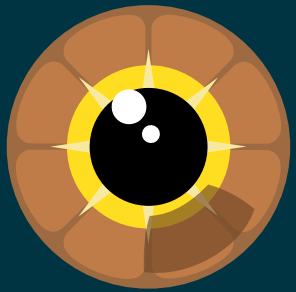
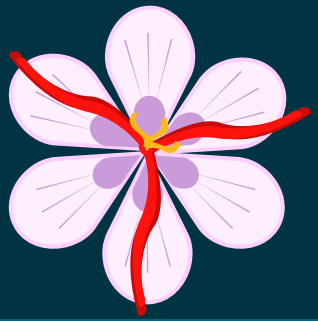

THE WORLD OF

CAROTENOIDS:

Colors, food and health

CaRed

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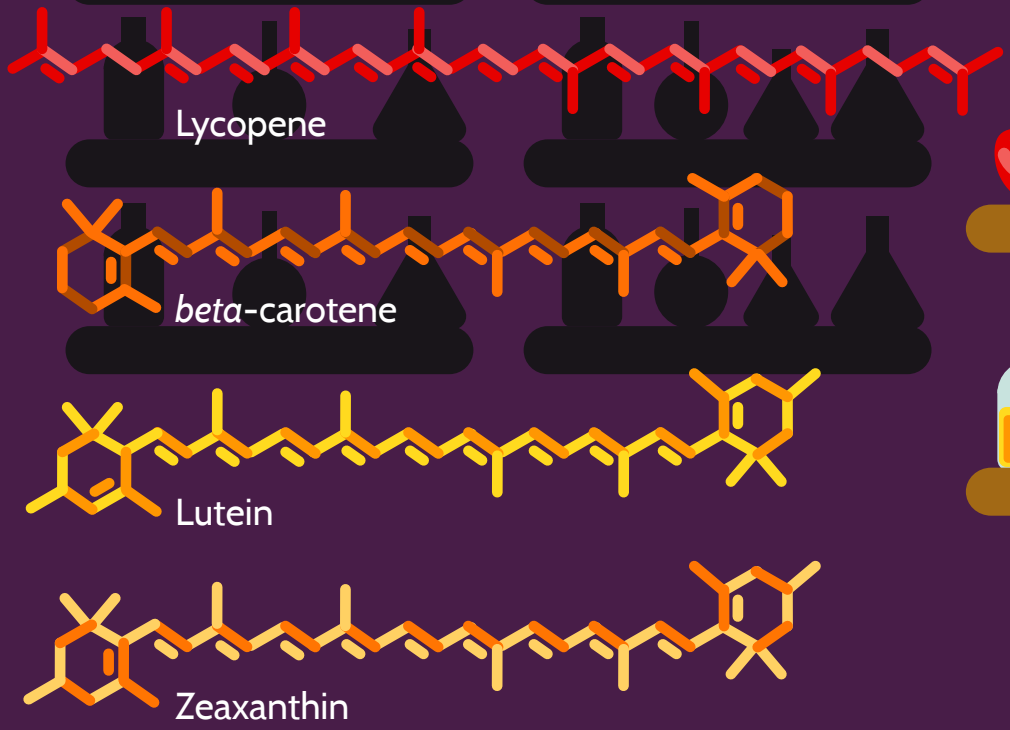
WHAT ARE CAROTENOIDS?

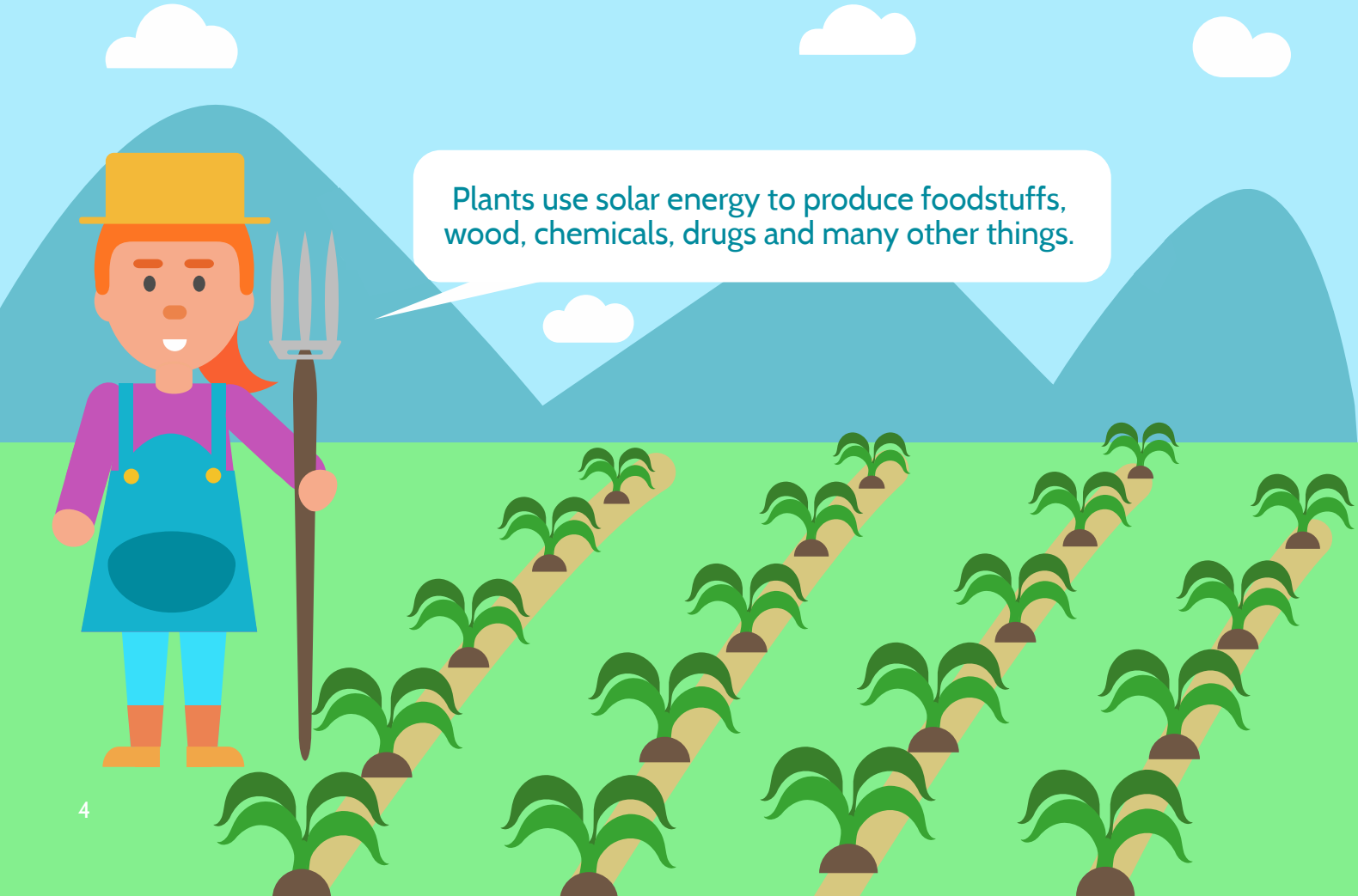
Carotenoids are a group of natural pigments. Their characteristic colors include yellow, orange, red, and many intermediate tones. They are named carotenoids because they were first discovered in carrots, whose scientific name is *Daucus carota*.

Hundreds of different carotenoids have been discovered in nature. Some of the most common provide red color to tomatoes (lycopene), orange color to carrots (*beta*-carotene) and yellow color to corn (lutein and zeaxanthin).

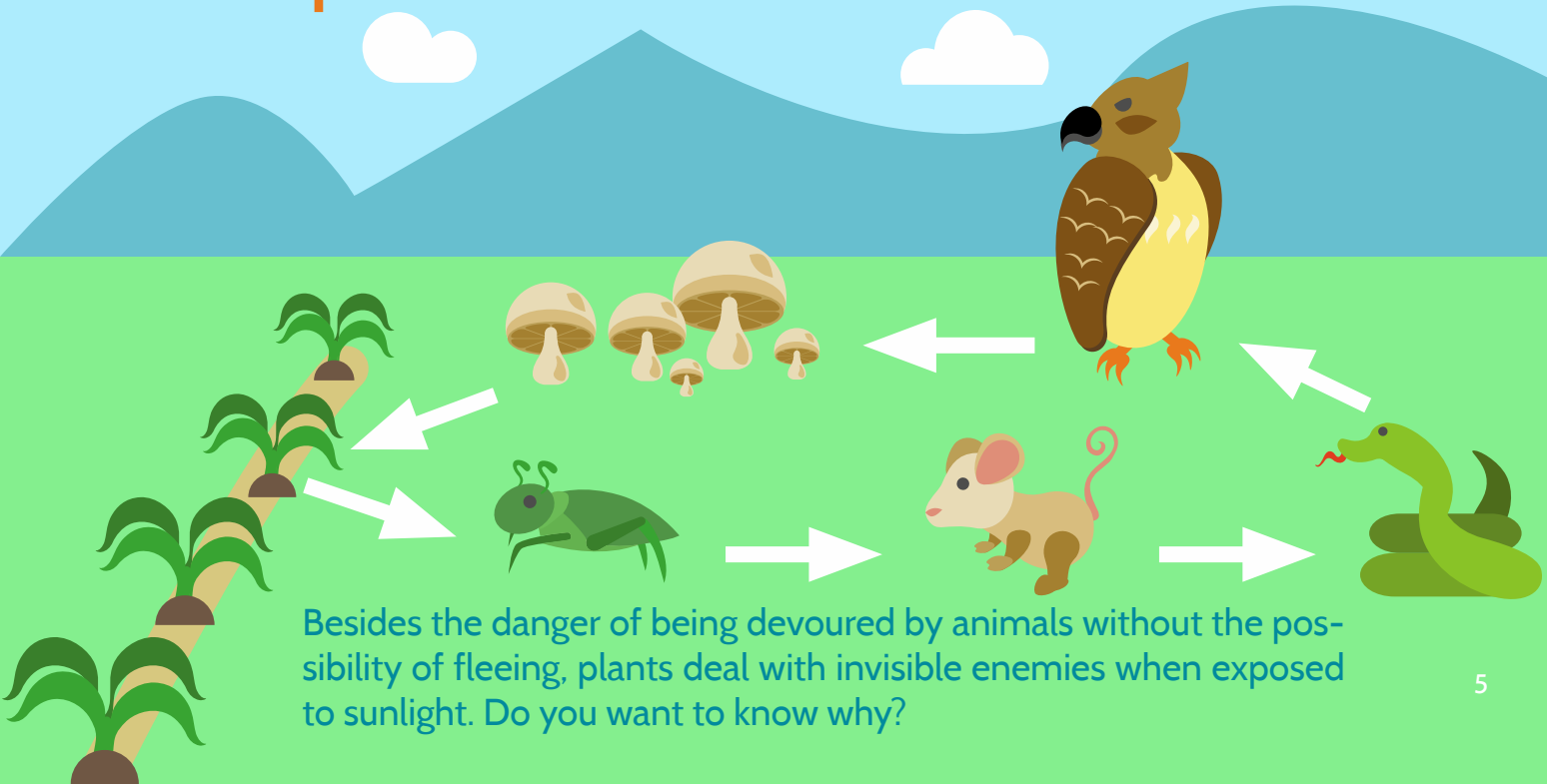


Carotenoids are necessary for photosynthesis, and photosynthesis is essential for life on our planet. Do you know why?

PLANTS LIVE DANGEROUSLY

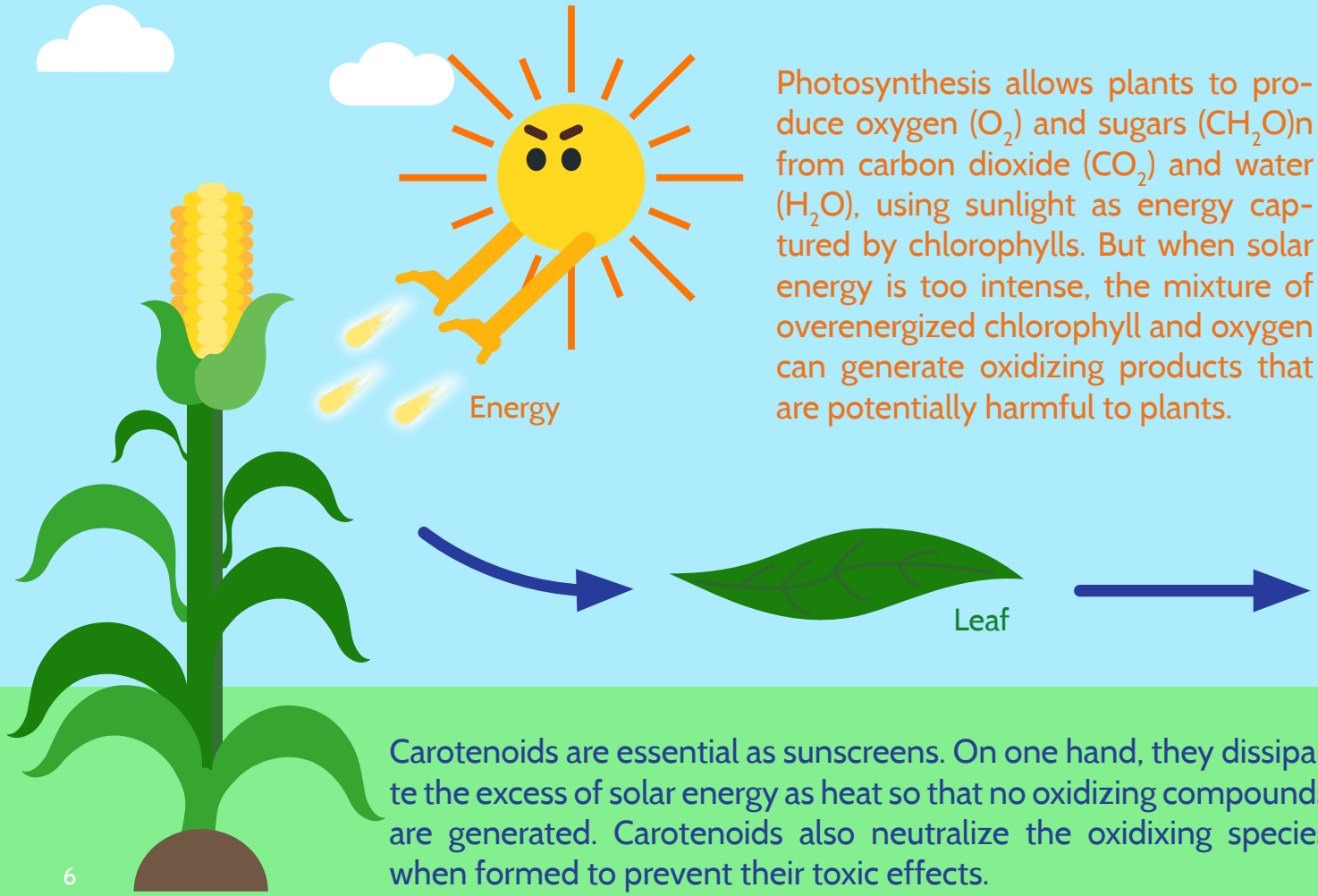


Life on our planet mostly relies on photosynthesis, which uses sunlight energy to support plant growth. Plants are at the base of the food chain, feeding insects, herbivores and their predators. Plants that we cultivate also feed us and our farm animals.



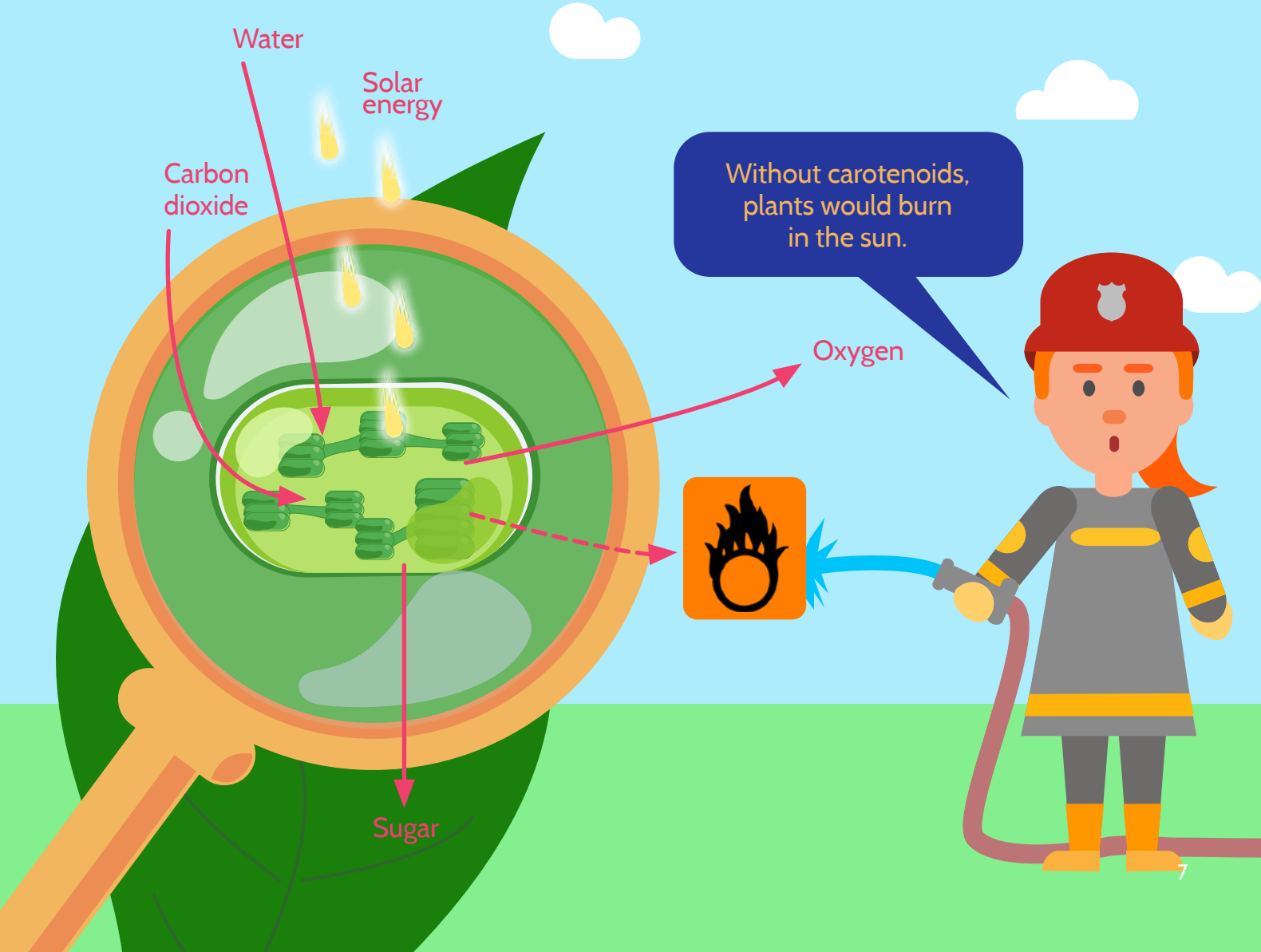
Besides the danger of being devoured by animals without the possibility of fleeing, plants deal with invisible enemies when exposed to sunlight. Do you want to know why?

CAROTENOIDS ARE SUN PROTECTANTS



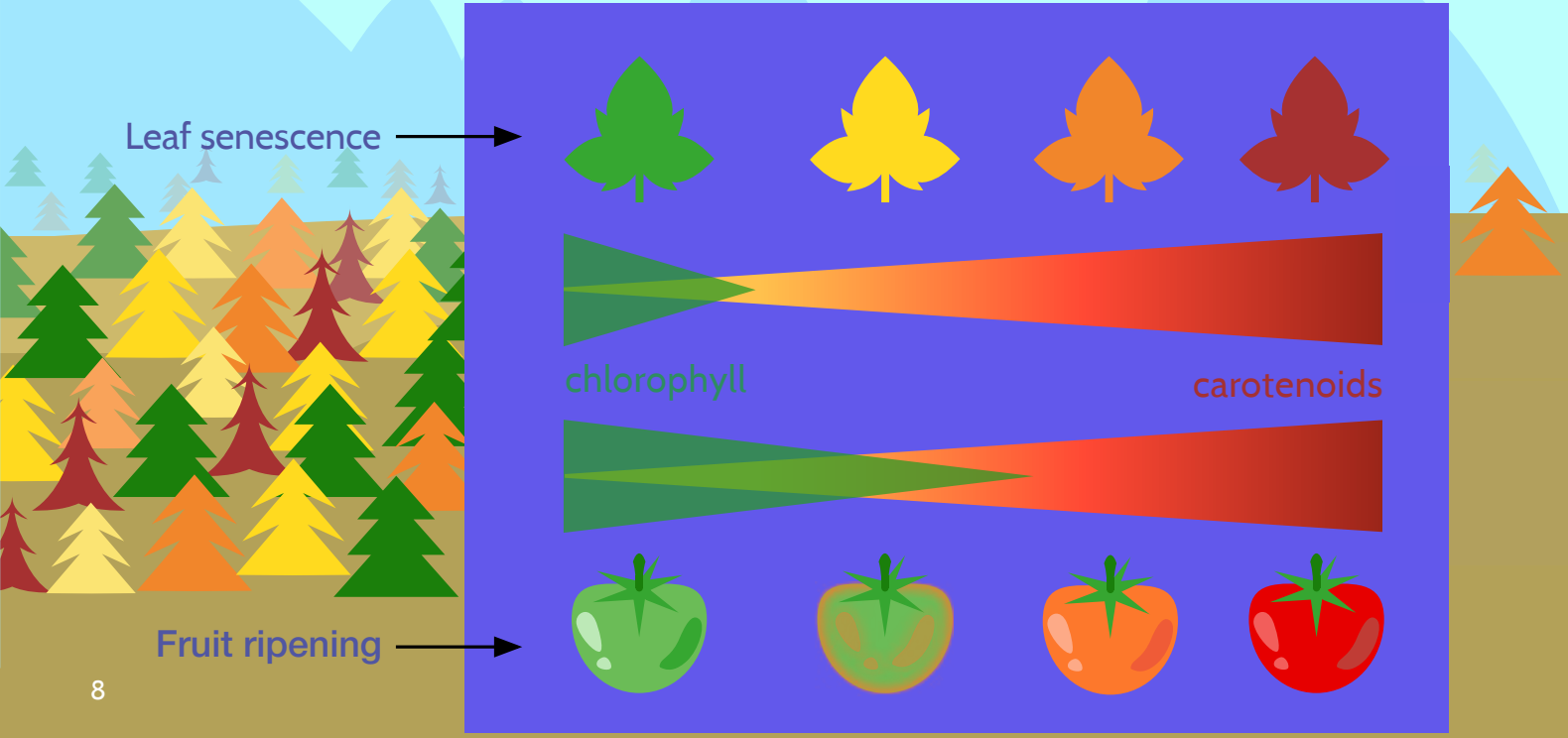
Photosynthesis allows plants to produce oxygen (O_2) and sugars (CH_2O)n from carbon dioxide (CO_2) and water (H_2O), using sunlight as energy captured by chlorophylls. But when solar energy is too intense, the mixture of overenergized chlorophyll and oxygen can generate oxidizing products that are potentially harmful to plants.

Carotenoids are essential as sunscreens. On one hand, they dissipate the excess of solar energy as heat so that no oxidizing compounds are generated. Carotenoids also neutralize the oxidixing species when formed to prevent their toxic effects.

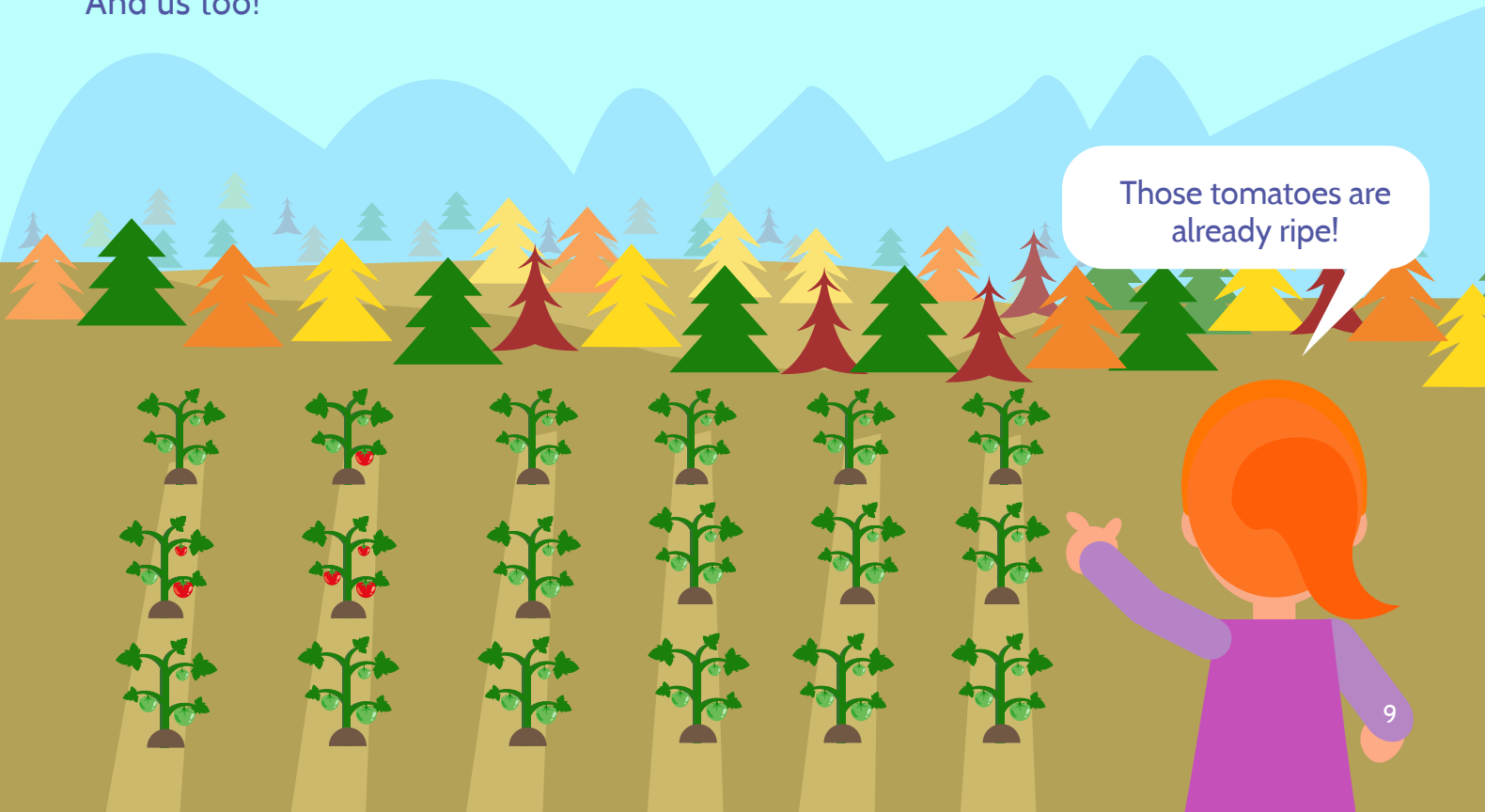

Water
Solar energy
Carbon dioxide
Without carotenoids, plants would burn in the sun.
Oxygen
Sugar

CAROTENOIDS PROVIDE COLOR

Photosynthesis needs chlorophylls, the pigments that give the characteristic green color to plants. The colors of carotenoids only become visible when chlorophylls are removed. This occurs in autumn, when the leaves of some trees enter senescence (that is, they age and die) and chlorophyll is degraded.

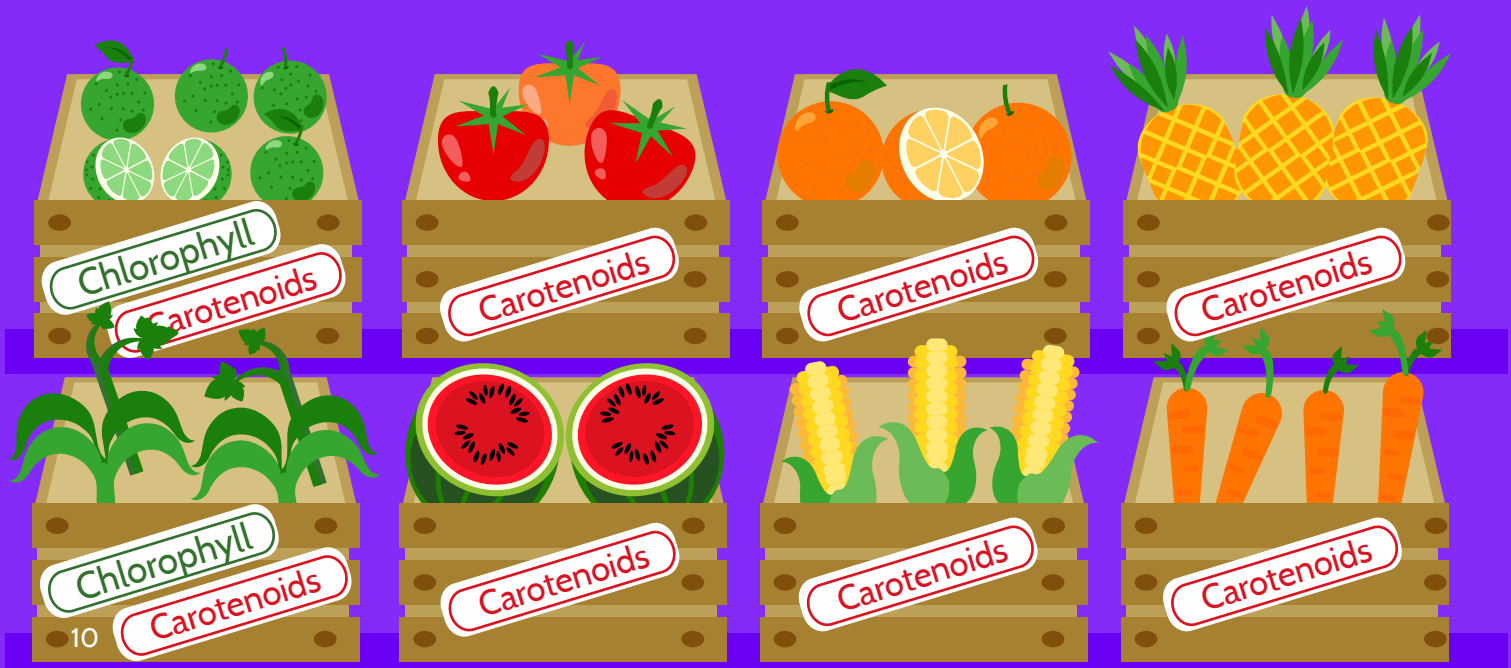


Chlorophyll also degrades during the ripening of many fleshy fruits. That's why carotenoid-rich ripe fruits display yellow, orange and red colors. Such pigmentation, together with the aromas produced by the breakage of some carotenoids, inform animals when fruits are ready to be eaten (so the seeds they contain inside can be dispersed). And us too!



MISLEADING COLORS

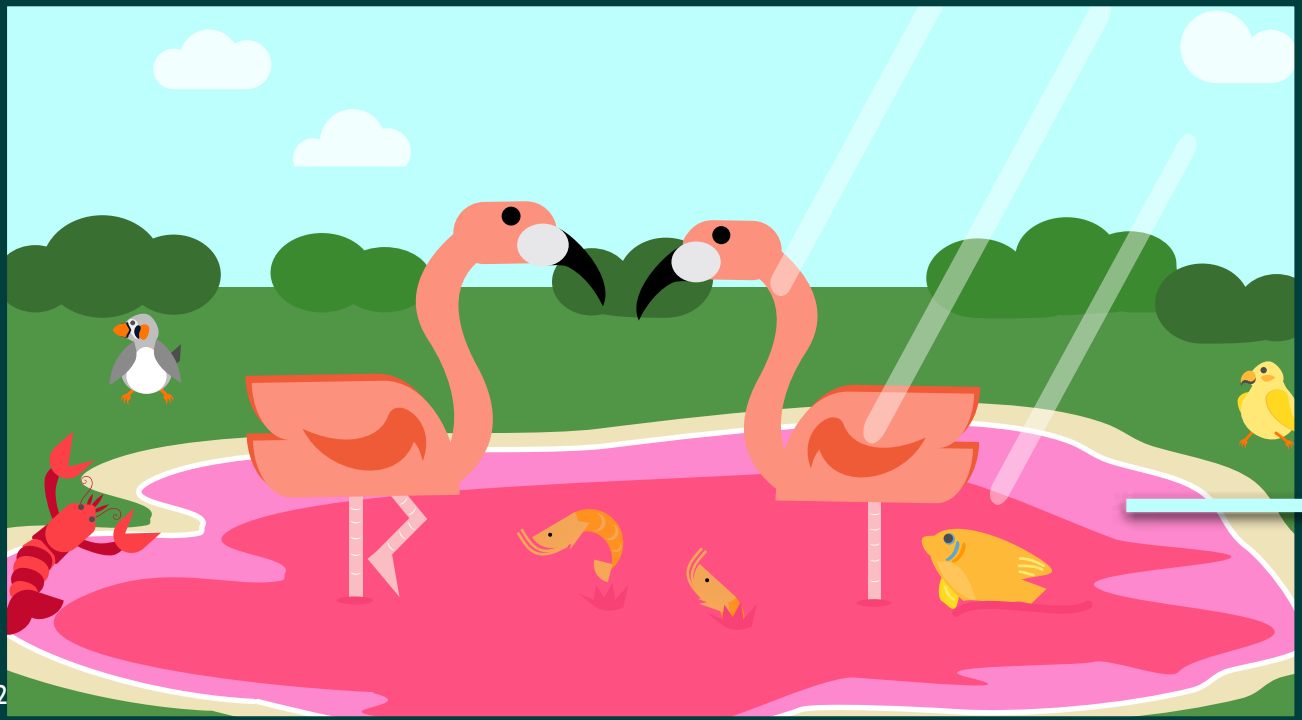
Green vegetables and unripe fruits have carotenoids but we cannot see them because they are masked by chlorophylls. But besides using chlorophyll and carotenoid pigments, nature has other ways of coloring plant products...



Some fruits and vegetables are colored in red (strawberries, cherries, pomegranates) or purple (grapes, plums, beets) due to other natural pigments such as anthocyanins and betalains.

MICROORGANISMS ALSO MAKE CAROTENOIDS

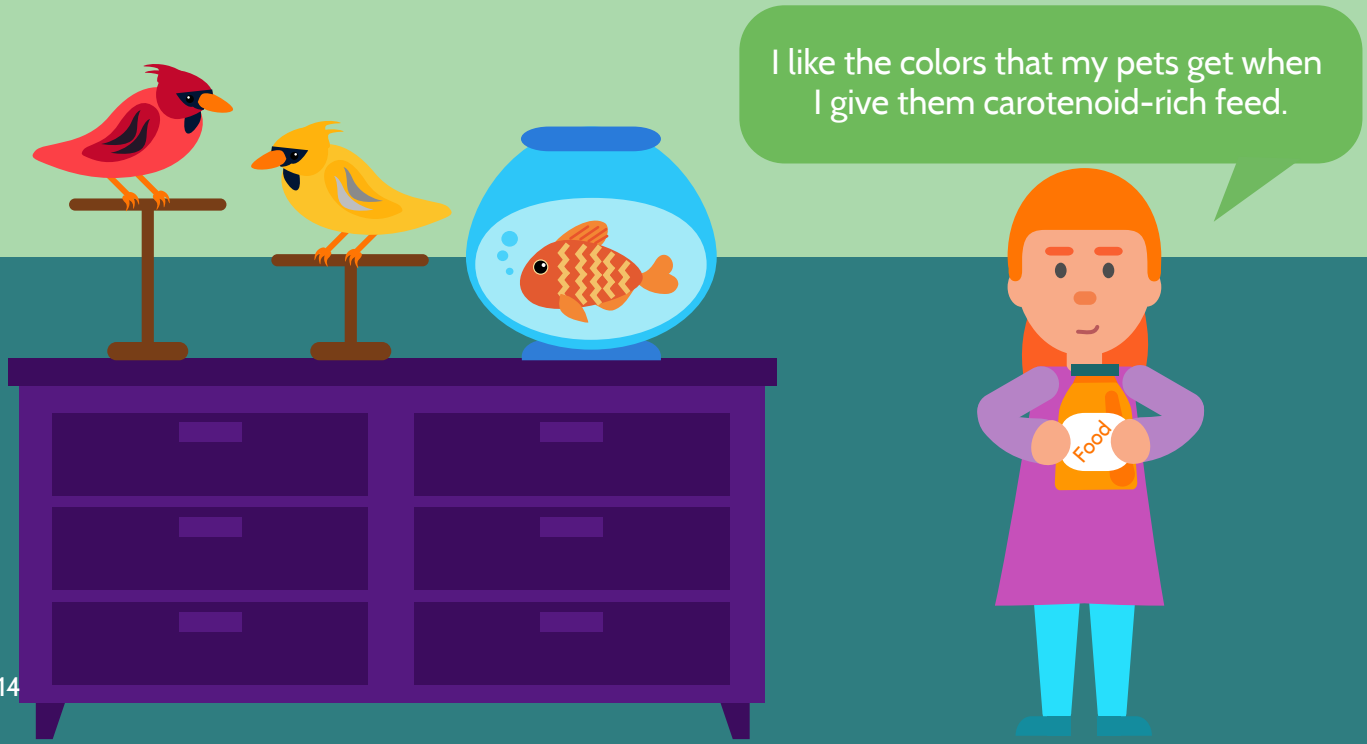
Carotenoids are produced by all organisms able to do photosynthesis and by some non-photosynthetic microorganisms such as bacteria and fungi. The characteristic pink hue of prawns, salmon or flamingos is provided by the microorganisms that they feed on.



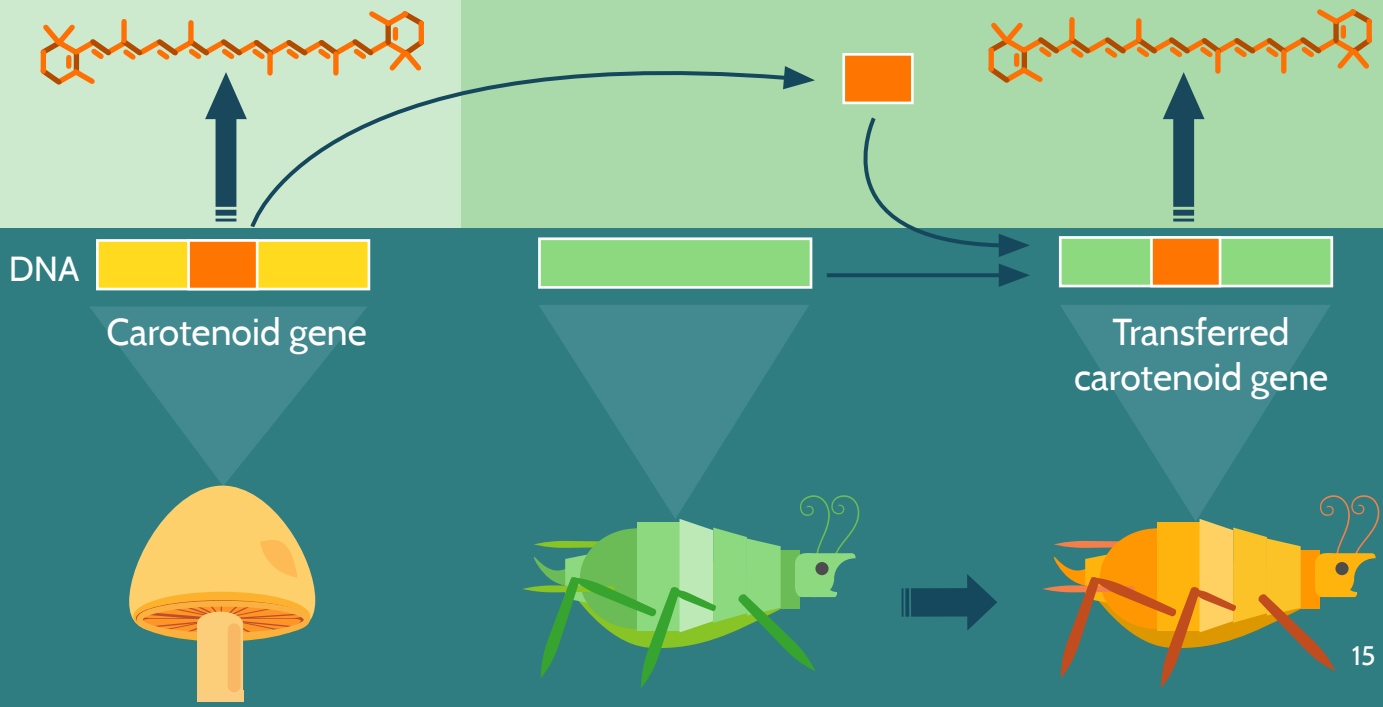

Some lakes and salt-lakes are full of microorganisms that produce carotenoids. That's why their water can look pink!

ANIMALS DON'T MAKE CAROTENOIDS... WITH SOME EXCEPTIONS

Like us, the vast majority of animals cannot produce carotenoids but take them in the diet. The carotenoid-derived colors of many birds and fish indicate good nutritional and health condition, helping them to find a mate.



Some aphids, mites and insects do produce their own carotenoids. They use fungal genes that incorporated to their genome through a process called horizontal gene transfer. They could therefore be considered as natural transgenic animals.



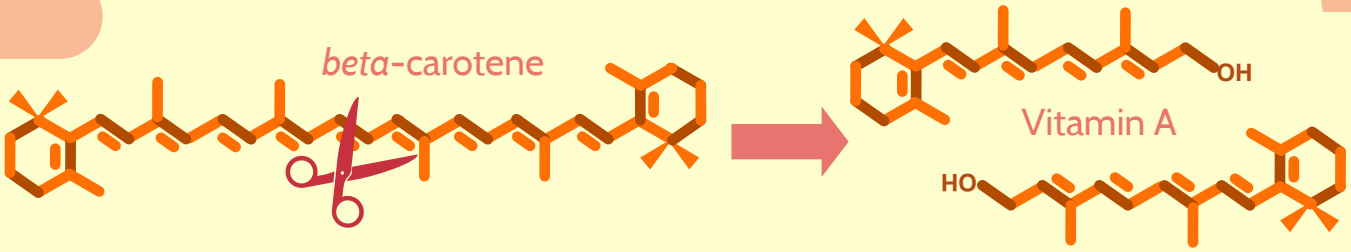
THE CAROTENOID INDUSTRY

Due to their properties as natural pigments, carotenoids are widely used in the food and feed industry.
Carotenoids, obtained by chemical synthesis or purified from natural sources, are used as colorants in drinks and foodstuff and are added to chicken and salmon feed to improve their meat color. Carotenoids are also used as dietary supplements and in the cosmetics industry.

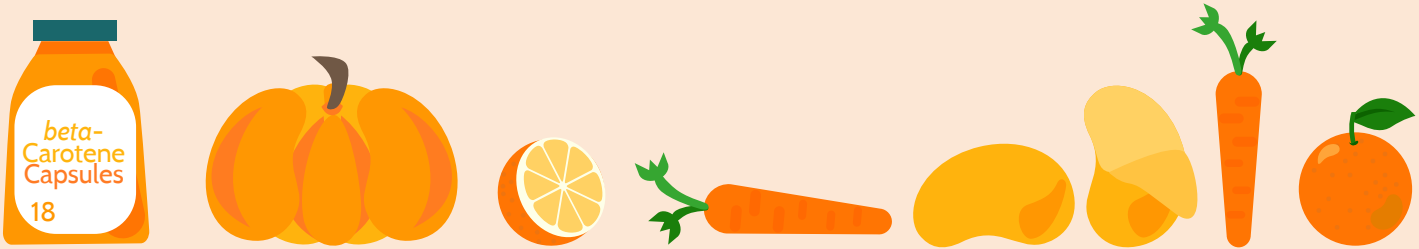
Besides attractive, carotenoids are healthy, particularly when they are directly taken from food.
Do you want to know why?

NUTRITIONAL AND HEALTH BENEFITS

Carotenoids are very important in our diet because some of them, including *beta*-carotene, are converted to vitamin A and other compounds named retinoids in our bodies.



Vitamin A and retinoids are essential for vision, keep our defences active, help with reproduction and participate in cell-to-cell communication. In addition, most carotenoids are antioxidants and activate different processes in our cells that decrease the risk of diseases such as obesity or diabetes.

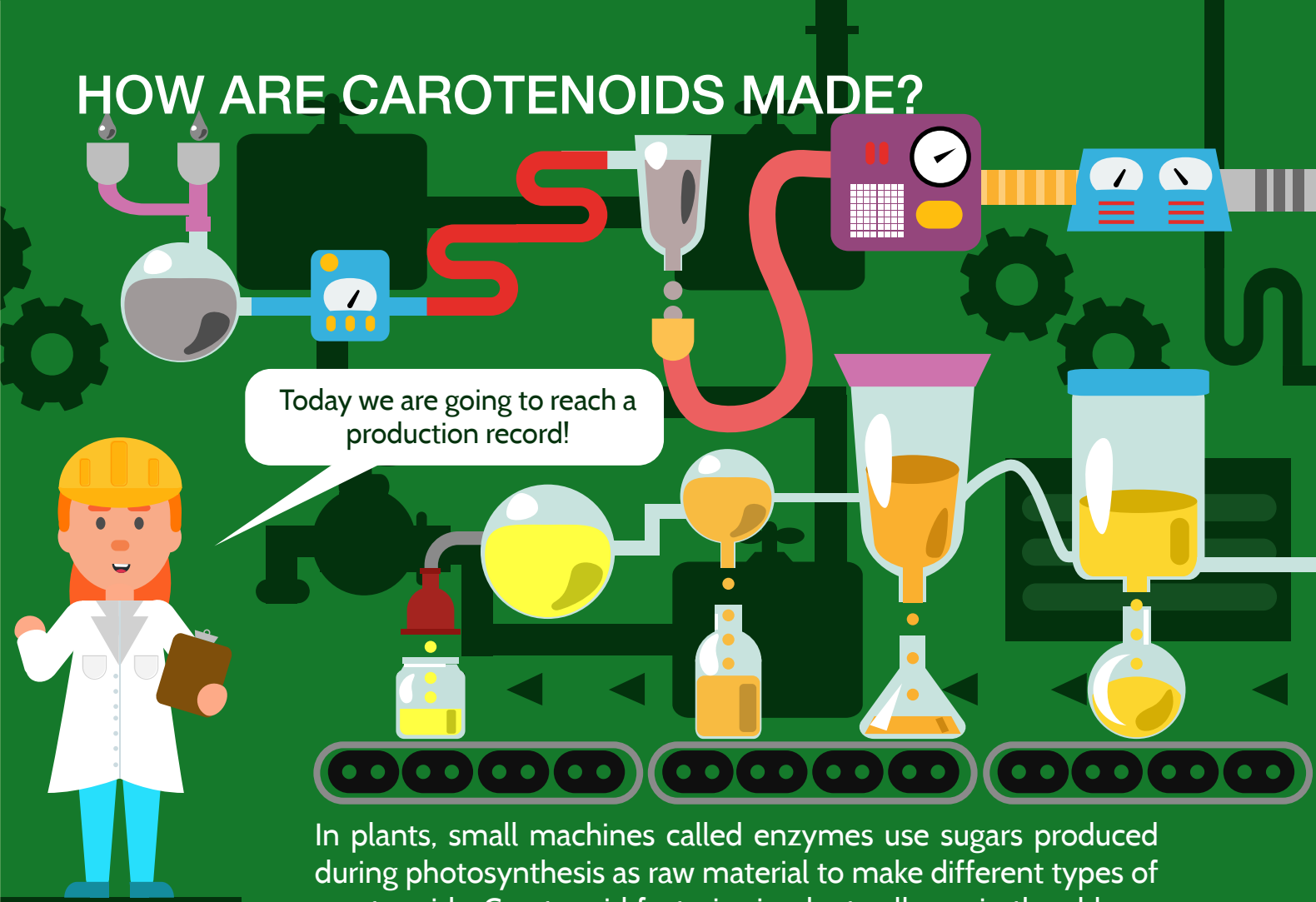


For all this, a carotenoid-rich diet, which is achieved by consuming many fruits and vegetables, is fundamental for our nutrition and health.

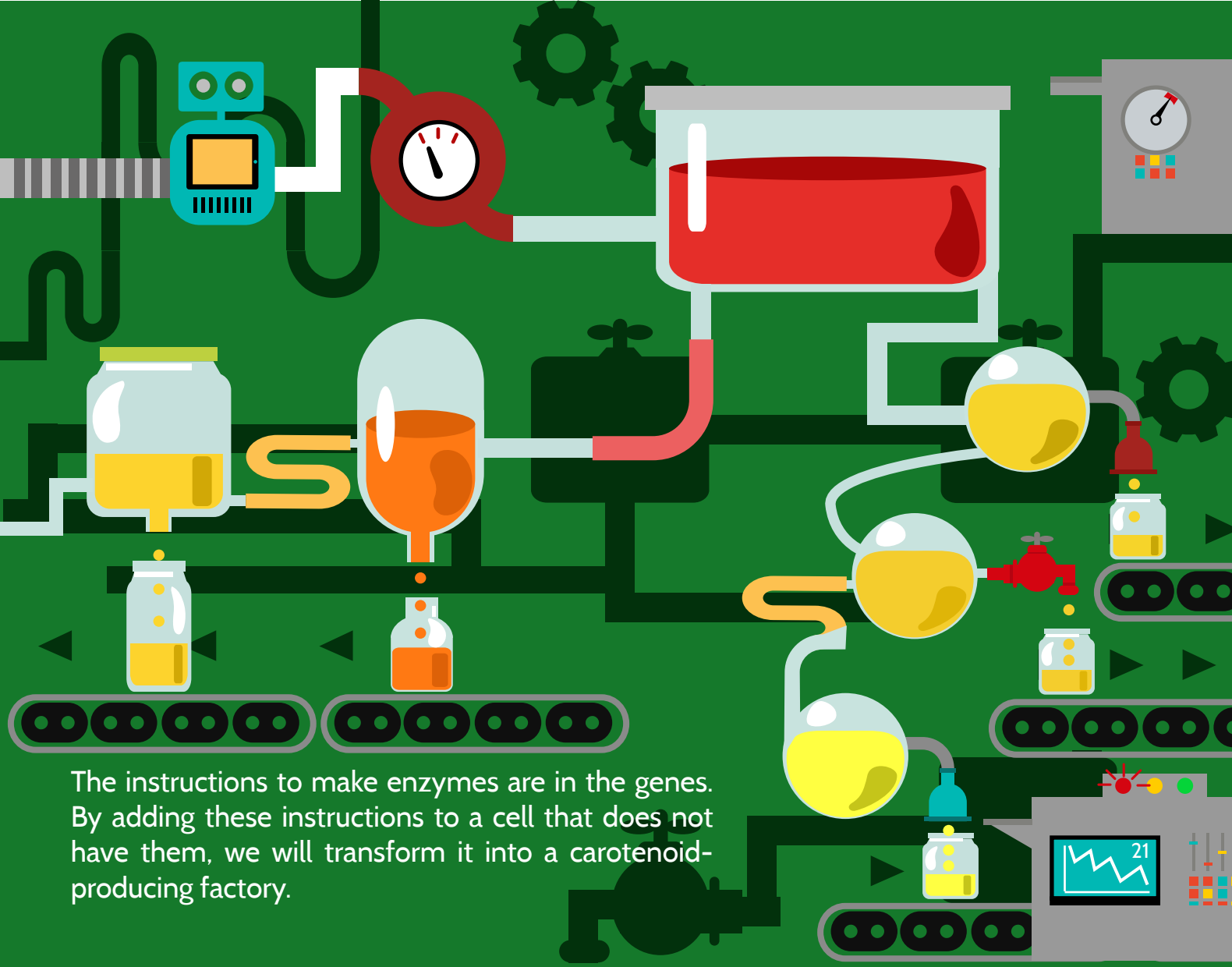
Vitamin A deficiency is rare in developed countries but it continues to be a very serious problem in many poor countries of Africa, Asia and America. Every year, hundreds of thousands of children in these countries become blind or defenceless against diseases because they do not consume enough carotenoids in their diet.

One way to fight against vitamin A deficiency in poor countries would be to increase the amount of carotenoids in their foods. Do you want to know how?

HOW ARE CAROTENOIDS MADE?



In plants, small machines called enzymes use sugars produced during photosynthesis as raw material to make different types of carotenoids. Carotenoid factories in plant cells are in the chloroplasts, the site of photosynthesis.

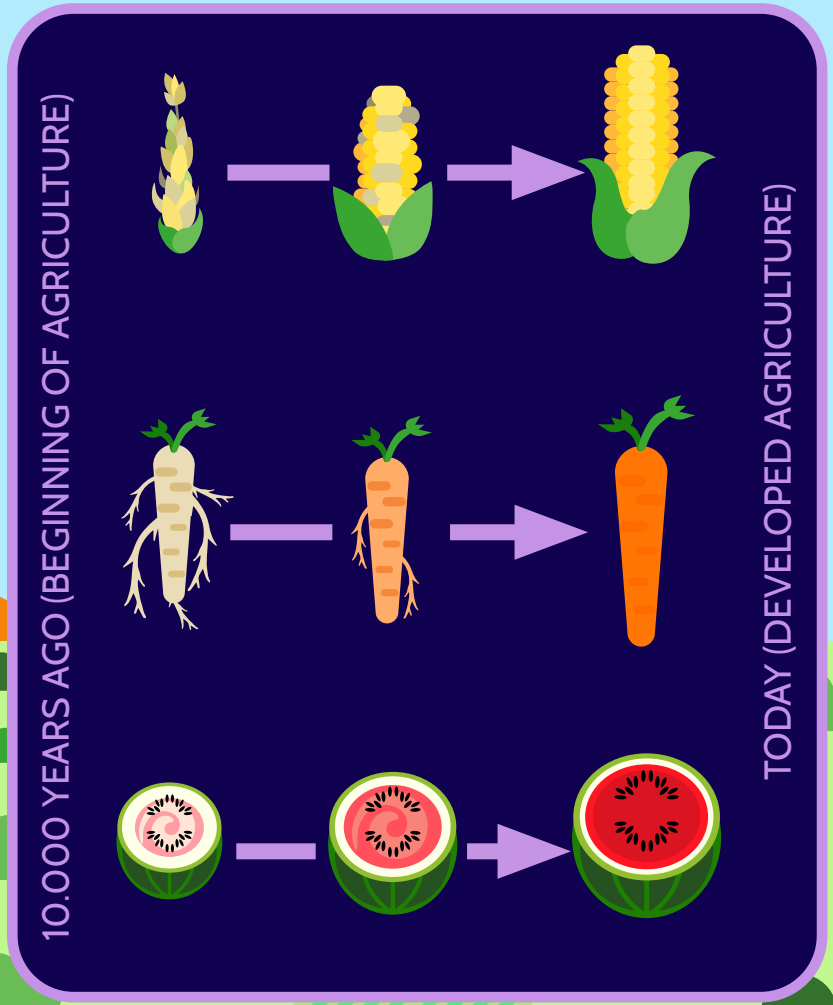


The instructions to make enzymes are in the genes. By adding these instructions to a cell that does not have them, we will transform it into a carotenoid-producing factory.

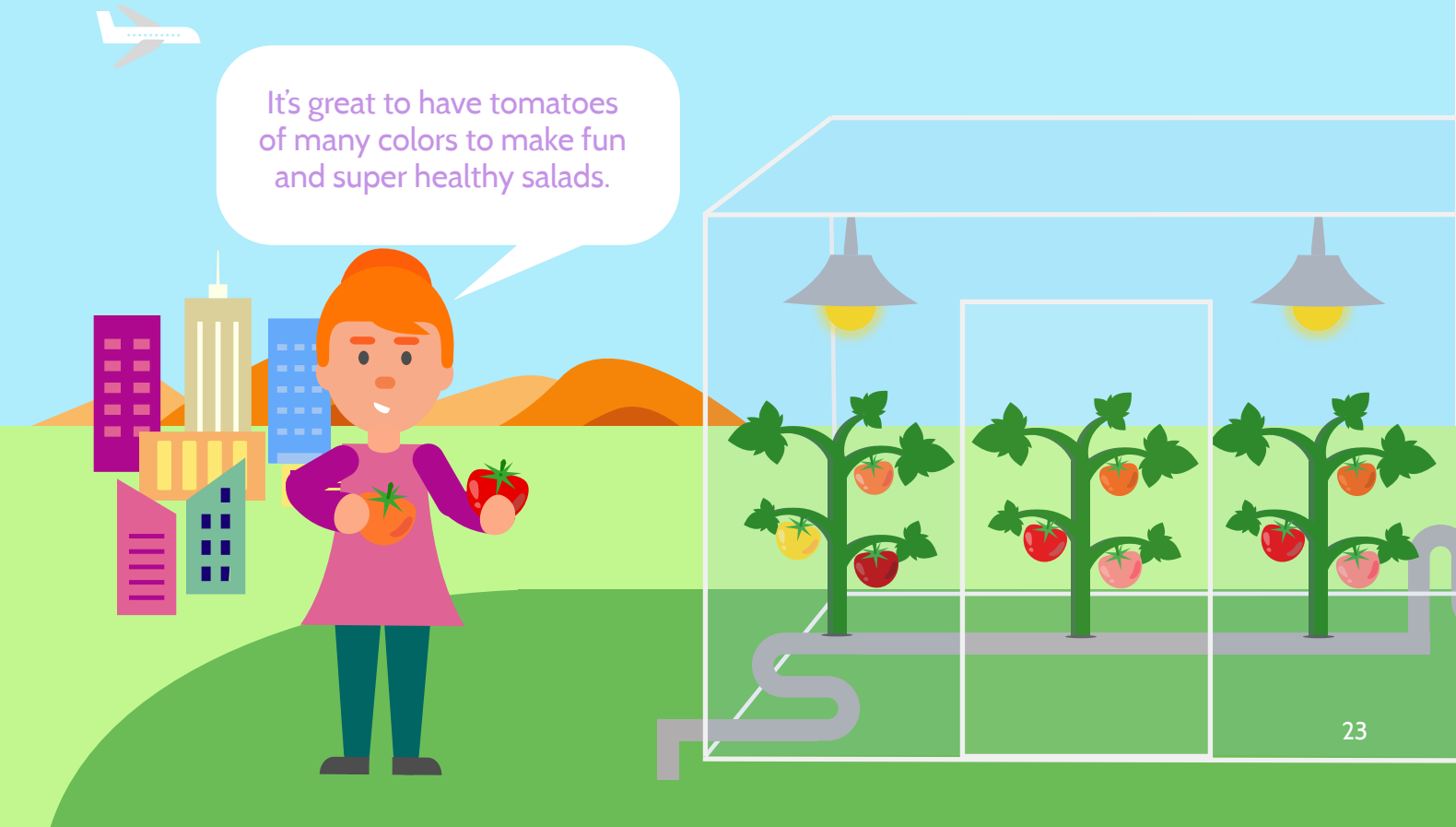
THE ACHIEVEMENTS OF AGRICULTURE

Since the beginning of agriculture, humans crossed different plant varieties to get others that were more resistant, productive, or nutritive.

Over thousands of years, this breeding process has generated random mixtures of carotenoid genes that have changed the color of many plants.



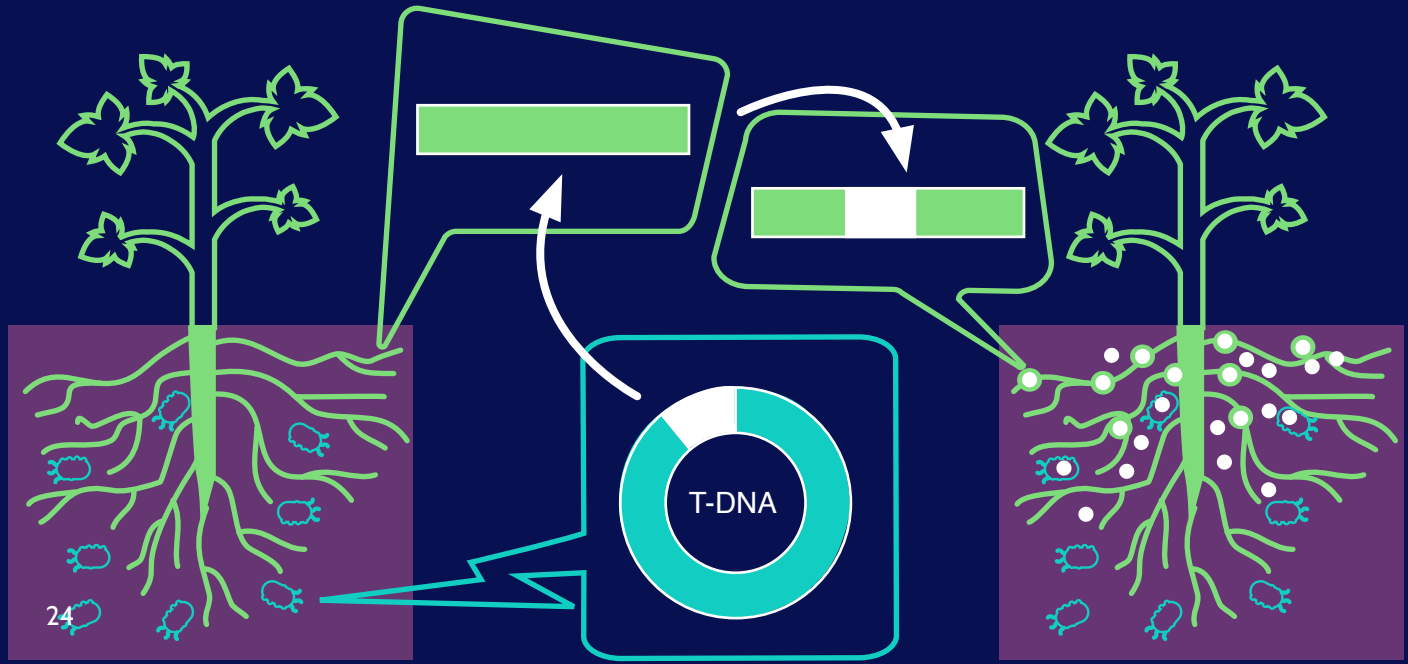
Today it seems normal to have yellow corn, orange carrots, red watermelons, or tomatoes of many colors. But the traditional crossing and selection methods have not been able to "color" other foods (like rice) with carotenoids. In these cases there is a fast and safe alternative: biotechnology.



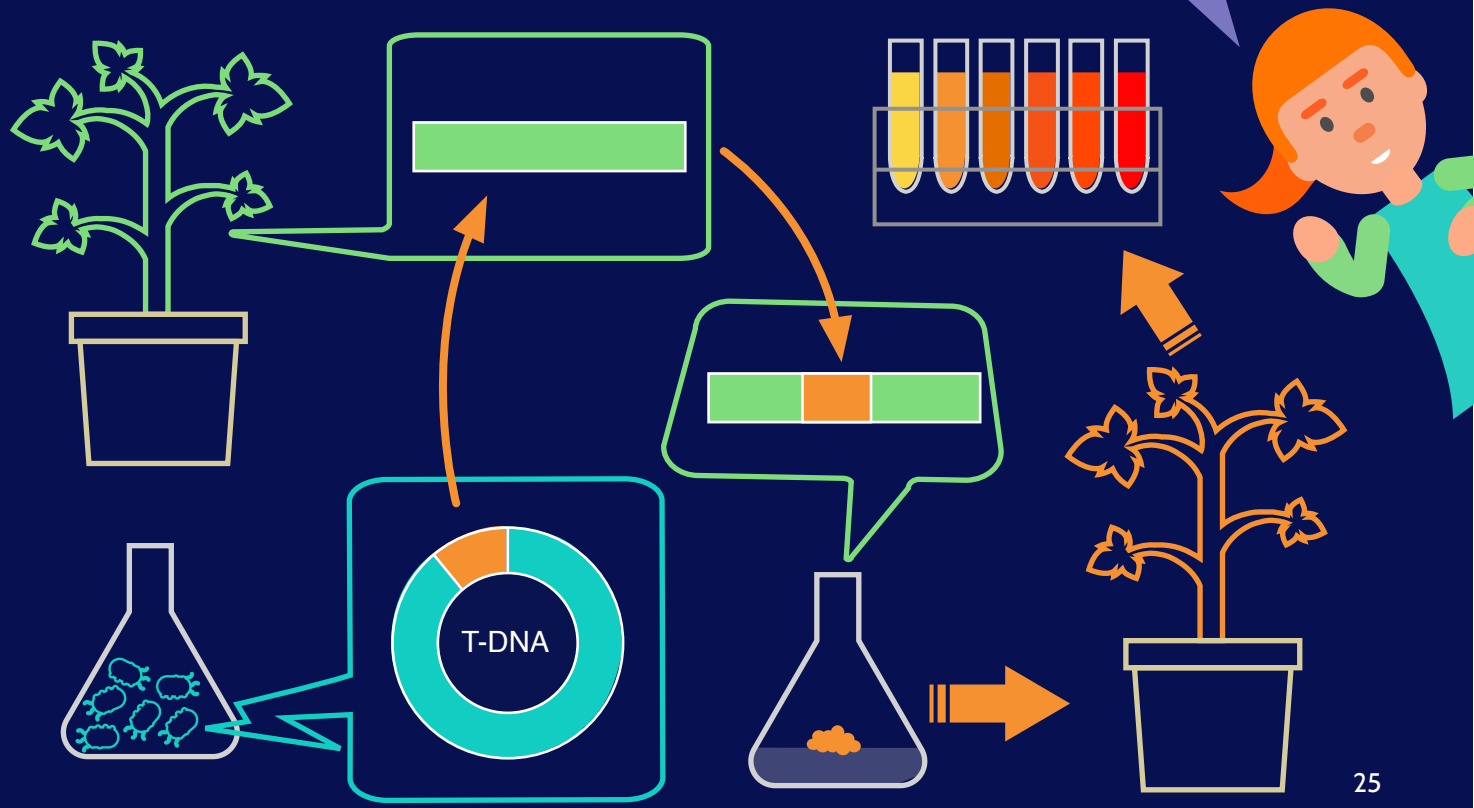
BIOTECHNOLOGY MIMICS NATURE

We have previously seen that some bugs are able to make their own carotenoids because they have incorporated several genes from fungi (the instructions) into their genome (that is, to their instruction manual).

Biotechnology does more or less the same. In nature there are bacteria that transfer genes to plants using a tool called T-DNA. Plants incorporate the bacterial genes and express them to make food for the bacteria.



Plant biotechnology uses the same bacteria but replaces the bacterial genes with carotenoid genes (or with other genes of interest) in the T-DNA. This way, the plant receives the instructions to make new carotenoids, to produce them in more quantity or to store them better.



COLORING FOODSTUFFS WITH DIFFERENT TECHNOLOGIES

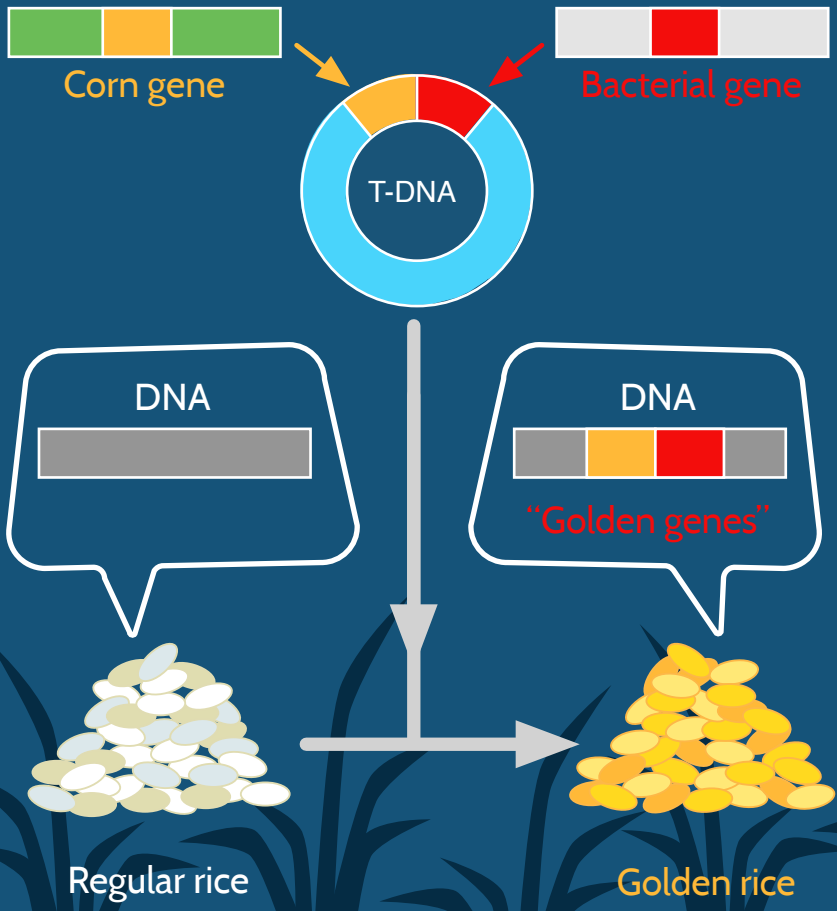
Traditional plant breeding methods require very long times and many cycles of crossing and selection to get a new trait (for example, a corn grain with carotenoids). In addition, these methods require that the plant that provides the genes of interest and the one that receives them could be crossed, which is not always possible. Another disadvantage is that genes that are not interesting and can even be harmful might also be transferred together with the genes of interest.

Donor corn cultivar

Recipient corn cultivar

New corn cultivar

Biotechnology is much faster, more effective, and safer. In a single step, the recipient plant gets only the target genes, which can come from any organism.



Biotechnology has succeeded to create rice enriched in carotenoids, in a very short time. This "golden rice" contains one gene from corn and another one from a bacterium to make *beta*-carotene, the main precursor of vitamin A.

Scientific thinking involves asking how our world works, doing experiments to verify hypotheses and drawing conclusions from the results. But also, it requires to contrast opinions, to accept and assess criticism and to continue challenging what we know with more questions to strengthen knowledge. Like Carlota, you probably have lots of questions and ideas about carotenoids. That is fantastic! Although nobody knows everything or has the absolute truth, there are scientists you can ask. Do you want to know who they are?

What is the role of carotenoids in autumm leaves?

How do you know if the color of a veggie is due to carotenoids or other pigments?

What is healthier: a green, a yellow, an orange or a red pepper?

Is it possible to produce carotenoids in any food using biotechnology?

How many genes do you need to make pink pineapples?

CaRed

In Spain there is a research network that includes groups working on different areas related to carotenoids. It's called CaRed and it's coordinated from the Centre of Research in Agrigenomics (CRAG), Barcelona. CaRed researchers cover four distinct but connected areas: carotenoid production in bacteria, fungi and plants, carotenoid manipulation through biotechnology, presence of carotenoids in food and feed products, and nutritional and health properties of carotenoids.

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Contact our scientists. They will answer your questions about carotenoids. They will be very happy to help you!

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