

UNITED WISDOM

The Boundary of Life: Why Life Is Difficult to Define

World and Consciousness

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W-16-N01 · EN

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Epigraph

“for both sleeping and waking presuppose the existence of soul”

Aristotle, On the Soul, II.1. Exact labelled clause from J. A. Smith's English translation. Here soul belongs to his philosophical account of the form and capacities of a living body.

What this article is about

An exhibition about the origin of life might display three cards: grows, reproduces, evolves. Each promises a quick answer, yet awkward questions soon appear. What grows: a boundary or an entire system? Must every individual organism produce offspring? How long should we observe something before judging a capacity it is not currently exercising? Defining life is difficult for reasons beyond missing information. We choose a unit, a set of properties, a test, and a purpose for the definition, then often forget those choices. This article separates philosophical explanation, a working scientific criterion, and a limited experimental finding. Aristotle provides a distinction between possessing a capacity and exercising it; modern primary sources show why system boundaries and careful reading of laboratory claims matter. A fictional museum connects these distinctions to particular statements. It cannot settle every biological borderline case, but it can clarify which answer actually follows from a specified question and the available observations.

I. One Label Conceals Several Questions

Imagine two curators, Lida and Anton, preparing an exhibition with a drawing of a cell, a membrane-vesicle model, and an image of a virus. Anton suggests one label: anything that can become larger and produce similar objects belongs to life. Lida asks why a visitor should accept that particular rule. Increasing size can involve adding material, while producing something similar can involve an external device. The drawing shows neither the source of the material nor the means by which the process continues. Their disagreement about a label therefore becomes a disagreement about which relationships belong inside the description. These exhibits and this conversation are invented; they illustrate how a question is framed rather than report museum research.

Before choosing a word, the curators can separate several questions. First, what is the object made of? Second, what happens to it under specified conditions? Third, which processes

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could continue as conditions change? Fourth, how are later states related to earlier ones? These questions call for different information. The chemical composition of one sample does not reveal the history of successive generations. A record of changing size does not disclose the whole mechanism that maintains an organization. Even a successful explanation of a process does not define every case that ordinary language calls life. Separating the questions makes the description more informative: one confident word gives way to particular relationships that can be discussed and examined.

Anton proposes a compromise: say that the definition is disputed. Visitors would then learn that people disagree without learning why. It would be more useful to show where the answers diverge. One speaker considers an isolated particle, another considers the particle and its necessary surroundings, and a third considers a sequence of changing systems. All three may use the word object while describing different units. The exhibition therefore adds a clarification: every property belongs to a specified bearer under specified conditions. This is an original principle for explaining a claim, rather than another definition of life. It helps reveal when a broad statement stands in for a research boundary that has not yet been chosen.

II. Capacity and Present Activity

At the beginning of Book II of On the Soul, Aristotle distinguishes having knowledge from actively using it; sleeping and waking help explain two senses of actuality. This is a philosophical argument about the form and powers of an organized body, rather than a modern account of cellular mechanisms. The useful logical distinction is that an activity's absence now need not mean the corresponding capacity is absent. The comparison has limits: soul cannot be turned into a measured addition to matter, and ancient physiology cannot be treated as contemporary biological findings. The historical text gives us a question to ask about a description.

Lida draws an imagined device with its indicator switched off. It might be functioning but disconnected, damaged, or purely decorative. The same visible state permits several explanations. Testing a capacity requires conditions in which its expression would be expected and a way to distinguish a result from coincidence. This diagram makes no biological claim: the fictional device illustrates reasoning. It shows why capable needs further specification. Capable of what, under which conditions, for how long, and because of which organization? Without those details, a possibility can become a convenient promise that has not been supported. The question concerns the grounds for the attribution, rather than the confidence with which someone states it.

The reverse mistake is possible too. A single performance is taken as evidence of a stable capacity even though the process was assembled and initiated externally. Imagine a teaching program that prints hello once because that word was entered in its sole line of code. Its output

does not demonstrate command of a language. Likewise, a claim about a system should distinguish an observed result from the broader capacity inferred from it. This does not require waiting forever or proving the impossible. It requires identifying the transition: what was directly observed, what a mechanism explains, and what remains a hypothesis about other conditions. That transition needs justification; a careful vocabulary cannot provide the justification by itself.

III. A Working Formula Has a Purpose

NASA Science's 2023 page gives a working formula: a self-sustaining chemical system capable of Darwinian evolution. It calls the definition informal and non-binding, and explicitly says it is not used to design missions or research projects. A label saying NASA definition therefore does not turn the formula into a universal acceptance standard. It offers a reference for discussion. The curators can present it as one particular approach, name its source and status, and ask what its components mean. An institution's name cannot replace examining the relationships between words, observations, and the conclusion someone proposes to draw.

A working rule differs from an explanation of an entire phenomenon because it serves a particular task. Suppose the museum requests descriptions only for exhibits whose material, source of change, and sequence of states are known. This rule is useful for preparing labels, yet does not disclose the nature of every possible exhibit. A selection system answers what will enter this exhibition; an explanation asks why the relevant processes occur. Confusing the two makes exclusion from a list look like proof that the phenomenon itself is absent. It therefore helps to state a rule's purpose: why it was introduced, what it allows us to compare, and which questions remain open. Purpose does not make a rule arbitrary, but it limits what applying it establishes.

Another distinction separates a required condition from sufficient grounds. If a condition is necessary for a chosen category, its absence rules out conformity with the rule. Possessing one necessary condition, however, does not confirm all the others. In our imagined exhibition, the card contains chemicals is extremely broad; it cannot alone establish a capacity for evolution. Even a long list of properties needs an account of why their joint presence should be decisive. A clear formula can help inquiry begin without removing this work. The shorter a label becomes, the more carefully it should preserve the connection between a criterion, an observed sign, and the limit of the conclusion.

IV. Whose Capacity Is It?

In Leslie Mullen's 2013 interview, Gerald Joyce interprets the working formula in terms of a population or system rather than every individual. He also relates self-sustaining to the information required for evolution, rather than the absence of external energy sources. This is an attributed interpretation by a participant in the discussion. It cautions against transferring a system's capacity to every component or equating informational sufficiency with complete isolation. It does not yet supply a ready test for every object. The remaining task is to describe the system clearly enough that its capabilities do not appear merely because its boundary has been quietly enlarged.

Lida draws three nested frames. The first contains a hypothetical element, the second contains that element and whatever its operation depends on, and the third contains a succession of changing combinations. A property attributed to the third frame cannot automatically be transferred to the first. In an imagined workshop, a team can repair a complex model although no member can perform every operation. This implies neither each member's complete independence nor the absence of a collective skill. The analogy does not model biological evolution; it exposes a mistake about distributing properties. A scientific diagram would need actual mechanisms, carriers of information, and relationships in place of the word team.

Complete independence from the surrounding world would be a very strong requirement. Anyone introducing it should explain why it is necessary for this particular question. A more concrete approach lists dependencies: material, energy, structure, instructions, and environmental conditions. It then distinguishes what belongs inside the system from what is supplied externally. Different dependencies cannot all be collapsed into one answer, independent or not. Receiving material and having each successive operation prepared outside the system describe different relationships. In the museum case, the useful question is not merely whether something enters from outside, but who or what enables the organization to continue. The answer should preserve its chosen level even when a wider frame seems more convenient.

V. A Borderline Case and an Explicit Boundary

Joyce discusses the viral genome in the context of a host cell: an isolated virus and a virus together with its host receive different assessments under his chosen condition. This illustrates how an assessment depends on the system considered; it does not deliver a universal verdict on whether viruses are alive. The exhibition should therefore say that a particular author applies a particular criterion to a specified unit. The short statement a virus evolves can conceal relationships needed to describe the process. It calls for context, rather than permission to give every disputed object the same status or declare the question meaningless.

The curators try another fictional example. A sealed box contains a model that changes only when an operator replaces parts according to an external plan. If the box is called the system, information in that plan remains outside it. Including the operator and plan produces a different object of inquiry. That larger object may be interesting, but the comparison must now concern this new collection. The exhibition cannot begin by showing the box, silently borrow the operator's capacities, and attribute the outcome to the box alone. This is a common explanatory boundary error. It also appears in accounts of machines, organizations, and scientific models when dependencies vanish from the final description.

Enlarging a boundary is legitimate when the change is declared and serves the question. The problem is changing the subject silently during an argument. Lida proposes two labels: what is known about an isolated element, and what is known about the encompassing system. If information for the first is limited, the second does not automatically fill the gap. Establishing an external dependence likewise does not decide which category the dependent element belongs to. That conclusion needs a chosen rule and its grounds. Distinguishing boundaries preserves the disputed example's value for inquiry: it reveals how the criterion works and where uncertainty lies, instead of turning the example into a quick rhetorical victory.

VI. Defining a Word or Explaining a Nature

In their 2002 paper, Carol Cleland and Christopher Chyba compare definitions of life with attempts to understand water through recognizable properties before molecular theory. Their philosophical argument distinguishes linguistic convention from empirical explanation. They also allow that life might not be a single natural kind with an eventual theoretical identification. Their position therefore cannot be reduced to a promise of one final formula. The narrower question for this article is how far listing familiar features explains a phenomenon and how far it merely helps us recognize it. This examines what a definition does; it does not abandon inquiry.

Imagine that the museum sells a family ticket and specifies the group's required composition for that price. Having checked the conditions, an employee can confidently apply the label: the rule was created for that decision. This supplies neither a theory of families nor an account of every human relationship. In another case, a researcher tries to explain why different substances behave as they do. Agreement about a name is insufficient; the explanation needs relationships that withstand observation and illuminate unfamiliar cases. Both sorts of definition can be useful in different ways. Confusing them either exaggerates the power of a convention or needlessly requires every everyday word to contain a law of nature already.

Lida asks Anton to divide the exhibition text into three lines: we call it, we observe, and we explain. The first records a usage rule, the second records available information, and the third offers a mechanism or theory. The lines can be related without being equivalent. Something may satisfy the museum's rule while its organization remains unexplained. An observation may challenge the rule without immediately supplying a replacement theory. This format keeps uncertainty productive by attaching it to a particular transition, rather than declaring all knowledge uncertain. Revising a label can then refine the question instead of conceding that every possible answer is equally arbitrary.

VII. What a Model-Protocell Experiment Showed

The primary abstract of Irene Chen, Richard Roberts, and Jack Szostak's 2004 paper describes fatty-acid vesicle growth: encapsulated RNA generates osmotic pressure associated with membrane-component uptake at the expense of relaxed vesicles. The authors then propose a conditional connection between more efficient RNA replication, growth, and evolution at a cellular level. The described process must remain distinct from that proposed extension. This article uses the abstract and figure captions, rather than the full protocol. They support a narrow account of a model process, not a declaration that a complete, independently evolving living system was created.

The curators remove the dramatic label scientists made life and identify the particular process represented in the model. This does not diminish the experiment's value. A specific mechanism can say more than a grand word because it allows questions about relationships between quantities and conditions. In our fictional exhibition, an accompanying diagram shows an initial state, a change, an observation method, and a justified inference. If a boundary's change was measured, the label should explain how the observed signal relates to it. Further questions about copying, maintaining organization, and continuing generations remain. They can be asked separately instead of placing every expected property inside the name protocell in advance.

A model allows a selected relationship to be studied while simplifying other relationships or supplying them externally. Model therefore means neither a complete copy of a natural system

nor a useless toy. Consider a route map that shows stops but omits terrain. It serves one question and is insufficient for another. Evaluating a laboratory example likewise depends on the relationship it was intended to display and what was actually observed. Success in a particular experiment does not oblige the model to perform every function of the phenomenon studied. The absence of those functions does not erase the observed result. The error arises when a successful check's scope is extended without additional grounds.

VIII. Three Answers Instead of False Certainty

For the teaching display, Lida introduces a wholly hypothetical rule K: a card qualifies if properties A, B, and C are all confirmed. These letters stand for no biological properties and propose no new definition of life; they illustrate a logical decision. Of the eight fully specified combinations of three binary properties, only yes, yes, yes satisfies K. Eight comes from 2×2×2, rather than research on nature. If a card says yes, yes, unknown, qualification cannot be concluded. An unknown third property is not an absent one, however: the available information simply cannot settle the application of K. The rule and the state of our knowledge should remain distinct.

The distinction matters in counting too. Suppose the fictional collection has twelve cards: four have all three properties confirmed, five have at least one confirmed absence, and three have incomplete information with no established conflict with K. There are four qualifying, five non-qualifying, and three unresolved cases; 4+5+3=12. We cannot report seven qualifying by adding every unresolved case. Nor can all eight remaining cards be called established failures. Unknown is a separate state of information. Keeping it separate leaves room for later investigation: new data can change the three cards' status without changing the rule. This arithmetic describes our imagined collection and measures nothing in biology.

K itself could also change, perhaps by retaining only A and B. That alters the grounds of classification rather than merely the amount of information. Results from the two rules cannot be compared as if increased knowledge were the only difference. The curators must identify which version governed each label. This separates three sources of revision: clarifying the object, obtaining new observations, and changing the criterion. All three sometimes change together; that makes an explicit account more useful. Otherwise, a disagreement about why an object failed yesterday and qualifies today can turn into a disagreement about the participants' honesty, even when the reason lies in a declared change of task.

IX. Testing Needs Time and Alternatives

A capacity concerns possible conditions, whereas an observation occurs in particular conditions. A conclusion must connect them through justification. In the fictional collection, the curators know an object did not change over an hour. This records only what happened during that hour under those conditions. A broader inference requires explaining why the conditions should allow the relevant process and why the observation period is adequate. A negative result cannot automatically be extended to every possible condition. Appealing to endlessly many possibilities does not establish a capacity either. Between these extremes lies a particular hypothesis, with conditions, an accessible observation, and a stated limit to the inference.

A positive signal needs examination as well. Suppose an indicator on the teaching display changes brightness. This alone does not show that the object of interest changed: lighting, the sensor, or an operator's intervention might explain the signal. The fictional example describes no astrobiological instrument. It distinguishes registering a signal from explaining its source. A useful next question is which observation would distinguish the proposed explanations. If every version predicts the same visible outcome, that outcome cannot select between them. Naming a proposed process adds no discriminating evidence; it simply identifies an account still to be compared with alternatives. The explanation must earn its specificity rather than inherit it from the label.

A limited check can still be informative. Establishing a particular dependency under specified conditions does not require resolving what life is in every possible world. It requires recording the scale of the result achieved. Lida gives visitors two separate lines: observed here, and might mean this under additional conditions. The second line need not be false; it has a different status. This distinction is also useful when reading a research abstract in which a factual description sits beside a proposed extension. It leaves space for further experiments by identifying both the achievement and the particular relationship that remains to be investigated. Uncertainty is then located rather than used to blur everything together.

X. A Category Cannot Supply an Entire Ethic

Life's boundary may affect how we treat things, yet one definition cannot yield a complete ethic. Anyone introducing obligations should identify their grounds: possible harm, affected beings' interests, relationships, accepted commitments, or another consideration open to discussion. Biological classification and a normative decision can inform one another without being identical. In particular, criteria involving reproduction, activity, or evolutionary capacity must not become measures of an individual human being's worth. This article draws no such inference. A scientific question about a system cannot measure human dignity or resolve a clinical or legal situation. Those questions require their own relevant grounds and participants.

The museum still has two reasonable options: a short label identifying a working criterion, or a display explaining differences among criteria. The choice depends on the exhibition's purpose, audience, and space; our fictional curators need not turn every label into a treatise. But shortening must preserve a meaningful anchor. Even a brief text can identify the bearer of a property, what was observed, and which question remains open. It can respect a visitor's time without offering false completeness. Clarity comes from selecting the relationship that matters, rather than promising that a familiar word explains the phenomenon's entire organization. The amount of detail should serve the question being asked.

Lida and Anton finish with more precise labels rather than a new final boundary. One names a process, another names dependence on an encompassing system, and a third states a working definition's status. Their fictional conversation illustrates a practical result of conceptual distinctions: a question becomes examinable when its subject, conditions, and transition to a conclusion are identified. Life can remain a difficult category without making every piece of information uncertain. We can know particular mechanisms, identify untested extensions, and debate different criteria's merits. That stance preserves accuracy and interest in inquiry together. It leaves the next substantive question available rather than replacing it with a categorical label.

What this means in practice

This optional exercise examines statements; it is neither a biological test nor a diagnostic method, and promises no improvement in thinking. You can use only the fictional museum case and stop at any point. Take the sentence this object grows, therefore it is alive. Write the observation, criterion, and conclusion separately. For the observation, say what changes and under which conditions. For the criterion, ask whether growth is sufficient or merely necessary. For the conclusion, identify the object it concerns. Where information is missing, leave a question open. You need not invent details to produce a completed table.

Next draw two frames: the object alone, and the object together with something the relevant process depends on. This does not invite including everything in existence. Choose one dependence that matters to the sentence, and explain why it enters the second frame. Compare the labels: is the property being assigned to the same unit? If the unit has changed, rewrite the inference to make the change visible. For Section VIII's hypothetical rule K, check 4+5+3 and explain why the three unknown cases cannot join either settled answer without more information.

Finally, compare these sentences: a model displayed boundary growth, and the model possesses every property of a living system. Identify at least one additional question between them. There is no need to answer it without data. Recognizing the transition from one result to a broader claim is enough. A possible outcome is a short revised label identifying a process, boundary, and limit of inference. It remains an original teaching exercise: actual inquiry requires suitable methods and information, while medical, ethical, and legal decisions cannot be grounded in this written exercise alone.

Key quotation

> *“A self-sustaining chemical system capable of Darwinian evolution.”*

The working formula quoted in Pat Brennan's NASA Science article, “Life on Other Planets: What is Life and What Does It Need?”, “Life That Evolves”, 2023. Exact original English. The source calls it informal and non-binding.

Connections between traditions

1. Capacity and its bearer. Aristotle, II.1, distinguishes possessing and exercising knowledge; Joyce's interview discussion of capable concerns a population or system. The comparison identifies both possible exercise and the unit credited with it. Boundary: an organism's philosophical actuality is not a population's Darwinian evolution.

2. Maintaining organization and continuing. Aristotle, II.4, separates maintenance from reproduction; Chen, Roberts, and Szostak's abstract describes boundary growth. These anchors distinguish maintaining one object from continuing a sequence. Boundary: the ancient account does not predict vesicle chemistry, and model growth does not establish complete life.

3. A working formula and an explanation. NASA Science's “Life That Evolves” states the formula's non-binding status; Cleland and Chyba's Section 3 distinguishes definition from theoretical understanding. The connection separates a reference for discussion from explaining a phenomenon's nature. Boundary: neither status nor philosophical objection tests every biological candidate.

4. Dependence and a system's frame. Joyce considers a virus with its host; Chen and colleagues describe a process in model vesicles. The comparison makes conditions explicit before a property is assigned to an isolated component. Boundary: viral evolution and physical growth have different mechanisms; a shared dependence question does not equate the objects.

5. A general category and a particular case. Cleland and Chyba's Sections 3–4 examine necessity, sufficiency, and possible natural-kind status; Aristotle's II.3 compares a general account with particular powers. The connection asks what explanatory work a category performs. Boundary: an ancient figure analogy neither settles the modern debate nor promises a final universal formula.

6. A criterion and an observed process. NASA's formula includes evolutionary capacity; Chen and colleagues' abstract and captions distinguish described growth from a conditional extension. The comparison identifies the transition from an indicator to a broad capacity. Boundary: a membrane-growth signal tests neither the whole formula nor the creation of life.

Primary sources

1. Aristotle, On the Soul, Book II. J. A. Smith translation, Internet Classics Archive. II.1–5 and the opening of II.6 read; actuality, powers, and functions provide the anchors. Neither original Greek nor other books were collated; ancient physiology is not adopted as contemporary fact.

2. Pat Brennan, NASA Science, Life on Other Planets. June 20, 2023, “Life That Evolves”: exact formula and working status. Relevant page text read; mission forecasts unused. The key quotation is original English.

3. Gerald Joyce / Leslie Mullen, Forming a Definition for Life. July 25, 2013 interview, NASA Astrobiology, sourced from astrobio.net. Entire interview read; system-boundary and capacity explanations used. Participant testimony, rather than a reading of the internal plan or laboratory experimental papers.

4. Carol E. Cleland, Christopher F. Chyba, Defining ‘Life’. Origins of Life and Evolution of the Biosphere 32, 2002, 387–393, DOI 10.1023/A:1020503324273. Complete primary text read; Sections 3–4 supply the anchors. The philosophical argument is not presented as settled consensus; cited historical experiments were not separately checked.

5. Irene A. Chen, Richard W. Roberts, Jack W. Szostak, The emergence of competition between model protocells. Science 305, 2004, 1474–1476, DOI 10.1126/science.1100757. Complete primary abstract and all three available PubMed figure captions read. Full protocol and supplements unread; the model process is not equated with creating complete life.

Tags

life, definition of life, boundary of life, biology, philosophy of biology, Aristotle, On the Soul, capacity, actuality, working definition, NASA, Gerald Joyce, Darwinian evolution, population, system boundary, viruses, host, protocells, membrane, RNA, osmotic pressure, model, experiment, necessary condition, sufficient condition, uncertainty, natural kinds, Cleland, Chyba, scientific explanation

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