Needless to say, there is a much larger litany of phenomenological information about sonoluminescence than given above, and no simple theory about the origin of the light, much less its spectral and temporal characteristics, has been given. There are ardent proponents of an incredibly diverse array of speculations about sonoluminescence, many of them supported by significant arguments or detailed calculations. An abbreviated list contains not only the obvious blackbody, shock waves, bremsstrahlung, and subtle collision effects, but also includes more exotic effects that derive from quantum electrodynamics. These recent experiments provide support for the most violent of these mechanisms simply because it seems that everything happens at once. What remains totally mysterious, however, is why there is such strong dependence on the gas mixture and the choice of liquids, and why such violent events are so strongly dependent on seemingly mild conditions such as the initial water temperature.

The entire apparatus is extraordinarily simple and low-cost for research at the frontiers of physics. Thus, it is ideal for undergraduate students who learn about electrical and acoustical resonances, impedance matching, normal modes, transducers and detectors for ultrasound, and a host of related topics that can lead to an interesting study of "flask spectroscopy."

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BOTANY

Plants See the Blue Light

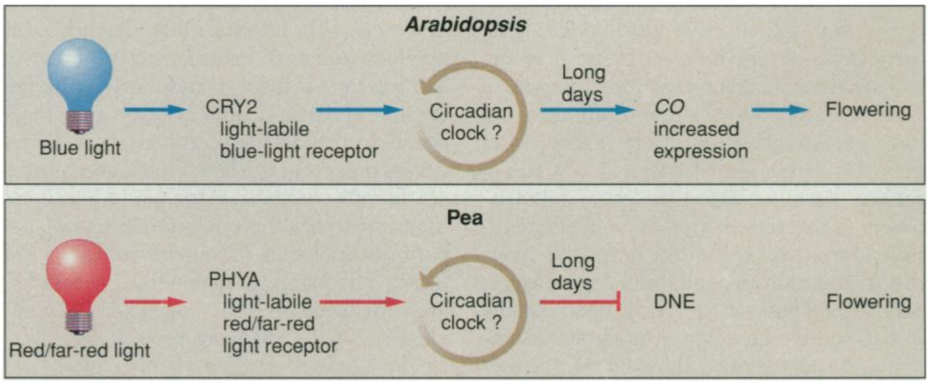
Paula Suárez-López and George Coupland

As day lengths increase in the spring, many plants respond by flowering. Others—such as one variety of tobacco that flowers in winter—flower when days get shorter (*1*). Day length is "seen" by a light-sensitive molecule in the leaf, phytochrome, which can sense red and far-red light (*2*). Indeed, mutations affecting one form of phytochrome, phytochrome A (PHYA), prevent the photoperiod response in the pea plant (*3*). However, *phyA* mutations only weakly affected photoperiodic responses in *Arabidopsis* (*4*), a plant widely used by researchers. On page 1360 of this issue, Guo *et al.* now show that *Arabidopsis* senses photoperiod through a different molecule, the blue-light receptor cryptochrome 2 (CRY2) (*5*).

Flowering of *Arabidopsis* is promoted by long photoperiods and delayed by short ones. Among the large number of mutations that either delay or promote flowering are those that decrease or abolish the response to photoperiod. For example, a group of late-flowering mutants, including two called *co* and *fha*, flower later than wild-type plants only under long days; the underlying mutations likely occur in a genetic pathway that triggers flowering when days get longer (*6*). Messenger RNA from the CO gene—proposed to encode a transcription factor—is more abundant in wild-type plants grown under long days than in plants grown under short days (*7*), and expression of the gene from a strong viral promoter causes day length–insensitive early flowering (*8*). These observations suggest that CO is transcriptionally regulated by daylength and in turn triggers flowering. In *Arabidopsis*, blue and far-red light promote flowering, leading to the suggestion that PHYA and a blue-light receptor trigger flowering (9). Guo *et al.* now show that the *FHA* gene encodes CRY2, a receptor for blue light recognized by its similarity to the blue-light receptor cryptochrome 1 (*cry1*) (*10*). Under long days *cry2* mutants show delayed flowering and reduced expression of CO, whereas overexpression of *CRY2* accelerates flowering and causes increased expression of CO under short days. This is consistent with the idea that *FHA* acts before CO in the long-day promotion pathway and is required for increased expression of CO under long days. There is about three times as much CO mRNA in wild-type plants as in the cry2 mutant, and about three times as much in wild-type plants under long days compared with those under short days. Such small changes in CO mRNA abundance might well be sufficient to affect flowering time, because increasing the dosage of the gene by introducing extra copies could accelerate flowering, and heterozygotes carrying one mutant and one wild-type copy of the gene flowered later than wild type (*7*).

Guo *et al.* also proposed that *CRY2* promotes flowering by repressing the inhibition of flowering caused by the red and far-red light receptor phytochrome B (PHYB), on the basis of the behavior of *cry2* and *phyB* mutants under different light qualities. Guo *et al.* suggest that CRY2 and PHYB act antagonistically to regulate flowering time. The CRY2 protein accumulates in plants growing in darkness but is unstable when plants are exposed to light (*10*), while PHYB is light stable (*11*), so for most of the photoperiod CRY2 would not be present to antagonize the repression caused by PHYB. Further genetic analysis should make the interactions between CRY2 and PHYB clearer.

The function of CRY2 may be aug-



Flowering time. Both *Arabidopsis* and pea flower in response to long days. This process is disrupted by mutations in genes encoding light-labile photoreceptors: CRY2 in *Arabidopsis* (*5*) and PHYA in pea (*3*). CRY2 promotes flowering through the up-regulation of the *CO* gene, whereas PHYA in pea acts by repressing the inhibitor of flowering, DNE. In both species the circadian clock might act as a timekeeper to measure day length.

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mented by CRY1. CRY2 is not required to promote early flowering under continuous blue light, perhaps because cryptochrome 1 (CRY1) promotes flowering under these conditions. In agreement with this, mutations called *elongated hypocotyl 4* (*hy4*), which affect the CRY1 protein (*12*), delay flowering in response to blue light or under short photoperiods (*13*). However, *hy4* mutations seem to have little effect on flowering time under long photoperiods of white light. Perhaps therefore CRY2 promotes flowering under constant white light and long photoperiods, but under constant blue light CRY1 is required for early flowering. A division in function between CRY1 and CRY2 has been shown in development of the seedling, in which CRY1 mediates high-intensity blue-light responses and CRY2 mediates low-light responses (*10*).

The promotion of flowering in response to long days requires a timekeeping mechanism that enables plants to measure day length. An endogenous circadian clock is thought to provide the timekeeper in the photoperiodic control of flowering time (*2*). In *Arabidopsis* the circadian clock shows a shorter period under light than darkness, and phytochrome as well as a blue-light receptor were demonstrated to mediate this effect (*14*). Conceivably CRY2 may act as a blue-light receptor that signals to the clock, enabling long and short days to be distinguished. A link between blue light, the circadian clock, and the photoperiodic control of flowering was previously suggested by the *early flowering 3* (*elf3*) mutation (*15*). This caused photoperiod-insensitive early flowering, disrupted clock function under continuous light, and led to hypocotyl elongation under blue light. The effect of *cry2* on clock function and of *elf3* on the *cry2* phenotype can now be tested.

Isolation of the genes affected by the other flowering-time mutations in the same class as CRY2 should provide biochemical functions for other members of the pathway. Perhaps these will also help with the challenges of determining how the activity of the pathway is regulated by day length and in which tissues of the plant the different components of the pathway act.

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EVOLUTION

After the End: Recovery from Extinction

Douglas H. Erwin

Shiva, the destroyer in the Hindu pantheon of gods, could be the patron of paleontologists as they scrutinize the intricacies of past biodiversity crises. Yet Shiva's dance of destruction clears the way for rebirth and renewal; it is this creative side of Shiva to which paleontologists recently have appealed as they investigate the recovery processes that follow mass extinctions. One particularly abrupt mass extinction, at the end of the Cretaceous period, provides a clean starting point for examining recovery patterns. An influential study of this period from the Texas Gulf Coast (*1*) revealed a pattern that has become the paradigm of recovery (*2*): A zone barren of fossils immediately above the extinction horizon is overlain in the more recent strata by a species-poor assemblage of surviving taxa, usually able to survive broad environmental conditions, and opportunistic blooms of some species, presumably taking advantage of empty ecological niches. This survival interval is succeeded by the diversification of new species and eventual rebuilding of communities.

But the generality of this model is called into question with the report on page 1327 of this issue of the first comparison of recovery patterns in several different biogeographic provinces (*3*). Jablonski has extended his previous studies of Late Cretaceous bivalves and gastropods through the mass extinction and into the first 10 million years of the Paleocene. In this detailed comparison of the recovery process in the U.S. Gulf Coast, northern Europe, northern Africa, and Pakistan–northern India, there is no evidence of opportunistic blooms outside of the U.S. Gulf Coast. The paradigm may not be so paradigmatic: It seems that the biogeographic complexities of the recovery process can overwhelm efforts to develop a general model.

Paleontologists have usually examined changing patterns of biotic diversity in one of two ways—as synoptic global compendia or as local investigations of a single section. Detailed comparisons of different regional diversity patterns have been uncommon in rocks older than 2 million years. This missing biogeographic component to recovery studies is particularly troubling, for the comparative analysis of recoveries is quite likely to yield ecologically and evolutionarily meaningful results. Distinct biogeographic regions are commonly semi-autonomous actors in the evolutionary play, and thus the "reality" of insights from global compendia has long been in doubt. Global compendia provide greater taxonomic scope than local studies, but they sacrifice ecological acuity and may average very different signals: Cretaceous oysters in Pakistan simply don't interact with carditid bivalves in Alabama. At the same time, the peculiarities of data from any individual location—with its particular preservational problems, changing substrates and environments, and restricted sampling—often limit the generality of conclusions drawn from such information. Although regional analyses are the most demanding sort of data to assemble, they provide the best trade-off among these competing problems.

The faunas of the four regions compared in the new report are each well documented; all of the regions show similar magnitudes of extinction and patterns of taxo-

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