**FIGURE 22.** Generalized chordate characteristics. A single stream of water enters the chordate mouth, flows into the pharynx, and then exits through several pharyngeal slits. In many lower chordates, water exits through the pharyngeal slits and enters the atrium, a common chamber enclosing the pharynx. Water exits the atrium through the single atrio pore. Also note the four hallmarks of the chordates: notochord, dorsal tubular nerve cord, postanal tail, and pharynx with paired slits, pouches, or clefts. (After Kardong)
FIGURE 24. Function of the notochord. A. The notochord lies above the body cavity and is axially incompressible; that is, it resists shortening in length. B. The notochord is laterally flexible. C. The consequences of muscle contraction in a body with and without a notochord. Without a notochord, lateral muscle contraction telescopes the body. A notochord prevents collapse of the body and muscle contractions on alternating sides efficiently flex the body in swimming strokes.
**FIGURE 25.** Comparison of nerve cord construction and placement among invertebrate and chordate body plans. (a) Basic annelid or arthropod body plan with a ventral, solid nerve cord. (b) Generalized chordate body plan with a dorsal, hollow or tubular nerve cord above the notochord which is in turn above the digestive tract. (After Kardong)
Figure 26. Successive developmental stages of a frog embryo. These semidiagrammatic cross sections follow the process of neural tube formation. (After Holmes, Huettner)
FIGURE 27. Basic pharyngeal architecture in a composite vertebrate embryo. The dorsal aorta is paired in the head but the ventral aorta is unpaired. A series of pharyngeal pouches has evaginated from the lateral walls of the digestive tract. Six aortic arches connect the heart and ventral aorta with the dorsal aorta. (The first aortic arch typically disappears before the 6th is formed.)
FIGURE 28. Frontal sections of pharyngeal regions in an embryonic shark (early, top left; late, top right) and frog (bottom). Roman I - VII mark the pharyngeal arches surrounding the pharyngeal pouches, clefts and/or slits. T marks the evagination of the thyroid.
FIGURE 29. Human embryo approximately 4/12 weeks after fertilization (5-mm stage).
FIGURE 30. Structural Anatomy of the subphylum Urochordata, class Ascidiae, Distaplia occidentalis. Larval form demonstrating basic chordate hallmarks (bottom). Detail of cerebral ganglion and structural relationship to the axial complex (upper left). Cross-sectional anatomy of postanal tail and axial complex (upper right).
FIGURE 31. Metamorphosis of the ascidian larva *Distaplia*. The planktonic non-feeding larva settles and attaches to the substrate. Adhesive papillae hold the larva in place. Contraction of the tail epidermis pulls the axial complex into the body and the larva sheds its outer cuticle following attachment. By 18 hours the branchial basket rotates to reposition the siphons and active feeding has begun as evidenced by the presence of a fecal strand. By 48 hours most of axial complex is resorbed, rotation is complete, and attachment to the substrate is firm. (R A Cloney)
FIGURE 32. Structural anatomy of the subphylum Cephalochordata, *Branchiostoma lanceolatum*. (a) Lateral view. (b) Cross section through oral hood. (c) Mouth area.
FIGURE 33. Comparative anatomy of the cephalochordate *Branchiostoma* (top) and the ammocete larva of a lamprey (Bottom). Although these forms bear a striking general resemblance the ammocete has a well-developed brain rather than a cerebral ganglion. The ammocete also has median eyes, a protonephretic kidney and other features lacking in amphioxus.
FIGURE 34. Summary of Garstang's Hypothesis of Chordate Heterochrony (The Paedomorphoic Hypothesis). Garstang proposed a series of literal evolutionary steps through larval stages, beginning with echinoderms and eventually producing chordates via heterochrony.
FIGURE 35. Hypothesis of Chordate Heterochrony: Echinoderms to protochordates. The proposed common ancestor of the protochordates (left) was bilaterally symmetrical and externally resembled an echinoderm auriculan larva. The ancestor's circumoral ciliated bands and their underlying nerve tracts moved dorsally, meeting and fusing to form the dorsal nerve cord. The adoral ciliated band gave rise to the endostyle and the pharyngeal ciliated tracts. The appearance of pharyngeal slits dramatically improves water-flow and feeding efficiency. The notochord is a locomotor advantage in the larger organism.
FIGURE 36. *Pikaia gracilis*, among the oldest known chordates. 520 million year old fossil recovered from the mid-Cambrian Burgess Shale Beds, British Columbia, Canada.
**FIGURE 37. Calcichordates.** Fossil of an early echinoderm calcichordate from Ordovician deposits (450 million years ago) (left). These animals show strong affinities with both chordates and echinoderms and may belong to an ancestral chordate lineage. Lateral habitus interpretation of a calcicochordate. Note the overlapping calcium carbonate plates covering the body (a distinct echinoderm feature). Also note that fossil interpretation is often at odds even within a single taxon.
FIGURE 38. Dipleuruloid Theory of Chordate Evolution. The tendency to abandon the sedentary lifestyle of filter feeding in favor of a more active predatory life initially favored development of a prechordate with notochord, muscular tail, and dorsal tubular nerve cord. Continuation of this trend gave rise to vertebrates, but urochordates and cephalochordates reversed the trend and returned secondarily to suspension-feeding life styles and forms.