Inside the oldest bird brain

Lawrence M. Witmer

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It has also been the central player in the debate on the origin of birds and avian flight. Although discoveries of feathered dinosaurs and archaic birds from China have advanced our understanding of the dinosaurian transition to birds, and the evolution of flight. The reconstruction is about 20 mm in length; the red areas are crystals of manganese dioxide deposited during fossilization.

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Researchers at the Natural History Museum in London isolated the part of the skull that in life encased the brain (Fig. 2). The braincase is so tiny — smaller than the last segment of your little finger — that Angela Milner, the team leader, safely carried it in a box in her shirt pocket from London to the University of Texas at Austin, where it could be analysed with high-resolution X-ray computed tomography. Using X-rays, the team ‘sliced’ the braincase so finely (each slice less than half the thickness of a printed page of Nature) that they were able to peer inside the thin bone at the brain cavity and inner ear (the organ of balance and hearing), which was then digitally reconstructed.

Obtaining an understanding of the brain and sense organs is a top priority for palaeontologists, because such knowledge can offer insight into the behaviour of extinct organisms not otherwise provided by the skeleton. In the case of Archaeopteryx, from the beginning the question has been — could the oldest-known bird fly? In the past, answers have been sought from aerodynamics, justifiably focusing on the structure of the wings and feathers. But flight isn’t just about wings, rudders and flaps. It’s also about the pilot and on-board computer, and those are the missing elements that this new study provides for Archaeopteryx.

The brain of Archaeopteryx was much like that of birds today, albeit of a primitive sort. It was larger than the brain of an average reptile of equivalent body size but smaller than any similarly sized modern bird brain. Its organization was also basically avian, with enhancement of those areas concerned with movement. Moreover, the visual centres are enlarged, suggesting that Archaeopteryx was a visually oriented animal. The new findings relating to the delicate inner-ear canals are particularly important, because recent studies have associated canal architecture with behaviour and mode of life. The canals of Archaeopteryx are again much more like those of birds than modern-day reptiles, suggesting that agility and coordination of head and eye movements were critical.

But is this the brain and ear of a flier? Some insight here can be provided by the entirely separate evolution of flight in pterosaurs, the extinct flying-reptile group...
Semiconductor physics

The value of seeing nothing

Jochen Mannhart and Darrell G. Schrom

Adding atoms to a semiconductor can improve its electronic properties. In an oxide, taking atoms away can have a similar electronic effect — one that could, it seems, be exploited in device applications.

By 2007, the information age will have hit a fundamental roadblock. Without major changes in technology, the spectacular improvements in computer performance that we have enjoyed for decades will cease, because transistors based on silicon and silicon dioxide will no longer be able to keep up with Gordon Moore’s famous law — that the number of transistors per unit area in an integrated circuit doubles every couple of years. But these limitations might be overcome if Si and SiO2 were complemented in these devices by other materials. The candidates of choice are oxides, which are already assuming a vital role in semiconductor electronics. Now Muller et al. (page 657 of this issue) show that it is possible to control the electronic properties of these materials with the nanoscale precision necessary for the information industry.

Oxides offer a broad spectrum of properties — some are excellent insulators, others are superconductors. Some oxides have flippable electric or magnetic dipoles, suggesting myriad device possibilities. Indeed, oxides such as bafnium dioxide are forecast to replace SiO2 in the transistors of laptop computers within only three years. Another oxide known as ‘Lustigem’ — alias strontium titinate (SrTiO3) — was a popular diamond substitute in the 1960s. If some of its oxygen atoms are removed, the glistering gem turns a deep blue (Fig. 1), and changes from insulating to conducting. This change in colour and conductivity is due to electrons that are left behind, because there is a difference in charge between an oxygen ion (O2−) and an oxygen atom, for each oxygen atom removed two electrons are added to the SrTiO3 matrix. Oxygen vacancies thus function as electron-donating dopants — an effect commonly achieved in semiconductors by replacing some atoms with others that contain more or fewer electrons than the atoms for which they substitute. But can doping through vacancies be implemented and monitored in a controlled way on the atomic scale?

It seems so. Muller and colleagues have made an unexpected double breakthrough. With unrivalled precision, they have measured the quantity and location of oxygen vacancies in films consisting of layers of fully oxidized SrTiO3 and of SrTiO3-δ, in which some oxygen atoms are missing. Their first major advance is to have grown alternating layers of doped (δ≠0) and undoped (δ=0) SrTiO3, where a layer may be as thin as three unit cells. Analogous ‘superlattices’ are used in conventional semiconductor technology to enhance the lifetime of charge carriers; in oxide superconductors, they are used to increase the supercurrent density. Muller et al. grew their superlattices using pulsed laser ablation — a popular research technique for depositing thin films of oxide materials. Deposition occurs when a laser beam hits a SrTiO3 target inside a vacuum chamber, vaporizing its surface into a plasma. Some of the vaporized atoms condense on a nearby substrate, again of SrTiO3, heated to 750 °C. Adjusting the oxygen pressure in the chamber controls the δ of the single crystalline SrTiO3-δ layers deposited.

To image the oxygen vacancies, the authors used a scanning transmission electron microscope (STEM). As the tightly focused electron beam of the STEM is scanned across a cross-sectional slice of the deposited superlattice, a map is made of the positions where electrons are scattered slightly by oxygen vacancies and related...