Protista and the Origin of Metazoans

**Goals:**
- Review characteristics of single cell body plan
- Explore the limitations of life as a single cell
- Learn some of the ways in which protists are important
- Evaluate evidence for the origin of animals from protist ancestors

**Introduction**

**I. Body Plan**

- **A. S.A./Volume Constraint**
- **B. Reynolds number**

**II. Important Protists**

- **A. In food webs**
- **B. Agents of disease**

**III. Origin of Metazoans**

Evidence for colonial origin and metazoan ancestors

Protista Defy Tidy Definition:

- >10 phyla, believed by some that they should be classified as Kingdoms
- Among them are the ancestors of multicell organisms including animals.

Body plan characterized by:

- **A. Unicellularity (most)**
- **B. Small Size (< 5-250 µm)**
- **C. Lacking Organ Systems (including a nervous system)**

Each individual is a cell that is functionally more versatile than any single cell from a multicell organism

Means of locomotion and associated structures are no longer considered key characters in establishing the phylony (evolutionary relatedness) of Protista.

Most Common TYPES of Protista:

- **Ciliates** (Phylum Ciliophora): externally ciliated
- **Sarcodinids**: 4 phyla of amoeboid types
  (Amoebas, foramenifera, radiozoans, heliozoans)
- **Flagellates**: several phyla of flagella-bearing types, including many photosynthetic forms and some important parasitic forms
- **Spore-Formers**: Phylum Apicomplexa and other very important parasitic forms
Kingdom Protozoa
Phylogeny is Complicated/Unresolved

<table>
<thead>
<tr>
<th>Alveolate Protozoa</th>
<th>Amoeboid Protozoa</th>
<th>Flagellated Protozoa</th>
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<tbody>
<tr>
<td><strong>PH CILIOPHORA</strong></td>
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<tr>
<td>(ciliates)</td>
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<td><strong>DINOZOA</strong></td>
<td><strong>GRANULORETICULOsa</strong></td>
<td><strong>EUGLENOZOA</strong></td>
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<td>(dinoflagellates)</td>
<td>(foramenifera)</td>
<td>Trypanosomes</td>
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<tr>
<td><strong>APICOMPLEXA</strong></td>
<td>(actinorians)</td>
<td>euglenids</td>
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<tr>
<td>(coccidians e.g. Plasmodium)</td>
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<td>trichomonads</td>
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<tr>
<td><strong>HELIOZOA</strong></td>
<td>(heliozoans)</td>
<td>Giardia</td>
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See pie chart ad taxonomic detail on pg 75

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I. Protistan Body Plan is Characterized by
   -- Primarily unicellular
   -- Small, 5-300 µm
   -- Lack organs (Lack a nervous system)

What constraints does the small unicellular body plan impose on the biology of protists?

SOFI Comments...
Too much phylogeny and evolution! This is not necessarily interesting to students.
I never knew what we had to learn and what he thought was just cool to know
I will not need to know most of the things I learned, but did learn things other than what I knew before. It was hard for me to get interested and excited, but the teacher was
This was one of my harder classes this semester. The tests were quite difficult and I really had to study to do well on them.
The grading is very fair. I really appreciate classes where you put in the effort you can do well and the professor doesn’t try to trick you with weird questions etc. on tests. It’s fair that everything on the tests we have gone over in class, it’s just the students job to decide if they want to study it or not. I wish more of my classes were like this.

Picture of the Day
Giant foraminifera
Notodendrodes antarctikus
- Eats crustaceans -important predator
Makes a sand case; selects grains of only certain sizes from sediments... Central to discussion about intelligence
Charles Darwin had this to say:
"The case of the three species of protozoan (I forget the names) which apparently select differently sized grains of sand, etc., is almost the most wonderful fact I ever heard of. One cannot believe that they have mental power enough to do so..."

http://kabinetofcuriosities.blogspot.com/2010/02/tree-foraminifera.html

I Inch (2.5 cm)
Notodendrodes antarctikus
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As a cell increases in size, exchange with the environment becomes more difficult.

\[
\text{Surface Area} \sim L^2 \\
\text{Volume} \sim L^3 \\
\text{Therefore } \frac{\text{S.A.}}{\text{V}} \text{ declines as } L \text{ increases}
\]

S.A./Vol relationship imposes a limit on cell size.

Some Amebas partly solve this problem.

Cytoplasmic streaming provides continuous mixing or circulation of the cytosol.

Small Size also affects scaling of physical forces.

Balance of inertia and drag on a moving organism depends on the size and velocity of the organism and on the viscosity of the medium. Expressed as Reynolds Number \((R_e)\):

\[
R_e = \frac{\text{velocity} \times \text{length of the organism}}{\text{viscosity of Medium}}
\]

When \(R_e\) is high, drag is relatively negligible (example, \(R_e\) is 30,000 for a dragonfly in flight).

When \(R_e\) is low, drag forces dominate movement (example, \(R_e\) for a protist could be <0.1).

In what way would low Reynolds numbers affect the ecology of protists?

Expressed as Reynolds Number \((R_e)\):

\[
R_e = \frac{\text{velocity} \times L}{\text{Viscosity of Medium}}
\]

What is life like at Low Reynolds numbers??

-- no inertia
-- force of gravity balanced by viscosity
-- yet ciliates travel 2 mm per sec. (8 body lengths)
-- feeding also affected

Vorticella feeding
Viscous forces can also be important in air but the medium is not very dense what conditions will produce a low Re??
Chagas’ Disease
*Trypanosoma cruzi*
(American trypanosome)

- Vector is a biting bug; parasite infects bug through feces
- Affects the nervous system and the heart; can be fatal

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Metazoa arose from Protozoa sometime before the Cambrian 1200-600 mya

- Which protozoan group was the ancestor??
- By what process was first metazoan formed??
- Are metazoans Monophyletic or Polyphyletic??
- What were the first Metazoans like??
- CAN WE EVER REALLY KNOW??

What is a “metazoan”??

- Eukaryotic and multicellular
- Cell differentiation and coordination; more than a colony or aggregation of cells
- Layers of cells organized into “tissues”
- Embryonic development; gastrulation

3 Phyla are Possible Candidates as Basal Group of all Animals

- Sponges
- Cnidarians
- Flatworms

Theoretically 3 ways in which a multicellular organism could evolve from a protist.

Symbiotic Hypothesis

Colonial Hypothesis

Cellularization Hypothesis
**Symbiotic Theory**

3 different types of cells come together forming first a symbiotic colony, then a composite organism.

**Strengths:** Origin of Eukaryotes from prokaryotes

**Weakness:** Genetic obstacles to reproduction. How do they integrate into a reproducing organism?

**Cellularization**

Metazoan ancestor a multicellular, bilateral ciliated protist that assumed a benthic lifestyle, with its oral groove directed toward the substratum. Surface nuclei became compartmented to produce a cellular epidermis producing a flatworm-like animal.

**Strengths:** Paramecium-flatworms are similar

**Weaknesses:** no evidence of "compartmentalization"; flatworms with complex embryology

**What about Cnidaria, Sponges?**

**Colonial Theory I**

Gastrea: Colonial flagellated protozoan gave rise to a blastula-like ancestor (blastea). Blastea invaginates to form gastrea. (Haeckle’s favorite)

**Strengths:** models exist (Volvox, choanoflag.)

**Weaknesses:** parallels animal embryology

**Choanoflagellates live as solitary and colonial forms**

**Similarities of Choanocytes (sponge cells) and choanoflagellates (protozoan)**

Choanocytes and Choanoflagellates
Model organization

Pandorina

Eudorina

Volvox

Opisthokonts share:
- Uniflagellate (reproductive) stages with flagellum at the posterior
- mitochondria with flattened, plate-like cristae

Genetic Evidence (18S r-DNA)

Based on sequence analyses of 5 proteins

Monosiga has 86% sequence homology with animals.

The Prostlan Origins of Animals and Fungi

Conclusions on Metazoan Origin

Evidence best supports the colonial theory

Choanoflagellate group is most likely ancestor:
- Evidence includes cell structure and genetic similarities
- Idea that metazoans are monophyletic is supported