What Killed Substantial Form?

David Banach
Saint Anselm College

What killed substantial form, and can it live again? Substantial form died at the beginning of the scientific revolution when a new method made it unnecessary and a new view of the senses revealed by this new method made it unknowable. Conway's Game of Life as a model for Mechanism reveals not only the problems that make it impossible for contemporary thinkers to take substantial form seriously, but also a way in which the idea might be revived in a different form. The proponent of substantial form in the modern world should not oppose mechanism, but should insist upon it. If a thoroughgoing mechanism is true, it implies its own limits and requires the resurrection of form in a way that even a mechanist could love.

What killed substantial form? I am in the unenviable position of a rookie cop watching a skilled detective and an expert medical examiner examining a body, formulating intricate and ingenious theories about the possible timing and cause of death, but being forced to point out the large axe protruding from the patient's skull. While I cannot help but admire and agree with Professor Hill's masterful diagnoses of the multiple maladies that afflicted the concept of substantial form during the early modern period, I am going to argue that the patient was already dead from a far more serious pre-existing condition incurred at the very beginning of the scientific revolution. It is this problem that prevents modern scientists from taking the idea seriously, and it is a solution to this problem upon which any hope of resuscitating the concept of substantial form depends. Substantial form died at the beginning of the scientific revolution when a new method made it unnecessary and a new view of the senses revealed by this new method made it unknowable. Its death was caused by a re-definition of the very nature of science.[1]

I. The Way of Necessity Vindicated

While the method of applying mechanism in the scientific revolution may have been new, the basic principles were developed by the Pythagoreans and articulated clearly in Plato's ***Timaeus*** (48e–56c) in the Way of Necessity. Here he describes how the properties of the various types of elements are necessitated by the geometrical properties of the fundamental particles that compose them, even providing instructions for geometrically constructing the regular, or Platonic, solids that form the basis of Earth, Air, Fire, and Water. The elements are explained through the geometrical properties of the triangles that compose them and their method of geometrical construction. The properties the Platonic solids have in interaction with other things are necessitated by their geometrical properties and the method by which they are combined or

[1] Of course the historical sources of these changes are far more complex than this suggests, and every new idea is in some way continuous with and prepared for by what has come before. But what we are really interested in here is not the particular history of the genesis of certain ideas in certain real human beings that lived long ago, but in how these ideas have been appropriated by the living. We want to know why the idea of substantial form no longer is alive for us, and whether it can live again in our understanding of nature.

interact with other particles. The method of proof by geometrical construction developed by the Pythagoreans and perfected by Euclid provides the model for how the properties of a complex thing are necessitated by the geometrical form of its parts and the rules of its construction. The essence of the way of necessity is external compulsion in accordance with laws that apply merely in virtue of the geometrical properties of an object and its construction.

Plato saw clearly that the Way of Necessity was not self-sufficient; it required a Receptacle or Medium, an active agent or demiurge to set up the initial conditions, and a more fundamental set of realities that provide the source of the rules that necessitate the actions of blind matter. He also saw that it was not adequate to explain most types of order found in the cosmos. In particular those things with an internal principle of action and those things that are ordered for the best could not be explained in this way. These required the Way of Reason and required a soul as the source of original actions and of order. In Aristotle, substantial form became the indwelling source of the order, unity, and identity of objects that require this type of explanation.

The Way of Necessity, as envisioned by Plato, was limited in its explanatory power. Only the most general properties of the elements could be explained in terms of the geometrical shape of the Platonic solids that composed them. Almost all of the observable properties of objects seemed to require a substantial form or soul to explain their order and unity. The Way of Necessity did enjoy some modest success in astronomy in the ancient world. The appearances of the heavenly bodies could be saved by constructing their paths through the combination of various circular motions in accordance with geometrical laws that then necessitated the paths of the heavenly bodies. The arrangement and ordering of these spheres was left to the Way of Reason and was the work of intelligence. With the exception of this limited sphere, and the work of Archimedes and some of the mathematicians of the Alexandrian school, all knowledge of the workings of nature required the use of the Way of Reason, as perfected by Aristotle in the ***Posterior Analytics:*** the method of intuiting through induction the forms of things that then formed the first principles of causal explanations. Until Copernicus, this was really the only game in town.

The essence of the new method introduced by Copernicus, and perfected by Galileo, was the recognition that the appearances presented to our senses were often not the real appearances that had to be saved. When we look to the heavens to see the sun moving across the sky, or the retrogression of the planets in their paths, what we are seeing is not the real motion that is to be explained geometrically, but merely the motion relative to us. The motion of the sun across the sky is not in the sun, but is only the motion it appears to have relative to our motion. Once one separates the relative motions from the absolute motions, the method of constructing these motions geometrically has some chance of success. As long as the motions the astronomer was trying to construct were not the real motions, but those due to the object's relation to us, the method of geometrical construction had no chance of success. As long as one believes that the planets are really engaging in retrogressions in the heavens, the problem of geometrically reproducing those appearances will be insoluble, as it had been for fifteen centuries. Once it was

recognized that the planets only appear to have retrograde motion because of the motion they have relative to our motion as we pass each other in our orbits, the orbits were mathematically accounted for within the century.

Galileo extended this method of purifying the appearances beyond the astronomical appearances and to the separation and independent modification of all sensible properties. In the first decade of the 17th century he is already undertaking the investigations of floating bodies (that would be published in 1612) and his investigations of motion (which would form the basis for his investigations in the ***Discourse on Two New Sciences***, published in 1638). He is applying Archimedes's methods of mathematical balancing and systematically manipulating the shape and weights of wax balls to determine the real cause of flotation. He is using inclined planes to alleviate the effects of air resistance and air buoyancy and to slow down and separate the different directions of motion in his investigation of the natural acceleration of motion and in his investigation of projectile motion. In each case he is discovering that the unity of the observed properties is an illusion. There is no one simple form associated with the shape that accounts for the flotation of objects; there is no one nature of the elements that compose a heavy object that accounts for its falling motion. In each case the motion we observe is the result of a conglomeration of different properties and forces; of air resistance and friction and momentum and gravity and buoyancy of air and water. Once the appearances are purified, by systematic manipulation in an experimental setting, to reveal only one motion or property at a time, the revealed simplified appearance is found to be amenable to mathematical or geometrical construction in accordance with the Way of Necessity.

This method is extended to an articulation of what has come to be known as the Principle of Relativity in the ***Dialogue on the Two Main World Systems*** (1632). Galileo arrived at the basic laws of terrestrial motion by distinguishing between the motion that an object has in itself and the motion it has relative to an observer. To an observer in space the object on the surface of the earth is moving in a circle at about 1,000 miles per hour as the earth rotates on its axis. How could we not feel such a motion, asked the opponents of the Copernican Hypothesis that Galileo was trying to answer in his first set of ***Dialogues***. Galileo's answer was to recognize that this motion was only relative to a stationary observer, and that the real motion of the object of an object was the motion it exhibited in an inertial framework or system of similarly moving objects. All of the objects on a ship traveling together at a constant rate are at rest with respect to each other in a single inertial framework, while to a stationary observer they are in motion.[2] The Aristotelian opponent, considering the set of perceived appearances to be a unity, cannot understand how the same nature (in the rock dropped from a stationary tower and the rock dropped from the mast of the moving ship) can have different natural motions. But the motion of the rock on the moving ship only appears different from that of the rock dropped from the stationary tower because of the point of view of the observer and their relative motion with respect to the object. The observed motion of the moving object is not a unity, to be explained by one nature. Once the appearances have been purified by separating the motion of the object from

[2] The relevant passage is at http://www.anselm.edu/homepage/dbanach/h-galileo-dialogue2.htm#section7d4.

the motion it has relative to the observer, its real motion becomes apparent and susceptible to mathematical analysis. From the point of view of an observer moving on the ship with the object, the motion appears the same as that observed by a stationary viewer viewing the fall from a stationary tower. The Galilean Principle of Relativity identifies such inertial frameworks as the place to find the real absolute motions of an object: The results of all physical experiments will be the same in all inertial frameworks. Galileo later[3] rails against the use of occult qualities in the explanation of the tides, since the oceans are composed of great masses of particles, their motions cannot be the result of natures deduced from properties merely relative to us or arising from impure complex interactions of properties.

The most clear and far reaching of Galileo's application of the new method of purifying the appearances is in his distinction of two kinds of properties in ***The Assayer*** (1623)[4], which would form the basis for the distinction of primary and secondary properties in modern philosophy. Like the tickle of the feather or the drunkenness produced by beer, most sensible qualities are not in the object waiting to be conveyed to us through the senses; they are merely the effects that the object has on our constitution. Once we separate the relative from the absolute within our perceptions, we find that most of the properties we found to be indicative of unities that required a single nature as their source are really not in the external world at all, but are the effects that the primary qualities of objects have on our constitutions. The primary properties that remain, once separated from each other through systematic experimentation, are all amenable to mathematical analysis and can be seen as being necessitated by the geometric properties of the objects. Just as in astronomy and the science of motion, most of the obstacles to understanding nature that seemed to require the Way of Reason or substantial form for their explanation, gave way to the method of geometric construction once one purified the appearances and separated the relative from the absolute to arrive at the real appearances to be saved.

This had two effects, one metaphysical and one epistemological. First, this made it clear that most of the unities we experience with the senses are illusory. They either arise from the way things effect or are relative to us, or they emerge from the combined effect of a manifold of mixed causal influences, which can be separated and shown to function and exist independently (as in the case of motion.) Galileo tells a little story in ***The Assayer***[5] of a man who hears a strain of beautiful music and sets out to find the cause of that sound, unaware that the various different sources he finds it arising from (a flute, a vibrating string, a cricket) are all impure phenomena and produce the real cause of sound in different ways. The species and unities revealed to us by the senses are not real and arise from the confluence of many different types of causes on our constitution. Second, it reveals that the process by which objects affect our senses and produce

[3] ***Dialogue on the Two Main World Systems***, Thomas Salusbury translator, 1661 edition, p. 837. Available at http://archimedes.mpiwg-berlin.mpg.de//docuserver/images/archimedes/galil_syste_065_en_1661/downloads/galil_syste_065_en_1661.text.pdf .
[4] The relevant passage can be found here: http://www.anselm.edu/homepage/dbanach/galileo.htm.
[5] In Stillman Drake, editor, ***Discoveries and Opinions of Galileo,*** Anchor Books, 1957, p. 256

these sensible qualities cannot convey any form or intelligible species.[6] Once one sees that it is only the combined effects of many corpuscles or agents, or the special way in which they happen to act relative to our constitution, it becomes impossible to think that the qualities they produce in us are identical, or even similar to, the principles of the unity of these effects, even if one were to try to imagine that there was a single principle behind these impure combinations of relative effects. Note that the problem here is not merely that what we perceive are merely accidents from which we cannot infer the substantial form with any certitude, but that (1) the properties we perceive are not attributable to any unity whatsoever; and (2) they can only be said to be accidents of us, not of any external unity.

When Galileo, in ***The Assayer***[7], is able to say **"**Philosophy is written in this grand book, the Universe, which stands continually open to our gaze. . . . It is written in the language of mathematics, and its characters are triangles, circles, and other geometric figures without which it is humanely impossible to understand a single word of it." Substantial form is dead. The Way of Necessity has prevailed. The proof will be in the extraordinary success these mathematical methods of construction will allow in both Galileo's studies of Motion and in Newton's extension of those methods to the motion of the heavens. It will matter little that the vast majority of phenomena cannot be constructed geometrically or reduced to mathematical properties. The promise of the method of describing the mathematical rules by which the purified appearances can be constructed will have been made clear by its initial successes; successes made possible precisely by the abandonment of research based upon the assumption of a single unity or substantial form behind appearances.

It will be left to other philosophers to make explicit the argument that Moliere would use to poke fun at the remnants of the idea of substantial form as they still existed in French medicine a half a century later when he makes fun of the doctoral candidate who explains that opium puts you to sleep because of its dormative nature.[8] If we have no access to the substance of a thing, then it is useless in the explanation of its actions and properties.

We try to use the substantial form of a thing to explain its actions. Since we have no independent access to the form, we find that we can only describe the substantial form of a thing as a faculty, in terms of what it does. Thus our attempts at explanation will be empty or circular. Acid eats away metal because it has a corrosive nature. Glass breaks because it is brittle. (But corrosive just means "eats away things," and brittle just means "breaks".) So the explanation is empty: "Glass breaks because it breaks." Descartes was able to give a perfectly formed version of this argument in 1642. Referring to substantial forms, he says:

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[6] This point is, I think, the rejection of what Hill calls the principle of Causal Likeness.

[7] Stillman Drake (1957), pp. 237–238.

[8] Moliere, ***The Imaginary Invalid***, first performed in 1673. An English translation is here: http://www.gutenberg.org/dirs/etext05/8mald10.txt and the relevant passage can be found here: http://www.anselm.edu/homepage/dbanach/dormative.htm.

> They were introduced by philosophers solely to account for the proper action of natural things, of which they were supposed to be the principles and bases . . . But no natural action at all can be explained by these substantial forms, since their defenders admit that they are occult, and that they do not understand them themselves. If they say that some action proceeds from a substantial form, it is as if they said it proceeds from something they do not understand; which explains nothing. . . Essential forms explained in our fashion, on the other hand, give manifest and mathematical reasons for natural actions, as can be seen with regard to the form of salt in my ***Meteors***. [9]

It is not only that substantial forms are useless as explanations since there is no way to access them independently of the thing to be explained, but also that the geometrical forms revealed by the scientific method allow the observed qualities to be logically deduced as the necessary results of its mathematical properties.

It might be claimed, as Hill does in his response to the argument from nominal essences, that this is merely an argument from ignorance, or it might be claimed that this merely abandons the task of explaining **why** things happens, of explaining the reason for connections, in favor of merely mathematically describing **how** they happen. But this would be to miss the force of the arguments. When early critics, such as Leibniz, pointed out that there remained some things such as the living force (***vis viva***[10]) or the gravitational force at a distance, about which Newton refused to form hypotheses, that still required a substantial form for their explanation, they missed the force of the Galilean arguments as well. None of these objections would bring a modern scientist any closer to reviving the concept of substantial form. With the success of the Way of Necessity as applied to purified appearances, the very nature of science had changed. An explanation in terms of the intrinsic properties of a nature no longer counted as a scientific explanation, even if such a nature did exist and even if such an explanation could be given. Without the apodictic certainty or necessity supplied by mathematical deduction, an account no longer counted as science. The whole scientific method was designed to see which regularities nature was necessitated to follow independent of the circumstances and across all transformations.[11] These arguments simply beg the questions against the Way of Necessity, which given the spectacular results of its first applications according to the new scientific method, had earned the right to demand that the burden of proof had shifted. To formulate hypotheses about the intrinsic sources of phenomena was both unnecessary and was giving up

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[9] Descartes. "Letter to Regius," January 1642, in *Ouevres de Descartes*, 11 vols., eds. Charles Adam and Paul Tannery, Paris: Vrin, 1974–1989. III 506, and in *The Philosophical Writings of Descartes*, 3 vols., trans. John Cottingham, Robert Stoothoff, Dugald Murdoch and Anthony Kenny, Cambridge: Cambridge University Press, 1984–1991, pp. 208–209.

[10] The ***vis viva*** is equivalent to what we now call kinetic energy. Leibniz had argued that the conservation of this was not explicable in merely mechanical terms. Leibniz, ***Discourse on Metaphysics,*** Sections XVII–XXI. Available at http://www.anselm.edu/homepage/dbanach/Leibniz-Discourse.htm . See also his "Essay on Dynamics" available in Jonathan Bennett's translation at http://www.earlymoderntexts.com/pdf/leibdyn.pdf .

[11] The pendulum was such an important case precisely because its regularities were independent of most of the influences that could interfere with it.

before the scientific method had a chance to explain these phenomena as necessary consequences of the geometrical structure of the objects involved (as gravity, for example, would ultimately be explained as a geometrical consequence of the curvature of space time by Einstein).

II. The Power of Mechanism: Lessons from the Game of Life

In order to see both the force that these arguments still have for Modern scientists and to see the inherent limitations of the Way of Necessity, I will use a computer program called a cellular automaton as a model of how mechanism works. When Stephen Wolfram wrote ***A New Kind of Science***[12], he envisioned a new kind of experimental science based upon simulations. His work on cellular automata (simple computer programs that manipulate simple pixels on a grid according to a simple program) had shown him that complex sets of regularities arise from these simple systems in ways that cannot be predicted practically from the simple rules. Philosophers, such as Daniel Dennett, have been interested in the most famous of these cellular automata systems, John Conway's Game of Life[13], for somewhat different reasons. Dennett has used the Game of Life to discuss the nature of physical patterns, the anthropic principle, and freedom and inevitability in deterministic systems.[14] The simplicity and transparency of these systems make them an ideal medium for investigating the relationship between the observed regularities of nature, the laws that give rise to them, and the reality that underlies and implements those laws. In particular, I believe that the clarity these models provide allow us to formulate a clear model of mechanism, to see its limitations, and to formulate a precise idea of what is left for a concept of substantial form to explain.

Conway's Game of Life involves just three rules. Each pixel or cell is surrounded by eight other pixels and will live or survive the next generation depending only on the contents of these eight cells and these three rules: (1) An unoccupied cell surrounded by exactly three filled cells will become full or alive; (2) A full or live cell surrounded by either two or three live cells remains alive; and (3) A live cell surrounded by more than three live cells dies, or becomes empty. Each generation, these rules are applied to each cell to generate the next generation. If we are to use this as a model of the physical world, each pixel would represent the most fundamental particle, and the three rules would constitute the fundamental laws of Nature. What is surprising is that these simple components and rules give rise to a vast and complex array of patterns which exhibit their own regularities and behaviors. There are moving patterns, stable patterns, oscillating patterns; in fact, a whole world of new types of objects[15] that, as Wolfram had noted, could not have been practically been predicted on the basis of a knowledge of the rules. Paul

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[12] Stephen Wolfram, ***A New Kind of Science,*** Wolfram Media, 2002.

[13] The game was introduced to the public by Martin Gardner in "The fantastic combinations of John Conway's new solitaire game 'life'," ***Scientific American*** 223 (October 1970), 120–123. A good introduction to the philosophical issued raised by the game is William Poundstone's ***The Recursive Universe,*** Contemporary Books, 1985.

[14] See Daniel Dennett, "Real Patterns," *Journal of Philosophy* (January 1991), 88(1):27–51; *Darwin's Dangerous Idea: Evolution and the Meanings of Life*, Simon and Schuster, 1995, Chapter 7; and *Freedom Evolves*, Allen Lane Publishers, an imprint of Penguin Books, 2003, Chapter 2.

[15] See Eric Weisstein's collection of animated images of Life patterns here: http://www.ericweisstein.com/encyclopedias/life/ .

Rendell has even designed a Turing Machine within the Life world[16], so, in principle, all computable processes could be simulated in the Life world. When one looks at the Life world one sees not a world of pixels, but a complex set of objects exhibiting their own set of regularities. Yet in this simple world, we can see that all of these entities that emerge from the complex interactions of the pixels are merely the result of the simple rules that govern the pixels and nothing else.

Take, for example, one of the most important Life patterns, the Glider.[17] (http://dbanach.com/Life/gliders.avi). This clip shows the gliders at slow speed first, so that one can see the individual stages as the pixels disappear and then reappear in accordance with the program. It then speeds up to show what appears to be a coherent pattern moving across the screen. (The camera zooms away to keep the gliders on the screen as they move outward.) This second clip shows a glider gun, or pattern that generates a stream of gliders endlessly: http://dbanach.com/Life/glider.avi. (This clip also starts out in slow speed then speeds up.) What is a glider? It appears to have a unity at each moment and a coherence over time that would require a substantial form. In this case, however, we know exactly what is going on: There is nothing but pixels on a screen following, and necessitated by, the three simple rules of the program.

Consider another pattern called the acorn[18] (http://dbanach.com/life/acorn.avi). This simple pattern, like many simple patterns in Life, develops, inevitably and in a completely predictable way, into an intricate pattern after a long development (over 5,000 steps in this case, into a pattern called the oak.) It would seem that the acorn must in some sense contain the information for the oak and that the same thing which forms the principle of unity of the acorn pattern determines its end state or ***telos*** and impels the change towards its goal. But, again, in this case, we know there is nothing but the pixels and the three rules at work. Is there a difference between the conviction we have in the case of a real acorn that there is a principle behind its unity which impels it towards its ***telos*** and the totally mistaken conviction we have in this case?

Certainly, real living things are much more complex; they reproduce and make copies of themselves, and the process of their development resists perturbation or interference in a way that makes one think that there is a unifying force at work. Random patterns in Life never give rise to anything with these properties (http://dbanach.com/life/random.avi), but neither do random patterns of elementary particles in the real world.

What would have to happen in the Life world to produce such patterns? The first thing that would be necessary is something like the energy conservation laws that govern our physical world. Most of the patterns, even the stable ones, in the Life world become unstable when they

[16] The original paper, Paul Rendell, "A Turing Machine in Conway's Game of Life," March 8, 2001, can be found at http://www.cs.ualberta.ca/~bulitko/F02/papers/tm_words.pdf. Rendell's page describing the design is at http://rendell-attic.org/gol/tm.htm.
[17] http://www.ericweisstein.com/encyclopedias/life/Glider.html.
[18] http://www.ericweisstein.com/encyclopedias/life/Acorn.html.

interact with other patterns, just as most of the elementary particles in our world have very short lives. The stable forms of matter that persist in our world are all equilibrium points or points of lowest energy for some physical system. Therefore, they exhibit a unity that resists perturbation since they are local minima; unless something perturbs them so that a lower energy state becomes available, they tend back to the equilibrium or original low energy state. None of the forms of matter we know would exist without laws making such situations possible. There is nothing particularly mysterious about this; the mechanical rules that govern energy in our world necessitate such possibilities. There is nothing, in principle, that makes it impossible to implement something like energy conservation rules in a cellular automata program.

Self-replicating patterns would be possible within the Life world as well. We already know that mechanical processes can replicate themselves since DNA and computer viruses replicate mechanically. (Since a Universal Turing Machine is possible within the Life world, we already know that these types of replication are possible in Life as well.) Darwin, of course, has shown how, given replication, variation, and natural selection, complex and improbable patterns might arise mechanically. Is there anything, then, about the complex forms in this world, of which we tend to say that they have substantial forms, that is different from the forms we can see in Life, where we know that the Way of Necessity alone is responsible? I find it difficult to avoid concluding that the answer to this question is no. Further it would seem that any explanation that could not, at least in principle, work in a world like the Life world would not count as a scientific explanation.

III. The Limits of Mechanism

Despite the power of mechanism, its very nature implies its own limits. The table below (Figure 1) summarizes how the Life world works as a model of the physical world and its limitations. Plato himself was clear about how the Way of Necessity implied its own limitations. He also saw clearly that the Way of Necessity was not self-sufficient; it required a Receptacle or Medium, an active agent or demiurge to set up the initial conditions, and a more fundamental set of realities that provide the source of the rules that necessitate the actions of blind matter. Using the Life world as a model of how mechanism works makes these limitations even more clear. The pixels that constitute this world must have a medium, in this case the screen. There must be a more fundamental reality which implements the program that governs the Life world, in this case the computer itself. Finally, there must be some agency that is responsible for the actual operation of the program, in this case the factory that made the computer, the programmer who put it into the computer, and the user who pushes the button to run the program. The essence of mechanism is external compulsion by some substrate neutral[19] rules or algorithms. Considering the Life World as a model shows that such a mechanism is not self-sufficient. Everything cannot

[19] See Dennett's account of algorithms in *Darwin's Dangerous Idea: Evolution and the Meanings of Life*, Simon and Schuster, 1995, Chapter 2 for a nice summary of the essential features of mechanism.

be pixels; there has to be a screen on which the pixels exist and a computer to run the program.[20] Getting clear about the nature of mechanism reveals that reality can't be mechanistic all the way down.

Element of the Life world	Element of Physical Reality it represents
Pixels (Functional Representations in CPU)	Fundamental Particles The Physical World
Program	Fundamental Laws of Nature
Computer (and the rest of the world)	Primal Reality that underlies our physical reality
Large sustainable patterns of pixels	Physical objects
Meta-regularities or side effects of the program.	Observable regularities of macroscopic objects.
Form	Structural constraints imposed by the medium or primal reality.

The Life world shows that every mechanical system has mechanical properties, the substrate neutral properties of the elements and their program driven behavior, as well as non-mechanical properties, call them primal properties. What can we know about these primal properties? If the rules that govern mechanism are substrate neutral, there is good reason to think that we **can't** know the nature of the fundamental reality that runs our world. (Could a Life world inhabitant tell if its world was being run on a PC or a MAC?)[21]

There need be no isomorphism, or one to one relationship, between the objects and regularities in the physical world and the entities and rules in the hardware and software of the primal reality. There is nothing corresponding to the glider in the computer that runs the Life program; there are only the pixels and the three rules as implemented in the program. The next section will consider whether there is enough of a connection between the observed patterns and meta-regularities and the primal reality to support a type of substantial form.

As an instructive aside, it might be useful at this point to consider what a modern mechanist, aware of these limitations, would make of monsters and mixtions. Since the species and other patterns in the physical world do not reflect any real species or forms in the primal reality, there is no particular problem with the possibility of their interactions producing

[20] Of course, any particular program can be running as a virtual machine within another program. (If a Turing Machine can exist in Life, we could implement another Life world on that Turing Machine.) Still, it should be clear that it can't be virtual machines all the way down.

[21] It is possible to implement a pattern in the life world that acts just like a single pixel in relation to the other such patterns around it, following the rules of Life. Such a pattern is called a unit life cell (http://www.ericweisstein.com/encyclopedias/life/UnitLifeCell.html). One could never know if one's world was running on simple pixels or on these larger simulated pixels, since both would follow exactly the same laws.

intermediate forms. Biologists now recognize that most well defined species often form hybrids with other species. Since species classification is no longer seen as reflecting a form or nature, but simply represents a separate lineage or clade in the evolutionary history of a group of organisms, hybrids will have no bearing on the status of species unless, as it turns out, their destiny is to develop into a separate lineage. But this is something that is never known at the time, but only becomes clear with time. Species are merely individual histories of the course of a population as it develops according to the evolutionary algorithm.[22]

One often hears from advocates of the concept of substantial form that the parts of complex objects are transformed within the new substance, that hydrogen in water, for example, is not the same as elemental hydrogen. This may or may not be true, but two things should be clear: (1) The independence and invariance of the laws of nature is a postulate of the scientific method. A regularity or rule would not be identified as a law of nature unless it operated independently of other laws and was invariant over different instances. The laws that govern the parts, at any rate, cannot be different. (2) Since the only things in the physical world that have any reality in the primal reality are the pixels and the three rules (in the real world this would correspond to the fundamental particles and the laws of nature that govern them), it does not really make sense to talk of them being transformed within the whole pattern or substance. There is nothing to transform. A pixel is just a bit of information, either on or off. One way of seeing the fundamental re-definition of science during the scientific revolution is to see that the abandonment of the concept of natures means that physical reality is composed of qualitatively identical bits of matter with no content or nature of their own, having only properties that arise from their arrangement in space and time, the primary properties.[23]

IV. Reanimating Substantial Form

Do the limitations of mechanism, as revealed by the cellular automaton model, require, or at least make it possible, for us to reanimate the cold hard corpse of substantial form. I think so, although, just as in the case of Frankenstein's monster, we may not all be equally pleased with the form that the reanimated corpse takes.

The most remarkable feature of the emergent patterns in the Life world is that they do not correspond to entities in the primal reality that gives rise to them, nor do the laws and regularities we can detect correspond to the laws that govern the program that gives rise to them (or any other laws governing objects in the primal reality). On the one hand, however, it is clear that their properties arise from formal aspects of the configuration of the pixels, and we can talk about the forms these patterns have and the universal constraints those forms put on their behavior, even though nothing in the primal reality that gives rise to those forms may have those properties. On the other hand, apart from the fact that it is capable of implementing the functions

[22] See Dennett's account of species in *Darwin's Dangerous Idea: Evolution and the Meanings of Life* (Simon and Schuster, 1995), Chapter 4.

[23] See J. A Wheeler and K. Ford, "It from Bit," in Geons, Black Holes & Quantum Foam, New York: W. W. Norton, 1998, for an account of the quantum nature of fundamental particles as bits of information.

we detect in the mechanical world, given substrate neutrality, we cannot know anything of the actual forms of causality that operate in the primal reality, or between it and our world. A thoroughgoing mechanism implies at least two non-mechanical levels of being: (1) a Formal Reality, however conceived, that describes the regularities and patterns that emerge from, but are not caused by, the rules of the program; and (2) an unintelligible Primal Reality that somehow gives rise to the implementation of the rules that generates this world.

It does not seem that we can infer that there must be an entity or rule that corresponds, in the primal reality, to each of the patterns or meta-regularities that we observe in the Life world, or its correlate in the physical world. We have already seen that there need be no isomorphism between the two levels.[24] There is no entity in either the hardware or the software of the computer that corresponds to the glider, apart, of course, from the pixels and their digital representations in the memory of the computer. It would seem difficult to identify substantial form with some entity or rule in the primal reality. The substrate neutrality of mechanism itself seems to preclude the necessity of positing one type of primal reality or other.

There do, however, seem to be features of the patterns and meta-regularities found in the Life or physical world that require some principle of explanation lacking in either the rules that govern the pixels or the objects and rules in the primal reality. We know, at the very least, that the patterns of electrons in the primal reality of the computer must have a formal structure capable of producing the form of the patterns and meta-regularities we find on the screen. For example, it has been proven that the maximum speed of any finite pattern in a horizontal or vertical direction is ½ the speed of the fastest propagated change in the Life world (called the speed of light by analogy to the role of the speed of light as the fastest possible signal in special relativity theory). This (1/2 c) is also the speed at which the glider travels. This does not seem to follow in any straightforward way from the three rules of Life, and it certainly is not part of the program that implements life, nor a restriction on the motion of patterns that is built into the screen. It does, however, seem to be a result of the formal limitations imposed by the structure of the grid of the screen and the formal structure of the rules as implemented on the screen by the program.

To take another example from the physical world, a certain species of bats forms a sphere as the great flock of the bats circles, emerging from an opening in the cave in which they spend the daytime hours. There is nothing in the laws of physics that determines this, nor is it determined by any law of the particular psychology of the individual bats, which are just flying according to their individual inclinations based upon cues such as light, variations in air pressure, the sounds from their neighbors, and the perceived distance between them and their neighbors. The sphere seems to emerge from the confluence of these individual causes in just the same way that Life patterns emerge from the rules. Yet, if one were to perform an experiment and see how many bat collisions (or bites!) one observed by probing at different points in the sphere, one

[24] For patterns that exhibit consciousness, this may be another matter, but that would be another paper: "A New Kind of Dualism," presented at the 2005 meeting of the Northern New England Philosophical Association.

would detect an interesting regularity: the number of collisions (or bites) would decrease in proportion to the square of the distance from the center of the sphere. Now, certainly, there is no law in the bats that takes this form. Likewise, if there were a parallel case in the Life world, there would be no law in the primal reality, programmed into the computer, that was determining this regularity. Yet it is clear that the source of the regularity is the constraints imposed by the form of the sphere, in particular the relation between the radius and surface area of a sphere ($4 \pi r^2$). Newton, of course, recognized the same relationship in deducing the inverse square law of gravitation[25], that mysterious force about which we are to pose no hypotheses. Even if we pose no hypotheses about what the source of gravity in the primal reality might be, we do know that something about it is spherical, or at least has the same formal constraints as the distribution of a uniform density onto the surface of a sphere.

Each pattern in the Life world, or its physical correlate, that exhibits a pattern with the type of coherence and unity that made us posit a substantial form before will have formal characteristics that determine constraints that cannot be directly derived from the mechanical rules of the Game and which derive from the formal constraints of the primal reality that implements the rules. These constraints will not be implemented in the Life world the way that the rules are implemented, mechanically, through the running of the program. These constraints are passed to the physical world non-mechanically through the very structure of the medium and the way in which the program is implemented into it.

The only entities and regularities that will be derived directly from the rules, mechanically, will be the pixels and their adherence to the three rules, the fundamental particles and the laws of nature that govern them in the physical world. All physical objects composed of particles, like all patterns composed of multiple pixels, and all meta-regularities observable in these patterns, will require something like substantial form, since they will not correspond to entities or rules in the primal reality. This seems to imply the remarkable fact that, if mechanism is true, the vast majority of the physical properties and laws that we can observe are not mechanical, including, ironically, the very laws of mechanics for macroscopic objects from which the idea of mechanism was first derived in the scientific revolution. (These macroscopic objects of course are merely emergent patterns arising from the real fundamental particles and the real laws that govern only them.)

So if mechanism, after killing substantial form, necessitates its revival, what form does this revival take? Unfortunately for the Aristotelian adherents of substantial form, it does not appear that substantial form can be an indwelling cause. The principle of the regularities we find in the physical or Life world cannot itself reside in that world. The essence of the mechanical world view that gives rise to this reanimated concept of substantial form is external compulsion; all of the features of the life world are necessitated by the implementation of the program

[25] If in both cases if we assume that the distribution of bats, or whatever is causing/carrying gravity, is uniform, then the same number of bats will be distributed over a surface area that increases in proportion to the square of the distance, making the density on the surface of the sphere decrease in inverse proportion to the square of the distance.

running in the primal reality. The principle of the regularities on the screen cannot itself be on the screen.

This difficulty is similar to an argument I have habitually used, only partially tongue in cheek, to attempt to torment my Aristotelian friends: the doctrine of substantial form as the indwelling or internal principle of change seems to make change impossible:

> (1) The cause of change must have as much actuality as the effect.
> (2) If the substantial form already has the actuality that present in the effect, then, the sufficient reason already being present, the effect would already be present, and there would be no change.
> (3) If the substantial form does not already contain the effect in actuality, then it is insufficient to produce it, and no change will occur.

(Note that it will not do to try to identify the source of the change in external causes, for then they, not that substantial form, become the principle of change, which is then no longer internal. This view becomes a sort of mechanism itself.) Plato, it seems, had good reason for placing the actualizing principle on a different level of reality than that which it actualizes. Mechanism, if it is true, implies the same thing for, perhaps, different reasons.

We have found the killer, then, but it is not to be feared. The proponent of substantial form in the modern world should not oppose mechanism, but should insist upon it. If a thoroughgoing mechanism is true, it implies its own limits and requires the resurrection of its previous victim in a form even a mechanist could love.