

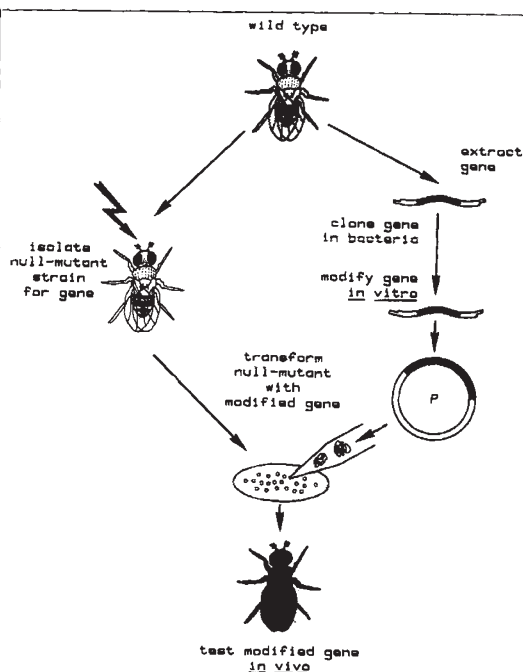
the same mechanism. The gene affects two crucial properties of biological rhythms: their sensitivity to phase-shifting signals and their resistance to changes in temperature. Both findings support the idea that the *per* gene is required in the oscillation processes or in setting up the oscillators during development (see ref. 3).

In the early 1980s, the *per* gene was cloned independently by two groups^{4,5}. The predicted amino-acid sequence of the coding region did not provide any immediate clues as to the function of the protein. Our concepts of clocks are moulded by technical devices such as the pendulum or the sand-glass, and we seem to be at a loss in guessing how temperature-compensated biological clocks are built. One hint pointing towards a model of the sandglass type comes from the observation that the amount of *per* gene product is negatively correlated with period length. Extra doses of the wild-type gene shorten the cycle, whereas subnormal expression of the gene elongates it⁶. Thus, *per* might be the sand in the sandglass or a valve regulating its flow.

A benefit of cloning a gene is that immunological and DNA probes can be obtained which allow expression of the gene and its product to be located. In this case, *per* expression is seen in the embryonic nervous system, in the larval salivary gland and in various tissues and cells of the pupa and adult fly^{7,8}. Does this imply that different tissues have their own clocks?

Last year, Young and co-workers at Rockefeller University reported¹ that gap junctions between the cells of the salivary gland are under the control of the *per* gene. Rhythmicity in this tissue is manifest in the intercellular coupling which is modulated with a circadian periodicity (cited in ref. 3). Young and colleagues propose that the behavioural rhythms are also based on the communication between cells and that the *per* protein exerts its influence at the cell surface or in the extracellular matrix. Whether or not this conjecture is correct, when faced with a complex behavioural phenotype and a complex pattern of gene expression, one would like to attribute particular aspects of one to certain features of the other. Ewer *et al.* in this issue¹ introduce conditional *in vitro* mutants as a new tool for this purpose.

These authors design a temperature-controlled *per* gene by fusing a heat-shock promoter to the *per* gene coding region and transform *per*⁰ flies with this new construct. (Heat-shock proteins are produced in response to stress and are present in most cells.) At high temperatures, these *in vitro* mutants express the *per* gene practi-



In vitro mutagenesis in *Drosophila*. *D. melanogaster* is well suited for the application of this method in behaviour research as the fly combines a rich behavioural repertoire with the following three technical criteria: (1) *Drosophila* genes can be isolated and modified *in vitro*; (2) so-called null mutants (animals without a particular gene) can systematically be found; and (3) a modified gene can be efficiently inserted into the genome of a null mutant.

cally everywhere in the body (as they express heat-shock genes), whereas at low temperature they show no or very little *per* expression. Ewer *et al.* demonstrate that *per* gene expression is necessary only during overt rhythmic behaviour, and that neither the normal developmental profile nor the spatial pattern of expression is essential for the oscillation. One can instantaneously 'switch on' the circadian locomotor rhythm in the adult mutant flies by turning on the gene, and switch the rhythm off as easily by turning the gene off. This result supports (but does not prove) the notion that the *per* gene is part of the oscillation process, but it contradicts those models which require that it is involved in the construction of the oscillator during development.

The function of the *per* gene is still obscure. But *in vitro* mutagenesis should enable *per* and other clock genes to be analysed so that the molecular basis of biological oscillators and their manifestation in behaviour can be understood. □

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Martin Heisenberg is Professor of Genetics at the Institut für Genetik und Mikrobiologie, Universität Würzburg, Röntgenring 11, 87 Würzburg, FRG.

Daedalus

The aerial tadpole

THE hot-air balloon, such an elegant craft in many ways, is a thermodynamic disaster. It burns propane at over 1,000°C, and just lets this temperature decay to 50°C or less, with no attempt to exploit the heat-flux for propulsive power. The snag, of course, is weight. A conventional gas engine would be far too heavy to be lifted by its waste heat discharged into a balloon.

Now Daedalus plans to use the balloon itself as an engine. His idea is to burn fuel in bursts, so that the envelope expands and contracts, ideally in mechanical resonance. This requires a closed envelope, without the conventional opening at the bottom. In the 'expansion' stroke, pressurized propane is released into the envelope through a valved injection burner, entraining air as it enters and burns. In the 'contraction' stroke the valve closes, and the hot air in the balloon cools and leaks out through the carefully controlled porosity of the fabric. Fins on the oscillating envelope could swim it through the sky like a gigantic jellyfish.

But the radial oscillation of a spherical balloon would not propel it very efficiently, even with very big fins. Daedalus's 'aerial tadpole' variant has a much superior mode of oscillation. Its long, cylindrical Zeppelin-type envelope is divided longitudinally into separate chambers, each with its own injection burner.

Each chamber is stressed just to buckling by internal sprung and tensioned fibres, so that in the cold the aerial tadpole takes up a zig-zag shape: each chamber is buckled in the middle. But the buckling of an inflated cylinder is very sensitive to small differences of internal pressure. If the burner on any chamber is briefly fired, the sudden rise of pressure straightens that chamber convulsively; inertial overshoot makes it buckle in the opposite direction during the subsequent cooling and contraction. So by firing the burners in proper sequence down the balloon, the sequential straightening and buckling of the chambers will create a lateral travelling wave of large amplitude, a huge resonant tadpole wiggle of the whole balloon, which will propel it with great efficiency.

The aerial tadpole will extend hot-air ballooning far beyond mere recreation. It can travel in any direction, even against the wind: it can hover like a helicopter, while being wonderfully silent, safe, cheap and, of course, delightful to look at. All sorts of short-haul travel, lifting and patrolling and aerial joyriding, will become simple and easy. Aerial tadpoles may even make flying safe enough for individual commuting — making possible the long-predicted traffic-jam in the sky.

David Jones