# EVOLUTION AND DEVELOPMENT OF CHONDRICHTHYAN SKELETAL MINERALIZATION

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Among the vertebrates, the group Chondrichthyes (Elasmobranchii [sharks, rays] and Holocephali) is distinguished by a predominantly cartilaginous endoskeleton, overlain by a mineralized layer of calcified tiles known as tesserae. The tesserae of rays are particularly well-developed, polygonal in shape with distinct upper and lower cellular zones and connected via a series of distinct spokes which leave open spaces between the tesserae; the development of these tesserae is also well understood, including some of the genes involved. However, it is becoming clear that the tesserae in the rays are not necessarily characteristic for the chondrichthyans, nor even the elasmobranchs. In the holocephalans (chimaeroids), mineralization in extant taxa comprise more irregularly-shaped units. In *Chimaera* (Chimaeridae), these show a reduced number of spokes and some fusion, while in *Callorhinchus* (Callorhinchidae), the spokes have become completely lost, the units themselves are very small, and substantial fusion occurs. Nevertheless, there are some similarities during development to the elasmobranchs. For example, in *Callorhinchus*, cartilage-producing cells become surrounded by the developing mineralization, but compared to the cellular ray tesserae, these are lost, rather than retained with the tessera. In the holocephalan fossil record (Symmorida, *Helodus*, Iniopterygiformes) skeletal mineralization includes larger, more polygonal tesserae, connected by small spokes, demonstrating that the tesseral morphology in extant forms is the result of reduced mineralization. In fossil rays (e.g., *Sclerorhynchus*), tesserae are polygonal, but appear closely appressed to one another suggesting that spokes are absent. Thus it appears that there may be different evolutionary trends between the main groups of chondrichthyans, with respect to skeletal mineralization.