duction in response to stress does not alter the level of production of either enzyme in immature pea pods by the pathogen (and elicitor), indicating that ethylene and the pathogen are independent stimuli of these two hydrolases.

Production of proteinase inhibitors I and II of tomato is greatly stimulated by wounding, although there is a low level of message in the unwounded plant (C.A. Ryan *et al.*, Washington State University, Pullman). Both the cDNA and genomic clones for these genes have been obtained from tomato and potato. Again polysaccharide fragments of cell walls are active as inducers. They are also potent elicitors of the castor bean and pea phytoalexins (C.A. West *et al.*, University of California, Los Angeles). The accumulation of the soybean phytoalexin, glyceollin, is preceded by increases in the activity of a number of enzymes including those involved in its synthesis (H. Grisebach, University of Freiburg). Infection of soybean with *Phytophthora megasperma* f.sp. *glycinea*, or treatment with a glucan elicitor from this fungus, leads to *de novo* enzyme synthesis which is controlled at the level of gene transcription. Using a radioimmunoassay for glyceollin it was shown that in soybean roots infected with a compatible race of the fungus, glyceollin accumulated only in the epidermal layer, whereas with an incompatible race glyceollin also accumulated to a high level in the root tissue, thus supporting the role of this phytoalexin in the plant's defense reaction.

Cell-wall polysaccharides clearly play a part in the regulation of gene expression in response to pathogen attack. But they may also have diverse regulatory functions in growth and development and may be an important class of regulatory molecules (P. Albersheim *et al.*, University of Colorado, Boulder). When most of molecular biology is devoted to proteins and nucleic acids it is timely to consider that carbohydrates may be more than just structural components of the cell. □

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100 years ago

THE employment of acupuncture by Chinese doctors forms the subject of an article in one of the last numbers of the *North China Herald*. A native public writer not long since claimed that a skilful physician in this department of medicine could cure such diseases as imbecility, fits, cholera, &c. The principle of cauterisation is simply that of counter-irritation; and the English writer bears personal testimony to its efficiency in the case of a slight sunstroke, although the operator was a simple Manchu peasant, and instrument a couple of copper coins. Very extraordinary cures are attributed to acupuncture by the Chinese. It is first performed in the hollow of the elbow of each arm. If the puncture draws blood there is no danger, but if no blood appears the case is regarded as very grave. But before abandoning the sufferer, puncture of the abdomen is tried.

From *Nature* **30**, 324, 31 July 1884.

Bacterial motion

Surprises from halobacteria

from Michael Spencer

INTEREST in the bacteria that thrive in saturated salt solutions has progressed far beyond the original desire to arrest the spoilage of salted meat. It is now clear that halobacteria show some unique features that give them an unusual fascination for molecular biologists. The best known of these is the purple membrane that functions as a light-driven proton-pumping system for driving the synthesis of ATP. Solar-energy buffs have even suggested that the system might usefully be harnessed to the generation of electricity (Singh, K. & Caplan, S.R. *Trends biochem. Sci.* **5**, 62; 1980). As part of their evolutionary adaptation to life in hot shallow salty pools, halobacteria have also developed a double linkage between light-sensitive membrane proteins and the flagella: one system drives them towards regions of high-intensity visible light, while the other helps them to avoid dangerously high levels of ultraviolet radiation (Hildebrand, E. & Schimz, A. *Photochem. Photobiol.* **38**, 593; 1983). It is in the actual operation of the flagellar motors that some surprising differences from other bacteria have now emerged.

The saga of flagellar motion (do they wiggle or actually go round and round?) has been running for many years, and progress with more common species was summarized only recently in these columns (*Nature, News & Views* **309**, 404; 1984). The evidence strongly favours the idea that each flagellum has an independent and reversible rotary motor, powered by a proton gradient. In many bacteria the flagella operate in bundles which rotate synchronously, but there is a topological restriction on the sense of rotation: if the flagella are coiled into left-handed helices the bundle can only rotate in a counter-clockwise direction when looking towards the body, while right-handed helices can only rotate clockwise. Halobacteria (which also have bundled flagella) appear to break this rule, and in a new paper Alam and Oesterhelt (*J. molec. Biol.* **176**, 459; 1984) discuss how this might be explained.

The reason for the normal restriction has been analysed in detail by Macnab (*Proc. natn. Acad. Sci. U.S.A.* **74**, 221; 1977), but can easily be demonstrated by twirling two wire helices between the finger and thumb. For one direction of rotation, two or more helices can rotate indefinitely with apparent propagation of helical waves away from the body, whereas with reversed rotation a state of 'jamming' rapidly develops which stalls the engine. In many species the resulting stress leads to a transient reversal of helix sense which makes the bundle fly apart, followed by a period of 'tumbling' and then a reversion to normal rotation. The result is that the bacterium sets off in a new randomly determined direction after each reversal. Reversals occur spontaneously even in the absence of stimuli, and control by receptors of external stimuli is exercised by varying the interval between reversals: when moving in a favourable direction, reversals are much rarer.

Halobacterium halobium, the organism studied by Alam and Oesterhelt, does not operate like this. In contrast to the frenetic activity of *Escherichia coli*, which darts about at a rate of $20\ \mu m\ s^{-1}$, *H. halobium* moves towards its goal at the more stately pace of $2\ \mu m\ s^{-1}$; and when subjected to an unfavourable stimulus it simply pauses briefly before moving backwards along the same line. Alam and Oesterhelt found to their surprise that there was no reversal in the sense of the helix, which remained right-handed throughout; all that happened was that the flagella rotated in the opposite direction, and yet the bundles never flew apart. The authors therefore asked themselves "whether each filament has an individual motor, whether all the filaments are mounted on a single motor plate, or whether halobacterial mobility is dependent at all on a rotatory motor".

The last hypothesis, which would nowadays be regarded as heretical, was discarded after experiments in which bacteria were observed to go round and round when their flagella were tethered to a glass surface with antibodies. Over the remaining two possibilities the authors rather hedge their bets. On the one hand, electron microscopy shows the members of a bundle apparently penetrating the cell surface in a tight coil, which would seem to exclude the insertion of each flagellum into a separate motor of the kind found in other bacteria. On the other hand, the cultures contain large numbers of detached flagella which aggregate spontaneously into long 'super-flagella', and it is possible that a motile bundle is simply one actively-driven flagellum with a number of inactive partners stuck to it. Alam and Oesterhelt suggest that further study of the system at lower salt concentrations, at which the morphology of the cell body remains unchanged but super-flagella are known to disaggregate, might provide the answer. They also draw attention to another interesting difference from other bacteria, in that *H. halobium* flagella show a much more complicated pattern of proteins on gel electrophoresis. These freaks of nature may have more puzzles in store for us yet.

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