Alpine rock cress uses a ribonucleic acid to measure its age and tell when it's the right time to flower

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The Alpine rock cress (*Arabis alpina*) grows up to 10-40 cm tall and can be found in Alpine regions up to 3,300 meters. The perennial plant requires exposure to a cold period and the right age to flower. Credit: MPI for Plant

Perennial plants flower only when they have reached a certain age and been subjected to the cold. These two circumstances prevent the plant from starting to flower during winter. George Coupland and his fellow scientists from the Max Planck Institute for Plant Breeding Research in Cologne have now discovered that the Alpine rock cress determines its age based on the quantity of a short ribonucleic acid.

Perennial plants carefully balance periods of growth and flowering to ensure that they can live for many years. They do not flower when they are still too young and small or produce flowers on all their side shoots. Also, they do not flower out of season and they continue to grow after flowering. In temperate regions they do not produce flowers during winter but only after exposure to a long cold period. This dependency on a cold stimulus is called vernalisation. George Coupland, Sara Bergonzi, Maria Albani and other scientists from the Max Planck Institute for Plant Breeding Research have now identified the molecular signals used by the perennial Alpine rock cress (*Arabis alpina*) to register its age and to realise that it has been exposed to vernalisation. Only when the right age has been reached and the chill has had its effect can flowers begin to form.

The Alpine rock cress measures its age based on the concentration of a short ribonucleic acid known as miR156. A purely regulatory nucleic acid, miR156 works like an hourglass. Just as the sand trickles through an hourglass and indicates the amount of time elapsed, so the concentration of ribonucleic acid in the Alpine rock cress decreases from week to week enabling the plant to measure its age. When the ribonucleic acid reaches its lowest level, the plant is old enough for flowers to form when it is also exposed to vernalisation.

"Under normal conditions, this point is reached five to six weeks after germination," says George Coupland. "We can alter the time of flowering and the effect of vernalisation simply by manipulating the miR156 concentration." If the Alpine rock cress produces a particularly large amount of miR156 as a result of a genetic trick, it does not flower at the usual time. The surplus of miR156 caused by this over production acts as a brake on a group of proteins which induce flower formation. If the genetic trick makes the plant produce less miR156 than usual, flower formation happens sooner: the Alpine rock cress is sensitive to vernalisation a mere three weeks after germination. Consequently, the ribonucleic acid is the most important timing mechanism for flower formation in the Alpine rock cress. Only when it has reached its lowest point can vernalisation take effect and cause flowers to form.

In the closely related model plant *Arabidopsis thaliana*, an annual, the effect of the ribonucleic acid is less pronounced. If the weather conditions are very good, it also flowers in the presence of a fairly large quantity of miR156. Only when the weather is poor for an extended period does it rely on its age and put flower formation off until the ribonucleic acid concentration has reached its lowest level. "This ensures that Arabidopsis even flowers in a grey and cold summer," explains Coupland. As an annual, the plant is compelled to accelerate its life cycle and to achieve flowering age as quickly as possible and thereby form seeds. The concentration of miR156 is simply overridden in favourable weather conditions. Perennial plants, by contrast, are governed strictly by age and vernalisation.

The reason why not all side shoots of the Alpine rock cress flower at once is also explained by miR156. These shoots form one after the other and are therefore not all the same age as the main shoot which flowers first. The miR156 concentration needs to decline in each side shoot individually for it to be sensitive to vernalisation and form a flower. These different ages within the plant are what make some shoot axes

flower each year and others only flower the following season, after the winter.

So how does the Alpine rock cress respond to vernalisation? This was another issue Coupland and his fellow scientists studied. They were able to demonstrate that this occurs independently of miR156. The effect of the cold stimulus causes another protein which acts as a brake on flower formation to disappear during winter. This protein has the somewhat cryptic name PEP1. It blocks an important flowering gene. The gene can only be read when PEP1 has disappeared in the winter chill.

And what is the practical benefit of this research? "It enables us to manipulate the concentration of miR156 to make plants flower when they are younger. This could make them quicker to breed," says Coupland. "For instance when cultivating new varieties of cabbage, such as cauliflower, white cabbage or curly kale. All of these members of the cabbage family also go through a long phase of juvenility and this can greatly delay experiments needed to breed new varieties."

More information: Sara Bergonzi, Maria C Albani, Emiel Ver Loren van Themaat, Karl JV Nordström, Rhenhou Wang, Kobinian Schneeberger, Perry D. Moerland und George Coupland, Mechanisms of age-dependent response to winter temperature in perennial flowering of Arabis alpina, *Science*, May 31, 2013; 340: 1094-1097

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