

# Most animal phyla originated in a brief span of geological time

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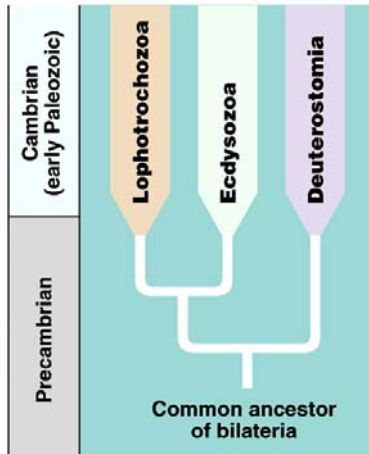
- The fossil record and molecular studies concur that the diversification that produced most animal phyla occurred rapidly on the vast scale of geologic time.
- This lasted about 40 million years (about 565 to 525 million years ago) during the late Precambrian and early Cambrian (which began about 543 million years ago).

- Nearly all the major animal body plans appear in Cambrian rocks from 543 to 525 million years ago.
- During this relatively short time, a burst of animal origins, the **Cambrian explosion**, left a rich fossil assemblage.
  - It includes the first animals with hard, mineralized skeletons

- The strongest evidence for the initial appearance of multicellular animals is found in the the last period of the Precambrian era, the **Ediacaran period**.
  - Fossils from the Ediacara Hills of Australia (565 to 543 million years ago) and other sites around the world consist primarily of cnidarians, but soft-bodied mollusks were also present, and numerous fossilized burrows and tracks indicate the presence of worms.
  - Recently, fossilized animal embryos in China from 570 million years ago and what could be fossilized burrows from rocks 1.1 billion years ago have been reported.
- Data from molecular systematics suggest an animal origin about a billion years ago.

- On the scale of geologic time, animals diversified so rapidly that it is difficult from the fossil record to sort out the sequence of branching in animal phylogeny.
  - Because of this, systematists depend largely on clues from comparative anatomy, embryology, developmental genetics, and molecular systematics of extant species.

- Some systematists studying animal phylogeny interpret the molecular data as supporting *three* Cambrian explosions, not just one.



- For the three main branches of bilateral animals - Lophotrochozoa, Ecdysozoa, and Deuterostomia - the relationships among phyla *within* each are difficult to resolve, but the differences *between* these three clades are clear, based on their nucleic acid sequences.
  - This suggests that these three clades branched apart very early, probably in the Precambrian.

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- Zoologists recognize about 35 phyla of animals.
  - For the past century, there was broad consensus among systematists for the major branches of the animal phylogenetic tree.
    - This was based mainly on anatomical features in adults and certain details of embryonic development.
  - However, the molecular systematics of the past decade is challenging some of these long-held ideas about the phylogenetic relationships among the animal phyla.

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## The remodeling of phylogenetic trees illustrates the process of scientific inquiry

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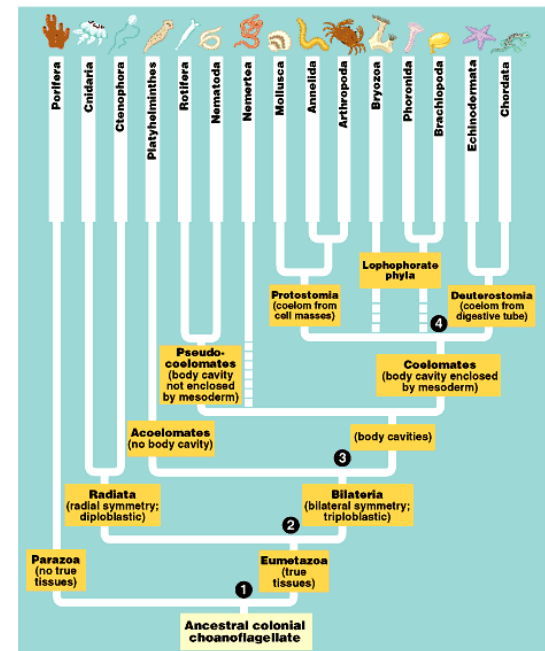
- It must be frustrating that the phylogenetic trees in textbooks cannot be memorized as fossilized truths.
- On the other hand, the current revolution in systematics is a healthy reminder that science is both a process of inquiry and dynamic.
  - Emerging technologies such as molecular biology and fresh approaches such as cladistics produce new data or stimulate reconsideration of old data.

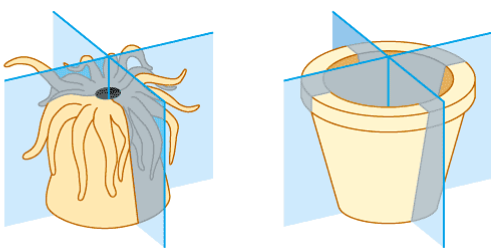
- New hypotheses or refinements of old ones represent the latest versions of what we understand about nature based on the best available evidence.
- *Evidence* is the key word because even our most cherished ideas in science are probationary.
  - Science is partly distinguished from other ways of knowing because its ideas *can* be falsified through testing with experiments and observations.
  - The more testing that a hypothesis withstands, the more credible it becomes.

- A comparison of the traditional phylogenetic tree of animals with the remodeled tree based on molecular biology shows agreement on some issues and disagreement on others.
- Though the new data from molecular systematics are compelling, the traditional view of animal phylogeny still offers some important advantages for helping us understand the diversity of animal body plans.

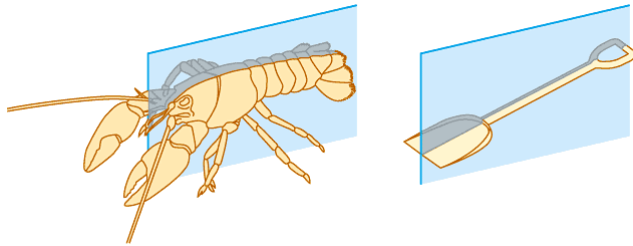
## The traditional phylogenetic tree of animals is based mainly on grades in body “plans”

- The traditional view of relationships among animal phyla are based mainly on key characteristics of body plans and embryonic development.
- Each major branch represents a **grade**, which is defined by certain body-plan features shared by the animals belonging to that branch.

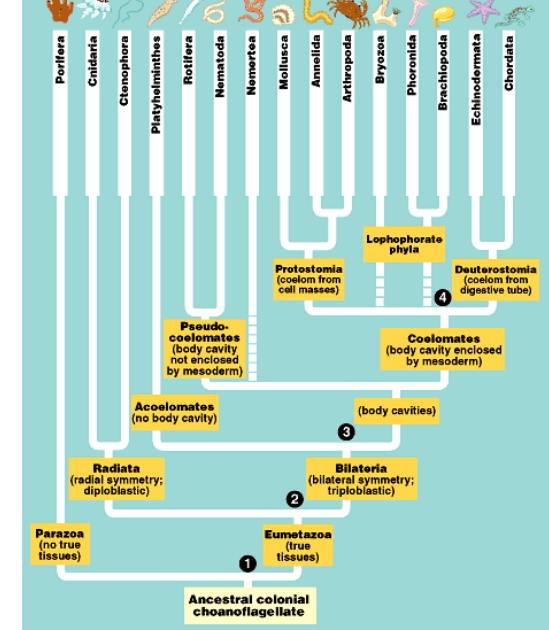




(a) Radial symmetry



(b) Bilateral symmetry

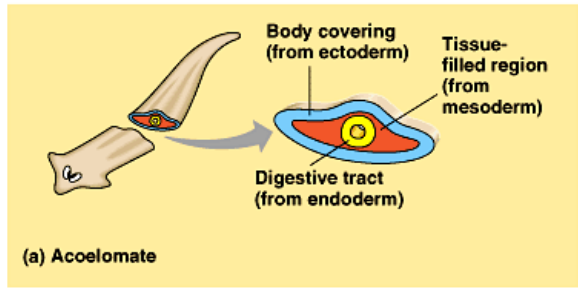


- The basic organization of **germ layers**, concentric layers of embryonic tissue that form various tissues and organs, differs between radiata and bilateria.
- The radiata are said to be **diploblastic** because they have two germ layers.
  - The **ectoderm**, covering the surface of the embryo, give rise to the outer covering and, in some phyla, the central nervous system.
  - The **endoderm**, the innermost layer, lines the developing digestive tube, or **archenteron**, and gives rise to the lining of the digestive tract and the organs derived from it, such as the liver and lungs of vertebrates.

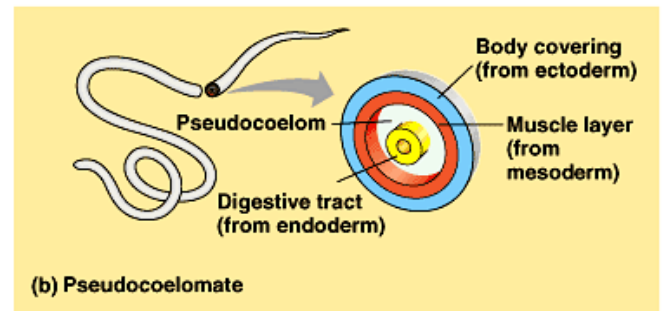
- The bilateria are **triploblastic**.
  - The third germ layer, the **mesoderm** lies between the endoderm and ectoderm.
  - The mesoderm develops into the muscles and most other organs between the digestive tube and the outer covering of the animal.

(3) The Bilateria can be divided by the presence or absence of a **body cavity** (a fluid-filled space separating the digestive tract from the outer body wall) and by the structure the body cavity.

- **Acoelomates** (the phylum Platyhelminthes) have a solid body and lack a body cavity.

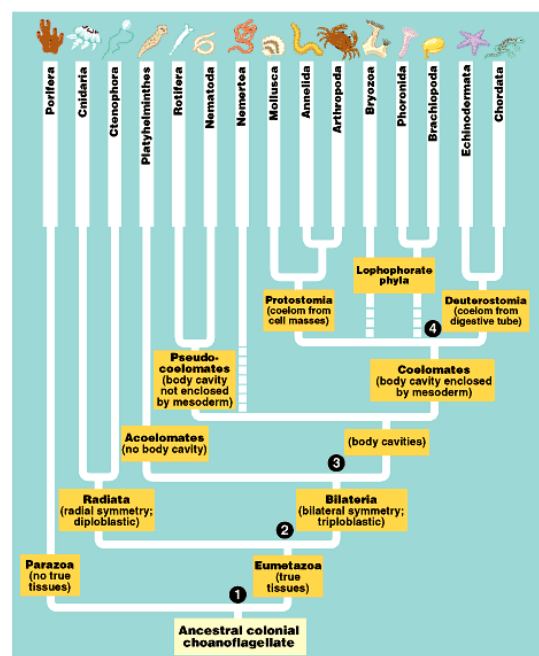
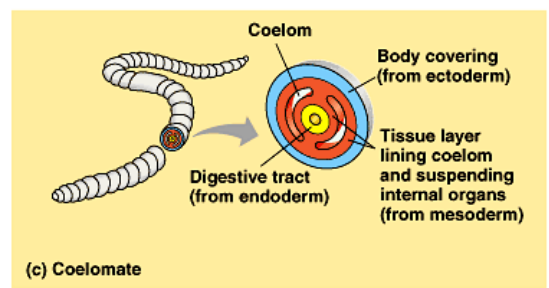


- In some organisms, there is a body cavity, but it is not completely lined by mesoderm.
  - This is termed a **pseudocoelom**.
  - These **pseudocoelomates** include the rotifers (phylum Rotifera) and the roundworms (phylum Nematoda).



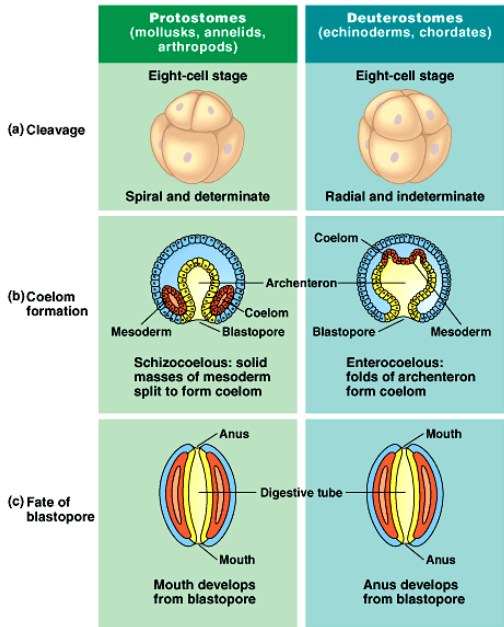
• **Coelomates** are organisms with a true **coelom**, a fluid-filled body cavity completely lined by mesoderm.

- The inner and outer layers of tissue that surround the cavity connect dorsally and ventrally to form mesenteries, which suspend the internal organs.



- A body cavity has many functions.
  - Its fluid cushions the internal organs, helping to prevent internal injury.
  - The noncompressible fluid of the body cavity can function as a hydrostatic skeleton against which muscles can work.
  - The presence of the cavity enables the internal organs to grow and move independently of the outer body wall.

- (4) The coelomate phyla are divided into two grades based on differences in their development.
- The mollusks, annelids, arthropods, and several other phyla belong to the **protostomes**, while echinoderms, chordates, and some other phyla belong to the **deuterostomes**.
  - These differences center on cleavage pattern, coelom formation, and blastopore fate.



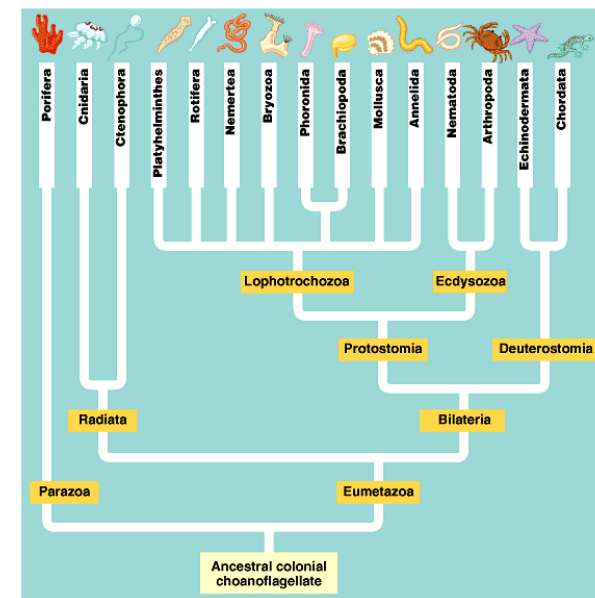
- Many protostomes undergo **spiral cleavage**, in which planes of cell division are diagonal to the vertical axis of the embryo.
  - Some protostomes also show **determinate cleavage** where the fate of each embryonic cell is determined early in development.
- The zygotes of many deuterostomes undergo **radial cleavage** in which the cleavage planes are parallel or perpendicular to the vertical egg axis.
  - Most deuterostomes show **indeterminate cleavage** whereby each cell in the early embryo retains the capacity to develop into a complete embryo.

- Coelom formation begins in the gastrula stage.
  - As the archenteron forms in a protostome, solid masses of mesoderm split to form the coelomic cavities, called **schizocoelous** development.
  - In deuterostomes, mesoderm buds off from the wall of the archenteron and hollows to become the coelomic cavities, called **enterocoelous** development.

- The third difference centers on the fate of the **blastopore**, the opening of the archenteron.
  - In many protosomes, the blastopore develops into the mouth and a second opening at the opposite end of the gastrula develops into the anus.
  - In deuterostomes, the blastopore usually develops into the anus and the mouth is derived from the secondary opening.

- Molecular systematics has added a new set of shared-derived characters in the form of unique monomer sequences within certain genes and their products.
  - These molecular data can be used to identify the clusters of monophyletic taxa that make up clades.
- In some cases, the clades determined from molecular data reinforce the traditional animal tree based on comparative anatomy and development, but in other cases, a very different pattern emerges.

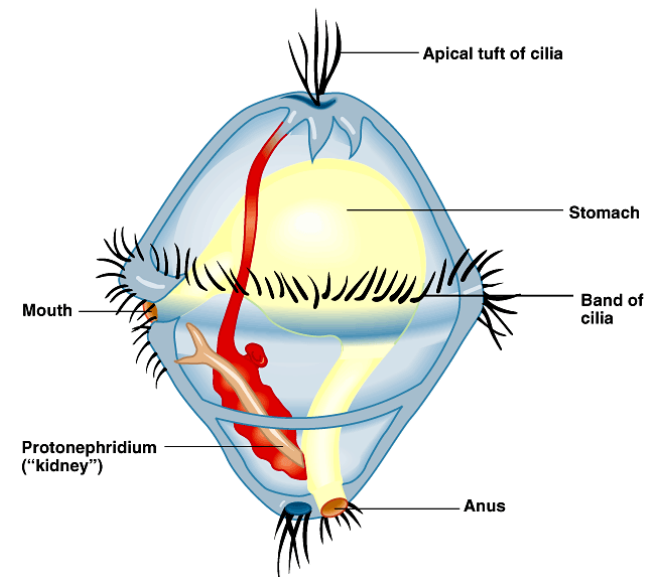
- This phylogenetic tree is based on nucleotide sequences from the small subunit ribosomal RNA.



- At key places, these two views of animal phylogeny are alike.
  - First, both analyses support the traditional hypotheses of the Parazoa-Eumetazoa and Radiata-Bilateria dichotomies.
  - Second, the molecular analysis reinforces the hypothesis that the deuterostomes (echinoderms and chordates) form a clade.

- However, the traditional and molecular-based phylogenetic trees clash, especially on the protostome branch.
  - The molecular evidence supports two protostome clades: **Lophotrochozoa**, which includes annelids (segmented worms) and mollusks (including clams and snails), and **Ecdysozoa**, which includes the arthropods.

- Traditional analyses have produced two competing hypotheses for the relationships among annelids, mollusks, and arthropods.
  - Some zoologists favored an annelid-arthropod lineage, in part because both have segmented bodies.
  - Other zoologists argued that certain features favored an annelid-mollusk lineage, especially because they share a similar larval stage, the **trochophore larva**.
    - This hypothesis is supported by the molecular data.

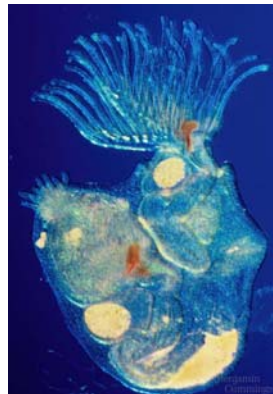


- Traditionally, the aculeate phylum Platyhelminthes (flatworms) branches from the tree before the formation of body cavities.
  - The molecular data place the flatworms within the lophotrochozoan clade.
  - If this is correct, then flatworms are not primitive “pre-coelomates” but are protostomes that have lost the coelom during their evolution.
- The molecular-based phylogeny splits the pseudocoelomates with the phylum Rotifera (rotifers) clustered with the lophotrochozoan phyla and the phylum Nematoda (nematodes) with the ecdysozoans.

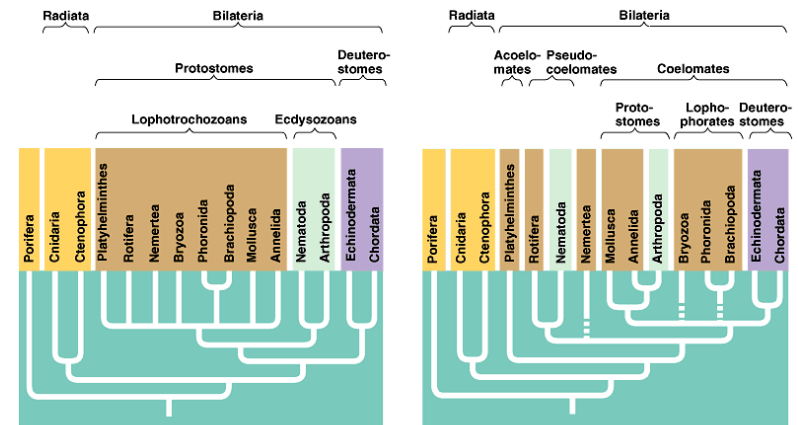
- The name Ecdysozoa (nematodes, arthropods, and other phyla) refers to animals that secrete external skeletons (exoskeleton).
  - As the animal grows, it molts the old exoskeleton and secretes a new, larger one, a process called ecdysis.
  - While named for this process, the clade is actually defined mainly by molecular evidence.



- In the traditional tree, the assignment of the three lophophorate phyla is problematic.
  - These animals have a **lophophore**, a horseshoe-shaped crown of ciliated tentacles used for feeding.
  - The lophophorate phyla share some characteristics with protostomes and other features with deuterostomes.
  - The molecular data place the lophophorate phyla among the phyla with the trochophore larvae, hence the name lophotrochozoans.



- In summary, the molecular evidence recognizes two distinct clades within the protostomes and distributes the acoelomates, pseudocoelomates, and lophophorate phyla among these two clades.



(a) Tree based on molecular comparisons

(b) Tree based on body-plan grades

• Our survey of animal phyla is based on the newer molecular phylogeny, but there are two caveats.

- First, the concept of body-plan grades still is a very useful way to think about the diversity of animal forms that have evolved.
- Second, the molecular phylogeny is a hypothesis about the history of life, and is thus tentative.
  - This phylogeny is based on just a few genes - mainly the small subunit ribosomal RNA (SSU-rRNA).
  - Ideally, future research, including fossil evidence and traditional approaches, will eventually square the molecular data with data from these other approaches.