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What Is the Folk Concept of Life?

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ABSTRACT
This paper details the content and structure of the folk concept of life, and discusses its relevance for scientific research on life. In four empirical studies, we investigate which features of life are considered salient, universal, central, and necessary. Functionings, such as nutrition and reproduction, but not material composition, turn out to be salient features commonly associated with living beings (Study 1). By contrast, being made of cells is considered a universal feature of living species (Study 2), a central aspect of life (Study 3), and our best candidate for being necessary for life (Study 4). These results are best explained by the hypothesis that people take life to be a natural kind subject to scientific scrutiny.

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KEYWORDS experimental philosophy; living being; biology; cells; natural kind; salient vs. universal features

1. Introduction

What is life? That is, what is characteristic of living beings such as cats, trees, and mushrooms, in contradistinction to rocks and rockets? This question is by no means new to philosophers, but in the past few decades it has received increased attention from scientists and ordinary people alike, due to the discovery of planets beyond our solar system. The natural question arising from these discoveries—Do these exoplanets host life?—can only be answered if we have a general idea about what life is.

It is no surprise, then, that the last few years have seen a number of new proposals for how best to define life (for example, Ruiz-Mirazo et al. [2004] and Bedau [2010, 2012]). But, instead of approaching a consensus, the field looks more divided than ever. This has to do with the relative ease with which actual or possible counterexamples can be produced (see, for example, Bedau [2010, 2012] for such a diagnosis).

Perhaps, though, there is a deeper reason for the continued disagreement. One possible explanation is that the concept of life is 'messy' and eludes definition in terms of necessary and sufficient conditions. In this vein, Pennock [2012: 5] claims that 'life is a cluster concept with fuzzy boundaries'; he draws on Wittgenstein's notion of family resemblance to make sense of the notion of life. According to Machery's even more pessimistic assessment [2012], our current theories on the formation of folk concepts imply that our folk concept of life cannot be defined. Another possible diagnosis of the widespread disagreement is that different authors adopt or assume different standards against which a proposed definition of life must be measured.

[1] This work is fully collaborative.

For instance, the question of what life is can be understood as a question about the folk concept of life, but it can also be interpreted as a scientific question, requiring a more precise and substantial answer (see, for example, Cleland [2012]). There is also the possibility that the question urges an explication à la Carnap (Beisbart [2017]; see Carnap [1950] on explication).

Whatever the aim of a particular definition of life, the folk concept of life (henceforth: the concept of life) is crucial for answering the question of what life is. This is obvious if the question is construed as asking for the content of the concept of life. But even if the question is meant more substantively, or is intended to prompt an explanation of the hallmarks of life [Bedau 2010], understanding the concept of life is vital because it helps to delineate the topic on which more information is requested. If the question is understood to demand a Carnapian explication of life, one important requirement is similarity to the existing concept of life. Furthermore, explication needs to be prepared by an appropriate appreciation of the content of the familiar concept [Shepherd and Justus 2015].

Accordingly, we find many references to the folk understanding of life in the literature on what life is, be they implicit or explicit (cf. Machery [2012: 147–8]). But, in the philosophical literature so far, most claims about the concept of life are based simply upon the authors' intuitions and not supported by any empirical evidence. The aim of this paper is to study the concept of life empirically. Our experiments, which employ a variety of methods, suggest that the concept of life is not as messy as has been suggested; rather, to most participants, a particular material constitution seems to form the essence of life.

As far as we can tell, almost no one until now has experimentally studied the folk concept of life in adult populations. As Kerbe notes, 'Research on adult populations on the living-nonliving and on the animate-inanimate distinction is a rare endeavor' [2016: 121]. Empirical work has rather focused on related but different concepts or on different population samples. For instance, some researchers have studied how ordinary folk make distinctions *within the broad class of living beings* to classify them (for example, Atran [1998]). Very recently, there has been empirical work on the concept of life, as understood by *researchers from biology*—namely, an interview-based study by Fernau et al. [2020] and a corpus study by Malaterre and Chartier [2021]. In developmental psychology, there is a long-standing interest in *children's* biological thinking and their understanding of life, at least since Piaget [1929]. An important issue in the background of this strand of research seems to be the question of whether, and in which sense, children's thinking is animistic (in anthropology, there is a parallel, and controversial, issue concerning animism in non-Western societies: see, for example, Forth [2018]; see also Tao [2016]). But findings on children's understanding of life cannot be extended to adults because empirical results suggest fundamental conceptual change during childhood and youth [Carey 1985]. Occasionally, though, developmental research has touched upon adults. For instance, the experiments of Inagaki and Hatano [1993] demonstrate that humans increasingly prefer mechanistic explanations of biological phenomena to intentionalist or vitalistic ones when they grow older (see also Inagaki and Hatano [2004]). Nevertheless, as far as we know, it is only Kerbe [2016] who explicitly turns attention to adult humans from Western societies when conducting interviews and observing focus group discussions. Regarding the concept of life, his main finding is that the most oft-used criteria in definitions of living beings are functionings of living beings, such as motion, change, and growth. Our methods are different and can distinguish between different kinds of features relevant to the notion of life. We will return to Kerbe's findings in due course.

In the last few years, many other concepts have been studied by using experiments, including the concepts of intentional action (for example, Knobe [2003]) and free will (for example, Nichols and Knobe [2007]). The concept of life is quite different from these other concepts, however, because there is a long history of scientific research on life. It is thus possible that findings from biology have had an impact on the folk concept of life. By contrast, concepts like that of intention have probably not been influenced by scientific findings; research that might ultimately affect our understanding of intentions is of much more recent origin, and its significance for the folk concept of intention is still debated. Naturally, then, we want to know to what extent the concept of life has been shaped by findings in biology. Our study also contributes to answering this question.

The paper is organised as follows. We start in section 2 by reviewing some proposed definitions of life. Given that they have been criticised as failing to list necessary and jointly sufficient conditions, we suggest allowing that the concept of life may be described by using salient, universal, and central features. Such features are studied in our four experiments, the results of which we discuss and present in section 3. In section 4, we summarise our findings and defend our main proposal—to wit, that ordinary people think of life as a natural kind with a distinct set of salient features and an underlying essence often cashed out in terms of organic material.

2. Life, its Features, and their Attributes

By now, the attempts to answer the question 'What is life?' form a venerable tradition (see Bedau and Cleland [2010] for an anthology). Aristotle, in *de Anima* [412a], characterised life as having 'through itself nourishment, growth, and decay' [350BC/2016: 22]. In the twentieth century, Erwin Schrödinger [1944] devoted a book to the question, one central idea being that life absorbs negative entropy. An oft-quoted answer was, more recently, given by NASA: 'life is a self-sustained chemical system capable of undergoing Darwinian evolution' (for example, Joyce [1994: xi]). An even more recent answer comes from Dupré and O'Malley [2009: 1] who propose that 'life arises when lineage-forming entities collaborate in metabolism' (see Trifonov [2011] for a statistical investigation of definitions of life). Although the details differ greatly, most definitions of life list one or more features of the following types to characterise life:

- functionings: things that living beings do or can do (for example, reproduce, grow, take up nutrition, move around);
- material building blocks (for example, molecules from organic chemistry, cells);
- organization (for example, complexity, integration through organs with characteristic functions);
- laws to which life is subject (for example, the principles of evolution).

So far, however, no definition of life has inspired widespread agreement. A very common type of criticism provides counterexamples to a proposed definition: critiques following this strategy accuse a given definition of misclassifying a real or clearly possible being as alive when it is not (or vice versa). This failure is taken to demonstrate that the functionings listed in the definition are not necessary or not jointly sufficient.

For instance, a definition that takes living beings to be constituted of organic molecules, as they are studied in organic chemistry, does not accommodate the possibility of living beings that have compounds of silicon as their material basis. It is thus subject to the charge of 'carbon chauvinism' [Sagan 2000: 46], and hence to the objection that this feature (being carbon-based) is not necessary for life. Likewise, a definition that requires living beings to be subject to the principles of Darwinian evolution might be too exclusive because the earliest forms of life might not have been subject to these principles [Cleland 2019: 42]. By contrast, proposals that define life in terms of functionings face counterexamples of the other type: robots do the same kinds of things, or might do so in the near future. Since robots are generally not taken to be alive (this attitude, of course, might change very quickly), they show that the features listed fail to be jointly sufficient (see Cleland [2019: ch. 2] for a criticism of famous definitions of life). In view of such counterexamples, Chyba and McDonald [1995: 216] conclude: 'It is now a commonplace that the various proposed definitions virtually all fail'.

Now, it is not uncommon for attempts to define a concept to fall prey to counterexamples. According to Cleland, analysing a concept in terms of necessary and jointly sufficient features is only possible for concepts that reflect our interests [2019: 389–90]. For Machery [2012: 153–5], psychological theories of concepts (for instance, the exemplar view) imply that folk concepts defy definition in terms of necessary and sufficient features.

Philosophers have offered various proposals on how concepts might be organised or structured beyond the traditional model of necessary and sufficient features. Unsurprisingly, some of these proposals have been identified as applicable to the concept of life and the related term 'life'. For instance, Shields [2012] proposes that 'life' is a core-dependent homonym—that is, a term that has several distinct (but related) meanings that cluster around one central idea. Appeal to Wittgensteinian family resemblances is an alternative way to account for 'messy' concepts, and, as mentioned above, we find this appeal in Pennock [2012], albeit regarding the scientific concept of life. A related strategy permits the account of a concept by using several features that tend to go together but need not always do so (see Diéguez [2013] for such a proposal, again related to the scientific concept of life).

A related insight is that features failing to be necessary and jointly sufficient might still be worth considering when we want to describe the concept. The crucial idea is that the features carry attributes other than necessity and sufficiency. In this vein, *saliency*, *universality*, *typicality*, and *centrality* have been proposed as attributes (of features) that in fact guide our thinking and that might be more important than necessity and sufficiency.

A feature is considered *salient* if it stands out from other features in our representation of a kind due to motivational or other cognitive factors. We thus use salient features to distinguish objects falling under a concept from other types of things. For example, producing engine noise is a salient feature in our representation of cars because it is a striking aspect of cars, one that most other objects do not have. Producing engine noise happens also to be a *typical* feature of cars because most cars produce engine noise. Note, however, that saliency and typicality can come apart. For instance, being comfortable to sit in is perceived to be a typical, but not salient, feature of a car, whereas going very fast might be salient but not typical.

If a feature is taken to hold for all tokens of a kind, then we call it *universal*. Universality is a prerequisite for necessity: if a feature, like the uptake of nutrition, does not hold for all actual species of life, then it cannot be a necessary condition for life. The converse conclusion does not follow: even if every actual life form takes up nutrition, taking up nutrition might not be a necessary feature for life.

Many scholars now believe that our concepts encode not only information about typicality and saliency, but also about whether and how these features are understood to depend on each other [Sloman et al. 1998; Hampton 2006; Del Pinal et al. 2017]. For example, the concept of a car carries information that occupants' comfort depends on the car's having seats. A feature is called *central* if many other features are thought to depend on it. For instance, having four wheels is a central feature in our representation of cars because going fast, being safe, being stable, etc. are taken to depend on it.

The connection between centrality and necessity is less straightforward than the one between universality and necessity. In principle, a feature can be central without being necessary,[1] and necessary without being central.[2] The connection is tighter, though, for concepts of natural kinds: as theoretical discussions on the structure of concepts have emphasised, natural kinds like water and tigers are conceived of as having essences [Keil 1989; Gelman and Wellman 1991; Hampton 2006]. These essences consist of features that are highly central and are usually considered necessary for the accurate application of the concept. For instance, many features of water depend on its having H_2O molecules. And, famously, having H_2O molecules has been argued to be necessary for being water ([Putnam 1975], but see Tobia et al. [2020]).

There are, then, at least three reasons why we should investigate the saliency, typicality, universality, and centrality of various features relevant to the concept of life. First, features that have these attributes guide our thinking about life in various important ways and are thus crucial for understanding the concept of life. Second, by finding out which features of life are universal and central, we will be able to make inferences about the necessary conditions for life. Third, investigating differences among features with regard to saliency, universality, and centrality might provide vital information about the structure of the concept of life—that is, whether we conceive of life classically (with necessary and jointly sufficient conditions), prototypically (encoding statistical information about which features living beings tend to have), or as a natural kind (with salient features on the one hand, and an essence on the other).

To find out what features are encoded in a concept and what their attributes are, an empirical investigation is needed. Psychologists have developed tasks that allow us to empirically determine how salient, universal (or typical), and central various features are conceived to be in our conceptual representations of kinds. And the method of cases that philosophers have used for a long time to identify the necessary conditions of concepts can also be used in experiments. We therefore turn now to our experimental studies.

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[1] Having a seat is a central feature of a chair. Without a seat, you cannot sit on it, it is not comfortable, etc. But having a seat is not necessary for being a chair. Chairs can have their seats taken off and remain chairs.

[2] Being male is a necessary feature of being a bachelor. But being male is not central. Being unmarried and young do not depend on being male.

3. Empirical Studies

In Study 1, we use a semantic feature production task to examine which features of life are considered salient by ordinary people. The results also serve to select features for the subsequent studies. We use frequency estimates to measure universality (and typicality) in Study 2. In Study 3, we use the surprise paradigm proposed by Sloman et al. [1998] to identify the level of centrality of various features of the concept of life. Last, we investigate which features might be necessary for life by using the method of cases (Study 4).

3.1 Study 1: Saliency

In Study 1, we aimed to determine the salient features that laypeople associate with the concept of life. We used a semantic feature production task because participants, when confronted with such a task, standardly name features that are highly salient to them for the application of a concept. For instance, common features that people name when given the term 'tiger' include 'striped', 'roaring', 'hunting', etc. These features are neither necessary nor universal, but are useful for distinguishing tigers from other animals (for further discussion, see Cree and McRae [2003] and McRae et al. [2005]).

3.1.1 Methods

In this and our subsequent experiments, we used the following pre-selection criteria: Approval Rate of at least 90% on previous studies on Prolific, Native Language English, Age ≥ 18. In all of our experiments, participants were first asked to pick what they considered to be living beings from a list of entities presented in random order. The list consisted of some paradigmatic examples of living beings (earthworms, humans, trees, white mushrooms), borderline and less clear cases (viruses, robots), and clear examples of things that do not live (chairs, stones, the moon). The point of this question was to make the participants aware of the broad range of living beings.

In Study 1, 102 participants (65 female, 36 male, 1 non-identified), $M_{age} = 32.39$ (SD = 11.60), were recruited on Prolific and randomly assigned to two different versions of a semantic feature production task.[3]

- First version. 'Which features are characteristic of species of living beings? You can name up to three features.'
- Second version. 'Which features do you think distinguish species of living beings from non-living entities?'

Here and in what follows, we requested that participants consider species rather than individuals. The underlying idea is that the concept of life has to cover a broad range of different species of living beings, and the fact that some species have considerably fewer members than others should not influence how we think about any species. Also, when it comes to universality (see Study 2 below), frequencies among species of living beings are more easily estimated than frequencies among individual living beings.

In the semantic feature production task, the participants could list up to three features. Almost all participants wrote down three features. We categorised 216 out of 286

[3] Note that there is no settled and prescribed phrasing for collecting the semantic features of concepts.

Table 1. Responses of the first 15 participants to the semantic feature task. We used eight categories to classify the responses: breathing, cells (no response among the first fifteen participants), evolution, growth, movement, nutrition, perception/consciousness, reproduction. In the online repository (see the link at note 5), a fully colour-coded table with all responses can be downloaded.

Participant	1st Feature	2nd Feature	3rd Feature
Person 1	Evolution	Growth	Energy processing
Person 2	… able to procreate …	… able to make energy	
Person 3	Growth		
Person 4	Evolution	Movement	Reproduction
Person 5	Eating	Growing	Reproducing
Person 6	Growth	Multiplication	
Person 7	Nutrition	Excretion	Growth
Person 8	breathing	taking in food	growing
Person 9	move	breath	grow
Person 10	Feel	Experience emotion	Breathe
Person 11	Able to die	Require resources …	Can grow/multiply
Person 12	Movement	Breathing	Temperature
Person 13	Develops	Grows	Changes
Person 14	growing	reproduction	adaptive
Person 15	Grow	Respire	Reproduce

responses into the following eight categories: breathing, cells/material, evolution, growth, movement, nutrition, perception/consciousness, and reproduction. The remaining 70 responses were not categorised because they mentioned things that happen to living beings (for instance, 'they die', 'birth'), referred to specific parts of the body (for instance, 'blood', 'brain'), named specific species (for instance, 'lizards', 'homo sapiens'), were too vague to be classified (for instance, 'purpose', 'natural', 'changes'), or were otherwise disqualified.

3.1.2 Results and Discussion

Table 1 lists the responses of the first 15 participants in the first version of the semantic feature production task to illustrate the way that the participants responded to the task, as well as how we categorised those responses.[4]

The results depicted in Figure 1 show the fraction of participants who responded with features belonging to the eight categories averaged over both versions of the semantic feature production task. There were no major differences ($\Delta > 10\%$) in the number of responses between the two versions (with the exception of reproduction), demonstrating the robustness of the task (the first number in brackets indicates percentages retrieved in the first version, the second number the percentages of the second version): breathing (42%, 50%), cells (6%, 14%), evolution (12%, 6%), growth (44%, 50%), movement (17%, 14%), nutrition (27%, 34%), perception/consciousness (10%, 14%), reproduction (44%, 26%).

The responses were most frequently classified into the categories of growth, breathing, reproduction, and nutrition. All of these are things that living beings do at the level of a whole living being, and most of these features are observable for many life forms. By contrast, at least typically, non-living beings do not reproduce or take up nutrition, which makes them easily distinguishable from living beings. Other features, such as being subject to evolution and being made of cells, cannot be directly observed, and

[4] For the complete dataset, criteria for categorization, and the actual categorization results, please go to the online repository at https://osf.io/rn679/?view_only=5ab6d7ca417a43a1bc6b037334ea27df

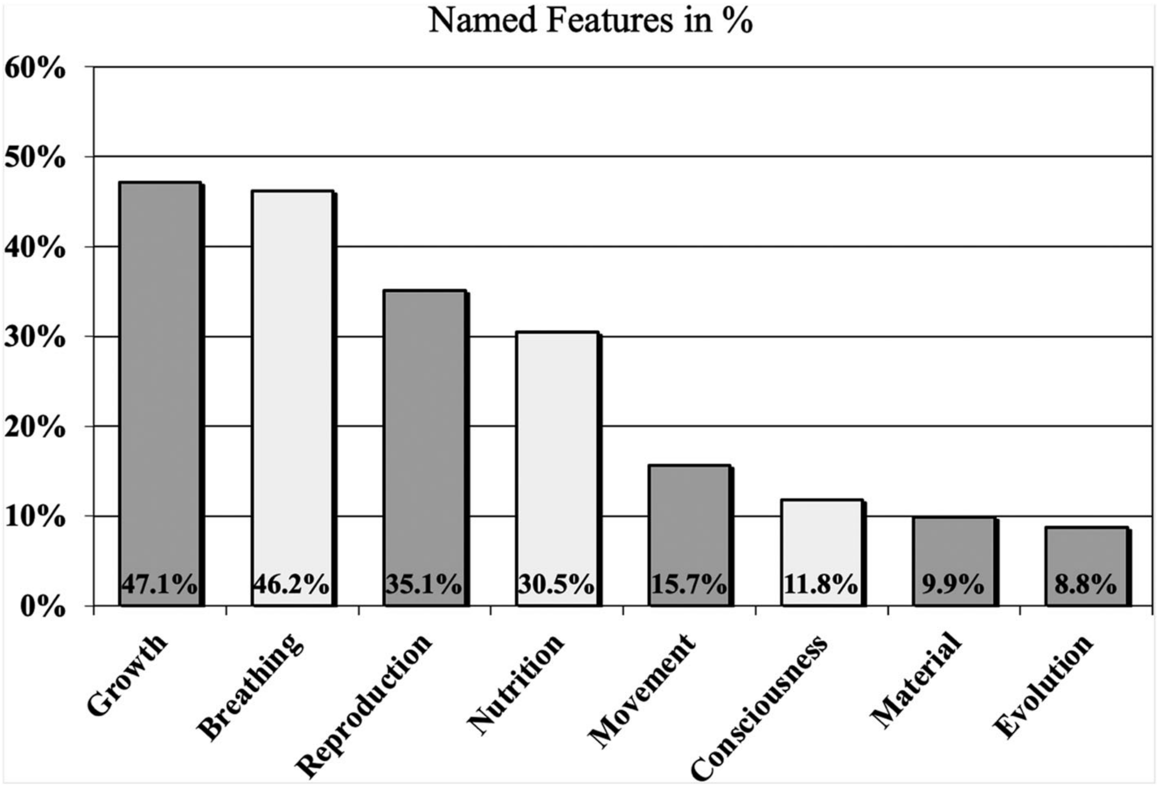

Figure 1. Most frequently named features of life as revealed in Study 1. Frequency is measured relative to people. Thus, 47.1% of people named growth as a feature.

so it is natural that they are not so often mentioned. Some of the features named most often are reminiscent of features often mentioned in prominent definitions of life: in particular, nutrition and growth feature in Aristotle's definition of life. Categories that draw on insights from biological research (for instance, cells or evolution) appear much less frequently. All in all, our experiment shows that people associate 'meso-scopic features' of whole living beings with the idea of life (here, the meso-scale is the scale at which we observe things and influence them), and people's answers are often biased towards humans or at least mammals.

3.2 Study 2: Universality

In Study 2, we investigated whether there are any features that people consider to be universal features of life. If a feature is considered to be universal, then that feature is understood to hold for all species of life. To measure universality, we asked participants to estimate how frequently a feature appears among the species of living beings.

3.2.1 Methods

In Study 2 and the subsequent Study 3, we investigated the following features: (a) autonomous movement, (b) consciousness, (c) growth, (d) nutrition, (e) reproduction, (f) perception, (g) made up of organic matter, (h) made up of cells, (i) being complex wholes made up of interacting parts, (j) subject to evolution by natural selection. These ten features were selected either because they were named by a substantial number of participants in the semantic feature production task ((a)–(f)), or because they are crucial features ((g)–(j)) according to definitions that have been proposed and discussed in the literature. Obviously, this list is not exhaustive. An additional selection criterion was the exclusion of those features that are difficult to understand for many laypeople. Schrödinger's [1944] proposal that life absorbs negative entropy and Dupré and O'Malley [2009]'s suggestion that life arises when lineage-forming entities collaborate in metabolism, are, unfortunately, likely to meet that criterion.

We considered two different descriptions of the material building blocks of living beings (namely, (g) and (h)) to appropriately trace the important idea that living beings are made up of a certain kind of stuff. In section 4, we will comment on the difference between the wordings. As a matter of fact, our results for organic matter and cells differ only slightly.[5]

We recruited 127 participants through Prolific. Of the initial recruits, 56 participants (30 female, 25 male, 1 non-binary), $M_{age} = 31.07$ ($SD = 10.29$), met the inclusion criteria specified below. The experimental design, predictions, and statistical tests of Studies 2 and 3 were pre-registered with the Open Science Framework.[6] Three control questions were asked before the test questions. These were as follows.

(1) 'Which of these entities live? (Please tick as many options you think appropriate).' A selection of animals, plants, and (presumably) non-living objects were given (see also Study 1).
2. 'What percentage of species consist of living beings that are made of atoms?'
3. 'What percentage of species consist of living beings that can do complex mathematical calculations?'

Questions 2 and 3 served as exclusion criteria. Participants who did not give an answer of at least 90% to Question 2 and at most 10% to Question 3 were excluded from further analysis (note that these criteria were not set after data collection but were also preregistered). These participants were likely to (a) wrongly interpret the question about 'species of living beings' as a question about living individuals (there are few species of living beings that can do complex mathematical calculations, but some of them have many members), (b) think too human- or mammal-centrically, or (c) entertain a worldview that either denies our current scientific knowledge about living beings (for example, by assuming that even bacteria can do complex mathematical calculations) or allows for the existence of entities (deemed living beings) not considered within science (for example, angels).

While related conceptions of life are certainly worthy of investigation, in this study we aimed to track the nature and structure of a conception of life that is, at least to some approximation, the subject studied by contemporary biological science. Indeed, participants who indicated that they identified with a Christian religion were more likely to fail the inclusion criteria.[7] The original sample consisted of 38% Christians, 27% Atheists, 17% Agnostics, and 18% Other. The final sample had a different make-up: 27%

[5] Our descriptions of those features that are functionings are vague. First, this is because it is open whether we mean things that living beings do often, do regularly, can do, or can do in certain parts of their lives. Second, it's not entirely clear in what some functionings (e.g. taking up nutrition) actually consist. For our experiments, we decided not to clarify things further, so as to keep the text of the vignette easily comprehensible.
[6] See https://osf.io/ch5wp/?view_only=2808fb9ab7264e1995e68cd2b25f5b49
[7] This is in accordance with observations by Kerbe [2016]. In his study, participants classified as esoteric and participants from a Catholic University tended to characterise life by using different terms than did people from other groups.

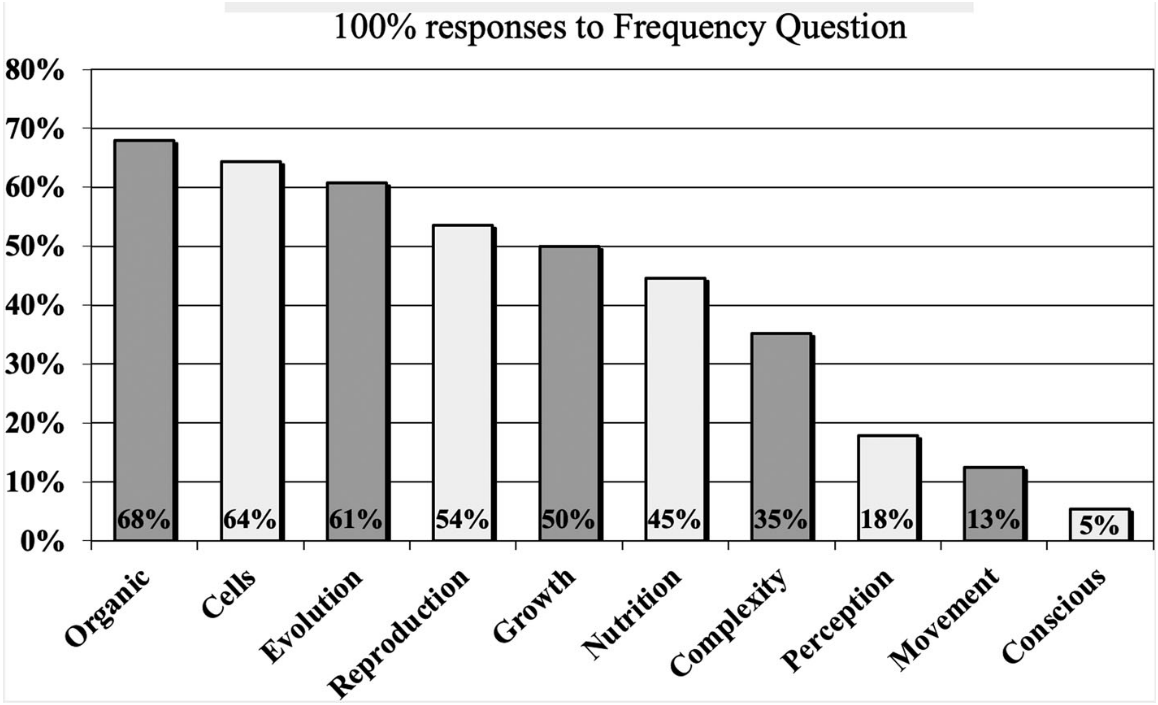

Figure 2. Percentage of participants who think a certain feature is universal (that is, who responded with 100% in relation to a given feature's frequency).

Christians, 32% Atheists, 30% Agnostics, and 11% Other. Similar effects of the exclusion criteria have also been observed for Studies 3 and 4. To make transparent how the exclusion of those participants affected our results, we have in each results section separately reported the outcomes of the studies when *all* participants are included.

We are aware that putting such exclusion criteria in place is not without problems, especially if the aim of our empirical studies is to investigate the 'folk' concept of life. Furthermore, our recruitment of native English speakers through Prolific raises questions about whether our results can be generalised to other populations or are likely to hold only for WEIRD people [Henrich et al. 2010]. Whereas empirical studies have investigated conceptions of life in non-Western societies (for example, Tao [2016]), cross-cultural as well as cross-linguistic studies on the folk concept of life could put our studies into a wider perspective.

All participants rated the perceived frequency of ten different features (presented in randomised order) among all species of living beings. Specifically, we asked, 'What percentage of species consist of living beings that [feature]?' People's answers were measured on a scale ranging from 0% to 100% in steps of 1%.

3.2.2 Results

A repeated-measures ANOVA was carried out. Responses to the various features turned out to be significant ($F(6.674, 367.084) = 33.72$, $p < 0.0001$, $\eta^2 = 0.38$). Figure 2 shows the number of participants (in %) who chose 100% for a given feature.[8]

[8] When the exclusion criteria were not applied, the percentages of participants who responded with 100% was substantially smaller for certain features: *organic material* (49.2%), *cells* (51.6%), *evolution* (39.1%), *reproduction* (40.6%), *growth* (43.8%), *nutrition* (40.6%), *complexity* (21.9%), *perception* (16.4%), *movement* (7.8%), *consciousness* (4.7%).

We conducted Pearson's χ^2-tests to investigate which features yielded 100% as a response from significantly more than half the participants. For the features *organic material* ($\chi^2 = 14.286$, $p < 0.001$), *cells* ($\chi^2 = 9.143$, $p = 0.002$), and *evolution* ($\chi^2 = 5.143$, $p = 0.023$), a significant majority indicated that these features are universal—that is, that these features appear in living species with a frequency of 100%. The features *reproduction* ($\chi^2 = 0.571$, $p = 0.450$) and *growth* were considered universal by around 50% of the participants, but not by a significant majority.

3.2.3 Discussion

Whereas the purpose of Study 1 was to uncover the most salient features in our conception of life, Study 2 aimed to investigate whether some features are considered to be universal features of life. While organic composition, examined via the two features *cells* and *organic matter*, played hardly any role in establishing the salient features of the concept of life, it was considered to be a universal feature of life for around two-thirds of the participants in Study 2. In contrast, reproduction, growth, and nutrition were each deemed universal among species of living beings by only about half of the participants. As our discussion about the connection between necessary and universal features suggests, we cannot conclude from our data that two-thirds of the participants consider organic composition to be a necessary feature of life. We can, however, infer that organic composition is, thus far, the best candidate to count as a necessary feature of the folk concept of life, given that only universal features can also be necessary features.

3.3 Study 3: Centrality

The conceptual centrality of a target feature indicates how many and how strongly other features are perceived to depend on the target feature. We decided to measure centrality by using the surprise paradigm, proposed and investigated by Sloman et al. [1998].[9] For this purpose, participants were asked to rate how surprised they would be to find out that there is a species of living beings that does not have a particular feature.

3.3.1 Methods

We recruited 129 participants through Prolific. 64 participants (36 female, 28 male, 0 non-binary), $M_{age} = 30.25$ (SD = 10.06), passed the inclusion criteria (see Methods section of Study 2 for details). After the control questions, all participants were serially presented with all ten features in randomised order. For each feature, we asked, 'How surprised would you be to find out that there is a species of living beings that does not have [feature]?' People's answers were measured on a 7-point Likert scale ranging from 'Not at all surprised' to 'Extremely Surprised'.

3.3.2 Results

All mean surprise ratings are depicted in Figure 3. A repeated-measures ANOVA with DV CENTRALITY and independent variable FEATURES (all ten features) was conducted ($F(7.246, 456.517) = 27.25$, $p < 0.001$, $\eta^2 = 0.30$). We conducted planned

[9] The surprise paradigm has been shown to deliver reliable results on the centrality of features for a wide range of concepts [Ahn 1998].

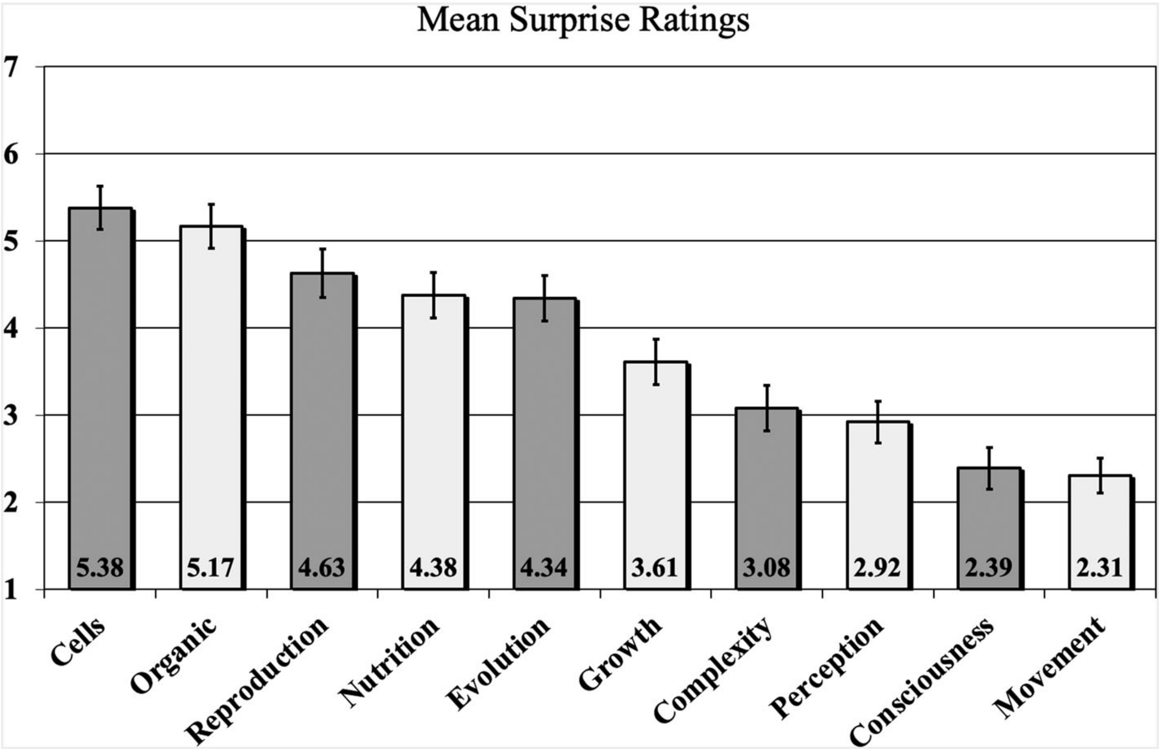

Figure 3. Average results for the centrality question for all ten tested features. Error bars indicate standard error around the means.

t-tests to investigate whether the average results for the selected features were significantly higher than the midpoint of 4. Only *organic material* ($t(63) = 4.72$, $p < 0.001$), *cells* ($t(63) = 5.49$, $p < 0.001$), and *reproduction* ($t(63) = 2.21$, $p = 0.031$) were significantly above the midpoint. *Nutrition* ($t(63) = 1.44$, $p = 0.156$), *evolution* ($t(63) = 1.34$, $p = 0.186$), and *growth* ($t(63) = -1.52$, $p = 0.134$) were around the midpoint but not significantly above it.[10]

We also examined whether the average values for *organic material* and cells were significantly higher, compared to those for *reproduction*, *nutrition*, and *evolution*. While the average ratings for *organic material* and *cells* were not significantly different from each other ($p = 0.373$), *organic material* was significantly higher than *nutrition* ($p = 0.011$) and *evolution* ($p = 0.001$), but not *reproduction* ($p = 0.105$), and *cells* was significantly higher than all three features: *nutrition* ($p = 0.001$), *evolution* ($p = 0.001$) and *reproduction* ($p = 0.036$).

3.3.3 Discussion

The centrality results show that cells and organic matter are the most central features of the concept of life: that is, of all features tested, organic material seems to be the one upon which most other features depend. Reproduction was the only other feature that participants considered to be a central feature of the concept of life. For all other features, the ratings were not significantly above the midpoint. The results suggest that material

[10] The average results were not significantly different from those for all participants (i.e. when the exclusion criteria were not applied) for the features *cells* (5.20 for all participants), *organic material* (4.91), *reproduction* (4.42), *nutrition* (4.41), *evolution* (4.38), and *growth* (3.75), *complexity* (3.55), and *perception* (3.22), all ps > 0.05. The mean values among all participants for *movement* (3.07) and *consciousness* (2.95), however, were significantly higher and closer to the midpoint than for the selected participants.

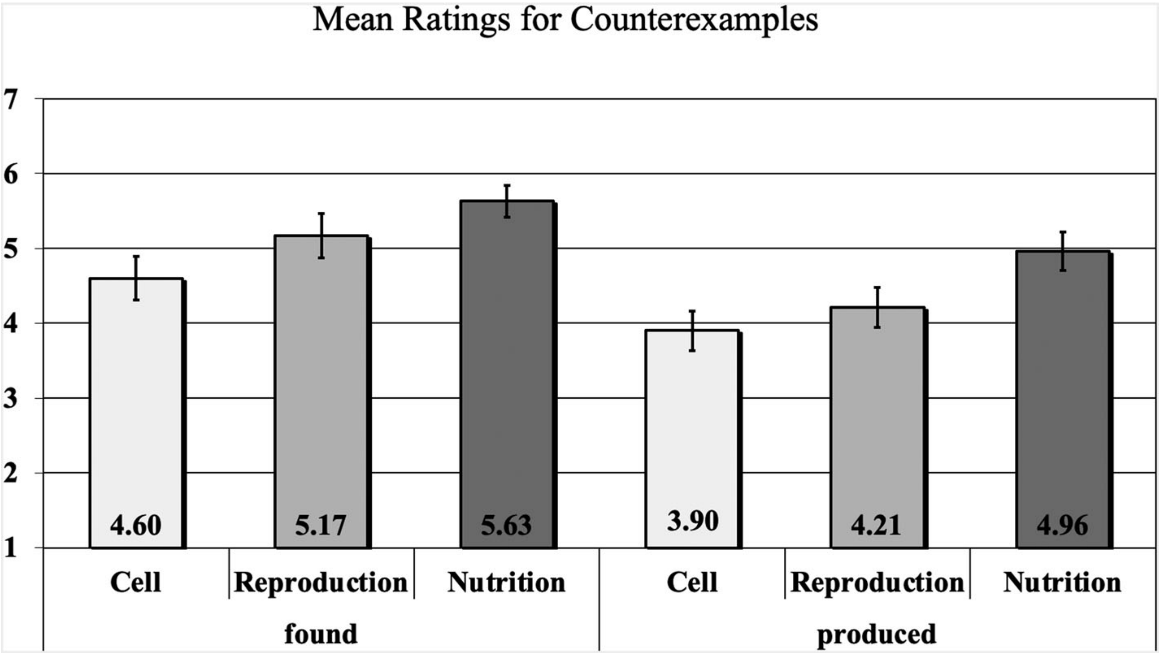

Figure 4. Mean values for the six conditions tested in Study 4.

composition plays a special role in our concept of life, similarly to the role that H_2O plays in the concept of water. Before we elaborate on this possibility, we present our last study, the goal of which was to investigate more directly the necessity of features.

3.4 Study 4: Necessity

Study 4 used classic-style vignettes to examine whether people believe one of the three following features to be necessary for life: (i) being made of cells, (ii) reproduction, (iii) nutrition uptake. More specifically, we tested people's intuitions on whether entities are living beings when lacking exactly one of these three features. We chose these three features because each scored relatively high in our universality and centrality studies; additionally, many scholars have identified these as necessary features of life.

Given that 'being made up of cells' was considered to be a universal and central feature of the concept of life, the main hypothesis of this study was this:

> **Necessity Hypothesis**. People agree less to the proposition that entities are living beings when they are not made of cells, compared to when these entities do not reproduce, or do not take up nutrition.

3.4.1 Methods

For this study, 523 participants were recruited through the Prolific website. We used the same inclusion criteria as in Study 2 and Study 3. 264 participants (128 female, 132 male, 4 non-binary), $M_{age} = 34.05$ (SD = 13.40), were included in the analysis. Methodology and hypotheses were pre-registered at the Open Science Framework.[11] We investigated the main hypothesis, both for cases in which the

[11] See https://osf.io/vamd9/?view_only=e513d4aa66f04a3e99c08b490d599efd

vignette stated that researchers have 'found' a certain type of entity, and for cases in which the vignette read that researchers have 'produced' a certain type of entity. Hence, we used a 3×2 design with independent variable FEATURE (cells, reproduction, nutrition), DISCOVERY (found, produced) and dependent variable AGREEMENT-THAT-LIFE. Participants were randomly assigned to one of the six conditions. Here is a sample vignette.

> **Vignette**. *Imagine that scientists have recently found [produced] a type of entity that takes up nutrition and is made of cells. However, these entities do not reproduce.*[11]

The participants were subsequently asked to rate their agreement with the statement 'These entities are living beings' on a 7-point Likert scale ranging from 'Totally Disagree' to 'Totally Agree'.

3.4.2 Results and Discussion

A 3×2 ANOVA with dependent variable AGREEMENT-THAT-LIFE and independent variables FEATURE and DISCOVERY was run ($F(5, 258) = 5.637$, $p < 0.001$, $\eta^2 = 0.01$). We also conducted planned t-tests to investigate differences in ratings among the three conditions, considering the 'found' and the 'produced' vignettes separately. For the 'found' vignettes, t-tests revealed that the average rating for *cell* was significantly lower than the rating for *nutrition* ($t(91) = 2.86$, $p = 0.005$), but not significantly different from the one for *reproduction* ($t(86) = 1.38$, $p = 0.170$). For the 'produced' vignettes, t-tests revealed that the average rating for *cell* was significantly lower than the rating for *nutrition* ($t(86) = 2.86$, $p = 0.005$), but not significantly different from the one for *reproduction* ($t(80) = 0.84$, $p = 0.403$).[12]

We also ran t-tests investigating whether mean ratings for the three features were significantly below the midpoint. For *cell*, the average response was not significantly different from the midpoint ($p = 0.173$); for *reproduction* ($p = 0.001$) and *nutrition* ($p < 0.001$), the mean ratings were significantly above the midpoint of 4.

We also looked at the distribution of the responses for *cell*, and found that 36% of the participants regarded cells to be necessary for life: that is, they gave responses lower than the midpoint, while 52% seem not to take cells to be necessary (and 12% responded with the neutral point '4').

The main finding of Study 4 is that reproduction and nutrition are not considered to be necessary features of life. Furthermore, the average responses do not allow any conclusive statement regarding the necessity of cells for life.

4. General Discussion

What does all of this mean for the folk concept of life? To provide a general discussion of our findings, we first answer two questions. (1) Which features of the folk concept of life are most important? (2) How much is it informed by scientific findings? We then propose that our findings are best explained by the hypothesis that the concept of life is a natural kind concept. We end by discussing the implications of our research for the search for life.

[11] See https://osf.io/vamd9/?view_only=e513d4aa66f04a3e99c08b490d599efd

[12] We decided to ask a question that is set in our times. While such a restriction has the advantage that people do not take an 'everything-is-possible-in-the-future' approach, it might have constrained people's imagination on what is, and what is not, possible.

Table 2. Overview of how the investigated features fare, in regard to saliency, universality, centrality, and necessity. For universality, centrality, and necessity, checkmarks apply if a significant majority agree with the feature or if the average response is significantly above the midline. Crosses apply if a significant majority disagree with the feature or if the average response is significantly below the midline. Zeros indicate no significant result either way. '?' means that the attribute of a feature has not been investigated in our studies and cannot be inferred from them.

Feature	Salient	Universal	Central	Necessary
Cells	✘	✓	✓	0
Organic Material	✘	✓	✓	?
Evolution	✘	✓	0	?
Reproduction	✓	0	✓	✘
Nutrition	✓	✘	0	✘
Growth	✓	0	✘	✘
Consciousness	✘	✘	✘	✘
Movement	✘	✘	✘	✘
Perception	✘	✘	✘	✘
Complexity	✘	✘	✘	✘

4.1 Which Features of the Folk Concept of Life Are Most Important?

The answer to this question clearly depends on what is meant by 'important features'. If we are interested in those features that are most salient, then we need to look at nutrition, growth, and reproduction (Study 1)—that is, features that describe what living beings characteristically do at a level accessible to human observation. This result is in qualitative agreement with results that Kerbe [2016] obtained by using interviews. People who had to argue that a stone is not alive appealed most often to these features: motion, change, growth, and metabolism. Three of them—motion, growth, and metabolism—are also among the top five features from our Study 1. Further, the features most often mentioned in Kerbe's and our Study 1 can be observed on a macroscopic scale. It is indeed plausible to think that people mention salient features not only when faced with a semantic feature production task, but also when challenged to show that a macroscopic object is not alive.

If, by contrast, our interest is in the universal or central features of life, then organic matter and cells win, hands down. They top the universality ranking, with two-thirds of the participants thinking that all species of living beings consist of organic matter and cells. Similar results were obtained regarding centrality: according to the surprise ratings, *cells* obtains the highest score for centrality and is significantly above the scores for *nutrition* and *reproduction*.

Finally, when it comes to necessity—which bears most directly on the possibility of identifying, for the folk concept of life, necessary and jointly sufficient conditions—our results are mainly negative: neither reproduction nor nutrition is considered necessary. Additionally, given the results for universality and centrality, almost all other features that we investigated can be ruled out as candidates for being necessary, at least if the folk concept is minimally consistent and does not assume features to be necessary that are not universal. The only features for which we cannot reject the possibility that they might be necessary are organic matter, cells, and evolution. Table 2 below summarises the results that we obtained in all four studies.

The experiments' lack of success in finding a feature that is necessary for the application of 'life' goes some way toward explaining why almost every definition of life has had difficulty in gaining support among a majority of philosophers and scientists: the ease with which scholars imagine and accept possible counterexamples to various definitions of life seems to be firmly rooted in our folk concept of life. At the same time, we can narrow down the range of features that are important to our concept of life. Some features that we have investigated simply play little-to-no role in our folk concept of life: movement, perception, complexity, and consciousness received low ratings for all four attributes that we investigated. Thus, of the ten features with which we started, we are left with six features that might matter for the folk concept of life.

But this is not all that our results delivered. They also show that a narrow focus on necessity misses vital aspects of the folk concept of life. Perhaps the most important result of the empirical studies that we conducted is the observed difference between salient features, on the one hand, and the universal and central ones, on the other. Cells, organic material, and evolution are not salient, but a significant majority consider these features to hold universally among all living beings. Additionally, cells and organic material are central, and the closest candidates for being necessary. In contrast, reproduction, nutrition, and growth are highly salient, but far fewer people consider them to be universal and central. Reproduction, arguably, being considered salient and also rather central, sits between the two sides.

How can this dichotomy be explained? Ultimately, we propose that the dichotomy reflects the very structure of our concept of life, which we will argue is a natural kind concept that encodes both an essence as well as surface properties. Before we detail our proposal, we would like to raise the question of how and why the features that we investigated have become prominent, specifically attending to the question of the influence of science.

4.2 How Much Is the Folk Concept of Life informed by Scientific Findings?

Among the features under investigation, cells and evolution were ascribed to living beings only due to related discoveries from modern (that is, post-Scientific Revolution) science. While the idea that many living beings consist of cells has been around since Robert Hooke (1635-1703), the hypothesis that all living beings are made of cells dates back only to the first half of the nineteenth century, when Matthias Schleiden and Theodor Schwann did their related research [Bolsover et al. 2011: 1]. Similarly, the idea that the plurality of species of living beings is evolution-based was developed in the nineteenth century.

Ascribing the feature of being composed of organic matter relies on scientific knowledge, too, if 'organic matter' denotes the kind of matter investigated in organic chemistry. That living beings have their material basis in various carbon compounds is clearly a finding from modern science. Admittedly, some might use the term 'organic matter' to refer to the kind of matter in which living beings consist, and these individuals might not have any idea what that matter is. In such cases, the ascription of organic matter to living beings is not grounded in scientific findings. But this less precise understanding of 'organic matter' is at least friendly to science, as it raises the question of what organic matter is, and such questions motivate scientific research.

On the basis of these clarifications, we can now tackle the second question. Again, the answer depends on the kind of features at which we look. The most salient features of living beings have not been brought to light by the sciences. If we turn to universal, central, and potentially necessary features, features with a scientific grounding become much more prominent: as already elaborated above, organic matter and cells are top-ranked among the universal and central features, and being composed of cells is the feature closest to being considered necessary. Evolution is also prominent: it is considered universal by a significant majority of people. Altogether, then, observable meso-features occupy centre-stage among the salient features, while features related to scientific inquiry become more prominent at the level of universality and centrality. This is not a surprise if salient features are used to classify entities as living beings in our daily lives, and if universal and central features tend to be those that we hear about from school and biology textbooks.

Our results accord well with findings showing that adults (Japanese college students) prefer mechanistic explanations of biological phenomena and thus explanations that are crucial for modern science. Interestingly, children of about six years prefer vitalistic explanations ([Inagaki and Hatano 1993: experiment 2]; see also Inagaki and Hatano [2004]). This suggests that there is a parallel between the phylogenetic and the ontogenetic development of the concept of life.

As mentioned before, the participants of our studies were primarily people from Western countries, in which deference to science is possibly more prominent and acceptable, when compared to other cultures. The influence of scientific findings on the folk concept of life might thus vary quite substantially across cultures.

4.3 Our Proposal: The Folk Concept of Life Is a Natural Kind Concept

How can we explain our findings, or at least organise them in a more illuminating way?

We propose that the folk concept of life is a natural kind concept, elaborated as follows:

(1) People think that life is a natural kind characterised by a certain essence.
(2) They pick out the natural kind by using salient features at the meso-level.
(3) They think that the essence can be identified by using scientific research.

In addition, we propose these:

(4) People are inclined to take certain material building blocks (cells or a certain kind of matter) to be part of the essence of life.
(5) They are open to revising this view as to what is part of the essence of life (upon, for instance, the production of new findings by science that require such a revision).

Here, our claims 1–3 refer to the folk concept of life, properly speaking; claims 4–5 report views that are not absorbed into the concept itself.

This proposal is obviously inspired by a strand of thinking about natural kind terms, prominently defended by Putnam [1975], Kripke [1980], and others. The rough idea is that such a term picks out a natural kind, not by using its essence, but rather by giving examples, or typical (if not universal) observable features. The kind is supposed to have an essence that is left to investigation. It is thus possible that some of the examples given do not belong to the kind. It might also turn out that some features used to pick out the kind are not instantiated by all members of the kind, or that they are not even typical of the kind.

We propose to apply this general idea about natural kind terms to the concept of life, as follows. The natural kind *life* is identified by using salient features of living beings. But what living beings really are is supposed to be determined by an essence subject to scientific inquiry. On current understandings, the material building blocks are believed to be at least part of the essence, but this might turn out to be false.

Of course, we cannot claim that our proposal can be read from our data. But, given that the idea of natural kind terms/concepts has its proponents among philosophers, it provides an accessible and plausible interpretation of the empirical data.

First, the gap between features that help to pick out the kind and those that constitute its essence (cf. claims 2 and 4 from our proposal) can explain why our studies have found that the salient features of life differ from the universal and central ones. The salient features are used to identify the natural kind, because it is natural to identify a kind by the features that are distinctive of it in the observable realm.[13] The central and the universal features, by contrast, are determined by the essence, and so they are different. Second, claim 3 of our proposal explains why features associated with scientific findings (cells, organic matter, evolution) are more important among the universal and central features than among the salient ones: the latter features are determined by the essence, and, according to claim 3, the essence is subject to scientific inquiry. Third, claim 4 of our proposal explains why cells and organic matter are so prominent when it comes to universality and centrality. Since the material building blocks of living beings are thought to be part of their essence, they are understood to be central, in that other features are taken to depend on them; for this reason, they are also considered to be universal.[14] Fourth, claim 4 also explains why being composed of cells is the best candidate for a necessary feature (as shown by Study 4): if specific building blocks are essential to life, they are necessary for all living beings. Fifth, and finally, claim 5 explains why the participants in Study 4 did not simply reject the idea that living beings might have different material building blocks. Since the participants take various material building blocks only as our current best candidate for the essence of living beings, they are inclined to allow for the possibility that new findings might identify a new essence.

So much for our justification of the proposal. Attentive readers will have noted that claim 1 did not figure in any of the explanations offered. However, we need claim 1 to bind the other claims together. Claim 1 provides the conceptual background needed for the other claims. It would not be needed if all concepts were meant to pick out natural kinds, but this is not plausible. We thus take it that only some terms are subject to the analysis that Kripke, Putnam, and others have suggested (Putnam [1975: 242–5] discusses the scope of his proposal); claim 1 then grants that 'life', as understood in ordinary language, is one of these terms.

Some alternative proposals about the concept of life are not fully ruled out by our data. For instance, the data are compatible with the claim that the concept of life identifies living beings by using Wittgensteinian family resemblances. The data are also compatible with the claim that we think of living beings by using a set of features that characteristically go together (homeostatic property clusters). But these alternative

[13] When all participants were included in the analysis, the results were not significantly different (all ps > 0.05). Average results among all participants for the 'found' vignettes were as follows: cell (4.41), reproduction (4.98), nutrition (5.50). For the 'produced' vignettes the mean values were these: cell (3.91), reproduction (4.29), nutrition (4.78).

[14] Our proposal does not provide an explanation of how, exactly, salient features are used to pick out the natural kind life, and we do not think that it is important to provide this explanation. The reason is that the features are not supposed to delineate the extension of the concept life; their role is, rather, to pick out, or point to, a natural kind.

proposals cannot account for some details of our findings—for instance, the contrast between salient and central features, or the prominence of some organic building blocks within both the central and the universal features. Wittgensteinian family resemblances consist in similarities between the 'family members', and it might well be that a huge fraction of them is perceived to share the same feature. But this is not implied by family resemblance *per se*. So, family resemblance cannot explain that many members of the family are perceived to share the same trait. The same point applies to the idea that concepts are prototypical (see Hampton [2006] for an overview). Things are similar when we turn to homeostatic property clusters. That properties are often co-instantiated due to natural processes does not imply that one feature is close to universal while others are not. Our proposal is superior because it can account for such details, which emerged in our data.

Our account is closely related to recent work by Cleland (for example, [2012, 2019]). She suspects that life is a natural kind (for example, Cleland and Chyba [2007: 125]), and she proposes to answer the question of what life is by using a theoretical identity statement. She argues that identity statements like 'Water is H_2O' are not definitions giving necessary and jointly sufficient conditions [2012: 138–9]. Our proposal accords well with Cleland's main idea. If it is on the right track, then ordinary people assume that there is an essence shared by living beings, and they expect progress in finding the essence of life from science—as does Cleland. With that said, there are differences between our proposal and Cleland's ideas. Most importantly, our proposal is about the folk concept of life, in which Cleland is not really interested. While we propose that the use of the folk concept of life *presumes* it to be a natural kind, she proposes that life is *in fact* a natural kind. Consequently, our view is, strictly speaking, logically independent of Cleland's. For, even if our proposal is right, life might not be a natural kind. Conversely, even if Cleland is right and life is a natural kind, this might not be part of our folk concept of life.

5. Scientific Research on (Extraterrestrial) Life

We would like to close by considering the consequences of our proposal for (1) scientific research on life, (2) an explication of life, and (3) the search for extraterrestrial life.

First, on our proposal, the folk concept of life is compatible with a huge variety of scientific findings about life. Whatever scientists might learn about the essence of life, the folk concept need not be changed. Our view on the essence of life might need to be revised, but we take it that this view is not part of the folk concept of life. Consequently, scientific progress will not shatter the folk concept of life, and there is no need for conceptual engineering to bolster scientific research on life. There is one caveat, however. If scientists can show conclusively that life is not a natural kind, then the folk concept is empty and should be discarded.

Second, if life is indeed a natural kind with an essence that includes composition from a suitable kind of matter, then the specification of the essence would provide an excellent explication of life. The *explicatum* (the new concept of life) would then be similar to the *explicandum* (the present folk concept) in several ways: both would take life to be a natural kind; and the extensions of the *explicatum* and the *explicandum* should not differ too much, given that people already assume today that the essence of life includes composition from a certain kind of matter. Further, the *explicatum* would be fruitful because natural kinds underwrite inductive generalizations and thus allow for powerful theories. The precision and simplicity of the explication (or lack of same) would depend on how, exactly, organic matter is understood. If life is a natural kind, but with a very different essence than people think it has, then the similarity between *explicatum* and *explicandum* in terms of extension might become smaller. But this should not be too much of a problem, given that life is currently assumed to be a natural kind, the essence of which is subject to further scrutiny.

Third, and finally, our proposal encourages exobiologists to search for traces of cells and organic matter. Since the idea of organic matter is not unambiguous (as we have shown above), it is not entirely clear what traces of organic matter are.[15] In any case, if no suitable traces of cells or organic matter are found on an exoplanet, this does not mean that the existence of extraterrestrial life has been decisively disproven for that place. It might instead be the case that the essence of life differs from what people take it to be. So, our proposal suggests a certain openness in the search of life. This openness is probably well served by searching for anomalies, as proposed by Cleland [2012: 141]. The idea is that, if various observations about exoplanets cannot be explained in terms of current wisdom, this might point us to new varieties of life that will ultimately help us to identify the essence of life. All in all, our proposal suggests a compromise between a focused search for traces of organic matter and a more open search.

One crucial result of our paper, then, is that, according to the folk concept of life, the question of what life is remains to some extent open. To put it briefly, ordinary folk are fallibilists about life. This strikes us as eminently reasonable. Neither philosophers nor scientists could do better than that.[16]

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[15] Our proposal does not assume that some material building blocks exhaust the essence of life according to the folk understanding of life (see Dumsday [2010] for the possibility of complex essences).
[16] For the same reason, it's not clear whether people are carbon chauvinists.

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