29.1C: The Evolution of Craniata and Vertebrata

Both genomic and fossil evidence suggests that vertebrates evolved from craniates, which evolved from invertebrate chordates.

Learning Objectives

• Explain how genomics informs scientists about chordate evolution

Key Points

• The clade Craniata includes animals that have a cranium: a bony, cartilaginous, or fibrous structure that surrounds the brain, jaw, and facial bones.
• Members of Craniata include the vertebrates and hagfish.
• Genomic evidence suggests that vertebrates diverged from cephalochordates (lancelets), which had previously diverged from urochordates (tunicates).
• Fossil evidence suggests that most vertebrate diversity originated in the Cambrian explosion 540 million years ago.
• Two whole-genome duplications occurred in early vertebrate history.

Key Terms

• cranium: the part of the skull enclosing the brain, the braincase
• genomics: the study of the complete genome of an organism
• Cambrian explosion: the relatively rapid appearance (over a period of many millions of years), around 530 million
years ago, of most major animal phyla as demonstrated in the fossil record

Craniata and Vertebrata

The clade Craniata is a subdivision of Chordata. Members of Craniata possess a cranium, which is a bony, cartilaginous, or fibrous structure surrounding the brain, jaw, and facial bones. The clade Craniata includes all vertebrates and the hagfishes (Myxini), which have a cranium but lack a backbone. Hagfish are the only known living animals that have a skull, but not a vertebral column.

Figure 1: Hagfish: Although it lacks a backbone, the hagfish is a member of the Craniata clade because it possesses a bony skull.
Vertebrates are members of the subphylum Vertebrata, the clade Craniata, and the phylum Chordata. Vertebrates display the four characteristic features of chordates, but they are named for the vertebral column composed of a series of bony vertebrae joined together as a backbone. In adult vertebrates, the vertebral column replaces the embryonic notochord.

Vertebrate Evolution

In the phylum Chordata, the closest relatives of the vertebrates are the invertebrate chordates. Based on the molecular analysis of vertebrate and invertebrate genomes (genomics), scientists can determine the evolutionary history of different phylogenetic groups.

According to these genomic analyses, vertebrates appear to be more closely related to the lancelets (cephalochordates) than to the tunicates (urochordates). This suggests that the cephalochordates first diverged from urochordates, and that vertebrates subsequently diverged from the cephalochordates. This hypothesis is further supported by the fossil of a 530 million-year-old organism with a brain and eyes like a vertebrate, but without the skull found in a craniate. A comparison of the genomes of a lancelet, tunicate, lamprey, fish, chicken, and human confirmed that two whole-genome duplications occurred in the early history of the Vertebrata subphylum.
Both fossil and genomic evidence suggests that vertebrates arose during the Cambrian explosion. The Cambrian explosion was the relatively brief span of time during the Cambrian period during which many animal groups appeared and rapidly diversified. Most modern animal phyla originated during the Cambrian explosion.