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Why I stopped worrying about the definition of life... and why you should as well

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Abstract In several disciplines within science—evolutionary biology, molecular biology, astrobiology, synthetic biology, artificial life—and outside science—primarily, ethics—efforts to define life have recently multiplied. However, no consensus has emerged. In this article, I argue that this is no accident. I propose a dilemma showing that the project of defining life is either impossible or pointless. The notion of life at stake in this project is either the folk concept of life or a scientific concept. In the former case, empirical evidence shows that life *cannot* be defined. In the latter case, I argue that, although defining life may be possible, it is *pointless*. I conclude that scientists, philosophers, and ethicists should discard the project of defining life.

Keywords Life · Concept · Definition · Astrobiology · Synthetic biology · Alife · Molecular biology · Evolutionary biology · Concepts

Life is live
Opus

1 Introduction

In various quarters—philosophy, biology, or computer science—people (let's call them "life definitionists") are pursuing a grandiose project: finding the definition of life. Despite substantial efforts, life definitionism has so far been unsuccessful, and a consensus about the definition of life is yet to emerge (Farmer and Belin 1992; Luisi 1998; Cleland and Chyba 2002). The history of life definitionism is reminiscent of the history of conceptual analysis in philosophy—a succession of proposals systematically

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rejected by other definitionists, often[1] on the basis of counterexamples. Consider some telling examples. Boden (1999, pp. 236–237) argues that life should not be identified with self-organization (Goodwin 1990; Kauffman 1995), because some chemical reactions, e.g., the Belousov–Zhabotinsky reaction, self-organize without being alive. When Bedau (1996, 1998) and Joyce (1994) argue (in different ways) that evolution is a necessary and maybe sufficient property of living creatures, Cleland and Chyba (2002, p. 388) notice that real (e.g., mules) and possible (e.g., creatures capable of metabolism, but not of replication) cases are inconsistent with this proposal (see also Goodwin 1990; Kauffman 1995; Luisi 1998; Boden 1999). Cleland and Chyba (2002, p. 388; see also Chyba and Mcdonald 1995) also note that "thermodynamic and metabolic definitions of life have difficulty avoiding counting crystals and fire, respectively, as alive." And so on… This should look familiar to readers of Plato!

This article argues that the bad record of life definitionism is no accident. Indeed, I make a case that defining life is a misconceived project. I propose a dilemma to the effect that this project is either impossible or pointless. Definitionists have to endorse one of the following two horns:

1. They take the notion of life to be a *folk* concept, i.e., the source of laymen's intuitions about what's alive and what's not. It is on a par with laymen's concepts of object (Spelke 1994), of disease (Keil et al. 1990), etc. If this is the definitionists' stance, I argue that, on *any* psychological account of people's folk concepts, life *cannot* be defined.
2. They take the notion of life to be a theoretical, scientific concept that is part of the theoretical framework of some science. It is on a par with scientists' concepts of molecule, cell, virus, etc. If this is the definitionists' stance, I argue that while perhaps doable, the project of defining life is *pointless*.

In either case, the conclusion is grim: Life definitionists have wasted a lot of time, energy, and money that would have been better used for other, more useful projects.

In Sect. 2 of this paper, I review the recent attempts at defining life. I spell out the reasons why a definition of life is often deemed necessary. Sections 3 and 4 expose the dilemma. Section 3 develops the first horn of the dilemma. In Sect. 4, I come to grips with the second horn of the dilemma. I conclude that we should discard life definitionism.

2 Varieties of life definitionism

The last decades have seen a burst of life definitionism. Motivated by impressive progresses in some fields within biology or by the needs of some recently developed disciplines, scientists and philosophers of science have proposed several definitions of life, both in scientific and in general public journals (e.g., Gould (2000) in *Time Europe*; Wade (1999) and Angier (2001) in the *New York Times*; Achenbach (2003) *National Geographic*). Official organisms, like NASA, have also endorsed specific definitions.

[1] But not always. For example, Fleischaker (1990) argues against the Darwinian chemical definition of life on the basis of its practical drawbacks (see also Luisi 1998, p. 617; Conrad and Nealson 2001, p. 16).

Reviewing these definitions would lead me astray since my argument does not depend on their details (several definitions are discussed in Sagan 1970/1998; Bedau 1996; Luisi 1998; Etxeberria 2004; Ruiz-Mirazo et al. 2004). Instead, in this section, I describe the fields where defining life has been seen as crucial.

Life definitionism derives mostly from three sources. First, the progresses in some well-developed biological sciences—evolutionary biology and molecular biology—have led their leading practitioners to look for definitions of life. Second, a definition of life is often supposed to be the solution to three problems that plague several young disciplines—artificial life, synthetic biology, astrobiology, and the research on the origins of life. Finally, outside science, ethics has given rise to questions about the proper definition of life.

Before examining these three sources in detail, we should ask what life definitionists are looking for—i.e., what a definition of life is. There are several types of definitions. The main distinction is between classificatory definitions and causal definitions. The point of classificatory definitions is to spell out a set of properties that are independently necessary and jointly sufficient for being a member of the defined classes. While causal definitions are also classificatory, the properties that constitute them have to be causally explanatory—viz. they have to explain why the members of the defined classes possess the properties they possess (see Locke (1689) notion of real essence). For instance, the molecular structure of water, H_2O, explains many properties of water, e.g., why it boils at 100°C. Now, one might ask, what kind of definitions have life definitionists been looking for? In fact, it is often unclear whether life definitionists are looking for a mere classificatory definition or for a full-blown causal one (but see Bedau 1996, 1998 for a clear position).[2]

Molecular biology has been one of the reigning sciences of the second half of the twentieth century. Boosted by the discovery of DNA, molecular biologists went on describing the cell's mechanisms in detail. Successes were many. Particularly, at the molecular level, scientists discovered an apparent underlying unity of all living beings, a finding that led some biologists and philosophers of biology to propose various definitions of life. For instance, Crick (1981) proposed that three properties are necessary and jointly sufficient for being alive: self-reproduction, evolution, and metabolism (see also Monod 1970). *Evolutionary biology* has been the other triumphing field within biology in the twentieth century. While biologists in the first part of the twentieth century were often reluctant to define life (Haldane 1937), leading biologists in the second half did not have such qualms (e.g., Maynard Smith 1986, pp. 1–8; Mayr 1982).

While most of the definitions that have been proposed in molecular and evolutionary biology are inspired by major scientific progresses, intuitive examples and counterexamples also play an important role in this brand of life definitionism. For example, Maynard Smith (1986, pp. 1–2) notes that flames and vortexes can maintain a constant

[2] A definition of life is not required for answering Schrödinger's question "What is life?" Instead, a satisfactory answer could consist of a theory about living beings—that is, a set of generalizations that are true of living beings. One could object that a theory can be turned into a definition by ramsification (Lewis 1970). Not necessarily, however. A theory about living beings would plausibly consist of *ceteris paribus* generalizations, and if one ramsifies a set of *ceteris paribus* generalizations about x, one does not end up with necessary and sufficient conditions for being an x. For the sake of space, I shall leave this issue aside.

form in spite of the fact that their component molecules change constantly—which is problematic for a definition of life that relies only on the notion of metabolism. Relying on examples and counterexamples is tantamount to appeal to the folk concept of life. Let's consider the case of counterexamples. For an objection against a definition to avoid begging the question, the counterexample has to fall under a concept of life shared by both the scientist who proposes a definition and the scientist who objects to this definition. Since both scientists disagree on the theoretical concept of life, the shared notion of life has to be the folk concept of life. We thus see that the folk concept of life is intertwined with this brand of life definitionism, even though scientists are explicitly looking for a theoretical definition of life.

Let's turn now to the second source of inspiration, starting with *artificial life*—or ALife.[3] ALife is a recent field involving both biologists and computer scientists (e.g., Langton 1989; Emmeche 1994; Lange 1996, pp. 225–228; Bedau et al. 2000; Wheeler et al. 2002).[4] Its original principles and leading research questions are borrowed from artificial intelligence. Thus, following artificial intelligence's distinction between cognition and its implementation, proponents of ALife hypothesize that robots or, more often, virtual entities could be *stricto sensu* alive.[5] Those virtual entities are usually programs that are stored in the memory of computers. They are supposed to possess various properties that are deemed to be criterial of living entities, e.g., self-organization, emergence, autonomy, growth, development, reproduction, adaptation, responsiveness, or evolution. C. G. Langton captures well the gist of the field (1986, p. 147; see the discussion in Sober 1992; Lange 1996; Olson 1997; Sterelny 1997; Boden 1999):

> The ultimate goal of the study of artificial intelligence would be to create "life" in some other medium, ideally a *virtual* medium where the essence of life has been abstracted from the details of its implementation in any particular model. We would like to build models that are so life-like that they cease to become *models* of life and become *examples* of life themselves.

An impressive example of this work is Thomas Ray's Tierra project (Ray 1992, 1994; see also Grand's Creatures described in Boden 1999, pp. 240–242). Tierra is a virtual memory-space, implemented in a world-wide network of computers, in which programs are stored. These programs copy themselves in other memory locations. Self-replication is usually accompanied by modification. This process is supposed to be analogous to Darwin's descent with variation. The programs compete "for access to the limited resources of memory space" (Ray 1994, p. 185). This leads to a process of evolution through some form of selection. Ray proposes that this results in a world of living creatures.

[3] "Artificial life" is sometimes used in a broader way to include synthetic biology (Bedau et al. 2000).

[4] The first conference on ALife took place in 1987 (Langton 1989) and the journal *Artificial Life* was created in 1994.

[5] This is known as "strong artificial life." Proponents of "weak artificial life" believe that ALife should aim at mimicking living beings. This distinction comes from artificial intelligence. For a discussion of the goals of ALife, see Wheeler et al. (2002).

Finding out a definition of life is often viewed as crucial for this scientific endeavor (e.g., Bedau 1996). Three considerations seem to justify this idea. First, proponents of ALife deal with entities whose status as living beings is *prima facie* indeterminate—neither clearly false (since they display some typical properties of *bona fide* living creatures) nor clearly true (since they lack other typical properties). Second, these entities fail to possess some properties that are characteristic of familiar living beings, for example, being embodied. Distinguishing between the merely typical properties and the essential ones is thus crucial for ALife (Bedau 1996). Finally, since proponents of ALife are in the business of creating new forms of life, having a prior conception of what life is often believed to be a condition for making progresses in this field (Bedau 1996). Finding out a definition of life is often believed to be the solution to these three issues—*the vagueness issue, the essentiality issue*, and *the direction issue*.

As a result, proponents of ALife have often argued about the correct definition of life (e.g., Bedau 1996, 1998; Boden 1999; Etxeberria 2004). For instance, Boden (1999) has argued that metabolism is a necessary property for being alive—thus, a component of a definition of life. It is rarely clear whether the concept of life at stake in ALife is the folk concept of life or a scientific concept of life. For instance, some necessary properties of living beings that are mentioned by Boden—evolution and adaptation—are obviously grounded in evolutionary biology. She also claims that life definitionism is a scientific endeavor that can lead to rejecting some intuitions (Boden 1999, pp. 243–245; see also Bedau 1996, 1998). But she simultaneously appeals to our commonsense intuitions about what's alive and what's not (e.g., Boden 1999, p. 237; see also Olson 1997), suggesting that she relies on the folk concept of life. Researchers in the other disciplines considered here also seem to vacillate between a theoretical concept and a folk concept of life.

Although a bit older than ALife (e.g., Lederberg 1960), *astrobiology* is still a young discipline.[6] It is linked to the development of astronomy and the progress of astronomical technologies (Lawler 1998). Since the seventies, various projects have been looking for traces of life on planets other than Earth. For instance, in 1976, NASA launched the *Viking* mission on Mars, with the task of finding a specific type of life traces—signs of microbial metabolism (Klein 1999; Cleland and Chyba 2002). Life definitionism has been striving in astrobiology (e.g., Chyba and Mcdonald 1995; Conrad and Nealson 2001; Chyba and Philips 2001; Cleland and Chyba 2002), boosted by the belief that a definition is required to build robots and systems able to look for life on other planets—that is, by the direction issue (Conrad and Nealson 2001; Cleland and Chyba 2002, p. 387).[7] The vagueness issue and the essentiality issue (Lederberg 1960; Conrad and Nealson 2001, p. 15; Bada 2001, p. 797) are very salient in this discipline as well. Just like in the disciplines considered previously, there is also an ongoing controversy

[6] The first issue of the journal *Astrobiology* appeared in 2001. The first issue of the journal *Origins of Life and Evolution of the Biosphere* appeared in 1968 under the name *Space Life Sciences*.

[7] "The philosophical question of the definition of 'life' has increasing practical importance. As science makes progress towards understanding the origins of life on Earth, as laboratory experiments approach the synthesis of life (as measured by the criteria of some definitions), and as greater attention is focused on astrobiology and the search for life on Mars and Jupiter's moon Europa, the utility of a general definition grows" (Cleland and Chyba 2002, p. 387).

between various definitions of life in astrobiology. For instance, Cleland and Chyba (2002, pp. 388–389) argue against the chemical Darwinian definition of life—"life is a self-sustained chemical system capable of undergoing Darwinian evolution" (Joyce 1994).[8] Interestingly, to argue against this theoretical definition, they rely on folk intuitions about which creatures are alive and on possible cases, in line with traditional conceptual analysis in philosophy. At the same time, they propose that the only way out of the stalemate between definitions of life is to find out the essence of all living beings empirically.

Since the 1960s (Miller and Urey 1959), another field, *synthetic biology*, has emerged and has grown steadily. The goals of that field are diverse, ranging from the manipulation of the genetic circuits that control cells to the transfer of synthetic chemical chains in bacteria to the synthesis of living cells. Within that field, many molecular biologists are aiming at designing self-replicating chemical systems in order to design more complex, synthetic molecular systems (e.g., Orgel 1995; Luther et al. 1998; see the review of Szostak et al. 2001; Ball 2004). One goal is to cast some light on the principles that underlie the formation of the simplest living systems and on the origins of life (Orgel 1995; Szostak et al. 2001). The three problems distinguished above bewildered synthetic biology as well. Synthetic biologists deal with chemical systems that are very simple—simpler than present-day bacteria (Mushegian and Koonin 1996, p. 10273; Szostak et al. 2001)—which raises the question, when do synthesized systems become truly alive? The essentiality and the direction issues are also very salient in this field. Often, synthetic biologists endorse without argument a standard definition of life. For instance, Luther et al. (1998, p. 247) rely explicitly on the definition of life that was proposed by Joyce (1994), and they conclude that the self-replication of chemical systems should be exponential because it appears to be a requisite for Darwinian selection. However, synthetic biologist also recognize that the definition of life is a controversial and important issue (Szostak et al. 2001).

The last relevant scientific discipline is *the research on the origins of life* (e.g., Luisi 1998; Nisbet and Sleep 2001; Hazen 2001).[9] Again, biologists in this field are faced with organisms that differ substantially from organisms that are obviously—either for the folk or for biologists—alive. Particularly, like in synthetic biology, they deal with organisms that are supposed to be simpler than cells: Scientists assume "the existence of some forms of life which we do not know presently" (Luisi 1998, p. 615).[10] They are thus faced with the vagueness issue and the essentiality issue: They need to decide whether these entities are alive. It is also sometimes assumed that a definition of life is key for designing useful experiments—the direction issue (Luisi 1998, p. 617).

[8] This is the definition of life endorsed by the Exobiology Program at the NASA.

[9] Hazen (2001) reviews the history of the field.

[10] Synthetic biology and the research on the origins of life are closely related disciplines. Hypotheses concerning the first forms of life can be tested in laboratory, using the tools of synthetic biology (e.g., Hazen 2001). The links with astrobiology are also sometimes tight. Miller and Urey (1959), one of the groundbreaking papers in synthetic biology, refers both to the origins of life and to extraterrestrial life (more recently, see, e.g., Bada 2001). However, those three fields should not be lumped together since their agenda, methods, and practical requirements are different.

Science is not the only area where defining life has been pursued since life definitionism is also important in contemporary *ethics*. Particularly, there is an ongoing debate about the prospects of environmental ethics. Advocates and opponents of environmental ethics wonder whether rights and, maybe, duties should be granted to every living being—and not only to humans or to sentient beings. It has been argued that progresses in this debate are contingent on a definition of life (Agar 1997, 2001). The solutions to other ethical questions, e.g., the use of stem cells for research purposes (Angier 2001) or the ethical consequences of reductionism (Cho et al. 1999; Wade 1999), are also often thought to depend on defining life.

Life definitionism has thus been flourishing in various fields. It is however plain that this project has not been carefully thought through. The nature of the desired definition is often unspecified, and life definitionists rely on both scientific considerations and folk intuitions, suggesting that it is not clear whether scientists and philosophers are trying to capture the folk concept of life or to elaborate a scientific definition.

3 First horn: Life as a folk concept

3.1 What is life definitionism?

Like "belief" or "emotion" in cognitive psychology (Griffiths 1997), "life" belongs both to the vocabulary of everyday English, expressing then a folk concept, and to the vocabulary of some special sciences, expressing one or many theoretical concepts. We have seen in Sect. 2 that many life definitionists hesitate between these two options, relying very often on the folk concept of life while claiming that they are looking for an empirical definition of living beings. But the project of defining life looks very different when you rely on the folk concept and when you endorse a theoretical concept. Thus, life definitionists have to decide whether they use the term "life" in its folk meaning or as a theoretical term (Bedau 1996, 1998). In this section, I take the notion of life to be the folk concept of life, spelling out the first horn of the anti-definitionist dilemma that was presented in the introduction.

Now, if the notion of life is a folk concept, what are life definitionists trying to do? I see two options. First, definitionists can assume that people's folk concepts—or at least some concepts, including the folk concept of life—are definitions, i.e., sets of properties that are taken to be necessary and jointly sufficient for being an instance of the concept. The definition of life underlies people's categorization judgments with respect to the class of living beings. Even if people are not able to spell out this definition, one can reconstruct it from their categorization decisions. Figure 1 summarizes this idea.

However, life definitionists do not have to assume that the folk concept of life is a definition, and they can remain noncommittal with respect to the nature of people's folk concepts. This second option assumes only that people's categorization decisions may be captured by a definition—even if they do not stem from a definition. Figure 2 describes this option.

Notice that both projects can be to some extent revisionary. Proponents of the first project do not have to assume that all categorization judgments derive from the folk

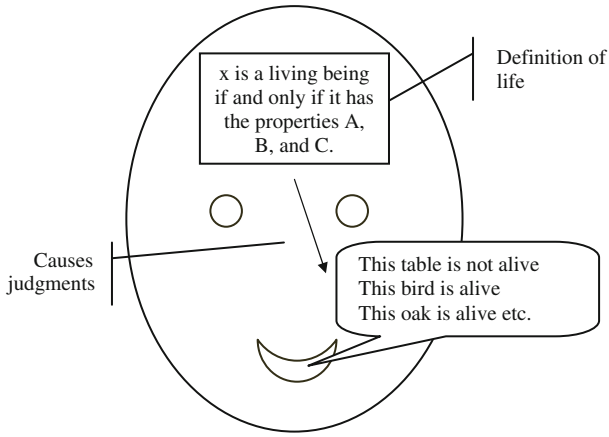

Fig. 1 A definition of life in our heads

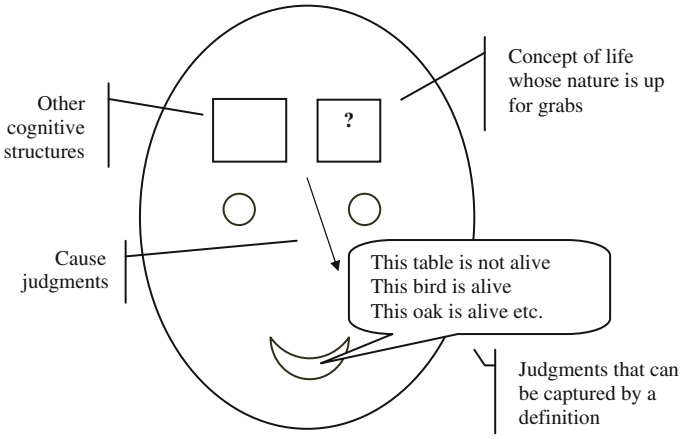

Fig. 2 Capturing folk judgments about life by means of a definition

concept of life. They can help themselves to the competence/performance distinction in order to claim that some judgments are performance errors. Similarly, proponents of the second project do not have to assume that all categorization judgments can be captured by a definition. Some judgments may be excluded in order to get hold of a definable set of judgments.

In the remainder of this section, I argue that if life definitionists are interested in the folk concept of life, life definitionism, however conceived, is a dead end. For, it is inconsistent with what we know about folk concepts and with the main psychological theories of what folk concepts are.

3.2 The psychology of folk concepts

A folk concept of *x* consists in the way ordinary people think about *x*, say, a class, a property, an abstract entity, etc. (for further detail on concepts, see Machery 2009).

Folk concepts form an important field in cognitive psychology. Many cognitive psychologists aim at spelling out particular folk concepts: For example, Spelke and her colleagues have characterized the folk concept of object in great detail (Spelke 1994). Other cognitive psychologists aim at specifying the properties that are true of all folk concepts: They attempt to provide a general theory of concepts (see the review in Murphy 2002 and the discussion in Machery 2005, 2009). The research on concepts done by these psychologists suggests that the project of defining the folk concept of life is hopeless.

It has been traditionally assumed that folk concepts are definitions: When people are thinking about x, they access a definition of x (see Fig. 1). Most philosophers since Socrates and Plato (Stich 1993) and, from the beginning of experimental psychology in the nineteenth century until the 1970s, most psychologists working on concepts (Machery 2007) have shared this assumption. Psychologists have however almost unanimously abandoned this assumption. Save for a few cognitive scientists (Jackendoff 1992; Pinker and Prince 1999), they came to the conclusion that almost no folk concept is a definition: We do not retrieve a definition of x when we think about x.

Let's consider the evidence against the idea that folk concepts are definitions. First, two thousand years of conceptual analysis in philosophy have been fruitless. There is no agreed-upon definition of good, justice, knowledge, etc. If folk concepts were definitions, surely philosophers would have managed to provide some definitions. One could reply that this fact only shows that some peculiar concepts—the very abstract concepts philosophers are interested in—are not definitions. However, the problem raised by the failure to find definitions generalizes to other, more mundane concepts. Fodor (1981) has cogently argued that defining the concept of painting is frail with the very difficulties that hamper the conceptual analysis of abstract concepts: For every proposed definition, it is possible to find a case that falsifies it. This is strong evidence for the generalization that, save for a few exceptions, no folk concept, including the folk concept of life, is a definition.

Life definitionists could stick to their guns. They could argue that the failure to find definitions merely shows that defining things is difficult, not impossible. Let's grant the point for the sake of argument. Other pieces of evidence are however harder to accommodate. Particularly, suppose that one concept is defined by means of another. For example, one could propose that to murder is defined as to kill intentionally plus some other conditions. This suggests that processing MURDER would take longer than processing KILL.[11] However, several experiments show that these two concepts are processed at the same speed (Fodor et al. 1980). Notice that the examples used by Fodor and colleagues (including KILL) are among the best cases for the claim that concepts are definitions.

Life definitionists could perhaps reply that definitions, including the definition of life, are in fact chunked: They are processed as units. For the sake of argument, let's grant the reply and consider another difficulty: The hypothesis that concepts are definitions has no explanatory power. It fails to explain the phenomena that have been

[11] I use small caps to name concepts.

found in the psychology of concepts since the 1970s. For example, it does not explain the fact that typical *x*'*s* are categorized more quickly and reliably than atypical *x*'*s* (Rosch and Mervis 1975; for a general review, see Murphy 2002; Machery 2009, Chap. 4). If concepts are definitions, why do the processes that access them display these properties?

Life definitionists could reply that definitions are not accessed by the processes underlying categorization, but by other processes (e.g., Osherson and Smith 1981). Thus, life definitionists should not worry that the properties of these processes are not explained by the hypothesis that concepts are definitions. At this point, however, life definitionists have to find some cognitive process whose properties are explained by the hypothesis that concepts are definitions. But most psychologists agree that there are none (Murphy 2002, p. 39).[12]

As a last resort, life definitionists could question the generality of the conclusion. They could concede that very few concepts are definitions, while insisting that the folk concept of life is one of these few concepts that are definitions, like, e.g., the concept of prime number. This will not do, however, since the concepts that are likely to be definitions are of a particular nature: Their definitions are *explicitly* known. We explicitly know that bachelors are adult unmarried men. This is obviously not the case of life. Various types of concepts for which no definition is consciously accessible have been studied—abstract concepts, concepts of events, concepts of middle-sized objects, and concepts of substances. There is no evidence that any of them is a definition. Why would the concept of life be an exception?

Obviously, the evidence discussed above bears on the first form of definitionism—capturing the folk definition of life (Fig. 1). If definitionists aim at spelling out this definition, and if there is no evidence that the folk concept of life is a definition, then life definitionism is misconceived.

What about the second option—capturing people's categorization decisions by means of a definition, whether or not people rely on a definition (Fig. 2)? It does not fare better. Since no definition has been found for abstract concepts, e.g., the concept of good, the concepts of activities (e.g., PAINTING), or the concepts of medium-sized entities (e.g., DOG), categorization decisions do not seem to lend themselves to definitions. This suggests that it is impossible to capture our folk categorization decisions by means of a definition (more on this below).

I conclude that if life definitionists are interested in the folk concept of life, there is little hope for life definitionism, however conceived.

3.3 Contemporary theories of concepts

I provide now a different argument against life definitionism: On any contemporary view about what folk concepts are, the concept of life cannot be defined. It is

[12] One could wonder why some cognitive scientists, particularly Jackendoff (1992) and Pinker and Prince (1999), believe that concepts are definitions. Pinker and Prince argue convincingly that some classes, particularly, the class of regular English verbs, are defined by a set of grammatical rules. They propose that this is true of a substantial number of concepts. However, they do not provide any evidence for this claim.

well-known that this field has failed to reach any agreement. Instead, several theories are competing with each other (Murphy 2002; Machery 2009). Psychological theories of concepts can be classified into five kinds.

- *The prototype view* (Rosch and Mervis 1975): A prototype encodes the properties that are typical of the denoted class. No property is judged to be necessary for being a member of the class. Categorization decisions are made on the basis of the similarity between the target and the prototype: If the target possesses a sufficient number of the properties that are represented by the concept, it is included within the class.
- *The exemplar view* (Medin and Schaffer 1978): A concept is a set of representations of individual members of the denoted class (exemplars). Each exemplar represents some properties of its reference. Categorization decisions are made on the basis of the similarity between the target and each exemplar: If the target possesses a sufficient number of the properties that are represented by each exemplar, it is included within the class. No property is judged to be necessary.
- *The theory view* (Murphy and Medin 1985): Concepts are in some respects similar to scientific theories, and they are used in processes that are similar to scientific reasoning. In particular, concepts are supposed to encode some nomological, causal, and functional knowledge. Categorization is often assumed to rest on some inference to the best explanation: *x* belongs to the category that provides the best explanation of its properties.[13]
- *The neo-empiricist view* (Barsalou 1999; Prinz 2002): Concepts encode, exclusively or mostly, some information about their reference in a perceptual format. Conceptual processes involve the cognitive systems dedicated to perceptual information processing.
- *Hybrid theories*: This view associates some of the views presented above.

Which of these views is correct? For present purposes, it does not matter.[14] What matters is that none of them assumes that concepts are definitions (vs. Fig. 1). Moreover, they all cause difficulties for the project of capturing most, if not all, categorization judgments by means of a definition (vs. Fig. 2). According to the prototype view and the exemplar view, people believe that no property is necessary to be a member of a class. The neo-empiricist approach agrees. According to the theory view, entities are categorized as being *x* on the basis of inferences to the best explanation. This view also suggests that categorization decisions are not made on the basis of necessary properties (see the toy examples in Murphy and Medin 1985). Thus, on any of these views of concepts, there is no necessary property for being categorized as alive, and there is little hope to capture categorization decisions about life by means of a definition of life.

Life definitionists could reply that if one puts aside some categorization decisions, one could capture the remaining decisions by means of a definition. Thus, even if

[13] There is a thriving field in developmental psychology that is focused on babies' and toddlers' concept of life (e.g., Johnson and Carey 1998). Evidence suggests that children possess a concept of life that satisfies the theory view of concepts. Even if children do have a theoretical concept of life, they could also have other concepts of life that could satisfy the other views about concepts (Machery 2005, 2009).

[14] It may be that many of them are true (Machery 2005, 2009).

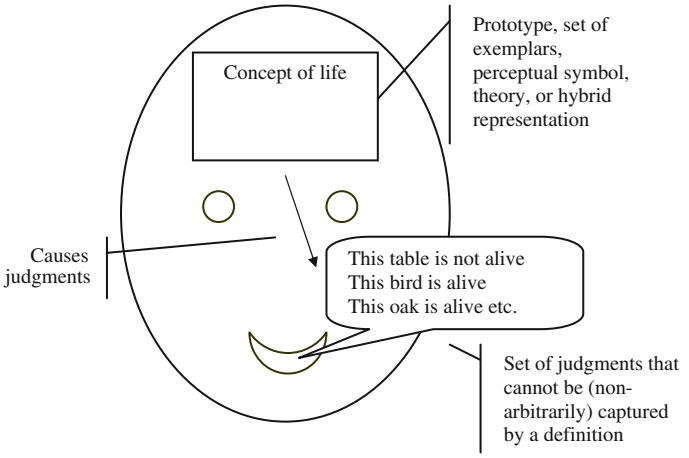

Fig. 3 The first horn of the dilemma

categorization decisions within the class of living beings rest on a prototype, on a set of exemplars, on a theory, or on a perceptual symbol, it may be possible to capture *most* of them, instead of all of them, by means of a definition of life. Although this is in principle possible, this move faces two challenging difficulties. If any of the views presented above is correct, a large number of categorization decisions might have to be excluded for the class of living beings to be definable. The definition that would capture the remaining categorization decisions would probably look arbitrary since it would capture only a small subset of our categorization decisions within the class of living beings. The second problem is even more challenging. There are plausibly many ways of restricting the set of categorization decisions to a definable subset. As a result, one would probably end up with several definitions. Which of them would be the concept of life? How could we choose?

In this section, I have assumed that the notion of life at stake in life definitionism is the folk concept of life. I have argued that if this is the case, the folk concept of life cannot be defined. Figure 3 summarizes the situation.

The first horn of the dilemma leads thus to a deadlock for life definitionists. What about the second one?

4 Second horn: Life as a theoretical concept

If the notion of life is not identified with the folk concept of life, it has to be identified with some theoretical concept within some scientific conceptual framework. This second option seems to be the most promising path for contemporary life definitionists. After all, most of them bring to bear data from biology, from computer science, or from systems theory (Varela et al. 1974) on Schrödinger's question. Thus, finding a definition of life seems to be a scientific investigation. Moreover, many have explicitly recommended this move. Boden (1999) argues that empirical considerations can lead us to sacrifice some folk intuitions about the properties of living beings. Similarly,

Cleland and Chyba (2002, pp. 389–391) argue on the basis of an analogy with the scientific definition of water as H_2O that the definition of life should result from the empirical discovery of the essence of living beings (see also Bedau 1996, 1998; Ruiz-Mirazo et al. 2004). Finally, definitions of life seem to reflect the developments of various sciences in biology (Luisi 1998, p. 613). In this section, I assume that the notion of life is a theoretical, scientific concept. I argue that this path is a dead end for life definitionists.

4.1 Two red herrings

I examine first two seductive reasons for claiming that the second horn of the anti-definitionist dilemma is a dead end. I argue that their appeal is illusory.

First, let's suppose that scientists could provide a theoretical definition of life. One could first object that leaving to an empirical science, say evolutionary biology or molecular biology, or to a science of the artificial, like ALife, the job of defining life is likely to lead to a definition of life that is substantially at odds with the folk notion of life. Since the folk category of living beings cannot be defined (Sect. 3), a theoretical definition would pick out a category that would differ from the folk category. Moreover, empirical sciences often modify substantially the folk categories. For instance, many folk categories of plants, such as the category of lilies, have no place within biology (Dupré 1981). Similarly, the folk category of emotions is divided into various classes by psychology (Griffiths 1997). As a result, one could ask life definitionists whether their proposed definition would really be a definition of *life*. In other words, one could object that instead of defining life, scientists would simply change the topic.

In reply, life definitionists could first emphasize that the radical modification of folk categories by mature empirical sciences is by no means necessary. For example, Atran has argued that most folk animal species are preserved within biology (Atran 1990). Second, life definitionists who embrace the second horn of the dilemma can live with some differences between the folk category of living beings and the scientific one. This is the price to pay if one is looking for an empirical, scientific definition of life. If these differences are minor and do not concern the paradigmatic living beings, the charge that scientists would be changing the topic would be unconvincing. Folk intuitions and definition-based scientific categorization decisions are in fact bound to agree on many cases, particularly on almost all paradigmatic cases of living beings and almost all paradigmatic cases of things. For any scientific definition of life, dogs, cows, birds, fish, insects, plants are bound to come out as living beings. Rocks and cars are bound to come out as things. Thus, the possible discrepancies between the class picked out by the supposed scientific definition and the folk category of living beings would not substantiate the objection that scientists are not defining life, but changing the topic.

Let's turn briefly to a second spurious worry. It could be objected to life definitionism that scientific definitions of theoretical terms are stipulative. Being a simple matter of stipulation, providing a scientific definition of life would thus be pointless since there is little to be learned from stipulative definitions.

This is however to misconceive the nature of theoretical definitions. Theoretical definitions are formulated in order to capture the properties of classes of entities that are assumed to be theoretically important, for example, of natural kinds. They are not stipulative, but descriptive. As such, they can be true or false. Defining "water" as H_2O illustrates this claim. Thus, looking for a definition of life is an empirical enterprise, not a stipulative one.

4.2 An embarrassment of riches

The problem with the second horn of the anti-definitionist dilemma ("the embarrassment of riches") stems from the fact that the term 'life' and the attempts to define life spread over many disciplines. As we saw in Sect. 2, definitions of life have been formulated in evolutionary biology, molecular biology, synthetic biology, astrobiology, research on the origins of life, ALife, and ethics. Across these disciplines, life definitionism is enmeshed within different agendas. Consider ALife and the research on the origins of life. Scientists working on the origins of life are interested in a definition of minimal life, i.e., a definition that applies to the simplest forms of life (Luisi 1998; Szostak et al. 2001). They are looking for a definition of life that is not too restrictive because they want to apply it to the entities they are concerned with (Luisi 1998, p. 617). Advocates of ALife should avoid this type of definition of life. Meeting the requirements posed by a restrictive definition of life—one that applies only to entities that are clearly alive—would justify the most ambitious claims of ALife. Meeting the requirements of weaker definitions would lead to the charge that ALife products are not truly alive. Consider another example. The evolutionary definition of life (Joyce 1994) may be attractive in synthetic biology since, in a lab, scientists can observe whether artificial products are capable of evolving. It is much less attractive in astrobiology, for *in situ* search for life spans over periods of time that are too short for finding evidence of evolution (Chyba and Philips 2001). Moreover, across these disciplines, research often focuses also on different phenomena. Astrobiology is interested in the molecular components of cells for practical purposes: These can be treated as clues for the presence of life on other planets. Of course, ALife pays no attention to them, since it promotes a functional definition of life. Finally, the divergence between definitions of life across disciplines is even more plausible when we move outside science: If it is unlikely that astrobiology and synthetic biology will narrow in on the same definition, there is even less reason to believe that ethical reflections on life and these scientific disciplines will agree on the definition of life (Cho et al. 1999).

One could object that I am exaggerating the differences between the disciplines under consideration. Particularly, the links between synthetic biology the research on the origins of life, and astrobiology are tight. True, but this is of little help. Notice first that even if these three disciplines were to narrow in on the same definition, their definitions could still be at odds with the definitions provided by evolutionary biology, molecular biology, ALife, and, *a fortiori*, ethics. Moreover, it is not clear that these three disciplines will end up with the same definition. Particularly, research on the origins of life focuses on the entities that may have given rise to the forms of life we are acquainted with, and it is not concerned with living beings whose molecular structure

could be entirely different from the molecular, carbon- and protein-based structure of actual living beings. By contrast, astrobiology deals often with such possibilities (Chyba and Philips 2001).

The embarrassment of riches shows that it is unlikely that all the disciplines will converge on the same definition of life. This conclusion is a hard blow for life definitionists who have endorsed the second horn of the dilemma, for appealing to the relevant empirical sciences instead of relying on the folk concept of life was supposed to be the royal path toward *the* definition of life. We are now likely to end up with several definitions of life, which naturally raises the following question: Which of these definitions would tell us what life is?

One could perhaps suggest that the situation is even worse for life definitionism since there is no agreement within each discipline on how to define life. For example, there are many definitions of life within artificial life or within astrobiology. These definitions may be extensionally different, leading to different classification decisions for the same items. However, this problem is in fact far less serious than the problem stemming from the plurality of disciplines since life definitionists could reply that the plurality of definitions within a given discipline is an empirical disagreement that will be resolved with the progress of the given science. Proponents of these definitions agree, for all intents and purposes, on the phenomena to be explained, on the theoretical tools to be used, etc. Thus, there is hope that disagreements within each discipline will be solved. As we saw, the case is different with the plurality of definitions of life across disciplines since different types of phenomena are under consideration, different theoretical tools are used, etc.

4.3 Objections and replies

One could first object that, if living beings are a natural kind, all the disciplines interested in the definition of life will end up with the same definition. It is however unclear whether living beings form a single natural kind since nature rarely yields a unique way of classifying the world. Given that the disciplines under consideration have different agendas and focus on different phenomena, it is plausible that the most useful classification of phenomena—for example, for inductive purposes—will vary across them.

One could also object to my argument that definitions of life are likely to vary across disciplines by noting that there is already a substantial amount of convergence among them. For instance, one finds evolutionary definitions in almost all the disciplines under consideration. This is true. However, it is also true that different definitions tend to be preferred in different disciplines because these disciplines have different agendas. For instance, evolutionary definitions are very popular within ALife (Bedau 1996, 1998), while they are often criticized within astrobiology (e.g., Conrad and Nealson 2001).

Life definitionists could perhaps suggest that our folk concept of life can be used to choose among the distinct theoretical definitions of life that would be found in the disciplines considered in this article. The idea could be the following. Each scientific definition of life is bound to be at odds with our folk concept of life in some respects

(Sect. 4.1). One could thus propose that the theoretical definition that is extensionally the less at odds with our folk notion of life is *the* definition of life. However, this solution is likely to fail. It is plausible that the distinct scientific definitions of life would disagree on cases that are neither clear cases of living entities nor clear cases of things according to the folk concept of life. If this were the case, appealing to the folk concept of life would not be useful. Furthermore, it is unclear whether using the folk concept of life would lead to an unambiguous ranking since all the assumed scientific definitions of life could differ from the folk concept of life in an equal measure. Finally, it is not straightforward to justify this appeal to the folk concept of life: If we are in the business of defining life scientifically, why would the definition that is the closest to an inadequate concept be *the* definition of life?

Life definitionists could also suggest conjoining the theoretical definitions developed by the sciences interested in the definition of life: x is alive if and only if it satisfies all the scientific definitions. The intersection of the classes denoted by these definitions is not empty since the scientific definitions have to agree on the paradigmatic living beings. However, this move is not satisfactory since the scientific definitions might agree only on the entities that are recognized to be alive by the folk. The resulting definition of life would be of no use to solve the problems that have motivated life definitionism. Moreover, conjoining the definitions is tantamount to producing a new, more stringent definition. This would simply worsen the embarrassment of riches: Why would we prefer this definition to any of the component definitions?

Alternatively, life definitionists could suggest disjoining these definitions: x is alive if and only it satisfies one of the scientific definitions. This is prima facie a seductive move, but it will not do. Disjoining the definitions is also tantamount to producing a new, less stringent definition, worsening again the embarrassment of riches. Moreover, in one sense, this would be conceding the main point of the section since one would thereby acknowledge that, because of the plurality of disciplines that have an interest in definition of life, one cannot provide a set of properties that are independently necessary and jointly sufficient for being alive.

Finally, life definitionists might grant that different sciences will end up with different definitions of life, while arguing that this is not a serious problem. As we saw in Sect. 2, the definition of life is often supposed to be instrumental in solving various scientific issues—the vagueness issue, the essentiality issue, and the direction issue—and also several ethical issues. If we really end up with several intensionally and extensionally different definitions, one could suggest (as does, e.g., Agar 1997) that to solve the problems raised in ALife, one should use the definition of life upon which scientists in ALife will in principle converge (*mutatis mutandis* for the other relevant disciplines). While I am sympathetic with this move, I note that relying on discipline-specific definitions is tantamount to conceding the main point of this section: There is no way to decide between distinct definitions of life. Figure 4 summarizes the situation.

To conclude, the second horn of the anti-definitionists dilemma is also a deadlock for life definitionists. If the notion at stake in the project of defining life is a scientific concept, while one may be able to define life, one is likely to end up with several extensionally different definitions of life. And there is no way out of this embarrassment of riches. The conclusion is straightforward: However the notion of life is

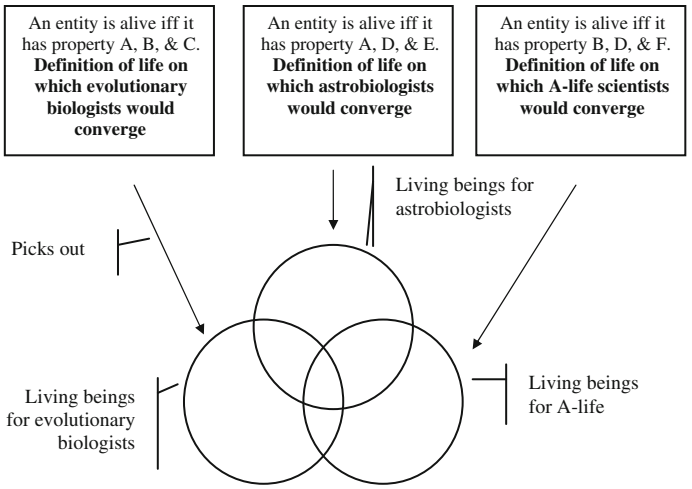

Fig. 4 The second horn of the dilemma

viewed, the prospects for life definitionism are poor. Defining life is either impossible or pointless. It would be better to discard life definitionism.

5 Conclusion

Life definitionism is thriving these days. In several disciplines—astrobiology, synthetic biology, research on the origins of life, and ALife—it is often believed that a definition of life would solve three central challenges: the vagueness issue, the essentiality issue, and the direction issue. The progresses of evolutionary biology and molecular biology have led some scientists to believe that a definition of life could be reached. Several issues in ethics have also prompted searching for this definition. Various definitions, often based on a mishmash of scientific considerations and of intuitive judgments, have been proposed. No agreement has been reached; far from it.

I have argued that this is no accident. Life definitionists have too often been careless: They have constantly mixed folk intuitions with scientific considerations. However, they have to decide whether the notion of life at stake is the folk concept of life or a scientific concept. In the first case, there is little hope of finding a definition of life since, like most folk concepts, the folk concept of life is not a definition, and it is unlikely to yield a set of intuitive judgments about what is alive that can be captured by a definition non-arbitrarily. In the second case, life can perhaps be defined. However, because the study of life spreads over several disciplines, life definitionists are likely to end up with several, intensionally and extensionally different definitions of life without having any means to choose between them. Defining life is then likely to be pointless.

This conclusion raises an obvious issue. In several disciplines, scientists have tied, more or less strongly, their research projects to life definitionism. If scientists ought to

discard life definitionism, what about these research projects? Should we discard them too? This is an intricate issue that cannot be adequately dealt with in this conclusion. It is sufficient to notice that scientists' and philosophers' belief that a definition of life was required by these projects might be a mistake. If this were the case, discarding life definitionism—as I recommend—would be painless.

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