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What is life? There are more than 100 answers to this basic question

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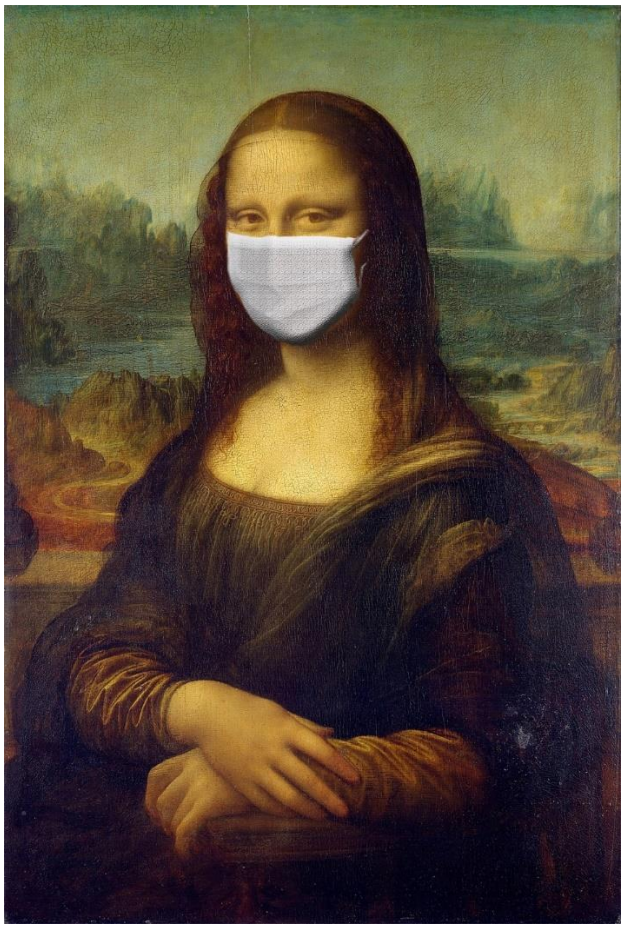

Modified version of Leonardo's Mona Lisa, with a mask designed to reduce the transmission of respiratory viruses. Source: Pixabay.

Like the COVID viruses that inspired this image, the Mona Lisa is not alive, but, 500 years ago, the substrate of the Mona Lisa was a living thing, a beautiful tree growing in northern Italy. When did it stop fitting the definition of life? What is life? Where is the border between the living and the inert?

My first biology lesson started with the teacher asking: "What is life?" It was a bit disappointing for me: I expected him to tell us, but my surprise did not end there. When, almost four decades later, my daughter took the same class, her teacher started with the same question! Have we made no progress?

I imagine that, many years ago, in some American university, some professor had the idea of starting a course, or a textbook, with the question "what is life?" and then it became customary; the approach is not new: over two thousand years ago, Socrates began his lessons with seemingly silly questions such as "what is a person" [1]. The idea behind this practice is that, if the student is forced to think about something, they will learn better, and be more critical, than if simply given a ready-made answer.

At least, that is what Socrates thought. The ancient Greek philosophers noticed that when a person loses much blood, they die; furthermore, with death, breathing stops and the body cools down, eventually decomposing. They concluded, with impeccable logic, that life had something to do with these factors, *blood, breathing, heat*. Blood, they said, contains a vital principle, a "soul", which, when spilled, takes life with it. With a blood transfusion, part of that “soul” is passed to another person, and this consideration leads to religious worries: Are sins mixed when souls mix? How will such a composite soul be judged in the afterlife? This is where the opposition of certain religious groups to blood transfusion must come from [2].

The Greeks were not concerned with the part of the soul lost when an injured person lost blood. They were after general principles to rationally understand the world, so they explained the “vital principle” like this: the stomach turns food into blood, which is the principle of life, and the heart sends it to the rest of the body; pulmonary respiration prevents the blood from overheating (that is the reason why we breathe more forcefully when we overheat). Semen is a man's liquid that heats menstrual blood to produce a new person, that is why unheated menstrual blood, turned into an useless vital principle, is discarded by the body. You do not believe it? Here is proof: in pregnant women, no menstrual blood descends, would add Aristotle. It could be said that the Greeks, even without microscopes and lacking most anatomical knowledge, understood correctly some parts of human physiology, 2,500 years ago! The correctly guessed the functions of the stomach and the heart, as well as the role of the lungs in maintaining body temperature.

Aristotle, however, found a problem with this explanation that worked for humans and other vertebrates: plants lack stomachs and hearts, and yet they are alive. So he defined life as the result of three capacities: nourishment, growth and reproduction.

> *Nourish, grow and reproduce", concluded Aristotle*

In my opinion, in the 24 centuries that separate us from Aristotle, no one has achieved a better definition of life. I can't think of any living organism that doesn't fulfill it, and I can't think of anything that has these three functions and yet isn't alive. Can you? Now we are ready to speak about the Mona Lisa.

The Mona Lisa is not painted on canvas, it is painted on a board taken from a poplar tree, possibly one like this one that some woodcutter must have cut down more than 500 years ago in northern Italy. Source: Wikipedia, CC BY-SA 3.0 License, Christian Fischer., Licencia CC BY-SA 3.0, Christian Fischer.

The Mona Lisa was a commissioned painting, and probably there were several versions, one of them given to Mr. Francesco del Giocondo, who wanted to see a portrait of his wife hanging on a wall. But the panel on which the Louvre version is painted was, more than five centuries ago, a living being, a beautiful poplar (Populus) from northern Italy, although I do not know if the particular species is clear, because the species available in Italy at the time are not well documented [4]. If

Leonardo had painted on the still-living tree trunk, would the Mona Lisa be considered alive? I think not, because being part of a living being does not automatically makes something alive: our nails and hair are not alive. We only consider the cells of an organism to be alive. Do cells meet Aristotle's three requirements? Yes, in its time as a poplar, that part of what would later become the Mona Lisa was nourished, grew and, although it did not reproduce (trunks are not reproductive tissue), they were part of an individual that could do so.

I have illustrated this article with a masked Mona Lisa. The mask reflects the fact that I am writing in the times of the COVID 19 pandemic. Not everyone knows the difference between a virus and a bacterium, and some people may think that a virus is alive. What is a virus? An impressively small “thing” that can end the life of the largest and strongest human.

Do viruses meet Aristotle's three requirements?

They do not: they do not feed; they do not grow and they do not reproduce. Viruses are just small genetic instructions that, introduced into the cell, turn it into a virus factory. Viruses are just the recipe, and the cell is the cook that has to provide the ingredients and do all the work to reproduce them.

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As strange as it may seem, defining life is a fundamental need. Let us think for example of law and space exploration.

If we have to legislate on abortion, murder and euthanasia —all phenomena that involve ending a life— we must be clear about *what life is*. For example, now that abortion is all over the news (year 2022), when someone asks "at what point does life begin after conception,"

they are asking the wrong question: life began only once, more than 3,5 billion years ago.

And when we look for life on other planets, which we can assume will be neither the green dwarfs of the old movies, nor forms identical to those on Earth, how can we distinguish it? Will there be living lakes on other planets, like in the novel *Solaris* by Polish writer Stanisław Lem? Can there be living beings made of gas, huge thinking clouds as I think Karl Sagan once suggested? In order to identify extraterrestrial living beings, NASA has defined life in a way that works outside our planet: "Life is a self-sustaining chemical system capable of Darwinian evolution" [4].

Other definitions have been proposed, in fact, more than a hundred — in my opinion, without any need— but perhaps you can find something useful among all of them, for which I recommend the article by Trifonov [3].

Mr. Trifonov concluded that the two most frequent aspects in the definitions are *being able to reproduce*, and the existence of *variations that allow evolution*. That is why viruses and prions are not alive: they cannot reproduce and evolve by themselves; they need to infect a living being that makes copies of them. However, organisms like mules cannot reproduce and yet are alive, so the old Greek explanation always seems more satisfactory:

Nourish, grow and reproduce, concluded Aristotle. I think he got it right. The rest, such as perception, locomotion and thought, are extras, as he said almost 2,400 years ago.

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