

HUMANITIES AND MEDICINE

What Is Life? Prerequisites for a Definition

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Biologists view life as transient while theologians see it as eternal. An unbiased definition for life would respect both views until one or both were eliminated by evidence. This paper identifies prerequisites for such a definition. First among these is that all assumptions be made explicit. Currently "life" is surrounded by implicit assumptions, e.g., that it is what organisms lose at death or that it is eternal, that its quality is inversely related to personal distress, that it originated some four billion years ago, and that animate matter can be distinguished from inanimate matter. None of these assumptions are supported by data. It is possible therefore that "life" is as meaningless as phlogiston. If life has meaning, i.e., if it is true, it must be as permanent as buoyancy, gravity, electricity, and the other truths of nature. Any definition for life that would permit such truth to be seen must be free of unwarranted assumptions. For the moment, at least, such a definition would need to be loosely structured and broadly focused. It would need to describe the long and convoluted process by which matter and energy form organisms which then evolve to form conscious organisms which then explore nature and eventually discover truth. Such a definition would include all the reactions and interactions of matter and energy and all the aspects of conscious discovery. It would suffer from superficiality, but, by being free from bias, provide a foundation for dialogue between biologists and theologians.

INTRODUCTION AND METHOD

Life is common to the vocabulary of two divergent disciplines: biology with its focus on events before death, and theology with its focus on events after death. In biology, life is assumed to be transient, i.e., the antonym of death. In theology, life is assumed to be eternal. Which assumption is valid? What, precisely, is life? Schrodinger called attention to the need for definition, but never measured life, or even specified its units of measure [1]. Does life come in liters or grams or calories? Is the total amount of life fixed or variable, and, if variable, how does it vary over time and space, and from

one organism to another, and across the different species? What amount of life presently exists on Earth? Is there a relationship between this amount and the state of the ecosystem, or the health of organisms, or the number or rate of births or deaths? These are the kinds of questions that students of life should expect to pursue in life science. But there are no answers and no reasonable approaches to finding any. The definition of life remains a problem with semantic as well as biological and theological implications [2-3].

From the biological perspective, life is nothing but biochemistry [1, 4-7], i.e., the "orderly and lawful behavior of matter"

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^bAbbreviations: ATP, Adenosine Triphosphate

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[1]. The evidence in support of this behavioral perspective is the apparent absence of any need to look beyond the ordinary laws of nature:

“No vital force, no soul...has come to light or seems to be required to explain biological phenomena” [8].

Without question, this behavioral perspective has been successful in explaining biological phenomena. The problem is that biological phenomena are transient, while life, according to theologians, is eternal. It is possible that the theologians are wrong, or that the current perception of biological phenomena is overly restrictive. Clearly, however, there is no proof that life is only biochemistry, or that it does or does not exist beyond death. The need is for a definition of life that is free from bias. It is the purpose of this paper to identify prerequisites for such a definition by scrutinizing the assumptions surrounding life. Of necessity, this effort will be loosely structured and broadly focused. It will encompass a wide spectrum of ideas and suffer from superficiality. But, if successful, it will lay a foundation for reasonable dialogue between biologists and theologians and dispel the illusion of opposition or incompatibility between the two disciplines.

RESULTS AND DISCUSSION

1. The meaning of life

What is life? “It is really impossible to define life” [9]. “When reduced to honesty, few will profess to know what life is, and some will argue that the word is meaningless” [10]. It is possible that life is meaningless, like the ether, phlogiston, and bodily humors. But life has a venerable history and is not easily dismissed. It is difficult however to know where to begin in the search for an unbiased definition.

Whatever we say of life is subjective and implies an assumption. We can specify neither life’s properties nor its boundaries. The prerequisites for an unbiased defini-

tion require that all assumptions be explicit. Unfortunately, the assumption that life is synonymous with animate behavior has become so commonplace among scientists that it is taken as fact. Consider, for example, the newly deciphered “Book of Life” [11]. It is in fact the blueprint for human protein synthesis. Is such information synonymous with life? Possibly, but the case awaits a definition. Until then, equating genetic information with life begs the question. This fallacy is common as is evident in work on various aspects of animate behavior entitled the origin [12], history [13], future [14], shape [15], diversity [16], synthesis [17-18], complexity [19], path [20], distribution [21], signs [22], color [23], logic [5], or quality [24] of life. And it is most evident in the common definition of biology, the scientific study of organisms, as the “study of life” or “life science” [3]. The fallacy is incorporated into textbooks, e.g., “Life is notoriously hard to define but we know it has certain properties” [25]. In fact we can’t know life’s properties or even if life has properties. Logic prevents us from knowing properties before we agree upon the definition.

After reviewing definitions for life, Korzeniewski concludes that none “probe into the very core of the essence of life” [6]. He attempts to rectify this failing but immediately assumes that life is identical to a living individual. Other assumptions are equally plausible. For instance we might assume that life is the collection of all living individuals over all time. The focus then would be on evolution, and, despite the current controversy between biologists and creationists, evolution began with a theological foundation [26].

At first glance, evolution can seem progressive [26], for organisms have changed over time to become gradually more intelligent. It is possible to imagine humans using intelligence to control evolution, e.g., colonizing space, adapting the genome to the new environments, and, in this way, inventing new species. And it is possible

that evolution will occur in just such a manner. But it is also possible that humans or their progeny will follow the dinosaurs into extinction. Nothing precludes evolution from being cyclic with organisms changing from simple to intelligent only to change back to simple and then again to intelligent repeatedly, and, possibly, forever. Cyclic phenomena are common in nature, e.g., planets around the sun, moons around the planets, electrons around the nucleus, the precipitation and evaporation of water, the circulation of blood and lymph, protein turnover, glycolysis, respiration, reproduction, and electromagnetic radiation. If we want an unbiased definition for life, we cannot assume that evolution is or is not cyclic.

If evolution is cyclic, we might say intelligent organisms are more advanced than simple organisms in the manner that 9:00 a.m. is more advanced than 8:00 a.m. But that wouldn't imply that a change in organisms from simple to intelligent or vice versa is improved anymore than would a change in time. Evolution could be as much a clock as is the rotation of the Earth.

Uncertainty is intrinsic to biological explanations [27]. Chemical and physical explanations employ objective definitions, explicit assumptions, and quantitative boundaries on time and space. And they yield predictions, within calculable limits of uncertainty, of how the system in question will change over time. Biological explanations fail in these regards. Because we lack evidence of evolution ever having run its course, the uncertainty in predictions on how organisms will change is boundless. We can't know if evolution will go to completion, or what completion might mean, or how close to completion evolution is now. We can't say whether evolution is reversible or irreversible, cyclic or non-cyclic.

Organisms prevail according to their ability to reproduce, and it is common for scientists to explain evolution in terms of reproductive advantage. But what, precisely, does that mean? If reproductive advantage were synonymous with kinetic advantage

on the approach to equilibrium or some other goal, then we would understand something of evolution. But we don't know what, if anything, evolution is approaching, and for that reason, "reproductive advantage" is deceptive. It has the feel of an explanation, but doesn't convey information. It simply states the obvious. Some organisms prevail and some don't. To say that those that prevail have the advantage is to say nothing more than that they prevail [28]. And organisms that prevail today, may vanish tomorrow, or next year, or next millennium. Speculating on evolution is like articulating laws of kinetics after watching only part of one reaction. If life is related to evolution, we have little evidence of what it is. Guessing that it is mystical or illusory is no less reasonable than guessing that it isn't.

It is common for scientists to define living systems in terms of reproduction [6], or, more precisely, "the capacity to be at least a partner in reproduction" [7]. But many conspicuously living systems, e.g., children, postmenopausal women, impotent men, sterile organisms, etc., have no natural capacity for participating in reproduction. And senescence or mitotic inhibitors can render organisms incapable of participating even in artificial forms of reproduction, and yet such organisms are unanimously recognized as alive. What is it about reproductively incompetent organisms that we recognize as alive? I suggest it is the same property that we recognize in fertile organisms, not reproductive capacity, but autonomous homeostasis [29]. All animate matter, and no inanimate matter, preserves some aspect of its internal environment constant and in disequilibrium with its external environment, and it does this autonomously. Certain inanimate systems, e.g., refrigerators, incubators, and climate-controlled buildings, do exhibit homeostasis, but these inanimate homeostatic systems are not autonomous. They require activation by human operators, and, for this reason, are recognized as inanimate.

It is common to think of life as what organisms lose at death, or, in other words, what distinguishes animate from inanimate matter. From old observations, we know that organisms lose no weight upon dying and, therefore, life, by this definition, is immaterial [30]. Behavior is weightless and homeostasis is a form of behavior [29]. It is tempting to define homeostasis as life. But that would be a biased definition, for it would imply assumptions on the difference between internal and external environments and the cause of that difference.

Imagine that a cell is animate because it autonomously maintains disequilibria across its membrane, e.g., the potassium concentration is higher and the sodium concentration lower intracellularly than extracellularly. In a similar manner our bodies preserve temperature at 37°C whether we reside at the equator or the poles. All living things maintain at least one disequilibrium between their internal and external environments. Viruses preserve the structure of their genomes.

If life is what distinguishes animate from inanimate matter, or, in other words, what organisms lose at death, autonomous homeostasis can seem an acceptable definition. There are two problems, however. First, except for the boundary across which disequilibrium is preserved, animate and inanimate matter are identical.

“Taking living cells apart reveals that they are composed of the same elements as inanimate matter, held together by the same chemical bonds, interacting by the same laws of physics” [8].

Homeostasis, therefore, has meaning only in reference to a boundary. Failure to detect a boundary would cause us to identify animate matter as inanimate. Imagine observing a blood cell from within its membrane. We would see water, salt, sugar, protein, nucleic acid, lipid, etc., i.e., only inanimate matter. We wouldn’t know whether we were observing *in vitro* or *in vivo* biochemistry. Only a comparison of the two sides of the membrane would permit us to see one side

being maintained in disequilibrium with the other. But that would require an extracellular as well as an intracellular perspective. From within the membrane, we would have no knowledge of any boundary or disequilibria, no inkling that cytoplasm was in disequilibrium with plasma let alone that plasma was in disequilibrium with its environment. The lesson is clear: before calling some collection of matter inanimate, we need to verify the absence of a boundary across which some member of that collection is preserved in disequilibrium. But that is impossible.

Second, when we do observe disequilibrium across a boundary, we have to decide which side of the boundary is alive. The immediate answer is the autonomous side, the side that is the cause of the disequilibrium. But which side is that? Is the cytoplasm alive because it generates the adenosine triphosphate (ATP)^b to move the ions, or is the plasma alive because it provides the glucose to make the ATP? It can be difficult, if not impossible, to distinguish cause from effect [31-33]. Perhaps the cytoplasm and plasma together form an autonomous homeostatic unit. Then the problem shifts to a higher level of complexity. Is the multicelled organism alive because it generates the ATP to maintain various disequilibria, or is its environment alive because it provides the nutrients to make the ATP? Perhaps the organism and its environment together form a homeostatic unit. Then the problem shifts to a still higher level of complexity. Is the Earth alive [34-35] because it maintains an atmosphere in disequilibrium with its surroundings, or is outer space alive because it provides the matter and energy to sustain Earth [36]? Perhaps the universe is alive, surrounded by a boundary of space-time. We can never be certain that all boundaries have been detected or that the cause of disequilibrium across them has been properly assigned.

Social insects create communities that act as superorganisms. Bees, for instance, preserve hive temperature constant and in disequilibrium with the external environ-

ment [37]. Termites preserve mound temperature and atmosphere constant [37]. But the boundaries of these superorganisms are not defined by the hives and mounds, for workers wander far and wide gathering needed matter and energy. The boundaries of these superorganisms, therefore, extend to the diffuse limits of these wanderings.

“It is useful to think of an insect colony as a diffuse organism” [38, p. 399]. But a diffuse boundary is made of time and space, and easily missed.

It is common to recognize time-space boundaries within which the distribution of species is preserved constant and in disequilibrium with the external environment [39]. Rain forests and coral reefs are spectacular examples, but all biomes are bounded by time and space [16]. We might wonder which side of these boundaries is autonomous, i.e., the cause of the disequilibrium. Is it the presence of food and habitat on one side or the absence of such on the other, the absence of predators on one side or the presence of such on the other that is the cause of the species disequilibrium? Perhaps both sides of the boundary cooperate to make the biome and its surroundings a homeostatic unit. But then we have simply expanded the boundary to include the surroundings. Wherever we chose to draw the boundary between a homeostatic unit and its surroundings, we are left with the same question: Which side of the boundary is alive, i.e., autonomous. Which side of the boundary is the cause of the disequilibrium?

Because of the inherent uncertainty in our ability to detect boundaries or to assign cause to disequilibrium across them, we can never be certain that we have identified inanimate matter. All we can say with confidence regarding inanimate matter is that we don't see autonomous homeostasis. We can never be certain that there isn't any, particularly as most constituents of animate matter are not homeostatic even across the boundaries that we do recognize, e.g., membrane, skin, scale, bark, etc. In plants and cold-blooded animals, for instance,

internal temperature approaches equilibrium with the surroundings. Yet these organisms are no less animate than warm-blooded organisms. In red blood cells, sodium is homeostatic while glucose is not. Yet it is the cell, the entire collection of matter within the membrane, that is recognized as animate, not the sodium. And there is no critical number of disequilibria that must be maintained to qualify a package as animate. Even one autonomous disequilibrium marks the entire package of matter as animate.

“The entire range of living matter on Earth, from whales to viruses, and from oak to algae, could be regarded as constituting a single living entity” [34].

“I have been trying to think of the Earth as a kind of organism, but it is no go ... If not like an organism, what is it like, what is it most like? Then, satisfactorily for that moment, it came to me: It is most like a single cell” [35].

If Thomas and Lovelock are correct, inanimate matter doesn't exist on Earth. We should wonder if it exists anywhere. The dichotomy between animate and inanimate matter may be false, a failure either to recognize disequilibria, or to assign cause properly. We can imagine disequilibria being maintained across space-time boundaries, and we can imagine that such boundaries encompass the universe [40-41]. For these reasons, we cannot presume that any matter is inanimate, and, since we cannot define animate matter except in contrast to inanimate matter, we are in danger of circular reasoning: animate matter is what manifests life and life is what is manifested by animate matter. It is possible that the present circumstances are too complicated to dissect. In that case, we might find relief by extrapolating to a simpler past.

II. The origin of life

Fossil evidence suggests that organisms first appeared on Earth some 3.8 billion years ago [42]. Scientists refer to this event as the “origin of life” [12, 43-44]. But that begs the question on at least three

counts: first, evolution might be cyclic, in which case what happened 3.8 billion years ago would be no more the origin than what happened 10 billion years ago or yesterday. Second, life might be independent of organisms, e.g., a principle or force, in which case organisms and life could have different origins, as do eyes and light. Third, all matter might be animate, in which case, what happened 3.8 billion years ago, would qualify only as the earliest example of a boundary across which we can imagine disequilibrium being preserved. Until we define life or animate matter without bias, it would be unscientific to close our minds to any possibility. Unfortunately the scientific discussions presume that life is a product of matter, e.g., “Deep in the seas, chemical processes were producing life” [45, p. 74]. In fact it is impossible to know if life is the product or the cause of animate behavior, or if life exists independently of animate matter, or even if animate matter differs from inanimate matter.

But notice how the bias originates and evolves: “There are two ways to define life. The first is to say that something is alive if it has certain properties... An alternative is to define as living any population of entities possessing those properties that are needed if the population is to evolve by natural selection” [46, p. 5]. Studies are then conducted on “something” that is alive and “populations of entities” that are living. We might even imagine how the “something” or the “populations” originated. But the adjectives “alive” and “living” are neither synonymous with, nor able to modify the noun “life.” Studies on these adjectives or the nouns they can modify say nothing about life.

In quest of semantic precision, I suggest we refer to the events of 3.8 billion years ago as the terrestrial origin of conventional organisms. One value in understanding these events is the possibility of identifying the cause of the disequilibrium that characterizes animate matter. If, as current thinking suggests, conventional organisms originated from so-called inanimate precursors [47],

the cause of the original disequilibrium must be assigned to so-called inanimate matter. But, for the reasons mentioned above, we can never be certain that matter is inanimate. We are left with two possibilities: either the power to create animate matter resides in inanimate matter, or there is no inanimate matter. Either way, the internal homeostatic matter that is commonly recognized as animate is not the cause of matter becoming animate. If in the course of evolution this internal homeostatic matter took on a causal role, the cause of that role remains in the external environment. And if we agree to call the cause of homeostasis animate, the external environment is that.

If evolution is cyclic, there is no evidence for a prior cycle having occurred on Earth, and, since the planet is less than 1 billion years older than the organisms of 3.8 billion years ago, there isn’t much time for a prior cycle to have run its course. Since the Sun will decay within 5 billion years, there isn’t much time for a subsequent cycle to run its course either [45]. Therefore, if evolution is cyclic, it must also be extraterrestrial. It is noteworthy in this regard that a cyclic model of the universe is as consistent with the available data as is a non-cyclic model [48].

Sagan suggested that billions of planets in our galaxy are inhabited [49]. But, he warned, that extraterrestrial organisms might manifest life in ways “stunningly different” from terrestrial biochemistry [49, p. 24], and challenged us to imagine “what else is possible?” I suggest a different calculation: What are the odds that a unique form of matter, i.e., animate, would appear only on Earth and involve only that small minority of matter that exists near its surface [16]? Is it not more likely that all matter everywhere is of the same form and that it is only our perception that makes so-called animate matter seem unique?

If Earth is alive, evolution may be more accurately described as the subdivision of animate matter into more numerous, intricate, and interconnected packages, in the

manner of early embryo development, than as the successive appearance of new species.

III. The quality of life

The semantic imprecision surrounding life has infected medicine, and is epitomized, perhaps, in standardized and “validated” questionnaires for assessing so-called quality of life [24, 50]. These measure an individual’s symptom distress, daily living activity, support network, and mental outlook, but they are not known to have anything to do with life. Instead, they summarize a person’s emotional state, their sense of happiness or contentment. This is closely related, if not identical, to a person’s individuality [51] and suggests that individuality is what people generally mean by “life.” It is clearly what Korzeniewski means by life [6].

What is individuality? It is the sense of being a unique and autonomous homeostatic unit. On a fundamental level, individuality is defined by competition for nutrients, habitat, and reproductive opportunity, and by immune tolerance [52-53]. On a more complicated level, it is defined by nervous representation [54]. Individuality encompasses the collection of a person’s peculiarities and is what we come to love. It is what we lose at death, what we fear losing, and what we mourn when lost. But it isn’t necessarily life. And if it were life, we should use “individuality” as a synonym, for it has greater precision. But individuality can’t be life for patients with senility and amnesia are recognized as having lost individuality, not life: “He is, as it were, isolated in a single moment of being, with a moat or lacuna of forgetting all round him... He is man without a past (or future), stuck in a constantly changing, meaningless moment” [55].

Individuality is based on the ability to distinguish internal from external environments and may be responsible for the sense of consciousness [54]. One function of this sense is to scan the environment for items of interest:

“A predatory animal directed by internal conditions of hunger scans the environment for the scent, sound or sight of prey; a running animal scans for the scent, sound or sight of a mate. Once detected, the senses focus and ‘lock in’ as the animal concentrates effort to track its quarry. I assume that scanning by the sense of consciousness is directed similarly by conditions within the organism and its environment... These internal conditions, along with others in the organism and in the larger environment direct the tracking process as the sense of consciousness pursues its quarry” [56].

What is that quarry? I suggest it is truth, i.e., that which does not change. Laws of nature give a glimpse of truth. The laws of buoyancy, gravity, electricity, thermodynamics, kinetics, genetics, nutrition, and immunity, for example, are as valid today as at the time of their discovery. It is possible that the laws will require some fine-tuning over time, particularly in the manner of their interpretation and application, but we have no experience of any law ever being suspended or overthrown. The laws of nature are our evidence for permanence. They give credence to the theologians’ argument that transient explanations are inadequate.

The laws are invariant not only with time, but also with individuality. They apply to everyone equally and, in that way, suggest that individuality is illusory. Homeostatic units are never autonomous. Individuality isn’t permanent and therefore isn’t true. We are all related. Everything is interconnected. This is the great lesson of ecology [16]. We are made of stardust and upon death become the dust from which new stars are made [36, 49]. If life is true, it cannot be the antonym of death. Individuality is that. Life, to be true, must be as immortal as the laws of nature.

Self is like life in that it has various meanings and no objective definition. To scientists and some philosophers, it is synonymous with individuality, i.e., a set of organizational tools for “coherencing” the

brain's plans, decisions, and perceptions [54]. To Hindus, Buddhists, and some philosophers, self is permanent, spiritual, and universal [57]. According to the former, hallucinogenic drugs and a variety of brain lesions demonstrate that self is a transient and disjointed concept. According to the latter, the former miss the point. Individuality is material and, therefore, not true. Self is true and spiritual. Like buoyancy, gravity, electricity, etc., the self is invariant with time and individuality. We cannot yet articulate the natural law of self consciousness, but we can extrapolate.

Six hundred years ago, there were many tenable opinions on the shape of our planet and its position in the solar system, on the nature of matter and energy, on the cause of plague, consumption, scurvy, rickets, and diabetes, etc. Now, on each of these issues, there is only one tenable opinion. As issues are settled objectively and information disseminated, opinions converge. We begin to think alike. In time, we will think even more alike. And, as our consciousness becomes more focused on truth, it becomes more permanent. The true self, like the true buoyancy and the true gravity, must be the same for everyone over all time [58]. Science is the means to true self-consciousness.

CONCLUSION

What is life? It is impossible to say, and, for that reason, should be defined as broadly as possible so as not to exclude anything reasonable. I suggest that life is best considered as a process. At the moment, life is the process by which matter and energy interact to form organisms that then evolve to form conscious organisms that then explore nature and eventually discover truth. There is no other word to describe this long and convoluted process. Life includes all the reactions and interactions of matter and energy, as well as all aspects of exploration and discovery, e.g., insight, ingenuity, creativity, endurance, and

luck. Because this process cannot yet be quantitated, it isn't adequate as a definition. It does, however, capture the prerequisites for a definition. It is free of implicit assumptions, and immaterial and therefore weightless. It animates the individual but survives all individuals, and may even be illusory. We can't say how the process was set in motion, where it is headed, how long it will continue, or what more might be involved, and, for these reasons, life is mysterious. But we can know this: on occasion, life does provide a glimpse of immortality.

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