

Paper -1 zoology

A chordate (/ˈkɔːrdeɪt/ *KOR-dayt*) is a [deuterostomic bilateral animal](#) belonging to the [phylum Chordata](#) (/ˈkɔːrˈdeɪtə/ *kor-DAY-tə*). All chordates possess, at some point during their larval or adult stages, five distinctive physical characteristics ([synapomorphies](#)) that distinguish them from other [taxa](#). These five synapomorphies are a [notochord](#), a [hollow dorsal nerve cord](#), an [endostyle](#) or [thyroid](#), [pharyngeal slits](#), and a post-[anal tail](#).^[8]

In addition to the morphological characteristics used to define chordates, analysis of genome sequences has identified two [conserved signature indels](#) (CSIs) in their proteins: [cyclophilin](#)-like protein and [inner mitochondrial membrane protease](#) ATP23, which are exclusively shared by all [vertebrates](#), [tunicates](#) and [cephalochordates](#).^[9] These CSIs provide molecular means to reliably distinguish chordates from all other [animals](#).

Chordates are divided into three [subphyla](#): [Vertebrata](#) ([fish](#), [amphibians](#), [reptiles](#), [birds](#) and [mammals](#)), whose notochords are replaced by a [cartilaginous/bony axial endoskeleton](#) ([spine](#)) and are [cladistically](#) and [phylogenetically](#) a subgroup of the [clade Craniata](#) (i.e. chordates with a [skull](#)); [Tunicata](#) or [Urochordata](#) ([sea squirts](#), [salps](#), and [larvaceans](#)), which only retain the synapomorphies during their [larval](#) stage; and [Cephalochordata](#) ([lancelets](#)), which resemble fish but have no [gills](#). The Vertebrates and Tunicates compose the clade [Olfactores](#), which is sister to Cephalochordata (see diagram under [Phylogeny](#)). Extinct taxa such as the [conodonts](#) are chordates, but their internal placement is less certain. [Hemichordata](#) (which includes the [acorn worms](#)) was previously considered a fourth chordate subphylum, but now is treated as a separate phylum which are now thought to be closer to the [echinoderms](#), and together they form the clade [Ambulacraria](#), the sister phylum of the Chordates. Chordata, Ambulacraria, and possibly [Xenacoelomorpha](#) are believed to form the superphylum [Deuterostomia](#), although this has recently been called into doubt.^[10]

Chordata is the third-largest phylum of the animal [kingdom](#) (behind only the [protostomic](#) phyla [Arthropoda](#) and [Mollusca](#)) and is also one of the most ancient taxons. Chordate [fossils](#) have been found from as early as the [Cambrian explosion](#) over 539 million years ago.^[11] Of the more than 81,000^[12] living species of chordates, about half are [ray-finned fishes](#) ([class Actinopterygii](#)) and the vast majority of the rest are [tetrapods](#), a [terrestrial](#) clade of [lobe-finned fishes](#) ([Sarcopterygii](#)) who evolved air-breathing using [lungs](#).

History of name

[\[edit\]](#)

The name "chordate" comes from the first of these synapomorphies, the notochord, which plays a significant role in chordate [body plan](#) structuring and movements. Chordates are also [bilaterally symmetric](#), have a [coelom](#), possess a [closed circulatory system](#), and exhibit [metameric segmentation](#). Although the name Chordata is attributed to [William Bateson](#) (1885), it was already in prevalent use by 1880. [Ernst Haeckel](#) described a taxon comprising tunicates, cephalochordates, and vertebrates in 1866. Though he used the German vernacular form, it is allowed under the [ICZN code](#) because of its subsequent latinization.^[4]

Anatomy

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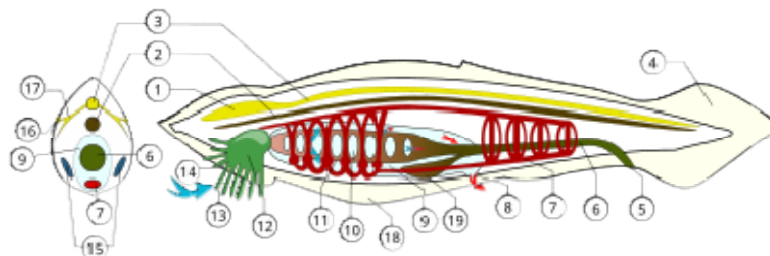
The glass catfish (*Kryptopterus vitreolus*) is one of the few chordates with a visible [backbone](#). The [spinal cord](#) is housed within its backbone.

Chordates form a [phylum](#) of animals that are defined by having at some stage in their lives all of the following anatomical features:^[13]

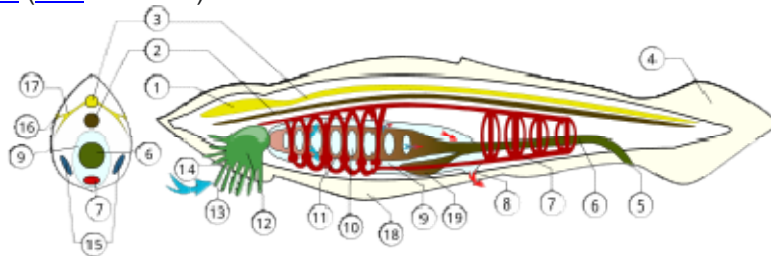
- A [notochord](#), a stiff but elastic rod of [glycoprotein](#) wrapped in two [collagen](#) helices, which extends along the central axis of the body. Among members of the [subphylum Vertebrata](#) (vertebrates), the notochord gets replaced by [hyaline cartilage](#) or [osseous tissue](#) of the [spine](#), and notochord remnants develop into the [intervertebral discs](#), which allow adjacent spinal [vertebrae](#) to bend and twist relative to each other. In wholly aquatic species, this helps the animal swim efficiently by [flexing its tail side-to-side](#).
- A hollow [dorsal nerve cord](#), also known as the [neural tube](#), which develops into the [spinal cord](#), the main communications trunk of the [nervous system](#). In vertebrates, the [rostral](#) end of the neural tube enlarges into several [vesicles](#) during [embryonic development](#), which give rise to the [brain](#).
- [Pharyngeal slits](#). The [pharynx](#) is the part of the [throat](#) immediately behind the [mouth](#). In [fish](#), the slits are modified to form [gills](#), but in some other chordates they are part of a [filter-feeding](#) system that extracts food particles from ingested water. In [tetrapods](#), they are only present during embryonic stages of the development.
- A post-anal tail. A muscular tail that extends backwards behind the [anus](#). In some chordates such as [hominids](#), this is only present in the embryonic stage.
- An [endostyle](#). This is a groove in the [ventral](#) wall of the pharynx. In [filter-feeding](#) species it produces [mucus](#) to gather food particles, which helps in transporting food to the [esophagus](#).^[14] It also stores [iodine](#), and may be a precursor of the vertebrate [thyroid gland](#).^[13]

There are soft constraints that separate chordates from other biological lineages, but are not part of the formal definition:

- All chordates are [deuterostomes](#). This means that, during [embryonic development](#), the anus forms before the mouth does.
- All chordates are based on a [bilateral body plan](#).^[15]
- All chordates are [coelomates](#), and have a fluid-filled [body cavity \(coelom\)](#) with a complete [serosal](#) lining derived from [mesoderm](#) called [mesothelium](#) (see [Brusca and Brusca](#)).^[16]



- 1 = bulge in [spinal cord](#) ("brain")
- 2 = [notochord](#)
- 3 = [dorsal nerve cord](#)
- 4 = [post-anal tail](#)
- 5 = [anus](#)
- 6 = [digestive canal](#)
- 7 = [circulatory system](#)
- 8 = [atriopore](#)
- 9 = space above [pharynx](#)
- 10 = [pharyngeal slit \(gill\)](#)
- 11 = [pharynx](#)
- 12 = [vestibule](#)
- 13 = oral [cirri](#)
- 14 = mouth opening
- 15 = [gonads \(ovary / testicle\)](#)
- 16 = light sensor
- 17 = [nerves](#)
- 18 = [metapleural fold](#)
- 19 = [hepatic caecum \(liver-like sack\)](#)



Anatomy of the [cephalochordate *Branchiostoma lanceolatum*](#). Bolded items are components of all chordates at some point in their lifetimes, and distinguish them from other phyla.

Classification

[\[edit\]](#)

The following schema is from the 2015 edition of [Vertebrate Palaeontology](#).^{[17][18]} The invertebrate chordate classes are from [Fishes of the World](#).^[19] While it is structured so as to reflect evolutionary relationships (similar to a [cladogram](#)), it also retains the traditional ranks used in [Linnaean taxonomy](#).

- **Phylum Chordata**
 - Subphylum [Cephalochordata](#) (Acraniata) – (lancelets; 30 species)
 - Class [Leptocardii](#) (lancelets)
 - Clade [Olfactores](#)
 - Subphylum [Tunicata](#) (Urochordata) – (tunicates; 3,000 species)
 - Class [Asciacea](#) (sea squirts)
 - Class [Thaliacea](#) (salps, doliolids and pyrosomes)
 - Class [Appendicularia](#) (larvaceans)
 - Class [Sorberacea](#)
 - Subphylum [Vertebrata](#) ([Craniata](#)) (vertebrates – animals with backbones; 66,100+ species)
 - Superclass '[Agnatha](#)' [paraphyletic](#) (jawless vertebrates; 100+ species)
 - Class [Cyclostomata](#)

- Infraclass [Myxinoidea](#) or [Myxini](#) (hagfish; 65 species)
- Infraclass [Petromyzontida](#) or [Hyperoartia](#) (lampreys)
- Class †[Conodonta](#)
- Class †[Myllokunmingiida](#)
- Class †[Pteraspidomorphi](#)
- Class †[Thelodonti](#)
- Class †[Anaspida](#)
- Class †[Cephalaspidomorphi](#)
- Infraphylum [Gnathostomata](#) ([jawed](#) vertebrates)
 - Class †[Placodermi](#) (Paleozoic armoured forms; paraphyletic in relation to all other gnathostomes)
 - Class [Chondrichthyes](#) (cartilaginous fish; 900+ species)
 - Class †[Acanthodii](#) (Paleozoic "spiny sharks"; paraphyletic in relation to Chondrichthyes)
 - Class [Osteichthyes](#) (bony fish; 30,000+ species)
 - Subclass [Actinopterygii](#) (ray-finned fish; about 30,000 species)
 - Subclass [Sarcopterygii](#) (lobe-finned fish: 8 species)
 - Superclass [Tetrapoda](#) (four-limbed vertebrates; 35,100+ species) (The classification below follows Benton 2004, and uses a synthesis of rank-based Linnaean taxonomy and also reflects evolutionary relationships. Benton included the Superclass Tetrapoda in the Subclass Sarcopterygii in order to reflect the direct descent of tetrapods from lobe-finned fish, despite the former being assigned a higher taxonomic rank.)^[20]
 - Class [Amphibia](#) (amphibians; 8,100+ species)^[21]
 - Class [Sauropsida](#) ([reptiles](#) (including [birds](#)); 21,300+ species – 10,000+ species of birds and 11,300+ species of reptiles)^{[22][23][24]}
 - Class [Synapsida](#) ([mammals](#); 5,700+ species)

Subphyla

[\[edit\]](#)

See also: [List of chordate orders](#)



Cephalochordate: lancelet. Pictured species: [Branchiostoma](#)

[lanceolatum](#)

Cephalochordata: Lancelets

[\[edit\]](#)

Main article: [Lancelet](#)

[Cephalochordates](#), one of the three subdivisions of chordates, are small, "vaguely fish-shaped" animals that lack brains, clearly defined heads and specialized sense organs.^[25] These burrowing filter-feeders compose the earliest-branching chordate subphylum.^{[26][27]}

Tunicata (Urochordata)

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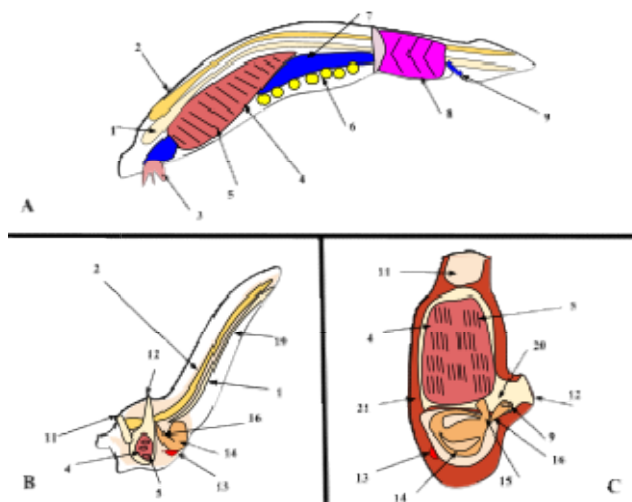
Main article: [Tunicate \(Urochordata\)](#)



Tunicates: sea squirts

Most [tunicates](#) appear as adults in one of two major forms, known as "sea squirts" and [salps](#). Both of these are soft-bodied filter-feeders that lack the standard features of chordates, which are only retained in their larvae. Sea squirts are sessile and consist mainly of water pumps and filter-feeding apparatus;^[28] [salps](#) float in mid-water, feeding on [plankton](#), and have a two-generation cycle in which one generation is solitary and the next forms chain-like [colonies](#).^[29] However, all tunicate [larvae](#) have the standard chordate features, including long, [tadpole](#)-like tails; they also have rudimentary brains, light sensors and tilt sensors.^[28] The third main group of tunicates, [Appendicularia](#) (also known as Larvacea), retain tadpole-like shapes and active swimming all their lives, and were for a long time regarded as larvae of sea squirts or salps.^[30] The etymology of the term Urochordata (Balfour 1881) is from the ancient Greek οὐρά (oura, "tail") + Latin chorda ("cord"), because the notochord is only found in the tail.^[31] The term **Tunicata** (Lamarck 1816) is recognised as having precedence and is now more commonly used.^[28]

Comparison of two invertebrate chordates



A. Lancelet, B. Larval tunicate, C. Adult tunicate

1. [Notochord](#), 2. Nerve chord, 3. Buccal [cirri](#), 4. [Pharynx](#), 5. [Gill slit](#), 6. [Gonad](#), 7. Gut, 8. V-shaped muscles, 9. Anus, 10. Inhalant [syphon](#), 11. Exhalant syphon, 12. Heart, 13. Stomach, 14. [Esophagus](#), 15. Intestines, 16. Tail, 17. Atrium, 18. [Tunic](#)

Craniata (Vertebrata)

[\[edit\]](#)

Main articles: [Craniata](#) and [Vertebrata](#)



Craniate: [Hagfish](#)

[Craniates](#) all have distinct [skulls](#). They include the [hagfish](#), which have no [vertebrae](#). [Michael J. Benton](#) commented that "craniates are characterized by their heads, just as chordates, or possibly all [deuterostomes](#), are by their tails".^[32]

Most craniates are [vertebrates](#), in which the [notochord](#) is replaced by the [vertebral column](#).^[33] It consists of a series of bony or cartilaginous [cylindrical](#) vertebrae, generally with [neural arches](#) that protect the [spinal cord](#), and with projections that link the vertebrae. [Hagfishes](#) have incomplete [braincases](#) and no vertebrae, and are therefore not regarded as vertebrates,^[34] but they are members of the craniates, the group within which vertebrates are thought to have [evolved](#).^[35] However the cladistic exclusion of hagfish from the vertebrates is controversial, as they may instead be degenerate vertebrates who have secondarily lost their vertebral columns.^[36]

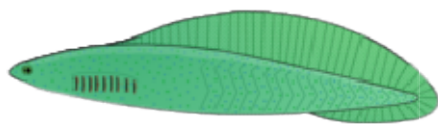
The position of [lampreys](#) is ambiguous. They have complete braincases and rudimentary vertebrae, and therefore may be regarded as vertebrates and true [fish](#).^[37] However, [molecular phylogenetics](#), which uses [biochemical](#) features to classify organisms, has produced both results that group them with vertebrates and others that group them with hagfish.^[38] If lampreys are more closely related to the hagfish than the other vertebrates, this would suggest that they form a [clade](#), which has been named the [Cyclostomata](#).^[39]

Phylogeny

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Overview

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[Haikouichthys](#), from about [518](#) million years ago in China, may be the earliest known fish.^[40]

There is still much ongoing differential (DNA sequence based) comparison research that is trying to separate out the simplest forms of chordates. As some lineages of the 90% of species that lack a backbone or notochord might have lost these structures over time, this complicates the classification of chordates. Some chordate lineages may only be found by DNA analysis, when there is no physical trace of any chordate-like structures.^[41]

Attempts to work out the evolutionary relationships of the chordates have produced several hypotheses. The current consensus is that chordates are [monophyletic](#), meaning that the Chordata include all and only the descendants of a single common ancestor, which is itself a chordate, and that [craniates](#)' nearest relatives are tunicates. Recent identification of two [conserved signature indels](#) (CSIs) in the proteins cyclophilin-like protein and mitochondrial inner membrane protease ATP23, which are exclusively shared by all [vertebrates](#), [tunicates](#) and [cephalochordates](#) also provide strong evidence of the monophyly of Chordata.^[9]

All of the earliest chordate [fossils](#) have been found in the Early [Cambrian Chengjiang fauna](#), and include two species that are regarded as [fish](#), which implies that they are vertebrates. Because the fossil record of early chordates is poor, only [molecular phylogenetics](#) offers a reasonable prospect of dating their emergence. However, the use of molecular phylogenetics for dating evolutionary transitions is controversial.

It has also proved difficult to produce a detailed classification within the living chordates. Attempts to produce evolutionary "[family trees](#)" shows that many of the traditional [classes](#) are [paraphyletic](#).

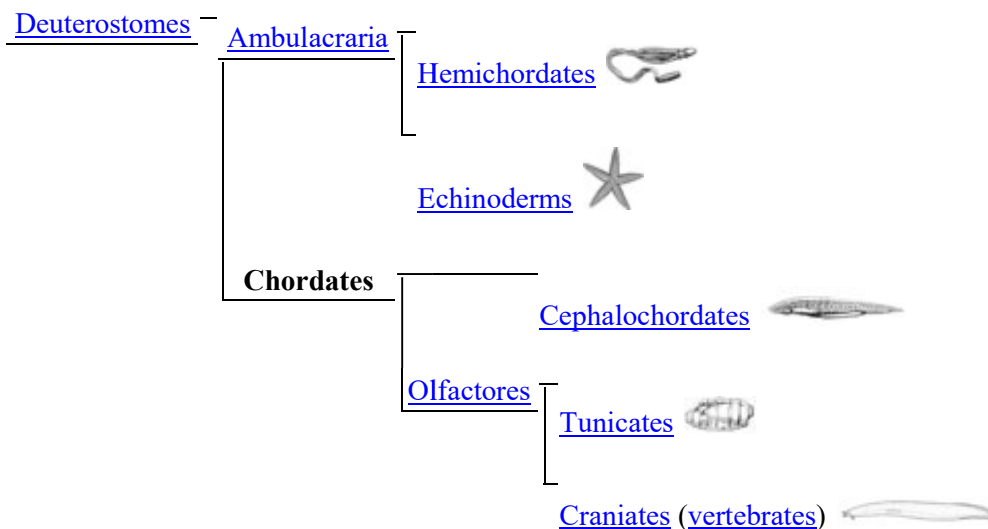


Diagram of the [evolutionary relationships](#) of chordates^[14]

While this has been well known since the 19th century, an insistence on only monophyletic taxa has resulted in vertebrate classification being in a state of flux.^[42]

The majority of animals more complex than [jellyfish](#) and other [Cnidarians](#) are split into two groups, the [protostomes](#) and [deuterostomes](#), the latter of which contains chordates.^[43] It seems very likely the [555](#) million-year-old [Kimberella](#) was a member of the protostomes.^{[44][45]} If so, this means the protostome and deuterostome lineages must have split some time

before *Kimberella* appeared—at least [558](#) million years ago, and hence well before the start of the Cambrian [538.8](#) million years ago.^[43] Three enigmatic species that are possible very early tunicates, and therefore deuterostomes, were also found from the [Ediacaran](#) period – [Ausia fenestrata](#) from the Nama Group of [Namibia](#), the sac-like [Yarnemia ascidiformis](#), and one from a second new *Ausia*-like genus from the Onega Peninsula of northern [Russia](#), [Burykhia hunti](#). Results of a new study have shown possible affinity of these Ediacaran organisms to the ascidians.^{[46][47]} *Ausia* and *Burykhia* lived in shallow coastal waters slightly more than 555 to 548 million years ago, and are believed to be the oldest evidence of the chordate lineage of metazoans.^[47] The Russian Precambrian fossil [Yarnemia](#) is identified as a tunicate only tentatively, because its fossils are nowhere near as well-preserved as those of *Ausia* and *Burykhia*, so this identification has been questioned.



A skeleton of the [blue whale](#), the largest animal, extant or extinct, ever discovered. Mounted outside the Long Marine Laboratory at the [University of California, Santa Cruz](#). The largest blue whale ever reliably recorded measured 98ft (30m) long.



A [peregrine falcon](#), the world's fastest animal. Peregrines use gravity and aerodynamics to achieve their top speed of around 242mph (390km/h), as opposed to locomotion.

Fossils of one major deuterostome group, the [echinoderms](#) (whose modern members include [starfish](#), [sea urchins](#) and [crinoids](#)), are quite common from the start of the Cambrian, [542](#) million years ago.^[48] The Mid [Cambrian](#) fossil [Rhabdotubus johanssoni](#) has been interpreted as a [pterobranch](#) hemichordate.^[49] Opinions differ about whether the [Chengjiang fauna](#) fossil [Yunnanozoon](#), from the earlier Cambrian, was a hemichordate or chordate.^{[50][51]} Another fossil, [Haikouella lanceolata](#), also from the Chengjiang fauna, is interpreted as a chordate and possibly a craniate, as it shows signs of a heart, arteries, gill filaments, a tail, a neural chord with a brain at the front end, and possibly eyes—although it also had short tentacles round its mouth.^[51] [Haikouichthys](#) and [Myllokunmingia](#), also from the Chengjiang fauna, are regarded as [fish](#).^{[40][52]} [Pikaia](#), discovered much earlier (1911) but from the Mid Cambrian [Burgess Shale](#) (505 Ma), is also regarded as a primitive chordate.^[53] On the other hand, fossils of early chordates are very rare, since invertebrate chordates have no bones or teeth, and only one has been reported for the rest of the Cambrian.^[54] The best known and

earliest unequivocally identified Tunicate is [Shankouclava shankouense](#) from the Lower [Cambrian Maotianshan Shale](#) at Shankou village, Anning, near [Kunming \(South China\)](#).^[55]

The evolutionary relationships between the chordate groups and between chordates as a whole and their closest deuterostome relatives have been debated since 1890. Studies based on anatomical, [embryological](#), and paleontological data have produced different "family trees". Some closely linked chordates and hemichordates, but that idea is now rejected.^[14] Combining such analyses with data from a small set of [ribosome RNA](#) genes eliminated some older ideas, but opened up the possibility that tunicates (urochordates) are "basal deuterostomes", surviving members of the group from which echinoderms, hemichordates and chordates evolved.^[56] Some researchers believe that, within the chordates, craniates are most closely related to cephalochordates, but there are also reasons for regarding tunicates (urochordates) as craniates' closest relatives.^{[14][57]}

Since early chordates have left a poor fossil record, attempts have been made to calculate the key dates in their evolution by [molecular phylogenetics](#) techniques—by analyzing biochemical differences, mainly in RNA. One such study suggested that deuterostomes arose before [900](#) million years ago and the earliest chordates around [896](#) million years ago.^[57] However, molecular estimates of dates often disagree with each other and with the fossil record,^[57] and their assumption that the [molecular clock](#) runs at a known constant rate has been challenged.^{[58][59]}

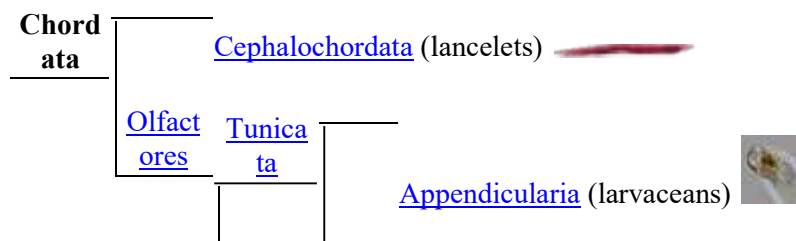
Traditionally, Cephalochordata and Craniata were grouped into the proposed clade "Euchordata", which would have been the sister group to Tunicata/Urochordata. More recently, Cephalochordata has been thought of as a sister group to the "Olfactores", which includes the craniates and tunicates. The matter is not yet settled.

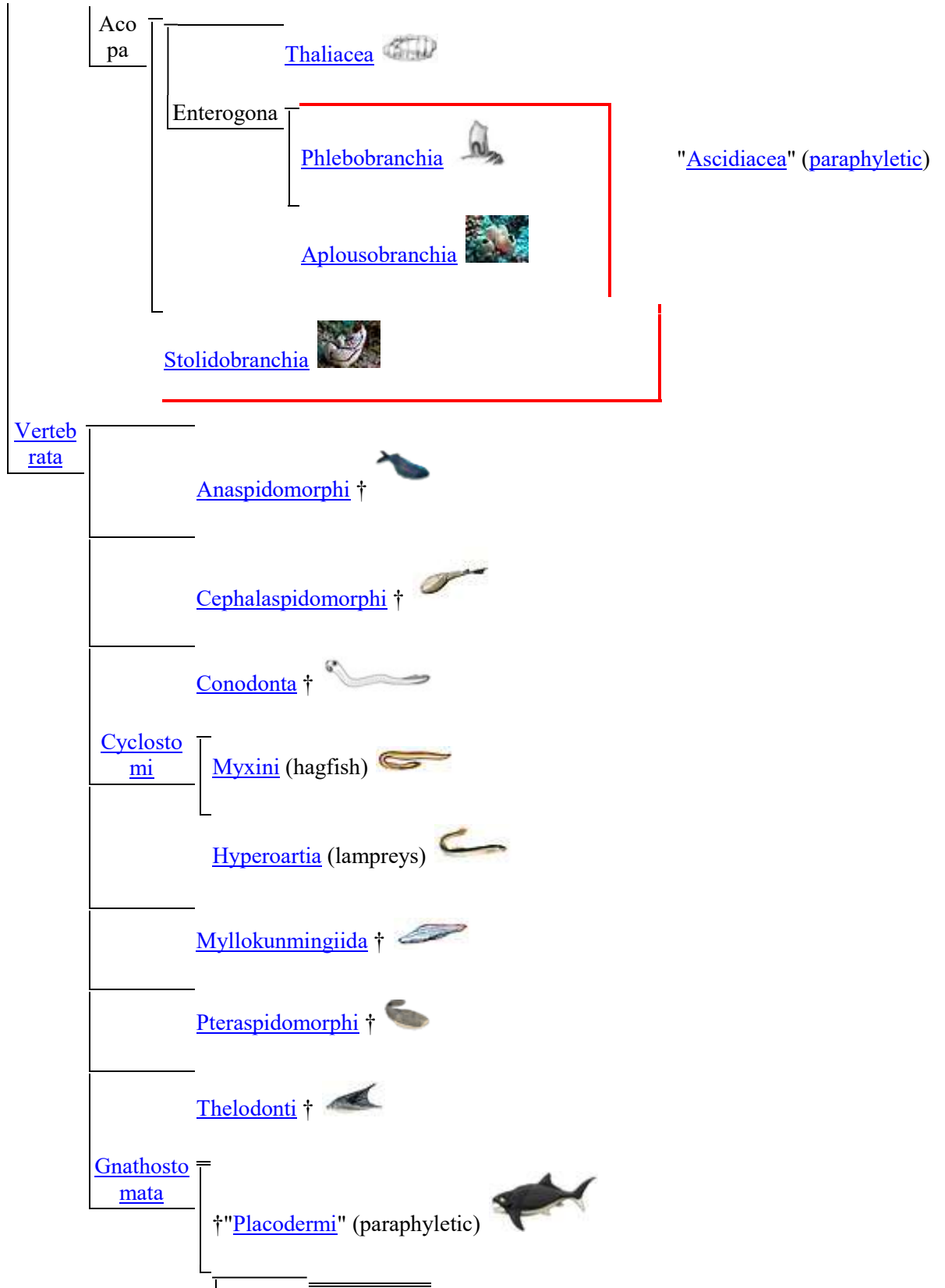
A specific relationship between Vertebrates and [Tunicates](#) is also strongly supported by two CSIs found in the proteins predicted exosome complex RRP44 and serine palmitoyltransferase, that are exclusively shared by species from these two subphyla but not [Cephalochordates](#), indicating Vertebrates are more closely related to [Tunicates](#) than [Cephalochordates](#).^[9]

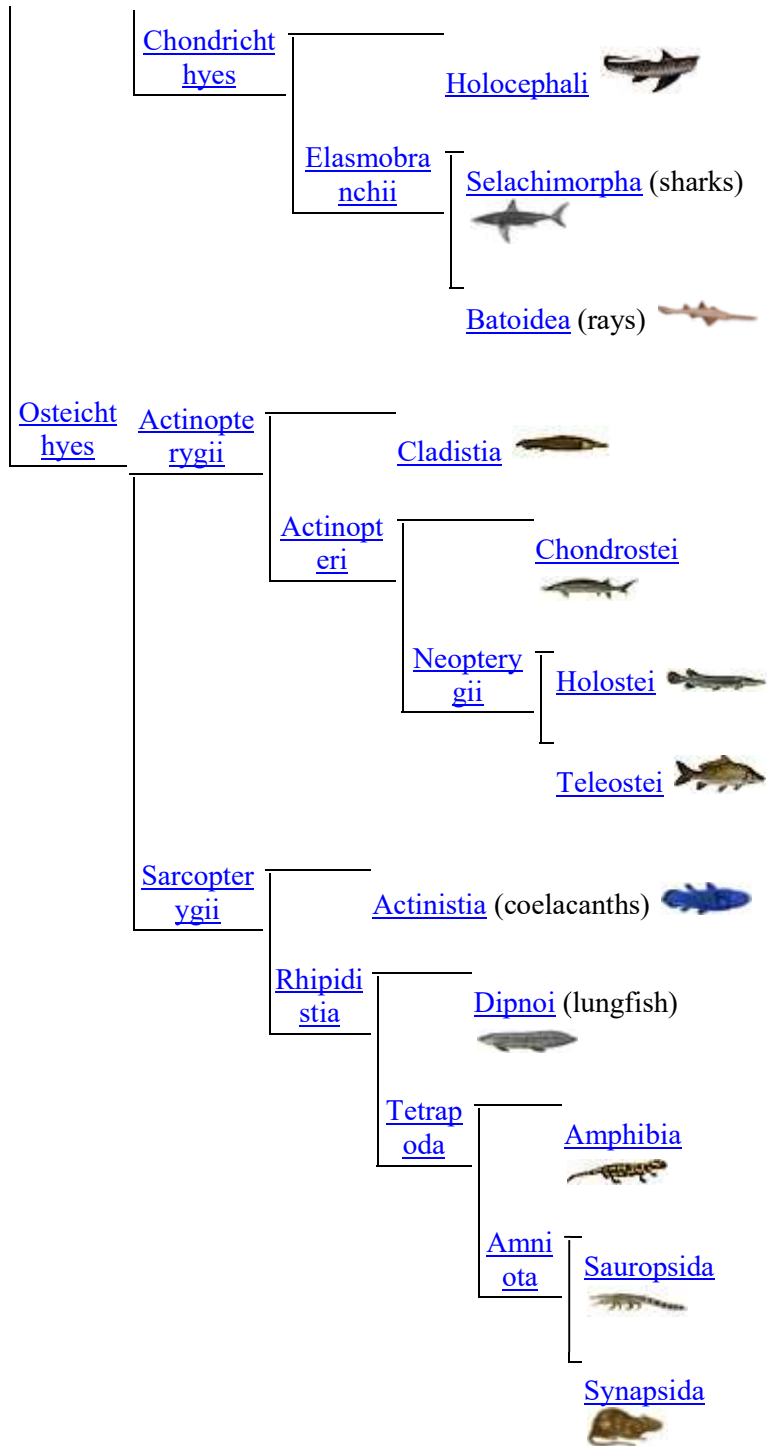
Cladogram

[\[edit\]](#)

Below is a [phylogenetic tree](#) of the phylum. Lines of the [cladogram](#) show probable evolutionary relationships between both [extinct](#) taxa, which are denoted with a [dagger](#) (†), and [extant taxa](#). Relatives of vertebrates are [invertebrates](#). The positions (relationships) of the lancelets, tunicates, and craniates/vertebrates are based on the following studies:^{[60][61][62][63]}







Closest nonchordate relatives

[\[edit\]](#)



Acorn worms or Enteropneusts are example of hemichordates.

The closest relatives of the Chordates are believed to be the [Hemichordates](#) and [Echinodermata](#), which together form the [Ambulacraria](#). The Chordata and Ambulacraria together form the superphylum [Deuterostomia](#).

Hemichordates

[\[edit\]](#)

Main article: [Hemichordate](#)

[Hemichordates](#) ("half chordates") have some features similar to those of chordates: branchial openings that open into the [pharynx](#) and look rather like gill slits; stomochords, similar in composition to [notochords](#), but running in a circle round the "collar", which is ahead of the mouth; and a [dorsal](#) nerve cord—but also a smaller [ventral](#) nerve cord.

There are two living groups of hemichordates. The solitary [enteropneusts](#), commonly known as "acorn worms", have long [proboscises](#) and worm-like bodies with up to 200 branchial slits, are up to 2.5 metres (8.2 ft) long, and burrow through [seafloor sediments](#). [Pterobranchs](#) are [colonial](#) animals, often less than 1 millimetre (0.039 in) long individually, whose dwellings are interconnected. Each [filter feeds](#) by means of a pair of branched tentacles, and has a short, shield-shaped proboscis. The extinct [graptolites](#), colonial animals whose fossils look like tiny [hacksaw](#) blades, lived in tubes similar to those of pterobranchs.^[64]

Echinoderms

[\[edit\]](#)



A red knob sea star, *Protoreaster linckii* is an example of [Asterozoan Echinoderm](#).

Main article: [Echinoderm](#)

[Echinoderms](#) differ from chordates and their other relatives in three conspicuous ways: they possess [bilateral symmetry](#) only as larvae – in adulthood they have [radial symmetry](#), meaning that their body pattern is shaped like a wheel; they have [tube feet](#); and their bodies are supported by [dermal skeletons](#) made of [calcite](#), a material not used by chordates. Their hard, calcified shells keep their bodies well protected from the environment, and these skeletons enclose their bodies, but are also covered by thin skins. The feet are powered by another unique feature of echinoderms, a [water vascular system](#) of canals that also functions as a "lung" and surrounded by muscles that act as pumps. [Crinoids](#) are typically [sessile](#) and look rather like flowers (hence the [common name](#) "[sea lilies](#)"), and use their feather-like arms to filter food particles out of the water; most live anchored to rocks, but a few species can move very slowly. Other echinoderms are mobile and take a variety of body shapes, for example [starfish](#) and [brittle stars](#), [sea urchins](#) and [sea cucumbers](#).^[65]