Astronomy

The Hoyle story

John Maddox

The achievements of Fred Hoyle, one of the twentieth century's great innovators in astronomy, were celebrated at a recent meeting. In many respects, it emerged, Hoyle's thinking was ahead of his time.

In 1952, Fred Hoyle delivered the first of the BBC's annual Reith Lectures under the title "Frontiers in Astronomy". The five talks, delivered in consecutive weeks, electrified his audience and won Hoyle an instant reputation as a popularizer of science. Half a century later, and some eight months after his death last year at the age of 86, a symposium under the same title* was convened to celebrate Hoyle's many achievements.

The meeting was held in Cambridge, UK, at the Institute of Astronomy, which Hoyle founded as the Institute of Theoretical Astronomy in 1966, and at St John's College, which elected him as a fellow while he was still a graduate student. The divided venue was a symbol of the spirit of the occasion: Cambridge's ambivalence towards Hoyle was matched only by Hoyle's ambivalence towards his old university. Another was that at the symposium even Hoyle's critics bit their tongues, acknowledging that he was "before his time". And C. Wickramasinghe (Cardiff Univ.), best known as Hoyle's collaborator on some of his later and more controversial ideas, roundly declared that "It is a myth that everything he did in his early years was brilliant and that everything he did after a certain date was rubbish". Nor was Wickramasinghe challenged on his dubious assertion that it is "now generally accepted" that the organic constituents of the first terrestrial living things were made in interstellar molecular clouds and were transported here by meteorites or comets.

The most telling account of Hoyle's precocity came from P. Solomon (State Univ. New York, Stony Brook), who had unearthed a paper published in 1943, in the *Proceedings of the Cambridge Philosophical Society*, when Hoyle was still a graduate student. The notion that molecular clouds cool by emitting radiation because of the rotational states of molecules was one of the ideas that first appeared there — and was then forgotten for almost 30 years. Solomon pointed out that, in the same paper, Hoyle used the idea to predict that the fragmentation of a cloud of gas (an early galaxy, say) into stellar nebulae would be constrained by the increasing opacity of collapsing regions, putting an upper limit on the mass of individual stars and restricting the numbers of Sun-like stars in galaxies (eventually pinned down in a paper dated 1949 to between 10^9 and 3×10^{11}).

The symposium was opened by W. Sargent (Caltech), himself a distinguished observer and Hoyle's principal adjutant on the Northern Hemisphere Telescope Review Committee. This was the body, set up in the mid-1960s, that eventually established the pattern of observing time for British astronomers in the past quarter of a century. Like the master of ceremonies at an awards dinner (except that there was no food and drink at 10:00 in the morning), Sargent rattled through Hoyle's lifetime of accomplishments.

Among them is the recognition of accretion (onto red giants in the first instance) as a general process affecting the smallest objects in the Universe (such as planets) and the largest — galaxies, our own included. Sargent stressed the importance of Hoyle's 1953 prediction that there is a long-lived excited state of the ^{12}C nucleus, the effect of which is to delay the conversion of ^{12}C into ^{16}O (by combination with ^{4}He nuclei), thus providing enough carbon in the cosmic mix to support carbon-based life. The prediction was confirmed by measurements by W. H. Fowler at Caltech and is now widely cited as an illustration of the Anthropic Principle, the notion that the existence of living things implies that the Universe must have satisfied the pre-conditions for the existence of life as it is found, a biogenic supply of carbon included.

But, Sargent continued, Hoyle went on to explain the difference between supernovae of type I (with degenerate Fermi–Dirac cores) and type II (which implode), although in both cases Hoyle erred by underestimating the importance of neutrino emission in energy export.

Then there is the paper (known as B^{2}FH), written with Geoffrey and Margaret Burbidge and W. H. Fowler on the synthesis in stars of the elements heavier than boron, which remains the universal framework for discussions of nucleosynthesis. Sargent went on to remind his audience that Hoyle had been the one to work out that stars 200 times as massive as the Sun could well have been formed in the early Universe and that he (with Wickramasinghe) first put the topic of interstellar dust on the astronomical agenda.

Sadly, of course, Hoyle was not present to receive the medal Sargent's talk seemed to presage. But others were. Margaret Burbidge (Univ. California, San Diego) gave a wistful account of how chance meetings at the Royal Astronomical Society in London, in Paris and at Cambridge grew into the collaboration that produced B^{2}FH. And H. Bondi (Churchill College, Cambridge) spoke of the genesis of 'steady-state' theory, which, in

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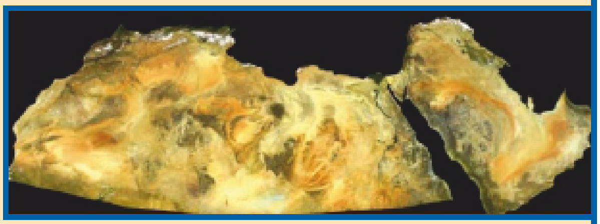
Earth science

African reflections



The outline of the geographical area shown here may be familiar, but the colouring won't be. This is north Africa and the Arabian peninsula, with the colours depicting the albedo of those parts of the region (almost all of it) that are arid and largely naked of vegetation. Albedo is a measure of the amount of solar radiation that is reflected back from a surface, into the atmosphere and space, and is therefore an essential parameter in climate modelling. Here, yellow corresponds to the highest albedos: the darker the shading, the lower the albedo (and the lower the amount of radiation reflected).

The albedo map comes from a paper by E. A. Tsvetsinskaya *et al.* (*Geophys. Res. Lett.* **29**, 10.1029/2001GL014096; 2002), in which the authors relate albedo measurements of unprecedented spectral detail taken by the Moderate-resolution Imaging Spectro-radiometer (MODIS), on the Terra spacecraft, to digitized maps of regional soil and rock types, at a 1-km spatial resolution. On the albedo image, the brightest parts correspond to areas of sand dunes; the darkest parts correspond to soil types known as vertisols, cambisols, rendzinas and luvisols, which occur mostly in and around the Atlas Mountains, and to volcanic and intrusive rocks.

The reason that the authors chose north Africa and the Arabian peninsula for study is in part because this huge desert belt is one of the most reflective areas on Earth. The energy gradient between this and adjacent areas, which absorb radiation strongly, can produce distinctive regional circulations in the atmosphere. The detailed analysis of albedo by spatial variation in the surface type should mean that this kind of data can more easily be accommodated in climate modelling. **Tim Lincoln** contrast to the Big Bang, holds that expansion of the Universe can be accounted for by the continual creation of new matter. It was Bondi, along with Thomas Gold, who produced the first version of a steady-state cosmology; Hoyle joined them later and during the 1950s crossed swords publicly and acrimoniously with the late Martin Ryle. This great dispute, reflected Bondi, need not have happened if everybody had been more circumspect and respectful of the provisional nature of newly gathered data. "Perhaps we were too ambitious", he acknowledged (in another context).

It fell to J. V. Narlikar (Inter-Univ. Centre for Astronomy and Astrophysics, Pune, India), another of Hoyle's former graduate students, to make the point that being ahead of your time is a dangerous business. The risk is that of being run over by the band-wagon that follows you. ■

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Developmental neurobiology

Cortical liars

Seong-Seng Tan

Inhibitory cells known as interneurons constitute a significant proportion of the neurons in the neocortex of mammalian brains. As far as interneuron origins are concerned, humans may be the odd man out.

For more than a decade, the interneurons found in the neocortex of the human brain have been disturbing the peace of developmental neurobiologists. Interneurons represent roughly 20% of cortical neurons and are responsible for modulating the firing of the principal neurons known as projection neurons. They do this by producing the inhibitory neurotransmitter, GABA. But where exactly interneurons originate in the embryonic brain remains controversial. On page 645 of this issue[1], Rakic and colleagues provide evidence that one source of these cells for the neocortex that is not so evident in other mammals provides the majority of interneurons in humans. This is a striking conclusion, for it might help to explain the greater complexity of the human brain and what can go wrong in mental illness.

The controversy over the origins of cortical neurons hinges in part on the difference between radial and tangential movement of the cells from their sites of origin to their final home in the layers that make up the neocortex. Until about ten years ago, accepted wisdom was that cortical neurons migrate only radially: this is a comfortable notion, for it implies that the neocortex is built according to a carefully crafted blueprint with only local, outwards migration to create the cortical columns.

However, that notion was upset by the demonstration, in rodents, that a significant percentage of neurons migrate tangentially some distance from their point of origin[2]. At that time, the identities of the tangentially migrating neurons were not known. But the fuss over migration patterns relates to the debate as to whether the embryonic neocortex is already carved into regionalized sectors[3] or whether the emergence of functionally distinct areas in the adult is controlled by other mechanisms. Widespread and indeterminate tangential dispersion of cells would, on the face of it, scramble any embryonic blueprint.

A bigger surprise emerged when second-generation cell-lineage studies revealed that tangential migration is associated with the development of interneurons, whereas projection neurons seemed to be the product of radial migration[4,5]. At that time it was assumed that both kinds of neuron are born in the cortical ventricular zone (VZ), the main site of cell birth in the neocortex from which new cells cross an adjacent layer, the subventricular zone (SVZ), into the emerging cortical layers. An outline of embryonic brain geography is shown in Fig. 1.

But why would interneurons — which constitute a minority of cortical neurons, yet have the same developmental environment as projection neurons — migrate in a different direction? There were thought to be at least two possibilities. Either the migration pathway itself was somehow involved in turning cells into interneurons, or the progenitors residing in the VZ were already specified to make either interneurons (which for some reason migrated only tangentially) or projection neurons (which migrated only radially).

Unexpectedly, neither explanation was in itself correct. Instead, studies on mutants lacking the gene-transcription factors Dlx1 and Dlx2 showed that in these animals cortical interneurons were severely reduced in number. What is more, most interneurons expressing Dlx1/2 were found to originate from a subcortical area[6], the ganglionic eminence (shown in Fig. 1). This gives rise to subcortical structures such as the striatum, but the studies with mutant animals indicated that it also furnishes at least 75% of cortical interneurons[7]. Work with other species, including ferrets, produced similar observations, suggesting that this is an ancient mechanism of cortical development.

But what about interneurons in the embryonic human neocortex? The first hint that they might behave differently came from work on a different structure known as the thalamus, an important relay station for the neocortex. Letinic and Rakic[8] discovered a migratory pathway that ferries interneurons generated in an external source, the ganglionic eminence, to the thalamus, and this pathway turned out to be absent from

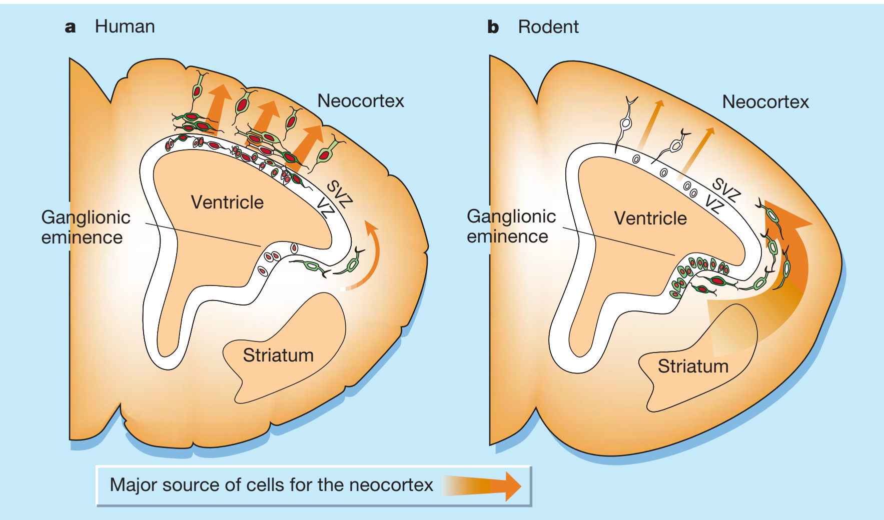

Figure 1 **Interneuron origins in the embryonic brain. The graphic shows half of a cross-section through human** (a) **and rodent** (b) **forebrains. Rakic and colleagues[1] provide evidence that, during development, about 65% of interneurons in the human neocortex originate locally in the ventricular zone/subventricular zone (VZ/SVZ) of the neocortex. In rodents, by contrast, the main source of interneurons seems to be long-distance tangential migration of cells from the VZ of a subcortical area known as the ganglionic eminence. The other 35% of human interneurons seem to be produced by this route. In humans, interneurons originating from the cortical VZ/SVZ express both the transcription factors Mash1 and Dlx1/2 (cells with red nuclei); interneurons from the ganglionic eminence express only Mash1 (white nuclei).**