Bone in the cartilaginous fishes

from Brian Hall

THE recent documentation by Peignoux-Deville *et al.*[1,2] of bone in the vertebrae of the backbone of the dogfish, *Scyliorhinous canicula,* a member of the cartilaginous fishes (Chondrichthyes), has important implications for biology because sharks and rays are grouped together as cartilaginous fishes on the basis of the presence of a cartilaginous skeleton in the adult and the absence of bone from any stage of the life cycle. In other vertebrates, such as man or the bony fishes, most of the cartilage of the embryo is replaced by bone in the adult.

Cartilage and bone are the two major skeletal tissues. The long debate in evolutionary circles over whether cartilage or bone arose first during vertebrate evolution resulted in classifications of the vertebrates that had cartilaginous fishes either on the main evolutionary line as the ancestors of all other fishes and amphibians, if you believed that bone arose late in vertebrate evolution, or as a side branch, if you believed that bone arose early[3].

Peignoux-Deville *et al.* examined vertebrae of the dogfish using X-ray analysis, labelling with tetracycline (a calcium-seeking fluorescent drug) and transmission electron microscopy. The upper halves (neural arches) of the vertebrae were found to consist of large-celled cartilage overlain by a layer of lamellar bone containing bone-forming cells (osteocytes). The bone was calcified, as confirmed by the uptake of tetracycline and by the presence of calcium phosphate (apatite) crystals. Average mineralization (1g mineral per cm^3 of bone) was the same in the cartilaginous and bony portions of the vertebrae. The association of the bone with the underlying large-celled cartilage suggests that the cartilage may have induced the bone to form in the same way as occurs in higher vertebrates[4]. Mutants are known in which cartilage fails to become large-celled (for example, *talpid* in the chick, *brachypod* in the mouse), with the consequence that bone fails to form around the cartilage. Cartilaginous fishes appear to use the same developmental mechanism to form bone. The cartilage of higher vertebrates also contains canals which both provide cells for centres of bone formation deep within cartilage and allow nutrients to reach the deeper recesses of cartilage, a tissue which lacks blood vessels. Hoenig and Walsh[5] examined vertebrae from 16 species of sharks and found that all had canals containing blood vessels and immature cartilage cells. They ruled out any bone-forming (osteogenic) function for these canals .... "the osteogenic function cannot apply to Elasmobranch vertebrae", following instead the traditional view that sharks lack bone. A closer examination of these vertebrae is clearly now required.

Previous studies had hinted at the presence of bone in the endoskeletons of sharks and definitely showed it to be present in the hard denticles which are embedded in the skin and at the base of the teeth[6-11]. The X-ray diffraction pattern of shark vertebrae is also identical to that obtained from bone[12], and this and the presence of the canals should encourage a closer examination of shark vertebrae. *Orhithoprion hertwigi,* a fossil shark from the Permian period, had a thick layer of bone around its lower jaw[13]. The presence of bone in both the jaw and the vertebrae is of especial interest as much of the head skeleton is derived from the neural crest[4,14], while vertebrae are mesodermal in origin. Sharks have retained bone-forming potential in cells with both of these embryological origins. Bone formation in cells on the surface of the vertebrae is presumably activated by association with underlying large-celled cartilage while cranial neural crest-derived cells are presumably activated by interaction with epithelia, as happens in other vertebrates[14].

The existence of bone in these sharks explains the previously paradoxical presence of the hormone calcitonin, which acts on bone to regulate calcium metabolism. The presence of bone also highlights the chanelling of thinking which follows the classification of a group of animal on the basis of the presence of one, albeit major, feature and the lack of another. Because the Chondrichthyes are classified as having a cartilaginous skeleton and lacking bone, we automatically think that they are incapable of forming bone. This lead to the spurious classifications of vertebrates mentioned earlier, to the conclusion that no feature (canals, calcitonin) could have anything to do with bone or bone formation, that the cartilaginous fishes have 'lost out' in evolution, not having the potential for growth, mineral metabolism and structural support possessed by their bony cousins, and that any suggestion of the presence of bone must be spurious for cartilaginous fishes lack bone. The simple observation of the presence of a tissue in one region of one species opens up many roads for future travel. □

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Hipparcos: space-age astrometry

from A.M. Cruise

THE measurement and cataloguing of stellar positions is one of the oldest branches of science and the results, gathered over the centuries, have been crucial in the formulation of our present concept of the scale and structure of the Universe. But astrometry is hardwork. To achieve a precision very much better than the arc second resolution of ground-based optical telescopes in a homogeneous manner over the whole sky seems impossible, with present instruments at least. It is no wonder then that astrometry has fallen from the front ranks of astronomical science, and spectroscopy and theoretical astrophysics have gained favour. Nevertheless, astrometry has some simple but profound truths to tell that are fundamental to the development of all branches of astronomy. By choosing the space astrometry mission 'Hipparcos', scheduled for launch in late 1986, the European Space Agency will transform many branches of astronomy and astrophysics.

The astrometric observations made from Hipparcos are hoped to have a precision of one or two milliarc seconds — one hundred to a thousand times better than is currently available for most stars. Such accuracy will allow both radio VLBI measurements and optical results to be specified in a consistent coordinate system.

Increased precision is not the only attribute of the Hipparcos catalogue. The instruments scanning sequence will allow observation of the whole celestial sphere during the two and a half year mission. About 1000,000 stars will be measured, including all stars down to ninth magnitude, and careful selection will ensure that there are always two or three

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