

Chapter 15

Meta+phenomenology: Primer Towards a Phenomenology Formally Based on Algorithmic Information Theory and Metabiology

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1. Introduction

To start, let us assume that our world is made of information whose dynamics are governed by algorithms. This idea, often called digital philosophy or digital physics, is quite established. As Gottfried Leibniz put it over 300 years ago: “Omnibus ex Nihilo ducendis sufficient Unum” (in order to produce everything from nothing, one is sufficient). In the last century, such a world view has been strengthened by the theories of Alan Turing, John von Neumann, Claude Shannon, and somewhat more recently, people such as Gregory Chaitin and Stephen Wolfram.

The implications of digital philosophy invoke vexing ontological and epistemological questions regarding the nature of our universe. If everything is computable, how can we reconcile the seemingly complex phenomena that we observe? While physics has primarily been

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explained via theoretical mathematics, other intellectual domains such as biology and phenomenology often remain unquantifiable and therefore irreconcilable with a digital philosophy.

However, starting from 1931, there was a paradigm shift marked by Gödel's incompleteness theorems and then later by Turing's 1936 publication "On Computable Numbers, with an Application to the Entscheidungsproblem". Gödel was the first to show that there exist truths that cannot be proven true. This was a major blow to traditional mathematics.

Gödel's proof was complicated, algebraically based on Georg Cantor's diagonal argument. Turing simplified the proof of incompleteness through the concept of a universal computer: a theoretical machine that can compute any computable function. It is also more dangerous. Turing's proof showed that uncomputable problems, and thus incompleteness, are ubiquitous.

Finally, in the lineage of incompleteness, comes Chaitin with an even more dangerous form of incompleteness. One showing the existence of maximally complex axioms that are not self-evident. This finding was the final nail in the coffin of the traditional world view of formalized mathematics.

Both Turing and Chaitin would go on to consider mathematical worlds that would model the complex phenomena of biology. Turing's investigations would rely on partial differential equations and not the more universal power of algorithms. This can perhaps be attributed to a few factors. The biological inquiry was rather focused on a particular phenomenon, morphogenesis, and it preceded the discovery of the structure of DNA. Also prior to the work of James Watson and Frances Crick, von Neumann, in a series of lectures published posthumously as the "Theory of Self-Reproducing Automata", outlined a computable system that exhibited the fundamental biological phenomenon of reproduction. In von Neumann's self-reproducing automata, a universal constructor takes as input a set of instructions for reproduction. For this reason, biologist and Nobel Laureate Sydney Brenner would recognize von Neumann's work as fundamental to his own DNA research. In particular, Brenner's understanding of

the phylogenic mechanism of DNA. That DNA was essentially a computer program which contained the biological instructions for production but not the means to execute those instructions. This concept is now understood as the differences between genotype and phenotype; the difference between the genetic code and the phenomenological expression of the genes.

Von Neumann not only explored the digital mechanism of self-reproduction, but also how complexity evolves in such a system. To do so, he proposed using Shannon's recently published theories of information as a measure of complexity.

At the time of von Neumann's lectures, Chaitin had yet to formalize Algorithmic Information Theory; a theory of program size complexity formally equivalent to Information Theory. Both Shannon classical Information Theory and Chaitin Algorithmic Information Theory focus on the complexity of objects through compression: the former statistically through measuring entropy and the latter by comparing the size of the smallest (most elegant) program to the size of the object that program outputs.

Algorithmic Information Theory might have been a more useful measure of complexity for von Neumann. This has been made clear in the last 10 years by Metabiology, Chaitin's toy-model of Darwinian evolution. Through an algorithmic information theoretic approach, Chaitin's metabiological model shows how a single software organism (a Turing machine) undergoing random algorithmic mutations will compute larger and larger integers (known as the Busy Beaver function) at evolutionary rates.

One of the hallmarks of Chaitin's work is his ability to understand a problem in the most minimal, essential way. The metabiological model does not contain a population or anything like sexual reproduction; just a single mutating organism. Nonetheless, Chaitin's elegant model has significant philosophical implications beyond the domain of evolutionary biology. For example, Chaitin's wife and collaborator, Virginia, uses Metabiology as an ontology for the human self-image and his student, Felipe Abrahao, has studied the effects of

metabiological models extended such that a population of software organisms shares information along edges in networks.

Chaitin himself recognizes that Metabiology goes beyond simply proving conditions in which continuous evolution occurs in toy mathematical worlds. A fundamental tenet of Metabiology is the relation between mathematical and biological creativity in terms of how new information enters the system of the metabiological model. He has also recently started to discuss theories of consciousness with respect to Algorithmic Information Theory drawing from David Chalmers' ideas set forth in "The Conscious Mind: In Search of a Fundamental Theory" in which Chalmers proposes that any physical system able to represent and process n bits of information contains n bits of consciousness. The fact that Chaitin's metabiological model seems to intrinsically incorporate notions of creativity and consciousness suggests a new understanding of experience; a new phenomenology. One based on a digital philosophy.

Historically, phenomenology has aimed to understand, in an objective manner, the subjective response to an experience. "Logical Investigations" by Edmund Husserl is often cited as establishing the field. His arguments are almost completely predicated on, as suggested by the title, logic. Not surprisingly, readings of Leibniz are also integral to his theses. Following Husserl, philosophers such as Martin Heidegger and Maurice Merleau-Ponty continued to deal with overarching concepts of phenomenology: consciousness, perception, intuition, intentionality, and subjectivity. Later, more focused subdomains were created to investigate specific perceptual mechanisms. For example, Gestalt psychology tries to understand the perceptual mechanism of gestalt formation; how several objects may or may not be perceived as one. This was initially studied in the visual scene by Kurt Koffka and then extended to the auditory scene by composer James Tenney and researcher Alfred Bregman.

Even though Husserl's phenomenology maintains a logical basis, it does not completely reconcile a digital philosophy or the epistemological consequences of incompleteness. This is another justification for a new phenomenology based on digital philosophy. One that would

further cement the arguments set forth in “Logical Investigations” by incorporating computation, Algorithmic Information Theory, and Metabiology.

On the surface, Chaitin’s model may seem void of concepts central to phenomenology: experience, perception, information exchange, subjective response, and by extension art and music. However, the metabiological model can be analyzed to show that the mechanism of the algorithmic mutation of Metabiology — an algorithm that takes as input a software program and outputs another (its mutated self) — can actually serve as a conceptual framework for a mathematical understanding of experience and subjectivity.

In order to lay the foundation for such an extended phenomenology, I will address three fundamental questions:

- (1) What is the digital mechanism of the experience?
- (2) How can a phenomenology based on digital philosophy account for subjectivity?
- (3) What is the ultimate objective of creativity?

As the title suggests, these expository thoughts aim to function as a primer towards a mathematical phenomenology based on digital philosophies and filtered through the lens of a composer seduced into epistemology. A primer towards the more ultimate goal of understanding, through mathematics and with a minimal set of conceptual assumptions, why beauty is the subjective response to an experience and not intrinsic to or characteristic of an object.

2. A Personal Note and Acknowledgments

As I am not a mathematician, I do not feel bound to the rigors of mathematics. I imagine this text will easily reveal that fact to the reader. Yet when one sheds the cloak of specialization all too common in our current world, we venture into territories that bear the fruit of new possibilities. And even if I fail in the process, at least I tried.

No other person has encouraged that mentality in me more than Greg Chaitin. Greg is a true polymath and intellectual wanderer. He deserves the ranks of those great thinkers who exhibit pure, unexplainable creativity (here I am thinking of other great mathematicians such as Leonhard Euler, Srinivasa Ramanujan, and von Neumann). I am grateful for his friendship and inspiration.

Three others that I feel compelled to thank are composers Larry Polansky, Curtis Roads, and James Tenney. Most of all for their friendship and mentorship, but also for the fact that they instilled in me an interest exploring other domains and a phenomenological approach to making music. The title, *Meta+phenomenology*, with the somewhat strange “+” sign, is a reverent nod to Tenney, who at the young age of 25, wrote a seminal thesis called “*Meta+Hodos*”, which explicates a phenomenological approach to music theory.

Naturally, I saw it fitting to merge these two interests: epistemology and phenomenology. The following ideas are my humble attempts to lay a general framework for phenomenology based on epistemology and digital philosophy.

3. Creativity, Inspiration and a Brief Overview of Metabiology

At the core of this new phenomenology, like Chaitin’s metabiological model upon which it is based, is incompleteness. It gives rise to the most fundamental aspect of all the post-Gödelian theories: that there exist problems that require infinite creativity. Chaitin’s findings are published in great detail in his paper *Life as evolving software*, but I will give an overview of aspects germane to the following discussion.

Metabiology is a toy mathematical model of Darwinian evolution. The fitness test of the model is an alternate version of Tibor Rado’s Busy Beaver Function in which $BB(n)$ is defined as the computer program of $\leq n$ bits that computes the largest whole number. This is an uncomputable function that, as Chaitin would say, requires an infinite amount of mathematical creativity because you can always define a larger and larger number: adding a number to itself, multiplying a number to itself, exponentiation, hyperexponentiation, etc.

Chaitin shows that approaching $BB(n)$ is also the same as getting a better and better lower bound on the Halting Probability, defined as the probability that a random computer program will halt.

In Metabiology, mathematical creativity equates to biological creativity. Evolutionary progress is measured by the rate in which a single mutating software organism calculates bigger and bigger numbers. There are ostensibly no bodies, no sex, and the environment is a software space. Time is measured by the number of mutations tried up to a given point.

The mutation functions are not point mutations or crossovers as in traditional biology. They are actually algorithms that take as input a software organism and output another organism. Such a mutation can be extremely powerful, allowing violent changes and giving an organism the potential to traverse the entirety of the software space as it mutates. The mutations are chosen randomly with a probability based on something akin to relative complexity in Algorithmic Information Theory, which is the size of the minimal program to compute string b from a given the minimal program to compute a . The only difference is that in Metabiology, the mutation algorithm is given a directly instead of the minimal program for a . This is how Chaitin defines distance in the environment of the software space.

Chaitin's proof of cumulative random evolution is predicated on comparing the rate of evolution in the model to two extremes: systematic search and intelligent design. In the former, mutations are tried in order of some computable function. The equivalent of complete randomness and not cumulative at all. In the latter, an Oracle is used to pick the best possible mutations in perfect order reaching the solution in linear time. Chaitin's toy model sits in between these two. Mutations are chosen at random, but with a probability determined by the altered version of relative complexity described above. His ultimate finding is that this version of random evolution is cumulative, progresses faster than systematic search, and has a lower bound that is slower than intelligent design. In intelligent design, the creativity is given absolutely and entirely by an Oracle. In cumulative random evolution, only a limited use of an Oracle is employed in

order to throw away non-halting algorithmic mutations as they run endlessly and never produce a new organism. Oracles are the source of inspiration. They are used to inject novelty and new information into the system, but there is no completely free lunch.

For our purposes, the most important aspect of the metabiological model is that creativity and inspiration are central to the model. This thesis simply extends Chaitin's equation between biological and mathematical creativity to *all* creativity and to *all* experiences.

4. The Digital Experience

An experience is transformative; comprised of an event/situation, a subject/observer, and the effect of the former on the latter. The metabiological mechanism of evolution, an algorithmic mutation that takes as input a computer program (a software organism) and outputs an altered version of the input, encapsulates this paradigm quite elegantly. In a digital phenomenology, the experience can be conceived of almost verbatim: an event algorithm takes as input a software organism and outputs a transformed version of it. At any given time, the software organism is defined as the accumulation of these experiences; the sum of these transformations.

Let us take the general notion of the artistic experience for example. Trivially put, an observer perceives an aesthetic object (or situation) created or framed by another person. This suggests that there is something that Metabiology, which only contains a single mutating organism, cannot account for: a population and the cumulative effect of information exchange between members of the population.

Chaitin addressed this issue to some extent in an earlier work, *Towards a Mathematical Definition of Life*. This article can be read as a sort of precursor for Metabiology and demonstrates that Metabiology is some 40 years in the making. In the paper, Chaitin describes how independent structures (which could be members of a population, aesthetic objects, etc.) within a digital scene can be differentiated. The boundaries are determined using mutual information from Algorithmic Information Theory, which is the difference between the

size of the minimal program that computes two strings compared to the sum of the sizes of the individual minimal programs that compute each string separately. Two strings that have a minimal amount of a mutual information are considered separate entities in the scene.

Chaitin seemed to jettison considering multiple structures in the formalization of Metabiology in favor of a simpler, more elegant model with a single organism. However, the mutation algorithm can actually contain a representation of entities within itself. This basically reintroduces sex into the equation. The result of shared information among members of a population. It also accounts for the setting/scene itself including aesthetic objects. Therefore, the analog of the mutation algorithm of Metabiology to the event algorithm of *Meta+phenomenology* does not necessarily preclude a population or sex and is powerful enough to represent the multiplicities that we are accustomed to in real-world artistic experiences, from artists to aesthetic objects to shared experiences among multiple members of the population (the sex of *Meta+phenomenology*). As such, there does not necessarily need to be a redefining of Metabiology in order to fit it to *Meta+phenomenology*. All that is required is an interpretation of the model through the alternative lens of experience as opposed to biology.

5. Towards a Proof of Subjectivity

A proper phenomenology must take into account subjectivity: how entities will react differently to similar experiences both between the entities and over time. Let's start with the first case as it seems simpler/clearer to explain. While Chaitin's model is instantiated with a single software organism, one could track multiple instances of the model starting with the same or different organisms. It is completely possible that the two organisms can go through mutations with a high level of mutual information at the same step in time. This would be the equivalent of a shared experience. The two mutation algorithms need not be the same, only similar. The differences between the organisms themselves and between

the mutation functions (no matter how similar they might be) will have varying effects. The metabiological model accounts for subjectivity between organisms in this way. Organisms are transformed to different extents as they pass through similar event/mutation algorithms.

The second case, varying experiences to similar stimuli over time might seem more complex, but is equally straightforward. There is a spectrum of experiences from those that are common and less transformative to those that are rare and more transformative. Further, once a rarer, more formative experience occurs, an experience of a similar nature may have a lesser effect. Simply put, what was once new, often becomes old; becomes normalized and canonized. Say for example, the first time you listen to a piece of music that truly changes you. You are likely to listen to it again and while it still has effect, that effect may wane over time. It seems reasonable to conjecture that something similar occurs in the metabiological model. That mutations similar to a highly transformative mutation that has already occurred will have a lesser effect over time. Also, the software organism itself will have changed between the two mutations (or, in the case Meta+phenomenology, the two experiences).

Novelty is also relative. An experience that is novel to one organism may not be to another who has already experienced a similar event. Leibniz suggests this in the “Monadology” where he posits a world made of monads that have varying scopes of perception. One monad, essentially the God monad, sees everything. So in the metaphenomenological model, monads are in the process of expanding their perceptual views; expanding their horizons.

This sketch proof of subjectivity also suggests a well-defined concept and measure of beauty based on the transformative effect of an event/mutation algorithm. One that reflects the equivalent of an evolutionary leap in the metabiological model. By definition, the effect of a particular event/mutation is largely based on the current state of the organism — the sum of the cumulative experiences up to that point — and likely more so than any entities, such as aesthetic objects, that may be represented within the mutation algorithm.

Another important issue is how status quo biases arise. To address this, we will make another conjecture. Organisms that have a high level of mutual information are more likely to be transformed a similar amount by mutations that have a high level of mutual information. This would show how status quo biases arise among similar members of a population and refute the greatest misunderstanding of some phenomenologies: that an aesthetic object possesses the universal quality of goodness or badness.

6. Conclusion: Transcendence and the Metaphenomenological Objective

Finally, we come to the discussion of whether or not there is a metaphenomenological objective; especially for intentional acts of transformation such as creative/artistic experiences. Is there a reason for doing something that often seems so impractical? What is the point of a novel experience?

In Darwinian evolution, survival itself is the biological imperative reached by overcoming obstacles that test the fitness of an organism. In Metabiology, the organisms are essentially mathematicians/computer scientists that are in an arms race to name larger and larger integers. But let us examine a somewhat hidden meaning of such a quest and then extend that to novel, artistic experiences.

Solving Chaitin's alternative Busy Beaver Function is equivalent to getting better and better approximations of the halting probability. The halting probability, in a way, can be seen as a representation of all truths because knowing n bits of the halting probability means knowing how many programs of size $\leq n$ halt. It is pure, compressed knowledge.

The software organisms of Metabiology, and by extension Meta+phenomenology, are striving to become Oracles, but since that is a never-ending process that requires infinite creativity, it is a never-ending pursuit. A pursuit towards total transcendence. Towards becoming gods.

Dedicated to *Charis von Ristok*, with whom I had the great opportunity to discuss the ideas in this text extensively. She listened to me rant about digital philosophy, constructively challenging me throughout, and always doing so elegantly and gracefully. I now realize more than ever the gravity of a particular type of experience; that of falling in love. In the metaphenomenological sense, the time we spent together as I wrote this was one of the most transformative experiences I have ever had and transcendent on a divine order.

Schloss Solitude

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Addendum: A Few More Thoughts/Treatises Related to Meta+phenomenology

The following treatises are ideas that I considered and/or removed from the original text after deciding the primer on Meta+phenomenology should be as succinct and clear as possible. I am grateful to the editors, Francisco Antonio Doria and Shyam Wuppuluri, for encouraging me to extend the chapter and allowing me to do so in the form of an addendum of treatises. They are intended to be rather episodic reflections on potential implications of Metabiology considered in the process of writing the original text. In particular, I would like to thank Shyam for not only encouraging me to extend the text but also becoming a caring, selfless friend in the process. His kind words and consideration helped fuel the following the ideas.

1. Run-Time Versus Program-Size

As with most of Chaitin's work, his proofs focus strictly on program-size (measured in number of bits) without reconciling run-time (the time it takes a program to halt). In the metabiological model, time is measured by the number of mutations up to a given point in the evolution even though the mutations themselves run for different amounts of computational steps. However, Cristian Calude's findings in *Most programs stop quickly or never halt* suggest that program-size and run-time might be reconcilable. For example, Chaitin's algorithm that approximates Omega, the halting probability, spawns and runs all programs of size less than n bits up until an arbitrary time-limit in order to determine a lower bound on Omega. The longer the

time-limit; the better the approximation. Given Calude's finding, a sufficient time-limit related to n should produce a very good lower bound on Ω .

2. Time in Finite Systems

In order to discuss time in finite systems, I will start by focusing on cellular automata. In an automaton on a finite grid (e.g., in the form of a torus), time can be a well-defined constant: the number of computations needed to update all the cells in the system. This is essentially the computational time needed to get from one frame to the next in the moving image that is the universe. Just as with automata, time in the metabiological model can be completely reconciled given a finite system with only halting programs (a version proposed by Chaitin himself). It is a constant equal to the run-time of the program that takes the longest amount of time to halt.

3. Time in Infinite Systems

If there exists an infinite amount of information in the system, it becomes much more difficult to conceptualize time and reconcile program-size with run-time. Assuming that all universal systems are somehow equivalent and that an understanding of time through cellular automata likely has some correlation/equivalence in the metabiological model, I will continue my focus on cellular automata. A cellular automata on an infinite grid can be partitioned into subsets of finite and infinite subgrids (parallel universes). If all the partitions are finite subgrids, time in the system as a whole can be conceptualized as an infinite number of finite parallel universes each of which abides by the well-defined concept of time described in the previous treatise. If any of the partitions are infinite (or there is only one partition, the infinite whole), then there is no well-defined concept of the "current state" of the system as a whole because an infinite grid can only update in infinite time.

4. Classical Versus Quantum Mechanics in A Digital System

Assuming that cells of automata (in both the finite and infinite cases) update serially, there are two topologies of space–time: the Euclidean distance between the cells in the multidimensional grid (the scope of the large scale: a classical topology) and the distance between cells with respect to when they are updated in a one-dimensional order (the scope of the small scale: a quantum topology). Some of the anomalies of quantum mechanics in our observable universe seem interestingly similar to phenomena in automata that result from the difference between these two levels. For example, quantum entanglement could be the particular case where two cells are far apart in the multidimensional grid but are actually neighbors in the one-dimensional update sequence resulting in bits of information that are seemingly correlated over vast distances in space (from the perspective and scope of the large scale). In the case of an automaton on an infinite grid, there would need to be a mechanism that triggers the one-dimensional update sequence at a given interval of time. This would spawn an ever increasing number of parallel computations (yet another notion of parallel universes if the update sequence is non-deterministic or differs upon every instantiation). Whatever the mechanism, by definition, there would be an infinite number of cells whose neighbors only update in infinite-time. It would be impossible to ever see the current states of these cells similar to, say, dark matter.

5. All Universal Systems are Equivalent: Tilings and Aggregation

As suggested in the previous treatises, it seems likely to me that all universal systems are equivalent and can be reduced to one another. Such equivalences are ubiquitous in mathematics (e.g., how an np -complete problem is reducible to all others np -complete problems). While I have focused primarily on Metabiology and

cellular automata, there is another universal system that warrants mention: tilings (specifically Wang-tilings). Through music, I have become fascinated by the history of the domino problem; the decidability problem that asks: given an arbitrary set of square tiles with colored edges, is there an algorithm that will determine if the set tiles the infinite plane such that adjacent squares share the same color on the abutting edges. Hao Wang conjectured that there was such an algorithm, but his student Robert Berger showed that the problem was undecidable by discovering a tile set that tiles the infinite plane strictly aperiodically. Such a construction should not exist if Wang conjectured correctly. Since Berger's proof, several other aperiodic tile sets have been discovered. The most obvious reason why tilings can be useful mathematical objects to explore is that they are toy models of how things "fit together" and aggregate (be it atomic structures, DNA, or higher order molecular constructs). Further, any Turing machine can be converted to a Wang tiling and Chaitin has also shown how Wang tiles can be used to represent the bits of Omega. Of particular interest is the work of Jarkko Kari, who has shown several problems involving tilings as undecidable. This is yet another example/model of incompleteness and infinite creativity in the evolution, aggregation, and construction of (toy, mathematical) objects. In particular Kari has defined a set of "directed Wang tiles" and shown that it is undecidable if an arbitrary set tiles and includes a "snake" (a path) that covers the infinite plane. Kari's paths are always adjacent tiles in the multidimensional tiling. It would be interesting to extend his work such that the snake can be disconnected. Intriguingly, Kari's directed tiles combine a multidimensional scale with a one-dimensional scale in a unified system.

6. Intuition and Inspiration: Further Considerations about Intelligent Design Versus Divine Intervention

The limited use of an Oracle in Metabiology and by extension *Meta+*phenomenology posits that there is no intelligent designer. However, it does suggest some form of divine intervention which

accounts for how new information enters the system. I would suggest that this is the phenomenological equivalent to intuition: the acquisition of new information by an organism in an act of inspiration. A failure to distinguish between a god/intelligent designer and a limited divine intervention is the fundamental flaw of most organized religions wherein beliefs grow out of a need to explain that which is not understood (the seasons, the movement of celestial objects, etc.). But as knowledge is accumulated, the notion of a god gets replaced by an understanding of our world. As concluded in the original text, we are in the process of transcendence and becoming Oracles ourselves. In *Life as evolving software*, Chaitin gives several “open problems”. Problems 5 and 6 relate to the rate of evolution: the former asks if there is a way to get a better upper bound on the rate of evolution (e.g., more akin to those that we see in the real-world) while the latter asks if there is a way to get a lower bound that is strictly slower than intelligent design. As Chaitin suggests in Problem 5, the range of potential evolutionary rates of cumulative random evolution should have a mean and variance. Perhaps it is possible to prove that cumulative random evolution has the potential to result in a system that evolves at a rate equivalent to intelligent design, but that it is *extremely* unlikely. In the case that the mean evolutionary rate in Chaitin’s model still reflects an evolutionary rate slower than we see in the real-world, it would be interesting to explore a notion of statistical feedback in the system by further weighting the probability of a mutation algorithm occurring such that the longer it has *not* occurred, the more likely it is *to* occur. This idea is borrowed from an algorithm frequently used by James Tenney in the compositional process to get a more uniform series of selections over a small number of trials (see *A few more Words about James Tenney: dissonant counterpoint and statistical feedback* by Larry Polansky, *et al.* for a detailed analysis of the procedure).

7. Intentionality and Feedback: A Beautiful Soup

By definition, the organisms in Metabiology contain their own history: evolution is cumulative. The current best solution to the Busy

Beaver Function is encoded in the organism itself in order to test the output of the next generation. Therefore, the organisms are always working with the best solution up to that point in the evolutionary process (the current state of the art and technology). This is a fundamental observation that I did not elaborate upon in the initial text. The creative act, in both the real-world and in Metabiology, is the invention. Of equal importance, is that the invention is demonstrated and shared such that the next generation is working with the knowledge accumulated up to that point. The analog in the real-world is as follows. An invention is made by a person, that person puts the invention in the public domain (i.e., publishes a paper, premieres a piece of music, etc.), the observers of those acts then process that information, which sometimes leads to new inventions. This explains an important aspect of phenomenology: intentionality. The act of disseminating knowledge into the public domain. This is elegantly encapsulated in Chaitin's model by the cumulative evolution of knowledge within the evolving organism! It can be seen as a feedback loop of sorts giving rise to more and more knowledge.

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