I BET YOU DIDN'T KNOW...

bees and caterpillars can change the evolution of plants

Dr Katharine Pemberton, PSTT College Fellow, links **cutting-edge research** with the **principles of primary science**

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Individuals are, by definition, different in some way to all others: they have different characteristics to each other. These could relate to any part such as leg length or eye colour in animals or stem length and flower colour in plants. These differences can be due to differences in genes and may give one individual an advantage over others. For example, giraffes with longer necks may be able to reach more food so they stay healthy and are more likely to have babies.

Over many generations, the characteristics of a group of animals or plants can change depending on which versions of characteristics are passed on to their children. This is Darwin's theory of evolution by natural selection. It is driven by anything that affects the survival of individuals and their likelihood of producing babies. Scientists at the University of Zurich in Switzerland have been studying how evolution in plants is driven by *pollination* and *herbivory*. Herbivory means the eating of plants by animals and animals that do this are called *herbivores*.

The scientists noted that the effects of pollination and herbivory on evolution have been studied before but that they have only been looked at separately. In real life, evolution is not controlled by only one thing but by a range of different things at the same time. For example, plants that need insects for pollination compete with each other to attract these insects. They may produce bigger flowers or sweeter scents to do this. Similarly, plants that are eaten by herbivores are more likely to survive if they develop ways to put off the animals that eat them. Plants may produce defensive poisons to do this.

If a plant has a certain amount of energy that it must use to produce flowers and to produce defensive poisons, it has to balance how much energy it puts into each of these two characteristics. The more energy it puts into one characteristic, the less it has for the other. In addition, and unfortunately for the plant, the effect of characteristics designed to attract *pollinators* may accidentally increase herbivory. For example, showy flowers attract pollinators but may attract herbivores too. Similarly, the production of poisons to put off herbivores could make nectar taste bad or make it partially poisonous and put off pollinating insects.

The scientists grew a species of plant related to the cabbage (*Brassica rapa*) in greenhouses to study its evolution (Figure 1). They divided the plants into four different groups. Some plants were pollinated by bees (Figure 2) while others were pollinated by scientists, who transferred pollen between plants using brushes ('hand' pollination). Some groups had caterpillar larvae added to them (Figure 3). The caterpillars fed on the plants, so these plants had to defend against herbivory.

Figure 1. Brassica rapa is a plant species growing in many cultivated forms including the turnip, some types of cabbages and field mustard. The scientists used a variety with a short life cycle of about 40 days which makes it suitable for experiments about evolution.

Figure 2. Bombus terrestris bumblebees were used as pollinators.

Figure 3. Pieris brassicae caterpillars were used as herbivores. These are caterpillars of the large white butterfly (also called the cabbage butterfly or cabbage white).

Table 1 shows the conditions in which different groups grew. In each of the different groups, there were 3 *replicate* sets of 36 plants. These meant that the scientists could check their results were reliable by comparing plants within each treatment group. Group 1 acted as a *control group* to represent how the plants could grow if they did not depend on pollinators for survival and were not affected by herbivory.

Table 1. the conditions for each group of plants.

Group	Pollination	Caterpillars
1	hand	X
2	hand	✓
3	bee	✓
4	bee	X

Each plant was allowed to grow and was then pollinated. After pollination, the plants produced seeds that grew into a new generation of plants. This new generation was then pollinated and produced seeds and so on for 8 generations. That means that the plants used at the start of the study were the great great great great great grandparents of the final plants in the 8th generation!

The scientists measured the characteristics in the 8th generation plants and compared them to the characteristics of the control group, which was assumed to be identical to the original great great great great great grandparent plants. They had evolved! The characteristics they measured included the scent and shape of flowers and the production of poisons to defend against herbivores. At the end of the study, there were differences in the characteristics of plants from each group, showing that the plants had evolved in different ways (Table 2).

Bee pollination led to greater evolutionary changes than herbivory from caterpillars. Plants that were pollinated by bees and did not have caterpillars, evolved more sweet-smelling flowers, which tended to be larger. The studies also showed that the bees clearly preferred these flowers to those from all other groups. This reflects how the plants had evolved over 8 generations to maximise their attractiveness to the pollinators.

However, the presence of herbivores changed the evolution of bee pollinated plants. If caterpillars were included with bee pollination, plants did not evolve sweeter smelling or larger flowers. Even so, these plants were still more popular with the bees than plants that had been hand pollinated. The scientists suggested that the plants evolved in a way that was a compromise between how attractive they were to bees and how they could defend themselves against herbivores. Plants that were more likely to be eaten by herbivores seemed to put more energy into defensive adaptations, meaning that they did not have so much energy to use for adapting their flowers.

Table 2. Summary of the effects of pollination and herbivory on different plant characteristics. ✓ s show a statistically significant change in the characteristics . Xs show no significant change.

Treatment – what were the plants exposed to?	Plant Traits		
	Flowers		Defence
	Petal size	Preference of bees	Production of defence poison in nectar or leaves
Pollination	✓	✓	X
Herbivory	X	X	✓
Pollination and herbivory	X	✓	✓

In conclusion, the scientists showed that there were evolutionary changes in the plants that were exposed to both pollination and herbivory. These changes were different to those in plants that were exposed to only pollination or herbivory. This is important because in the real world, most living things evolve in response to more than one thing at a time, particularly as humans change natural *ecosystems*. If a living thing invests in being better at one thing, it may not be able to save itself from another.

Questions to discuss:

What changes in the environment do you think might affect the evolution of plants' characteristics?

How do you think plants might evolve because of these environmental changes?

In the classroom, children can compare the different characteristics of flowering plants, and investigate how different characteristics could give some species an advantage over others. Details of pattern-seeking investigations are given in the Teacher Guide that accompanies this article.

GLOSSARY

control group
the group in an experiment that does not receive treatment by the researchers and is then used to compare how the other tested subjects do

ecosystem
a community of living things (e.g. animals and plants) in a habitat, together with the non-living parts of the environment (e.g. air and water)

herbivores
animals that eat only plants

herbivory
the eating of plants by animals

pollination
the transfer of pollen grains from the male anther of a flower to the female stigma of the same flower or another flower

pollinators
an animal that moves pollen from the male anther of a flower to the female stigma of a flower. Some birds, bats, butterflies, moths, flies, beetles, wasps, small mammals, and bees are pollinators

replicates
the same experiment is repeated many times

species
a group of living things with similar characteristics which are capable of breeding and having offspring

The paper that inspired this work was:

Rapid plant evolution driven by the interaction of pollination and herbivory.

By Sergio E. Ramos and Florian P. Schiestl.

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