BIO 221
Invertebrate Zoology I
Spring 2007

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http://www4.nau.edu/isopod

Lecture 7

Totipotent:

Cells can transform into any cell type.

Historical Remarks

2. Early invert. zoologists considered them allied with Cnidaria

a. But were later classified by R. E. Grant (*Grantia*) as Porifera

Historical Remarks

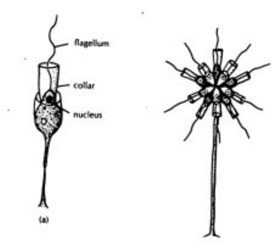
3. Later students recognized them as distinct from other animal phyla

a. Huxley (among others) suggested classification as PARAZOA -

Evolutionary Origins

1. Possibly derived from choanoflagellates

a. Note similarity in colony structure to inner walls of sponge.



Evolutionary Origins

2. As we will see, sponge embryology seems to contradict this

a. Early stages do resemble early development of true Metazoa

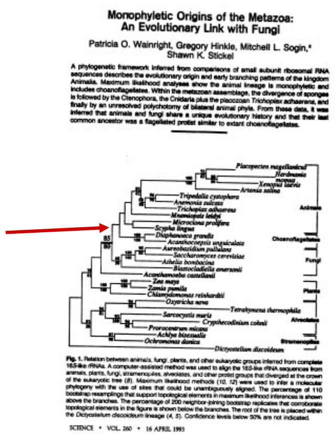
b. This similarity, however, could represent convergence.

Evolutionary Origins

3. However, Molecular evidence (Wainright et al. 1993)

a. Suggests close link between choanoflagellates and sponges

b. Tree branch with fungi as sister group has sarcomastigophroans as sister group.



Monophyletic Origins of the Metazoa: An Evolutionary Link with Fungi

Patricia O. Wainright, Gregory Hinkle, Mitchell L. Sogin,* Shawn K. Stickel

A phylogenetic framework inferred from comparisons of small subunit ribosomal RNA sequences describes the evolutionary origin and early branching patterns of the kingdom Animalia. Maximum likelihood analyses show the animal lineage is monophyletic and includes choanoflagellates. Within the metazoan assemblage, the divergence of sponges is followed by the Ctenophora, the Cnidaria plus the placozoan *Trichoplax adhaerens*, and finally by an unresolved polychotomy of bilateral animal phyla. From these data, it was inferred that animals and fungi share a unique evolutionary history and that their last common ancestor was a flagellated protist similar to extant choanoflagellates.

Fig. 1. Relation between animals, fungi, plants, and other eukaryotic groups inferred from complete 16S-like rRNAs. A computer-assisted method was used to align the 16S-like rRNA sequences from animals, plants, fungi, stramenopiles, alveolates, and other protist groups that diverged at the crown of the eukaryotic tree (8). Maximum likelihood methods (10, 12) were used to infer a molecular phylogeny with the use of sites that could be unambiguously aligned. The percentage of 110 bootstrap resamplings that support topological elements in maximum likelihood inferences is shown above the branches. The percentage of 200 neighbor-joining bootstrap replicates that corroborate topological elements in the figure is shown below the branches. The root of the tree is placed within the *Dictyostelium discoideum* lineage (4, 5). Confidence levels below 50% are not indicated.

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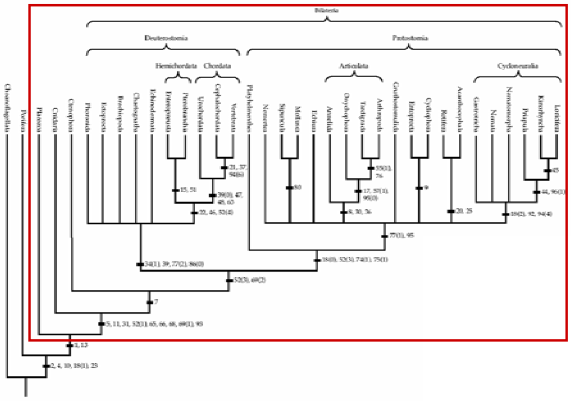
Evolutionary Origins

4. With respect to other groups (Conway Morris 1992; Brusca and Brusca 2004)

a. Porifera are the ***sister group*** to the rest of the Metazoa.



Number of Described Species

1. Approx 5,000 described species
a. 150 freshwater.
b. The rest (97%) are marine (suggests marine ancestry).
c. at least 4,000-6,000 are ***undescribed.***

The Importance of This Group

1. Sponges are a major component of invertebrate subtidal (intertidal) communities.
a. Often are the dominant life form.
b. In coral reefs are second only to corals themselves.
1. in some systems seem crucial to existence of corals as well.

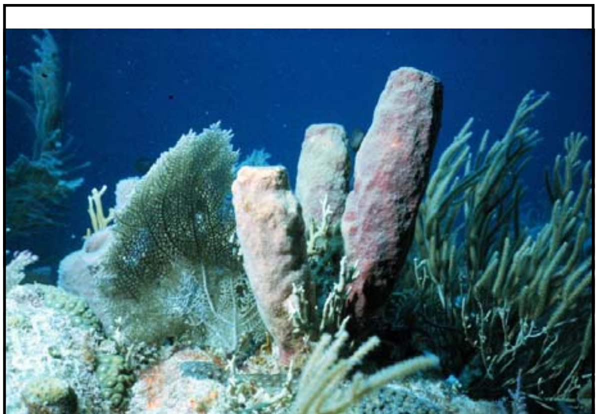
Filterers of DOC

2. Sponges are significant filterers of DOC (dissolved organic carbon), esp in coral reefs

a. coral reefs usually considered nonproductive waters

b. however, this is because of the action of sponges.

c. removal of turbidity allows corals to photosynthesize



The Importance of This Group

Exhibit important relationships with other animals

a. shelter for many species

1. *Leucetta losangelensis*: isopods, amphipods.
2. *Geodia* in Caribbean can house 16,000 shrimp.

The Importance of This Group

Some animals cultivate sponges on their bodies for protection.

c. They produce secondary compounds.

1. Permits predator avoidance; *Tedania*
2. Some produce secretion that are virus, bacteria killers.

Spicule Characteristics

a. Some allow sponges to be predators *Asbestopluma* sp.- have modified spicules that capture zooplankton as prey.

1. See article by Kelly-Borges 1995

2. calls into question the current classification of sponges as exclusive filter feeders.

Spicule Characteristics

3. Other recent work suggest that in fact, calcareous sponges are closer to metazoans than Hexactinellida and Demospongia.

a. produce hard substrate with spicules.

b. in Antarctic, spicule masses greatly increase species diversity.

Bioerosion

5. Certain sponges are significant agents of bioerosion.

a. *Cliona* decomposes reefs and mollusc shells.

b. thus they recycle $CaCO_3$ into reef habitat.

c. some species also etch silica.

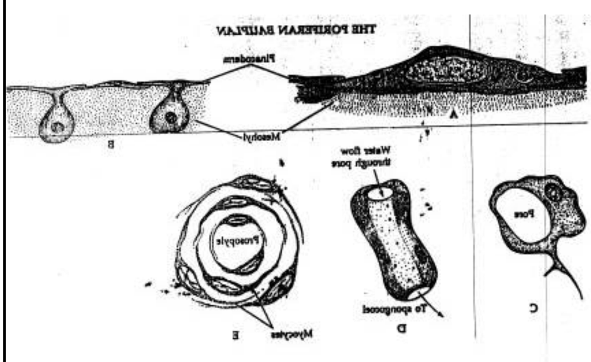
Box One

Characteristics of the Phylum Porifera

1. Metazoa at the cellular grade of construction; without true tissues; adults asymmetrical or radially symmetrical
2. Cells tend to be totipotent
3. With unique flagellated cells—choanocytes—that drive water through canals and chambers constituting the aquiferous system
4. Adults are sessile suspension-feeders; larval stages are motile
5. Outer and inner cell layers lack a basement membrane
6. Middle layer—the mesohyl—variable, but always includes motile cells and usually some skeletal material
7. Skeletal elements, when present, composed of calcium carbonate, silicon dioxide, and/or collagen fibers

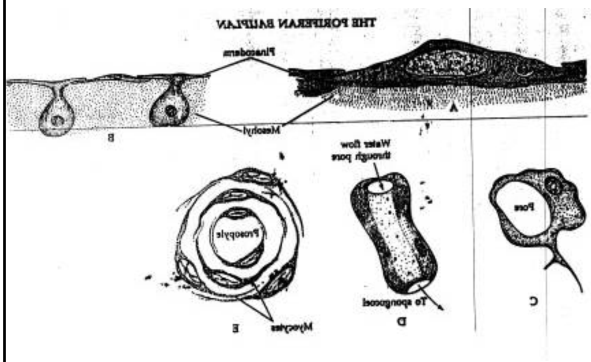
Poriferan Structure

1. Two cell layers, but different from true diploblastic organisms.
a. Outer later:
1. pavement of cells - pinacocytes
2. perforated by holes ostia
a. holes formed by specialized cells – porocytes.



Porocytes

1. Notice that a single cell makes the hole.
2. Contractile elements can close the hole if necessary.



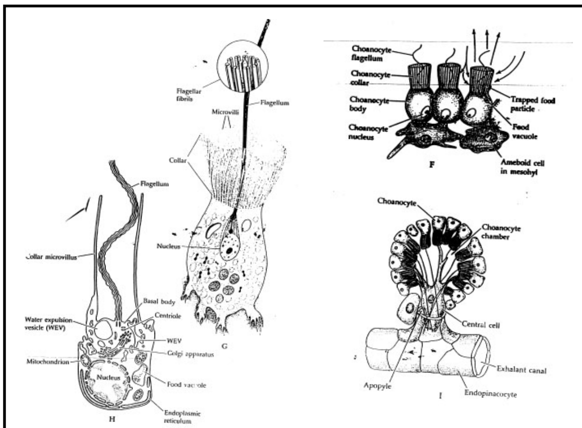
Poriferan Structure

b. Inter layer: ***choanocytes***

1. Flagellae create a current; ostia --> spongocoel -> osculum.

a. Small particles trapped on collar, phagocytised by cell.

1. Feeding efficiency increased by increased choanocytes.



Aquiferous System

1. This is the term used to describe the ***network of channels*** that run within sponges.
2. Its organization and function is similar to that of a vertebrate or other closed circulatory system.

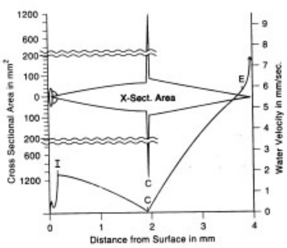
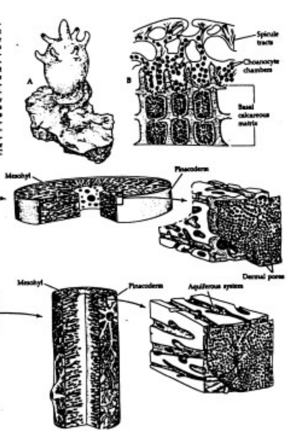


FIGURE 3–15 Velocity of water passing through different parts of the sponge canal system *(Microciona prolifera)* as related to the cross-sectional area of the passageway. I is the inhalant surface; C is the choanocyte chambers; E are the apertures of the exhalant canals; O is the osculum. *(From Reiswig, H. M. 1975. The aquiferous systems of three marine Demospongiae. J. Morphol. 145(4)493–502.)*

Figure 2

Sponge body forms. A, The unusual demosponge *Coeloscphaericon hatchi* (height in life 27 mm). B, The coralline sponge *Merlia normani* (vertical section) has a basal calcareous matrix within which individual compartments are filled by secondary deposition. The superficial soft part of the body contains the choanocyte chambers and is supported by tracts of siliceous spicules. C, The demosponge *Haliclona permollis*, a sponge with a tubular type of architecture; three successive levels of magnification are shown, from left to right. D, *Microciona prolifera*, a demosponge with a more solid type of architecture; three successive levels of magnification are shown, from left to right. (A after Hartman 1963; B after Bergquist 1978; C and D after Reiswig 1975.)



Aquiferous System

Surface area is increased

1. Increased surface area, makes water movement more difficult.
2. Necessarily limits the size of sponges.
3. Although they can get very large.

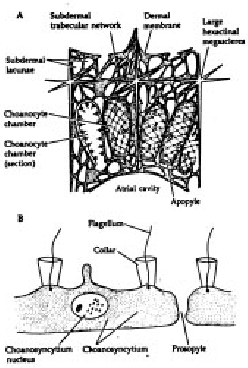


Figure 6

Internal anatomy of Hexactinellida. A, The body wall of *Euplectella* (transverse section). A dermal layer covers the trabecular network. B, The choanosyncytium of *Aphrocallistes vastus* (vertical section). (A after Bergquist 1978; B after Reiswig 1979.)

In Hexactinellida,

choanocytes exist within trabecular structure of skeleton.

1. In some species, choanocytes may form ***syncitia.***

Amoebocytes

1. Amoebocytes - totipotent cells that also provide a "circulatory" system.

a. these cells are also part of the middle "layer" of tissue in sponges.

b. middle layer (***mesohyl***): amoebocytes, archaeocytes (primitive cells).

1. variation in sponge morphology often due to differences in thickness of this layer.

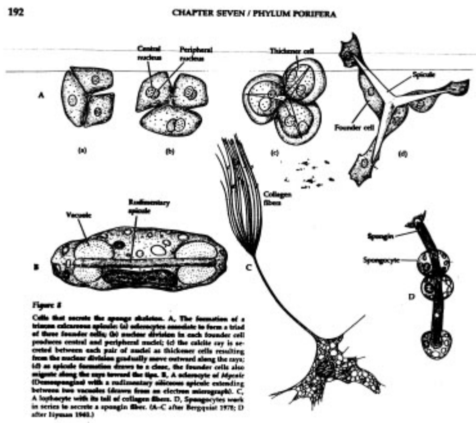


Figure 8
Cells that secrete the sponge skeleton. A, The formation of a triaxon calcareous spicule: (a) sclerocytes associate to form a triad of three founder cells; (b) nuclear division in each founder cell produces central and peripheral nuclei; (c) the calcite ray is secreted between each pair of nuclei as thickener cells resulting from the nuclear division gradually move outward along the rays; (d) as spicule formation draws to a close, the founder cells also migrate along the rays toward the tips. B, A sclerocyte of *Mycale* (Demospongiae) with a rudimentary siliceous spicule extending between two vacuoles (drawn from an electron micrograph). C, A lophocyte with its tail of collagen fibers. D, Spongocytes work in series to secrete a spongin fiber. (A–C after Bergquist 1978; D after Hyman 1940.)

Amoebocytes

c. Give rise to all sorts of other cell types

1. provide transport function
2. also form skeletal elements
3. spicules - provide structural support

a. hard - $CaCO_3$, SiO_2

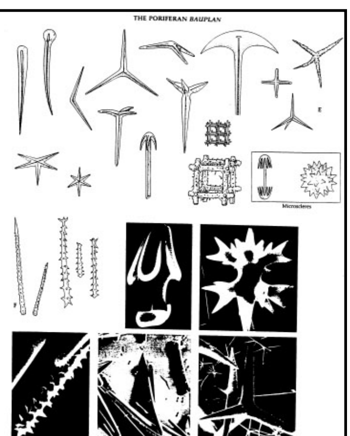
b. soft - protein, bath sponges

Spicules

1. These elements may be large or small

a. ***macroscleres*** - large spicules

b. ***microscleres*** - small spicules

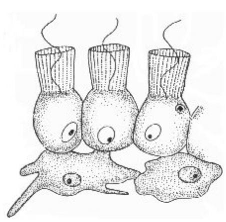


Spicules

2. Are used in sponge systematics.
6. Most of what we know about early sponges is from these.
a. real blooms in abundance in Jurassic, Cretaceous periods.
b. we don't know much about spongin containing sponges.

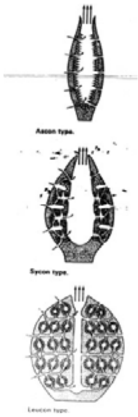
Amoebocytes

3. Amoebocytes also give rise to gametes, mucous secretion, nerve cells, contractile cells.



Relative Amount and Location of Choanocytes

a. Unique and characteristic of sponges.
b. Distribution within sponges is important.
1. this is the basis for identifying the functional grade of the sponge.
2. relative complexity has cost and benefits.
3. Part of why these grades cross phylogenetic lines.



Poriferan Body Types:

Asconoid

Syconoid

Leuconoid

Asconoid:

a. vase shaped

b. path of water:

1. ostium

2. spongocoel (with choanocytes)

3. osculum

c. example: *Leucosolenia*

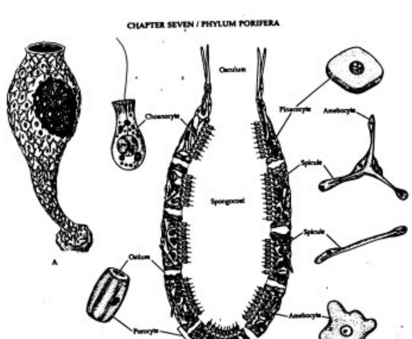
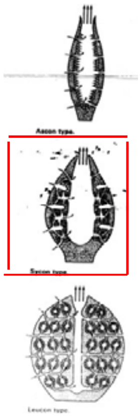


Figure 4

The asconoid condition. A, An olynthus, the asconoid form that follows larval settlement in calcareous sponges. B, Major cell types in an asconoid sponge. (A from Bayer and Owre 1968; B after Sherman and Sherman 1976.)

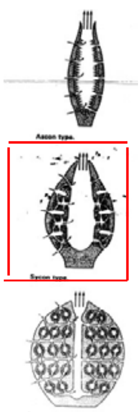
Syconoid



a. often vase shaped, internally more complex than asconoid sponge.

b. Although sometimes, members of the same species may exhibit both grades.

Syconoid



b. Path of water:

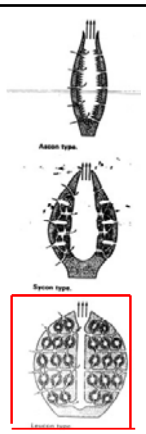
1. ostium

2. *prosopyle* - entry into area with choanocytes

3. choanocyte chamber - radial canal in lab

4. spongocoel

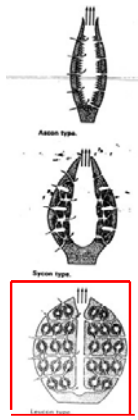
Leuconoid



a. Usually irregular - internally very complex

b. Path of water:

1. ***dermal pores*** (*ostia*, but they are more numerous and irregularly spaced.



Leuconoid

2. Dermal pores ->***incurrent canal***

3. ***prosopyle***

4. ***choanocyte chamber***

5. ***apopyle*** - exit from choanocyte chamber

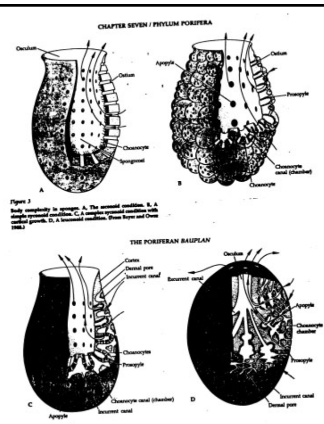
6. ***excurrent canal*** - reduced spongocoel

7. ***osculum*** (usually many)

Three Structural Grades of Sponges

a. This does NOT reflect evolutionary relationship

b. Good example of difference between *clades* and *grades*



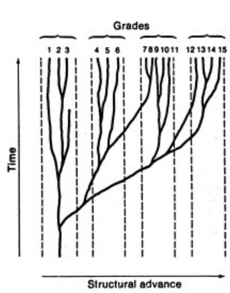
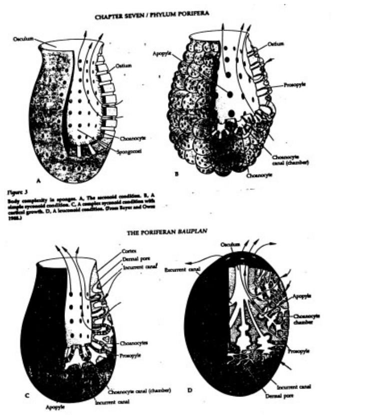


FIGURE 2

Grades and clades. A group of species (e.g., 1, 2, 3) with a recent common ancestor forms a clade; a group with the same level of structural organization (e.g., 7–11) forms a grade. Members of a clade may belong to different grades because of differential evolutionary rates. (Modified from Simpson 1961)



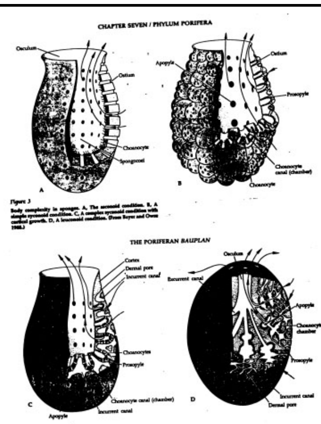
1. What is the relationship between increasing complexity and size of osculum (excurrent pores)?

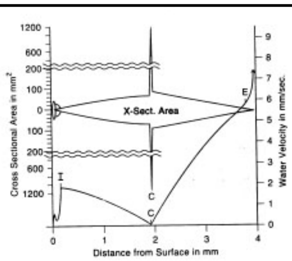
a. note that the larger the spongocoel, the more water must be moved

b. One way to solve this problem is to make the spongocoels ***smaller***.

1. This influences the cross sectional area of the sponge.

2. Also influences the flow rate.





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Systematics

1. Four classes (probably 3)

a. designations based on spicule type.

b. NOT on structural grade.

Class Calcarea

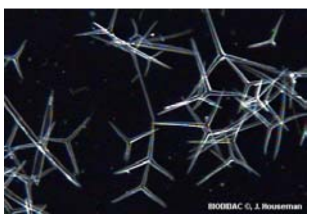
a. spicules are calcareous

b. occur in shallow marine environments

1. depth appears limited by solubility of $CaCO_3$

2. deeper depth, more soluble, less support

c. tend to encrust hard substrates.



Class Calcarea

d. Differences within taxa are based on embryology, choanocyte characters.

e. Examples:

1. *Leucosolenia*

2. *Leucetta*

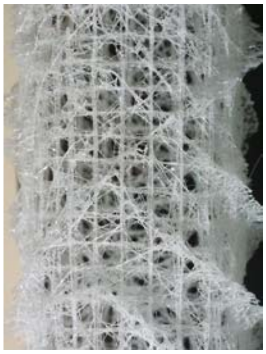
Class Hexactinellida

a. Spicules are siliceous; six-rayed.

b. Occur in deep water environments, especially at high latitude.

1. Solubility of SiO_2 increases with temperature

2. seems to limit these sponges to cold water.



Class Hexactinellida

c. Tend to be upright, inhabit hard or soft substrates

d. major divisions based on attachment structures

1.also relative rigidity of body.

2. May be placed elsewhere as separate phylum.

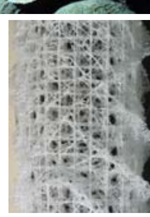
Class Hexactinellida

1. *Euplectella*

a. pairs of *Spongocola* shrimp may live inside spongocoel.

b. Excellent example of obligate monogamy; eumonogamy.

c. Inhabited sponges are presented as wedding gifts in Japan.



Class Demospongiae

a. Skeletons of silica and protein (sometimes entirely of this).

b. Inhabit all types of freshwater and marine environments.

Class Demospongiae

c. Highly diverse group that comprises most species.

d. Divisions based on

1. location of embryos - brooded or not, oviparous or viviparous.
2. proportion of spicules as microscleres or megascleres.

"Class Sclerospongiae"

1.Has been recently absorbed into the Demospongiae and Calcarea.

2. Tend to live in crevices in coral reefs and caves.

3. Contains ALL three types of spicules.

4. $CaCO_3$ spicules form an internal mass.

5. Many feel should be absorbed into the other classes.