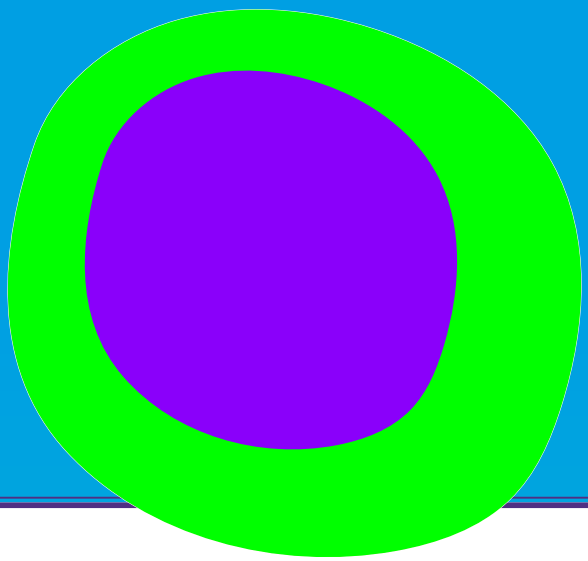
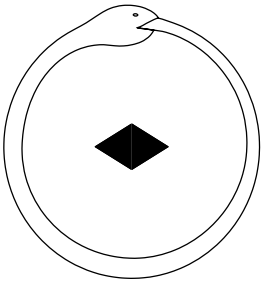


THE ANCESTRAL MEMORY OF THE PLANT METABOLISM

Fabio Scarano

notebooks
SELVAGEM



The ancestral memory of the plant metabolism

Fabio Scarano

This notebook consists of the translation of the transcription of Fabio Scarano's talk about the Sun, filmed on 14 March 2024, at the exhibition Mbaé Ka'á *showcased by the Botanical Garden of Rio de Janeiro. Fabio's video can be accessed here as part of the Sun Cycle, which comprises 17 talks.*

But the magician is the Sun behind all of this. To create all this life, this magician needs some sort of translator-interpreter. I think the Sun's translator-interpreters are the plants that do this through photosynthesis. And photosynthesis really is magic.

These incredible beings manage to capture molecules of carbon dioxide and water, that in interaction with light produce the oxygen we breathe, water and carbon molecules, especially sugars. And this transformation occurs through a whole biochemical process, which we don't need to detail here. I will just highlight these entities, the chloroplasts, that are very important in the process.

So much is said about innovation that it seems like everything is innovation these days. We usually associate the word "innovation" with machines, with the technological, the technical. Photosynthesis, for me, is the great innovation of the last 4.5 billion years of our planet's existence because without it the diversity of life that exists today would not exist. Primo Levi, an Italian, Jew, chemist and fantastic writer, describes carbon in the periodic table[1] and the text is beautiful. How can a chemist describing carbon be poetry? Well, it is! He ends the text by saying that the day we humans manage to photosynthesise, we will be gods just like the plants. They are the ones who have this magical ability to create the conditions for life.

1. *The Periodic Table*, a book by Primo Levi, published in English in 1984.

I am going to tell you a little about the experience I had while studying photosynthesis. Photosynthesis is an ancient mechanism that has evolved over time. The original form of photosynthesis, to which we are referring, carried out by most plants, is called C_3. We call it C_3 because three carbon molecules come out at the end. Since then, two other forms of photosynthesis have appeared. One of them is called C4 and is carried out by productive plants that generate more carbon molecules at the end of this process of transforming light energy into chemical energy. A classic example of a C_4 plant is sugar cane, a very productive and fast-growing plant.

And there's another mechanism called crassulacean acid metabolism (CAM). We say it is a photosynthetic mechanism, but it is not exactly photosynthesis because it takes place in the absence of light. It is a nocturnal carbon fixation. It is a mechanism that evolved especially in plants found in dry places, desertic places even. The place where CO_2 enters plants is the same place where water exits during transpiration. So if the plant is in a really warm place, in order to perform photosynthesis, it will lose a lot of water. The balancing between gaining carbon and losing water is critical for the plant. In this way of performing photosynthesis, the plant spends the whole day with its stomata – which are like the pores in our skin – closed. Imagine us not sweating under the Rio de Janeiro Sun. Our bodies will heat up. These plants often have thermotolerant enzymes – they resist intense heat. If you touch the leaf surface during a time of hot Sun, you will feel a heat of over 40 degrees Celsius. But the plant can handle it. When night comes, it opens its pores – contrary to other C_3 and C_4 plants. When it opens its stomata at night, it assimilates atmospheric CO_2 in a small quantity. In the absence of light, it stores these molecules in the form of big carbon molecules. Then, during the day with sunlight, when it closes its pores, it is able to break down these molecules and fix carbon. It is much less carbon than if the photosynthesis took place in sunlight, but this way it doesn't lose water. This mechanism is very common in bromeliads, orchids, cacti, and the plant I studied the most, from a group called clusia. Here in the Botanical Garden of Rio de Janeiro, in the *restingas* area, you will see some beautiful clusias. Today, there are a lot of clusia that are used for ornamental purposes, but not all of them

have this mechanism. It is the only group of trees that can perform this type of nocturnal photosynthesis. Anyway, the clusia is a long story, but the story I wanted to tell is another one.

The story I wanted to tell has a strong dialogue with what our dear Ailton Krenak and Anna Dantes so often speak about the ancestral future, about the possibility of imagining futures starting from ancestry. I was working on the Itatiaia Plateau. If you haven't had the chance to visit it, I highly recommend the Prateleiras and Agulhas Negras regions. This rupestrian area has a very unique landscape: for me, it is one of the most beautiful places in the world. Around 25 years ago, we found two plants there: a bromeliad called *Fernseea itatiaiae*, which is an endemic plant – it only exists there – and another plant, a cactus called *Schlumbergera obtusangula*. These two plants are part of exclusively CAM botanical groups, groups that only carry out photosynthesis at night.

The CAM is the pinnacle of photosynthesis evolution, it is where photosynthesis went furthest in the evolutionary process, meaning it is the most recent. In Itatiaia, what happens in this plateau region? You will find these plants at an altitude of over 2400 metres, which is very high. Over there, for about 60 nights a year, the temperature is below zero degrees Celsius. In this scenario, if the plant's leaves store lots of water, what happens? CAM plants generally possess succulent leaves. You may be familiar with the *Crassulaceae* family, which has little beach plants with very thick leaves – if you pick them up on the beach, snap them and suck on them, you will taste a little salt. Have you ever done that? When the temperature drops below zero at night, if the leaf is full of water, the water freezes and the leaf bursts. The leaf bursts, the plant stops photosynthesising and dies. So, in this kind of environment, it is expected that the CAM mechanism doesn't have much adaptive value.

And what happened? We found the first record of C_3 plants within these two groups. Yes, the ancient, ancestral photosynthesis. These plants have not lost, somewhere in their biology, the ancestral memory of the previous photosynthetic mechanism. Therefore, for these two species to appear in the world, they only succeeded by resorting to the ancestral mechanism. So the future of these plants, in those places, resided in ancestry.

If we picture CAM metabolism as an innovation in the evolution of life on Earth, we can get confused and think that evolution is a kind of progress, that it is linear and that after CAM there will be something else. But evolution is not linear. It meanders, it spirals, like the serpents of Selvagem. It is like DNA. So it goes through several paths. And we carry these memories within us.

The memory of photosynthesis is not in us because we haven't learnt how to do it yet, as Primo Levi rightly reminds us. But maybe one day we will be able to access some memory of our algae and bacteria ancestors. Maybe then we will be able to perform photosynthesis. This teaching from plants shows that life is, once again, a Sun's child. Life has resources, it has endless baggage. And memory is essential. I think we scientists sometimes confuse scientific discoveries with some kind of progress. And then, we tend to refer to what's left behind as old, we judge it to be less valuable, and we forget about it. I believe that the human world is filled with oblivion. I think our ignorance is often culturally and politically induced in our social relationships and our relationships with the world. My grandmother, for example, always treated us with plants. I have learned a few things from her, but I have lost her vast knowledge of dealing with plants. Some of it is passed down and stays, but much is lost. We have a problem with memory, which I don't think plants have. Plants have memory. And we tend to think we are so intelligent. Human beings tend to think they are so intelligent, but I would like to see them photosynthesise. The memory and the ability to anticipate are lacking in us.

Photosynthesis is very important here too, because many plants photoinhibit themselves. Plants that grow in the woods, on the ground, in the forest, when they receive too much light, become photoinhibited. Their photosynthetic apparatus is damaged, the leaf withers. Everyone has a little plant at home, and you can see the plant's relationship with the Sun. You can see it photoinhibiting itself. So there is the right dose – that is another wise thing about the plant. It deals with doses of this magic formula from the Sun. Sometimes, if it gets too much, it will not be good. There is a proper measure of how plants use it.

Plant intelligence is an intelligence of life. Returning to the theme of innovation, it is very important to realise that life is intelligent.

The Latin word *intelligere* means to discern, to choose between. All that lives, chooses. And the living being's choice is what allows for survival and adaptation to what the environment imposes. This adaptive capacity is greater as the ability to anticipate what is going to happen increases. Plants anticipate. They have a circadian rhythm controlled by the Sun, just as we have our own rhythm of going to sleep and waking up. Wanting to see if plants photosynthesised during the day or night, we did experiments with light. I don't do these experiments anymore, because it was like torturing the plant. Changing the rhythm of the plant sleeping and waking up makes it freak out and eventually die.

The relationship with the Sun is a very intimate one, and it is a relationship of presence. Due to being sessile and fixed, the plant has nowhere to run if things change. What guarantees the plant the ability to adapt, acclimatise and anticipate events is presence. This is another important thing for us to learn from plants at a time when we have no presence. We are always connected to our gadgets, which distracts us. You are here, but you are thinking about something else. The plant is there and it is paying attention to everything. This is a kind of intelligence that I don't think we can give up either.

Presence, innovation and translation: I think that's how I summarise the relationship between plants and photosynthesis. I insist on what Primo Levi used to say: let's hope that one day we have the wisdom to photosynthesise. Let's see if we get there.

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