in head orientation is not easy. Maybe, suggest Witmer *et al*., it relates to the large cranial crests borne by many derived pterosaurs, including *Anhanguera*, which could have affected skull aerodynamics during flight and required some repositioning of the head. But this is inconsistent with the recent discovery of large cranial crests in several basal pterosaurs[8,9], and their occasional absence in *Anhanguera* for instance. Alternatively, could head depression be related to feeding? *Anhanguera* and other derived pterosaurs have been interpreted as aerial fish-catchers[10], a feeding style that would have benefited from a downward-directed skull — especially as it may have permitted some stereoscopy, enabling accurate judgement of distance to a moving target. Again, however, there are inconsistencies. Many derived pterosaurs, such as the flamingo-like, filter-feeding form *Pterodaustro*, were not airborne fishers. But several basal forms were, as a specimen of *Rhamphorhynchus* with a fish in its belly eloquently testifies. Yet they still fished successfully with their level heads.

A more persuasive answer to this problem lies on the ground (Fig. 1). Like their reptilian ancestors, basal pterosaurs with their relatively short arms were condemned to walk with the body and head in a near-horizontal position, aligned with the lateral semi-circular canal. By contrast, functional studies[11] suggest that derived forms used their relatively long arms to prop themselves upright. But because they still needed to see in front of them as they walked, this required some restructuring of the skull and its posture, one consequence of which would have been reorientation of the semicircular canals.

Attractive as they are, these ideas do not address the extraordinarily large size of the floccular lobes in pterosaurs. Witmer *et al.* suggest that this region of the brain may have been responsible for coordination of the head, eye and neck, permitting gaze-stabilization during flight. Such an ability would have been useful for aerial hunters that relied primarily on sight. But not all pterosaurs had such a lifestyle, so this is not an entirely satisfactory explanation.

Far more convincing, in my view, is Witmer and colleagues' proposal that the floccular lobes were responsible for processing large volumes of sensory data generated by the wing membranes. This is a plausible idea, because in other vertebrates the floccular lobes receive sensory inputs from skin and muscles. New, extraordinarily well-preserved pterosaur material from Germany[12] and China[13] shows that the wing membranes were highly complex, containing structural fibres, blood vessels and a fine network of muscles. These features would have given the wings the ability to collect and transmit sensory information about local conditions within the membranes, enabling pterosaurs to build up a detailed map of the forces experienced by the wings from moment to moment. Processing via the floccular lobes could have allowed them to respond very rapidly, through localized contraction or relaxation of muscle fibres within the membrane and coordination with fore- and hind-limb movement. Equipped with their 'smart' wings, pterosaurs would have had excellent flight control. Despite their antiquity, they could even have outperformed modern birds and bats. ■

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Medical technology

Balancing the unbalanced

Frank Moss and John G. Milton

Elderly but healthy people are often seriously injured in falls. Exploiting the phenomenon of stochastic resonance, biological physicists have designed a shoe with a vibrating insole that helps maintain balance.

To stay upright, the human body uses exquisitely complicated and delicate feedback control, operating through the sensory and central nervous systems[1]. It does so in ways similar to a performer balancing a pole on a finger[2], by applying minute forces and torques through muscles in the feet, ankles and knees. But these muscles must receive signals that convey information on how much force to apply through which muscles. This information is initially supplied to the central nervous system by neurons located in various joints and the soles of the feet. With ageing, the sensory thresholds of these neurons increase. The information they transmit is therefore degraded, impairing balance.

As they report in the *Lancet*[3], J. J. Collins and his colleagues have successfully tested an idea about how information from the periphery of the sensory system might be enhanced. They find that the application of a random vibratory stimulation to the soles of the feet can reduce 'postural sway', and improve balance in both young and elderly human subjects. Inexpensive, easily constructed insoles, made of viscoelastic silicone gel, generated the stimuli. Three mechanical vibrators, about the size of three stacked coins, were embedded in each insole, one in the heel and two in the forefoot regions. They were driven by random voltage generators, and the resulting vibrations propagated throughout the gel.

Collins *et al.* measured postural sway by monitoring the position of reflective markers attached to each subject's shoulder using motion-analysis cameras. They applied the vibratory stimuli at random times, unknown to the subjects, and at strengths that were slightly below each subject's threshold of perception. Analysis of tracings of the marker motion quantified the threshold at which sensory feedback mechanisms kicked in to stabilize sway, enabling the authors to statistically characterize the subjects' balance control[4]. All subjects showed clear improvement with the introduction of vibratory random fluctuations ('noise'), with the elderly group showing the largest benefit. Other studies indicate that patients whose balance is impaired by stroke or by nerve damage associated with diabetes might also benefit[5]. The insoles have not yet been tested on subjects in motion, however, nor have they actually been shown to reduce falls, for example during walking or climbing stairs.

How does the beneficial effect arise? The information content of subsensory stimuli is known to be increased by the addition of noise through stochastic resonance[6,7]. This phenomenon is rooted in the physics of systems with thresholds, such as sensory neurons. Such systems transmit information by means of markers, or action potentials, which are generated when a threshold is crossed. Noise added to a subthreshold stimulus increases the threshold-crossing rate, thus improving the quality of the transmitted information, and the optimal noise intensity yields the maximum improvement. Much has been written on the subject (for instance, for a review focused on perception, see ref. 8). Experimentally, the effect has been demonstrated in the tactile system[9,10] and, as applied here, in behavioural processes in both animals[11] and humans[12] that depend on perceptive thresholds.

But Collins and co-workers[3] did not specifically search for the optimal noise intensity — the characteristic signature of stochastic resonance. So the benefits might arise from a different cause. The upright human body behaves like an inverted pendulum that is controlled by time-delayed feedback mechanisms[13]. Thus it could be that the vibrating insoles stabilize posture by introducing random, vertical vibrations[2], or by making the subjects more aware of the extent of their swaying. But neither of these possibilities is likely: first, because the insoles do not induce motion of the pivot point (the ankle and foot); and second, because the stimulus is not perceptible.

Theory aside, Collins and colleagues' observations point to a potentially valuable way of tackling a serious medical problem. Falls are the most common cause of trauma, and the largest single cause of accidental death, among the elderly. Moreover, at least in the Western world, an increasing proportion of the population is entering the elderly category. Further research and development work will be needed. But if simple and inexpensive vibratory soles could reduce falls by even a small fraction, the benefits would be considerable. ■

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Neuroscience

States of mind

Dario L. Ringach

In the brains of anaesthetized animals, neurons create spontaneous patterns of activity that resemble representations of visual stimuli. This finding may change our notions about visual perception.

Every waking moment, as we experience the world through our eyes, groups of neurons in our brain fire electrical impulses to enable us to perceive our surroundings. But what happens in our brains when our eyes are closed? In the absence of visual stimulation, the region of the brain that processes this information, the visual cortex, is not 'silent' — the neurons continue to fire. Until now, it was thought that these spontaneous patterns of activity were random, but on page 954 of this issue, Kenet *et al.*[1] report that this is not so. Instead, the cortex seems to show intrinsic patterns of activity that evolve over time by switching among a specific set of states. Remarkably, these states resemble the patterns of activity that are produced in response to certain visual stimuli. Studying how the intrinsic cortical states interact with incoming visual information might bring us closer to understanding perception.

Activity in the visual cortex depends not only on the nature of a visual stimulus, but also on the state of the cortex at the time of stimulation[2]. This, in turn, depends on several factors, including the sequence of the preceding stimuli, the behavioural state (for example, levels of alertness or expectation) and the background pattern of brain activity that occurs in the absence of stimulation — the so-called spontaneous or ongoing activity.

Classical studies of brain function aim to measure the average behaviour of a neuron in response to a particular stimulus. In such experiments, the spontaneous activity in the

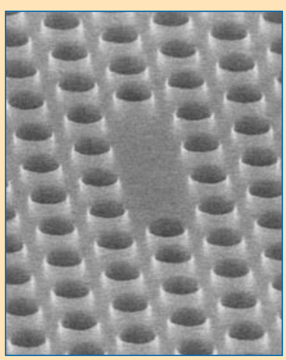
Photonics

Defective quality

In most areas of technology, defects are rarely welcome. For instance, in the semiconductor material inside a computer chip, defects might trap electrons and block the flow of current. But in photonic crystals, introducing precisely engineered defects could hold the key to a range of applications, including telecommunications and quantum computing. A new principle for the design of such defects is presented in this issue, by Susumu Noda and colleagues (*Nature* **425,** 944–947; 2003).

The periodic structure of a photonic crystal forms a 'bandgap', which forbids the propagation of light within a well-defined range of wavelengths. Making defects in the structure can then capture and confine light, creating a photonic cavity that can control light in ways that are not possible with conventional optics.

The photonic crystal investigated by Noda *et al.* consists of a thin slab of dielectric material, such as silicon, with a two-dimensional array of sub-micrometre-sized holes cut into it. There is a variety of ways to create defects in this structure, such as making one or more of the holes bigger or smaller, or removing them completely. Previous attempts at confining light in a photonic crystal have generally concentrated on the size or number of defects, or the manner in which light is coupled in and out of them. These authors, however, have investigated the



properties not of the defect holes themselves, but of those surrounding them.

First they introduced a defect in the photonic crystal with the absence of three adjacent holes (pictured). Without further modification, this makes an abrupt interface between the defect and the surrounding array, the severity of which allows trapped light to leak out. But by shifting the position of the holes on each side of the defect, Noda *et al.* found that they could soften this interface and reduce light leakage. And by doing so by just the right amount, the confinement efficiency, or quality factor, of the defects improves by as much as 100-fold, compared with previous studies.

This approach, which the authors refer to as "confining light gently to confine it strongly", should improve the performance not only of similar two-dimensional systems but of photonic crystals in general.

Ed Gerstner