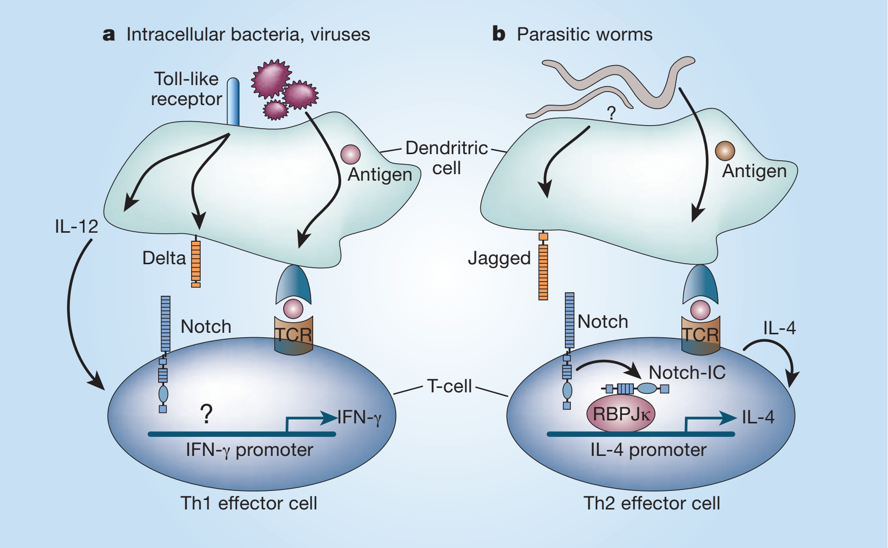

Figure 1 **Stimulating the Th1 or Th2 response. In both pathways, dendritic cells internalize the pathogen. They present its antigens to T cells, which recognize antigens through their T-cell receptors (TCR).** a, **Organisms such as intracellular bacteria or viruses are recognized by the Toll-like receptors on dendritic cells; the resulting signals induce the secretion of interleukin-12 (IL-12) and differentiation of CD4 T cells into the Th1 lineage that produces gamma interferon (IFN-γ).** b, **How dendritic cells recognize larger pathogens, such as parasitic worms, is not known. But the end result is differentiation of Th2 effector cells regulated by T-cell-produced interleukin-4 (IL-4). Information[1,2] on the link between dendritic cells and T cells suggests that the former express different Notch ligands — Delta or Jagged — under different conditions. Jagged is specifically induced by stimuli known to induce Th2 differentiation. Notch signals (Notch-IC) can induce transcription of IL-4 through direct binding of RBPJκ to the IL-4 promoter[1].**

*Medical Institute, University of Washington,*
*Seattle, Washington 98195, USA.*
*e-mails: smlehar@u.washington.edu*
*mbevan@u.washington.edu*

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Earth science

# Kinks and circuits

Norman H. Sleep

Flow in the Earth's mantle buffets ascending mantle plumes, causing surface 'hotspots' to move relative to each other. A chain of deduction offers solutions to an age-old puzzle about hotspot behaviour.

More than thirty years have passed since the advent of the theory of plate tectonics. Rigid plates and the narrow, deformable boundaries dividing them explain much of the action on the Earth's surface. Plumes of hot material rising from great depth in the mantle are thought to feed 'hotspots', producing surface tracks of volcanism in the middle of plates (such as the Hawaiian islands), and regions of very active mid-ocean-ridge volcanism (such as Iceland). Complicating this picture are zones of deformation, such as the Basin and Range province in the United States, that exist within supposedly rigid plates. In their paper on page 167 of this issue, Steinberger *et al.*[1] integrate these processes and make them relevant to both field geologists and geodynamicists.

Their work centres on the Hawaii–Emperor bend, a kink in the chain of islands and seamounts that was produced between about 43 million and 50 million years ago, and is evident from even casual observation of a map of the Pacific basin (Fig. 1, overleaf). This feature has long been the 'poster child' example of a change in plate motions; in this case, movement of the Pacific plate is thought to have changed relative to the underlying stationary hotspot. Viewed more

## 100 YEARS AGO

**OXFORD. – The following is the text of [a speech] delivered by Prof. Love in presenting recipients of the degree of D.Sc. *honoris causa* at the Encaenia, June 22, in the presence of the Chancellor of the University:- THE HON. CHARLES ALGERNON PARSONS. Duobus fere millibus abhinc annis Heron Alexandrinus turbinem quemdam per ludum excogitavit, qui vapore calido actus per tubos inflexos afflante converteretur. Carolus Algernon Parsons inter Hibernos nobilissimus, scientiae etiam laude insignis, ita Heronis vestigiis institit ut, quod ille ludendi causa finxerat, ipse in usum nostrum converteret, quo facilius homines naturae imperarent. Optime sane meritus est de omnibus qui urbes habitant, quibus vias et domos luce electrica hoc invento usus illustravit, neque minus profuit Nerea temptantibus, cum his turbinibus impulsae per altum naves celeritate inaudita ferantur recta semper carina adeo ut navigantium incommoda magna ex parte adleventur.**

From *Nature* 7 July 1904.

## 50 YEARS AGO

**The main point I wish to make, therefore, is that success in analysing biological molecules by X-rays may explain to us why they have the structure they have. To make a comparison once more with the mineral world, we see that silicon and oxygen together build very stable structures which are light and have a high melting point, and that is why most of the earth's crust is made of silicon and oxygen. Their tetrahedral frameworks conveniently accommodate certain other elements, and correspondingly it is found that these rank next to silicon and oxygen in order of frequency of occurrence in the rocks. On the other hand, carbon, nitrogen and oxygen, together with hydrogen, build structures which are relatively unstable, but which are capable of an infinite complexity. This is so because the atoms are fastened together by bonds which have definite positions. Hence Nature has used these elements to make the complex structures of living matter. Now, as in the case of the silicates, we shall perhaps be able to see further into the reason for the arrangements of these elements which Nature actually uses. If in due course we make a voyage to Mars by a rocket-ship, we can confidently predict that mineralogy will be very much the same on Mars as it is on this globe of ours.** **Sir Lawrence Bragg**

From *Nature* 10 July 1954.

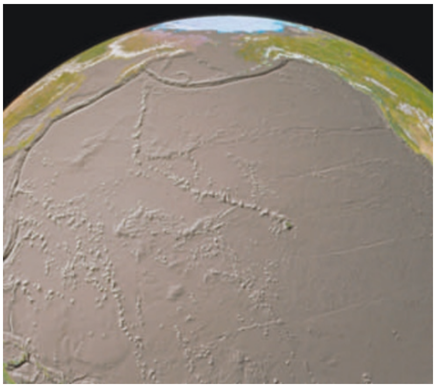

Figure 1 **Spot the bend. Start at Hawaii and follow the features trending west-northwest until they take a sharp turn north.**

T. VAN SANT/GEOSPHERE PROJECT, SANTA MONICA/SPL

carefully, however, hotspots move with respect to each other and to the Earth's spin axis. Geodynamicists want to resolve these effects independently of changes in relative plate motions.

Mantle plumes are merely upwelling conduits of hot, low-viscosity material in the mantle flow, and clearly must move with respect to each other: the conduit ascends buoyantly while being dragged rather like smoke from a chimney on a windy day. Steinberger *et al.*[1] model the fluid dynamics of this 'mantle wind' by including the observed plate motions. Much of the conduit height is within the very viscous lower mantle, which flows slowly, giving the illusion (and convenient approximation) that hotspots are fixed. They are not, but most of the time move at less than a centimetre per year. Although the Hawaiian hotspot moved faster at some times, it did not do so in a way that would create a sharp bend in the Hawaii–Emperor track.

Steinberger *et al.* then direct their attention to inadequacies in understanding the relative motions between plates. In case you think this has been sorted out to decimal places in the past 30 years, it hasn't. We can calculate relative plate velocities in the past only where plates were in contact at ridge boundaries (where plates are separated by a ridge, creating new crust) or transform boundaries (where they are sliding past one another). At subduction zones, where one plate slides beneath another, the information about past behaviour, encapsulated in palaeomagnetic data in the sea floor, becomes lost. Mathematically, the relative velocity $\mathbf{v}$ between plates A and B is $\mathbf{v}(A,B) = \mathbf{w}(A,B) \times \mathbf{r}$, where $\mathbf{w}$ is the rotation 'pole' vector and $\mathbf{r}$ is the radial vector to the surface point where velocity is measured.

To study the fixity of hotspots, one needs to estimate the velocity of plates, such as the African and Pacific, that are not in contact by ridge boundaries. Formally, this requires summation of rotation vectors around a 'plate circuit', $\mathbf{w}(A,B) + \mathbf{w}(B,C) = \mathbf{w}(A,C)$. This procedure becomes problematic if, at some point in the circuit, two plates have only a short boundary. Then one cannot accurately determine the component of the rotation vector in the direction of $\mathbf{r}$, as it produces no velocity. This component, however, produces velocity elsewhere when added to the circuit. In connecting up plate relationships around the circuit, Steinberger *et al.*[1] carry through errors in their analysis and keep this problem in check.

Next, the authors had to take into consideration the fact that some plates are not really rigid, especially within continents, which precludes a simple circuit. For times before 43 million years ago (older than the Hawaii–Emperor bend), they get considerably different results by treating the Antarctic plate as rigid, or alternatively taking the circuit through the extinct mid-ocean ridge in the Tasman Sea between Australia and the Lord Howe Rise — a continental fragment that was then attached to New Zealand on the Pacific plate. They prefer the latter solution (see Fig. 3 on page 170) as it gives the bend in the Hawaii–Emperor chain at the right time.

This work makes sufficiently precise predictions to interest the field geologist. For example, the models imply that deformation within the New Zealand plate occurred between 65 million and 83 million years ago, and that there was considerable deformation within Antarctica between 43 million and 83 million years ago. These are surmises that can be checked by field work.

To test their calculations relating to the Hawaiian hotspot, Steinberger *et al.* included analyses of three other hotspot tracks in different parts of the world that have produced island or seamount chains — Réunion (in the Indian Ocean), Louisville (in the Pacific) and Tristan (in the Atlantic). As with Hawaii, an important constraint comes from the estimation of palaeolatitudes — shifting latitudinal position in the past — especially of volcanic edifices that are still submerged. The reason that Steinberger *et al.* worked with only four tracks is that, perhaps surprisingly, numerous submarine edifices have not yet been sampled and dated, let alone drilled for palaeomagnetic studies. But the four that they have worked with provide consistent results, supporting the conclusion that there was a significant change in relative plate motions at the time that the Hawaii–Emperor bend was created.

What does such a change imply for the past and present geodynamic behaviour around the circuit? Plates move far too slowly for inertia to be relevant. Buoyancy forces associated with plate age in the crust and uppermost mantle, and with slab material in the deep mantle, evolve too slowly to realign plate motions quickly. But factors associated with the shallow parts of subduction could have a considerable effect.

In search of a mechanism for an abrupt plate reorganization, Steinberger *et al.* point out that the Antarctic plate may have become strong enough to be rigid around the time the Hawaii–Emperor bend occurred, and that this may have triggered a change in the circuit, with slab subduction being initiated along a transform fault boundary in the Philippine Sea; today this is the Marianas subduction zone. Once started, subduction provides a driving force. The viscosity of the mantle increases with depth, so much of the driving force comes from the upper few hundred kilometres of the slab. That is, once it was under way, subduction beneath the Marianas quickly increased the change in plate motions.

I expect that debate will continue on the relative fixity of hotspots, the rigidity of tectonic plates and mantle dynamics. Meanwhile, more geological data will come in hand, and seismological studies will continue the task, just begun, of resolving the current behaviour of plume conduits[2]. Such work will batten down our understanding of the present-day effects of the mantle wind. ■

*Norman H. Sleep is in the Department of Geophysics, Stanford University, Stanford, California 94305, USA.*
*e-mail: norm@geo.stanford.edu*

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Ion channels

# Gate expectations

Maria L. Garcia

The opening and closing — gating — of ion channels in response to specific stimuli is crucial for cell function. The membrane-partitioning activities of two venom toxins give insights into the mechanisms involved.

The membrane surrounding a biological cell forms a highly selective barrier that allows the cell to control its internal environment. It consists of an assembly of lipids and proteins. Some membrane proteins form channels through which ions can flow. These ion channels are said to be 'gated' if they can be opened and closed, and the trigger for this can be electrical, chemical or mechanical stimuli. Ion channels are widely distributed throughout the human body, and in many cells different