Investigating the Tree of Life

Phylogeny is the evolutionary history of a species or group of related species

- The discipline of systematics classifies organisms and determines their evolutionary relationships
- Systematists use fossil, molecular, and genetic data to infer evolutionary relationships

Hierarchical Classification

- Linnaeus introduced a system for grouping species in increasingly broad categories
- The taxonomic groups from broad to narrow are domain, kingdom, phylum, class, order, family, genus, and species
- A taxonomic unit at any level of hierarchy is called a taxon

Three Domains of life

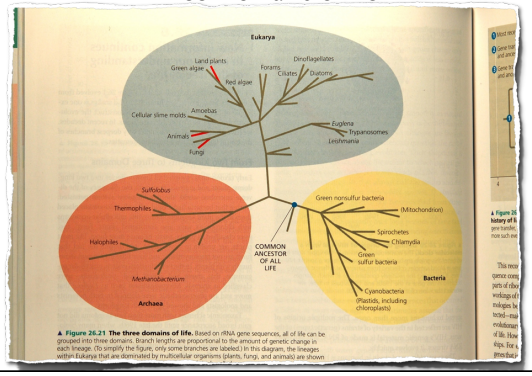


Fig. 26-3

Species: *Panthera pardus*

Bathynomus giganteus

Genus: *Panthera*

Bathynomus

Family: Felidae

Cirolanidae

Order: Carnivora

Cymothoida

Class: Mammalia

Crustacea

Phylum: Chordata

Arthropoda

Kingdom: Animalia

same

Bacteria | Domain: Eukarya | Archaea

same

Linking Classification and Phylogeny

Systematists depict evolutionary relationships in branching phylogenetic trees

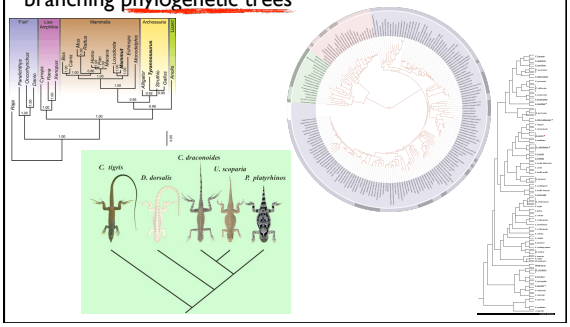
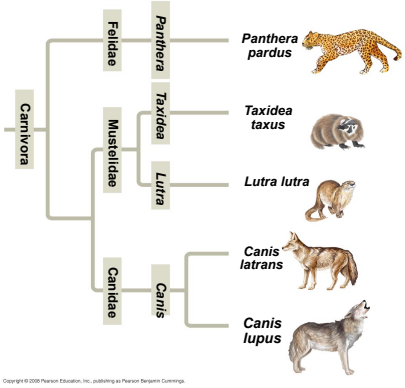
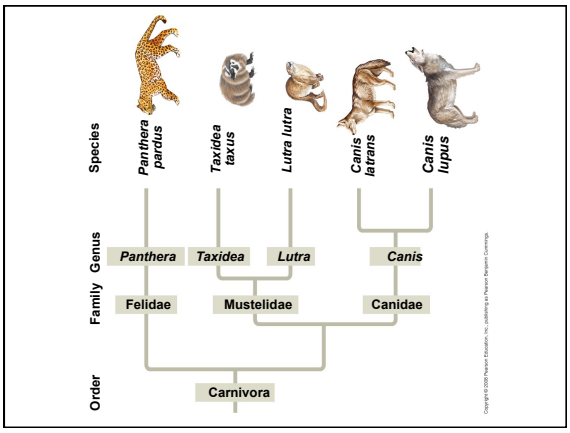


Fig. 26-4





- A phylogenetic tree represents a hypothesis about evolutionary relationships
- Each branch point represents the divergence of two species

Sister taxa are groups that share an immediate common ancestor

Different Kinds of Trees

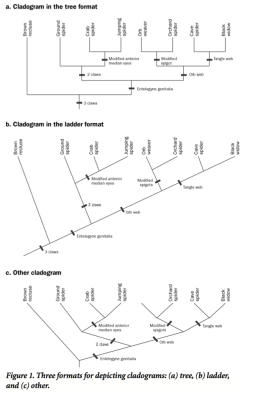
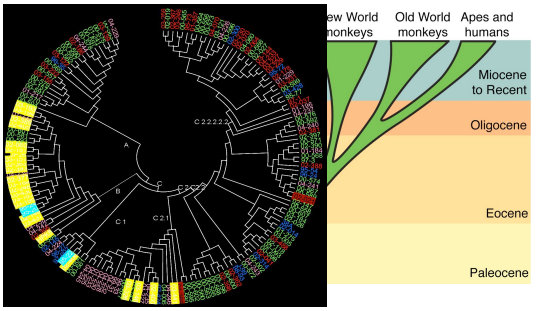
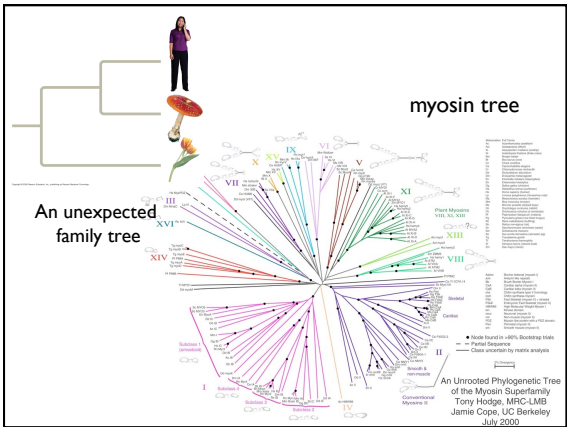


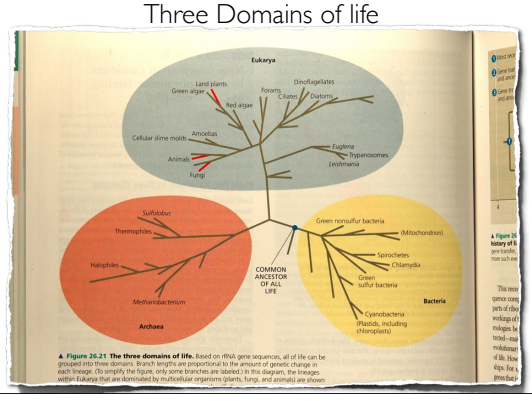
Figure 1. Three formats for depicting cladograms: (a) tree, (b) ladder, and (c) other.

Different Kinds of Trees

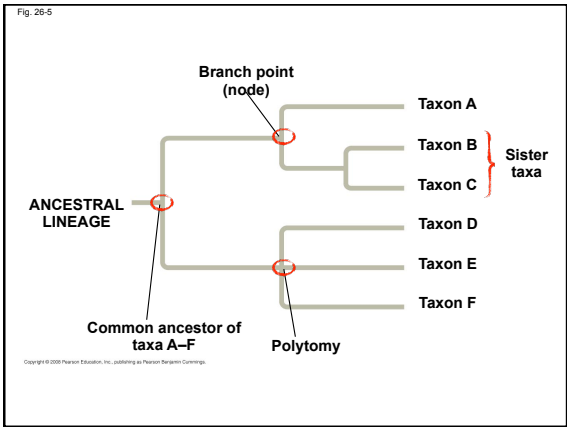




Three Domains of life

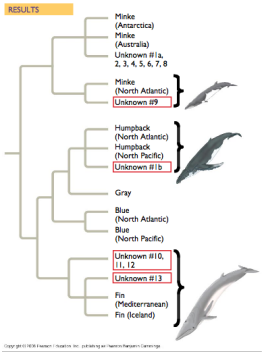


- A rooted tree includes a branch to represent the last common ancestor of all taxa in the tree
- A polytomy is a branch from which more than two groups emerge

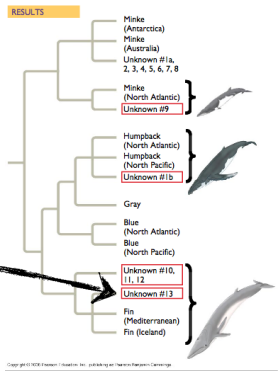


What We Can and Cannot Learn from Phylogenetic Trees

- Phylogenetic trees do show patterns of descent
- This phylogenetic tree does not indicate when species evolved or how much genetic change occurred in a lineage
- It shouldn't be assumed that a taxon evolved from the taxon next to it



Unknown #13 is most closely related to:
(a) Gray whale
(b) Blue whale
(c) Fin whale
(d) Minke whale or
(e) Humpback whale



Applying Phylogenies

- Phylogeny provides important information about similar characteristics in closely related species
- A phylogeny was used to identify the species of whale from which "whale meat" originated

Where did this fish come from?
.....and what is redfish and whitefish anyway?

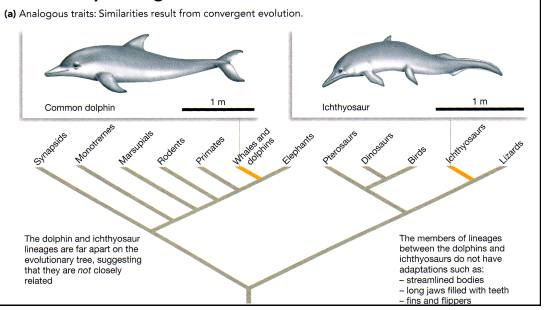
Phylogenies are inferred from morphological and molecular data

- To infer phylogenies, systematists gather information about morphologies, genes, and biochemistry of living organisms
- Organisms with similar morphologies or DNA sequences are likely to be more closely related than organisms with different structures or sequences

Identifying Homology and Analogy

- When constructing a phylogeny, systematists need to distinguish whether a similarity is the result of homology or analogy
- Homology is similarity due to shared ancestry
- Analogy is similarity due to convergent evolution

Convergent evolution occurs when similar environmental pressures and natural selection produce similar (analogous) adaptations in organisms from different evolutionary lineages



- Bat and bird wings are homologous as forelimbs, but analogous as functional wings
- Analogous structures or molecular sequences that evolved independently are also called homoplasies
- Homology can be distinguished from analogy by comparing fossil evidence and the degree of complexity
- The more complex two similar structures are, the more likely it is that they are homologous

Evaluating Molecular Homologies

Systematists use computer programs and mathematical tools when analyzing comparable DNA segments from different organisms

?

Why do systematists need computers to analyze DNA sequences?
(a) systematists are lazy
(b) there are too many phylogenetic trees to evaluate
(c) it is the right thing to do
(d) there are too many beetles

The number of possible trees can be astronomically large

- for 5 species there are 15 trees possible (fully resolved)
- the number of trees increases explosively as the number of species goes up
- 50 species= 3×10^{76} possible unrooted trees
- 30 million species (the estimated to be alive to day = $10^{300,000,000}$)
- no computer today can search through that quantity of trees

$$(2n-3)!! = \frac{(2n-3)!}{2^{n-2}(n-2)!}, \text{ for } n \geq 2$$

total rooted trees and

$$(2n-5)!! = \frac{(2n-5)!}{2^{n-3}(n-3)!}, \text{ for } n \geq 3$$

Joseph Felsenstein, 1978

Felsenstein, J. 1978. The number of evolutionary trees. Systematic Biology.

1 taxon = 1 tree
2 taxa = 1 tree
3 taxa = 4 trees
4 taxa = 26 trees.....

COUNTING TREES 31

TABLE 1. THE NUMBERS OF ROOTED TREES WITH n LABELLED TIPS AND WITH UNLABELLED INTERIOR NODES. THE LEFT COLUMN COUNTS ALL TREES, THE RIGHT COLUMN ONLY BIFURCATING TREES.

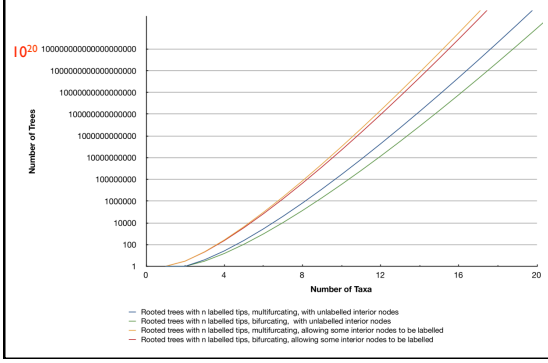
n	All trees	Bifurcating trees
1	1	1
2	1	1
3	4	3
4	26	15
5	236	105
6	2,752	945
7	39,208	10,395
8	660,032	135,135
9	12,818,912	2,027,025
10	282,137,824	34,459,425
11	6,939,897,856	654,729,075
12	188,666,182,784	13,749,310,575
13	5,617,349,920,544	316,234,143,225
14	181,790,703,209,728	7,905,853,580,625
15	6,353,726,042,486,112	213,458,046,676,875
16	238,513,970,965,350,048	6,190,283,353,629,375
17	9,571,020,586,418,569,216	191,898,783,962,510,625
18	408,837,905,660,430,516,224	6,332,659,870,762,850,625
19	18,522,305,410,364,568,764,416	221,643,095,476,699,771,875
20	887,094,711,304,094,583,095,296	8,200,794,532,637,891,559,375
21	44,782,218,857,751,551,087,214,592	319,830,986,772,877,770,815,625
22	2,376,613,641,928,796,906,249,519,104	13,113,070,457,687,988,603,440,625

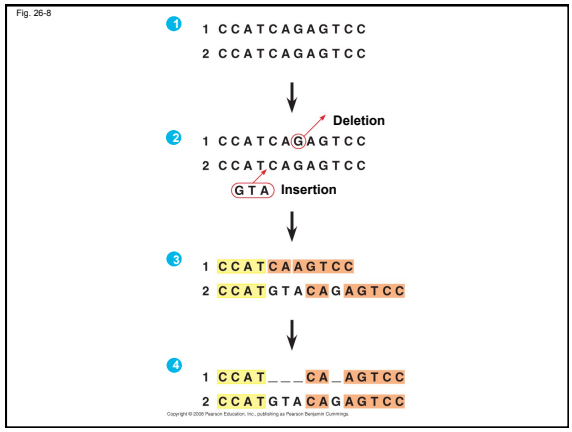
arise directly from a pre-existing interior node only if that node has only one immediate descendant. It must therefore always be a labelled interior node (although some of the labelled interior nodes will have two immediate descendants). There will be different numbers of ways of adding species n to a tree, depending on how many of these eligible labelled interior nodes there are. Letting n = number of labelled nodes, m = number of labelled interior nodes with two descendant, and p = number of labelled interior nodes with exactly one descendant, we wish to compute $V(n, m, p)$, so that by addition over all m and p we can obtain the total number of bifurcating trees with partially labelled interior nodes (as before, including the case where none is labelled). The recurrence relation is:

TABLE 2. THE NUMBERS OF ROOTED TREES WITH n LABELLED SPECIES, ALLOWING MULTIFURCATIONS AND ALLOWING SOME INTERIOR NODES TO BE LABELLED.

n	Number of trees
1	1
2	3

How many trees did you say?

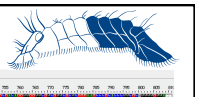


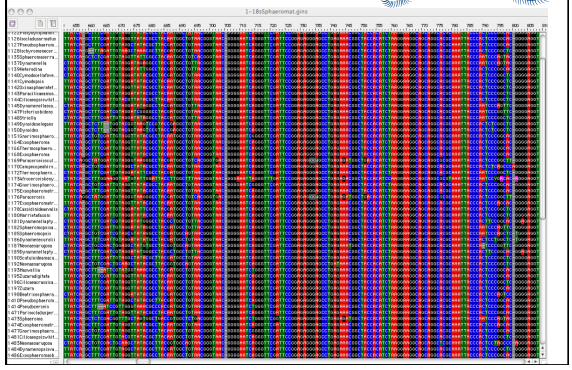


- It is also important to distinguish homology from analogy in molecular similarities
- Mathematical tools help to identify molecular homoplasies, or coincidences

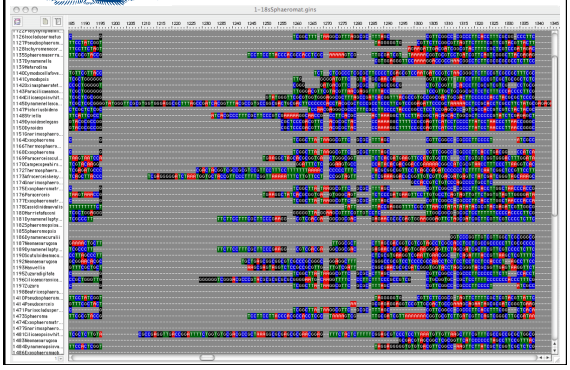
Molecular systematics uses DNA and other molecular data to determine evolutionary relationships

Stems - 18S rDNA

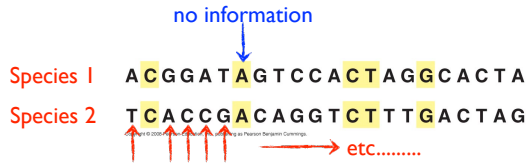




Hyper-variable regions - 18S rDNA



Shared characters are used to construct phylogenetic trees



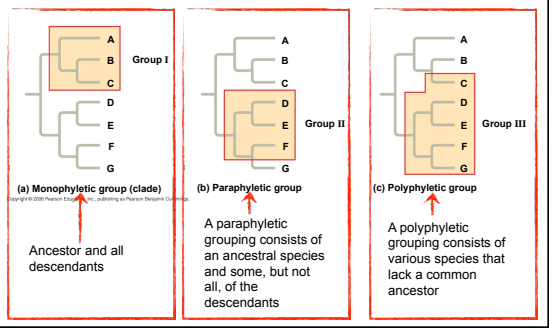
Once homologous characters have been identified, they can be used to infer a phylogeny

Cladistics

Cladistics groups organisms by common descent

- A clade is a group of species that includes an ancestral species and all its descendants
- Clades can be nested in larger clades, but not all groupings of organisms qualify as clades
- A valid clade is monophyletic, signifying that it consists of the ancestor species and all its descendants

Fig. 26-10



Shared Ancestral and Shared Derived Characters

In comparison with its ancestor, an organism has both shared and different characteristics

- A shared ancestral character is a character that originated in an ancestor of the taxon
- A shared derived character is an evolutionary novelty unique to a particular clade
- A character can be both ancestral and derived, depending on the context

Inferring Phylogenies Using Derived Characters

When inferring evolutionary relationships, it is useful to know in which clade a shared derived character first appeared

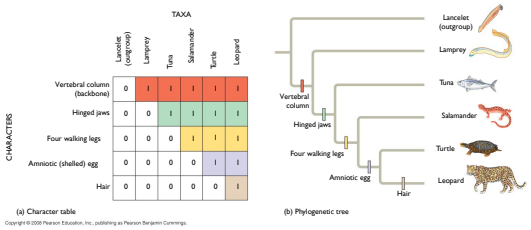
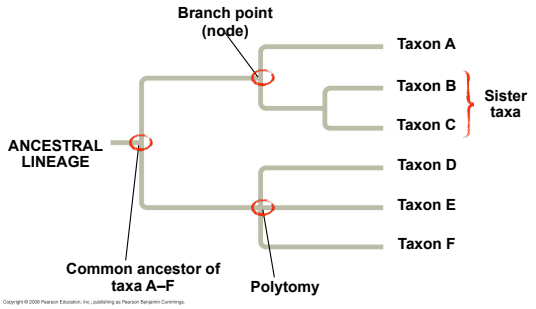


Fig. 26-11

Fig. 26-5



Phylogenetic Trees with Proportional Branch Lengths

In some trees, the length of a branch can reflect the number of genetic changes that have taken place in a particular DNA sequence in that lineage

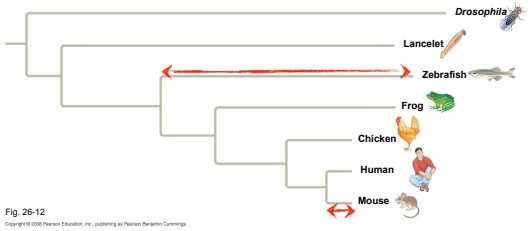
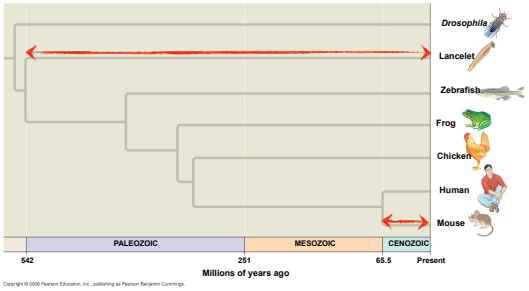


Fig. 26-12

In other trees, branch length can represent chronological time, and branching points can be determined from the fossil record



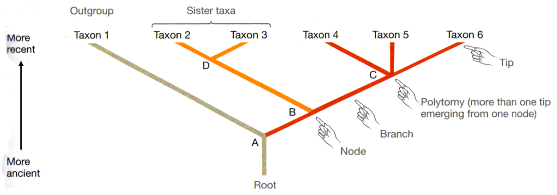
Maximum Parsimony and Maximum Likelihood

- Systematists can never be sure of finding the best tree in a large data set
- They narrow possibilities by applying the principles of maximum parsimony, maximum likelihood, Bayesian inference, and soon simultaneous analyses

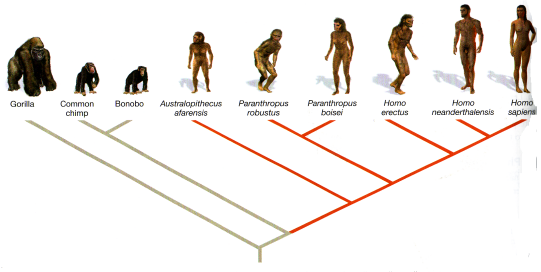
Maximum parsimony assumes that the tree that requires the fewest evolutionary events (appearances of shared derived characters) is the most likely

The principle of **maximum likelihood** states that, given certain rules about how DNA changes over time, a tree can be found that reflects the most likely sequence of evolutionary events

Reviewing Phylogenetic Trees



Example of Phylogenetic Tree



A phylogenetic tree showing the relationships among some of the great apes. Chimps and gorillas walk on all four legs, but all other species on this tree walk on two legs and are considered hominins. EXERCISE Add a mark on the phylogeny, and label it "origin of walking on two legs." Circle and label a pair of sister species. Circle and label the monophyletic group called hominins. Label one of the outgroups to the hominins.

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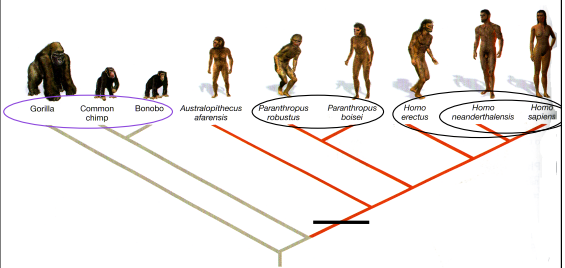

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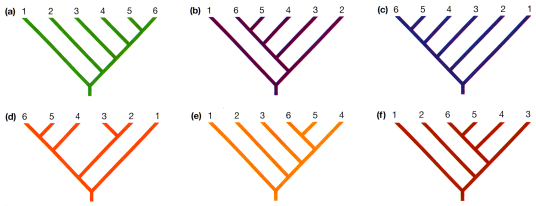
Alternative ways of drawing the same tree

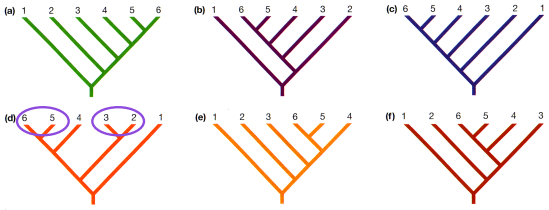


QUESTION Five of these six trees describe exactly the same relationships among taxa 1 through 6. Identify the tree that is different from the other five.

Five of these six trees describe EXACTLY the same relationship among taxa 1 through 6.
Which tree is different from the other five?

?

Alternative ways of drawing the same tree

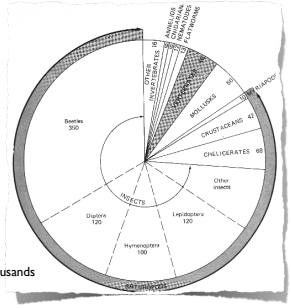


QUESTION Five of these six trees describe exactly the same relationships among taxa 1 through 6. Identify the tree that is different from the other five.

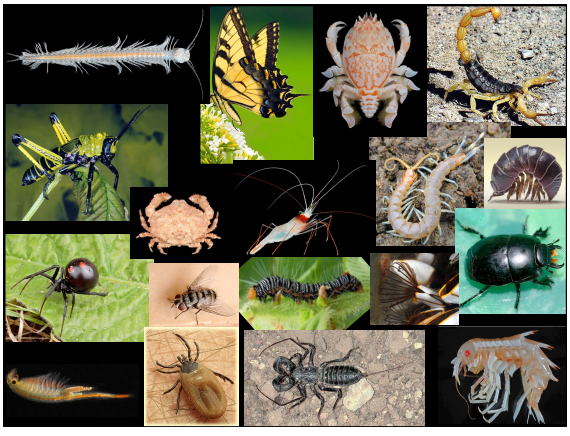
Biodiversity

- more than 1 million arthropod species described
- zoologists estimate 3 million to 100 million undescribed species

The Beetles Rule



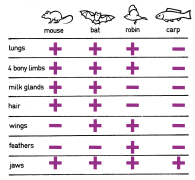
numbers in thousands

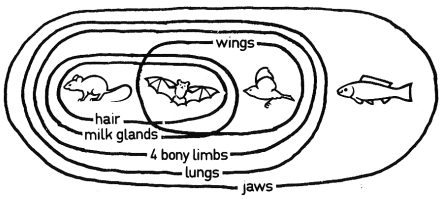


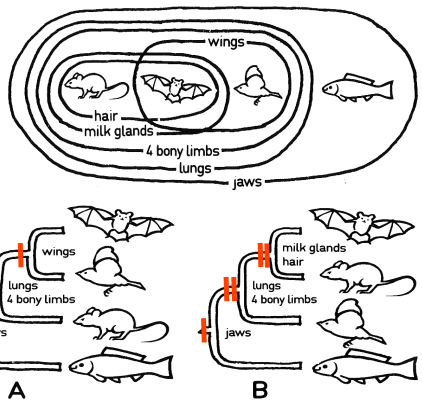
Data Matrix

	mouse	bat	robin	carp
lungs	+	+	+	−
4 bony limbs	+	+	+	−
milk glands	+	+	−	−
hair	+	+	−	−
wings	−	+	+	−
feathers	−	−	+	−
jaws	+	+	+	+

Sort into groups



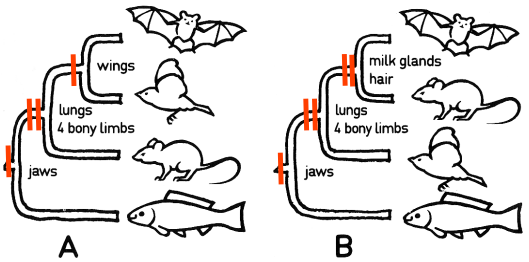




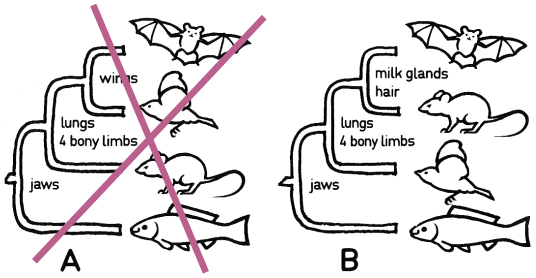
So which of the two phylogenies would you select as the better supported phylogenetic hypothesis?

?

Multiple trees



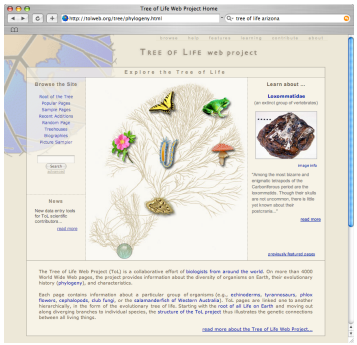
Multiple trees



Choose cladogram B, because it is supported by 5 shared features. Cladogram A is supported by only 4 shared features.

An Introduction to Animal Diversity

Tree of Life

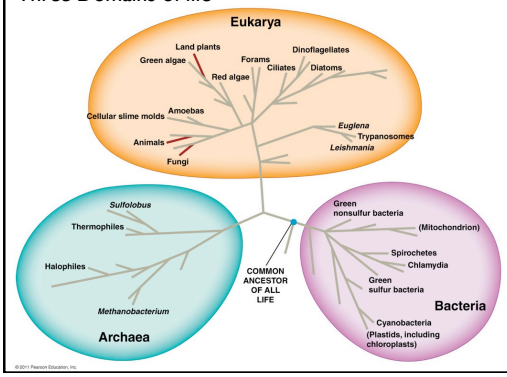


Animal Diversity

- 3 domains (Archaea, Bacteria, Eukarya)
- Within the Eukarya (protists, plants, fungi, animals)
- 35 phyla of animals --- 95% of all animals are INVERTEBRATES!

Animal Diversity

Three Domains of life



Animals are an extremely diverse kingdom of life

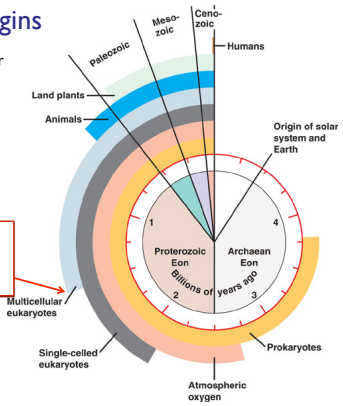
- Millions of species
- Many of the phyla arose ~530 mya
- Vertebrates and invertebrates
- Most animal species are invertebrates

Animal Life Begins

- Animals have been around for more than a billion years
- The animal kingdom includes not only great diversity of living species, but even greater diversity of extinct ones

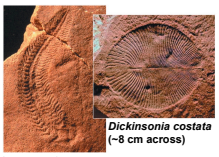
No multicellular organisms for 2/3rds of earth history!

565 MYA



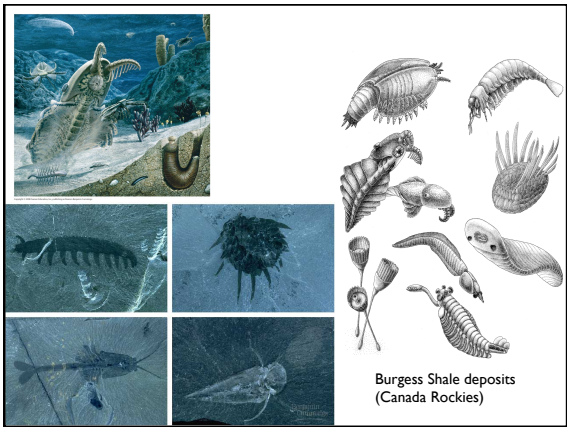
Animal diversification began more than half a billion years ago

- The oldest generally accepted animal fossils that have been found are 575–550 million years old.
- Animal diversification appears to have accelerated rapidly from 535 to 525 MYA, during the Cambrian period, known as the Cambrian explosion.
- The most celebrated source of Cambrian fossils is the Burgess Shale containing a cornucopia of perfectly preserved animal fossils.



Dickinsonia costata (~8 cm across)

Spriggina floundersi (~3 cm long)



Burgess Shale deposits (Canada Rockies)

Details on the Cambrian explosion

Possibly caused by

- increasingly complex predator-prey relationships or
- an increase in atmospheric oxygen.

Much of the diversity in body form among the animal phyla is associated with variations in where and when homeotic genes are expressed within developing embryos.

Of the 35 or so animal phyla, all but one are invertebrates, (they lack vertebra).

www.ucmp.berkeley.edu/cambrian/camb.html

Properties of animals

Eukaryotes

Heterotrophs

No cell walls

Eat by ingestion (mostly true)

Some exceptions (e.g. tape worms)

Diploid (mostly true)

Some exceptions (e.g. some social insects)

Sexual (mostly true)

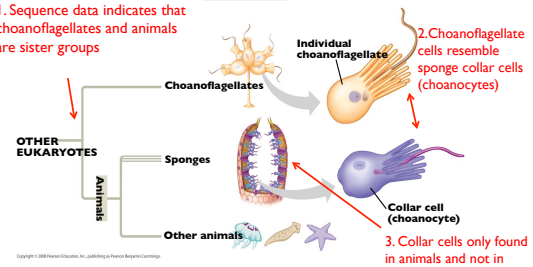
Some exceptions (e.g. parthenogenesis in some sharks or jellyfish)

Choanoflagellate-like organisms are thought to be the animal "ancestor"

Common ancestor of animals probably a colonial flagellated protist related to **choanoflagellates**, a protistan group that arose between 675 and 875 MYA

EVIDENCE

1. Sequence data indicates that choanoflagellates and animals are sister groups

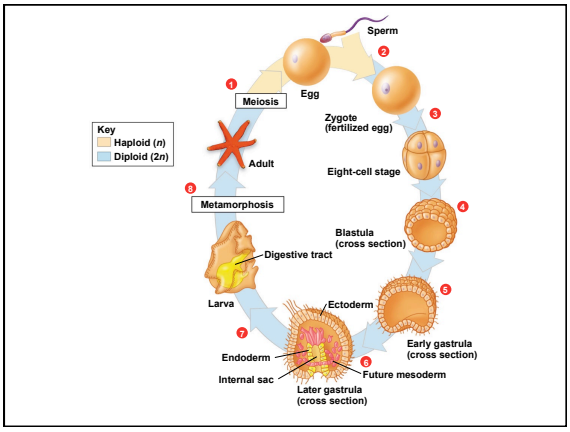


2. Choanoflagellate cells resemble sponge collar cells (choanocytes)

3. Collar cells only found in animals and not in protists

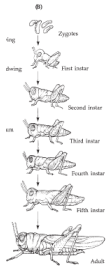
9 General Animal Characteristics

1. Animals are multicellular
2. Cells lack cell walls
3. Animals are heterotrophic (vs. autotrophic)
4. Most reproduce sexually w/diploid stage usually dominating life cycle
5. After a sperm fertilizes an egg the zygote undergoes cleavage, leading to the formation of a blastula, embryonic tissues and gastrula.
6. Cell specialization: specialized neural cells (nervous tissue) and muscle cells (muscle tissue) are unique to animals
7. During development three germ layers give rise to the tissues and organs of the animal embryo. Animal body plans vary by organization of tissues.
8. Tissues are held together by structural proteins such as collagen.
9. All animals, and only animals, have the highly conserved *Hox* family of genes that regulate the development of diverse body form.



Differences in development across animals

Direct development



- After the gastrula stage, many animals develop directly into adults.
- Other animals develop into one or more larval stages before taking the adult form.
  - A **larva** is an immature individual that looks different from the adult animal.
  - A larva undergoes a major change in body form, called **metamorphosis**, and becomes a reproductively mature adult.

Metamorphosis

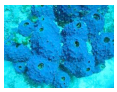
Examples: sea star, crabs, butterflies
Not pillbugs (rollypollies)

Animals can be characterized by basic features of their "body plan"

- Animal body plans vary in
  - presence of true tissues
  - symmetry
  - number of embryonic layers
  - presence of a body cavity
  - details of their embryonic development
- These characters, as well as DNA sequence, can be used to determine the phylogeny of animals.

Types of symmetry in animals

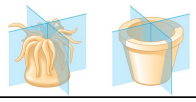
- Animals can be categorized according to body symmetry (or lack of it) – both present in fossil record for 550 million years
- In general – symmetry fits lifestyle
- Animals either have **radial** or **bilateral** symmetry
- (note exception of sponges)



Radial symmetry

have a top and bottom but lack back and front or R and L sides. An imaginary slice through the central axis divides them into mirror images.

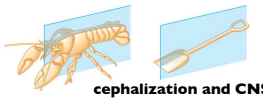
Most sessile or passive planktonic
Allows organisms to meet environment well from all sides



Bilateral (two-sided) symmetry

Animals with **bilateral symmetry** have mirror-image right and left sides and a

- distinct head, or **anterior** end,
- tail, or **posterior** end,
- back, or **dorsal**, surface, and
- bottom, or **ventral**, surface.

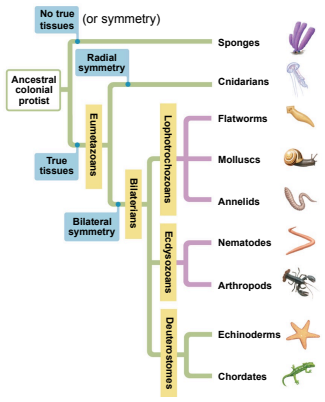


cephalization and CNS

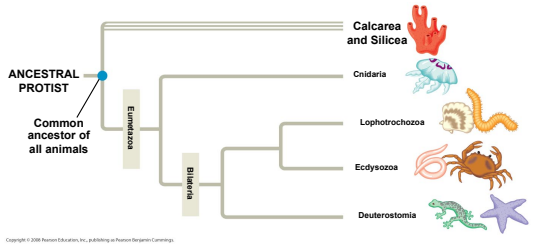
Invertebrates: animals without backbones

THE MARCH OF THE PHYLA!

Invertebrate Phyla



(Figure 18.4)



Phylum Arthropoda

The most abundant phylum!

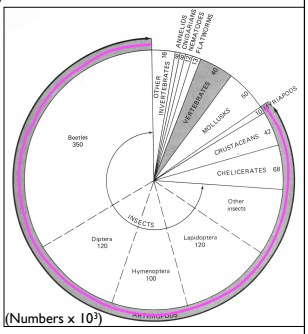
- There are > 1 million species of **arthropods** (including crayfish, lobsters, crabs, barnacles, spiders, ticks, and insects, many zooplankton).
- Arthropods have
  - an **open circulatory system** and
  - an **exoskeleton of chiton**, an external skeleton that protects the animal but must be shed in the process of **molting** to permit growth.
  - The body of most arthropods includes a **head, thorax, and abdomen**, although these segments may be fused.

What are the numbers?

2/3 of described species of animals are arthropods. The vast majority of known animal species (> 1 million! spp)

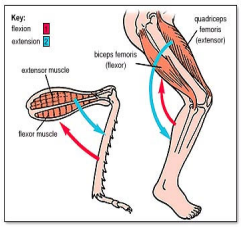
On the criteria of species diversity, distribution, and sheer numbers, arthropods are the most successful animal phylum! Found in nearly all habitats of the biosphere

Think JOINTED EXOSKELETON!



(Numbers x 10^3)

The Exoskeleton



- made of a tough fibrous material called chitin.
- gives the skeleton strength and flexibility.
- several pairs (5 or more) of jointed appendages (movable arms and legs).

Arthropod Diversity

- The body of an arthropod
  - is completely covered by the cuticle, an exoskeleton made of chitin
- When an arthropod grows
  - it molts its exoskeleton in a process called ecdysis
  - ecdysiast = stripper

Arthropod Limbs

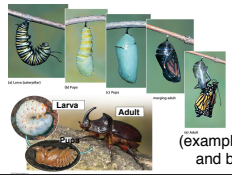
Arthropod Molting

Arthropod Flight

Types of metamorphosis in insects

- Insect life cycles often include **metamorphosis**, during which the animal takes on different body forms as it develops from larva to adult.
  - More than 80% of insect species undergo **complete metamorphosis** in which a free-living larva transforms from a pupa into an adult.

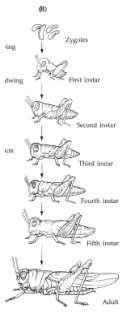
Other insect species undergo **incomplete metamorphosis** in which the transition from larva to adult is achieved through multiple molts, but without forming a pupa.



Complete metamorphosis (indirect development)

(example: butterflies and beetles); not pillbugs

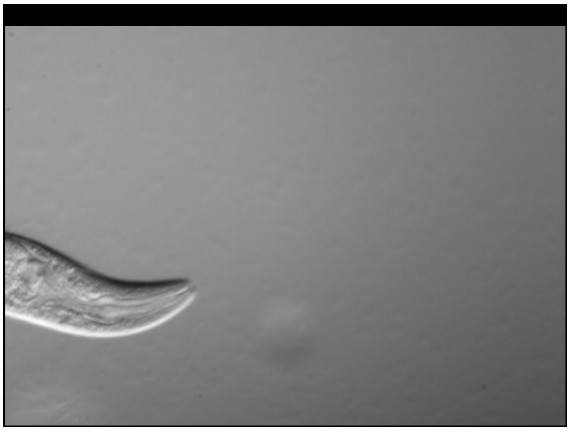
Incomplete metamorphosis (direct development)



Phylum Nematoda

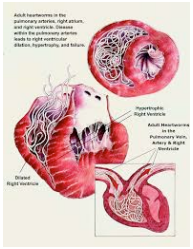
Have a pseudocoelom and a complete digestive tract

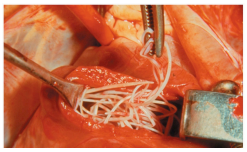
- **Nematodes** or roundworms (phylum Nematoda) are abundant and diverse, with ~500,000 species. Nematodes have
  - bilateral symmetry,
  - three tissue layers = triploblastic
  - a nonliving **cuticle** covering the body that prevents them from drying out,
  - a pseudocoelom body cavity that functions to distribute nutrients and as a hydroskeleton, and
  - a **complete digestive tract** with a mouth and anus.



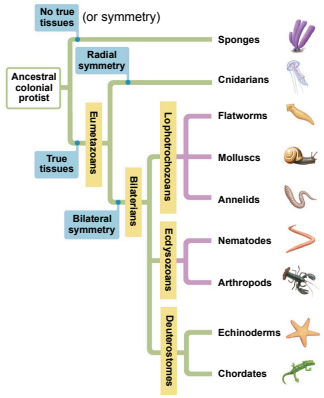
Nematodes

- Although about 25,000 species of nematodes have been named, estimates of the total number of species range >500,000.
- Humans host at least 50 species of parasitic nematodes.





Invertebrate Phyla



(Figure 18.4)

Phylum Platyhelmenthes (Flatworms): the simplest bilateral animals

- The vast majority of animal species belong to the clade Bilateria, consisting of animals with bilateral symmetry.
- **Flatworms** are the simplest bilaterians.
- Live in marine, freshwater, and damp terrestrial habitats.
- Some are parasitic and others are free-living.

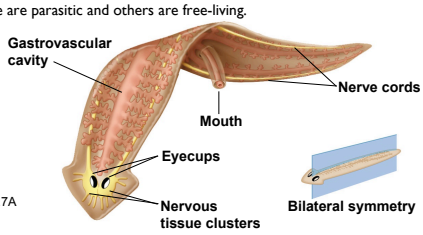


Figure 18.7A

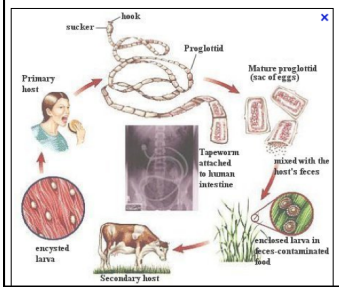
There are three major groups of flatworms

1. **Free-living flatworms** (planarians) have
   - heads with light-sensitive eyespots,
   - flaps to detect chemicals,
   - dense clusters of nerve cells that form a simple brain and a pair of nerve cords that runs the length of the body
   - a branched gastrovascular cavity with a single opening.

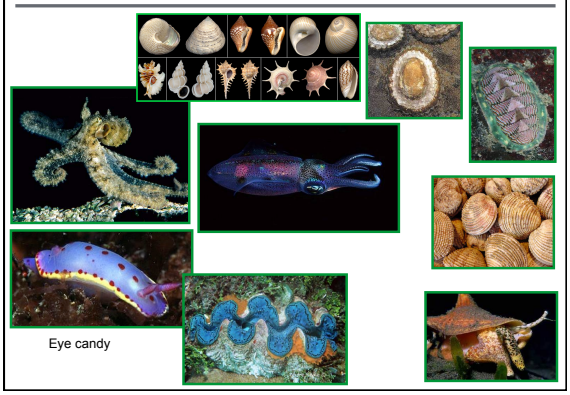
2. **Flukes** are parasitic flatworms with complex life cycles and suckers to attach to their hosts.

3. **Tapeworms**

are parasitic inhabitants of the digestive tracts of vertebrates,
consist of a ribbon-like body with repeated units,
have an anterior *scolex* armed with hooks and suckers that grasp the host,
have no mouth, and simply absorb nutrients across their body surface.
Units at the end of tapeworms are full of ripe eggs that pass out of host.



Phyla Mollusca

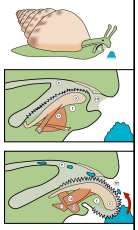


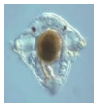
Eye candy

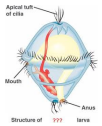
Diverse variations on a common body plan

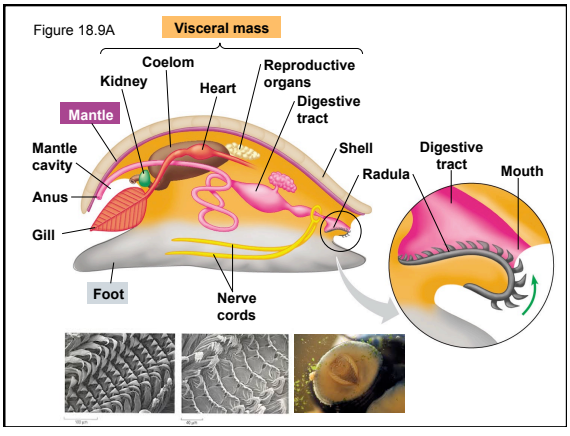
Molluscs (phylum Mollusca) have

- a **muscular foot** that functions in locomotion,
- a **visceral mass** containing most internal organs,
- a **mantle**, which may secrete a shell that encloses the visceral mass, and
- a **true coelom** and a circulatory system that pumps blood throughout the body.
- Many molluscs feed with a rasping **radula**, used to scrape up food.
- The life cycle of many marine molluscs includes a **ciliated trochophore larval stage**.







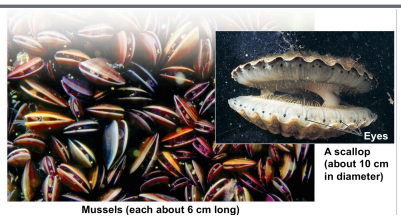


Molluscs: Gastropods

The largest group of molluscs and include the snails and slugs.

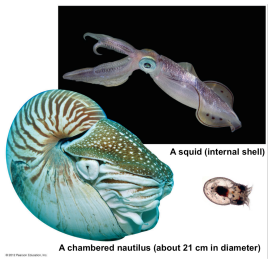
- found in fresh water, marine, and terrestrial environments,
- the only molluscs that live on land, using the mantle cavity as a lung, and
- often protected by a single, spiral shell.
- Slugs have lost their mantle and shell and some have long colorful projections that function as gills.

Molluscs: Bivalves



- Include clams, oysters, mussels, and scallops and
- Have shells divided into two halves that are hinged together.
- Most bivalves are sedentary suspension feeders, attached to the substrate by strong threads.

Phyla Mollusca: Cephalopods



- Are fast, agile predators,
- Have large brains and sophisticated sense organs, including complex image-focusing eyes,
- Have a shell that is large in a nautilus, small and internal in a squid, or missing in an octopus.
- Squid are fast, streamlined predators that use a muscular siphon for jet propulsion.
- Octopuses live on or near the seafloor, where they are active predators.

(direct development in octopuses)

Squid are the largest invertebrates

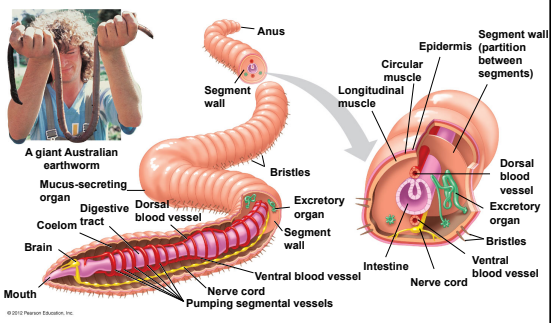
Phylum Annelida: The segmented worms

Annelids have

- **segmentation**, the subdivision of the body along its length into a series of repeated parts,
- a **true coelom** that functions as a hydrostatic skeleton,
- **triploblastic** tissue organization
- a **nervous system** that includes a simple brain and ventral nerve cord, and
- a **closed circulatory system** in which blood remains enclosed in vessels throughout the body.

Annelids are found in damp soil, the sea, and most freshwater habitats.

Figure 18.10A



3 classes: Oligochaetes, Polychaetes and Leeches

Types of annelids

Oligochaetes (earthworms) ingest soil and extract nutrients, aerating soil and improving its texture.

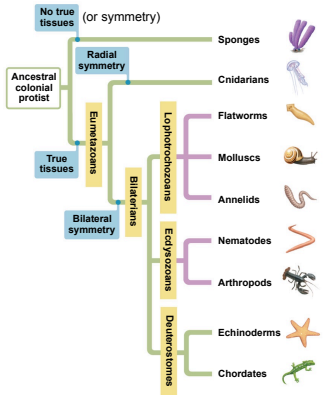
Polychaetes are the largest group of annelids.

- Each polychaete segment has a pair of fleshy appendages with stiff bristles or chaetae.
- Polychaetes search for prey on the seafloor or live in tubes and filter food particles.

Most **leeches** are free-living carnivores; or blood suckers.

- Blood-sucking leeches use razor-like jaws, secrete an anesthetic and an anticoagulant, and suck up to 10 times their own weight in blood.

Invertebrate Phyla



(Figure 18.4)

Phylum: Cnidaria

- Characterized by radial symmetry
- Two tissue layers—epidermis and digestive lining—with a jelly-filled middle region.
- Cnida (nematocysts) – stinging cells (hallmark of the phyla)

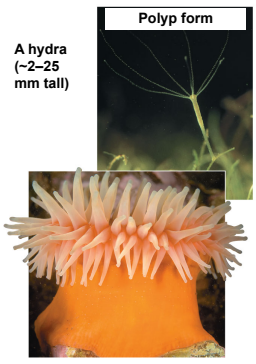
Cnidarians exhibit two kinds of body forms.

- The most sedentary **polyp** body is cylindrical with tentacles projecting from one end and/or
- The more mobile **medusa** form is exemplified by a jellyfish.

Figure 18.6A&B

A marine jellyfish (~6 cm in diameter)

A hydra (~2–25 mm tall)

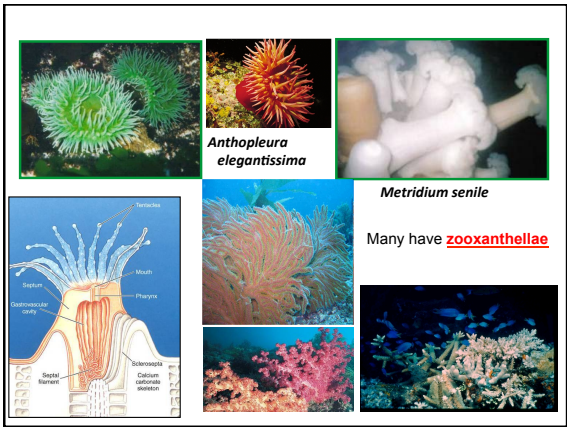


A sea anemone (~6 cm in diameter)

Phylum Cnidaria: with stinging cells

Cnidarians are carnivores that use their tentacles to capture prey and to push prey into their mouths.

- The mouth leads to the **gastrovascular cavity**, which functions in digestion and circulation and as a hydrostatic skeleton.
- **Cnidocytes** are unique stinging cells that capture prey and function in defense.

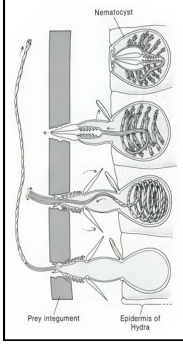


Cnidocytes

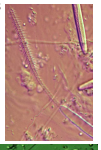
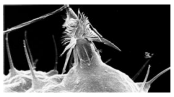
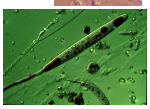
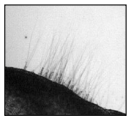
- Complex intracellular organelles cnidocytes (specialized cells that produce nematocysts)

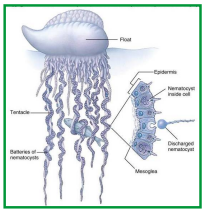
PURPOSE
- Food capture
- Protection

Cnidocil - triggered chemically or mechanically; operculum pops open, rapid change in pressure discharges thread (~ 3 msec.)







Ex: Portuguese man-of-war (*Physalia*)

passive feeders; lure prey by wriggling individual specialized tentacles

Prey Mimicry

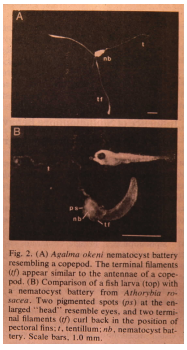
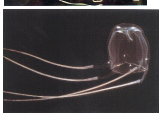


Fig. 2. (A) *Agalma okeni* nematocyst battery resembling a copepod. The terminal filaments (*tf*) appear similar to the antennae of a copepod. (B) Comparison of a fish larva (top) with a nematocyst battery from *Athorybia rosacea*. Two pigmented spots (*ps*) at the enlarged "head" resemble eyes, and two terminal filaments (*tf*) curl back in the position of pectoral fins; *t*, tentillum; *nb*, nematocyst battery. Scale bars, 1.0 mm.


(Purcell 1980)

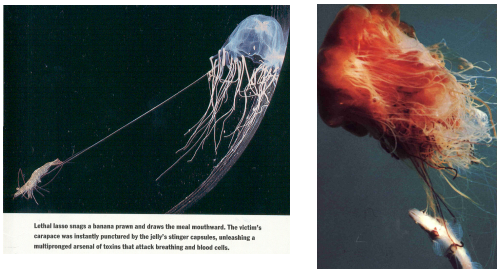
Box Jellyfish/Cubomedusae (*Chironex fleckeri*)

- Medusa is cuboidal
- Tentacles hang from corners
- Polyps reduced or absent
- Highly toxic nematocysts
- Can eat large fish

death can occur 3-20 min after sting

Why so deadly?



Lethal lasso snags a banana prawn and draws the meal mouthward. The victim's carapace was instantly punctured by the jelly's stinger capsules, unleashing a multipronged arsenal of toxins that attack breathing and blood cells.

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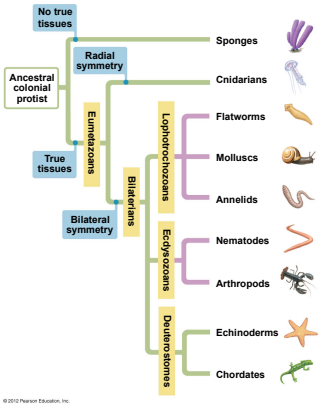
Figure 18.15



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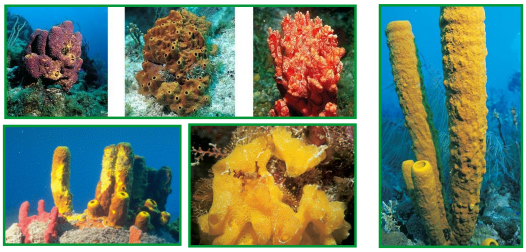
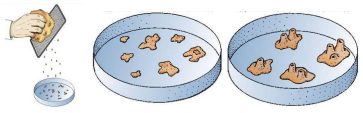
Phylum Porifera (sponges)



- No symmetry
- No tissues
- Spicules
- Very primitive/basal



Sponge Anatomy

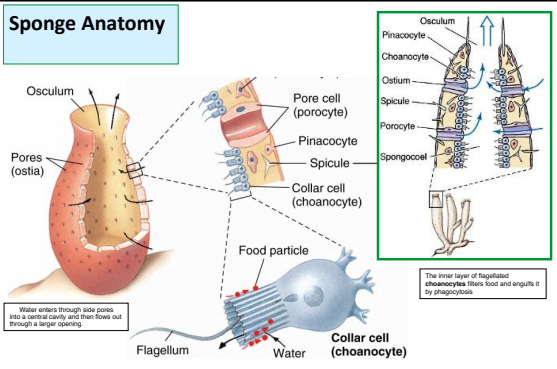
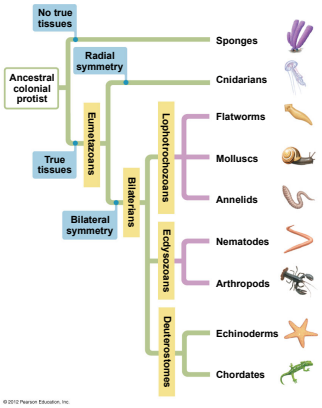


Figure 18.15



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Phyla Echinodermata

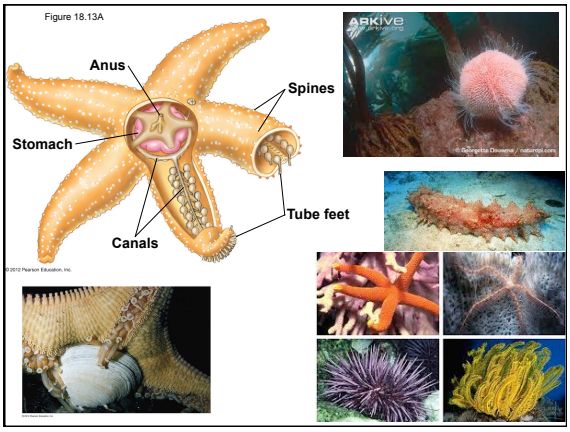
Echinoderms have spiny skin, an endoskeleton, and a water vascular system for movement

Echinoderms: a diverse group including sea stars, sea cucumbers sand dollars, and sea urchins,

- slow-moving or sessile
- all marine
- radially symmetrical, and
- deuterostomes (along with the chordates).

Echinoderms have

- an **endoskeleton** of hard calcareous plates under a thin skin,
- a **water vascular system** based on a network of water-filled canals that branch into extensions called tube feet, and
- the ability to regenerate lost arms.



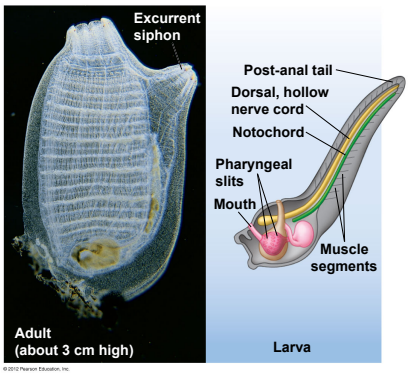
Features of our own phylum, Chordata

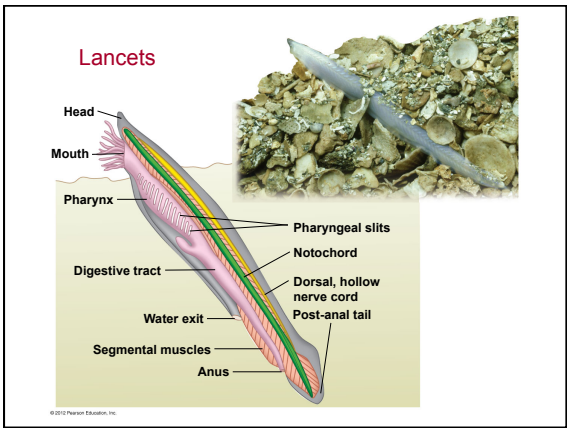
Contains vertebrates and their invertebrate ancestors.

The simplest chordates (tunicates and lancelets) lack a backbone.

Most **chordate** embryos and/or adults possess

- a **dorsal, hollow nerve cord**,
- a flexible, supportive **notochord**
- **pharyngeal slits**, and
- a muscular **post-anal tail**.




Lancets
Head
Mouth
Pharynx
Pharyngeal slits
Notochord
Digestive tract
Dorsal, hollow nerve cord
Post-anal tail
Water exit
Segmental muscles
Anus