genesis is organized in this way. A likely answer is that sequential production is more efficient than concurrent production (it would be interesting to discover a developmental mutant that allowed the simultaneous production of eggs and sperm). It can also be asked whether a further reduction in sperm production might be favoured by natural selection if this led to a greater decrease in generation time. A temperature-sensitive mutant of the *fem-3* gene (*e2006*) markedly reduces sperm production and leads to a modest decrease in generation time. However, this mutant has a much lower fitness than either the wild-type or the *tra-3(e2333)* genotype. So far, no mutant has been identified that outperforms the wild type.

The use of specific developmental mutants as a tool to explore trait fitnesses is a notable development in life-history studies. The work also provides an excellent example of a trade-off — between fecundity and development time — that is often invoked though little demonstrated. Classical life-history theory normally predicts that selection for high fecundity will be greatest in *r*-selected populations continually kept below carrying capacity by density-independent mortality. One curious consequence of the natural history of *C. elegans* is that in crowded populations one would expect natural selection to favour genes for higher fecundity; the advantage of a short generation time shows itself only when the population is exponentially growing most of the time.

Hodgkin and Barnes's study raises other questions. Why, for instance, does the nematode produce many more eggs than it has sperm to fertilize? Presumably these extra eggs are occasionally fertilized by rare males. But in that case, why are there not more males in the population? Studies with *C. elegans* have proved highly productive in several fields; they now seem set to build bridges between evolutionary and developmental biology. □

H. C. J. Godfray is in the Department of Biology and the NERC Centre for Population Biology, Imperial College, Silwood Park, Ascot SL5 7PY, UK. Paul H. Harvey is in the Department of Zoology, University of Oxford, South Parks Road, Oxford OX1 3PS, UK.

ELECTRON TRANSFER

Switches in enzymes

Barry Halliwell

LIVING organisms move electrons over considerable distances, with great speed and specificity: indeed, it is the flow of electrons through the metabolic network that sustains all life. An appropriate arrangement of transition-metal centres can mediate electron transfer because these metals readily accept and donate electrons, but in biological systems such reduction–oxidation centres are often insulated from one another by lumps of protein. How, then, do electrons cross this barrier? J. E. Baldwin, G. M. Morris and W. G. Richards[1] describe a neat switching mechanism that they say can do the job.

The complex metalloprotein systems of respiration and photosynthesis are essential to energy production. The superfamily of cytochromes P-450 are haem-containing enzymes that also use electron flow to accomplish a wide range of tasks, from hydroxylating toxic compounds to encourage their secretion, to participating in the synthesis of hormones and bile acids[1]. Finding out how electrons are transported is also important for understanding why these processes sometimes go wrong: if electrons leak away from their correct path between reduction–oxidation centres, or if too many are passed on at a time, harmful free oxygen radicals can result that may be involved in the ageing process and several human diseases, including cancer[2,3]. So how do electrons get from the surface of a protein to an internal metal ion-containing centre? In enzymes containing two or more spatially separated centres, how are electrons transferred between them? In multi-component electron-transfer systems, what makes the electrons follow the correct path rather than short-circuiting[4,5]?

Baldwin *et al.* use a cytochrome P-450 system from the soil bacterium *Pseudo-*

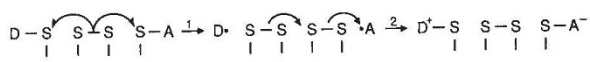

FIG. 1 Electron transfer by covalent switching requires spin unpairing and the breaking of covalent bonds in a heterolytic fashion (both electrons going to one of the products). The example shown here involves sulphur ligands and disulphide bridges. D is an electron donor and A an electron acceptor. In step (1) single-electron transfers occur from the disulphide bridges to the other two sulphurs, generating D· and A· radicals. In step (2) a double-electron transfer regenerates the disulphide bridge. The net effect is electron transfer from D to A. This mechanism is postulated to mediate electron transfer from the reduced FAD ring on putidaredoxin reductase to the iron–sulphur cluster of oxidized putidaredoxin via an intermediate disulphide. (Figure reproduced from ref. 1.)

RÉSUMÉ

Small change

ONE of the classic physics experiments of this century has been reincarnated by radioastronomers who measured the deflection of radio waves from the distant galaxy P0201+113 as they passed close to Jupiter (*Astr. J.* **102**, 1879–1888; 1991). The classic experiment was by Arthur Eddington and colleagues, showed who during a total eclipse in 1919 that the curvature of space by the Sun's gravity, predicted by Einstein, was sufficient to deflect the light from a distant star. But where Eddington and colleagues sought a deflection of 1.75 arcseconds, Jupiter's deflection of just 17 milliarcseconds required R. N. Treuhaft and S. T. Lowe to combine radiotelescopes in California and Australia (separation 10,600 km) to give astrometric measurements with the remarkable resolution of 160 microarcseconds.

Yeast released

WHAT does yeast want with an enzyme that digests chitin, the cellulosic bathmat that makes up certain cell walls? This chitinase has now been cloned and sequenced by M. J. Kuranda and P. W. Robbins (*J. biol. chem.* **266**, 19,758–19,767; 1991) and has a curious structure; first comes a signal sequence; then a region that contains the catalytic site; and, separated from this by an abundantly glycosylated segment, in which more than half the residues are serine or threonine, is a chitin-binding domain to fasten the enzyme to its substrate. And the need for the chitinase? Kuranda and Robbins have the answer, for they show that when the gene is wrecked, the dividing yeast cells form indissoluble clusters. Now yeast cell walls contain only about 1 per cent of chitin, but all of it at the septum that divides mother from daughter cell — a kind of umbilicus that only the chitinase will cut.

Current change

JUST as canaries were used to warn of gas in mines, brachiopods could be used as indicators of climate change in the geological record say G. B. Curry and K. Endo (*Geology* **19**, 1101–1103; 1991). Over the past 10,000 years, *Terebratulina retusa* has spread from the Canary Islands as far as Spitzbergen; the cold-loving *T. septentrionalis*, by contrast, thrives in the Davis Strait between Greenland and Baffin Island, venturing as far south as eastern Canada, their larvae borne by the Labrador current. But isolated relict populations still survive off Finnmark and Norway. It seems that the end of the Ice Age signalled a rapid northward migration of *T. retusa* at the expense of its cousin, and that the dispersal of brachiopod larvae could be used to chart ocean currents in the more distant past.