Workshop: The Evolution of Animalia
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Perhaps even more than the other Eukarya, Animalia is characterized by a distinct progression of complexity in form and function as one moves from the more primitive to the more derived taxa. Early in animal evolution, major changes in body symmetry, embryonic germ layers, and ontogenetic origins of major anatomical structures diverge in the nascent monophyletic groups.

Over the course of this workshop, you will review the major changes that occurred during the evolution of Kingdom Animalia. By the end of the workshop, you should be able to

1. List the synapomorphies that distinguish animals from other eukaryotes
2. Understand the meanings of asymmetry, radial symmetry and bilateral symmetry
3. Be able to recognize the major animal phyla on the basis of
   a. body symmetry
   b. embryonic germ layers
   c. presence or absence of an internal body cavity
   d. ontogeny and morphology of the internal body cavity
   e. ontogenetic differences between protostomes and deuterostomes.
4. Be able to recognize acoelomate, pseudocoelomate and coelomate body plans
5. Distinguish between
   a. spiral and radial cleavage
   b. determinate and indeterminate cleavage
   c. schizocoely and enterocoely

I. What is an Animal?

Animals are eukaryotes, and hence may share a distant common ancestor with some or all other eukaryotes. However, there are several characteristics that set animals apart from all other types of organisms. List those characteristics below:

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

II. Germ Layers

Comparisons of ontogeny are sometimes used to devise phylogenies.

1. At what stage in an embryo's development are germ layers first present?
2. Which germ layer(s) form first, and where are they located?

3. Complete the following table

<table>
<thead>
<tr>
<th>PHYLUM</th>
<th>Germ Layers</th>
<th>Name of middle layer</th>
<th>Derivation of middle layer (ectoderm, endoderm or neither)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Porifera&quot;</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Cnidaria</td>
<td></td>
<td></td>
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<tr>
<td>Platyhelminthes</td>
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<td></td>
<td></td>
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<tr>
<td>Nematoda</td>
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<td></td>
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<tr>
<td>Annelida</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Echinodermata</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

a. What other Phylum has germ layer development characteristics similar to Cnidaria's?

b. What other Phylum/a show(s) germ layer development similar to Nematoda's?

c. What other Phylum/a show(s) germ layer development similar to Annelida’s?

d. What other Phylum/a show(s) germ layer development similar to Echinodermata’s?

Do you think that these ontogenetic similarities indicate monophyly in each of these cases? If not, why not? Discuss.

III. Body Symmetry: Define the following.

1. asymmetry -
2. radial symmetry -
3. bilateral symmetry -
4. oral surface -
5. aboral surface -
   6. dorsal -
   7. ventral -
   8. lateral -
   9. medial -
10. cephalic/anterior -
11. caudal/posterior -
12. sagittal section -
13. mid-sagittal section -
14. transverse section -
15. cephalization

Draw and Discuss

1. Asymmetry
   a. In the space below, sketch an example of an animal with no plane of body symmetry.

   b. Which animals are characterized by the lack of true body symmetry? Are the monophyletic? Is the absence of a character useful for developing phylogenies? Discuss.
2. Radial Symmetry
   a. In the space below, sketch examples of animals radial symmetry, including biradial, quadriradial, pentaradial and hexaradial symmetry.

   b. Which animal phyla are characterized by radial symmetry?

   c. Do you think radial symmetry in these phyla is homologous? Discuss.

3. Bilateral Symmetry
   a. In the space below, sketch an example of an animal exhibiting bilateral symmetry.

   b. Which animal phyla are characterized by bilateral symmetry?

   c. What is the functional significance of cephalization? Why do you think the majority of animals are bilaterally symmetrical? Discuss.

**IV. Internal Body Cavity**

Your textbook, course notes and other resources often provide you with a cross-sectional view of the three animal body plans. To demonstrate your understanding of the anatomy of acoelomate, pseudocoelomate and coelomate animals, sketch each of the three plans in LONGITUDINAL section. Label ectoderm, endoderm, and mesoderm/mesenchyme, intestinal lumen, parietal and visceral surfaces.

**ACOELOMATE:**
1. What is the function of the pseudocoelom?

2. Why is the pseudocoelom considered a “persistent blastocoel”?

COELOMATE:

3. What is the function of the coelom in the following coelomate phyla?
   a. Annelida -
   b. Mollusca -
   c. Arthropoda -
   d. Echinodermata -
   e. Chordata; Vertebrata -

4. Do your answers to #2 and #3 tell you anything about possible evolutionary relationships and monophyly of the taxa involved? If you’re not sure, then give your reasons. Discuss well!
V. Protostomes and Deuterostomes
The most derived lineages of eumetazoans have an internal body cavity (coelom; pronounced see-lome’) lined on both the parietal and visceral surfaces with mesoderm. However, the two major (putatively) monophyletic groups of coelomates achieve this adult anatomy in different ways. Other ontogenetic features also suggest that although the protostomes and deuterostomes share a common ancestor, the taxa within each lineage are distinct unto themselves. Consider the following and discuss.

1. What phylum might be an appropriate outgroup you could use to determine which protostome and deuterostome character states are primitive?

2. What might a hypothetical common ancestor of protostomes and deuterostomes have looked like?

3. Describe some possible ontogenetic origins of the following in a hypothetical common ancestor of protostomes and deuterostomes:
   a. origin of mesoderm (i.e., from ectoderm or endoderm?)
   b. fate of the blastopore (mouth or anus?)
   c. cleavage at the 4- to 8-cell stage (i.e., spiral or radial?)
   d. determinate or indeterminate cleavage?
   e. embryonic location of the circulatory system
   f. embryonic location of the nervous system

4. Do you think the coelom of an Annelid is homologous or analogous to that of a Chordate? Discuss.

VI. Diversification and Progression of Complexity
You should now have a good grasp of the progression of complexity in ontogeny and anatomy of the animals. Using the phylogenetic tree on the following page, place each of the characters listed at the proper place where it originated in an ancestral lineage, giving rise to today's extant animal phyla. At the root of the tree, begin with a hypothetical ancestral colonial flagellate. (Note that this phylogenetic tree does not include all animal phyla, and it's only the most recent hypothesis. It could change as new data become available.)

   a. diversification of cell types
   b. gastrulation
   c. ectoderm & endoderm (diploblasty)
   d. mesenchyme (mesoglea with cellular components)
   e. true mesoderm (triploblasty)
   f. pseudocoelom
   g. coelom derived via schizocoely
   h. coelom derived via enterocoely
i. blastopore becomes the mouth
j. blastopore becomes the anus
k. circulatory system dorsal in the embryo
l. circulatory system ventral in the embryo
m. nervous system ventral in the embryo
n. nervous system dorsal in the embryo
o. spiral, determinate cleavage
p. radial, indeterminate cleavage

Hypothetical Phylogeny of Animalia (www.tolweb.org).
1. The tree above is based on molecular data. Are the morphological characters you placed on the tree consistent with a most parsimonious explanation for the evolutionary relationships shown?

2. How is it possible that morphological data and molecular data might not produce trees that are congruent with each other? Discuss.

**DISCUSSION QUESTION**
Why is it important for humans to understand phylogenetic relationships of animals? Can you think of any practical applications, or is this just "science for science's sake?"