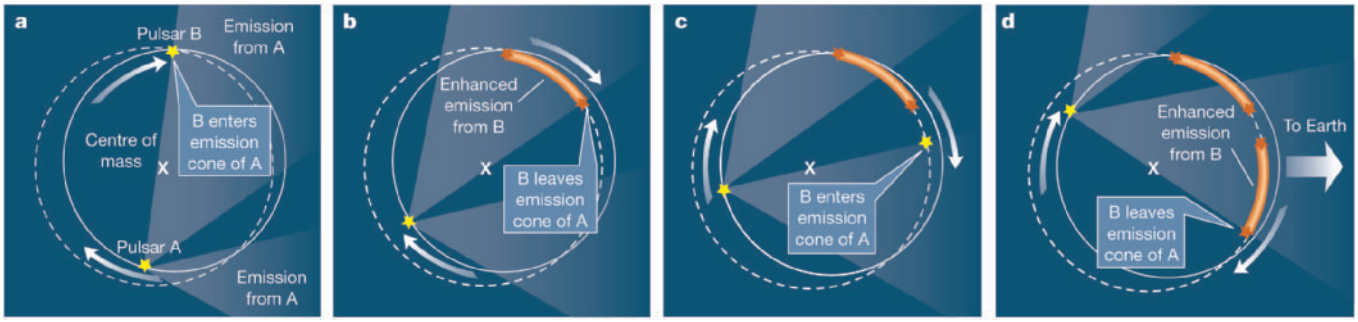

Figure 1 **The double-pulsar system J0737−3039. The orbit of the pulsars, seen here from above the orbital plane, is so compact that it would fit inside the diameter of our own Sun (1.4 million kilometres). The radio emission from one of the pulsars, B, is known to be strongest in two particular regions of the orbit, and now Jenet and Ransom[4] propose an explanation for why this is so. They assume that the other pulsar, A, emits radiation in a wide, hollow-cone beam. Panels** a–d **are snapshots of the pulsars' motion, showing the area swept out by A's beam.** a, **B intercepts A's beam and is stimulated to emit.** b, **This emission continues (orange band) until it enters the hollow midsection of A's beam and its emission is reduced.** c, **B is stimulated again as it enters the active part of A's beam for a second time.** d, **Once more, the emission is reduced when B moves out of A's beam. The orange bands representing stimulated emission from B match the regions of heightened emission seen in observations of the system. (Graphic derived from an animation at www.physics.mcgill.ca/~ransom/0737_Bflux_model.mpg)**

As well as explaining observations, Jenet and Ransom's model makes testable predictions about the past and future visibility of the binary system. This is because the proposed geometry is strongly dependent on the relative orientation between A's emission beam and the line of sight from Earth. This angle varies with time through geodetic precession (a relativistic effect[5] that occurs when the spin axis of an orbiting body is misaligned with the angular momentum axis of the binary system). The perturbing effect of B on the space-time of A causes the spin axis of A to precess around the angular-momentum axis. The strong gravitational field produced in the double-pulsar system means that A's spin axis precesses through a full 360° in 75 years. Similarly, B precesses every 71 years. These are the shortest geodetic precession periods ever observed and as a result the emission beams of A and B also move in and out of our line of sight within these timescales. This effect probably explains why the system was not visible during a previous survey of the sky over a decade ago[6].

Using this precession rate in their two best-fit solutions, Jenet and Ransom predict that the emission beam of A will precess out of our line of sight in either 4.5 or 14 years, depending on the solution considered. Within the next year, as changes in A's beam geometry begin to accumulate, significant variations in the shape of that pulsar's radio pulses are expected; they should be sufficient to enable observers to decide between the two model solutions. As Jenet and Ransom point out, it is not yet certain whether the same precession effect will be observed for B because the wind from A might have caused its spin axis to align with the orbit.

Nature has provided a magnificent spectacle. Time, however, is most definitely of the essence as these two neutron stars may not be visible for much longer. Observational astronomers are now working feverishly to characterize this system further, taking data at many wavelengths across the electromagnetic spectrum. If we assume that the new model continues to describe the observations, the theoretical challenge is now to establish whether it is feasible to 'jump-start' a neutron star and what physical processes could cause this to occur. ■

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Hearing

Tightrope act

David P. Corey and Marcos Sotomayor

A component of the 'tip link' that conveys tension to mechanically sensitive ion channels in the inner ear has been identified. The finding raises new questions about elastic elements in our hearing apparatus.

A snatch of music from far away or a slight turn of the head to find its source generates mechanical stimuli that are detected by hair cells of the inner ear. A bundle of finger-like stereocilia rises from the upper surface of each hair cell; stimuli that deflect these stereocilia by just a few nanometres can be reliably perceived. Biologists have a detailed understanding of the morphology and biophysical properties of the mechanically sensitive apparatus at the tips of stereocilia, but not of the protein constituents of this apparatus. In this issue, however, Nicolson and colleagues[1] and Müller and co-workers[2] describe how they identified a major constituent of the tip link — an extracellular filament that is stretched like a tightrope between the tops of adjacent stereocilia.

Mechanical stimuli that deflect a hair bundle towards its tallest stereocilia cause the tip links to tighten (Fig. 1a, overleaf). This tension is conveyed to specialized 'transduction' channels at each end of the tip link, which open to allow ions into the cell (Fig. 1b). This is the process of mechanotransduction, and is the first step in sending a signal to the brain. Within each stereocilium, several dozen myosin-1c molecules set a resting tension on a tip link and its channels, to bias the system to its most sensitive point.

Other than myosin-1c, the molecular contributors to mechanotransduction have not been positively identified. But some components of stereocilia have been identified from studies of genes that are defective in people or mice with inherited deafness. For instance, genes that are mutated in the human Usher's syndromes — which produce both deafness and blindness — have been found to encode the myosin-7a, harmonin, SANS, protocadherin 15 and cadherin 23 proteins[3]. Defects in any of these cause the stereocilia bundle to fall apart, suggesting that they participate in other, lateral links that connect adjacent cilia. In younger mice, cadherin 23 is most abundant near the transduction apparatus at the tips of stereocilia. But it was thought to disappear in adults, suggesting a role in development but not in mechanotransduction[3].

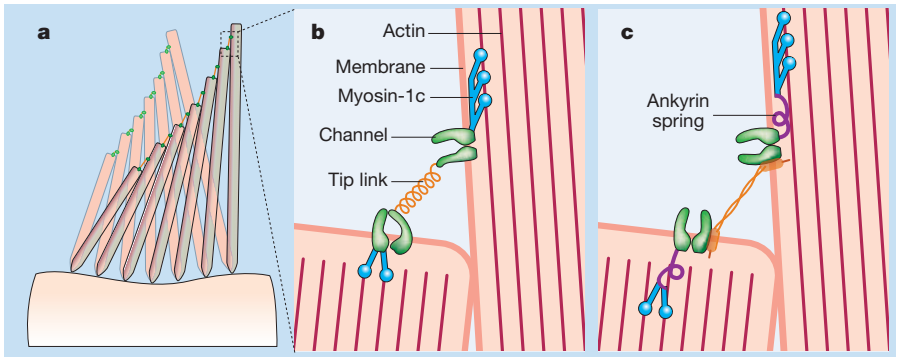

Figure 1 **Models for mechanotransduction in hair cells of the inner ear.** a, **Deflection of a hair cell's bundle of stereocilia, in response to a sound or a movement of the head, causes the stereocilia to bend and the tip links between them to tighten.** b, **In the traditional model of this mechanosensory apparatus, the tip links are elastic. They attach to ion channels at each end, which open in response to tension on the tip links. Myosin-1c is a motor protein that sets a resting tension on the tip link and channels; it is in turn anchored to actin filaments within the cell.** c, **An alternative model in which the tip link is inextensible (see also ref. 8), but the channels instead contain or are attached to intracellular elastic elements made of numerous repeats that are typical of ankyrin proteins.**

Now, however, cadherin 23 is shown to be a major component of the tip link itself. Nicolson and colleagues had previously identified a mutant zebrafish, christened *sputnik*, that showed compromised inner-ear function and the splayed bundles typical of Usher's syndromes[4]. These authors have now found[1] that the *sputnik* gene encodes cadherin 23. Moreover, an antibody that binds to cadherin 23 labels the tips of stereocilia in wild-type zebrafish, but does not do so in *sputnik* mutants. Most importantly, the authors show that *sputnik*-mutant hair cells lack tip links.

Meanwhile, using a sensitive antibody, Müller and colleagues[2] discovered that cadherin 23 does not disappear from the stereocilia of older animals, as thought[3], but is restricted to the stereocilium tips. The stereocilia of adult bullfrogs show a similar pattern; cadherin 23 also occurs between the tallest stereocilium and the adjacent kinocilium, where similar links are found. Electron microscopy revealed the binding of antibody specifically to the tip links themselves, and to the related kinociliary links.

As a further test, Müller and colleagues[2] looked at the effects of buffers or ions that either chelate or displace Ca^{2+} ions; tip links are known to be severed by such treatment, but reappear in 5–10 hours[5]. The authors found that these treatments also remove cadherin 23 from stereocilia, but that it returns in 24 hours. In addition, cadherin 23 binds to myosin-1c (the protein that sets the resting tension in tip links) when both proteins are made together in non-hair cells. Finally, cadherin 23 mediates binding between adjacent cells that express the protein in culture. The two groups[1,2], using various methods in three different species, have thus provided strong evidence that cadherin 23 is a major constituent of the tip link connecting adjacent hair cells. (It is apparently not the only one: an antibody that recognizes a protein of a lower molecular mass also labels the tip link[6].)

How does this fit with the biophysics of mechanotransduction? Sensitive physiological measurements indicate that the hair-cell ion channels are mechanically in series with a 'gating spring', which has a stiffness of about 1 millinewton per metre and can stretch by 10–20 nm at physiological forces (tens of piconewtons)[7]. The tip link itself was initially assumed to be the gating spring; indeed, textbook illustrations usually show the tip link as an extensible element. Yet high-resolution electron micrographs[8] reveal it to be a double helix, 8–11 nm wide and 150–200 nm long, that does not look very stretchy (Fig. 2a).

The discovery that cadherin 23 is a component of the tip link fits with the notion that this link is not very elastic — and so might not be the gating spring. Like other members of its family, cadherin 23 has numerous extracellular regions (27 in this case) known as cadherin domains, which enable cadherins on one cell to form parallel dimers that interdigitate with cadherin dimers from another cell[9]. As cadherin domains are about 3 nm wide and 5 nm long (Fig. 2c), a tip link formed by a dimer of dimers would be 8–12 nm in diameter and 140–280 nm long, depending on the extent of interdigitation (Fig. 2b) — fitting well with the electron micrographs of the tip link[8]. At the atomic level, cadherins do not seem very stretchy. Each cadherin domain of 110 amino acids contains seven structural features known as β-strands, tightly linked by hydrogen bonds (Fig. 2c)[10]. Our molecular dynamics simulations indicate that there is little stretch with applied force until the β-strands unfold at (unphysiological) forces of several hundred piconewtons (M.S., D.P.C. and K. Schulten, unpublished results).

If the tip link is not the gating spring, what is? The spring could be within the transduction channel itself. Nicolson's

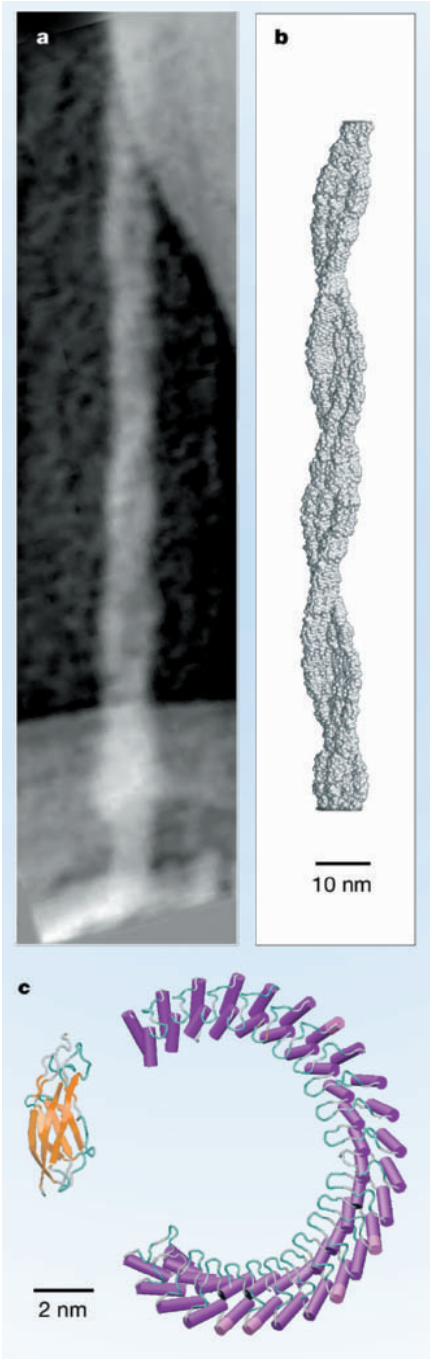

Figure 2 **Structure of the tip link, and molecular models.** a, **Electron micrograph of a single tip link extending between adjacent stereocilia. The scale is as in** b**; reproduced from ref. 8 by permission of the US National Academy of Sciences.** b, **Possible molecular structure of a tip link, given the new finding[1,2] that the cadherin 23 protein is one component of this link. We constructed the model from four filaments — each containing 27 extracellular cadherin 'domains' — arranged as a dimer of dimers.** c, **Left, a single cadherin domain, showing the tight packing of β-strands (arrows)[10]. We have found this domain to be rather inelastic, suggesting that the tip link, too, might not be as stretchy as traditionally thought. Right, 24 ankyrin domains, showing how the α-helices (cylinders) pack to form a superhelical structure[13] that is rather more springy.**

group[11] found previously that the channel TRPN1 is likely to mediate mechanotransduction in zebrafish. This channel has 29 so-called ankyrin repeats, which form a thin helical structure (Fig. 2c) that has been suggested to be elastic (V. Bennett, personal communication) and to serve as a gating spring[12]. Indeed, our simulations of ankyrin have demonstrated the appropriate stiffness and elongation.

So perhaps each tip link, now identified[1,2] as containing cadherin 23, is more like a stiff cable than an elastic spring. And perhaps each transduction channel carries its own spring, in the form of numerous ankyrin repeats. If so, the textbook figures must be redrawn, and more questions answered. What is the relevant channel in vertebrates other than zebrafish, many of which lack TRPN1? Could another member of this channel family be connected to a separate ankyrin spring in mammals? How are these proteins attached to each other, and how might other Usher-associated genes be involved? And what does this marvellous machinery do in photoreceptors of the eye, which express many of these proteins but have no obvious use for mechanotransduction? ■

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Meteoritics

Stars in stones

Sara Russell

Silicate minerals that predate the Solar System have been detected inside primitive stony meteorites. Isotopic analysis suggests that the silicates probably condensed around dying ancient stars.

Meteorites that date from around the time of the formation of the Solar System — a little over four and a half billion years ago — are testament to the events that occurred before and during planet formation. Most of the interstellar dust that went into forming planetary precursors was melted, vaporized, shocked and, once incorporated into asteroids, further heated and damaged. This has caused the chemistry and isotopic composition of minerals from meteorites to become more homogeneous. But a few mineral survivors predate these events. These presolar grains originated around stars that were the predecessors of our own, and made up part of the interstellar medium before collapsing into our Solar System. Several carbonaceous and oxide presolar grains have been identified in meteorite samples. Nagashima *et al.*[1] have now uncovered presolar specimens of silicates, the most common rock-forming minerals (page 921 of this issue).

This discovery is impressive, because presolar silicates are much more difficult to find than presolar carbonaceous and oxide grains. The latter are resistant to acid and can be separated out of a meteorite by dissolving away the major components — silicates and metal. The solid residue that survives can then be examined for grains of interest. This technique has been compared (by Edward Anders) to burning down a haystack to find the needle, and is more than a little distressing for meteorite curators. Nevertheless, it is a relatively straightforward way for researchers to find presolar gems.

The presolar grains identified so far are all chemically resilient enough to have survived this acid processing: silicon carbide, graphite, aluminium oxide and spinel, at levels of up to a few parts per million. Diamonds, which make up to 0.1% of some meteorites, might also be presolar, but their carbon-isotope composition and variable relative abundance in ancient objects has raised some doubt about this[2]. Because these gems condensed around ancient stars, they offer unique insight into how stars synthesize isotopes, how easily different parts of the star mix together and how grains condense in the relatively cool circumstellar region. They also provide a snapshot of the interstellar medium several billion years ago, so we can judge how the composition of our Galaxy has evolved since before the Sun came into existence.

As well as studying presolar grains in

100 YEARS AGO

To the April number of the *Independent Review* Dr. A. R. Wallace contributes the first part of an article on "The Birds of Paradise in the Arabian Nights." In the introductory paragraphs the author states that he is generally disposed to believe in the truth of the popular legends connected with natural history, the assertion that vipers swallow their young being a case in point. Accordingly he is predisposed to look with favour on the theory that the "Islands of Wak-Wak" mentioned in the "Arabian Nights" are really the Aru Islands, and that they take their name from "wawk-wawk," the cry of the great bird-of-paradise. The portion of the article contained in the issue before us deals only with the identification of the locality to which "the bride with the feather-dress" was brought with the south-eastern lower slopes of the Elburz Mountains. We shall await with interest Dr. Wallace's proofs that "Hasan" actually visited the home of the birds-of-paradise.
From *Nature* 28 April 1904.

50 YEARS AGO

A very important group of higher Primates has been discovered in Africa, the Australopithecinae. They include *Australopithecus*, *Plesianthropus* and *Paranthropus* from South and most probably "*Meganthropus africanus*" from East Africa. The position of *Telanthropus* from the *Plesianthropus*-layers of Swartkrans is still under dispute. The large amount of data now at hand leaves no doubt that the Australopithecinae are members of the Hominidae… The reduction of the dentition only affects the face; their increase in brain capacity is slight and depends upon the absolute size of the species; the possession of a sagittal crest in the large specimen parallels the development of the same structure in the anthropoids. It seems that towards the end of the Pliocene period the early Hominidae were separated into several branches — Australopithecinae in Africa, *Gigantopithecus* (and undescribed forms) in China, Pithecanthropi in Asia — and that only one of them, the Pithecanthropi, by a harmonious reduction of the whole dentition and — this is the most important point — by an exaggerated and accelerated increase of the brain capacity, gave rise to the Hominidae, of which group we are the most human members. **G. H. R. von Koenigswald**
From *Nature* 1 May 1954.