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Genes under control: Scientists develop gene switch for chloroplasts in plant cells

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The organelles of photosynthesis—the chloroplasts - have their own DNA, messenger RNA and ribosomes for forming proteins. Max Planck scientists have now discovered how to regulate the formation of proteins in the chloroplasts. They can use so-called riboswitches to switch the genes in the chloroplasts of tobacco plants on and off. These riboswitches could provide future benefit by making plants capable of delivering drugs or raw materials, or by improving the biological safety of genetically modified plants.

In order for a gene to create a protein, the gene's DNA must first be converted into what's known as messenger RNA. These RNA molecules are the instruction manuals that show the ribosomes - the cell's protein factories - how to build a protein. A few years ago, scientists studying bacterial cells discovered sections in certain messenger RNAs that metabolic products (metabolites) can bind to. In doing so, they induce the RNA molecule to change its spatial structure and make it possible to switch protein production on or off. For the bacteria, these sections - the riboswitches - provide a fast and efficient way of controlling protein synthesis. Unsurprisingly, it had previously been impossible to demonstrate the presence of such riboswitches in the chloroplasts of plant cells.

Max Planck scientists based in Golm near Potsdam were recently the first to modify and insert riboswitches into the genetic material of the chloroplast in order to control the formation of certain chloroplast proteins. The scientists smuggled a gene into the chloroplast DNA and equipped it with a riboswitch. Theophylline, a substance found in the tea plant, was used as the "switch": it has the capacity to bind to the riboswitch on the messenger RNA, thereby enabling the chloroplast ribosomes to read the RNA. "When we spray the tobacco plants with theophylline, we find that the chloroplasts form the corresponding protein. In the absence of theophylline, no protein is produced. So the theophylline riboswitch allows us to switch a gene on or off at will and see what effects result," explains Ralph Bock from the Max Planck Institute of Molecular Plant Physiology. This had previously been a difficult thing to achieve, given that the chloroplast genome contains numerous genes which are essential for survival. Switching one of these genes off permanently would result in the death of the cell, rendering it useless for further investigation.

However, studying the way chloroplasts work in more specific detail is not the only thing that can be done with the theophylline riboswitch. Riboswitches could also play an important role in the biotechnology of the future, given that chloroplasts are well-suited to the production of potential drugs. That's because each tobacco cell contains as many as 100 chloroplasts. The chloroplast genome is therefore present in many copies. As a result, it is capable of building more proteins than the DNA in the cell nucleus. By way of example, the Potsdam-based scientists modified the genes of the tobacco plant such that it was able to produce large quantities of an antibiotic in its leaves.

Chloroplasts rarely spread through pollen

Proteins could be produced in much larger quantities in genetically modified chloroplasts. In many cases, however, these foreign proteins damage cellular metabolism or photosynthesis if the cells produce them continuously. Consequently, the growth of such plants is often inhibited or extremely slow. Riboswitches could prevent that. They could be used to switch on the corresponding genes when the plant is already fully formed and about to be harvested. Foreign genes have another advantage in the chloroplasts besides this: they are inherited almost without exception through the female egg cell. It is therefore extremely rare for foreign genes to spread through the pollen of the tobacco plants.

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