Science & Plants for Schools

# Epigenetics

by Stephen Day

## The hidden secrets of inheritance

### New ways to adapt and evolve

**Rooted to the spot, plants cannot run away from problems. Instead, they adjust their growth and metabolism to cope. So, exposed to strong winds, plants grow shorter, broader stems and smaller leaves; or if temperatures approach freezing, many plants synthesise 'antifreeze' proteins.**

**Now, scientists studying epigenetics have found evidence that plants not only adapt themselves to local conditions, they may also be preparing future generations.**

### The epigenetic 'OFF' switch

Epigenetics is the science of those parts of inheritance that do not depend on DNA sequences. Our DNA encodes our genetic inheritance—all of our genes and the control sequences that influence when and where they are active. In contrast, a major feature of our epigenetic inheritance are chemical modifications to DNA and to chromosome proteins that apply a long-term 'OFF' switch to genes [1]. For example, by attaching methyl ($CH_3$) groups to DNA (DNA methylation), cells can cause the corresponding region of a chromosome to pack more tightly—putting it beyond the reach of enzymes needed for gene activity. If you think of DNA as a library and a gene as a book of instructions, then epigenetic inheritance acts by locking particular books shut.

The pattern of methyl groups on DNA can be copied when chromosomes replicate, allowing it to pass through generations of cells and from an organism to its offspring. However, cells can also re-activate genes by removing the chemical 'OFF' switch—making epigenetic inheritance controllable.

Most current theories of adaptation and evolution are based on an organism's inflexible genetic inheritance, where variation depends on chance mutations to the DNA sequence. Now, biologists studying epigenetics are trying to uncover the roles of this more flexible system.

### Remembered stress

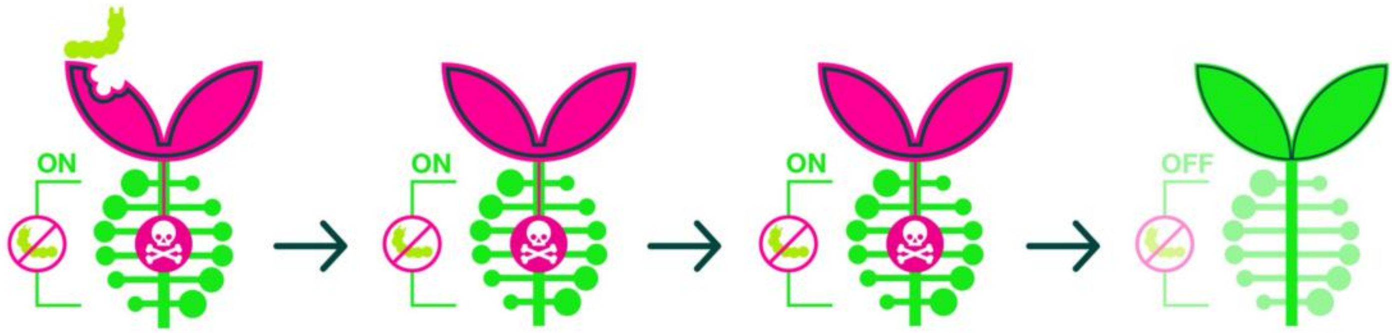
One possibility is that organisms are tailoring their offspring's epigenetic inheritance to give them a competitive advantage. In recent years, for example, plant biologists have accumulated numerous examples of parent plants that appear to prepare offspring for stresses the parents experienced in their own lives—such as being eaten by a herbivore, attacked by a disease, or exposed to heat or salt water. One of the clearest cases was discovered by Georg Jander and his colleagues through research on the responses of *Arabidopsis thaliana* (thale cress) to caterpillars [2].

When attacked by herbivores, plants boost their physical and chemical defences: tobacco makes more nicotine; nettles grow new leaves with more stings; and *Arabidopsis* synthesises higher concentrations of toxins called 'glucosinolates'. Signals from damaged tissue activate these defences throughout the plant and even after the attack is over, the plant remains primed for defence—if damaged again, it mounts a faster, stronger counter-attack.

Jander's group—at the Boyce Thompson Institute for Plant Research in Ithaca, New York—exposed *Arabidopsis* plants to caterpillars and tested what effect this had on the plants' offspring. The next generation, they found, grew up primed to defend themselves. If attacked by caterpillars, they responded more strongly—reducing caterpillar growth by 40% compared to caterpillars feeding on control plants.

Even if the first child generation was not attacked, the effect continued in the second generation—the 'grandchildren' of the original plants. If second generation was also caterpillar free, however, the effect vanished in the third generation—confirming the flexibility of epigenetic inheritance.

The results are extremely interesting but took place in the controlled conditions of a lab. It remains to be seen how important the effect will be in the messier environment of the real world.




*Parent plant - defences triggered by caterpillar attack*

*1st generation - germinated with pre-primed defences*

*2nd generation - germinated with pre-primed defences*

*3rd generation - the effect vanishes*

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Jander suggests it could depend on the life history of the plants involved.

“Epigenetic inheritance of environmental stress responses is likely to be most useful for short-lived annual plant species with rapidly germinating seeds,” he says. “For something like an oak tree, the maternal environment is probably not very predictive for that which a progeny tree will encounter 50 or 100 years later.”

Given that most major crop plants are annuals then if Jander is right, it may be feasible to use this phenomenon to boost a crop’s resistance to pests or diseases. “It should be possible to ‘prime’ the stress tolerance of progeny by treating seed production fields in an appropriate manner,” he says.

## Reversible evolution?

Unlike an attack by caterpillars, some environmental stresses such as polluted soils or climate changes can last decades or centuries. Could changes to epigenetic inheritance help plant populations to adapt to such long-term problems—acting as a kind of ‘soft’, reversible evolution? A study on the genetics and epigenetics of mangroves suggests this could happen.

Biologists at the Instituto de Pesquisas, based in the Rio de Janeiro Botanic Gardens, have been investigating the effect of different environments on two populations of mangrove trees (*Laguncularia racemosa*) [3]. One population lives by a tidal river and receives regular supplies of nutrients deposited by incoming tides. The other grows by a salt marsh where the plants are both nutrient-deprived and subject to high salt concentrations. By the riverside, mangroves grow as trees over 35 m tall, whereas in the harsh conditions by the marsh, they grow as bushes, less than 5 m high. The researchers analysed the DNA sequences of mangroves at the two sites and also the pattern of methyl groups on the DNA. They found that where the plants grow makes little difference to their DNA sequence but has a large effect to its methylation pattern.

Compared to the riverside trees, mangroves by the salt marsh have fewer methyl groups on their DNA and these vary less in their positions. It is not clear if the difference in DNA methylation relates to the different growth patterns at the two sites, but the results suggest that harsh conditions by the salt marsh may have driven the local mangrove population to a particular and narrow range of epigenetic inheritance—perhaps helping the plants to adapt.

Jander is satisfied that long-term, epigenetics-based adaptation exists.

“I think that epigenetic variation plays a role in environmental adaptation. Particularly in a time of relatively rapid climate change, epigenetic gene regulation might allow plants to adapt more rapidly than changes in actual DNA sequence,” he says. “Epigenetic changes also have the advantage that they are more reversible than genetic changes.” So if environment changes were transient—if the mangroves’ salt marsh flooded regularly—plants could revert back to their original state.

This article was written to accompany the poster ‘Epigenetics: The hidden secrets of inheritance?’, published by Science and Plants for Schools, April 2014. For further details, see www.saps.org.uk/epigenetics

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**References**

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