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Theme and variations

Model organisms are powerful research tools for exploring fundamental biological questions, but no one model can encompass the full diversity of plant life.

Last month, UK Research and Innovation (UKRI) posted an article on their website that highlighted the role of *Arabidopsis thaliana* in plant science research both from an historical perspective and with a particular focus on current work funded by the UK's Biotechnology and Biological Sciences Research Council (BBSRC)[1]. The original version of the article ended with a quotation from Professor Neil Hall, Director of the Earlham Institute, that read "No matter what plant is being worked on, the original insight came from Arabidopsis". You won't find this quotation on the website now, but with the Wayback Machine fewer things are completely lost from the internet than you might think.

The meaning of Professor Hall's comment is clear: research on model organisms — be they mice, yeast, zebrafish, *Arabidopsis* or whatever — has been fundamental to the advance of genetics and modern biology. *Arabidopsis* is small, has a short lifecycle, is easily transformed and has a relatively compact genome, all of which make it an ideal experimental subject. It would be hard to think of another plant species that has come close to providing as much fundamental information about plant biology. However, when the quotation made its way onto Twitter there were plenty of people who were quick to point out the many things that *Arabidopsis* does not do, and which it cannot therefore teach us about.

We have discussed the relative merits of model and non-model plants in the past[2], but it is a topic that is well worth revisiting. *Arabidopsis* is not the only model plant. Rice (*Oryza sativa*), *Nicotiana benthamiana*, *Brachypodium distachyon*, tomato (*Solanum lycopersicum*) and others can make a claim to be experimental models, especially when studying relatively common features that *Arabidopsis* happens not to display. In this issue, for example, there is work on the accumulation of sugars in fruit, using apple (*Malus domestica*) and tomato as experimental systems[3], and on the improvement of photosynthetic performance by the introduction of a red-algal Rubisco into tobacco (*Nicotiana tabacum*)[4].

The power of the model plant is that conclusions derived from experiments involving it can be generalized to other, perhaps even all, plants. However, sometimes it is the unique features of a particular group or individual that are its most valuable attribute. Non-models have power too. *Helichrysum umbraculigerum*, for example, has a particular specialist metabolism. It has evolved a pathway for synthesizing cannabinoids that is unrelated to that used by *Cannabis sativa*[5]. Not only does this make available an alternative source for these medically relevant compounds but it also provides hitherto unknown cannabinoids with potentially novel properties.

Some members of the group of nonvascular land plants known as hornworts (genomes of which were published in *Nature Plants* three years ago[6,7]) are unique among plants in having pyrenoids. Pyrenoids are subcellular organelles within chloroplasts that are absent from almost all plants, although present in many green algae. These are phase-separated organelles formed by the binding of a repeating but essentially unstructured protein with Rubisco. Despite having a worldwide distribution, hornworts are a frequently overlooked group of plants — often quite literally, as they have a form that is generally low-growing and favour damp or humid environments. Around a third of hornwort species contain pyrenoids within their chloroplasts. The pyrenoid itself is surrounded by a starch sheath, which contains bicarbonate transporters that act to raise the concentration of carbon dioxide in the vicinity of the Rubisco enzymes, increasing their efficiency. The fact that pyrenoids can function in hornworts suggests that they could also be engineered into crop plants to improve yields and both nitrogen- and water-use effeciency[8].

The British statistician George Box is credited with the saying "All models are wrong, but some are useful". *Arabidopsis thaliana* has proved its usefulness as a model over and over again, but the unique features of each group and species can be more useful still.

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