

**WHEN FORM OUTLASTS ITS MEDIUM:**  
*A Definition of Life Integrating Platonism and Thermodynamics*

**AVSHALOM C. ELITZUR**  
*Unit for Interdisciplinary Studies,  
 Bar-Ilan University, 52900 Ramat-Gan, Israel*

## **1. Foreword**

“Life,” mused Søren Kierkegaard, “can only be understood backwards; but it must be lived forwards.” We all know life first hand, but formulating this knowledge in scientific terms proves to be an elusive task (Fry, 2000; Korzeniewski, 2001; Lazcano, 1994; Luigi Luisi, 1998; Morowitz, 1992; Palyi et al., 2000; Palyi et al., 2002; Rizzotti, 1996; Schrödinger, 1945).

My own attempt to meet this challenge has taken a long path. I began with writing down all the characteristics of the known living organisms that seemed to be fundamental, shifting viewpoints between biology, physics, and philosophy. Naturally, the resulting list was long, way far from the categorical “Life is ...” statements that most theorists are after. But as time went by and I revised the list time and again, something began crystallizing, perhaps not unlike the way a mathematician’s many-sheets scribbles eventually converge into a single elegant equation. Finally, a new “Life is...” has emerged, proposed here on Section 10.

Because some novel insights have been gained during the various stages of this search, I present in this article the entire way of thinking that has lead to the proposed definition.

## **2. A “Wet Biology” Prologue**

When seeking to abstract life, to refine a single unifying principle that underlies its countless manifestations, perhaps there is no better starting

point than an encounter with a living thing in the flesh – moving, moist, unexpected, even offensive – like the one that I had not long ago. I was crossing a garden late at night when, out of the carpet of dry leaves, pinecones and pebbles that covered the ground, a toad suddenly leaped high and scared me for a moment. It was this sudden movement of the little creature, which had been lying motionless like all the other lifeless things surrounding it, which made me acutely aware of its uniqueness amongst these inanimate objects. Spontaneity, the capability of being the *agent* rather than the *subject* of motion and change, is the first characteristic of life that meets the eye.

Surely, however, the toad was equally alive before leaping, while sitting still. It was also alive during the summer months when it laid dormant underground. Moreover, life dwells, though in different ways, also in the grass and moss, and even in the seeds within the dry pinecones scattered over the garden's soil. The dividing line between animate and inanimate is therefore not always as clear as in the case of a running, screaming and biting animal, but it is surely there. What, then, is that state that makes something “alive”?

### 3. Dry Abstractions: Form Outweighs Intensity

Clearly, it was the *spontaneity* of the toad's leap that has made it so distinctly alive. Newton's law relates the change in a body's state to the force acting on it:  $F=ma$ , or  $a=F/m$ , where  $a$  is the acceleration, namely, the change in the object's motion (or rest),  $F$  the force exerted on it and  $m$  its mass. Acceleration, then, is proportionate to the force divided by the body's mass. Hence, for a pebble to leap as high the toad did, it would have to be given an appropriate kick. The toad, in contrast, leaped by itself, the only external “force” acting on it being a few photons that impinged on its retina. The acceleration in this case has no proportion to the physical magnitude of the external force which has initiated it.

Of course, the conflict is only superficial: The organism, using energy resources within it, exerts additional force on itself in response to the minor force from outside. But here a genuine hallmark of life emerges: It is the *form* of the external action, rather than its *magnitude*, that determines the magnitude of the organism's reaction. The light falling on

the toad's eye from the garden's lamppost, for example, was much stronger, yet it did not elicit the frightened response as the weaker light coming from the approaching human. So, if viewing the organism as one whole – ignoring for a moment its being composed of numerous different parts – we can point out a crucial difference between an inanimate and an animate object. The former reacts to the sheer *magnitude* of forces, while the latter reacts to their *configuration*.

Notice, moreover, that the configuration is largely independent of its medium. In the case of the toad, another form of energy (sound, scent, etc.) may elicit the same response if it carries the same warning.

#### **4. Generalizing: The Living Form Outlasts its Medium**

Much as the above encounter confronts us with life's fleshy side, it also highlights life's abstract aspects. For more than two decades I have listened to toads every autumn croaking from the garden's pond, occasionally even seeing a few. Surely there were individual differences between their bodies and croaks, but I failed to notice them. Numerous toads, which to human perception are indistinguishable from the one I saw, inhabited that garden for many years, begetting one another, till the one that I encountered. It is the *form* which has prevailed, while individual animals came and perished.

This ability of form to outlast its substance appears even ontogenetically, during the life of the individual organism. The toad which I saw has probably exchanged all its molecules within the last few years, but it has retained its form. To be sure, it has been an embryo and then a tadpole, and later grew up till reaching its adult size, but even during those intermediate stages the toad's form outlasted (at least partially) the matter of which it was made.

Note that "form" equally refers to the toad's croaks and leaps. It therefore denotes not only spatial structures but temporal patterns as well.

These observations cannot fail to remind us of Plato's philosophy, where the concept of form, and that of ideas in general, featured so prominently. For Plato, pure form had greater reality than the concrete objects molded in that form. Similarly, ideas existed prior to their material

realization. Abstract forms and ideas, not material objects, are the foundation of reality, which is why an abstract discipline such as mathematics is so powerful for mastering the physical world.

Aristotle took exception with this view, reasonably arguing that forms cannot exist without some matter of which they ought to be made. Yet Aristotle was an avid biologist, and it is very likely that his lasting preoccupation with taxonomy and with the notion of a species reflected his attempts to struggle with his mentor's challenge. This is even more evident in his speculations about the formation of the embryo, where the interaction of "form" and "matter" (roughly equated to "male" and "female," respectively) somewhat echoes Plato's thinking.

We need not go deeply into this ancient debate when seeking for a definition of life. Yet it is very striking that Plato's argument has a close affinity to two of life's most prominent hallmarks, namely, reproduction and metabolism. In both cases the same wonder occurs: *Matter assembles and disassembles with the inflow and outflow of matter into the living body, and with the births and deaths of countless individual bodies, but the form prevails.*

## **5. The Thermodynamic Aspect: The Living Form Feeds on Information**

Plato's ideas referred to a world which is, by definition, ideal. As our world is far from that, we must complement Platonism with the branch of physics that studies just what makes our world so far from ideal. Thermodynamics studies, *inter alia*, the increase of entropy, which degrades all forms into chaos. Oddly, however, it is the thermodynamic laws that enable life not only to preserve forms against degradation but even to refine and improve them. Thermodynamics shows how, alongside with matter and energy, the living organism processes a third vital currency, namely, information (Elitzur, 1994, 1995; Lahav et al., 2001). A brief introduction to information's role in life would therefore be in order.

For a diver's watch to be waterproof, its designer must use a great deal of information about the conditions undersea. What, then, about a fish? The question makes us realize that "adaptation" means that a great deal of information has been incorporated in the adapting species' genome.

Information processing, therefore, underlies evolution, an insight that we owe to the famous “Maxwell’s demon” paradox (Leff and Rex, 1990). Consider a closed box, full with gas in equilibrium and divided by a partition into two halves. A tiny demon within the box directs the gas molecules’ motions by opening and closing a microscopic door in the partition. Eventually, hot gas forms on one half of the box and cold gas on the other. Entropy has been reduced. But such a reduction normally requires a proportionate energy investment that would increase entropy elsewhere, in compliance with the Second Law. For the demon, however, the energy required for sorting molecules is negligible. A violation of the Second Law seems to ensue.

The paradox was resolved once it was pointed out that the demon needs *information* in order to perform its task. The acquisition of this information (or, more precisely, the repeated erasure of old bits for receiving new ones [Leff and Rex, 1990]) has its cost in energy, which increases entropy more than the entropy reduced by the demon’s sorting. From this principle, which assigns an energetic price to information, a complementary principle follows: The use of information can *save* energy. For example, when we open a lock with a key we utilize the information embedded in the key, which makes the enormous force needed for breaking the lock unnecessary (someone else, of course, has already paid the energy cost of engraving the information on the key).

Biological adaptation, I suggest, abounds with such uses of information for saving energy. A tiger, for example, exerts enormous mechanical force to kill its prey. But in the same jungle dwells a cobra that can kill the same prey by merely spitting into its eye. What is striking in the latter case is the apparent disproportion between the negligible force exerted by the predator and the fatal result suffered by the prey. The secret lies in the snake’s choice of the appropriate neurotoxin (in this case, cobrotoxin) that precisely matches the acetylcholine receptors at the ends of the prey’s muscles. Similar precision is manifested by the choice of the vulnerable point in the prey’s body (once the venom has penetrated the prey’s eye, its own vascular system carries it from there over the entire body!). In other words, the cobra makes spectacular use of information about its prey’s physiology and neurochemistry, thereby saving the energy that the tiger would have to invest for the same purpose of bringing the prey down. Notice that the tiger is taken here merely as an arbitrary baseline for assessing the cobra’s efficiency; the tiger’s is also a successful organism

and its onslaught is also aided by a great deal of information. Still, the force exerted by snake's venom, in comparison, is literally infinitesimal – of molecular scale. It suffices because it is exerted, thanks to the utilization of information, with enormous precision. Of course, the acquisition of this information was paid dearly by the snake's ancestors during the species' evolution, enabling their fortunate descendant to save energy nowadays.

We can therefore formulate the utility of information thus: *With the aid of information, it is possible to perform a given work with much less energy than in the absence of information, as this little energy is invested at the right place and/or at the right time.* Living organisms, then, are lawful Maxwell demons: They save energy by using information, the energetic price of which being already paid by earlier generations during the harsh struggle for survival.

## **6. Maxwell's Demon in Action: Life Operates at the Micro-Level for Macro-Effects**

With the above principles in mind, the toad's sudden spontaneous leap, which appeared to be such a unique characteristic of life, can be illuminated in a new light. If the living organism is a lawful Maxwell demon, then, with the aid of the information, it can act at the microscopic level, producing numerous microscopic effects which then converge into one large macroscopic effect. It is on this small-scale level, unknown to our ancestors, in which one of the most important features of life lies. Medieval thinkers argued that an organism is alive because a non-material soul dwells in it. Their rationale was that there is no material difference between a living toad and one that had just died. It seems to be the same object in both states, hence the only difference could be the soul that has perished or left the body.

The modern answer to this challenge of dualism is based on what we have learned about life's microscopic level since then. What seems to be a homogenous tissue of a leaf, a bone, etc., is in reality a myriad of enormously complex cells, resembling one another in numerous molecular details, eventually succumbing to death but promptly being replaced by new, almost identical ones. Death of the organism occurs when *minute*

changes, too small and too many to be reversed or even noticed, occur together in *numerous* cells. It is this microscopic process, occurring immediately after death, which, unknown to our ancestors, gave them the impression that a non-material agent was moving life. Living forms, then, are maintained due to the great precision orchestration of their myriad microscopic mechanisms (Dolev and Elitzur, 1998).

The uniqueness of the biological motion is now illuminated in a new light. Compare the toad's leap from the ground with the opposite occurrence of a pebble falling on the ground. In the latter case, a highly ordered motion of the macroscopic object degrades into a myriad of disordered motions (i.e., heat) of the ground atoms, in compliance with the Second Law of Thermodynamics. In the toad's leap, however, something extraordinary occurs: *Numerous microscopic interactions between actin and myosin molecules within the toad's muscles converge into one macroscopic movement!*

Another hallmark of life thus emerges. The macroscopic manifestations of life are always a mere tip of a microscopic iceberg. This holds even for micro-organisms, as their collective actions lead to macroscopic phenomena, such as a lake turning green due to algae or a human succumbing to influenza. *Life gives rise to an extremely precise cooperation between numerous microscopic motions, separated in space and/or time, orchestrated so as to converge into the same large-scale outcome.*

## **7. Platonism Again: Forms Transcend Space and Time**

The living organism, then, is not a "thing" in the ordinary sense. Whereas a rock is a rock and an iceberg is an iceberg only as long as their matter does not disintegrate, a toad remains a toad even though its matter *keeps* disintegrating; it is its form that prevails. And whereas the rock's or iceberg's interactions with other objects are determined mainly by their gross physical characteristics, such as mass and velocity, the toad's interactions are more determined by the minute atomic details of its DNA, the poison molecules in its paratoid glands, or the neurotransmitter secretions in its synapses. The living form thus assumes a causal role in itself, just like mass, momentum and charge. In fact, life enables the

organism's form to largely override its more fundamental physical parameters.

This realization should pervade our use of biological notions. "Self preservation," for example, means that the organism preserves its form and not its matter. Similarly "survival of the fittest" favors not the fittest individuals but the fittest makeups. And a "selfish gene" in the form of a particular DNA segment often leads to its own destruction in favor of copies of it elsewhere. In short, *metabolism and reproduction, life's two most prominent features, are two aspects of form's supremacy over its medium.*

Once a form is considered to be a thing, just like a concrete chunk of matter, an important distinction emerges between the two kinds of things. A material object can reside only in one place at a time. Not so with a form: If there are many objects with exactly the same form, then there is one form that exists in many places at the same time!

This formulation might sound like a mere play of words, but in the next section I will show that it is this illocality of form that enables life to increasingly transcend space and time limitations. Notice, first, that illocality is already implicit in our biological parlance. When we say that "the gene BRCA1 is responsible for breast cancer" or "the fox is common in the British Isles," we do not refer a certain DNA segment within some individual cell, nor to a particular animal, but to one form whose copies abound in numerous places and times. True, the biological form is a far cry from Plato's ideal forms that reside out of space and time, and yet it is able to gradually transcend space and time limitations.

## **8. Platonism and Thermodynamics Merging: Evolution Involves an Increase of Informational Invariance**

The Platonic and the thermodynamic aspects of life now begin to converge. Since the organism is not an ordinary chunk of matter but a form that survives its matter, and since form can reside in numerous places at the same time, this illocality of form enables the information accumulated within the organism's genome to become increasingly more *valuable*.



But how can one quantify the information value of a certain DNA sequence? This is a highly disputed issue, which we can avoid by addressing one special aspect of information, namely, the scope of its relevance. The Cobra's venom is so powerful because it matches the nervous systems of *all* vertebrates. Consider next plants' geotropism, namely, the mechanism that enables the organism to sense the direction of the gravitational force. Many plants develop individual forms in adaptation to the local conditions, e.g., the ground's slope or sunlight's direction. Yet a few trees, such as the fir and the cypress, have a uniform shape which is largely independent of the local conditions. Interestingly, these uniform trees always grow straight upwards, as they rely mainly on gravity, which is the same everywhere. In fact, the evolution of geotropism means that "knowledge" of gravity was long ago obtained by the plant's genome, for, had Newton's  $G$  been other than  $6.67 \times 10^{-11} \text{ N m}^2/\text{kg}^2$ , the statoliths within the plant's cell would fail to properly sediment in the ambient fluid. Here again, the organism gains information about a feature of the environment that prevails in *all* locations, on Earth, in *all* times.

In some cases the information accumulated in an organism's genome is so subtle, hence so abstract, that it can surprise even the human mathematician. Take, for example, the 13-years cicada and its relative, the 17-years cicada. The nymphs of these species develop below ground and after 13 or 17 years they emerge and molt to the adult stage. Their massive brood emergence is believed to overwhelm predators, which are mostly birds.

Is this just another example of sibling species? No, for there are *three different cicada species, each having a 13- and a 17-years subspecies* (Grant, 2005; Williams and Simon, 1995). Clearly, these species could not have simply evolved from one another, because each species could have evolved from either the 13- or the 17-years subspecies of the other species, leaving the emergence of the complementary 17- or 13-years subspecies unexplained. It is evolution, then, that has come up, three times, with the same pair of primary numbers in its search for numbers that do not divide into smaller numbers, mainly in order to prevent convergence of prey's and predator's life-cycles (Dawkins, 1987; Gould, 1977).

These examples demonstrate an essential feature of biological information: This information concerns *invariant* features of the

environment (Elitzur, 1997). The information encoded in the cobra's venom does not concern only an individual animal, nor a particular species, but something common to *all* vertebrates. The information encoded in the plant's geotropic mechanism is valuable *everywhere*. The information used by the cicada concerns the life cycles of *all* its predators. The latter case exhibits an even more invariant kind of information: Numbers are the subtlest aspect of physical reality! In fact, evolution gives a very profound clue as to how such a level of abstraction has been reached: The cicada has obtained information not merely about its environment but about the information obtained by other information-processing systems – higher-order information, so to speak. First, the cicada's predators have “learned to count the years” so as to establish their specific life cycles, in order for all males and females of the same species to reach sexual maturity at the same time. Then, after these numbers were taken, the cicadas had to “find” the numbers that do not divide with any of these cycles. This sequence is not much different from the way human arithmetic developed over the centuries: The ancient discovery of numbers has later enabled the recognition of special numbers such as primary numbers, whose properties were derived from those of the ordinary numbers. Plato would probably be pleased to learn that numbers have played a role in the lives of insects long before the appearance of human arithmetic!

Evolution, to reiterate, is a process by which information about the environment is accumulated in the species' genomes, and this information's relevance becomes increasingly broader. We are now in a position to prove a more specific hypothesis: *Evolution is a very efficient mechanism for extracting environmental information out of the environmental noise*. A simple analogy would serve as a useful introduction. Consider the light coming from a distant star. Its information content is poor. The reason for this is not, as one might think, the light's weakness; light can easily be amplified. Rather, it is the fluctuations (atmospheric and optic), that pollute the information carried by the star's dim light. In other words, the information coming from the star is inflicted with random noise. For the small human pupil, this signal-to-noise ratio is too great to resolve. The Newtonian telescope overcomes this difficulty with the aid of a large concave mirror, up to a few meters, that collects the light signals over a large area and concentrates them on the telescope's lens. Here an efficient resolution of signal from noise takes place: The

constant signals (coming from the star) are additive, while the random fluctuations (caused by other factors) are much less so. Let  $s$  and  $\Delta s$  denote signal and noise, respectively. Then, joining the radiation coming from  $n$  points,

$$\frac{S}{\Delta S} \rightarrow \frac{nS}{\sqrt{n}\Delta S} = \frac{\sqrt{n}S}{\Delta S}.$$

Noise thus “cancels out” in comparison to the strengthening of the signal. The same principle is utilized by all antennae.

The biological analogy is clear. Consider a single, only slightly advantageous mutation. At the individual level, this mutation can hardly affect survival; an organism possessing it might happen to fall victim to an accidental calamity while an organism lacking it might survive by sheer luck. If, however, the mutation has managed to be replicated in large numbers within a certain population, the above dynamics takes over. With  $n$  being large (many organisms over many generations), even the slightest advantage will eventually gain dominance over the population. In information theory terms, the weak environmental feature that gives a slight advantage to the mutation is amplified by evolution. Elsewhere (Elitzur, 1994) I have pointed out several other such “proto-cognitive” capabilities of evolution.

Let us summarize: *Alongside with matter and energy, organisms constantly process information.* It is common knowledge that the genome contains information as to how the organism should be assembled. But as Maynard-Smith (1999) has pointed out, this information is useful only by virtue of its reference to the particular *environment* in which this organism must live. The central concept of evolutionary theory, namely, adaptation, thus gains a novel meaning. Adapting to a certain environment necessitates, first and foremost, reliable quantitative information about it.

## 9. Inventorying the Hallmarks of a Living Organism

Based on the above discussions, we are ready to prepare a tentative inventory of the physical attributes of the living organism, leaving the definition of life itself for the next stage. Which of life’s hallmarks should come first? Rather than trying to assign them any order of importance, let

us adopt a more pragmatic order: First let those properties that immediately meet the eye be pointed out. Next shall come the properties that appear over longer observation periods and those that are revealed when going down to the smaller scale level. Still, as the recurrent cross-references below indicate, life itself defies any attempt to describe it in a linear order.

**A Living Organism**, then, is a system in which **Life** is embodied by exhibiting the following properties:

1. **SELFHOOD**: The organism's ingredients – matter and energy – form a distinct entity, as
  - 1.1. **INTEGRITY**: the organism's parts, which, in the absence of life, would have been dissociated, remain connected.
  - 1.2. **ANIMATION**: Yet the organism is not static: Its parts, which, in the absence of life, could have been still, are often in change and motion.
  - 1.3. **ORGANIZATION**: Both the organism's structure (1.1) and dynamics (1.2) maintain strict coordination in space and time. Nonrandom patterns such as regularity, uniformity, rhythm and symmetry make the organism's constituents causally related to one another more than to external objects.
2. **AGENCY**: Although the organism is subject to external forces, it is also the agent of spontaneous actions, initiated and brought about by its own energy resources, released in response to inner events.
3. **COGNIZANCE**: The organism's reaction to external force does not follow the straightforward  $F=ma$  relation, as its own resources of potential energy release additional force during the reaction. Its reaction, therefore, depends not only on the external force's *magnitude* but on its *configuration* as well.
4. **PURPOSE**: The organism's spontaneous actions (2) and its reactions to external events (2), while causally following past events, turn out to be directed by future goals as well: Out of several, equally-possible actions, the organism takes only that one which is likely to bring about a particular outcome in the future
5. **SELF-ACTION**: on the organism itself. In the long run, *all* the organism's actions eventually affect itself,

6. PERPETUATION: preserving its selfhood (1) through
7. METABOLISM: incessant replacement of parts of the organism that leave it, such that even when the organism's form changes, it maintains its integrity (1.1), animation (1.2) and organization (1.3); as well as
8. REPLICATION: replacement of the entire organism: Even by the time the entire organism ceased to be alive, (an)other organism(s), carrying part or all of its essential characteristics, may have been produced by it.
9. NOVELTY: New elements always appear in the organism's dynamics, due mainly to entropy but
10. PROGRESS: systematically selected such that the organism's properties become more and more prominent.
11. INFORMATION PROCESSING: Together with matter and energy, the living organism incorporates, stores, exchanges and processes information. This information is accumulated during phylogeny (evolution) and/or ontogeny (learning) and takes part in all biological processes. It is information exchanged between the organism's inner constituents that enables the organism to maintain itself (1); it is information about surrounding events that enables the organism to discern (2) events that bear on its survival, to anticipate (4) them and to adequately respond (2) to them; it is the information constituting the organism's blueprint that enables it to replicate (8); and it is information about a particular environment that underlies adaptation to that environment. Biological information increases the efficiency of any work carried out by the organism, by the principle "less and less energy, but more and more precisely at the right place and/or the right time." Biological information eventually attains higher value as
  - 11.1. REFLEXIVITY: the living organism processes information not only about its environment but also about other information-processing systems like itself, thereby gaining higher-order information; and as
  - 11.2. ABSTRACTION: the processing of environmental information reveals ever more subtle regularities in the environment, i.e., patterns that are ever more invariant in space and time, like natural law itself.

## 10. The Definition

Can an inventory of characteristics – assuming that they are indeed essential – converge into a concise definition? The main insight inspired by the encounter with the toad, and later reflected in the inventory, is that life manifests a striking degree of supremacy of form over its medium. Each organism's form is embedded, of course, in matter, but it *outlasts* the individual chunk of matter in which it is embodied. Both metabolism and replication are manifestations of this principle.

Based on this aspect of life, here is the first attempt at definition:

**“Life is** a process by which a form outlasts the medium in which it is embedded.”

Immediate objections are expected. The living form does not remain unchanged, as organisms grow and species evolve. But then, growth and evolution make the organism even more capable of outlasting its medium, and of overriding the physical constraints to which an inanimate object of the same mass and chemical composition would be subject. A better proposal would therefore be

**“Life is** a process by which forms become increasingly independent of the medium in which they are embedded.”

By referring to “forms” in plural our definition encompasses also the organism's change of form. It is, Platonically speaking, not just “a form” but “form” in general – the *idea* of form – that outlasts its medium, thanks to life. The adverb “increasingly” means that evolution makes forms *more and more* liberated from the physical constraints of their medium.

Still, the definition is not exclusive enough. A tornado is a very unique form, made of air and debris which are constantly replaced by new air and debris, such that only the tornado's form remains and its power even increases. Yet a tornado is certainly not alive. But we now recall that the supremacy of form over the medium holds not only for the organism's body but also for what this body reacts to, namely, environmental information (see sections 5-8). Information, by definition, is characterized by its *configuration* rather than by the type of matter or energy in which it is stored or carried. As we have observed, the organism reacts to the *information itself* rather than to its medium. This property is much more

typical of living organisms, and together with the above characterization gives a sharper definition:

**“Life is a process by which forms become increasingly independent of the medium in which they are embedded, by interacting not only with their environment’s matter and energy but also by interacting with the forms, *as* forms, which are embedded in the environment.”**

Information, then, is a special kind of form, which abounds in the organism’s environment, and the living organism discerns and utilizes these subtle forms in order to enable its own form to outlast its medium.

Information, however, rarely appears in Nature in its ideal form. This is why, alongside with Plato’s lofty ideas, we summoned also the mundane science of thermodynamics which obliges form and information to constantly erode. In section 8 we pointed out the way an evolving population overcomes this informational erosion and extracts environmental signals from the environmental noise: Reproduction utilizes the statistical advantages of large numbers in order to increase the signal-to-noise ratio. We can therefore give our Platonic definition a last, information-theoretical twist:

**“Life is a process by which forms become increasingly liberated of the constraints of their material medium, thereby appearing in a multitude of places and times, thereby interacting not only with the local, random aspects of the environment, but, increasingly, with the invariant spatio-temporal regularities underlying Nature, namely, physical laws themselves.”**

Would this definition prove satisfactory next time one encounters a living organism and wonders what makes it alive? The answer must be left to you, the reader. The next animal or plant that you will see has a unique form, assembled of numerous sub-forms, patterns, rhythms and regularities in space and time. These forms last despite the fact that the matter and energy of which they are made are constantly lost, only to be replaced by other matter and energy, over and over again, yet the form outlasts them all. And this form, which constantly interacts with other things, interacts not only with the matter and energy of which these other things are made, but mainly with their forms. Form gradually became liberated from the physical constraints of its medium, though never fully independent of it as in Plato’s world of ideas. So when human thoughts

long survive their originators, in language, in letters and on the Internet, this is the most natural consequence of what life is all about.

### **11. Requiem to the Toad: Life's Essence and Value**

The living thing which I encountered was a rather unassuming species, grey-brownish, moist and coarse. But some other members of the order *Anura*, to which toads and frogs belong, are among the most beautiful creatures on Earth. Their striking colors signal that they are highly poisonous, which means that highly valuable medical information about us, their most menacing enemies, is concealed in their skins. Unfortunately, most of this knowledge is being rapidly lost to humanity. *Anura* and all amphibians are going extinct all over the world (Houlahan et al., 2000). The devastation caused by humans to the biosphere are changes to which these little creatures turn out to be most vulnerable. Ecologists keep warning us that these species are only early indicators of a global catastrophe that threatens all life on Earth, us as well.

Much as the definition of life's *essence* is elusive, the search for its essential physical characteristics seems to enforce on our mind also life's *value*. Life is unique, amazing, precious – and sacred.

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