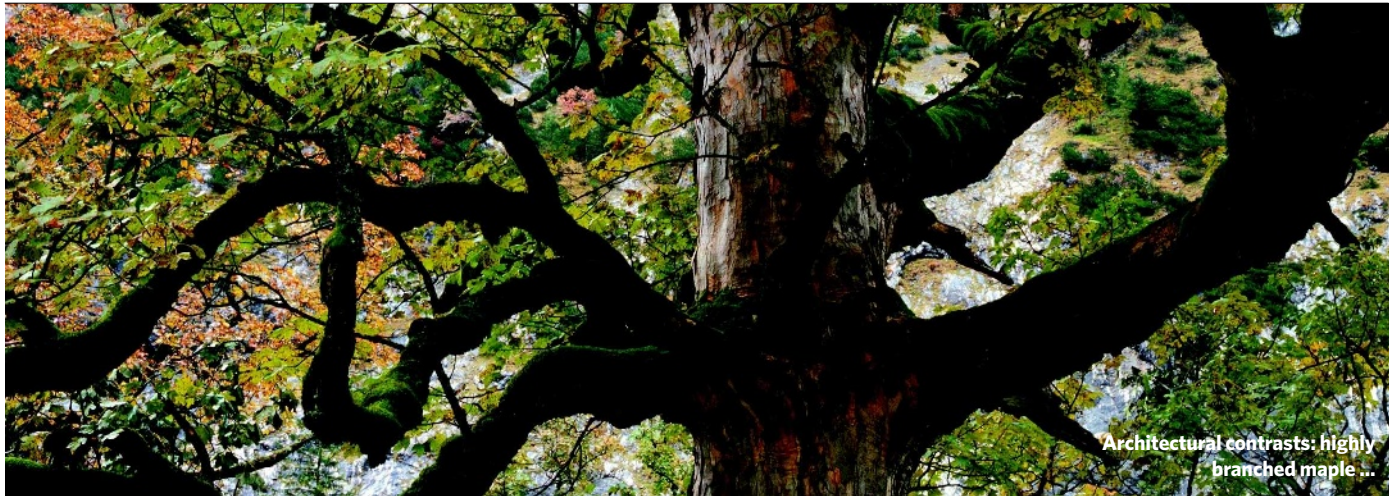


## NEWS &amp; VIEWS



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## PLANT BIOLOGY

# Hormones branch out

Harry Klee

**Evidence points to the existence of a hitherto uncharacterized type of hormone that controls different aspects of plant growth and interaction. The hunt for that hormone is heating up.**

Plants can't move around and so have evolved elaborate biochemical communication systems to control growth in response to a changing environment. One of those systems involves the ability to make shoot branches. Branching habit defines the architecture of a plant, and elsewhere in this issue Gomez-Roldan *et al.*<sup>1</sup> (page 189) and Umehara *et al.*<sup>2</sup> (page 195) open a fresh avenue in the quest to find out precisely what those regulatory factors are.

Consider two tree species, maple and redwood, with greatly different architecture. A Californian redwood achieves great height because it is apically dominant; the apical shoot suppresses growth of subapical lateral shoots. By contrast, a maple is less apically dominant, has multiple growing shoot tips and becomes highly branched. Although architecture is largely determined by genetics, a plant must be able to modify its growth in response to the environment. If the dominant shoot is destroyed, for example, the plant responds by initiating growth of a subapical shoot bud.

Hormones are essential to the communication network that provides plants with growth plasticity. Two classes of hormone in particular, auxins and cytokinins, have long been known to influence apical dominance<sup>3</sup>. In recent years, genetic and biochemical evidence has implicated another class of hormone in branching control, one derived from carotenoids<sup>4–6</sup>. Plants that have mutations in genes

encoding carotenoid-cleaving dioxygenases (CCDs) are highly branched, indicating that some substance normally suppresses the growth of lateral shoots<sup>7,8</sup>. Grafting and gene-expression studies indicate that the substance is produced principally in roots and is translocated to shoots, where it suppresses subapical shoot outgrowth. This substance, therefore, conforms to the classical definition of a hormone: it is produced in one tissue and translocated to another where it exerts a strong effect on growth.

Gomez-Roldan *et al.*<sup>1</sup> and Umehara *et al.*<sup>2</sup>



report a considerable advance in identifying this new class of hormone. Between them, they have used common experimental plants — pea, *Arabidopsis* and rice — to show that levels of strigolactones, a group of terpenoid lactones thought to be derived from carotenoids, are significantly reduced in *ccd* branching mutants. The two studies are complementary in terms of their approaches and the test plants involved, and are consistent in their conclusions. Application of strigolactones to mutants restores normal branching. Crucial evidence comes from mutant plants that have a defect in the signaling pathway downstream of strigolactone. The defect is in a control component of the pathway, an F-box protein, which is postulated to transduce the hormone signal<sup>9</sup>. These mutants are not deficient in strigolactone synthesis and do not respond to application of strigolactone.

Strigolactones are compounds that stimulate seed germination in plants, such as *Striga*, that parasitize the roots of other plants<sup>10</sup>. They also act as signals for symbiotic interaction with the arbuscular mycorrhizal fungi<sup>11</sup> that colonize roots and facilitate the uptake of soil nutrients by plants. But the link with above-ground shoot branching was unexpected. Both groups<sup>1,2</sup> propose that strigolactones are themselves either hormones or their biosynthetic precursors. Although the teams' findings link the biosynthetic pathways of strigolactones with the elusive branching hormone, the details of

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the pathway(s) have yet to be determined.

Strigolactones contain a large, four-ring backbone structure, probably derived from a carotenoid<sup>12</sup>. So far, three enzymes that might be involved in its synthesis have been identified by extensive mutation screenings of various plant species, but this is too few to synthesize such a complex structure. Nonetheless, applications of small amounts of strigolactone restore branching mutants to normal<sup>1,2</sup>, indicating that if a strigolactone is not the actual hormone, it is very closely related to it.

Strigolactones are produced by the roots of many plants and the CCD genes are present in all higher plants. The involvement of strigolactones in mycorrhizal symbiosis suggests that they have a pivotal role in coordinating plant growth below as well as above ground. Mycorrhizal fungi promote root growth and, in turn, shoot growth. By extension, strigolactones could be the regulators that modulate appropriate shoot outgrowth. That parasitic plants in turn monitor such an influential root-produced compound is a marvellous example of co-evolution.

The identification of compounds that alter branching, mycorrhizal colonization and the germination of parasitic-plant seeds offers hope that customized chemicals can be designed to change these various responses. Species of *Striga* and *Orobanche* — another group of parasitic plants — cause massive crop losses in the developing world, especially in Africa. A cheap chemical that stimulates premature germination of these parasites would have immediate and widespread application. Similarly, chemicals that predictably alter plant architecture would be welcomed, particularly by the part of the horticultural industry that produces ornamental plants.

With these papers<sup>1,2</sup>, we have moved closer to the identification of an entirely new class of plant hormone, and now have a biochemical handle on the control of several aspects of plant growth. Full characterization of the biologically active compounds that regulate branching should permit rapid progress in our understanding of the downstream signalling events, and of how this pathway interfaces with the auxin and cytokinin signalling pathways. ■

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## GAMMA-RAY BURSTS

# Light on the distant Universe

Jonathan Grindlay

**Observations of a long-lasting  $\gamma$ -ray burst, one that has the brightest optical counterpart yet discovered, challenge theoretical understanding of these bursts but may enhance their usefulness as cosmic probes.**

On a clear night, from one of Earth's increasingly rare dark sites, one can see roughly 3,000 stars with the naked eye. All of these point sources of light are stars within our Milky Way galaxy, and most are closer than about 1,500 light years. It is only with the rare catastrophic end of a massive star's life, in a gargantuan explosion resulting from the collapse of the stellar core, that nature extends our visible reach with a supernova.

Possibly one in every thousand supernovae is not 'normal': as the core collapses past the state of a neutron star to a black hole, the spinning disk around the nascent black hole launches a powerful jet that 'drills' its way out of the overlying star<sup>1</sup> and produces an even more extreme blast: a long-duration  $\gamma$ -ray burst (GRB). These bursts typically last between 3 and 100 seconds, and are followed by fading afterglow emission at longer wavelengths (X-ray, optical, infrared and sometimes radio). On page 183 of this issue, Racusin *et al.*<sup>2</sup> report observations of the optically brightest GRB yet seen. The optical emission of this burst, dubbed GRB 080319B, is a hundred times brighter than the previous record holder.

GRB 080319B was detected by the Burst Alert Telescope (BAT) onboard NASA's Swift satellite on 19 March 2008. Only automated telescopes detected it, but it would have been visible to the naked eye for about 40 seconds — and thus whoever saw it would have witnessed the most distant astronomical object ever directly seen. Spectra of the optical afterglow measured its redshift as  $z = 0.93$  (ref. 3), which corresponds to a light travel time of 7.4 billion years, placing GRB 080319B more than halfway back to the Big Bang and the origin of our Universe.

The only 'normal' supernova visible to the naked eye in the past 400 years, SN 1987A, was detected<sup>4</sup> on 24 February 1987. Its optical brightness was comparable to that of GRB 080319B, but it occurred a mere 163,000 light years away in our neighbouring satellite galaxy, the Large Magellanic Cloud. How could the similarly bright optical flash of GRB 080319B be in any way connected to the process of stellar death, given its approximately  $5 \times 10^4$  times greater distance? The answer is 'beaming' — in which, instead of the isotropic, relatively slow emission from a normal supernova over days to months, a large fraction of the total energy of a GRB is collimated into a narrow and highly relativistic jet (that is, its bulk outflow velocity is very close to the speed of light).

Racusin and colleagues<sup>2</sup> show that the jet in GRB 080319B almost certainly has a two-component structure: a jet approximately  $8^\circ$  across surrounding a narrower (about  $0.4^\circ$ ) central core of higher relativistic speed for which outflow velocities are within about five parts in ten million of the speed of light. For about 100 seconds, the collimated radiation beam observable from this jet was an intense beacon illuminating the intervening Universe. It came from a GRB that occurred around 3 billion years before the Sun and Earth formed.

X-ray, optical and radio observations of GRBs have shown that their afterglow emission is due to the collision of a beamed jet with the surrounding wind from the pre-supernova star and interstellar medium, and that beaming is directly indicated by the 'jet breaks' in the afterglow light curves<sup>5</sup>. Even more convincing evidence for the relativistic expansion of the jet was provided by the radio observations of another GRB — GRB 970508 — which showed<sup>6</sup> that its total energy was about ten times lower than inferred from a spherical explosion, implying a jet with an opening angle of about  $30^\circ$ . However, until the remarkably complete broadband spectral and temporal coverage of GRB 080319B, it had not been possible to directly constrain the radial structure of the jet.

Observations began before the BAT detection with optical imaging from wide-field telescopes that were already observing another burst, GRB 080319A, which was only  $10^\circ$  away from GRB 080319B and had gone off only 30 minutes before. This was a remarkable coincidence, given that the BAT observes only about two GRBs per week over the full sky. Ultimately, the afterglow from GRB 080319B was observed to fade by eight orders of magnitude in flux over six weeks by a worldwide suite of telescopes spanning 11 orders of magnitude in wavelength.

A prediction<sup>2</sup> of the high outflow velocities inferred for the central jet is the production of even more luminous, prompt GRB emissions of much higher-energy  $\gamma$ -rays. Such emissions would be easily detected by the recently launched Fermi Gamma-ray Space Telescope. But absorption of such high-energy  $\gamma$ -rays by the dense optical-ultraviolet photons produced by synchrotron emission in the same internal shock region could attenuate such emissions, despite the small angle scattering in the narrow jet.

The ultra-relativistic core of the jet in