

exact  $n$ -body solutions — for each  $n$ , the desired solution exists. Buck's conditions, however, need be satisfied only in the limit of  $n \rightarrow \infty$ ; they need not hold for any finite  $n$ . Consequently, Buck has to argue that, for large enough  $n$  the motion approximates the limiting motion. But small forces remain which would pull particles off the curve. So how long will it take for these contrary forces to destroy the looped orbits? From what we know about the stability of Newtonian mechanics, the orbits might persist for a long time, but they are more likely to deteriorate rapidly. This is a crucial question, and a difficult one to answer.

So we may never see a real example of Buck's looped solutions. Yet, as the history of celestial mechanics has proved, there are ways to convert approximate solutions into useful tools. For instance, the mathematical definition of collisions requires point masses to meet at the same place at the same time. In a sense, each particle eventually treats its colliding partners as clumped in one spot, so we might expect them to align in a manner similar to that required by the central configuration constraints. That indeed happens: for a complete gravitational collapse<sup>4</sup> and for any collision<sup>5,6</sup>, the configuration formed by the colliding particles approximates a central configuration. By exploiting this approximation, much of what we know about the mathematics of collisions has been obtained.

Similarly, should particles escape from any configuration with close to the lowest possible escape velocity, they will end up far from the main cluster, travelling slowly. We might expect that the competing attracting forces of other particles will eventually cancel to create a force similar to that in a two-body equation. This approximation to a central configuration has been used to derive the general evolution properties of Newtonian

$n$ -body systems<sup>6,7</sup>. For example, expanding clusters of galaxies should slowly form central configurations, while the clusters separate from each other at a more rapid rate. In this spirit, we must work out how best to exploit Buck's idea to improve our understanding of the  $n$ -body problem. □

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### Neurobiology

## Columns, slabs and pinwheels

Nigel W. Daw

For over 30 years neurobiologists have been intrigued by how the outer layer of the brain — the cerebral cortex — is organized into columns of cells. These develop mainly after birth, under the control of activity driven by the sensory input. There are many models for this development, and, on page 73 of this issue, Wolf and Geisel<sup>1</sup> argue that they are all subject to symmetry principles. These principles lead to some general conclusions about the ways in which the columns develop, independent of when and how development occurs.

The columnar organization of the cerebral cortex was first demonstrated by Mountcastle<sup>2</sup> in the somatosensory cortex, then elaborated by Hubel and Wiesel<sup>3</sup> in the visual cortex. They discovered that cells in a column, extending from the surface of the cortex to the white matter directly underneath, have similar properties. Working with cat visual cortex, Hubel and Wiesel showed that two properties are organized in a columnar fashion — ocular dominance (response to the right or left eyes, or both) and orientation selectivity (selection for the orientation

of a bar; horizontal, vertical or some angle in-between). Because almost every cell has these two properties, there are two overlapping columnar maps. When the macaque visual cortex was investigated, a third property was included — colour. This inserted into the ocular-dominance and orientation-selectivity maps, with a pattern of blobs recognizable in cytochrome-oxidase stains centred on the ocular dominance columns.

Hubel and Wiesel<sup>4</sup> went on to show that recordings made from long, oblique penetrations of an electrode into the visual cortex yield a steady change in the orientation selectivity of the cells. Sometimes the progression is clockwise, sometimes anticlockwise, and occasionally it is interrupted by a sudden shift in orientation. They suggested that orientation is organized in a series of parallel slabs (the ice-cube model). Later, Braitenberg and Braitenberg<sup>5</sup> argued that the evidence was better explained by a set of orientation domains radiating out from centres (the pinwheel model). The development of a technique for imaging a large area of the cortex and working out the orientation sensitiv-

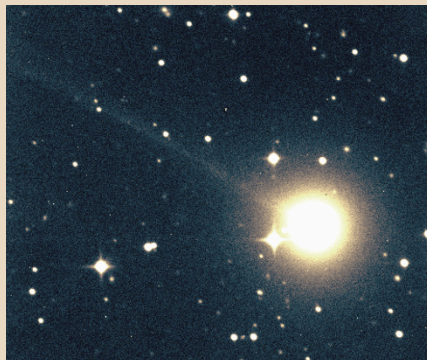
### Meteors

## Things that go bump in the night sky

Every 33 years, or thereabouts, the Leonid meteor shower is spectacular — so many meteors fall that it is called a storm. The last time was in 1966, when up to 40 meteors a second were seen; and back in 1833, watchers even heard sounds. That could be telling us about processes occurring on comet 55P/Tempel–Tuttle (shown here), the creator of the Leonids.

As comets are heated by sunlight, their ices sublime. The breeze of this sublimation lifts debris off the comet nucleus, and some of these pieces eventually get swept up by the Earth. We see them as meteors — usually just a streak of light, created by a body a few millimetres in diameter. Larger bodies produce brighter fireballs.

Sounds are much rarer, but in 1833



many observers heard hissing, crackling and popping noises. These were probably 'electrophonic sounds', created by very-low-frequency radio waves, in turn generated by turbulent plasma in the wake of a disintegrating meteoroid. According to

Martin Beech (*Astron. J.* **116**, 499–502; 1998), the falling bodies must have been well over a metre across to produce such sounds.

That is much too big to have been lifted off the nucleus of Tempel–Tuttle by sublimation pressure. So how did these great lumps of dirt escape the comet? Perhaps there are cavities in the nucleus that are only occasionally lit by the Sun, producing violent outbursts that can shoot out large bodies.

We may be in for another big show from the Leonids this year, around 17 November. Then, it may even be possible for astronomers to see these large meteoroids directly, or to see them hitting the Moon. And if you're watching, listen out.

Stephen Battersby

TIM PUCKETT

ity for a series of different orientations in the same animal allowed Bonhoeffer and Grinvald<sup>6</sup> (using intrinsic signals of activity from upper layers of cortex<sup>7</sup>) to show that the pinwheel model is correct.

There are many models of how the cortex develops to achieve this pattern<sup>8</sup>. Cats and macaques show a pattern of orientation selectivity as soon as the eyes open shortly after (or at) birth. But ferrets, which are born at an earlier stage of development, show little orientation selectivity when their eyes open. Instead, orientation selectivity develops to adult levels during the fifth and sixth weeks after birth, under the influence of nerve-cell activity<sup>9</sup>.

Wolf and Geisel<sup>1</sup> now suggest that all models for the development of orientation selectivity are subject to symmetry principles. The authors first assume that columns with a similar orientation preference tend to be a particular distance apart. Their second assumption is that patterns resulting from (i) shifting the pattern parallel to the cortical surface; (ii) rotating the pattern parallel to the cortical surface; and (iii) shifting all orientation preferences by the same angle, will arise with the same probability. Their final assumption is that the pattern arises from many random factors, and that Gaussian statistics apply. Their mathematics then shows that the expected density of pinwheels is given by

$$\rho = \frac{\pi(1+\alpha)}{\Lambda^2}$$

where  $\Lambda$  is the average spacing of columns, and  $\alpha$  is a number that describes the structure of spatial correlations. One therefore expects to find at least  $\pi$  pinwheels in an area of size  $\Lambda^2$ .

In fact, the density of pinwheels varies from 3.75 in an area of size  $\Lambda^2$  in macaque, to 2.1–2.6 in tree shrew, with intermediate values for squirrel monkey, ferret and cat. Thus, either there is some process that prevents development from being carried to completion in the cat and tree shrew, where the value is substantially below  $\pi$ , or the density of pinwheels develops to a value greater than  $\pi$ , then decreases through annihilation of pinwheels. Wolf and Geisel propose that such an annihilation could occur through melding of a pair of pinwheels — one with clockwise chirality and another with anticlockwise chirality.

The annihilation of pinwheels is an intriguing possibility. But it is not supported by the few observations available, which show a series of orientation maps that does not change much with age<sup>8</sup>. Areas with longer stretches of parallel slabs — which are predicted to arise when two pinwheels merge — do not seem to appear much more frequently in the older patterns. So, Wolf and Geisel's predictions still need to be rigorously tested. Moreover, the mathematics

assumes that there are no intrinsic places in the cortex that would attract the formation of pinwheels. This has been suggested as a factor in positioning of the blobs for colour in the macaque visual cortex<sup>10</sup>.

Wolf and Geisel have used mathematical approaches that are common in physics but rare in biology. In turbulent flow, for example, aspects of a system's behaviour can be predicted from basic symmetries without knowing the detailed nature of the interactions between components of the system. Because the nervous system is made up of billions of cells and trillions of synapses, with detailed interactions that are unknowable in practice, mathematical approaches may have a future in predicting the overall behaviour of the system. □

### RNA processing

## A tale of two tails

David Bentley

The fate of RNAs in the nucleus is determined by the polymerase that made them. For example, the same primary transcript that will give rise to a messenger RNA if made by RNA polymerase II (pol II), will never mature if it is made by pol I, pol III or a bacteriophage RNA polymerase<sup>1,2</sup>. How can we explain this link between the machines that make and process mRNAs? On page 93 of this issue, Hirose and Manley<sup>3</sup> bring us one step closer to an answer. They report that the carboxy-terminal domain (CTD) — a protein domain unique to pol II — acts as part of the protein complex that fashions the 3' end of the mature mRNA by cleavage and polyadenylation.

The formation of 3' ends is a two-step process in which the RNA transcript is cleaved downstream of the sequence AAUAAA, then a poly(A) tail is added at the cut end. RNAs made *in vivo* by pol II lacking the CTD — a conserved repeat of the

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sequence YSPTSPS, found at the carboxy terminus of the pol II large subunit — are not efficiently capped, spliced or cleaved at the poly(A) site<sup>4,5</sup>. This suggests that the CTD helps to target mRNA processing factors to pol II transcripts<sup>6,7</sup>. Hirose and Manley have now discovered that the CTD facilitates the 3' RNA cleavage reaction, even in the absence of transcription. They suggest that, in effect, the CTD is a cofactor for 3' processing.

Production of a mature mRNA 3' end can be reconstituted *in vitro* with cleavage/polyadenylation specificity factor (CPSF), cleavage-stimulation factor (CstF), cleavage factors CFI and CFII, and poly(A) polymerase (PAP)<sup>8</sup>. The association of CPSF and CstF with the CTD *in vitro*<sup>4</sup>, and the colocalization of CstF and phosphorylated pol II *in vivo* (Fig. 1), indicate that a stable 'mRNA factory' complex of pol II with processing factors carries out synthesis and

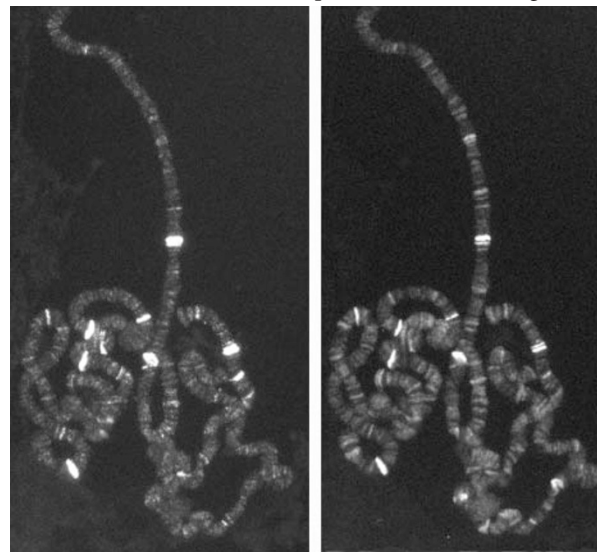


Figure 1 Colocalization of the cleavage-stimulation factor CstF and phosphorylated RNA polymerase II (pol II). Immunofluorescence of *Drosophila* polytene chromosomes with anti-pol II monoclonal antibody (left) and rabbit antibody against Suppressor of forked, the *Drosophila* homologue of CstF (right). (Courtesy of M. Sikes and A. Beyer, University of Virginia.)