Phylogeny of Life on Earth

"The affinities of all the beings of the same class have sometimes been represented by a great tree... As buds give rise by growth to fresh buds, and these if vigorous, branch out and overtop on all sides many a feebler branch, so by generation I believe it has been with the great Tree of Life, which fills with its dead and broken branches the crust of the earth, and covers the surface with its ever branching and beautiful ramifications."

Charles Darwin , 1859

www.tolweb.org

Diversity

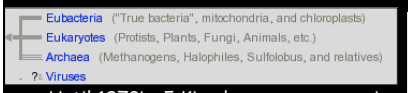
Goals:

To explore in broad terms the phylogeny of Metazoa and the diversity of invertebrate animals.

- Improve your ability to interpret phylogentic trees
- Become familiar with the current understanding of the phylogeny of major groups of organisms
- Review Linnean taxonomic classification
- Identify/learn about unique characteristics of invertebrates, especially those living in water

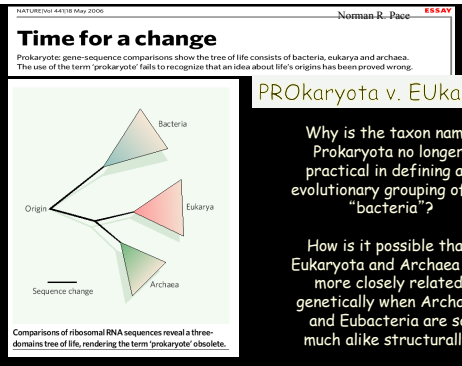
Phylogeny of Life on Earth

(from TREE OF LIFE PROJECT)



The major branches of living organisms (Domains)

- Until 1970's, 5 Kingdoms were recognized was:
  Bacteria (Prokaryota Domain)
  Protista, Fungi, Plantae, Animalia (Eukaryota)
- Archeans discovered in 1977 by Carl Woesa and George E. Fox in phylogenetic trees based on the sequences of ribosomal RNA (rRNA) genes
- First called Archeabacteria, but now 4 phyla of Archeans
  Archea are VERY different from Eubacteria



NATURE|Vol 441|18 May 2006 ESSAY

Norman R. Pace

Time for a change

Prokaryote gene-sequence comparisons show the tree of life consists of bacteria, eukarya and archaea. The use of the term 'prokaryote' fails to recognize that an idea about life's origins has been proved wrong.

Comparisons of ribosomal RNA sequences reveal a three-domains tree of life, rendering the term 'prokaryote' obsolete.

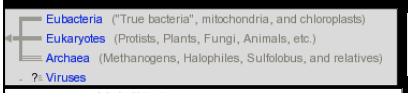
PROkaryota v. EUkaryota

Why is the taxon name Prokaryota no longer practical in defining an evolutionary grouping of all "bacteria"?

How is it possible that Eukaryota and Archaea are more closely related genetically when Archaea and Eubacteria are so much alike structurally?

Phylogeny of Life on Earth

(from TREE OF LIFE PROJECT)



The major branches of living organisms

Eukaryotes
Opisthokonts
Multicellularity

Opisthokont lineage :
-unicellular motile stage bearing a single posterior flagellum
-flattened mitochondrial cristae
-a unique ~12 amino acid insertion in the protein EF1alpha.

Invertebrate Diversity

(with an introduction to biological classification)

Loosely based on Ch 1, Pechenik

Linnean System of Nomenclature

Phylum Mollusca
Class Gastropoda
Order Pulmonata
Family Helicidia
Genus *Helix*
Species *pomatia*

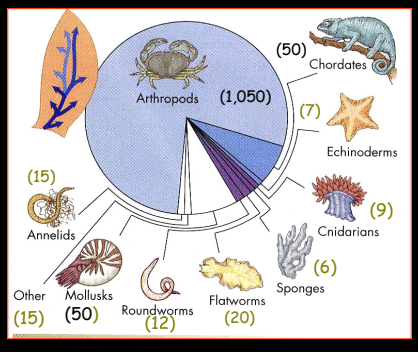

Helix pomatia

By convention, species are referred to by their genus and species name. Use of its common name, "land snail" or "escargot" may be ambiguous in some contexts.

Linnean System of Nomenclature

"Land Snail"	"Black Turban Snail"
Phylum Mollusca	Phylum Mollusca
Class Gastropoda	Class Gastropoda
Order Pulmonata	Order Prosobranchia
Family Helicidia	Family Trochidae
Genus Helix	Genus Tegula
Species pomatia	Species funebralis
Helix pomatia	Tegula funebralis

Within the Animal Kingdom or Metazoa, there are about 32-33 distinct groups or phyla



What is a Phylum?

Is a Phylum a natural unit?

Grouping of organisms that have a common design, (body plan), *and share one or a group of fundamental characters that distinguish them from other phyla.*

Or simply , a primary division of a kingdom, as of the animal kingdom, ranking next above a class in size.

Ex. Phylum Arthropoda: jointed exoskeleton

Ex. Phylum Chordata
Why not phylum Vertebrata????

What is a Species?

A group of similar organisms that can potentially interbreed successfully in nature.

Is a species a natural unit?

What about Class
Order
Family
Genus ?

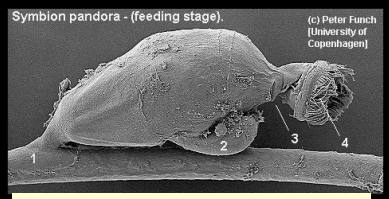
Phylocode

More important to understand phylogeny then it is to perfect taxonomy

Two Newest Phyla

Phylum Cycliophora: discovered in 1994 living attached to the lips of lobsters

(by Reinhardt Kristensen and Peter Funch who also discovered the Loricifera in 1986)



Key:
1 – adhesive disc attached to bristle surrounding lobster's mouth
2 – dwarf male
3 – anus
4 – ring of cilia around mouth funnel

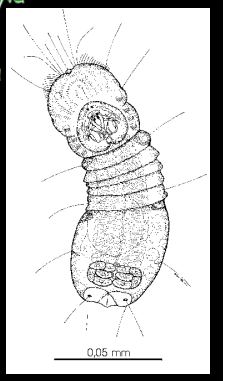
SEM image kindly supplied by Peter Funch, University of Copenhagen.

Two Newest Phyla

Phylum Micrognathozoa

Discovered in a cold spring in Greenland

by R.M.Kristensen & P. Funch (2000)



Rather than new discoveries of higher taxa, most phylogenetic research today is focused on understanding the relationships and evolution of known groups.

Xenoturbellida: The Fourth Deuterostome Phylum and the Diet of Worms

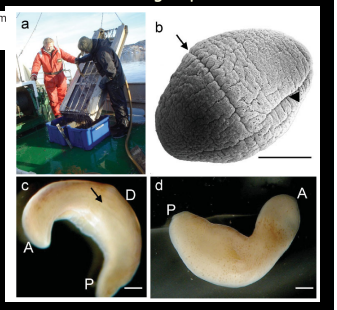
Maximilian J. Telford*

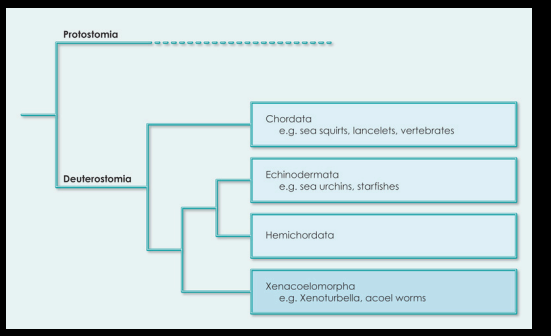
2008
Genesis 46:580-586

•1915 described as a flatworm
•1997 a mollusc based on r-DNA

Xenoturbella

•20 new phylum Xenoburbellida
•2011 combined with acoel flatworms into Xenocoelomorpha

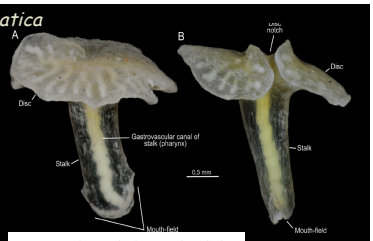


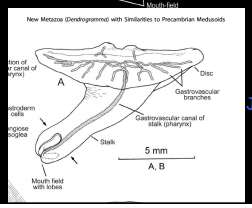


Dendrogramma enigmatica
incerti sedis

Collected from
400-1000m
Off Tamania in 1986

Not Ph Ctenophora
Or Ph Cnidaria





Just *et al.* 2014
PLOS one
Vol 9: 1-11

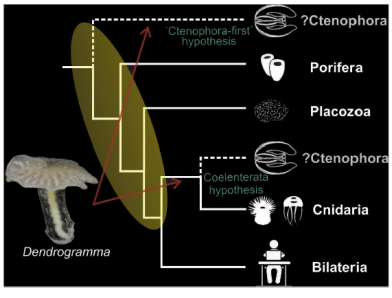


Figure 8. Possible positions of *Dendrogramma* in a simplified phylogeny showing the deepest splits in the metazoan Tree of Life. The position of Ctenophora is controversial so two possibilities have been shown with dashed lines, one as sister group to the remaining metazoans (the 'Ctenophora-first' hypothesis), and one as sister group to Cnidaria (Coelenterata hypothesis) (based on [6,7,8,24,25]. We suggest that *Dendrogramma* most likely is related to Ctenophora and/Cnidaria (red arrows) due to general similarities in body organisation (see Discussion). However, depending on the position of Ctenophora and on whether certain aspects of *Dendrogramma* (e.g., mesoglea and gastrovascular system) are ancestral for Metazoa or modified, *Dendrogramma* can be positioned in a variety of ways below Bilateria (yellow oval).
doi:10.1371/journal.pone.0102976.g008

Where do invertebrates live?

- Most species live in terrestrial habitats, (roughly 900 K or about 80% of all species)

- However, only 9 phyla have invaded land and only two are highly successful terrestrial inhabitants

- 16 phyla are exclusively marine; in the oceans we find the greatest higher order diversity

- Three phyla occur only as parasites

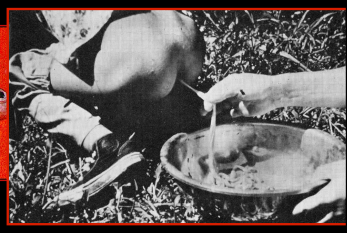
Exclusively parasitic phyla:

Acanthocephala: spiny-headed worms; gut parasites of vertebrates, especially fishes, mammals

Nematomorphs: horsehair worms, juvenile parasites in arthropods

Mesozoa: also degenerate animals that parasitize invertebrates, particularly cuttlefish and octopuses

Nematomorph



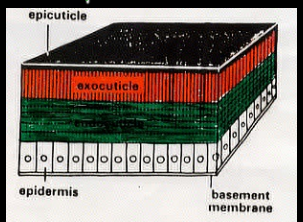
Parasitism:
-- most phyla have parasitic groups
-- 3 phyla are exclusively parasitic

What invertebrates have been most successfull in colonizing terrestrial habitats?

Arthropods!!

Why Arthropods?

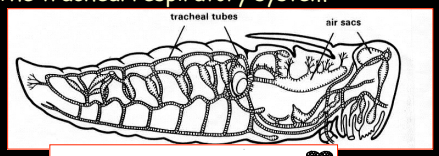
Cuticle provides support and a barrier to water loss. A waxy component makes the cuticle waterproof

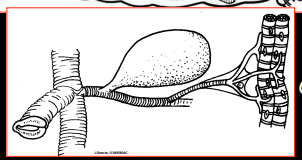


Body wall of an arthropod. The *epicuticle* is thin and non-chitinous. *Exocuticle and endocuticle* are a composite of chitin and proteins. The *epidermis* secretes the cuticle and is underlain by a *basement membrane*.

Why Arthropods?

The tracheal respiratory system





Close up

What other phyla have invaded land?

Based on Pechenik table 1.1

	Water	Air
Humidity	High	Low
Density (support)	High	Low
Viscosity (resistance)	High	Low
Oxygen solubility	Low	High
Oxygen Diffusion	Low	High
Nutrient Content	High	Low

What are the implications of each of these differences for organisms living in these habitats?

Unique Features of Aquatic Animals

1. Gas exchange through gills, body wall
2. Absorption of dissolved nutrients
3. Fertiliziation by broadcast spawning
4. Rigid skeletal support not necessary
5. Drifting way of life possible
6. Suspension and filter feeding
7. Sedentary life style possible

Unique Features of Aquatic Animals

Gas exchange, excretion, absorption

Works well for animals of very small size, animals that are flat, and animals that are mostly water:
cnidarians, sponges, flatworms

Unique Features of Aquatic Animals

Gas exchange, excretion, absorption

Larger animals, animals with thicker integuments require gills, kidneys and other organs

Unique Features of Aquatic Animals

Fertiliziation by broadcast spawning

Not common in arthropods, cephalopods

Limitations due to diffusion and dispersal of gametes.

Adaptations?

Unique Features of Aquatic Animals

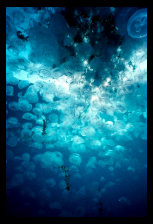
1. Gas exchange through gills, body wall
2. Absorption of dissolved nutrients
3. Fertiliziation by broadcast spawning
4. Rigid skeletal support not necessary
5. Drifting way of life possible
6. Suspension and filter feeding
7. Sedentary life style possible

Unique Features of Aquatic Animals

Due to the density of water, a rigid skeletal support not necessary; Drifting way of life possible

Hydrostatic skeleton

Two ways to be a drifter



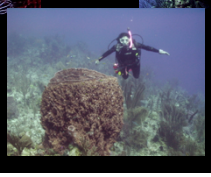
Plankton Video

Unique Features of Aquatic Animals

Suspension and filter feeding is common and sedentary life styles are possible

Fan worms

Cnidarians
(black sea rod)



Sponges

Unique Features of Aquatic Animals

Suspension and filter feeding is common and sedentary life styles are possible

Problem with suspension feeding:
getting sufficient food from a diffuse source

Two solutions to concentrating food:

1. let currents do the work and use an effective prey capture device (e.g. cnidarian stinging cells)

2. Use cilia to create a current, and mucus or cilia to capture food particles:

- ciliary reversal mechanism
- opposed band mechanism
(deuterostomes v. protostomes)

Sedentary life style is possible.

Modular growth is prevalent among some groups.

-Modular vs. unitary life styles

- Ramets and genets

-What might be the advantages of modular body plan?

- Growth vs. reproduction

Why aren't all animals modular?

TABLE 1. MEAN SPECIES DURATIONS IN MILLIONS OF YEARS FOR CLONAL AND ACLONAL SCLERACTINIAN CORALS

	number of species	mean duration	standard deviation
aclonal corals	376	9.06	5.51
clonal corals	1005	9.57	6.06

Jackson and Coates, 1986