameters fall into two groups. He found that eight changes in a few of the twenty (by his count) fundamental parameters presently known in our standard model of physics (empirically-derived particle masses, matrix parameters, and a variety of constants), are fine-tuned to produce black hole fecundity (universes with trillions of black holes), and universe longevity, and complexity (multi-billion

year universe lifespans, capable of complex internal life). These special parameters would thus be highly conserved in replication of complex universes. That would make them developmental (in evo devo language), a topic known to theorists as the fine-tuning problem. Other fundamental parameters, per Smolin and others, do not appear to be sensitively tuned for universal fecundity, longevity, and complexity, but rather create phenotypically different universes, which are all black hole fecund, long-lived, and complexity-permitting. By analogy with biology, this second group can be considered evolutionary parameters (again in evo devo language, not Smolin's). In this scenario, each universal civilization may be in the process of turning into something analogous to a seed, a developmental structure that packages its evolutionary history and experience in a way that transcends our apparently finite and potentially dying universe, just as seeds transcend finite and dying biological bodies. An equivalent biological analogy for our universe itself might be an ovarian follicle, a developmental structure that assembles many potential seeds and puts them in a competitive selective system to generate the best new seed.

Fortunately, such claims are increasingly testable by scientific simulation. Just as we are beginning to construct phylogenetic trees of living systems, which allow us to discriminate between developmental (highly-conserved) and evolutionary (variable) gene complexes, we are now beginning to construct cladistic trees of universe morphology, which may allow us to discriminate between conserved and variable fundamental parameters. We are early in such work, and most potential universal variants, and the ways that their laws emerge, perhaps via symmetry-breaking, remain mostly beyond simulation today. But as physical theory and computers advance, simulation testing of universe phylogenetics models may become increasingly informative.

In biological systems, intelligence transcends the senescing body via replication, through the "immortal" germline tissue. In universal systems, intelligence may transcend the senescing body of our universe via replication as well, using intelligence-collecting black holes as "immortal" germline devices. Gardner (2000, 2003, 2007) has also proposed advanced intelligence as the replicator of our universe, but his intriguing work does not require the black hole mechanism, or evo devo dynamics. If the transcension hypothesis is correct, inner space, not outer space, is the final frontier for universal intelligence. Our destiny is density.

6. METI Implications: A Prime Directive May Block All One-Way Messaging By Advanced Civilizations

To recap, if ours is an evolutionary developmental universe, all civilizations are engaged in two fundamental processes: 1) unpredictable, and often reversible experimentation, innovation and diversity generation (evolution) and 2) a predictable, constrained, and often irreversible, complexity-sustaining life cycle, that accelerates toward universal replication (development). Note that very different types of messaging occur in these two processes. Evolutionary processes require two-way communication. Competition, cooperation, and natural selection all require constant feedback and adjustment of the message to the local environment. Developmental processes, by contrast, use one-way communication (from the genes to the organism and environment), and the message is not altered by the local environment within any life cycle. For example, developmental genes specify somatic development in top-down, one-way fashion, including life cycle progression and many aspects of organism behavior. To understand the uncanny strength of developmental constraints on behavior, look at studies of human identical twins that were separated at birth.

Top-down, one-way, global control (development) is needed in any evo devo system, but in genetics, this is perhaps 2-5% of the system. The vast majority of change occurs by bottom-up, two-way, local control. Consider centrally planned, command economies, dominated by one-way communication from the government. A certain degree (2-5%?) of central planning is always needed, and this need increases during a crisis, but on average, centrally planned economies are outcompeted by ones that locally self-organize their own laws, markets, and prices via two-way, evolutionary communications. As in life, evolutionary experimentation may be the primary process of the universe. As in life, universal development may provide *only* the special framework within which evolution occurs.

Given these insights, we may propose that if the closest receiving civilization for a METI (message to extraterrestrial intelligence) beacon is on average 100 light years away, by the time any technology-using civilization can send a message, their local evolution will be proceeding so fast that the send-receive cycle (200 years) will be far too long to aid in local evolutionary complexity construction. In other words, the special self-

organization of our universe, with its speed of light limit and the great gulf between intelligent civilizations allows only developmental messages over interstellar distances. Such one-way messages are useful only for control and constraint, not for innovation or complexity construction. The vast light-distances between civilizations, their continuous local acceleration via STEM compression, and the curious time-travel properties of black holes together suggest the great unlikelihood of any civilization communicating through normal “slowspace” on their way to their respective transcensions. For example, assume that we immediately discover evidence of life on a planet 100 light years distant. If it takes an average of 600 years for each civilization to be able to enter a local black hole, we could conduct a maximum of *three* two-way information exchanges before one of us transcended. Due to this severe two-way messaging limit in normal space, such communication would be a very rare, very local, and short-lived phenomenon.

But interstellar communication may be even rarer than this. Assume that our future science discovers that we live in an evo devo universe constrained to transcension, and that all civilizations will be computationally incomplete (not “Gods”, see Gödel 1934) and evolutionarily diverse. We may then be able to prove, using information theory, that sending one-way METI or probes containing simple information (already known to the sender) is not worth the cost to send, and sending advanced information or probes will only reduce the evolutionary diversity in all civilizations receiving and implementing the message. Consider the likelihood that any advanced information we sent to other civilizations would just push them into their black hole transcension in a more clonal way, and we’d meet significantly less-interesting and useful “copies of ourselves” in our later merger, a fate we might seek to avoid by all reasonable means. One of the key lessons evolutionary development teaches us is that evolution abhors monocultures and clonality wherever it arises. Variety is evolution’s central signature. Monocultures are sterile, static, and far more susceptible to disease. Some clonality exists in lower organisms (hydra, sponges, etc) but it rapidly becomes rarer as complexity increases, perhaps because the evolutionary cost of clonality (the reduction in expressed variation) is so much higher in complex organisms.

Enforcing our own particular evolutionary path to transcension on other civilizations, via one-way transmission of messages or probes containing our learnings, would condemn them, if they were less advanced than us, to transcending in substantially the same way we did, by significantly decreasing the remaining variability of their evolutionary paths. The equations we send them would be imperfect, the way we frame the knowledge would be from our unique and incomplete world view. If all complex cultures are morally bound to follow Dick’s (2003) Intelligence Principle, and thus to maximize their civilization’s intelligence, with a moral strength proportional to their complexity, then the receiving civilizations would be bound to do one of two things: 1) ignore the message, if they were wise enough or 2) listen to the communication and thereby jump their complexity, taking them much closer to the black hole/merger point in a single step. In the latter case, we would have cheated them out of their own evolutionary search for unique solutions, and the evolutionary path from where they were beforehand to the complexity level represented in our message would no longer be evolutionary, but would look very much like ours. As Baxter (2011) reports, no less a SETI-thinker than Arthur C. Clarke (1992) apparently considered this when he mused, “It might be better, in the long run, for us to acquire knowledge by our own efforts, rather than be spoon-fed”.

One could imagine these receiving civilizations might still want to explore “all possible evolutionary paths” prior to transcension. But could they? Their computational resources will be finite, and their simulations incomplete. Moreover, to attempt to do so, they would have to stop their developmental acceleration. In the transcension hypothesis, and in biological development, acceleration (sustained positive feedback) is a key feature of the path to replication. The rest of the lifecycle runs on either deceleration (normal growth) or equilibrium with negative feedback (homeostasis). For example, the first phase of biological growth, from fertilized zygote to prepubescent adult, is a long physiological and energy flow deceleration. But once puberty starts, the path to replication is unavoidably accelerative. Consider the behavioral accelerations in courtship that lead to mate selection, the chemical accelerations that produce the Graafian follicle every 30 days in the mammalian female, the sexual accelerations leading to insemination, and the sperm competition accelerations leading to fertilization. Likewise, from the fast, hot Big Bang to the formation of the first galaxies, our universe at first decelerated in structural and functional emergence. But for roughly the last ten billion years, our leading-edge systems have been accelerating in structural and functional complexity emergence, as represented by Sagan’s Cosmic Calendar metaphor. If our universe’s intelligence is on a developmental path to replication, and intelligent life is a key part of the replicative mechanism, it may have precious little capacity to suspend that acceleration.

If our universe is self-organized for massively parallel and individually unique evolutionary computations of reality, and for continuous local acceleration followed by instantaneous civilization merger and natural selection, one-way non-local information transmissions may in fact always be provably destructive of variety by future information theory. As a result, a type of "Prime Directive" against one-way non-local messaging would seem likely to be a moral development emerging in all sufficiently advanced civilizations, once they recognize that they are on course to a black hole destiny. A variation of this idea in the Fermi paradox literature is called the [zoo hypothesis](#) (Ball 1973), the idea that advanced civilizations avoid contact with less advanced civilizations so that they do not influence their evolutionary development. The transcension hypothesis is thus a specific variant of the zoo hypothesis.

Could an advanced civilization improve the total intelligence of the universe by sending interstellar nanoprobes or other highly miniaturized technology to monitor all developing cultures and, if necessary, intervening subtly and undetectably in such cultures in cases where they would otherwise perish through no fault of their own? Perhaps. But only if the natural processes of development were so defective that the vast effort and risk of such intervention were justified. To this author, given the smoothness and predictability of local acceleration of complexity to date, the universe seems to be doing a very, very good job of protecting accelerating complexity development. No intelligent intervention seems necessary or prudent. Note furthermore that the clandestine monitoring program, even if it were true, means little to us as a matter of science or practice, as to be morally defensible it must be undetectable, except perhaps in rare cases of failure (note: great science fiction plot here). If such a program existed, it would be an intelligent augmentation of natural processes of developmental immunity, a topic will discuss in our final section. But far more important and relevant to science than determining whether intelligence-guided immunity exists is the determination of whether an extensive degree of universe-guided developmental immunity already exists in our current physics, as the transcension hypothesis falsifiably claims.

7. SETI Implications: Evidence of Transcension May Be Emanating from Earth-Like Planets

Fortunately, directed search for extraterrestrial intelligence (SETI) can provide some empirical tests of the transcension hypothesis. The hypothesis predicts regular cessation of weak, unintentionally-emitting communication signals ("leakage signals" of radar, radio, TV, etc.) emanating from all early technological civilizations soon after they develop the ability to use electromagnetic communications technology. For humans, this period may be as short as 200 years (Smart 2002a). The hypothesis further predicts that an astronomically short time later these civilizations would reorganize their solar system's planetary matter to achieve vastly greater STEM density, efficiency, and computational capability, a transition we may call a developmental singularity (Smart 2008). If computational acceleration continues at its present superexponential rates (Nagy et. al. 2010), an asymptote to this acceleration must soon be reached. If Lloyd's and Krauss and Starkman's calculations of a 600 year limit for Moore's law are roughly correct, then just 400 years after radio silence, each intelligent civilization may suddenly, from our perspective, reorganize itself into near-black hole dense matter. Specific steps along the STEM compression pathway might vary a bit from civilization to civilization, but what seems clear is that a rapid increase in density must happen, perhaps only a few hundred years after radio silence occurs.

Thus, even though we seem very likely to live in a biofelicitous universe, with perhaps millions of Earth-like planets in our galaxy alone, when we look for signs of their intelligence they should be very rare indeed. We can expect that early civilizations would all emit leakage signals, perhaps most commonly in the low frequency range (tens to hundreds of megahertz, where Earth television and radar commonly broadcast). We can also expect that they would likely construct early and weak METI mini-beacons of the type that we have constructed so far on Earth. But if transcension is correct, later civilizations would never construct advanced beacons, because if they did, such a message would provably reduce, in a future information theory, the evolutionary complexity of all civilizations receiving it.

Regular cessation of leakage signals and METI would thus be common in a life-ubiquitous universe under transcension physics. Smart 2002a estimates that in our galaxy alone, if there are 2 million to 2 billion civilizations our age or older in the Milky Way, occupying the galactic habitable zone, a ring of stars around our galaxy's core, then assuming a 200 year signal lifespan we should currently be able to detect anywhere from 20 to 20,000 low power leakage signals in our sky, if we had a radiotelescope sensitive enough to survey the entire galaxy. On

average 0.1 to 100 of these would be in their last year of transmission prior to transcension. One would cease transmitting every four days to ten years, and if the cessation curve was predictable in space and time, this would be experimental evidence of a developmental transcension hypothesis.

Unfortunately, we are unlikely to build radiotelescopes with the ability to detect our first leakage signal soon. Loeb and Zaldarriaga (2007) propose that the Murchison Wide-Field Array in Australia, presently under construction, might detect leakage signals from the nearest thirty light years. But this includes only 11 G-type stars, a discouragingly small population. Forgan and Nichol (2010) propose that the Square Kilometer Array, which may come online in 2019, might detect such signals from the nearest 300 light years (~1,000 G-type stars). But as they point out, Earth was "radio loud" for only ~100 years, before becoming "radio quiet". On Earth, we've already moved most of our communications to the much higher bandwidth inner space domain of fiber optics, a development that seems likely to be universal and irreversible, considered from the standpoint of STEM compression. They estimate an average radio loud leakage window of only 100 years, and argue that SKA detection probability may be as low as 10^{-7} . Moreover, Benford (2010) proposes their estimates of leakage detectability are systematically high, due to overestimates of signal strength and integration time. Radiotelescope based SETI may thus take several more decades to yield fruit, and might require much larger ground based arrays, or even space-based arrays, such as the one proposed by Heidmann (1993) for the *Sahacrater* on the far side of the moon.

Optical SETI, by contrast, appears to offer a much higher likelihood of early success. Our present exoplanet hunters such as the ESA's Gaia mission, to be launched in 2013, will use photometry (slight dimming of the star during planetary transits) to seek exoplanets within 200 parsecs (670 light years) of Earth, more than twice the critical distance of the SKA. But most importantly, with optical SETI we are not looking for a narrow 100-200 year leakage window, but are mapping a binary event across all stars: the existence or nonexistence of Earth-like planets exhibiting signs of life, their distribution in the galaxy, and the way this binary state changes with time.

We now have a few optical methods that can be used for detection of exoplanet atmosphere, such as polarimetry changes during transits. If transcension is an inevitable developmental attractor for intelligence, both planetary and atmospheric signatures (transit photometry, orbital phase, polarimetry, etc.) and life signatures (oxygen and methane lines, electromagnetic leakage signals, etc.) must disappear from intelligent planets when they collapse themselves into inner space. In a collapse, most of the planet's mass may remain (some energy must also be expended, but not much in highly efficient systems), and their parent star will continue to undergo small radial velocity changes due to the gravitational effect of planetary orbit. This is detectable on Doppler spectroscopy out to about 160 light-years from Earth by our best ground-based telescopes today. But in collapsed planets there will no longer be a photometry change during transit. Also, the great density of the collapsed planet may create a telltale gravitational lensing signature during transit.

The transcension hypothesis seems to make a few more specific and falsifiable SETI predictions. First, optical SETI should allow us to discover evidence of what we may now call a galactic transcension zone, an inner ring of each galactic habitable zone that contains far older planets that have long ago transcended and collapsed themselves to near black hole or black hole densities. We might call this a an expected forthcoming "missing planets problem," an absence or a much lower frequency of life-signature exoplanets observed in the inner rings of the habitable zone. Second, we should discover a well-defined outward growing edge of the transcension zone, where intelligent planets of the right age and distance from the galactic core regularly flip their states and become highly STEM dense objects. Third, we should discover that Earth is near the outward edge of the transcension zone, as we appear to be within a millennium of our own transcension, assuming this event coincides with reaching the local limits of the "Moore's law acceleration," referred to earlier.

Finally, we may find black hole dynamics in post-transcension solar systems that seem potentially artificial, such as low mass X-ray binaries with a companion star of spectral type G, and an extreme mass ratio of 1000 to 1, such as would occur if a Jupiter-mass black hole began accreting our parent sun. We might even find active black hole migration toward the galactic center, or other unusual processes. With luck and hard work, our existing exoplanet hunters might be a decade or less away from being able to discover a missing planets problem, if one exists, to map the outward-growing edge of the transcension zone, whose nearest edge may be within 600 light years of Earth, if one exists, and to make other discoveries that would be consistent with transcension. We shall see.

8. Resisting Transcension: Developmental Immunity, Morality, and Developmental Failures

When we consider the accelerating processes of STEM density, STEM efficiency, and computational capability growth that appear to be leading civilizations toward transcension, we must ask why these curves hold across so many types of physical systems and such long spans of historical time. Why do we not see more fluctuations in the J-curve of energy rate density flow in leading-edge systems across cosmological time (Chaisson 2001)? Or in the J-curve of GDP per capita in Western Europe between 1000 and 2000 AD (Maddison 2007)? Or in the J-curve of price-performance of computing and communications technology from the 1800s to 2010 (Kurzweil 1999,2005, Nordhaus 2007, Magee 2009, Nagy et. al. 2010)?

If accelerating leading edge computational capabilities (intelligence emergence) is part of the developmental “genes” (special initial conditions, parameters, and laws) of our universe, then the ability to access ever greater STEM densities and efficiencies to produce such intelligence must also be a developmental process. In biology, developmental processes become increasingly smooth and resilient as they progress along the life cycle toward replication. The more computationally complex the living system becomes prior to its senescence, the more adaptive strategies and pathways it can use to find the next, more STEM efficient and STEM dense physical substrate, if one exists in universal phase space. In biology, developmental failure rates can be very high at birth, but they drop drastically as development progresses. Initially, many seeds (gametes) are sown, and very few (or just one) take hold. Then, as zygotic growth begins, spontaneous abortions occur very frequently in the first few days and weeks, but developmental failure (miscarriage) rates drop rapidly thereafter (Goldhaber and Fireman 1991). Even after birth, the closer multicellular organisms get to their sexual maturity, the lower their annual mortality risk (Olshansky and Carnes 1997). It is possible that in living systems, the closer development gets to the replication point in any life cycle, and the greater the number of completed cycles since emergence of the first replicator, the more mechanisms of developmental immunity may buffer against both internal and external sources of disruption. For example, consider how predictably and concurrently two genetically identical twins will hit their developmental milestones. Again, we do not find such smoothness in evolutionary processes, which are defined by chaotic diversity, disruption, punctuation, and creativity.

If developmental immunity exists at the scale of the universe, natural physical processes protecting accelerating complexification and transcension, we will increasingly be able to find evidence for it. At scales larger than humanity, we can find immunity candidates in the unreasonably life-friendly nature of the universe as a system (Davies 2004), and in Earth’s geophysical systems, as characterized in the Gaia hypothesis (Lovelock and Margulis 1974). Gaia is a controversial topic, but it might make physical sense if our universe’s developmental physics have self-organized, perhaps over many previous universal life cycles in the multiverse, to provide geological and climatological homeostasis on special planets, and thereby greatly increase life’s resilience. Bostrom et. al. (2008) and others have written on the possibility of existential risks, events or processes that might lead to human extinction in coming centuries. I have argued (Smart 2008) just how unreasonably low these existential risks (species-killing meteorites, solar flares, gamma ray bursts, pandemics, wars, etc.) appear to be. Furthermore, all previous Earth catastrophes appear to have only catalyzed the acceleration, and presumably the statistical immunity, of complexity development. For example, no metazoan genes were likely lost in the K-T meteorite catastrophe, rather metazoan phenotypes were pruned, and much new mammalian morphological complexity emerged immediately afterward. Once we have transitioned to postbiological life (Dick 2003), we can presume our immunity to astrophysical events will take yet another major leap forward in resilience/immunity (Smart 2008).

Even at the human scale, where evolutionary variation surrounds us, and where universal developmental processes may be hardest to see, social morality, and the moderating effects of increased technological complexity on human societies (Inglehart and Welzel 2005), show the signs of being developmental. Even as the intensity and scope of individual acts of violence has steadily increased with the advent of modern technology, a number of scholars (Elias 1978, Gurr 1981, Stone 1983,1985; Sharp 1985; Pinker 2011) have documented the progressive reduction in the average frequency and severity of violence in developing human societies since the Enlightenment (1600-1800s). This pattern is particularly pronounced in the sixty years since our two world wars (Human Security Report 2010; Goldstein 2011). Behavioral psychologists document that human beings are in general surprisingly civil to each other, and with rare exception, their expressions of violence are both short-lived and largely symbolic,

even under conditions of great deprivation and duress. The rare cases we see of sustained sociopathologies and of sustained warfare and civil conflict are curiously self-limiting in their effect (Gintis 2005). Furthermore, the level of technologically aided transparency and immunity we can foresee permeating our planet in coming decades will be astounding (Brin 1998b). Assuming superethical AI's are in charge, any actions taken by violent, criminal, or impulsive biohumans may be detected and counteracted long before they can become a global problem.

As we contemplate the future of our increasingly lifelike technologies, it is hard to imagine their consciousness, feelings, empathy, and moral constraints. Yet if morality and immunity are developmental processes, if they arise inevitably in all intelligent collectives as a type of positive sum game (Ridley 1998, Wright 1997, 2000), they must also grow in force and extent as each civilization's computational capacity grows. Each civilization has and needs individual moral deviants (Bloom 1995), but in all developmental processes, such deviancy gets profoundly better regulated with time. While evolutionary process is best characterized by divergence and speciation, the hallmark of developmental processes is *convergence and unification*. A planet of postbiological life forms, if subject to universal development, may increasingly look like *one integrated organism*, and if so, its entities will be vastly more responsible, regulated, and self-restrained than human beings. If developmental immunity exists, planetary transitions from life to intelligent life, and from intelligent life to postbiological life should be increasingly high-probability. The exact probabilities of each of these transitions also seems likely to be empirically measurable by future astrobiology and SETI.

How might SETI measure the average probability of transition from a civilization like ours to a developmental singularity? Consider two likely scenarios for our future in an evo devo universe: failure to transcend, due to an insurmountable resource or other block to progress or self-destruction, sometimes called the Great Filter hypothesis (Hanson 1996), or successful transcension. Evo devo theory would argue that the failure scenarios are all a result of evolutionary variation disrupting a developmental process, and the success scenario is a result of development resisting evolutionary perturbations (Smart 2008). As any biologist who has attempted genetic engineering knows, almost every mutation one introduces by experiment, or guided by current theory, is deleterious, particularly in developmental genes, which are highly conserved. In other words, the ways to fail developmentally are many, and unpredictable, while the ways to succeed are few, and highly predictable. As Tolstoy (1877) famously said: "Happy families are all alike; every unhappy family is unhappy in its own way." Quantitatively, developmental processes in biological systems are guided toward a normal or log-normal distribution of the phenotype (e.g., height, blood pressure, IQ, multicellular pattern, etc.) in parameter space (Giurumescu et. al. 2009). Development seeks to hit a future structural and functional target, and will fall off narrowly to each side of it in a statistically predictable way. Evolutionary processes, by contrast, are stochastic (Champagnat et. al. 2005). Their outputs, and thus their failure modes, are creative and stochastic, or random within constraints. The size of the constraint envelope can be predictable, but the failure instances within the envelope will be unpredictably unique. Therefore, if evolutionary processes contribute significantly to transcension, many transcensions should occur stochastically in time and space within the galactic transcension zone (the constraint envelope). Some of these in fact might be evolutionary failures, not transcensions, and sorting the two might be difficult. Furthermore, we should expect some failures that involve METI or interstellar expansion rather than transcension. If our galaxy is biofelicitous, the fact that we have not seen either to date (unless you take stock in ufologists, which I do not) argues that evolution is subservient to development in this case. If developmental processes are the dominant component of transcension, we should expect the galactic transcension zone to be well defined, and transcensions to occur in an orderly fashion within the zone, with a normal or log-normal distribution in space, time, and other phenotypic parameters at the outward-growing edge of the zone. It is this signature, if it exists, that would allow us to calculate a robust, resilient developmental process, and a high probability of transcension in each individual case.

In a universe run by transcension physics, committed messaging and spacefaring civilizations would be developmental failures, statistically very rare late in the life cycle of developing systems. Such civilizations would either consciously know that they are doing damage by messaging and sending probes, and would attempt to rationalize and legitimize this morally dissonant behavior (for a variant of this scenario, see Clarke 1953), or they would be too simple to know this, in which case they would not get very far before they got smart enough to understand the damage they were doing. David Brin, a careful thinker on the Fermi paradox and author of the first broad review the topic (1983) notes that Biker Gangs and other groups on Earth are cheerfully happy to contravene any social standard, and they are a good analogy for why the transcension hypothesis could never hold in every

case. At the same time, developmental process is extremely robust to local variation. In the same way that genetically identical twins have different fingerprints and organ microstructure, yet look the same from across the room, biological development hits its global target even with local chaos and contingency. In fact, self-organizing systems rely on stochasticity (random perturbations and catalytic catastrophe occurring within a predictable constraint envelope) to find their global attractors, a phenomenon von Foerster called "order from noise" (Heylighen 1999). Our present day, primitive human desire to be galactic colonizers, our individualist wish to be rebels and break free of transcension physics, may be as unlikely to manifest in a world with postbiological life and morality as an infectious bacterium's "desire" to replicate indefinitely while inside a human body, or an individual quanta of energy's "desire" to break free of Newtonian mesoscopic physics. Such events, while plausible from the "perspective" of the bacterium or the quantum state, become very rare in these environmental contexts.

With sufficiently advanced SETI, we might discover brief broadcasts or occasional episodes of minor galactic engineering occurring in small portions of a very few galaxies. But because of the acceleration of complexification and the vast distances between civilizations, it seems impossible that even an earliest-to-emerge civilization, however oligarchic, could prevent multi-local transcensions in any galaxy. In theory, one can imagine a contrarian civilization releasing interstellar probes, carefully designed not to increase their intelligence (and so, never be able to transcend) as they replicate. But what could such probes do besides extinguish primitive life? They certainly couldn't prevent multilocal transcensions. There seems no game theoretic value to such a strategy, in a universe dominated by accelerating transcension. Finally, if constrained transcension is the overwhelming norm, we should have much greater success searching for the norm, not the rare exception. As Cirkovic (2008) and Shostak (2010) have recently argued, we need SETI strategies that focus on places where advanced postbiological civilizations are likely to live. In the transcension hypothesis, this injunction would include using optical SETI to discover the galactic transcension zone, and define its outward-growing edge. We should look for rapid and artificial processes of formation of planet-mass black holes, for leakage signals and early METI emanating from life-supporting planets, and for the regular cessation of these signals as or soon after these civilizations enter into their technological singularities.

9. Acknowledgments

The author is grateful to [Alvis Brigis](#), [David Brin](#), [Robert Freitas Jr.](#), and [Clement Vidal](#) for helpful comments and critiques. Critiques, edits, or omissions? Let the author know at johnsmart{at}gmail{dot}com. Thank you.

10. References

- Adams, Henry B. 1909 [1919]. The Rule of Phase Applied to History. In: *The Degradation of the Democratic Dogma*, Macmillan, pp. 267-311.
- Amato, Ivan. 1991. Speculating in precious computronium. *Science* 253(5022):856-57.
- Asimov, Isaac. 1956. The Last Question. *Science Fiction Quarterly*, Nov 1956, pp. 7-15.
- Ausubel, Jesse H. 1996. Materialization and Dematerialization: Measures and Trends. In: *Technological Trajectories and the Human Environment*, J.H. Ausubel and H.D. Langford (eds), National Academy, 1997, p. 135-156.
- Ball, John A. 1973. The Zoo Hypothesis. *Icarus* 19(3):347-349.
- Barrow, John D. 1998. *Impossibility: The Limits of Science and the Science of Limits*, Oxford University Press.
- Banks, Iain. 1988. *Consider Phlebas*, St. Martins Press.
- Baum, Eric. 1983. [Discussion]. *Physics Letters B* 133(185).
- Baxter, Stephen. 2011. SETI in Science Fiction. In: *Searching for Extraterrestrial Intelligence: SETI Past, Present, and Future*. Shuch, H. Paul (Ed.), Springer. p. 364.
- Bekenstein, Jacob D. 1981. Energy cost of information transfer. *Physical Review Letters* 46:623-626.
- Benford, James. 2010. SETI and Detectability. Retrieved from: Centauri-Dreams.org, 10.28.11.
- Bettencourt, Luis M.A. et al. 2010. Urban Scaling and Its Deviations: Revealing the Structure of Wealth, Innovation and Crime across Cities. *PLoS ONE* 5(11):e13541.
- Blascovich, Jim and Bailenson, Jeremy. 2011. *Infinite Reality: Avatars and the Dawn of the Virtual Revolution*, William Morrow.
- Bloom, Howard K. 1995. *The Lucifer Principle : A Scientific Expedition into the Forces of History*, Atlantic Monthly Press.
- ———. 2000. *Global Brain: The Evolution of Mass Mind from the Big Bang to the 21st Century*, Wiley.

- Bohn, Roger E. and Short, James E. 2009. *How Much Information?* Global Information Industry Ctr, U.C. San Diego. Dec 2009
- Bostrom, Nick (Ed). 2008. *Global Catastrophic Risks*, Oxford University Press.
- Bouso, Raphael. 2002. The holographic principle. *Reviews of Modern Physics* 74(3):825-874
- Brin, G. David. 1983. The 'Great Silence': the Controversy Concerning Extraterrestrial Intelligence. *Q. Journal of the Royal Astronomical Society* 24:283-309.
- ——— 1998a. *Heaven's Reach*, Bantam Books.
- ——— 1998b. *The Transparent Society*, Addison-Wesley.
- Broderick, Damien. 2002. *Transcension*, Tor Books.
- Carroll, Sean B. 2005. *Endless Forms Most Beautiful: The New Science of Evo Devo*, Norton.
- Chaisson, Eric J. 2001. *Cosmic Evolution: The Rise of Complexity in Nature*, Harvard U. Press.
- ——— 2003. [A unifying concept for astrobiology \[\$\Phi_m\$ \]](#). *International Journal of Astrobiology* 2(2):91-101.
- Champagnat, Nicolas et. al. 2005. Unifying evolutionary dynamics: from individual stochastic processes to macroscopic models. *Theoretical Population Biology* 69(3):297-321.
- Cirkovic, Milan M. 2008. Against the Empire. *Journal of the British Interplanetary Society* 61.
- Clarke, Arthur C. 1953. *Childhood's End*, Ballantine.
- ——— 1982. *2010: Odyssey Two*, Granada.
- ——— 1992. Greetings, Carbon-based Bipeds! *Life Magazine*, Sept 1992.
- Coleman, Sidney. 1988. Black holes as red herrings: topological fluctuations and the loss of quantum coherence. *Nuclear Physics B* 307(864).
- Criswell, David R. 1985. Solar System Industrialization. In: *Interstellar Migration and the Human Experience*, B.R. Finney and E.M. Jones (eds.), U. California Press.
- Davies, Paul C.W. 2004. How bio-friendly is the universe? arXiv:astro-ph/0403050
- ——— 2007. *The Goldilocks Enigma: Why Is the Universe Just Right for Life?*, Penguin.
- Dick, Steven J. 2003. Cultural evolution, the postbiological universe and SETI. *Internat'l Journal of Astrobiology* 2(1):65-74.
- Dutton, John M. and Thomas, Annie. 1984. Treating Progress Functions as a Managerial Opportunity. *The Academy of Management Review* 9(2) 235-247.
- Elias, Norbert. 1978[2000]. *The Civilizing Process: Sociogenetic and Psychogenetic Investigations*, Wiley-Blackwell.
- Eshleman, Von R. 1979. Gravitational Lens of the Sun: Its Potential for Observations and Communications over Interstellar Distances. *Science* 205, 1133-1135.
- ——— 1991. Gravitational, plasma, and black-hole lenses for interstellar communication. In: *Lecture Notes in Physics* 390, 299-299.
- Forgan, Duncan H. and Nichol, Robert C. 2010. A failure of serendipity: the Square Kilometre Array will struggle to eavesdrop on human-like extraterrestrial intelligence. *International Journal of Astrobiology* 10(2):77-81.
- Forward, Robert L. 1980. Technical Appendix. *Dragons Egg*. Ballantine. pp. 286-308. Forward's hard-science conceptualization of accelerated intelligent life inhabiting the surface of a neutron star. Inspired by Frank Drake in 1973.
- Frank, Juhan et. al. 2000. *Accretion Power in Astrophysics*, Cambridge U. Press.
- Frolov, Valeri P. et al. 1989. Through a black hole into a new universe? *Physics Letters B* 216:272-276.
- Fuller, R. Buckminster. 1938 [2000]. *Nine Chains to the Moon*, Doubleday.
- ——— 1979. *Synergetics 2: Further Explorations in the Geometry of Thinking*, Macmillan.
- ——— 1981 [1982]. *Critical Path*, St. Martin's Griffin.
- Gardner, James N. 2000. The selfish biocosm: Complexity as cosmology. *Complexity* 5(3):34-45.
- ——— 2003. *Biocosm: The New Scientific Theory of Evolution – Intelligent Life is the Architect of the Universe*, Inner Ocean Pub.
- ——— 2007. *The Intelligent Universe: AI, ET, and the Emerging Mind of the Cosmos*, New Page.
- Gilbert, Horace D. 1961. *Miniaturization*, Reinhold Publishing Corp.
- Gintis, Herbert et al. (eds.) 2005. *Moral Sentiments and Material Interests: The Foundations of Cooperation in Economic Life*, MIT Press.
- Giurumescu, Claudiu A. et. al. 2009. [Predicting Phenotypic Diversity and the Underlying Quantitative Molecular Transitions](#), *PLoS Computational Biology* 5(4):e1000354.
- Gödel, Kurt. 1934. On Undecidable Propositions of Formal Mathematical Systems, lecture notes taken by Kleene and Rossner at the Institute of Advanced Study. Reprinted in Davis, M. (ed.) *The Undecidable*, Raven Press, 1965.
- Goldhaber, Marilyn and Fireman, Bruce. 1991. The Fetal Life Table Revisited, *Epidemiology* 2(1):33-39.
- Goldstein, Joshua S. 2011. *Winning the War On War: The Decline of Armed Conflict Worldwide*, Dutton.
- Gould, Stephen J. 2002. *The Structure of Evolutionary Theory*, Harvard U. Press.
- Gurr, Ted R. 1981. Historical Trends in Violent Crime: A Critical Review of the Evidence. In: *Crime and Justice: An Annual Review of Research*, iii, p. 285-353.

- Hanson, Robin. 1996[1998]. The Great Filter - Are We Almost Past It? <http://hanson.gmu.edu/greatfilter.html>
- Harris, Steven B. 2008. A Million Years of Evolution. In: *Year Million*, Damien Broderick (ed.), Atlas & Co.
- Harvey, David. 1989. *The Condition of Postmodernity: An Enquiry into the Origins of Cultural Change*, Blackwell
- Heylighen, Francis. 1999. Order from noise. Ret. from: Principia Cybernetica Web, pcp.lanl.gov/ordnoise.html, Oct. 2011.
- ——— 2007. Accelerating Socio-Technological Evolution: From Ephemerization and Stigmergy to the Global Brain. In: *Globalization as an Evolutionary Process*, Modelski, George et. al. (eds.). Routledge.
- Hawking, Stephen W. 1987. Coherence down the wormhole. *Physics Letters B* 195(337).
- ——— 1988. Wormholes in spacetime. *Physical Review D* 37(904).
- ——— 1993. *Black Holes and Baby Universes – and Other Essays*, Bantam.
- Heidmann, Jean. 1994. Saha crater: A candidate for a SETI lunar base. *Acta Astronautica* 32(6)471-472.
- Human Security Report. 2010. [Human Security Report 2009/2010: The Causes of Peace and the Shrinking Costs of War](#), Human Security Research Group.
- Iranfar, Negin et al. 2003. Genome-Wide Expression Analyses of Gene Regulation during Early Development of *Dictyostelium discoideum*. *Eukaryotic Cell* 2(4):664-670.
- Inglehart, Ronald and Welzel, Christian. 2005. *Modernization, Cultural Change, and Democracy: The Human Development Sequence*, Cambridge U. Press.
- Johansen, Anders and Sornette, Didier. 2001. [Finite-time singularity in the dynamics of the world population, economic and financial indices](#). *Physica A* 294(3-4):465-502.
- Kardashev, Nikolai S. 1964. Transmission of Information by Extraterrestrial Civilizations. *Soviet Astronomy* 8(217).
- ——— 1997. Cosmology and Civilizations. *Astrophysics and Space Science* 252, Mar 1997.
- Kirschner, Marc W. and Gerhart, John C. 2005. *The Plausibility of Life: Resolving Darwin's Dilemma*, Yale U. Press
- Koh, Heebyoung and Magee, Chris L. 2006. A functional approach for studying technological progress: Application to information technology. *Technological Forecasting & Social Change* 73:1061-1083.
- ——— 2008. A functional approach to technological progress: extension to energy technology. *Technological Forecasting & Social Change* 75:735-758.
- Korotayev, Andrey, et. al. 2006. [Introduction to Social Macrodynamics: Secular Cycles and Millennial Trends](#), URSS.
- ——— 2006. [Introduction to Social Macrodynamics: Compact Macromodels of World System Growth](#), URSS.
- Krauss, Lawrence M. and Starkman, Glenn. 2004. Universal Limits on Computation. [arXiv:astro-ph/0404510v2](#)
- Kurzweil, Ray. 1999. *The Age of Spiritual Machines: When Computers Exceed Human Intelligence*, Penguin.
- ——— 2005. *The Singularity is Near: When Humans Transcend Biology*, Penguin.
- Lehnert, Jean-Luc et. al. 2009. [The Return of the Phoenix Universe](#).
- Leskovec, Jure et al. 2005. Graphs over Time: Densification Laws, Shrinking Diameters, and Possible Explanations. KDD05, Aug 21-24, 2005, Chicago, IL.
- Levy, Pierre. 1998. *Becoming Virtual: Reality in the Digital Age*, Basic Books.
- Lineweaver, Charles H. et. al. 2004. The Galactic Habitable Zone and the Age Distribution of Complex Life in the Milky Way. *Science* 303(5654):27.
- Lovelock, James E. and Margulis, Lynn. 1974. Atmospheric homeostasis by and for the biosphere – The Gaia hypothesis. *Tellus* 26(1):2-10.
- Lloyd, Seth. 2000a. Ultimate physical limits to computation. *Nature* 406:1047-1054.
- ——— 2000b. [How Fast, How Small and How Powerful? Moore's Law and the Ultimate Laptop](#), Edge.org.
- ——— 2001 [2002]. Computational capacity of the universe. *Physical Review Letters* 88: 237901 (2002). Also at: [arXiv:quant-ph/0110141v1](#) (2001).
- Loeb, Avi and Zaldarriaga, Matias. 2007. [Eavesdropping on Radio Broadcasts from Galactic Civilizations with Upcoming Observatories for Redshifted 21cm Radiation](#). *Journal of Cosmology and Astroparticle Physics* 1:20-27.
- Maccone, Claudio. 1992/1994. Space Missions Outside the Solar System to Exploit the Gravitational Lens of the Sun. In: *Proceedings of the International Conference on Space Missions and Astrodynamics*, C. Maccone (Ed.), Turin, Italy, June 18, 1992, and *Journal of the British Interplanetary Society* 47, 45-52.
- ——— 1998. *The Sun as a Gravitational Lens: Proposed Space Missions*. IPI Press.
- ——— 2010. Personal Communication. Discussion at the Second IAA Symposium on Searching for Life Signatures, 6-8 Oct 2010, Kavli Royal Society International Centre, Buckinghamshire, United Kingdom.
- Maddison, Angus. 2007. *Contours of the World Economy: 1-2030 A.D.: Essays in Macro-Economic History*, Oxford U. Press.
- Magee, Chris L. 2009. [Towards Quantification of the Role of Materials Innovation in Overall Technological Development](#). Working Paper ESD-WP-2009-09, Massachusetts Institute of Technology.
- McNerney, James et. al. 2009. The Role of Design Complexity in Technology Improvement. *PNAS* 102(46):16569-16572.
- Meyer, François. 1947. *L'accélération évolutive. Essai sur le rythme évolutif et son interprétation quantique*, Librairie des Sciences et des Arts, Paris, 67p.

- ——— 1954. *Problématique de l'évolution*, Presses Universitaires de France, 279p.
- Modis, Ted. 2002. *Predictions: Ten Years Later*, Growth Dynamics.
- Nagamine, Kentaro and Loeb, Abraham. 2003. [Future Evolution of Nearby Large-Scale Structures in a Universe Dominated by a Cosmological Constant](#). *New Astronomy* 8:439-448.
- Nagy, Bela et. al. 2010. Superexponential Long-term Trends in Information Technology. SFI Working Paper.
- Narayan, Ramesh, and Quataert, Eliot. 2005. Black Hole Accretion. *Science* 307(5706):77-80.
- National Science Foundation Report. 2006. *Simulation-Based Engineering Science*, National Science Foundation.
- Negroponte, Nicholas. 1996. *Being Digital*, Vintage.
- Nemet, Gregory C. 2006. Beyond the Learning Curve: Factors Influencing Cost Reduction in Photovoltaics. *Energy Policy* 34:3218–3232.
- Nordhaus, William D. 2007. [Two Centuries of Productivity Growth in Computing](#). *The Journal of Economic History* 67:128-59.
- Nottale, Laurent et al. 2000a. [On the fractal structure of evolutionary trees](#). In: *Fractals in Biology and Medicine, Vol. III*, Proceedings of Third International Symposium, Ascona, Switzerland, March 8-11, 2000, Ed. G. Losa, D. Merlini, T. Nonnenmacher and E. Weibel, Birkhäuser Verlag, pp. 247-258.
- ——— 2000b. [Les Arbres de l'Evolution \(The Trees of Evolution\)](#), Hachette.
- OECD. 2009. [Toward Green ICT Strategies](#), OECD Working Party on the Information Economy.
- Olshansky, S. Jay and Carnes, Bruce A. 1997. Ever Since Gompertz. *Demography* 34(1):1-15.
- Orgel, Leslie. 1974. *The Origins of Life: Molecules and Natural Selection*, John Wiley & Sons.
- Pinker, Steven. 2011. *The Better Angels of Our Nature: Why Violence Has Declined*, Viking.
- Polastron, Lucien. 2009. *The Great Digitization and the Quest to Know Everything*, Inner Traditions.
- Reich, Eugenie S. 2013. [Spin rate of black holes pinned down](#). *Nature News*, 06 Aug 2013
- Richards, Mark A. and Shaw, Gary A. 2004. [Chips, Architectures and Algorithms: Reflections on the Exponential Growth of Digital Signal Processing Capability](#). Submitted to *IEEE Signal Processing Magazine*, Dec 2004.
- Ridley, Matt. 1998. *Origins of Virtue: Human Instincts and the Evolution of Cooperation*, Penguin.
- Sagan, Carl. 1977. *The Dragons of Eden: Speculations on the Evolution of Human Intelligence*, Random House.
- Sahal, Devendra . 1979. A Theory of Progress Functions. *IIE Transactions* 11(1) 23-29.
- Sandberg, Anders. 2010. An overview of models of technological singularity. Presented at: AGI2010 Conference, 8 Mar 2010, Lugano, Switzerland.
- ——— 1999. [The Physics of Information Processing Superobjects: Daily Life Among the Jupiter Brains](#). *Journal of Evolution and Technology*.
- Sharp, James A. 1985. Debate: the history of violence in England, some observations. *Past and Present* 108(Aug):206-15.
- Shostak, Seth. 2010. What ET will look like and why should we care. *Acta Astronautica* 67(9-10)1025-1029.
- Smart, John M. 2000. [Intro to the Developmental Singularity Hypothesis](#), AccelerationWatch.com.
- ——— 2002a. [Answering the Fermi Paradox: Exploring the Mechanisms of Universal Transcension](#). *Journal of Evolution and Technology* June 2002.
- ——— 2002b. [Understanding STEM, STEM+IC, and STEM Compression in Universal Change](#). AccelerationWatch.com.
- ——— 2008. [Evo Devo Universe? A Framework for Speculations on Cosmic Culture](#). In: *Cosmos and Culture: Cultural Evolution in a Cosmic Context*, Steven J. Dick, Mark L. Lupisella (eds.), NASA Press, pp. 201-295.
- ——— 2010. *The Transcension Hypothesis*, Presentation at the Second IAA Symposium on Searching for Life Signatures, 6-8 Oct 2010, Kavli Royal Society International Centre, Buckinghamshire, United Kingdom.
- Smolin, Lee. 1992. Did the Universe Evolve? *Classical and Quantum Gravity* 9:173-191.
- ——— 1994. [The fate of black hole singularities and the parameters of the standard models of particle physics and cosmology](#).
- ——— 1997. *The Life of the Cosmos*, Oxford U. Press. See Appendix, p. 398 (Phoenix Ed.) for Smolin's black hole fecundity fine-tuning observations.
- ——— 2006. The status of cosmological natural selection. arXiv:hep-th/0612185v1.
- Stapledon, Olaf. 1937. *Star Maker*, Methuen.
- Stone, Lawrence. 1983. Interpersonal Violence in English Society, 1300-1980. *Past and Present* 101(Nov):22-33.
- ——— 1985. Debate: the history of violence in England, a rejoinder. *Past and Present* 108(Aug):216-24.
- Strominger, Andrew. 1984. Vacuum topology and incoherence in quantum gravity. *Physical Review Letters* 52(1733).
- Susskind, Leonard. 2008. *The Black Hole War: My Battle with Stephen Hawking to Make the World Safe for Quantum Mechanics*, Little, Brown and Co.
- Swenson Rod and Turvey, M.T. Thermodynamic Reasons for Perception-Action Cycles. *Ecological Psychology* 3(4)317-348.
- Teilhard de Chardin, Pierre. 1955. *The Phenomenon of Man*, Harper & Row.
- Taylor, Edwin F. and Wheeler, John A. 2000. *Exploring Black Holes: Introduction to General Relativity*, Addison Wesley Longman.

- Tipler, Frank. 1997. *The Physics of Immortality*, Anchor.
- Tolstoy, Leo. 1877. *Anna Karenina*, The Russian Messenger.
- Thorne, Kip. 1994. *Black Holes and Time Warps: Einstein's Outrageous Legacy*, W.W. Norton and Co. See page 100 for one treatment of gravitational time dilation.
- Vidal, Clément. 2008. [The Future of Scientific Simulations: from Artificial Life to Artificial Cosmogenesis](#). In *Death And Anti-Death*, ed. Charles Tandy, 6: Thirty Years After Kurt Gödel (1906-1978).:285-318. Ria University Press.
- ——— 2010a. [Computational and Biological Analogies for Understanding Fine-Tuned Parameters in Physics](#). *Foundations of Science* 15, no. 4: 375-393.
- ——— 2010b[2011]. [Black Holes: Attractors for Intelligence?](#) Presentation at the Second IAA Symposium on Searching for Life Signatures, 6-8 Oct 2010, Kavli Royal Society International Centre, Buckinghamshire, United Kingdom. Submitted for publication.
- Vinge, Vernor. 1986. [Marooned in Realtime](#), St. Martin's Press.
- ——— 1993. [The Coming Technological Singularity](#). Presented at the VISION-21 Symposium, NASA Lewis Research Center, 30 Mar, 1993.
- Wright, Robert. 1997. *The Moral Animal: Evolutionary Psychology and Everyday Life*, Pantheon.
- ——— 2000. *Non-Zero: The Logic of Human Destiny*, Pantheon.
- Yeh, Sonia and Rubin, Edward S. 2007. A centurial history of technological change and learning curves for pulverized coal-fired utility boilers. *Energy* 32:1996–2005.
- Zotin, A. 1984. Bioenergetic Trends of Evolutionary Progress of Organisms. In: Lamprecht, I. and Zotin, I. (eds), *Thermodynamics and Regulation of Biological Processes*, Walter de Gruyter, p. 453.