forces to support their weight and to drive them forward through the air. Aircraft get support from their wings and thrust from their engines, but birds and bats get both from their wings, by flapping them. These mechanisms can help us to understand the difference between the gaits.

Air is driven roughly at right angles to the path of the wing through it. The downstroke drives air downwards and backwards, providing weight support and thrust. The upstroke of fast flight (Fig. 1*a*) drives downwards and forwards, tending to cancel out the thrust of the downstroke. To prevent this, the forces produced by the upstroke must be reduced, either by reducing the wingspan so that less air is moved by the wings, or by weakening the vortices so that the air is driven less fast. (This can be done by adjusting the angle of incidence of the wings.) Rayner has argued (*Biona Rep.* **5**, 27; 1986) that it is most economical to reduce wing span and keep vortex strength (circulation) constant as kestrels and bats seem to do.

Figure 1*c* shows a possibility for hovering and very slow flight, when the wings can be flapped so as to move backwards (relative to the air) in the upstroke. Circulation may be reversed at the end of each stroke so that the wake is a series of linked vortex rings, a ring for each downstroke and one for each upstroke. Hummingbirds seem to do this, but the vortices have not been demonstrated. Many insects apparently are able to do the same (Ellington, C.P. *Phil. Trans. R. Soc.* B**305**, 1; 1984).

The slow gait (Fig. 1*b*) is intermediate between the other two. Circulation is eliminated but not reversed in the upstroke, so vortices (and useful forces) are produced only in the downstroke. There is scope for an optimization theory that would predict the speed at which the change should be made between the slow and the fast gaits. □

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Circadian rhythms

Benzodiazepines set the clock

from A. T. Winfree

THE time will come when a traveller leaving for the airport, having frantically searched for and found his ticket, will still not be ready: it will be necessary to dash to the medicine cabinet to rummage for the inevitably misplaced bottle of jet-lag pills. Elsewhere in this issue (*Nature* **321**, 167; 1986) Fred Turek and Susan Losee-Olsen, in a simple, straightforward experiment with triazolam and hamsters, provide the strongest hint yet that the elusive jet-lag pill is within reach.

Like any other mammal, humans have a persistent strong tendency to regularity in the ups and downs of diverse physiological functions, such as core temperature and the alternation of sleep and waking. The latter regularity has a native circadian periodicity close to 25 hours, and is usually synchronized by the 24-hour alternation of day and night, so it is called the biological clock. The mechanism of this clock seems rooted in the central nervous system, particularly in the suprachiasmatic nucleus of the hypothalamus. A gene whose alleles determine the periodicity of the circadian clock of the fruitfly has recently been sequenced: it appears to be a proteoglycan (Jackson, F.R. *et al. Nature* **320**, 185; 1986).

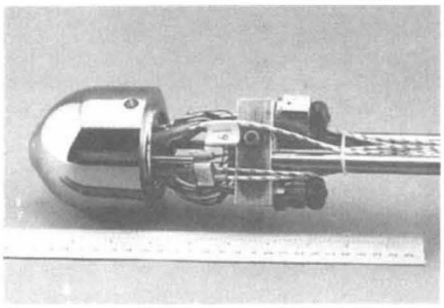
Little more is known of the mechanism of circadian clocks, but their pharmacological sensitivity has recently provided us with some powerful hints about phase shifts such as those one encounters during east–west travel. Ionophores, brain hormones and neurotransmitter analogues are conspicuous among agents capable of permanently shifting the phase of the clock, much as visible light has long been known to do. Alternating light and darkness is the leisurely agent of synchronization that normally guides plants, invertebrates and mammals (including humans) to a standard phase relationship with the environment after a shift of phase. But gradual entrainment to local time requires exposure to cycle after cycle of the synchronizer; would it not be better if we could abruptly set our internal clocks in advance, much as we set our watches? My own favoured procedure involves exposure to bright sunlight at a carefully planned hour (Daan, S. & Lewy, A.J. *Psychopharm. Bull.* **20**(3), 566; 1984), but this is not necessarily convenient if, for example, it is snowing or it is night-time. Pharmaceutical assistance towards synchronization has long been sought; one need only stand in the aisle of any intercontinental jetliner to hear many superstitions about, for example, coffee, diet, alcohol and sleeping pills.

Turek and Losee-Olsen seem to have found a real effect — that of benzodiazepines — although the results of clinical trials have not yet been reported. Benzodiazepines, used for several years in the management of insomnia and related mental disorders, may act by potentiating the action of the inhibitory neurotransmitter γ-aminobutyric acid, which is known to be present in the suprachiasmatic nucleus. But its impact on circadian rhythms has never before been tested in the standard experimental protocol used by Turek and Losee-Olsen. These authors recorded the activity rhythm of a hamster for two weeks (so that the rhythm could be reliably extrapolated to the following days), then injected the animal intraperitoneally with a dimethyl sulphoxide vehicle at any one of eight equally spaced 'times of day' in its circadian cycle. The rhythm continued as anticipated. But if the vehicle carried a benzodiazepine (2.5 mg of triazolam, equivalent to about 5 times a heavy dose for an adult human) then the timing of subsequent activity was disrupted, causing an immediate phase advance or phase delay of about one hour. The exact amount of the delay depends dramatically and quite reproducibly on the timing of the dose, a dependency unlike that caused by stimulation of the retinohypothalamic pathway for phase-shifting by light. Hence Turek and Losee-Olsen have found a new avenue of entry into the clock mechanism.

The potential practical interest of their results lies in the hope that the same or a related fast-acting, quickly eliminated chemical without conspicuous side-effects may also abruptly reset the circadian clock in humans. If so then we may soon find ourselves carrying pills and a schedule whenever we cross time zones at a pace much in excess of one per day. The schedule will prescribe when and what dose of pills to take to achieve an immediate advance or delay appropriate to the foreseen change of longitude.

The result of Turek and Losee-Olsen raises another intriguing question — in three or four of the eight recordings shown not only is there an abrupt phase shift, but also the periodicity of the clock is substantially altered for at least a week. Yet the

Forward on fusion



A REVIEW article on page 127 of this issue describes experiments that provide new optimism for the possibility of generating power from nuclear fusion. The picture above shows the target capsule used to hold the deuterium-tritium mixtures for muon-catalysed fusion experiments at the Los Alamos Meson Physics Facility in 1984. The target was electrically heated to 800 K and then cooled to 14 K with liquid helium. Up to 150 fusions per muon (average) were observed with this apparatus.

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