# Playing with photosynthesis

## THE SAME NUMBERS OF PLANTS THAT WE HAVE COULD BE TWEAKED TO PRODUCE MORE FOOD, SAYS **S ANANTHANARAYAN**

A burgeoning global population, pollution, land degradation and encroachment all point to crises of food supply in the coming decades. Better methods, better technology are hesitantly suggesting solutions.

The spacing of plants, crop rotation, control of fertiliser, getting plants to grow for longer hours, would all do their bit. But revving up the process of photosynthesis, the engine of plants to produce food in the first place, would multiply the benefits of the other ways to do better.

Myat T Lin, Alessandro Occhialini, P John Andralojc, Martin AJ Parry and Maureen R Hanson, from Cornell University and Rothamsted Research, UK, report in the journal *Nature* that they have made a change in the genetic factor that is the key to photosynthesis in the tobacco plant, a change that makes the plant more efficient in using the carbon in the air to make food, with the help of sunlight. Tobacco is a typical plant often used for research and there are prospects of transferring higher efficiency in tobacco to other, food producing plants.

The capacity of plants to generate carbohydrates from $CO_2$ and water and release oxygen at the same time with the help of sunlight has come from ancient precursor cells called *cyanobacteria*. The very early atmosphere of the earth was highly deficient in oxygen and was not suitable for life forms, as we know them, to arise. The life forms that flourished were many that are *oxygen intolerant*, and then there were the single-celled cyanobacteria, which had the apparatus for photosynthesis.

It is thought that it was this group of organisms that added to the atmosphere its content of oxygen by pulling the carbon out of $CO_2$. In the early earth, any free oxygen created was absorbed by iron to form oxides, or by organic matter and oxygen intolerant organisms could survive. About 2.3 billion years ago, these oxygen sinks got saturated and free oxygen began to build up. Many life forms got extinct, except for a few that survive only in the harshest, oxygen-free corners of the earth — and with the rise in available oxygen, oxygen-consuming organisms multiplied and thrived. Great biodiversity and complexity emerged and continued to rise till there was a balance in the level of free oxygen.

In this growth of oxygen-dependant life forms, like present day plants, the cells of the new organisms made use of portions of the existing cyanobacteria to generate an enzyme called *Rubisco*, which gives the cells the capacity of photosynthesis. But a problem with Rubisco, which plants picked up, is that the mechanism had evolved in an oxygen-free environment, and the enzyme does not have a way to tell the difference between oxygen ($O_2$) and $CO_2$. Thus, while the useful function of photosynthesis in plants is to loosen the C from $CO_2$ and form carbohydrates, in the presence of oxygen, plants also expend resources in separating the two Os in $O_2$. This makes the process of photosynthesis in plants, while astonishing in the sophistication of light gathering and optimising energy, rather wasteful in using some of the energy in a counter-productive way.

Myat T Lin, Maureen R Hanson and Martin AJ Parry

A tobacco plant engineered to completely depend on a cyanobacterial enzyme for carbon fixation. Rothamsted Research.

Two ways have evolved for plants to get around this problem. One is with a version of Rubisco that does discriminate between $O_2$ and $CO_2$, but this version is 30 per cent less efficient at fixing $CO_2$. The other way is to keep the first version of Rubisco, but with a device called a *$CO_2$ Concentrating Mechanism*, to increase the level of $CO_2$ around the enzyme. Most plants that are regarded as crops have followed the first way and thus they have a built-in limitation. The way out may be to manipulate the $CO_2$ levels around the leaf, which may be something like a CCM. Plant biologists are, hence, engaged in trying to get a CCM into crops, which would bring about a direct jump in the plant output.

But in some plants, mostly weeds, microalgae and in cyanobacteria, CCMs have evolved on their own and these organisms maintain a high efficiency of photosynthesis. Cyanobacteria, in fact, may be the most successful micro-organisms in the world. They are found nearly everywhere and in large quantity. They cover thousands of square kilometres in the sea, as blue-green algae, and account for most of the cleaning of $CO_2$ in the atmosphere.

They are in the soil and because they also fix atmospheric nitrogen, which is inert and useless for plants, into the reactive form that plants need, they are the largest source of natural fertiliser for all vegetation.

The way CCMs work in cyanobacteria is by modifying the environment within the cell so that $CO_2$ concentrates near where the Rubisco enzyme is found. In this way, action on oxygen is largely eliminated and Rubisco can now work efficiently. With this mechanism in place, cyanobacteria have not needed to make any changes in the structure of Rubisco and they retain the ancient form, which is almost three times more efficient than the form found in crops.

Efforts to introduce CCMs, as are found in some plants and also cyanobacteria, have not been successful. The current team used genetic engineering to modify the DNA of tobacco plant cells involved in photosynthesis so that the cells created a basic form of the cyanobacteria Rubisco. The team carried this out with the refinement that had not been tried in earlier, unsuccessful attempts, also introducing proteins that are involved in the assembly of Rubisco. They found that using particular helper proteins like this seemed to created structures, within the bodies that are active in photosynthesis, that were related to the factors that caused concentration of $CO_2$ in cyanobacteria.

The resulting tobacco plants showed clear higher competence in photosynthesis, equally with both kinds of supporting proteins. But the method, basically of introducing the higher output enzyme, appears to have effectively increased the capacity of the tobacco plant to generate carbohydrates using sunlight. The tobacco is typical of plants that are the major crop plants and further research promises more effective CCM, and later transfer to more economically important plants.

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# DRAMATIC RESPONSES

## **TAPAN KUMAR MAITRA** EXPLAINS THE PROCESS OF CALCIUM RELEASE FOLLOWING FERTILISATION OF ANIMAL EGGS

Fertilisation of animal eggs is a striking example of the importance of calcium-mediated signal transduction following a receptor-ligand interaction. In many animals, when sperm that have undergone several prior steps of activation bind to the surface of mature eggs and unite with them at fertilisation, a striking sequence of events ensues.

One of the early responses of the egg — within 30 seconds to several minutes after fertilisation — is the release of calcium from internal stores.

This calcium release occurs initially at the site where the sperm penetrates the egg surface and then spreads across the egg, much as a ripple on the surface of a pond spreads away from the site where a pebble strikes the water. The wavelike propagation of calcium release can be visualised using calcium indicators.

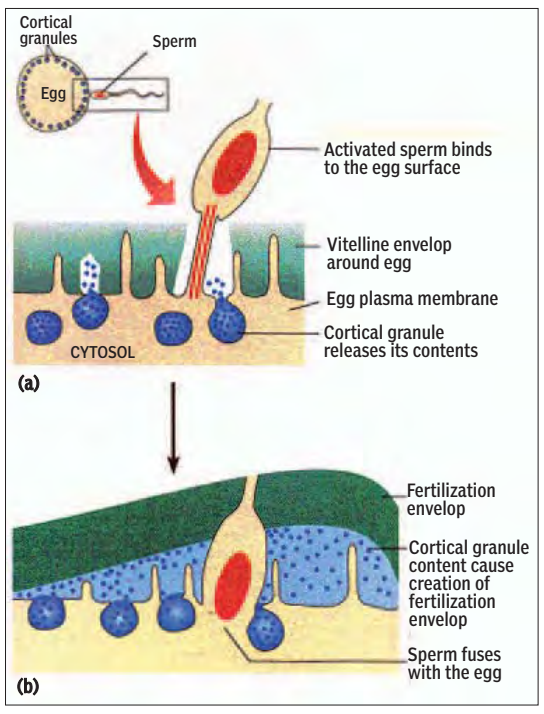
The release is necessary for two crucial events. First, it stimulates the fusion of vesicles, known as cortical granules, with the egg plasma membrane, resulting in the release of the granule contents outside of the cell. Cortical granules contain several proteins and enzymes, the release of which results in alterations of the protein coat surrounding most eggs (typically known as the vitelline envelope). These alterations render the egg unable to bind additional sperm, thereby preventing more than one sperm from fertilising the egg.

This process is known as the slow block to polyspermy. (An earlier fast block to polyspermy involves a transient depolarisation of the egg plasma membrane.)

The second major function of calcium is egg activation, which involves the resumption of many metabolic processes, the reorganisation of the internal contents of the egg and other events that initiate the process of embryonic development.

Many features of the slow block to polyspermy and egg activation can be initiated by treating unfertilised eggs with calcium ionophore in the absence of sperm, demonstrating the key role elevated calcium levels within the egg play in its activation. Egg activation is a good example of how a dynamic change in calcium concentration can result in dramatic cellular responses. In other cases, it is the oscillation of calcium concentration over time that elicits a cellular response.

Calcium oscillations occur in neurons and in fertilised mammalian eggs and may contribute to stable changes in the state of these cells. Calcium oscillations are also important in regulating the opening and closing of stomata in plants.




The role of calcium in the slow block to polyspermy in sea urchins: A sperm cell (a) that has been activated binds to the egg surface, resulting in local calcium release and cortical granule exocytosis. The result (b) is the creation of the fertilisation envelop, which prevents additional sperm from penetrating the egg.

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# Changing mortality rate

## A SNAKEBITE REMEDY IS ALL SET TO BE TURNED INTO A FIRST-AID TABLET

The Indian developers of an anti-venom formulation designed to be taken orally, which has shown promising results in laboratory tests, are hoping to develop it into a tablet that could be taken straight after snakebites.

Anti-venom is currently injected into patients. And since injections are often stored at hospitals that are many miles away from the rural locations where most snakebites occur, patients must usually wait for hours after being bitten before they can receive treatment.

Three-quarters of patients who die from snakebites do so before they reach hospital.

Because of this "we have felt that taking care of transit time damage will be most crucial", says researcher Roshnara Mishra of the University of Calcutta, who led the team that published details of the formulation last month (7 August) in ***PLOS Neglected Tropical Diseases***.

In the formulation, anti-venom is coated in alginate, a cheap and non-toxic gum-like substance made from sugar. The researchers showed that this protected the anti-venom from being digested in intestines taken from mice, and that it remained effective at neutralising snake venoms after passing through this tissue.

"A globally initiated 'anti-venom as first-aid' can change the mortality rate markedly," says Mishra.

Matthew Lewin, a researcher at the California Academy of Sciences, USA, says, "It's a cool idea to cloak the anti-venom in alginate. Who wouldn't want to be able to swallow something to counteract deadly venom?"

Lewin has developed a cheap anti-paralytic nasal spray to treat snakebite victims. Yet he says anti-venoms can be dangerous. As they have high complication rates and, if mishandled, the side effects can be worse than the bites themselves, he says these should always be given in a hospital.

Anti-venom is also expensive and costs in excess of Rs 4,000 per dose, but Mishra says that any oral formulation based on alginate, which is inexpensive, would cost little more than this. She says her team now plans to develop the oral formulation further and eventually test it in clinical trials.

Roshnara Mishra (left) says her team now plans to develop the oral formulation further and eventually test it in clinical trials.

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## PLUS POINTS

A mock up of what Rhinorex condrupus looked like.

### Big nose mystery

The remains of a 30ft-long dinosaur that had a snout so large it was branded "King Nose" have been discovered after being left in storage for two decades. Scientists came across the unusual duck-billed creature, which has been named Rhinorex condrupus, in storage at Brigham Young University's Museum, Utah. It was originally excavated from Utah's Nelsen rock formation in the 1990s.

Dr Terry Gates and Dr Scheetz said it was only as they started to reconstruct the fossil that they realised they had found a new species. "We had almost the entire skull, which was wonderful," Gates said, "but the preparation was very difficult. It took two years to dig the fossil out of the sandstone it was embedded in — it was like digging a dinosaur skull out of a concrete driveway."

Based on the recovered bones, the paleontologists estimated that Rhinorex — which translates roughly to King Nose — was about 30feet long and weighed over 8,500 lb. It lived around 50 miles from what is now the Utah coast in a swampy environment, and is the only complete hadrosaur fossil from the site — thus helping to fill in some gaps about habitation segregation during the late Cretaceous period.

"The purpose of such a big nose is still a mystery," said Gates. "If this dinosaur is anything like its relatives, then it likely did not have a super sense of smell; but maybe the nose was used as a means of attracting mates, recognising members of its species, or even as a large attachment for a plant-smashing beak.

### Natural born killers

Chimpanzees and humans have one key trait in common — both are natural born killers, scientists have shown.

According to evidence, our closest animal relatives have an almost psychopathic tendency towards violence.

Evidence suggests our closest animal relatives have an almost psychopathic tendency towards violence and slaughter that is not the result of human interference. A widely held theory is that chimps only turn on each other when humans disrupt their forest habitats or food supplies. The research, published in *Nature*, indicates this is wishful thinking. In reality, chimps fight and kill to get what they want and "eliminate rivals", say the authors.

US lead scientist Dr Michael Wilson, from the University of Minnesota, said, "This is an important question to get right. If we are using chimpanzees as a model for understanding human violence, we need to know what really causes chimpanzees to be violent."

### Spider app

As spiders pop up indoors more frequently over the autumn months, scientists have created an app to help arachnophobes understand the creatures they are so terrified of. The number of spiders increases in the autumn because males search for a mate, often seeing them venture indoors. To help people learn more about the 12 most common spiders THAT become temporary house guests at this time of year, the Spider in Da House app by the Society of Biology features tools including photos and information on the creepy crawlies. Spiders featured on the app include the rare spitting spider, which usually only dwells in older properties and is rarely active in the daytime. It is named after its method for catching prey — which sees it fire a sticky liquid from its modified poison glands to pin down its dinner.

A more common sight is the jumping spider, often found on the walls of houses and easily recognised by its squared off head and two very large eyes, which give it the best vision of all the spiders. The most common type is the zebra spider, recognisable by the distinctive black and white strips on its abdomen.

The app, available on the Apple App Store and Google Play, also helps users to identify whether spiders are male or female — with females often being larger than the males. Professor Adam Hart, from the University of Gloucestershire, explained that while spiders were feared by many, the creatures were in fact very helpful pest controllers. "By eating flies and other insects, spiders are not only providing us with a pest control service, but are important in ecosystems.

KASHMIRA GANDER/THE INDEPENDENT