Mindless mastery

Plant intelligence

Traditional definitions of intelligence use movement as a criterion. But are the adaptive behaviours shown by individual plants also 'intelligent'?

Anthony Trewavas

For centuries, plants have been regarded as passive creatures. Their development is thought to be predetermined, with only temporary interruptions in response to stress. Because plants lack obvious visible movement, they seem to be bereft of behaviour and intelligence. Yet they dominate every landscape, representing 99% of the biomass of the Earth. There is a clear conflict between the commonly held view and the success of plant life. Only now are we beginning to expose the remarkable complexity of plant behaviour. A revolution is sweeping away the detritus of passivity, replacing it with an exciting dynamic — the investigation of plant intelligence is becoming a serious scientific endeavour.

From their evolutionary beginnings, photosynthesizing plants eschewed movement because light was freely available. But colonization of the land meant that essential resources were distributed as a spatial and temporal mosaic, and competition for them became more fierce. For the sessile plant, new forms of behaviour evolved to allow efficient foraging in the local environment. Growth (and embryogenesis) continued throughout the life cycle but instead of a predetermined programme, development was adapted plastically to respond to changing environmental resources and characteristics.

The shapes and forms of stems, leaves and roots, tissue cell numbers and types, can all vary hugely. Monoecious plants can change from male to female and back again. Environmental influences on the parent can show their effects three, four, even twenty generations down the line. But the primary variation comes from modular development, the repetitive programme that generates enormous numbers of leaves, buds, flowers and roots. A plant can consist of one bud, one leaf and a flower, or millions of them; the same is true of roots. We simply do not understand this organizational plasticity, but plasticity is foresight!

Plants continuously screen at least 15 different environmental variables with remarkable sensitivity — a footprint on the soil or a local stone, for example, are perceived and acted upon. We either know or can guess the receptors for most of these signals, which are transduced in fractions of a second through large numbers of small GTPases, second messengers and a thousand protein kinases. The flow of information is continuous. Integrated responses are constructed after reference to the bank of internal information that specifies the plant's ecological niche.

But coordinated responses require communication, and research in this area has exploded. Internally, plant cells and tissues communicate with each other using proteins; nucleic acids; many hormones; mineral, chemical, hydraulic, mechanical, oxidative and electrical signals; peptides; various lipids; sugars; wall fragments; and other complex carbohydrates. Quite how individual plant cells accommodate this prodigious amount of information is not understood. But even anatomically uniform cells exhibit enormously different responses to a single signal. A huge reservoir of individual cell behaviours can be coordinated to produce many varieties of organism behaviour.

But how is this linked to 'intelligence'? As humans, we recognize intelligence by the diagnostic of movement — but this is not a complete definition, as the chess-playing computer that beat Garry Kasparov made very clear. The function of intelligent behaviour in any organism is, of course, to increase fitness. If intelligence is defined as adaptively variable behaviour during the life of the individual, then, in plants, behavioural plasticity by the individual is where intelligence should be apparent. But simply looking for intelligent behaviour in ordinary greenhouse-grown plants is unlikely to be productive. Challenging environmental circumstances are required to elicit intelligent responses by any organism. Imaginative construction of situations in which plant choice and intention can be tested are now providing revelations.

The growing shoot can sense its nearest competitive neighbours using near-infrared light, predict the consequences of their activities, and if necessary take avoiding action. The shape, growth and direction of the stem are altered to maintain an optimal position relative to sunlight; leaf positions are adjusted to optimize light collection. When competitive neighbours approach the stilt palm, the entire plant simply moves away by differential growth of the prop roots supporting the stem.

The rhizomes of individual clonal herbs (prostrate stems that carry buds and roots) can select a habitat by growing into and foraging in areas that are free of competitors and/or have rich resource conditions. Many of the buds change fate and develop into leaves instead of rhizomes, but a search capacity is maintained as other rhizomes of the same plant elect to grow into poorer soils where they thin out, grow more rapidly and disperse. Roots track three-dimensional humidity and mineral gradients in soil with explosive growth responses when resource-rich patches are encountered, but deliberate evasive action is taken when competitors' roots approach.

The dodder, a parasitic plant, assesses the exploitability of a new host within an hour or two of its initial touch contact. If these are deemed to be insufficient, the plant continues searching for other, more profitable, hosts. But if the decision is made to exploit the host, the dodder coils about it with a particular number of coils (and eventually suckers) that depends on the assessed future return. Several days later, the dodder begins to take its host's resources.

How is such intelligent behaviour computed without a brain? Cellular calcium mediates most plant signals, and calcium waves inside cells offer computational possibilities. The challenge is set — remarkable years of discovery lie ahead. ■

Anthony Trewavas is in the Institute of Cell and Molecular Biology, University of Edinburgh, Edinburgh EH9 3JH, UK.

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The parasitic dodder coils around a hapless host.

FURTHER READING

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