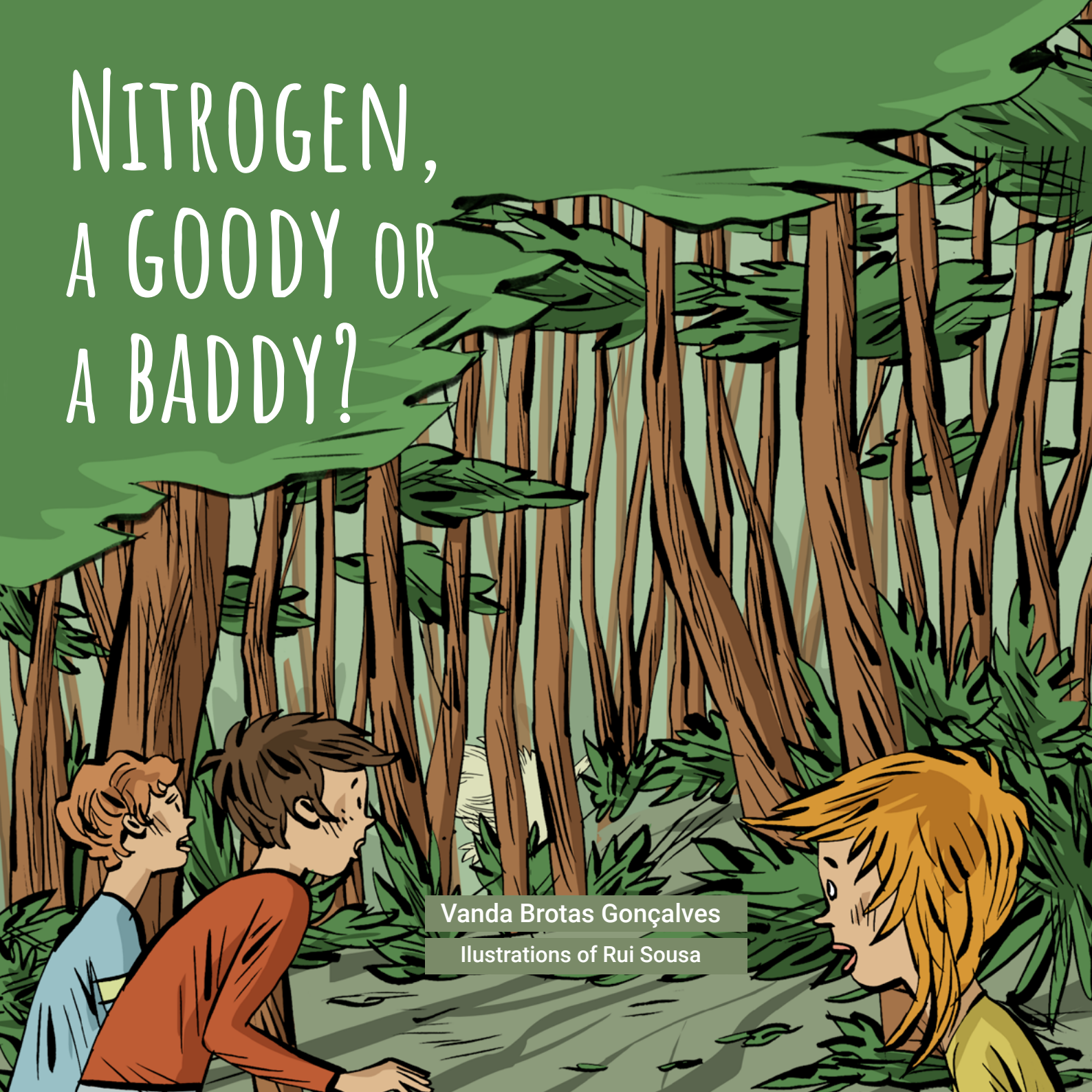


NITROGEN, A GOODY OR A BADDY?

Vanda Brotas Gonçalves

Illustrations of Rui Sousa



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WHEN DEAD FISH APPEAR IN THE LAKE

Every year, in October, the school would organize a picnic by the lake. It was an important event, that everybody looked forward to.

Georgie and four of his classmates were in charge of choosing the perfect site for the picnic. They walked on the footpath around the edge of the lake looking for hidden frogs amongst the aquatic plants, playing stone skipping on the lake's calm water surface.

Finally, they found the perfect spot for the picnic, a large and flat area, where the grass was shadowed by large trees, and where the lake was not too deep.

It was Reuben who was the first to notice: **there were many dead fish along the broad-leaved water plants and the water smelled like rotten eggs.**



THE WICKED SPELL COMPETITION

When the group arrived at school, there was no chance of reporting the dead fishes found in the Lake. The Teacher had launched a competition to commemorate Halloween: **the student who could come up with the most terrible and wicked Spell would be the winner.**

After a very exciting afternoon, with the most terrible and threatening spells, no one understood why Madeleine was the winner. Madeleine was a new girl in school. She was tall, skinny, not very chatty; hence, she was not very popular.



The winning spell was the following:

"I will make a spell so that all nitrogen atoms of your body will completely volatilize".

Nitrogen?? Asked some of the students, looking puzzled. They never had heard the word.

"I am sure I do not have any nitrogen in my body" grumbled Noah.

— "I eat meat, fish, vegetables, fruit, but never nitrogen" said Patricia.



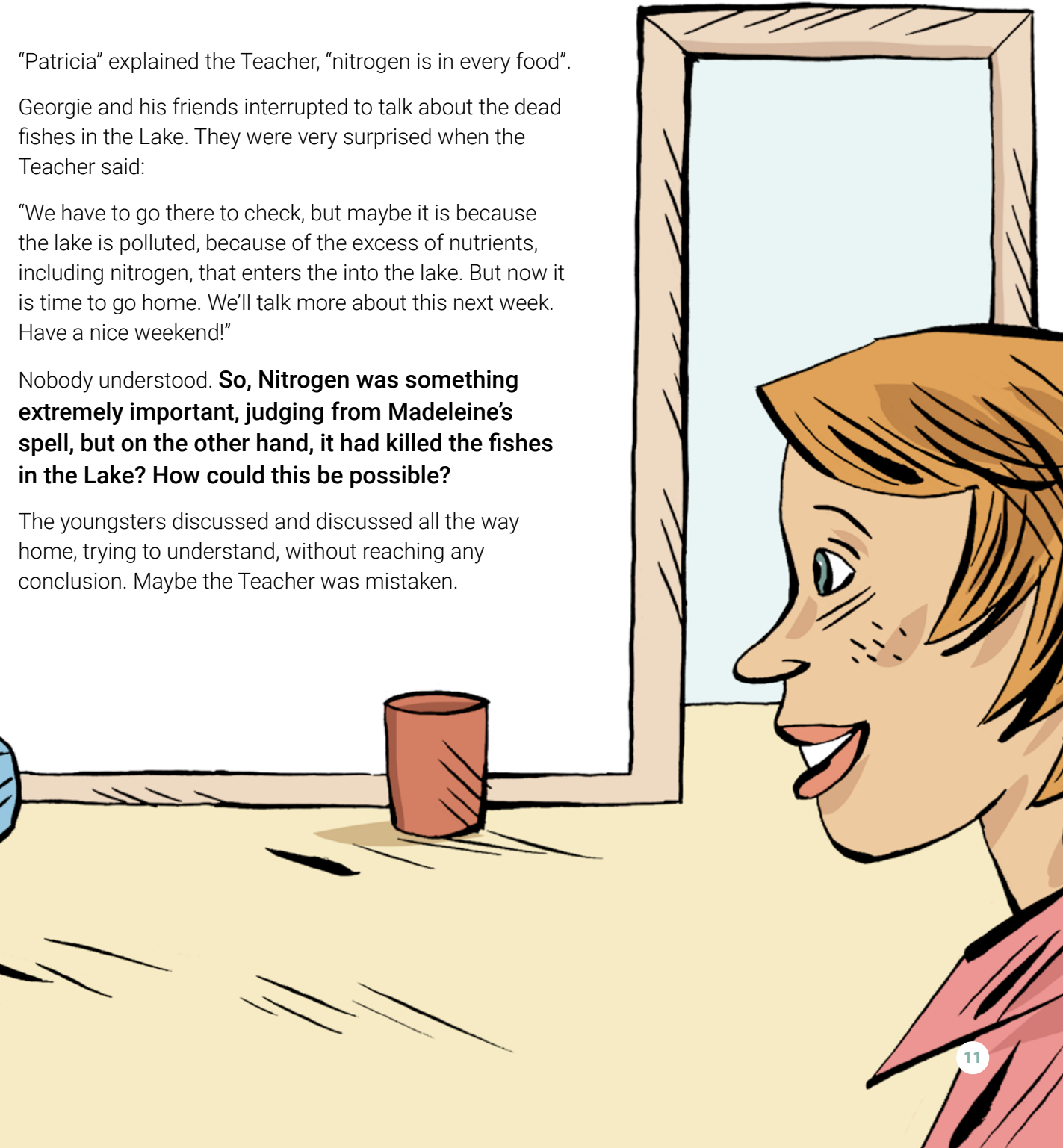
"Patricia" explained the Teacher, "nitrogen is in every food".

Georgie and his friends interrupted to talk about the dead fishes in the Lake. They were very surprised when the Teacher said:

"We have to go there to check, but maybe it is because the lake is polluted, because of the excess of nutrients, including nitrogen, that enters the into the lake. But now it is time to go home. We'll talk more about this next week. Have a nice weekend!"

Nobody understood. **So, Nitrogen was something extremely important, judging from Madeleine's spell, but on the other hand, it had killed the fishes in the Lake? How could this be possible?**

The youngsters discussed and discussed all the way home, trying to understand, without reaching any conclusion. Maybe the Teacher was mistaken.



THE BIG BAD NITROGEN

During the weekend Georgie and his mates went to the lake again to check for the dead fish.

They were also aiming to look for the mysterious Nitrogen and to punish him severely. The surface of the lake was completely still, with some floating air bubbles and some greenish circles.

"That's algae" explained Georgie, "if they were plants they wouldn't float and would have roots, but they aren't as nice as the seashore algae, the seaweeds".

They searched everywhere but could not find Nitrogen anywhere.

Finally, Sunday morning, Nitrogen was sighted in the middle of the trees, in the darkest and densest part of the forest. It was just for a fraction of a second, but it was clearly Nitrogen, it had a body covered in white fur and a huge head with two sticking up ears. Moreover, Johnny was able to distinguish its growls above the soft rustling of the leaves.



Extremely happy with themselves, they rushed to the city park, to meet up with all the other classmates. Speaking all at the same time, they begun to tell how they had seen Nitrogen, promising they would capture him for good, with a for the moment secret strategy.

“Nonsense” said Madeleine, **“the Nitrogen monster with hairy ears does not exist at all, except in your mind. What does exist are nitrogen atoms. They exist but are invisible, and no plant or animal can live without nitrogen atoms, so nitrogen is good”**.

“But, if nitrogen is good, why is it killing the fish?” said Georgie, angrily.

“Why don’t you all go and do some proper research, instead of fighting imaginary monsters?” suggested Madeleine turning her back on him.



BUT WHERE IS NITROGEN COMING FROM?

Monday morning, the Teacher met a split and stressed class. Georgie's followers utterly convinced that Nitrogen was bad and Madeleine's supporters defending that Nitrogen was good.

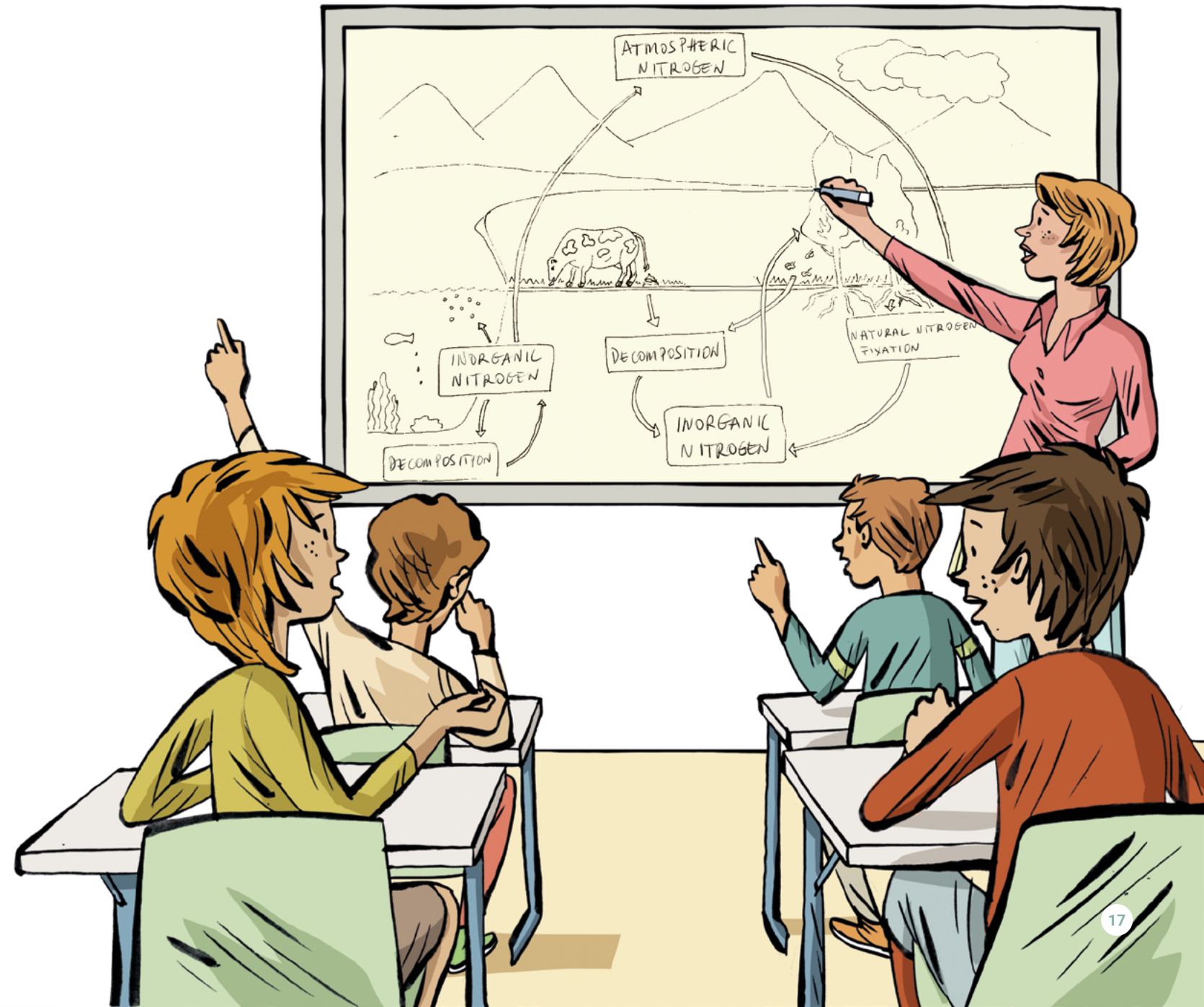
Hence, she explained what the Nitrogen was, and how the Nitrogen cycle worked. She showed images, graphs, figures, charts, tables... Then she had a brilliant idea: she invented the game of the nitrogen atoms and molecules! She divided the class into three groups. The first group represented the nitrogen atoms, the second group were the oxygen atoms and the third were hydrogen atoms.

"Now, pay attention, asked the Teacher, each nitrogen atom will hold hands with another nitrogen atom, and climb up

on the tables. You represent the nitrogen molecule that exists in the atmosphere, constituting almost 80% of the air we breathe. Then turning to the other students, she added: "Now, one nitrogen atom will hold hands with three oxygens: you are another molecule, nitrates. **Nitrates are nutrients indispensable for plant growing.** Finally, one nitrogen atom will hold hands with four hydrogen atoms: you are the ammonium molecule, which it is also a nutrient. **Both nitrate and ammonium are fertilizers, as plants need them to be able to grow. Ammonium is also produced by degradation of organic matter, I mean, when plants or animals die and decompose.**

Happy with the outcome of the game, the Teacher grabbed her mobile to make a selfie with everyone. At this very moment Layla, quite upset, left her group, announcing:

"I do not want to be the ammonium molecule, it is a bad nitrogen molecule".



And the turmoil started. The molecules splitting apart, everyone talking at the same time.

“There is no good and bad nitrogen”, the Teacher said, raising her voice amongst the confusion, “I’ve already explained to you that nitrogen is an element indispensable to life! However, when in big quantities, it can have negative effects in the environment”.

“But how can it be good and bad at the same time?” asked one of the boys.

“That’s like everything else”, the thin shy voice of Marianne was heard. “It’s like kisses. Kisses are good, but when there are too many, your face gets all smeared and wet.”

Everyone burst out laughing.

“Ok, but why did the fishes died?” insisted someone.

“Well”, the teacher explained, “the lake is in an area that collects drainage from a few factories. Maybe there is a factory or even a sewage treatment plant (sewage is the liquid residues from our houses, factories, and everywhere else, in fact: liquid waste) that releases sewage without proper treatment, thus with excess nitrogen. The nitrogen will end up in the lake.

As a consequence, algae grow very much and very fast, forming a surface layer, which stops the oxygen flow from the air to the water. Therefore, fish die because they cannot breathe enough oxygen. Another possibility are the cows. Cows produce lots of manure that can drain off into the lake, when it rains, again bringing too much nutrient to the water”.

“But not my grandfather’s cows, I am sure!” protested Tom. “They are very sweet cows, who can’t harm anyone”.

A somewhat lively and disorganised discussion continued, where someone even proposed that the nitrogen from the cows was the good nitrogen and the one from the factories was the bad nitrogen. The teacher repeated, “no, it’s not that easy”.



MYSTERY SOLVED

Because of the mystery of the dead fish, the students would meet up in the city park, every afternoon, after school. The mystery had to be solved urgently, preferably before the picnic day. Everyone had opinions and ideas, but the discussions would go on and on, and no conclusion was reached.

The cows could not be the source of the bad nitrogen since most of their parents, brothers and neighbours had cows, worked with cows, and earned money from milk and cheese. On the other hand, at the sewage treatment plant (UWWT, Urban Waste Water Treatment plant, as written on the signboard), the only person they knew was Henry's next door neighbour. And Henry was not terrible fond of her. Therefore, it was decided unanimously that the UWWT was the cause of the bad nitrogen.

So, an Exploratory Group with four brave students was appointed. Its mission was to search around the lake and discover if there was indeed untreated sewage coming from the UWWT. The group left at dusk, exploring the entire area near the UWWT, without finding anything suspicious. Suddenly, in the dark night, desperate screams were heard. It seemed that Little Zach was being swallowed by the ground.



Little Zach had fallen into a hole. He was half buried in a smelly and repulsive sort of muddy liquid. His mates helped him out, whilst noticing some strange white smoke coming out from the ground.

"How could you fail to understand?" exclaimed Madeleine, the following morning, when she was told about their adventures. "It is obvious that Little Zach fell into sewage; the sewage should be inside the plumbing, but instead, it was out in the open, hidden by the vegetation. The white smoke you saw is due to water condensation in the air, as it was coming out at high temperatures."

"Haha, mystery solved!" Patricia raised her finger up, mimicking the Teacher.

"The untreated sewage goes directly to the lake, carrying massive quantities of nitrogen. The white smoke is due to condensation of the warm sewage water. The lake gets an overdose of nutrients, the plants overgrow. Then, plants rot and decompose, consuming loads of oxygen. The poor fish are left without enough oxygen to breath, so they die!"



WHAT TO DO NOW?

A few days later, graffiti with huge red letters had appeared on the big UWWT walls. The graffiti **"No to the dead fishes, Yes to an unpolluted Lake"**, was repeated 10 times, although in the ninth and tenth it was "No to the dead fishes, Yes to an *in*polluted Lake".

After the visit of a team of journalists, and news report on the local television, the war of the bad nitrogen and the good nitrogen had attained alarming proportions. Everyone, adults, youngsters, children, talked passionately about nitrogen. Every morning, rumours would appear, each one more terrible than the previous one.

For example:

- 1) Nitrogen is a dangerous nasty chemical; the fish were all poisoned. Soon, everybody that eats fish from the lake will be covered with green pimples.
- 2) OR that someone killed the fish just to blame the cows, in order to destroy the income of many families.
- 3) OR that nitrogen was present in the air we breathe.

4) OR that the whole thing was fake news, just to keep tourists away from the town, harming the city shops and restaurants profits.

5) OR that there were some bacteria, hidden in plant roots, that would remove nitrogen from the air. Nitrogen would thereafter be transported to the edible parts of the plants. People would eat the plants without realising that they were absorbing nitrogen as well.

OF THESE FIVE RUMOURS, GUESS WHICH IS/ARE THE TRUE ONE(S)?



NO TO THE DEAD FISHES
**YES TO AN
UNPOLLUTED
LAKE!**

WE NEED TO THINK OF EVERYTHING AT THE SAME TIME

By then, everybody was extremely busy. The Teacher had asked for help from the University so that she could explain the complex nitrogen cycle better. And together, Teacher and students, organized a poster exhibition.

The farmers and cow owners discussed with the fishermen how to reduce the impact of fertilizers and cow manure to the lake. The CEO of the UWWT, after several meetings with the mayor, the farmer and tourism associations, started to fix the problem of the broken sewage plumbing. In one of those meetings, someone suggested to do a nitrogen event.

Hence, the following Sunday, the population organized the Nitrogen Festival, which took place in the city main square. Reporters filmed the whole event with drones, while the firefighters' band played cheerful tunes in the bandstand.



The aim of the event was to describe the nitrogen cycle, to show the composition of the nitrogen based nutrients and to explain that nitrogen was part of amino acids, which are the building blocks for proteins. Also, **when proteins, that exist both in plants and animals, start to decompose, nitrate and ammonia are formed, which, in excess, may be harmful to the environment.**

Everyone was given a coloured T-shirt, and paraded orderly along the main street. There were several colours, each colour representing a different atom. The Teacher was leading the event. Holding a megaphone, she explained every step of the nitrogen cycle and its relevance to the organisms and the ecosystem. The parade started with the young kids of the nursery school, who were the nitrogen molecules in the atmosphere. Madeleine and a group of the 8- and 9-year olds were the nitrate and ammonium molecules, good in small quantities, crucial for the growth of plants; they waved happily to the public, throwing coloured confetti.

Then the adults. Firstly, the town VIP's, marching solemnly, pretending to be amino acids, followed by all the other adults, arm in arm, pretending to be amino acids linked together in proteins.

At a sudden sign from the teacher, a sort of theatre play happened, everybody moving very quickly and shouting very loudly. The proteins broke down and grabbed everybody wearing the green t-shirt (the oxygen atoms), even those who were still holding hands as nitrate molecules. The parade turned into a confused and hilarious fight, with the oxygen atoms trying to escape from the greedy amino acid molecules.



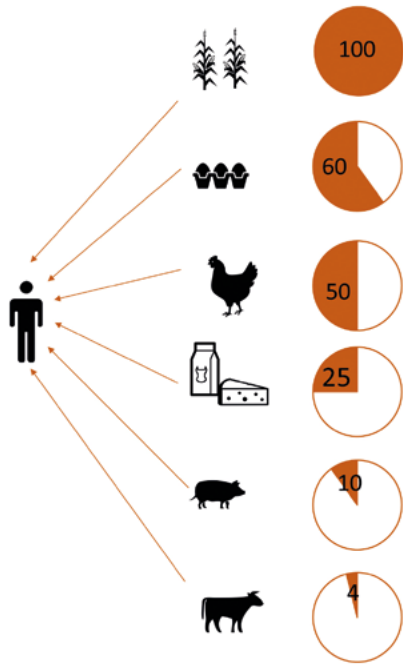


Finally, the 9- 12- year olds from the city and all nearby villages represented the bad nitrogen, bad in big quantities. To clearly show that they were really the baddies, they were wearing scary masks and carried fluorescent swords. They yelled very loudly, threatening everyone around them. Needless to say, Georgie and his mates belonged to this group.

The event was a huge success. The video was uploaded online and got 1 745 891 likes.

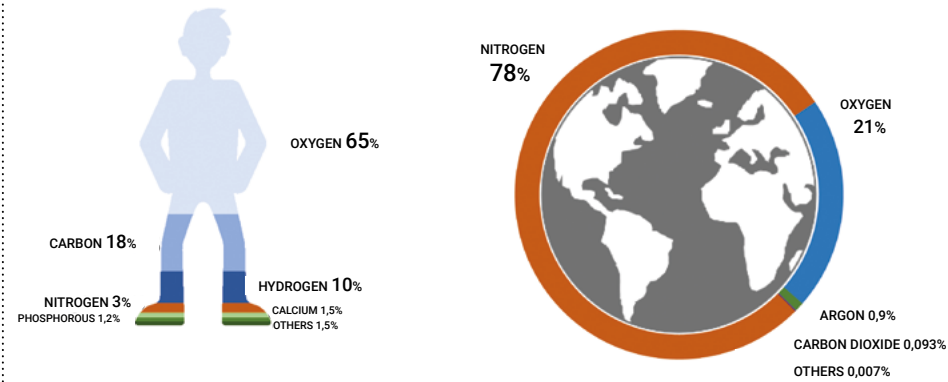
Many visitors and tourists were attracted to the city. The mayor, the parish councils, the farmers, the fishermen, the factory staff from the region, the CEO and the employees of the UWWT plant, all realised the importance of not polluting the environment and accepted the changes proposed by an expert commission.

The picnic, by the lake, was the funniest and the best anyone could remember.



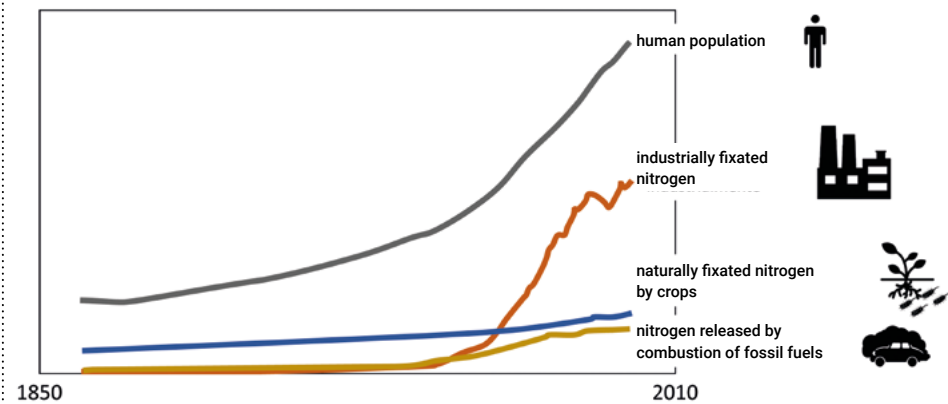
FOOD EFFICIENCY: ANIMAL VS. VEGETAL PROTEIN

The image represents the percentage of nitrogen taken up by a human, when choosing to eat animal protein instead of vegetable protein, of the same nutritional value. When opting to eat cow's meat, we just intake 4% of the nitrogen we would if eating vegetable protein. All the remaining nitrogen was lost in the several steps of agriculture, some in the soil fertilization to get the cattle's food, another in the cattle's growth and due to food waste.



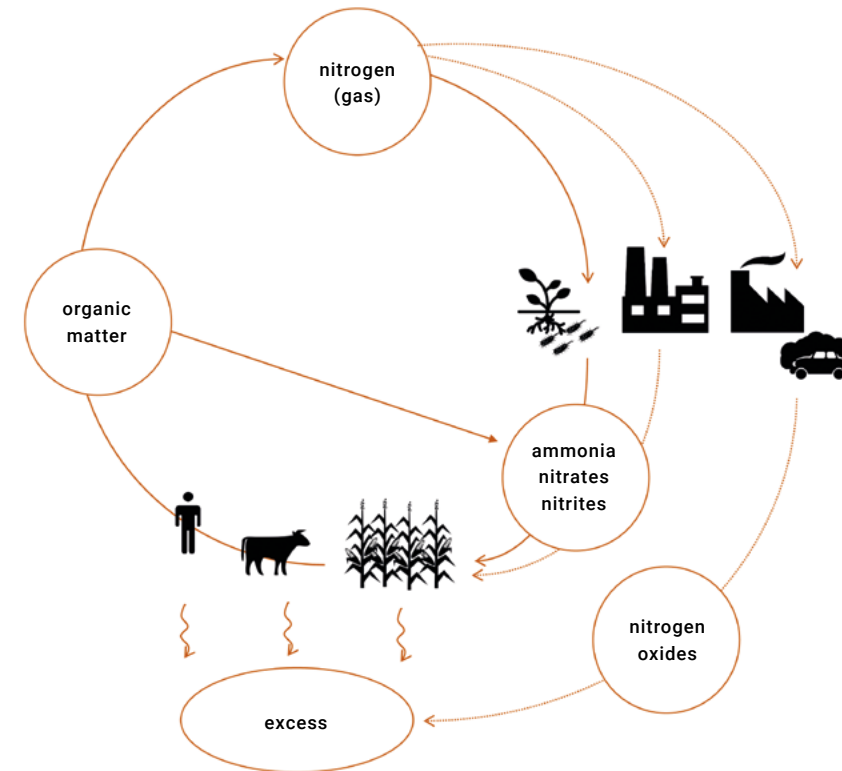
NITROGEN ON EARTH

Nitrogen is the most abundant gas in the Earth's atmosphere, as N_2 , a non reactive gas. In living beings' nitrogen is fundamental for creating proteins, representing about 3% of the human weight.



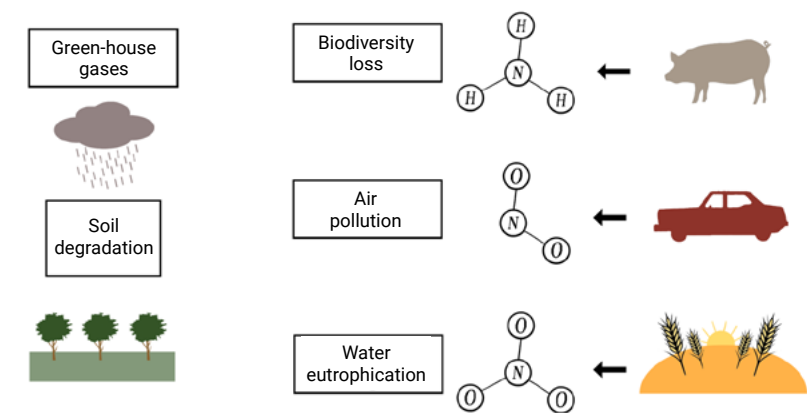
INDUSTRIALLY FIXATED NITROGEN AND HUMAN POPULATION

Before the industrial revolution, nitrogen used in agriculture was just the one fixated by natural processes. In the beginning of the XX century it was discovered how to do the same process industrially, being the base to produce fertilizers, and the green-revolution after the war. Since 1950, intensive agriculture became possible due to the supply of nitrogen via fertilizers, and it feeds half of the current human population.



NITROGEN CYCLE AND HUMAN INTERVENTION

Until the industrial revolution, nitrogen's cycle was ruled by natural processes: nitrogen in the atmosphere (N_2) is fixated by bacteria in soil and water, transforming it into a reactive form, like ammonia (NH_3), nitrate (NO_3) or nitrite (NO_2); this reactive nitrogen is used by plants, and then animals and humans, for growth. All the nitrogen present in organic matter returns to the cycle in the form of excrements or decomposition. Human intervention after the industrial revolution (dotted line) produced nitrogen industrial fertilizers, that now feed agriculture. The use of fossil combustions creates another reactive nitrogen species, the nitrogen oxides, besides the ammonia that is lost into the atmosphere. The ecosystems are not prepared to use all the extra reactive nitrogen, creating an excess that is lost in the soil, water or atmosphere, with negative impacts for the environment.



BIBLIOGRAPHIC NOTES

VANDA BROTAS GONÇALVES is a biologist, Professor at the Faculty of Sciences of the University of Lisbon (FCUL), and a Researcher at the Centre MARE, where her main research line has been microalgae and its function in ecosystems, including eutrophication (extra input of nutrients into ecosystems), portrayed in this story.

She wrote *Histórias para Meninos Não Quero* (Stories for Children I Don't Want To) now part of the National Reading Programme; *O Namorado da minha mãe* (My mum's boyfriend), *A menina que via o mar de várias cores* (The girl that could see the sea in many colours), published by Gradiva, and *Os meus amigos Triops* (My Triops friends), edited by *Liga para a Proteção da Natureza*.

RUI SOUSA was born in Lisbon in 1966. Finished his degree in Arts, at the Faculdade de Belas-Artes of Lisbon, in 1992. In the last thirty years he's divided most of his work between illustration and painting, collaborating with editors, newspapers and magazines, and performing exhibitions.

Together with Animanostra, directed the animation film *Um caso bicudo* (A difficult case).

He is the author of four childrens' books.

As a complement of his trips, he also worked in «Urban Sketcher», with published notebooks.

What would you do if you find lots of dead fish in your favourite lake?

If you are anything like Georgie and Madeleine you'll want the answer to why they might have lost their desired picnic spot.

The villain in this story (or the hero)? Nitrogen!

So, what is nitrogen? is it good or bad? Where it comes from, and how it got to the lake? Is it from the cows, the sewage, maybe from the air?

Came and find out Georgie and Madeleine's journey in the search for bringing the town's lake into its former beauty.

