MAX AND LILY TRAVELERS OF A FUTURE ERA

Max and Lily are two friends who live in the future. Together they travel around Europe and map the great science achievements of their time. Their world is like science fiction: sustainable, healthier and safe, thanks to the scientific research that serves society.

ABOUT

The adventures of Max and Lily are part of the European Project STIMULATE. The project aims to reveal the importance of Advanced Materials in our everyday life in an innovative way, by producing a documentary film and an interactive computer game.

http://www.materialsfuture.eu/en/about/

The project is funded from the European Union's Seventh Framework Programme under grant agreement No 608995.

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FROM MATTER TO ADVANCED MATERIALS

Everything is made of materials

It was a hot summer evening. Max and Lily were lounging in their office. Max was surfing online and Lily was reading a novel. In a moment of inspiration, Lily closed her book. “Look around you” she encouraged Max from the comfort of her leather desk chair. “How many different materials can you recognise?” Max raised his eyebrow and yawned. “Seriously!” she said. Max got up making a silly face and started counting: “Well, there is wood, metal, wool, stone…”

“Which of those are processed and which are raw?” she asked.

“Well, it depends on the definition! The leather you’re sitting on is processed. The wood of your desk is too but it is less processed than paper. But all of them have somehow been through processing. We are not sitting in the woods!” Max replied.

He sat down, looked at her and asked her what she had in mind that made their surrounding stuff so interesting.

“It’s something I read... I am just wondering what life would be without materials,” Lily replied in a dreamer’s voice.

Advanced materials are behind everyday life applications

“You’d better wonder what life would be without advanced materials,” he replied, he took out of his pocket his new cell phone, took off the battery and showed off the memory card. “Do you see it? One Terabyte of storage, in a chip smaller than a pea. It stores more than 1000 hours of high resolution video. And also, look at this,” he took the battery off and waved it in front of her: “It harvests energy either from the sun or from motion and it lasts for weeks. I can’t remember the last time my battery ran out”.

Lily nodded and also pointed out the advanced materials sometimes found in the human body: from contact lenses to stents and artificial limbs. And she also mentioned, kind of enthusiastically, that her sun lotion contained nanoparticles. Tiny particles, 10.000 times thinner than a human hair that could protect over a broader UV range than the traditional sunscreens. Max, on the other hand, was more interested in the advanced materials that brought maximum efficiency in computers, automobiles, cell phones and solar panels. Lily was interested in solar panels too, as a renewable source of energy. She was always interested in green technologies. They kept talking and talking, almost competing in who would add more advanced materials in the conversation.

“You know what would be nice?” Max said “To map all these advanced materials that have reshaped our world and made things faster, stronger, cheaper and more efficient”.

“And also healthier and more sustainable,” Lily added.

“We could go on a trip around Europe and see the technologies based on advanced materials that revolutionised our life,” he said, reopened his laptop screen and started typing frantically, looking for potential destinations.

“But wait, how would you define an advanced material?” Lily asked.

Which materials can bare the title of “advanced”?

“You know, super materials; materials with an extremely high performance regarding one property,” Max replied.

“Such as?” Lily insisted.

“Ultra hard materials… or superconducting materials that conduct electricity with zero resistance. Or the ones who dislike water and strongly repel it, the superhydrophobic ones. Or the nanomaterials, as you said previously. The ones inside your sun lotion: nanoparticles and also, nanosheets, nanotubes, nanowires,” he said.

“How about the ones imitating nature? Humans have always imitated nature to create their technologies. From studying birds to enable human flight, to structural colouring that allowed us to get rid of environmentally harmful dyes and bleaches,” Lily continued.

“Sure, bio mimicry is in,” Max agreed and resumed typing.

“And also, exotic materials, like shape memory alloys; you know, materials that can remember a particular shape and reveal it when needed,” Lily added quickly.

“And those as well, I like those,” Max muttered and then said enthusiastically: “It is on! Europe, here we come!”

Lily stared at him, as he was checking them in online. “That was fast,” she said.

FROM CARBON TO TREASURE

He unrolled it to display a 14 inch touch screen and started tapping it to choose a movie from the hundreds he had saved there. He did so smirking. “It is not only about aircrafts though” he told her. “Graphene is a super material that revolutionised electronics”.

Graphene in numbers

Graphene is actually an extremely thin flake of ordinary carbon. Its unique properties could materialise the dreams of everybody working in electronics and in many other technologies.

10 times better at conducting heat than copper

100 times stronger than steel but also very flexible

1,000 kilometres per second is the speed of electrons travelling in it, making it an excellent electric conductor

10,000 times thinner than a human hair

100,000 times lighter than regular printing paper

& 98% transparent to light, yet so dense that nothing can pass through it

An imaginary 1 square metre graphene-made transparent cradle would weigh less than a milligram and it could safely hold a 4 kg new-born baby!

In a nutshell

The above characteristics could lead not only to tremendous efficiency improvements to existing technologies but also to a brand new world of applications. Transistors could be made much faster and smaller, touch screens lighter and more robust, plastics 30 degrees more resistant to heat, pollution sensors several times more sensitive. Electronics could be flexible, lighter, stronger, damage-resistant and eco-friendly.

However, scientists still study the properties of this material and the fruits of these studies haven’t ripened yet. So we can only wait to see if our graphene dreams will ever come true like in Max and Lily’s world.

Next stop… Paris

In the meanwhile, our two heroes get ready for landing… Stay tuned to find out what the Eiffel Tower looks like in the future and how it helps power a whole suburb thanks to organic electronics.

THE CITY OF LIGHTS

Max and Lily were enjoying their evening at a typical café Parisienne. As the last of the sun's rays were hidden beyond the horizon, the lights of the Eiffel Tower lit up, giving the city its unique night colours.

"Did you know that back in 2013 there was an illumination ban?" Max started, "all the stores and non-residential buildings had to switch off their interior lights by 1 a.m. at the latest".

"I suppose the carbon dioxide emissions were reduced, but it must have been a little sad… the city of lights… lightless?" Lily said. "But now, look at this glorious view!" she added, pointing at the twinkling Eiffel Tower and surrounding illuminated monuments and museums. "And they all are powered by the sun. Do you see the fuchsia building over there? Its paint is actually a coating of organic solar cells".

Max rolled his eyes at Lily and laughed: "Fuchsia? Is that even a colour? And don't get me started with organic solar cells. Do you know what organic means? Do you even know what a solar cell is?"

Lily sat up straight in her chair and answered his challenge. She started by explaining that a solar cell is a device that absorbs light from the sun, converts it to electric energy which can be used either directly (by lighting a lamp for example) or stored in batteries.

'An organic solar cell,' she continued, 'also called a plastic solar cell, is made of polymers or fullerenes, carbon compounds shaped like a buckyball. And a plastic solar cell has taken over plastic properties: it is flexible, inexpensive and easy to make. And it can be recycled!

"And it also has an expiry date just like most plastics do!" Max said and pointed out that the traditional solar cells made of silicon were lasting longer and were cheaper too. He then showed her his mobile phone which had an integrated silicon solar cell to charge the battery. Lily also took her mobile phone out and showed off its flexible and fashionable case, made of an organic solar cell. Max made fun of it, as his device was charging faster.

"But it is not only the energy they provide us with, it is also the energy we consumed to make them" Lily insisted. "Organic solar cells need less energy to be produced and you should take this into consideration when talking about efficiency" said Lily.

She went on talking about a new "army" of materials, perovskites, named after the famous mineralogist Lev Perovski, which have been enlisted in the battle for efficient and sustainable photovoltaics. These are compounds incorporating both organic and inorganic parts in their structures. These materials are generally abundant, sustainable and very efficient.

“Well, if we talk about efficiency, why not use gallium arsenide for our solar cells? That is efficiency! And they are so robust and durable” Max insisted.

“But… but those odd-named chemical compounds can be toxic! They should be kept out of the world!” Lily said almost fuming.

“Indeed” Max said amused “they are the solar cells used in space! Where do you think satellites get their power from? They aren’t plugged into our power grids” he teased her.

Lily, realising he was just pulling her leg, calmed down and smiled. She laid back and looked around at the public buildings; all painted in different colours, including the Eiffel tronics!

BATTERIES RECHARGING

“We need to stop at a charging station” Lily announced casually, leaving the Soleil Highway and joining the European Route E15. The two friends were leaving Paris and going to Como, the home-town of Alessandro Volta, the inventor of batteries.

“Why didn’t you say this earlier?” Max complained, watching the empty road in front of them. “We must have passed at least three charging stations while in the city”. Lily kept driving calmly. “We will find one on our way” she reassured him.

Half an hour later, just after passing Fontainebleau, they found an on-street car charging station and Lily stopped. They both got

out and put the car's plug in the socket. "Fifteen minutes until it's fully charged" announced Lily. "What? Back home we have a rapid mode and it does in half time" Max said. "What's the rush?" Lily asked. "Let's have a walk around; the nature is so beautiful here. There is a forest close by".

Max passed on the suggestion as he also wanted to charge his laptop somewhere. Lily said that the electric cars' charging station wasn't suitable for charging any other device. Max argued that the basic principle was the same.

Batteries all do the same thing: they convert the chemical energy stored in them into electrical energy.

They all have two terminals, a positive one and a negative one, called electrodes that are made of special materials. There is also a material separating them, the electrolyte. Electrolytes have a special ability: they contain many charges that can move within them. The positive charges go to one electrode and the negative charges to the other, because of a chemical reaction that takes place. This means that inside a battery we have a directed flow of electric charges. The electrical current that gives power to a device, like a laptop, is the continuation of this flow outside the battery, through a wire.

The battery is exhausted when all the charges of the electrolyte have reached their destination on the electrodes. This is when all its available chemical energy is consumed.

While charging, a battery takes electrical power from the socket to convert it back into chemical energy. The charges that enter the electrolyte move now in opposite directions and electrical energy is consumed to build up chemical energy.

Depending on the properties of the materials that the batteries are made of, their energy capacity changes, because some materials can store more chemical energy than others. The element that has been used widely for carrying and storing the electric charges inside the batteries is lithium. Lithium however is not a common material. Advanced materials have decreased the charging time and have replaced materials that were rare on our planet, like lithium, or very toxic, like cadmium, lead or mercury. New batteries have electrodes that are made of carbon-based nanomaterials like carbon nanotubes and are leakage-free because charge-conducting polymers replaced all their liquid parts.

"These are all great" Lily started "but how do they bring you to the conclusion that you can charge your laptop here?"

"Same process, same materials, why not?" Max insisted, secretly checking there were only five minutes left for full charge.

"Because this charger would burn your laptop, that's why! This source is too strong. The voltage is huge!"

"What's the voltage?" Max asked innocently.

Lily paused, wondering if he was kidding her and then decided to answer. "It is basically the tendency of electric charges to move between two points. Between the two electrodes we were talking about. If we imagine the electrical current to be water flowing in a river, the voltage is the height difference between 2 points. It makes the water flow in a certain direction, like a waterfall does. The height difference that is used to

charge your laptop is 220 Volts. The height difference that is now charging our car is more than 500 Volts. Your laptop will be destroyed; it can't hold so much power".

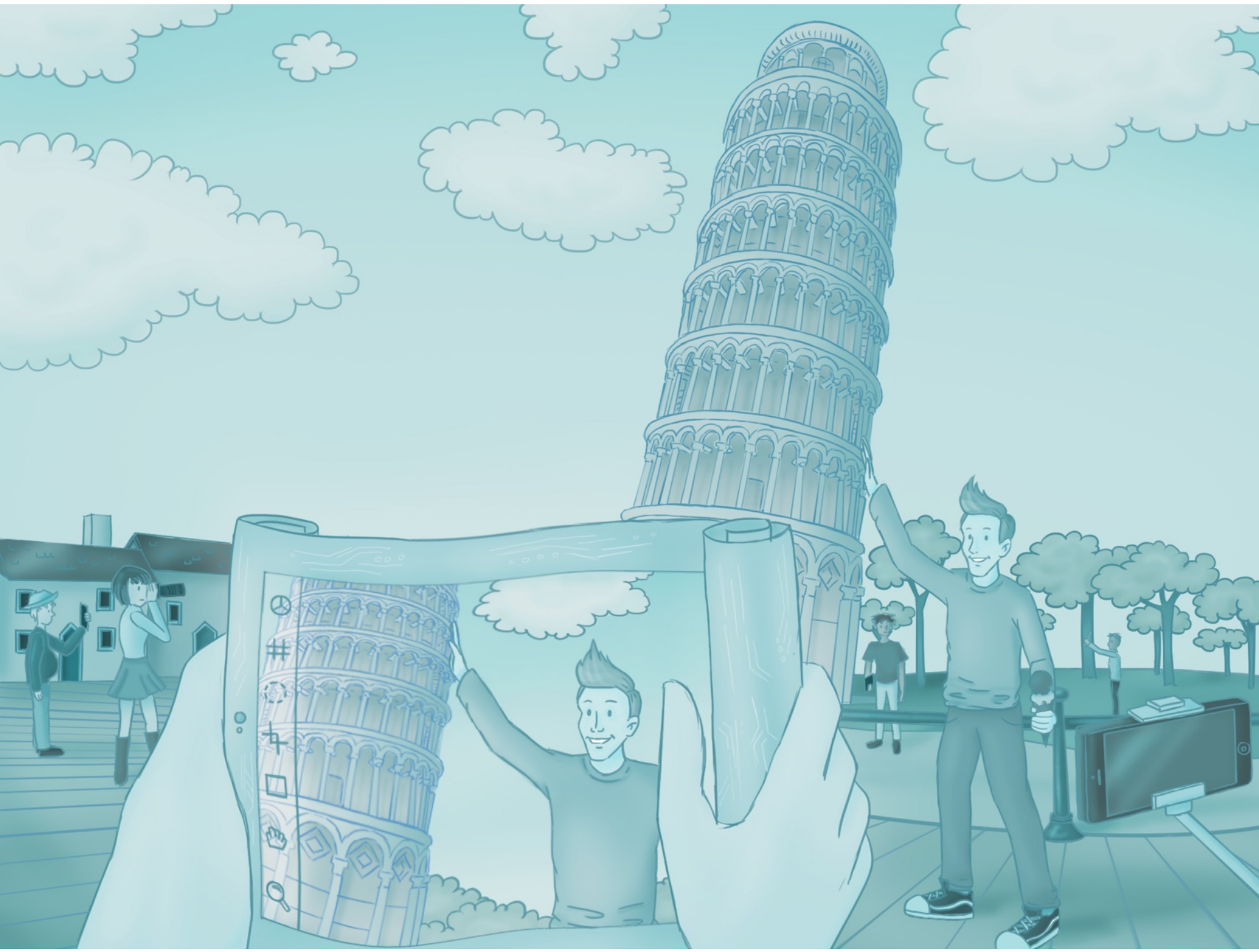
"Oh, so it is due to this high voltage that our car is already charged?" Max asked smirking.

Lily suddenly realised he was teasing her, all this time trying to escape a walk in the forest,. She started walking towards the woods, while Max yelled at her "Wait! The car's battery is fully charged! Come back! We can always go for a walk at the next charging station… after 800 kilometres!"

THE BUILDING BLOCKS OF OUT SOCIETY

“I think the problem was the bricks. They were either too soft or too brittle! Clay bricks at that time were not very good, as you can imagine” Max said looking at the bell tower.

“This is not the case here. The building is not even made of bricks! It is made of marble and it was too heavy and the ground too soft according to the guide” Lily said and showed him her display, where a hologram of an Italian History Professor was speaking. “The bricks are fine. They are the building blocks of our civilisation… literally!”



“Really? Bricks? That’s what you consider the building blocks of our civilization?” Max was laughing. “What is it then?” Lily asked. “Steel? Wood? An advanced material? A peculiar alloy?”

“Well, look around you! What do you see?” Max said. Lily did look around and saw the Tower of Pisa, the Cathedral, the Piazza del Duomo, all the buildings… they were made of bricks or marble. Max then asked her to see the people around. All the tourists were equipped with various types of cameras, cell phones, tablets, phablets and all kinds of electronic gadgets.

“So what? Electronics is the building block?” All electronic devices are made of circuits;transistors, chips, diodes, resistors. And all of them are built around a material with a conductivity that can be tuned, a semiconductor.

A conductor, as its name implies, is a material that conducts current, meaning it permits the electrical current to flow through it, while an insulator is the opposite: it doesn’t conduct current. This happens because conductors have free electrons in their structure that flow freely, while insulators’ don’t. Conductors include materials like silver or copper (metals) while insulators include glass and paper.

A semiconductor stands in the middle: it may conduct current, depending on the conditions around it or it may not. We can easily change the conductivity of a semiconductor by modifying the number of free electrons that it contains by, heating it up, illuminating it, or changing the electric field around it. Heating up the semiconductor enables electrons to break free and move freely between the atoms, hence the term ‘free electrons’.

Some of the most famous semiconductors are Silicon and Germanium.

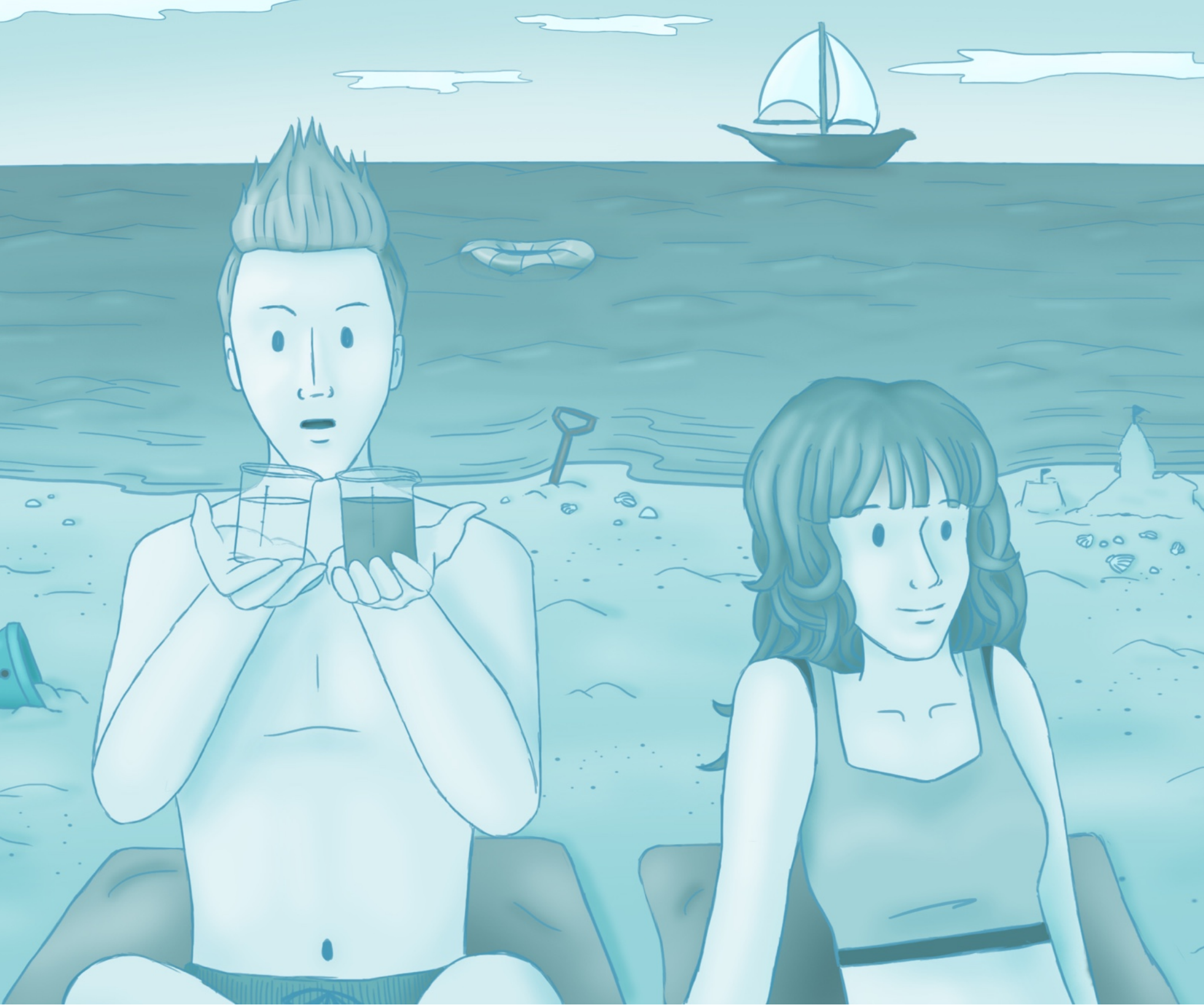
Semiconductors are the building blocks of all electronic devices analogue and digital,, like diodes, transistors, solar cells, LEDs and displays, integrated circuits, sensors. Imagine a world with no electronic chips: no radio or TV, no computers, no videogames, no cell phones or tablets, no electronic medical equipment, no advanced control boards in cars or airplanes… this is a world with no semiconductors.

“Ok, so semiconductors are the building blocks of our world? That means germanium and silicon? Have you heard of Silicon Valley, Silicon Glen etc? They are meant to be super high-tech places.”

“In fact, it is not only silicon or germanium. There are many more semiconductor materials and all of them contain traces of other elements like boron or phosphorous. These additions change the number of free electrons. Combinations are good”. This thought was subconsciously leading him to combine the famous Italian gelato with chips. He ordered vanilla with chocolate chips with a big smile.

“How many free electrons are there in your ice cream?” Lily teased him.

“Gelato could be the building block of my diet!” Max replied with a full mouth.



CRYSTALL CLEAR

“Will you please go bring me some water?” Lily asked Max, playing with her eyelashes in a cute way. Max however, was lying on his back, enjoying the warm sun and did not move. Lily insisted and asked him again. He got up and showed her the beautiful, endless sea lying in front of them. “There you go. Just go for a dive and get as much water as you want”. Then, he put on some extra suntan lotion and got back in his initial position.

“Max! I meant some water to drink!” Lily clarified. “I can’t drink sea water. Do you want me to get sick?”

“You won’t get sick, you will only have some illusions and then maybe some brain damage. You’d better not drink a lot of it” he replied in his sweetest voice.

Lily understood she had lost her case, got up, put her hat on to be protected from the glorious Greek sun and headed for the kiosk. She bought some water and returned back. Max saw her and raised waiting. When she approached, he got disappointed. “You didn’t bring any for me?”

Lily blinked. “Don’t you see the Mediterranean in front of you? Get some water from there if you wish”, she replied.

“This wouldn’t be efficient, you know” Max started, deciding to re-approach one of his favourite topics. “In order to drink sea water, we need to desalinate it first and this is not efficient. It costs too much energy”.

“Excuse me; are you living back in the 21st century? This is when water desalination was not energy efficient” Lily said mocking him. “Nowadays a very big part of the population gets to drink purified or desalinated water”.

Max stood up, always ready to give a speech full of passion. Water desalination, he started, is way more expensive than getting fresh water from rivers, or ground water or even from recycling water. However, due to many people being excluded from fresh water sources in the past, scientist had to search for drinkable water where water was plenty: in the sea.

Using membranes, scientists were filtering water for a long time. All membranes are basically materials with tiny holes that block the larger particles out while they allow the smaller ones to go through. If the holes are tiny enough they may allow only the water molecules to pass and keep everything else out. This method was good enough to separate also toxic particles from the water. But it was an expensive one for desalination.

Boiling salt water and collecting its steam was another method used to separate it from salt or other pollutants. This method was inefficient too.

Lily drank some more water from her bottle and asked him if he knew that human beings are made of more than 70% of water. Max couldn’t understand why she would ask him such a question and stopped talking for a moment.

Lily told him that once more, nature had already found the solution to the problem beforehand. Biomimetic membranes! Humans, animals and plants are made of cells. The outer part of each cell is a membrane. And in a variety of different animal and plant cells, these membranes contain a special type of protein called aquaporin.

Water can flow rapidly through the cell membrane thanks to aquaporins, while other molecules cannot. Aquaporins selectively bind to water molecules and let only them through. This type of water transport is very efficient and it has been used to improve water desalination membranes and reduce their operational and energy costs.

Max was both impressed and thirsty. He complimented her and tried to take the bottle from her hands in the same time. Lily was quicker though.

“If you wish to drink water, you will either walk to the kiosk to buy some or start your personal desalination business here, in the beautiful island of Crete. Is this clear?” she asked.

LET THERE BE COLOUR

Max was quietly suffering while he accompanied Lily to one of the most popular shopping districts in Barcelona. Lily on the other hand, was over the moon. She was going around touching fabrics, trying colours and mentally calculating the maximum budget she could spend on shopping.

“Do you think we could leave now and try to do something more… sciency?” Max said in a tired voice. Lily stopped but not because of Max. She froze in front of a shop, staring at the dress in its window. “This is it” she said and stormed inside.

Max also had a look at the window and froze. “Oh no!” he muttered and followed her in a hurry.

Lily was touching and caressing a dress that looked like a peacock. Max rolled his eyes and asked her what was so special about that dress, anyway.

“Well, you wanted to do something more relevant to science, didn’t you?” Lily asked. Max was puzzled. “I didn’t mean biology of the birds” he managed to say. Lily laughed. “This is high tech structural colouring!” she corrected him, paid for the dress and went off the store, holding it like a prize.

They sat down in the edge of a fountain and Max asked for some more clarifications. Lily started by telling him that many centuries ago, Isaac Newton and Robert Hooke suggested that the peacock’s feathers are coloured blue and green because of their structure. Their surface morphology makes light reflect in such a way that we see them coloured, while in reality they are pigmented brown with melanin.

“In this case light behaves as a wave” Lily said and threw a tiny pebble in the fountain. The pebble caused a circular wave. Next Lily threw three pebbles together. They all caused waves that interacted with one another. In some points, the waves were added together creating a bigger shape while in some other points, the waves destroyed each other.

“This is wave interference – I know this phenomenon” Max interrupted.

The surface of the material the dress was made of, as well as the real feathers of a peacock, consists of tiny parallel lines. This microstructure reflects light in different angles. This way, different colours appear at different angles.

“Please tell me this has more applications than clothes” Max interrupted again.

“This is haute couture!” Lily protested. “And yes, there are numerous applications. Surfaces that provide radiant colours but also surfaces camouflaged thanks to this biomimetic material. Moreover… low reflectance glass… or efficient optical switches”. Max liked this and nodded satisfied.

“This structure allows us to control light at a scale of nanometres. This is how the security hologram on your credit card is made! Imagine silicon wafers that are carved in a way that they look coloured, while in fact they are not. Imagine chips, optical chips using light instead of electricity. They carry data way faster”. Lily concluded.

“You know what? After all these, I don’t find this peacock dress so terrible anymore” Max said happily, trying to make a compliment. Lily gave him a nasty look but couldn’t resist adding that it is not only peacocks that have this special feature. Butterflies, other type of birds like bee-eaters and macaws also share similar structures. And with that, she got up and announced it was time to go back to the shops!

PRINTING EVERYTHING

Max and Lily had been enjoying a nice walk in the Hyde Park. Max especially, was trying to get closer to the Speakers' Corner, having in mind a variety of science and technology topics he would like to analyse to anyone willing to listen. Lily on the other hand was happily strolling around, taking pictures of the fancy birds, ducks, swans and other colourful creatures, until something weird caught her eye.

A tiny little duck seemed to be under some kind of distress. After observing it for some moments, Lily discovered, to her shock that it had lost its leg. She showed it to Max and they both approached. Lily took it in her arms and asked Max if they could do something. Max, always having a problem solving mindset, came up with a great idea.

"Do you remember that 3D printing business we saw in our way here?" he asked and added quickly that their moto was "We print everything". If they print everything, he continued, they could print a prosthetic duck leg, couldn't they?

"Of course we can!" a red faced man was smiling to them in a reassuring way. He was the head of the prosthetics department of that business. "We have even printed long lasting vascular networks" he added proudly. He then took millions of photos of the duck's good leg and started to design the prosthetic one. He even recommended a surgeon who could place the leg safely.

Max and Lily discussed with him the kind of material that would fit best to the prosthetic leg. Plastic, metal, ceramics and wax were the main choices they had. In order to make an informed decision, they asked more details on how 3D printing worked.

They already knew that 3D printing is a process where an object is created. Layer by layer, the printer adds material to a specific pattern, until the entire object is formed. There are no limitations to the object's shape.

The number of its applications has also been limitless. Anything can be printed: from objects of art, design or sculpture, to handy everyday items, like a spoon or a screw and from jewellery or fashion accessories like printed hats, to the most complex components of aerospace or automotive devices. Some of the most extreme printings ever produced include entire houses or even… pancakes! Both architecture and gastronomy used 3D printing successfully in their respective businesses.

3D printing also revolutionised prototyping; Product development received a boost, as getting more than one version of a product in the early stages of its making was made easier. Consequently the optimum solution was reached in a quicker and more efficient way.

Some of the most important and unexpected applications however, are found in the fields of

medicine and biology. Researchers have printed out cells from the kidneys, the liver and even the heart. Ceramic dental implants, metal hip joints and replacement knees were designed in the computer in great detail and then printed for the patient's needs.

Now Lily was holding the little patient in her arms; unexpected it might be, but both she and Max were determined to help the duckling receive a functional new leg.

NEW MEDICAL ALIES

Max was fully occupied by playing a video game, while Lily was bored waiting for their gate to open at the Heathrow airport. Max turned his body left and right holding tightly his thin screen and it seemed like he was trying to avoid something.

“What are you doing there?” Lily asked half-curious, half-sleepy. Max didn’t look at her in order to keep focused on his game but answered quickly: “Believe it or not, I am doing my homework”. Lily was so surprised that she got up and approached him.

“Seriously? We are on a trip around Europe, we have five days left before going back and you are doing your homework?”

“Yes, I am” Max replied and almost jumped on his feet, trying to pass through an invisible obstacle. He seemed to be glued in his tablet.

“What kind of homework is that interesting?” Lily asked him and poked his arm. Maxed stopped moving and got a pain expres-

sion in his face. The screen reflected a huge GAME OVER in glowing letters.

“Oops!” Lily goofed. “Sorry”. Max lied in his seat feeling disappointed. “This was my physiology homework! We had to land the nanorobot on the virus through the blood stream” he said in a sad voice.

Lily gave him a puzzled look, so Max started explaining. In the nano scale, meaning in a scale a billion times smaller than a metre, nanotechnology has provided the possibility of successfully detecting diseases at early stages and delivering drugs to specific cells using nanoparticles. Thanks to nanotechnology, surgeries and side effects of the pharmaceutical treatment can be minimised.

Three components need to be combined in order to have a clever drug targeting system. Firstly, we have a targeting group, which can be a protein or an antibody or a charged molecule that will recognise and bind with the target tissue where the problem is located. Secondly, we need a carrier on which the drug is attached, or in other worlds, we need someone who will carry the drug. This can be a liposome or a nanoparticle or a macromolecule such as a protein, DNA, or a carbohydrate. Finally, we need the drug that cures the tissue.

In order to avoid the carrier’s destruction by the body’s immune system, we put a coating on its surface, a biocompatible polymer. This polymer works like an invisibility cloak, making the drug invisible to the immune system. Apart from hiding it, it can make it also less toxic. A popular polymer that does this work is the PolyEthulene-Glycol, also known as PEG.

The next step of a drug delivery system is a nanorobot. Microscopic devices that can be either synthetic or even biological, that, sense, process information and actuate at the nanoscale. These devices can be used both for diagnostic and therapeutic purposes. They use their sensors to detect a problem and then, through the blood stream, they travel and release the necessary amount of drug on the right spot. Nanorobots may reach areas in the human body that are difficult or impossible to reach otherwise. They require minimal invasive surgery, as they can easily be inserted in the body, because of their small size, they can detect diseases at very early stages and they can fight infections inside the body. It is like a new powerful soldier has been added to the army of our own immune system; an ally to the white cells and the other defence mechanisms of our body.

“Drug delivery systems are developed for treating diabetes, cancer, AIDS, Alzheimer’s disease and many other diseases”, Max concluded and showed off in his tablet the sophisticated simulation of the blood stream and a nanorobot navigating through it.

But Lily was quicker than him. She grabbed the device and pressed the START icon. “No worries, Max” she said. “I will do your homework for you” and she started playing, trying to find her target, driving through the artery and trying not to crush on the red blood cells.

BUILDING NEW LEAVES

After wandering around in the cosmopolitan area of Amsterdam and taking pictures with the famous picturesque canals, Max and Lily headed to the acknowledged University of Amsterdam. In their solar energy initiative, called Solardam, they were working on artificial photosynthesis projects.

They both felt that there was no better way of ending their journey than getting to know something more about this admiral process, a process imitating nature's way of producing energy for billions of years, in order to produce energy for the human civilisation needs.

"We use energy for many things, but three are the most basic reasons" Lily started. "For heating, electricity production and transport. Artificial photosynthesis is helping us with the latter two".

Max however, couldn't help but feel a little disappointed. He held in eye level a beaker that contained a photocatalytic cell in water. There were lots of tiny bubbles rising up. "This is the artificial leaf?"he asked reading the label. "I expected something… greener" he complained.

"Like what?" Lily asked. "It may not be coloured green, but it works under the same principle as a leaf" she continued. "Do you even know what photosynthesis is?" she teased.

Max said he perfectly knew what photosynthesis was. Plants take solar energy and convert it into chemical energy. They use the carbon dioxide they capture from the atmosphere and water to create their food, glucose, and oxygen.

"Glucose is a carbohydrate" Lily added. "And this artificial leaf you are holding there does something similar. It uses solar energy to split water into oxygen and hydrogen. Do you see these bubbles? These are oxygen and hydrogen. Oxygen is coming from the front side of the leaf and hydrogen from the back side. Hydrogen is used as a fuel.

While in nature the "usable fuel" is carbohydrates, proteins and fats, in this case scientists were looking for fuel to power cars and electricity to run devices. Artificial Photosynthesis is the process of preparing fuels from nothing more than carbon dioxide, water and sunlight. It is a vital process, the foundation of a world that no longer needs fossil fuels.

There is also another path the artificial photosynthesis has followed: combining carbon dioxide with water to produce hydrocarbons. Made of hydrogen and carbon, hydrocarbons like coal, gasoline or natural gas have been used for centuries as fuels. This type of artificial photosynthesis also has the advantage of reducing the carbon dioxide in our atmosphere.

"But how is this done?" Max wondered loudly. Lily said there was one word that would explain it all: catalysts. A catalyst is a material that speeds up a chemical reaction. New catalysts have been

developed in order to enable artificial photosynthesis.

When these catalysts are coupled with materials that absorb light, an efficient generation of fuels

high stability is titanium dioxide. Apart from this, metal alloys have proven to be efficient catalysts. A peculiar one, the Nickel Molybdenum Zinc alloy (NiMoZn) is very efficient in hydrogen production.

such as methanol becomes possible. At the beginning, precious metals like platinum or iridium were used as catalysts. They were very pricey however, so new ones had to be developed, in order to reduce the cost. A catalyst that is harmless, environmentally friendly and also has very

Both Max and Lily were impressed by this achievement. It may not look like a leaf, but the artificial leaf reduced carbon dioxide providing fresher air, and was used to create fuels that power both cars and electric devices. Efficiency, caring for the environment, sustainability. The

THERE IS NO GOODBYE

Lily was sitting in her seat, a little sad and melancholic. She was never good at goodbyes and she didn't want their trip to reach an end. Max was trying to cheer her up by saying silly jokes. In the end, he decided to change his strategy. He took off his pocket his favourite and always handy tablet, he unrolled it and switched it on. He grinned.

"5 Terrabyte of photos will certainly cheer you up!" he said to her. Lily looked over his shoulder and saw themselves eating ice cream in Italy, swimming in the Greek islands, strolling around Paris, playing with the ducks at London's Hyde park, shopping in Barcelona and having fun in Copenhagen. "It has been quite a journey" she said, trying to smile.

"From graphene to photovoltaics, from batteries to fuel cells, from structural colouring to artificial photosynthesis, from 3D printing to drug delivery, our world is changing and developing. It becomes more efficient, it becomes more environmentally friendly, it becomes more sustainable. It is actually becoming a better place" Max said.

"And you know what? You and I are parts of this scientific evolution that never stops. So, as far as I am concerned, there is no goodbye! There are many more things to discover and invent and I am looking forward to it. Are you not?"


There is
no
goodbye!
It's all about
efficiency