Quantum optics

Cheat detection

Alice and Bob are getting divorced, but who keeps the dog? They could toss a coin for it, but as they now live apart, how can Bob be sure, if Alice tosses, that she won't lie about the result?

In most cryptographic problems of communication between two parties, the challenge is to eliminate third-party eavesdropping. But in the 'coin-tossing protocol', which is relevant to real-world situations such as remote signing of contracts, the issue is a lack of trust between the communicants. Can quantum cryptographic methods stamp out cheating? Yes, they can, say G. Molina-Terriza *et al.* (*Phys. Rev. Lett.* **94,** 040501; 2005).

The authors have staged a quantum-optical enactment of a protocol that works as follows. The result is decided by many throws — the best of 100, say. Alice tosses each coin and encodes the outcome in the angular-momentum quantum state of a photon in an entangled pair. This encoding determines the quantum state of the other photon in the pair, which has been sent to Bob. But Bob cannot determine the state of his photon until Alice sends him the information on her own photon — in essence, until she tells him how the coin fell. So he bets on the toss, and then Alice sends him a signal encoding the 'actual' outcome, which Bob can verify by performing a measurement on his own photon.

Because of its probabilistic nature, some such measurements will fail — Alice won't be able to encode the true outcome. But the crucial point is that if Alice is systematically cheating, this shows up as a higher than average rate of 'failures', and Alice can do nothing to suppress this tell-tale signature of dishonesty. **Philip Ball**

Agrobacterium-mediated genetic transformation has become a staple for basic plant research, as well as a principal means of generating transgenic plants for the agricultural biotechnology industry. However, at least for commercialization purposes, a tangled patent thicket complicates *Agrobacterium*-based plant-transformation technology. For this reason — as well as for more fundamental reasons of scientific interest — it would be interesting to determine whether other species of bacteria could, like *Agrobacterium*, serve as 'plant genetic engineers'. Although several previous papers have indicated that other bacterial species could incite plant tumours when engineered to carry a Ti-plasmid[7–9], molecular evidence for the actual transfer of DNA from these bacteria to plants has been lacking. Broothaerts *et al.*[1] now provide this evidence.

In their study, the authors used *Rhizobium* species NGR234, *Sinorhizobium meliloti* and *Mesorhizobium loti* — representatives of two different bacterial families. They first introduced a 'disarmed' Ti-plasmid that lacks a T-DNA region into these bacteria. This Ti-plasmid contained virulence genes, the protein products of which are necessary to act on a T-DNA and transfer it to plants (Fig. 2). Then Broothaerts *et al.* introduced a second plasmid containing a T-DNA region into these non-*Agrobacterium* species and into a disarmed *Agrobacterium* strain. This T-DNA contained a gene that encodes resistance to the antibiotic hygromycin, as well as *gusA*, a gene that directs the expression of the marker enzyme β-glucuronidase. To safeguard against misinterpretation of the data should the bacterial strains be mixed up, the T-DNAs introduced into *Agrobacterium* and non-*Agrobacterium* species contained different molecular 'tags'.

The authors used these bacteria to infect several different plant species, representing two major higher-plant groupings: species from the dicots (which are highly susceptible to *Agrobacterium*-mediated transformation) included tobacco and the thale cress *Arabidopsis*; from the monocots (which are considerably less susceptible), the authors used rice. The generation of plants that express β-glucuronidase and are resistant to hygromycin indicated successful transformation by all bacterial species tested. This was confirmed by DNA-blot analysis and by the sequencing of T-DNA–plant-DNA junctions recovered from plants transformed with non-*Agrobacterium* species. Moreover, the junctions from these plants resembled those previously characterized as a result of *Agrobacterium*-mediated transformation. Therefore, the processing, transfer and integration of T-DNAs from the different bacterial species probably occurred by the same mechanisms.

Broothaerts and colleagues' results also suggest that non-*Agrobacterium* species are capable of the full range of genetic transformation mechanisms shown by their *Agrobacterium* counterparts. The transformation of *Arabidopsis* involved a 'flower dip' protocol, which targets female reproductive (germ-line) cells[10]. However, tobacco and rice were transformed via somatic tissues — leaves and callus cells, respectively — which probably involves a different mechanism[11].

The authors further found that although non-*Agrobacterium* bacterial species could be engineered to genetically transform several plant species, the transformation efficiency was relatively low, ranging from less than 1% to almost 40% of that of *Agrobacterium*-mediated transformation, depending on the species and transformation assays used. Broothaerts *et al.* note, however, that alterations in transformation conditions (the age and type of plant tissue inoculated, for instance) could enhance these frequencies. The low frequencies of *Agrobacterium*-mediated transformation of many 'recalcitrant' plant species have been substantially increased through such manipulations over the past 20 years.

Broothaerts and colleagues' findings[1] will no doubt have implications for plant science and biotechnology. The ability of several bacterial species to transfer genes to plants also reinforces the possibility that such horizontal gene flow may have contributed to plant evolution. It is already known that the genomes of some plant species contain remnants of what were probably ancient transformation events by *A. rhizogenes*[12,13]. In some instances, the *Agrobacterium*-derived transgenes are now expressed in a regulated manner in the host plant[14], hinting that these genes have become an important part of the plant's genetic make-up. We may find that transgenes from other bacteria have likewise been assimilated by plants. Our understanding of the importance of horizontal gene flow in the evolution of higher organisms should be enhanced by knowledge of the mechanism of such transmission, and of the range of organisms that can participate in these events. ■

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