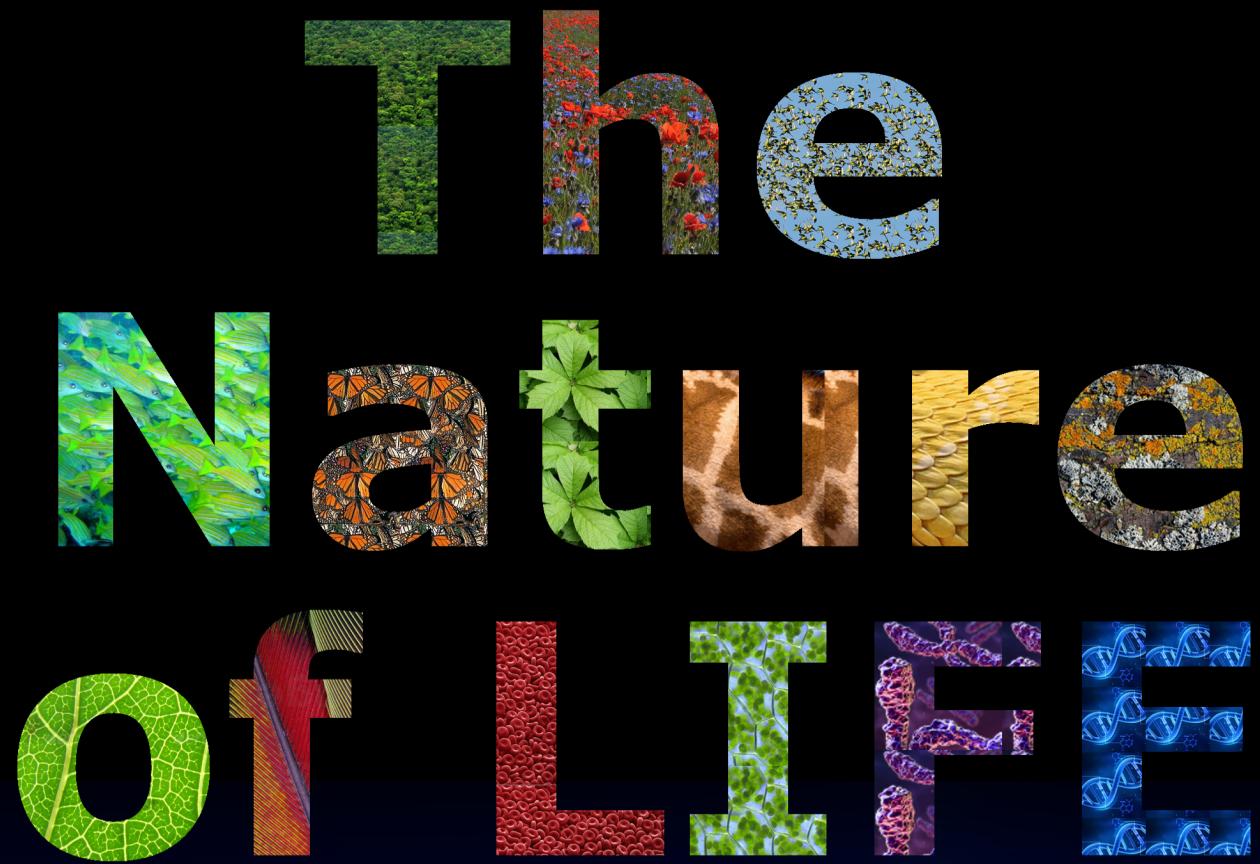


# The Nature of Life



by **Reik Oberrath**

# The Nature of LIFE

An essay about its scientific essence and a thought work  
about its theoretical description

Reik Oberrath

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*To my wife and my son,  
they make my life worth living.*

+++

*To my mother and sister,  
they contributed essentially to my life in the past.*

+++

*To my friends,  
the conversations with them helped me greatly thinking about life and writing this essay.*

+++

*To my Ph.D. supervisor,  
she taught me during my academic life to look at the big picture.*

# **Contents**

Preface . . . . .	1
1. How to define the term ‘definition’ ? . . . . .	3
7. How to detect life? . . . . .	6
Postface . . . . .	9

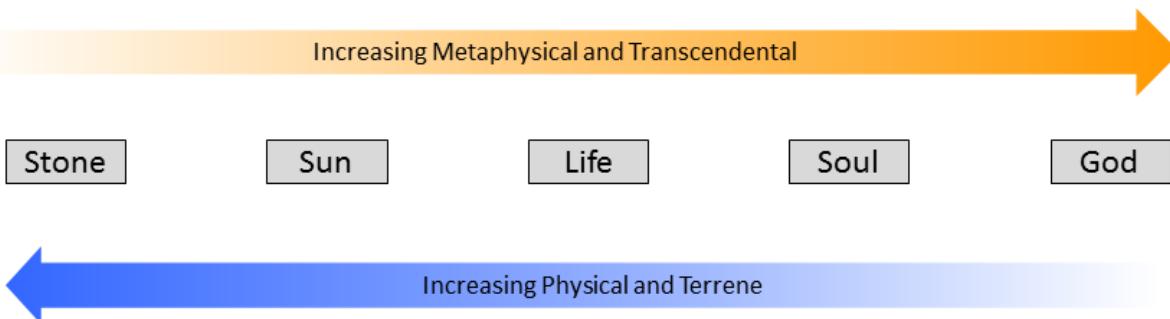
# Preface

One aim of this essay is to suggest an understanding and definition of the term ‘Life’ that may be acceptable and usable in a general way. A second aim is to summarise and recapitulate some general information about the phenomenon ‘Life’. You may agree to some of the statements of this essay or you may not, but if it makes you thinking about the nature of life, then, writing it was worth its effort. The first four chapters contain a number of different definitions and the last four chapters discuss them. Before I start defining terms, however, I would like to address the following two questions.

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Firstly, does it basically make sense to define the term ‘Life’ in a general, objective way? The opinion exists that doing so is not a good idea. I think there are several reasons for this opinion.

a) We associate the term ‘Life’ with a certain mystery and fascination, as we do for other terms as well, such as ‘Soul’ or ‘God’ for example. I think these associations have the same cause: all these terms are metaphysical, because they can have a very personal meaning. However, different terms are metaphysical to different degrees as shown in the figure below. You may argue about the examples used there and you may find better examples for the gradients explained, but I think you will understand the basic statement: the term ‘Life’ has two characteristics in medium degree: a metaphysical and a physical. In its physical characteristic it can be studied, analysed and defined scientifically. In its metaphysical characteristic it can be described by the means of humanities.



b) Borderline cases are typical for many biological categories, mainly for phylogenetical ones. Such categories, formulated as definition or not, are cupboards in the intellectual world of human beings. There will always be cases that do not fit into existing cupboards: the borderline cases. However, they do not take sense and usefulness from building categories. In contrast, they are helpful reminders, that our categories are only an attempt to reflect reality, and that reality itself is something else, something more complex. The existence of borderline cases must not be a reason to avoid defining terms. Otherwise, a meaningful communication would hardly be possible.

c) What would be the benefit of a common understanding and definition of life? Probably not much. Obviously, teaching and research of life sciences and biology does well without. However, I wonder how such a huge amount of teaching and research in very different disciplines such as e.g. botany, neurobiology, biomechanics, genetics, socio-biology, ecology, medicine... can be held together by a thin band consisting of no more than a couple of phenomena. For a better interdisciplinary collaboration and mutual understanding between life scientists as well as comprehension for each other, it may be helpful to share solid common ground: a concept of life in which all life scientists find their intellectual root.

d) A definition for a term does only make sense, if you understand the circumstance, the concept, which is named by this term. Currently, scientists of all disciplines do not have something like a theory of life, a general concept or commonly agreed idea what life actually is. This means, that we currently use of the term 'Life' without a concrete or precise perception what we mean by it. Therefore, as soon as someone reckons to see a common concept in the various phenomena of life, then I think, trying to formulate a definition is highly appreciated.

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### **Secondly, is it fundamentally possible to define the term 'Life' in a general, objective way?**

25 years ago when I was studying biology, I was taught that there is no definition of the term 'Life'. The best scientists can do, is to list attributes that can be associated with life<sup>1</sup>. On the first glance that sounded plausible to me, because life is such a complicated thing. This statement remained logically to me also on the second glance: we know only one kind of life - the one of the biosphere of Earth. In contrast, science does know many different forms of mammals. There are mammals with and without fur, teeth and legs. There are ground bound, sea living and flying mammals. There are even mammals that lay eggs. Because zoologists know so many different kinds of mammals, they can precisely tell which the key attribute is that all mammals feature: they lactate their offspring. Unfortunately, biologists do know only one kind of life and, therefore, it is impossible for them to tell which of the attributes is essential for life. Possibly, scientists will not recognize life if one day they meet lifeforms in a very different form than Earth life. Thus, to define life, we cannot do better than to simply list attributes that are typical for animated beings, can we?

On the third glance, however, there may be indeed a way to conceive the very nature of 'Life'. I put a new view into discussion that may lead to a better understanding of life. It will not, of course, clear all the questions about life, but it may provide a generally acceptable and useful understanding and definition. Before I explain my idea, I would like at first to define the term 'definition', because definitions are the spine of this essay and I want to make clear, how difficult it is to formulate a good definition especially for such a complicated thing as life.

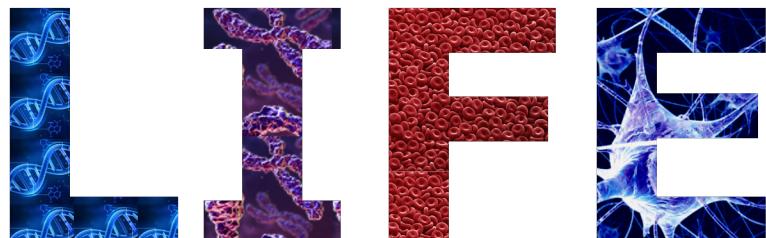
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*(Dear reader, you may already imagine that this essay is going to be theoretical. Right! The following chapters represent a kind of mind gymnastics. You don't care much about definitions and abstract stuff? Then, please, go ahead with chapter 5.)*

<sup>1</sup>[http://en.wikipedia.org/wiki/The\\_Seven\\_Pillars\\_of\\_Life](http://en.wikipedia.org/wiki/The_Seven_Pillars_of_Life)

# 1. How to define the term 'definition' ?

Of the following three definitions, 1.1 and 1.2 are using a metaphor. A definition is a wall of words built to isolate a specific meaning from other meanings and from nonsense. Both definitions have the same shortcoming: they are too narrow because they only catch one of two important aspects. In contrast, the definition “*A definition is a statement*” would be too broad, because many statements do not represent definitions. Definition 1.3, which is illustrated in the figure of page 4, may be precise by bringing the aspects of 1.1 and 1.2 together: a definition represents both a term and the idea behind this term.



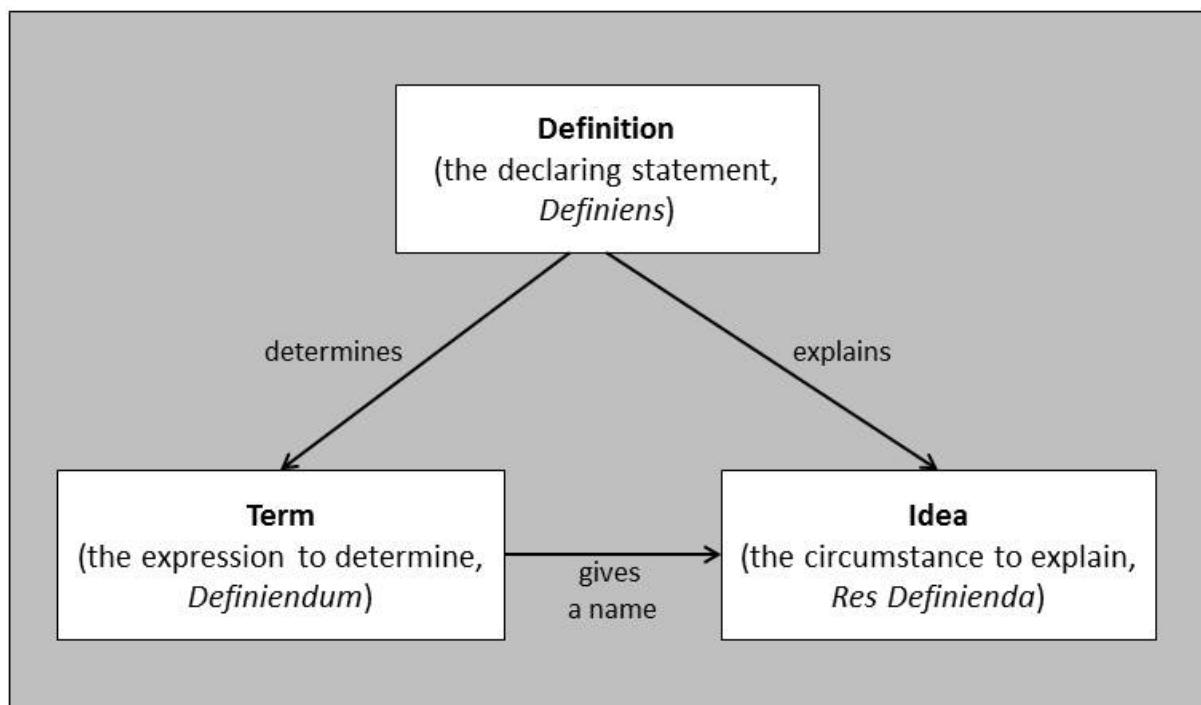
1.1 A definition is the fencing of an idea<sup>1a</sup> made by a wall of words (clarification of a circumstance).

1.2 A definition is the fencing of the meaning of a term<sup>1b</sup> made by a wall of words (terminology).

1.3 A definition is a statement, that simultaneously represents both an idea<sup>1a</sup> (clarification of the circumstance) and the meaning of the term<sup>1b</sup> that stands for this idea (terminology).

**1a** An idea is the conception of a circumstance within the intellectual world of a human being.

**1b** A term is a name for an idea<sup>1a</sup>, respectively for the circumstance behind this idea.



When searching for a definition of life, a number of statements can be found in the net, e.g.

**Definition I:** Life is “the period between birth and death.”<sup>2</sup>

This definition uses terms which only have a meaning if you already know what life is. The gain of this definition may be that life is not infinite. However, no ancestor of any living unicellular organism died, because these organisms undergo cell divisions and do not decay. In addition, this definition implies that embryos do not live.

**Definition II:** Life is an “organismic state characterized by capacity for metabolism, growth, reaction to stimuli and reproduction.”<sup>3</sup>

Here, the approach is applied to list attributes associated with life. However, life is not a state. To be alive is a state and life is the process that keeps alive.

**Definition III:** Life is “the condition that distinguishes organisms from inorganic objects and dead organisms”<sup>4</sup>

In this definition life is explained by its opposite which is no help if you are searching for the very nature of life. The question remains unanswered what the essential difference between organisms and inorganic objects actually is.

**Definition IV:** Life is “a characteristic distinguishing objects having signalling and self-sustaining processes from those that do not.”<sup>5</sup>

This definition is scientifically useful, but it calls life a characteristic of objects. This focuses on individual organisms and misses to consider the aspects such as the biosphere or evolution.

**Definition V:** Life is “a self-sustaining system capable of Darwinian evolution.”<sup>6</sup>

This statement is known as the “working definition” of life used by the American space agency NASA. Although it is scientifically meaningful, it has its limitations - therefore called “working definition” by its originators. This definition calls life a system, but these systems (the organisms) are only the concrete implementation of life - they are alive - but life itself is a concept that covers this phenomenon. Furthermore, an individual organism is not capable of evolution; it is a very tiny part of it.

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These suboptimal examples illustrate how hard it is, to formulate a good definition for such a strange thing as life. The chapters 2, 3 and 4 contain attempts to do better.

<sup>2</sup><http://dictionary.cambridge.org/dictionary/english-german?q=Life>

<sup>3</sup><http://www.merriam-webster.com/dictionary/life>

<sup>4</sup><http://dictionary.reference.com/browse/Life>

<sup>5</sup><http://dictionary.cambridge.org/dictionary/english-german?q=Life>

<sup>6</sup>[http://www.evolutionnews.org/2013/07/gerald\\_joyce\\_de074891.html](http://www.evolutionnews.org/2013/07/gerald_joyce_de074891.html)

## 7. How to detect life?

In chapter 1, the NASA working definition of life has been discussed: “Life is a self-sustaining system capable of Darwinian evolution.” It has been formulated by scientific experts on NASA’s demand for the purpose to detect extra-terrestrial lifeforms. Nevertheless, for this purpose the definition is completely useless and has been, therefore, never applied. It contains nothing concrete to search for and, furthermore, evolution in Darwin’s meaning can virtually not be determined by experiments. Thus, the best NASA can do is to search indirectly for traces of life that we know well: metabolites. Experiments to do so can be performed automatically as already done from the lander units of the two Viking space probes in 1976. To leave Earth, visit celestial bodies and perform scientifically experiments is basically a good (and perhaps the best) idea to detect life, but how likely is it to be successful in this challenge?

One limitation of this approach is that searching for metabolites that are familiar to us, can only detect life that is relatively similar to Earth life. Possibly existing exotic lifeforms remain undetected. Another limitation is that we have to wait for a space mission until a promising celestial body comes near by Earth. There are some interesting places in the solar system (moons of gas giants), but they are still out of reach. Even a successful lander mission on, for example, the icy Jupiter moon Europa is not very promising until the lander unit is able to reach the ground of the frozen ocean. The problem is, that Jupiter and its moons lay outside of the circumstellar habitable zone of our sun and that’s where water is liquid and life most likely to be expected. Outside of this habitable zone there are only special niches promising, such as possibly existing black smokers<sup>7</sup> below the frozen surface of Europa’s ocean.

What about life detection outside our solar system? Due to the hardly imaginable and really enormously huge distances between stars we possibly will never reach extrasolar celestial bodies. Personally, I regard the collapse of our modern high-tech world due to global mismanagement and ecological damage to our planet (as described by Jared M. Diamond<sup>8</sup>) much more realistic than a voyage to our nearest stellar neighbour with returning information about it. Currently there is only one human built vehicle that just left our solar system: Voyager 1. Although this is technically a spectacular achievement, for the purpose of detecting life, however, it is less than the attempt of a louse leaving its tree to walk to another continent. Thus, sending spaceships will not do it.

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<sup>7</sup>[http://en.wikipedia.org/wiki/Hydrothermal\\_vent#Black\\_smokers\\_and\\_white\\_smokers](http://en.wikipedia.org/wiki/Hydrothermal_vent#Black_smokers_and_white_smokers)

<sup>8</sup>[http://en.wikipedia.org/wiki/Collapse:\\_How\\_Societies\\_ChOOSE\\_to\\_Fail\\_or\\_Succeed](http://en.wikipedia.org/wiki/Collapse:_How_Societies_ChOOSE_to_Fail_or_Succeed)

Another approach uses the fastest information carrier that exists: electromagnetic radiation such as light. The SETI program follows this approach by scanning the sky, by collecting a huge amount of data and by mining this data for promising patterns that may indicate intelligent life as a source for it. This approach could be extended to all kinds of life. I think that the mechanism described by definition 3.1 in chapter 3 creates a kind of abstract pattern called self-similarity. This means: concrete observable patterns that appear repeatedly, but always found in a new variation, similar but not identical! The idea behind this approach is as follows:

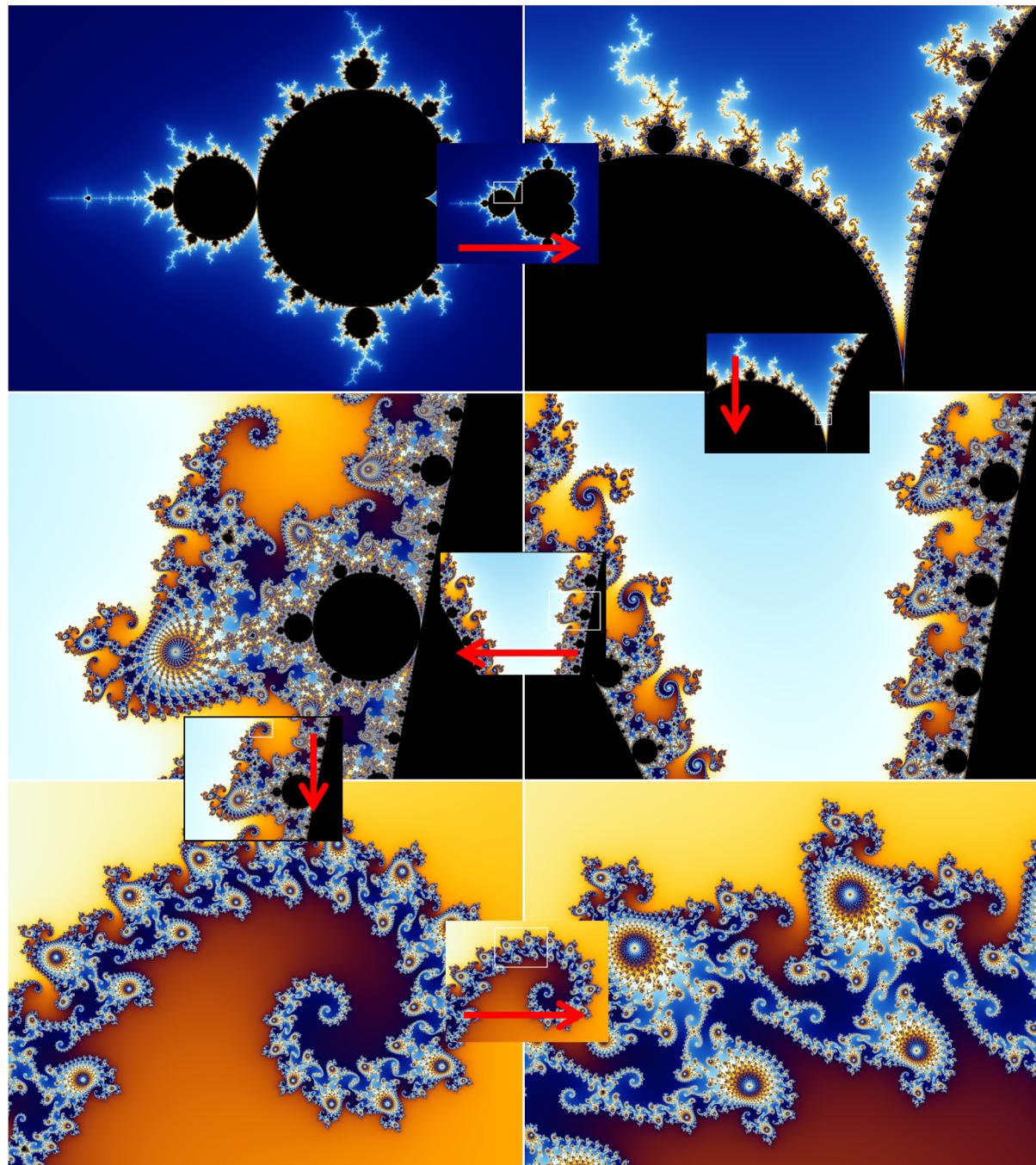
### The Life Pattern

On the one hand, life is very much like a mathematical fractal (see figure on page 28): similarities wherever you look all over again, again and again, but if you go a little into detail, you do not find the patterns to be exactly identical. On the other hand, life is very much different to a mathematical fractal: life changes over time all over again, again and again, whereas the mathematical fractal represents a perfectly constant formation.

Of course, the search for self-similarities is only a heuristic and no deterministic method to detect life. Sand dunes in deserts may be interpreted as self-similarities but do not represent lifeforms. Thus, this method may serve only as an indicator where a closer look for life would be promising. The fate of this method is possibly the same as the NASA working definition of life mentioned above: practically unusable. Presumably, it is unlikely that we will ever meet alien organisms, although it is extremely likely that they are out there. But of course, nothing is for sure. This is another expression of the grand mystery of life as described by definition 4.2.

Anyway, the idea of self-similarities nicely illustrates the abstract nature of life and may help to understand the general concept that we human beings name ‘Life’.





A fractal<sup>9</sup> is a mathematical (or natural) formation with a striking self-similarity (patterns that vary over different scales). Most popular is the Mandelbrot fractal shown here: the complete fractal and a series five cut-outs, each showing an enlarged cut-out of the preceding. The small images with red arrows illustrate where the cut-outs are taken from. Picture Credits<sup>10</sup>.

<sup>9</sup><http://en.wikipedia.org/wiki/Fractal>

<sup>10</sup>[http://www.misterx.ca/Mandelbrot\\_Set/M\\_Set-IMAGES\\_&\\_WALLPAPER.html](http://www.misterx.ca/Mandelbrot_Set/M_Set-IMAGES_&_WALLPAPER.html)

# Postface

This essay has two aims. Firstly, it suggests an understanding and definition of the term ‘Life’ that may be generally acceptable and usable. The core statement is the one of chapter 3, respectively definition 3.1. Secondly, it summarises and recapitulates some general information about the phenomenon ‘Life’. Of course I am highly interested, whether these aims have been achieved. Therefore, I would like to ask you for feedback.

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If you do not like writing long comments, I suggest to rate the whole essay, single chapters or individual definitions by the following scores:

- ++ I totally agree.
  - + I agree with restrictions.
  - 0 I understand, but do not have a clear opinion.
  - There is some truth in it, but basically, I disagree.
  - I totally disagree.
  - ? I do not understand.
- 

If you find my English far from being perfect, I will not disagree. I have not written this essay in my mother language, in order to maximise the number of people that potentially read it. I am confident, however, that the meaning of my writing becomes clear enough to be understood. If you are an English native speaker who would like to review my formulations and wording, feel free to contact me. Language improvements will surely lead to a better understanding of the essay’s content and meaning.

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Please contact me by using the contact formula ‘Email the Author(s)’ available at <https://leanpub.com/the-nature-of-LIFE>. Your feedback will shape future versions of this essay. Thank you very much for your interest.

## Release Notes

Software developers often follow a good practice when naming a release candidate: they set three single version numbers together. The first one is increased for a fundamental renewal, the second one for significant modifications such as meaningful additions and the third one for smaller changes such as corrections. My current considerations about life will change, when new information - for example your feedback - is processed in my thoughts. Consequently, this thought work about life is supposed to evolve and, therefore, needs versioning.

Current version: **v1.2.0**

For the current version a large number of language corrections and of improvements to explain details has been made, but mainly, the new chapter 8 “Robots vs. Lifeforms” has been introduced.

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## About the author



I started studying biology at the University of Tuebingen in 1990. I did my diploma in 1996 after finishing my thesis about the colour change of Pulmonaria flowers and its interplay with insect pollinators. From 1997 until 2000 I did my Ph.D. at the University of Aachen. I specialised in macroecology and studied the interactions of plants and their animal seed dispersers. After my Ph.D., I finished my academic life.

In 2000 I started to work as software developer. Gaining expertise in the field of software development and Informatics, I applied the broad view of a macroecologist to computer systems and founded with my collaborator a knowledge base called *Clean Coding Cosmos*.

Having intensely worked on both biological systems and computer systems, I was able to learn the meaning of their similarities: information-processing. This experience inspired and enabled me to write this essay.