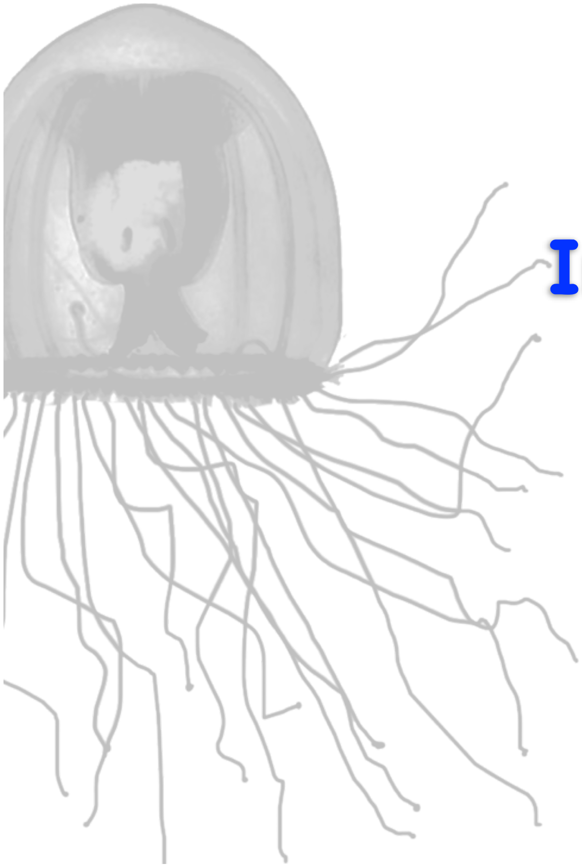


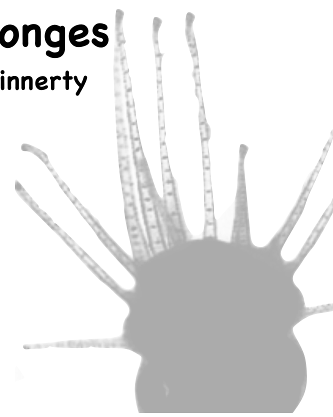
Tropical Marine Invertebrates

CAS BI 569

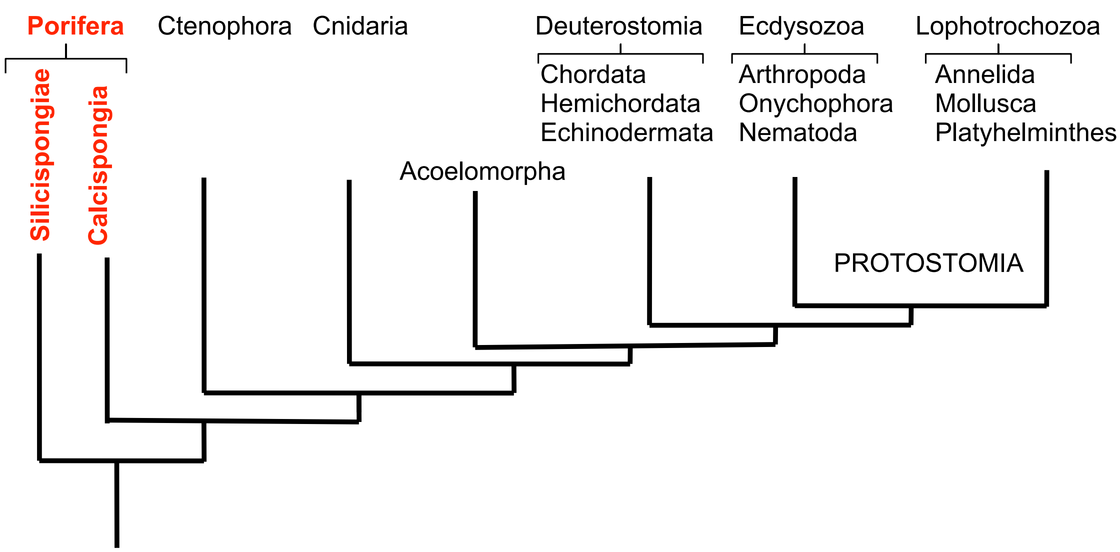
PHYLUM PORIFERA

The Sponges

by J. R. Finnerty



Animal Phylogeny

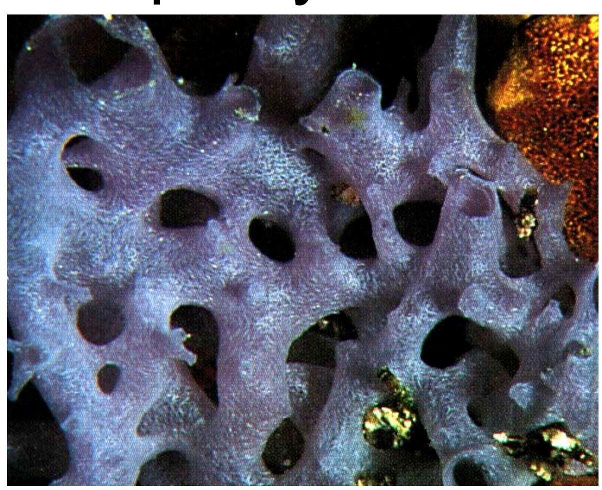


Phylum Porifera

- Porifera (Latin: “pore bearing”)
- oldest animal phylum
- simplest animal phylum (4-5 cell types)
- 5-10,000 species
- 98% are marine; 2% are freshwater
- sessile (immobile)
- benthic (seafloor)
- filter feeders (suspension feeders)
- a deep-sea species of *Asbestopluma* is known to be carnivorous (Vacelet & Boury-Esnault, Nature 1995)

Sponge Simplicity

- lack epithelia (?)
- lack a gut
- incapable of extracellcular digestion
- no true muscle cells (although the pinacocytes are capable of contraction)
- no nervous system
- no sense organs
- no fixed primary body axis - no regionalization along such an axis



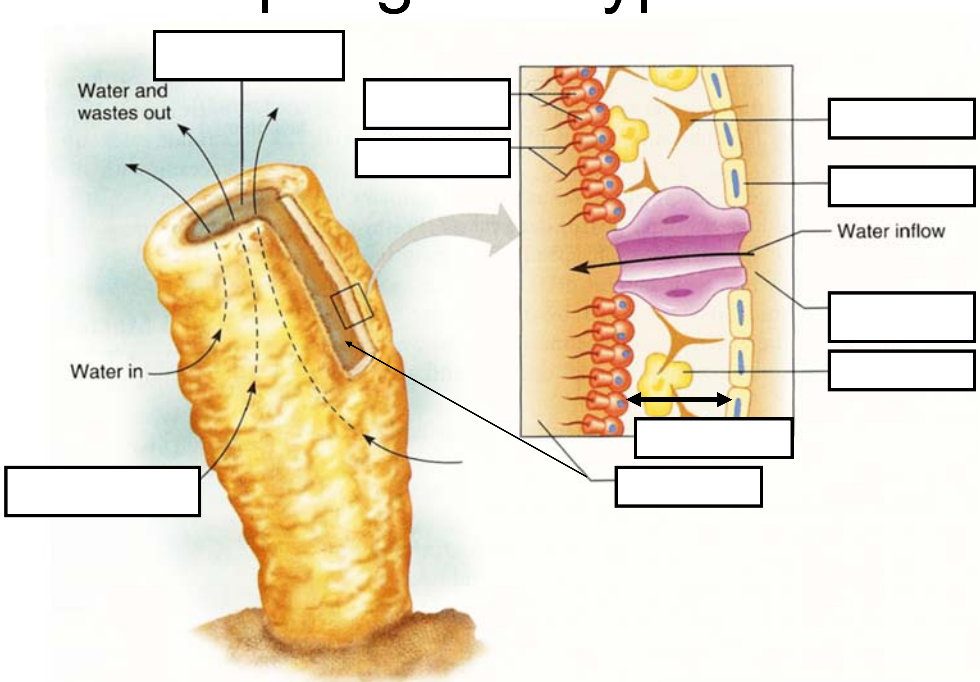
Epithelia in Sponges?

Epithelia and integration in sponges

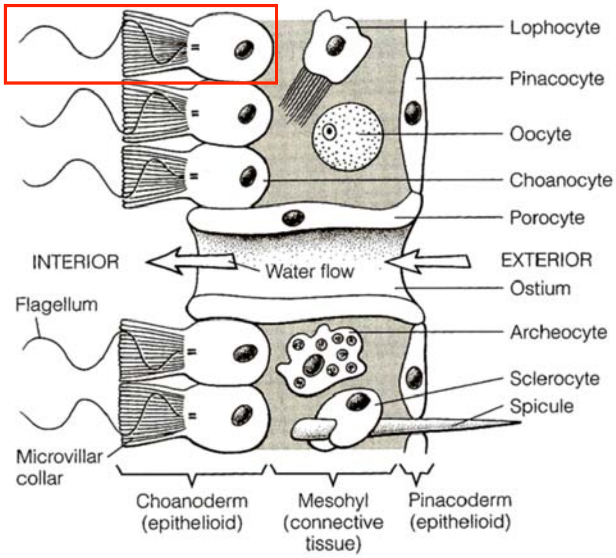
Leys, Nichols, & Adams

An epithelium is important for integrity, homeostasis, communication and co-ordination, and its development must have been a fundamental step in the evolution of modern metazoan body plans. Sponges are metazoans that are often said to lack a true epithelium. We assess the properties of epithelia, and review the history of studies on sponge epithelia, focusing on their homology to bilaterian epithelia, their ultrastructure, and on their ability to seal. Electron micrographs show that adherens-type junctions are present in sponges but they can appear much slighter than equivalent junctions in other metazoans. Fine septae are seen in junctions of all sponge groups, but distinct septate junctions are only known from Calcarea. Similarly, all sponges can have collagenous sheets underlying their epithelia, but only homoscleromorphs are established to have a distinct basal lamina. The presence of most, but not all, gene families known to be involved in epithelial development and function also suggests that sponge epithelia function like, and are homologous to, bilaterian epithelia. However, physiological evidence that sponge epithelia regulate their internal environment is so far lacking. Given that up to six differentiated epithelia can be recognized in sponges, distinct physiological roles are expected. Recognition that sponges have epithelia challenges the perception that sponges are only loose associations of cells, and helps to relate the biology and physiology of the body plan of the adult sponge to the biology of other metazoans.

Sponge Bodyplan



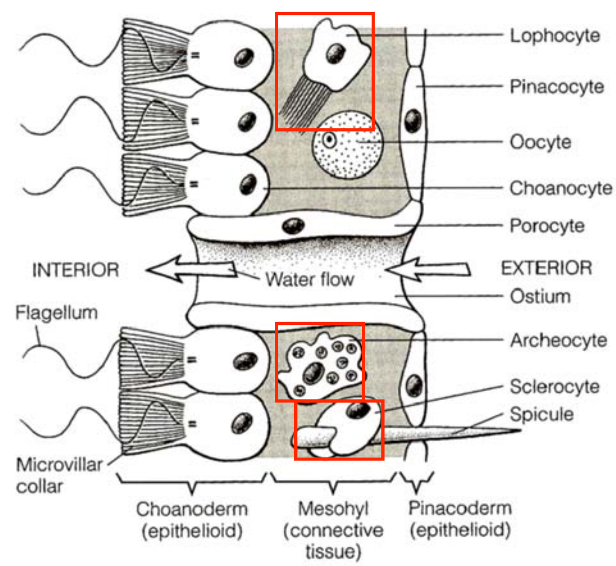
Sponge Cell Types



CHOANOCYTES

- single large flagellum
- also known as **collar cells** —cytoplasmic extensions form a “collar” around the base of the flagellum
- similar to choanoflagellates
- **3 functions**:
  1. generate water currents
  2. capture food particles
  3. capture incoming sperm for internal fertilization

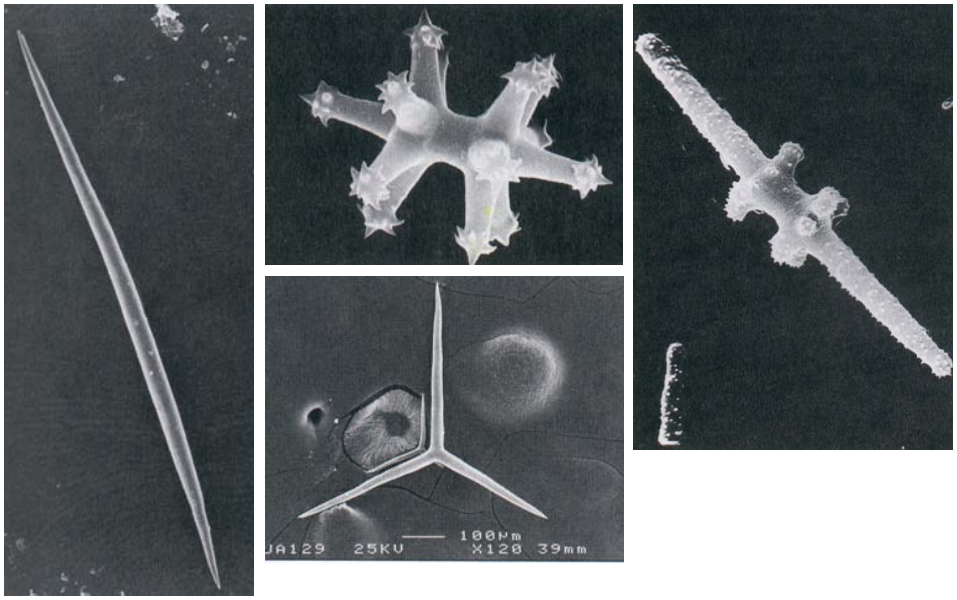
Sponge Cell Types



AMOEBOCYTES

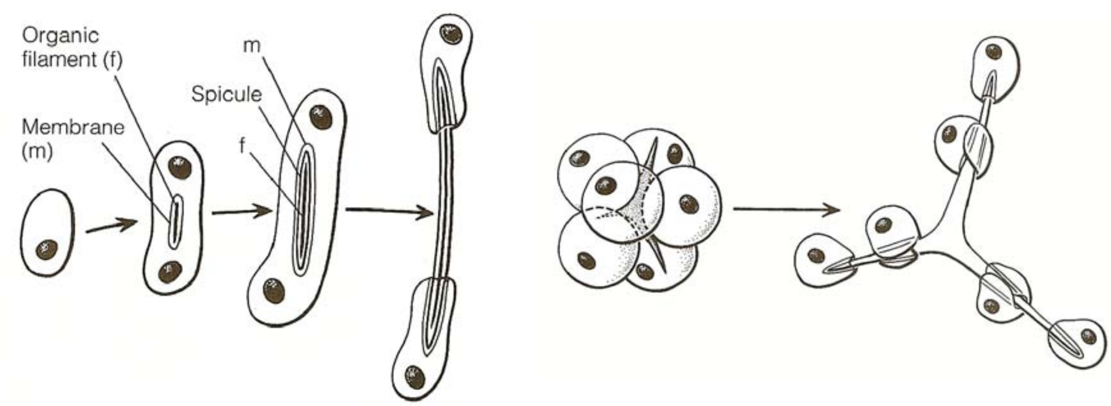
- “lophocytes,” “archaeocytes,” and “sclerocytes”
- amoeboid cells that move about the mesohyl
- **5 functions**:
  1. Secrete spicules and collagen (spongin)

Sponge Spicules



Spicule Synthesis

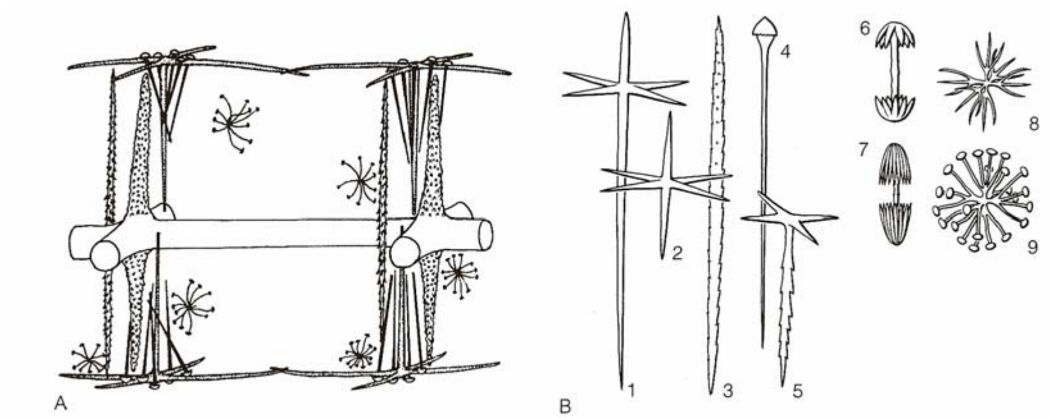
Spicules are secreted by the amoebocytes



Ruppert et al., Figure 5-11

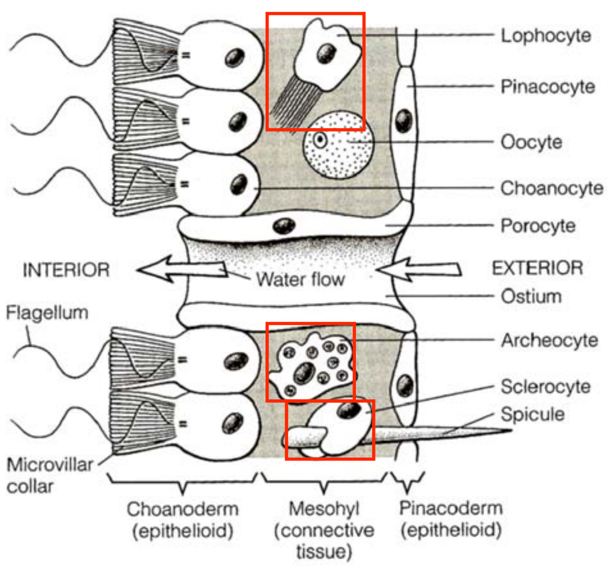
Sponge Spicules & Skeletons

Farrea (Hexactinellida)



Ruppert et al., Figure 5-9 a-b

Sponge Cell Types

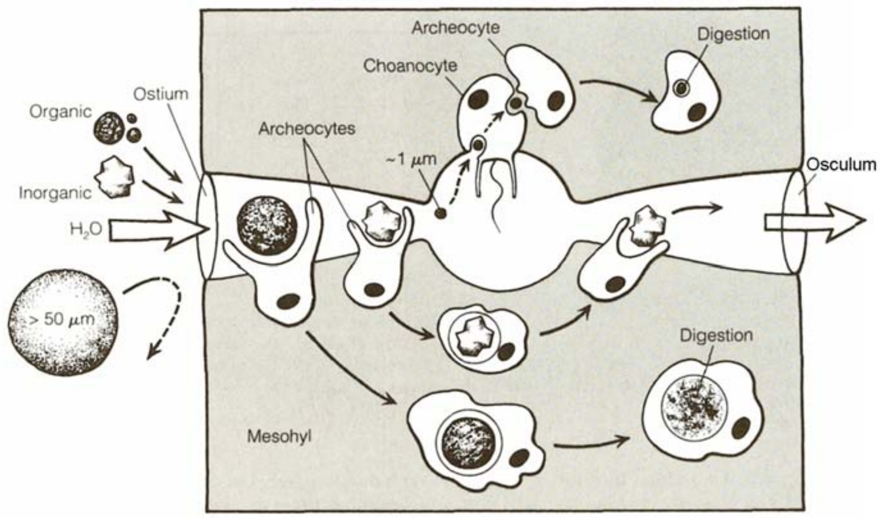


AMOEBOCYTES

- “lophocytes,” “archaeocytes,” and “sclerocytes”
- amoeboid cells that move about the mesohyl
- **5 functions**:
  1. Secrete spicules and collagen (spongin)
  2. Intracellular digestion
  3. Food storage
  4. Waste removal
  5. Give rise to gametes

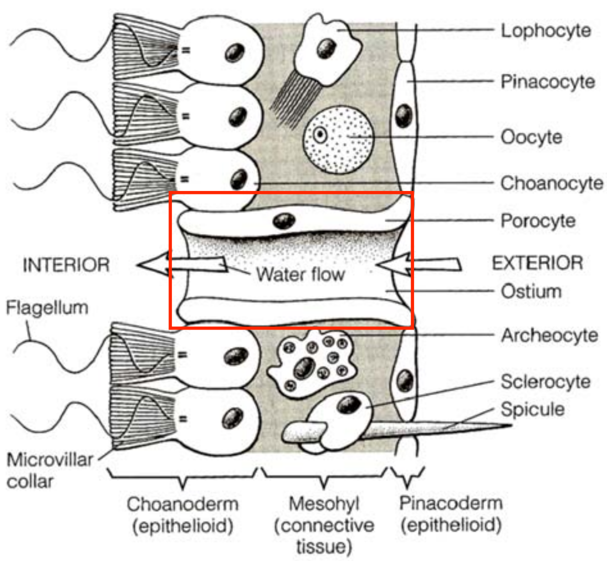
Intracellular digestion

Performed by the amoebocytes (aka archaeocytes)



Ruppert et al., Figure 13

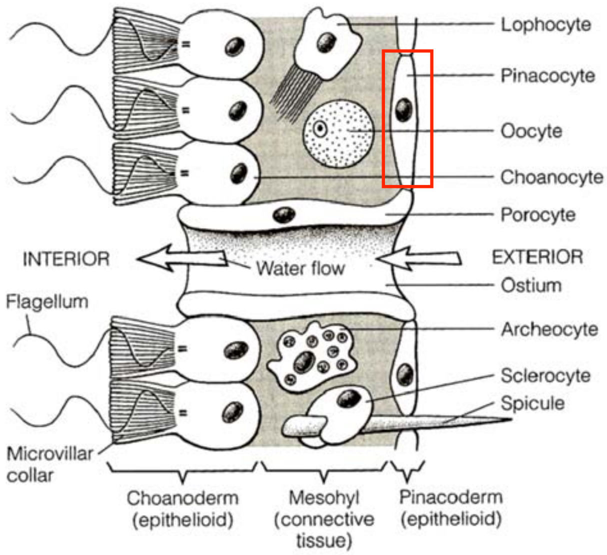
Sponge Cell Types



POROCYTES

- Cylindrical cells with central pores (ostia)
- The route whereby water enters the spongocoel

Sponge Cell Types

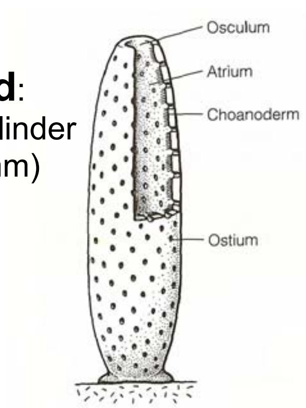


PINACOCYTES

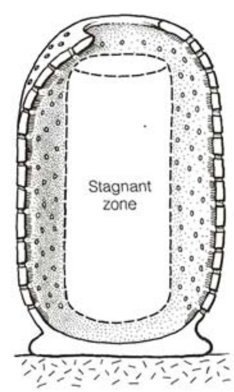
- Flat (squamous) cells that form the outer skin of the sponge (pinacoderm).
- Pinacoderm not a true epithelium because no basal lamina.
- Pinacocytes are capable of contraction.

Sponge Bodyplan Variations

Asconoid:
- Simple cylinder
- Small (1mm)

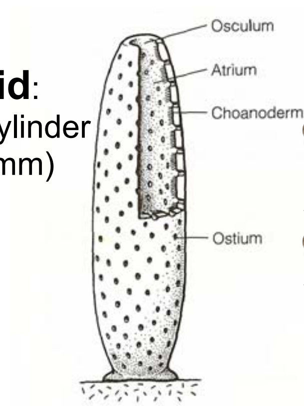


Large Asconoid:
- Not viable.
- Flagella cannot generate currents in center of spongocoel.

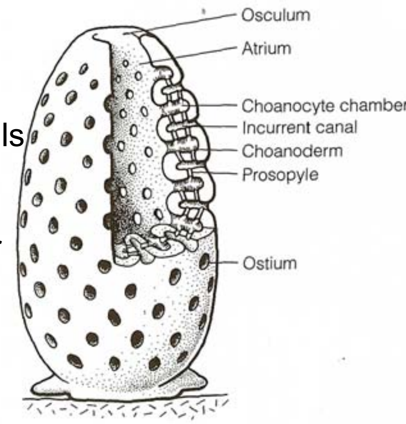


Sponge Bodyplan Variations

Asconoid:
- Simple cylinder
- Small (1mm)

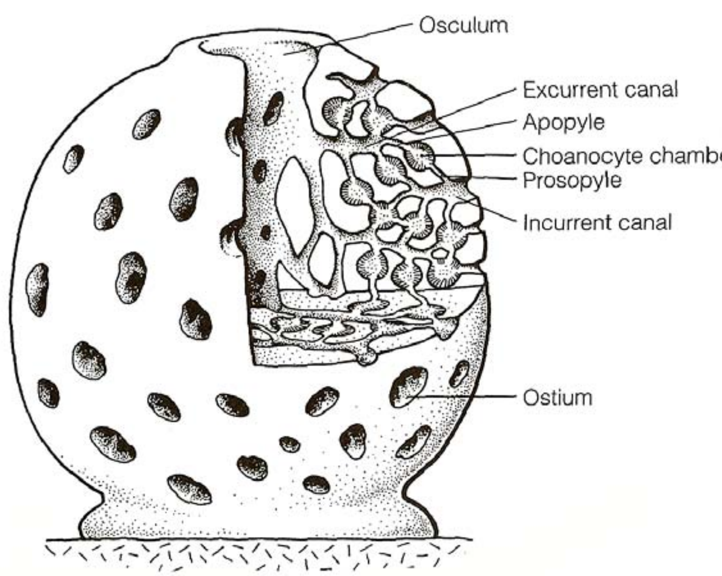


Synconoid:
- Convoluted walls provide greater surface area.
- Achieves larger sizes (> 1 cm).



Sponge Bodyplan Variations

Leuconoid:
- Thick walls house thousands of choanocyte chambers lined with beating flagella.
- Water enters and exits these choanocyte chambers via small capillary-like tubes.
- Leuconoind sponges achieve the largest size among sponges (> 1.0 m).



Sponge Classification

Class Calcarea: spicules are composed of calcium carbonate ($CaCO_3$).

Class Demospongiae (80% of all sponges); the spicules may be composed of spongin or silica, but never calcium carbonate. Spongin is a proteinaceous filament made of collagen.

Class Hexactinellida: sponges whose bodies are supported entirely by 6-rayed silica spicules—also called glass sponges. Glass sponges are syncytial. In a syncytium, multiple nuclei share the same cytoplasm.

Sponge Classification

Calcispongia

Class Calcarea: spicules are composed of calcium carbonate ($CaCO_3$).

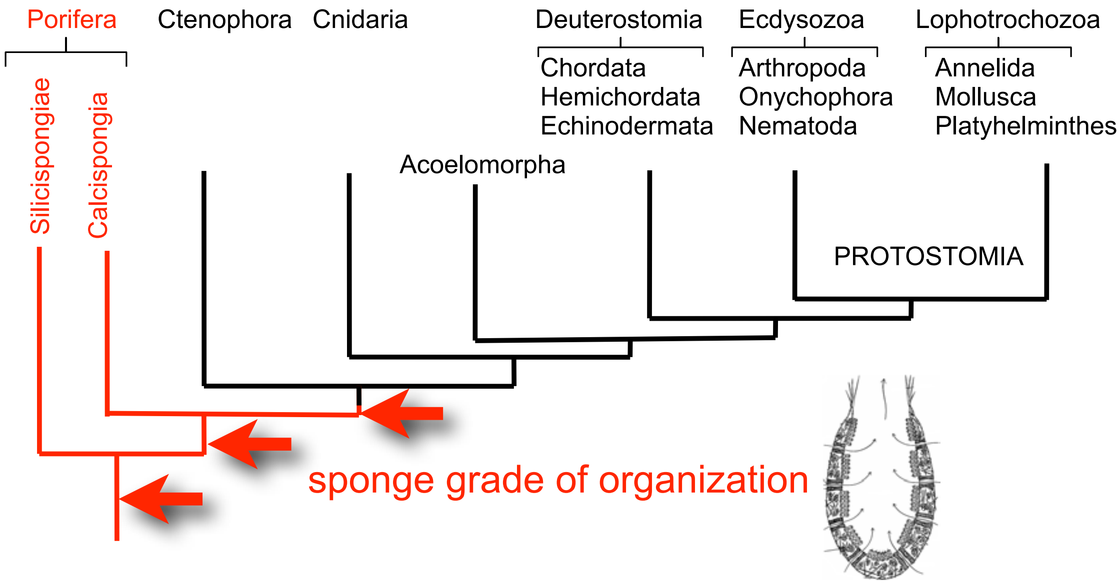
Silcispoingia

Class Demospongiae (80% of all sponges); the spicules may be composed of spongin or silica, but never calcium carbonate. Spongin is a proteinaceous filament made of collagen.

Class Hexactinellida: sponges whose bodies are supported entirely by 6-rayed silica spicules—also called glass sponges. Glass sponges are syncytial. In a syncytium, multiple nuclei share the same cytoplasm.

Animal Origins

- The earliest animals are thought to have been sponge-like (sessile filter-feeders that used flagella bearing cells to create feeding currents).
- The best evidence for the ancestral eumetazoan exhibiting a sponge “grade of organization” is that two lineages of sponges (Silicispongia and Calcispongia) emerge from the base of the Metazoan phylogeny.

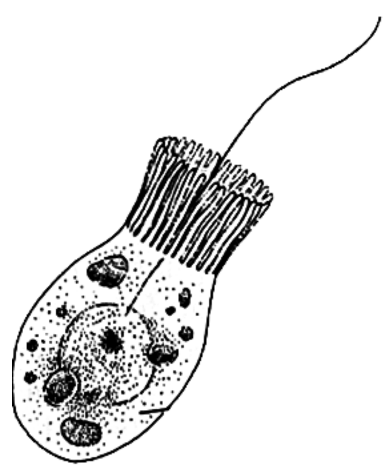


Sponges & Animal Origins

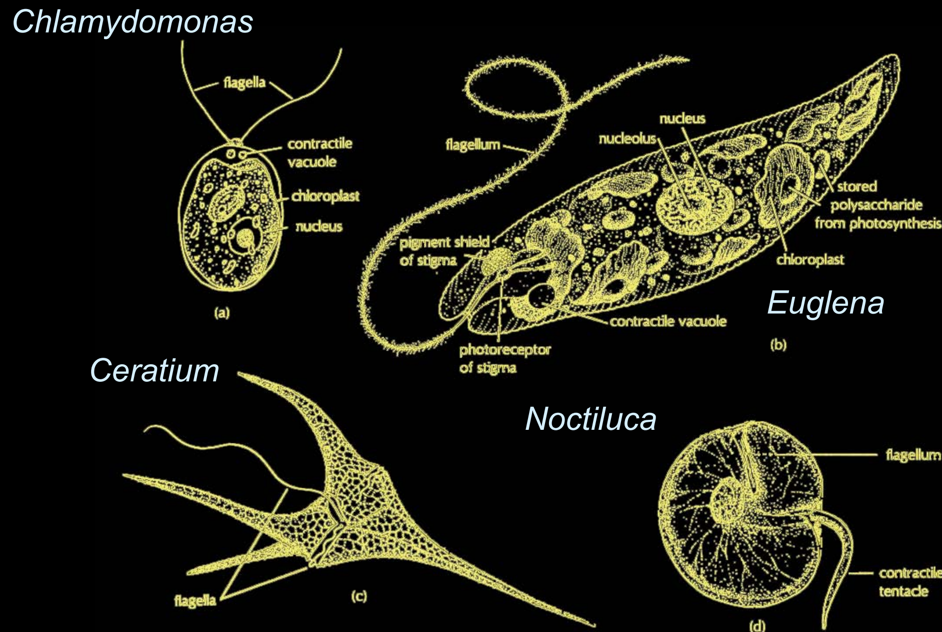
The first sponge-like animal is thought to have evolved from a flagellated protoctistan resembling a modern day choanoflagellate (the collared flagellates).

- The choanoflagellates are thought to be the sister group to the Metazoa. (King, N. and S. B. Carroll. 2001. Receptor tyrosine kinase from choanoflagellates: molecular insights into early animal evolution. Proc Natl Acad Sci U S A. 98:15032-7.)

- Sponge choanocytes are very similar to single-celled choanoflagellates.



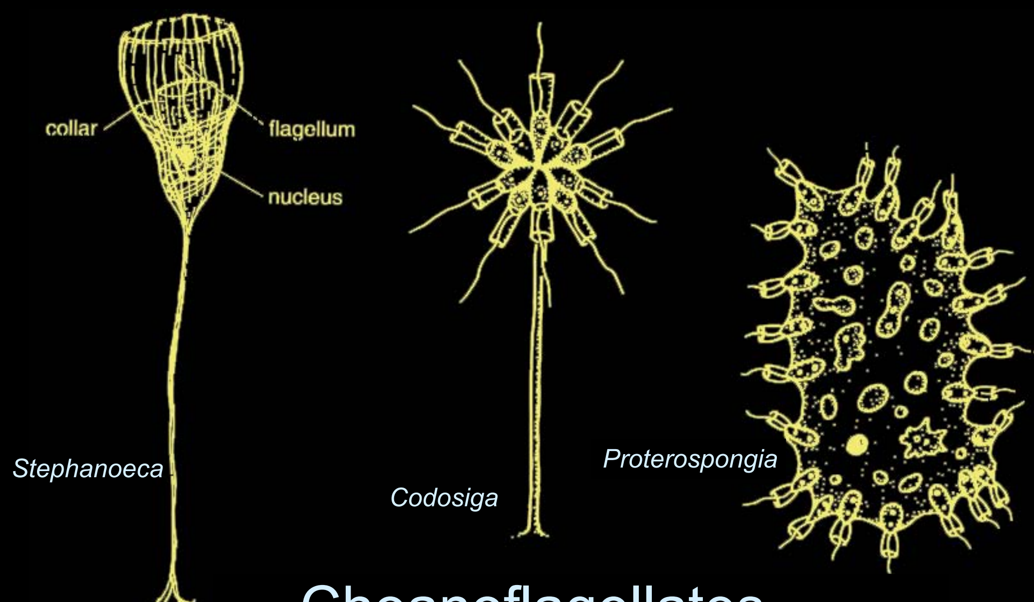
Phytoflagellates use flagella to generate locomotory currents.



Phytoflagellates

From: Pechenik (2000) Biology of the Invertebrates

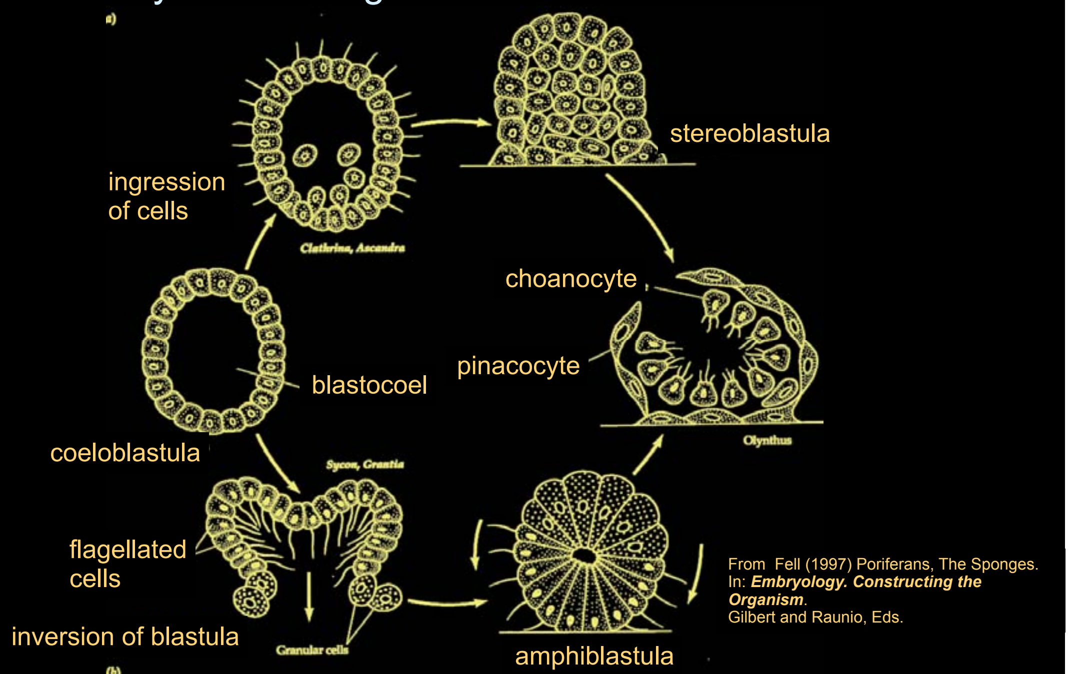
Choanoflagellates use flagella to generate feeding currents.



Choanoflagellates

From: Pechenik (2000) Biology of the Invertebrates

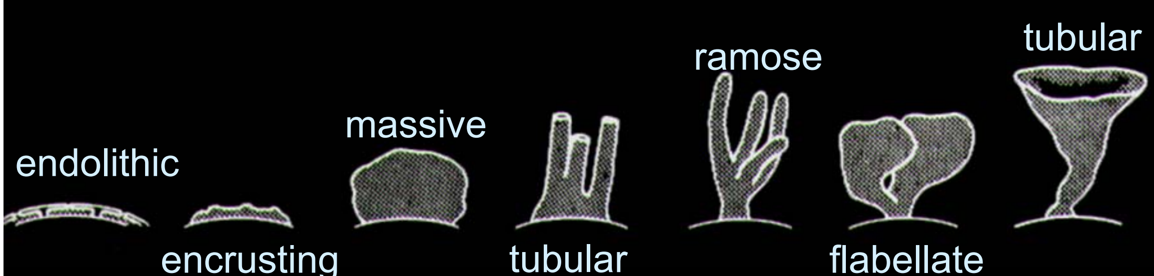
Over their lives, sponges use flagella to generate both locomotory and feeding currents.



From Fell (1997) Poriferans, The Sponges. In: ***Embryology. Constructing the Organism***. Gilbert and Raunio, Eds.

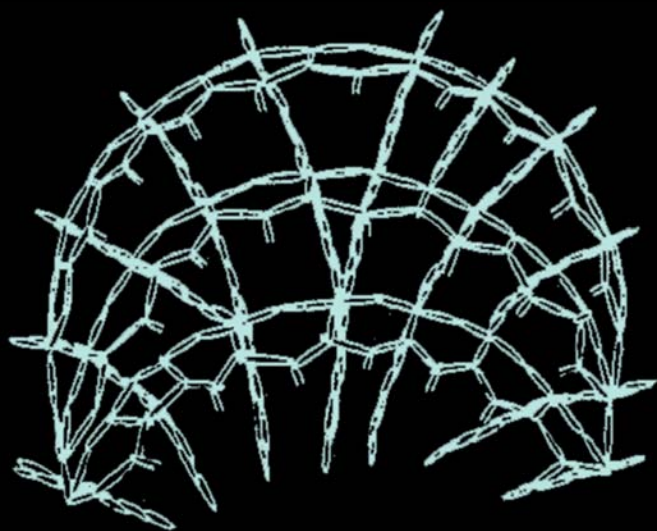
Sponge Ontogeny

Sponge Body Forms



(*The Invertebrates*, Stachowitsch 1992)

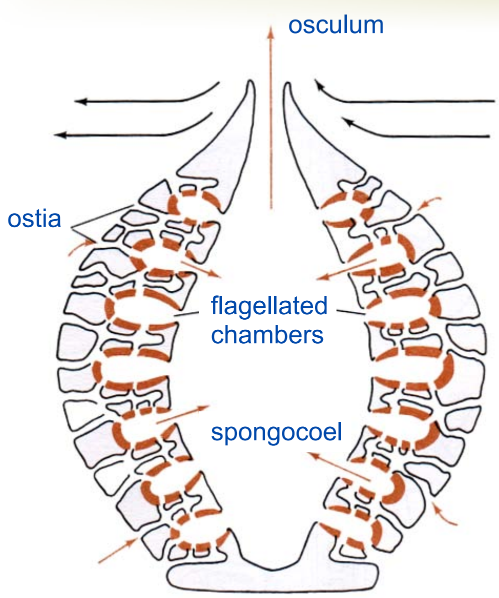
Sponge Growth



- Growth by radial accretion.
- No fixed primary body axis.
- Multiple growth axes
- Splits in the growth axes

(Kaandorp 1991; 1994)

Filter Feeding



From Animal Physiology, Eckert et al., (1988)

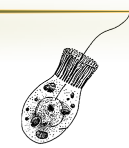
- **3 functional challenges**
  1. rapidly move a lot of water
  2. efficiently extract food
  3. use as little energy as possible
- Sponges can pump 1/2 their volume every second; 40,000 times their volume every day.
- During vigorous exercise, the human heart pumps only 1% of the body's blood volume per second.

Trade-Off in Pump Design

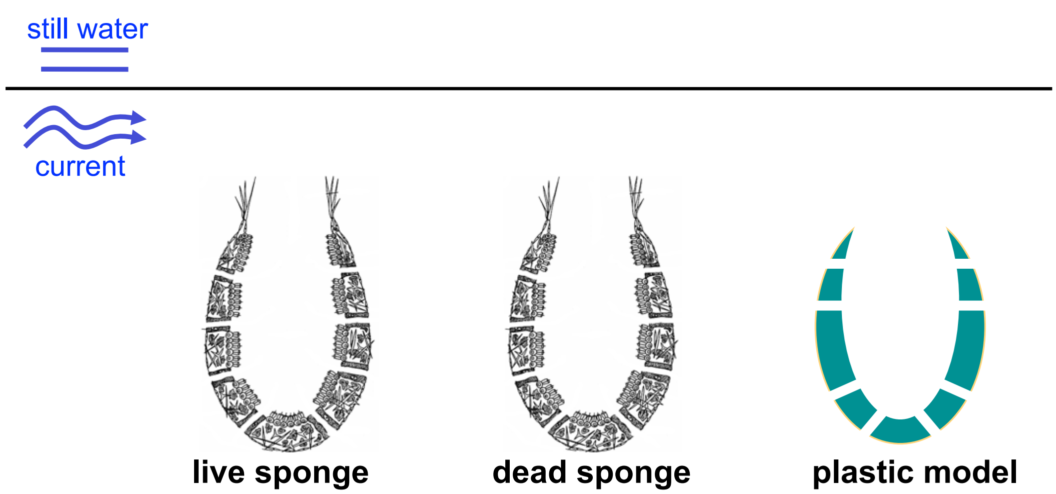
- **All pumps work by increasing the pressure of the fluid flowing through them.**
- There are **3 RELEVANT VARIABLES**:
  1. The power output of the pump (energy/time)
  2. The increase in pressure imparted by the pump to the fluid
  3. The flow rate
- Power output = (increase in pressure) X (flow rate)
- **Tradeoff**: for a given power output, the pump can generate a high pressure increase with a low flow rate or a low pressure increase with a high flow rate.
- Sponges are **low pressure** / **high flow** biological pumps. The pressure differential between the interior of the spongocoel and the region immediately outside the ostia is ~ 0.00001 atmospheres.
- Sponge can take advantage of very low pressure differentials to generate a high flow rate because **they present very little resistance to the flow of water**.

Two Pumping Mechanisms

I. **Active pumping mechanism:** the action of the flagella in the choanocytes

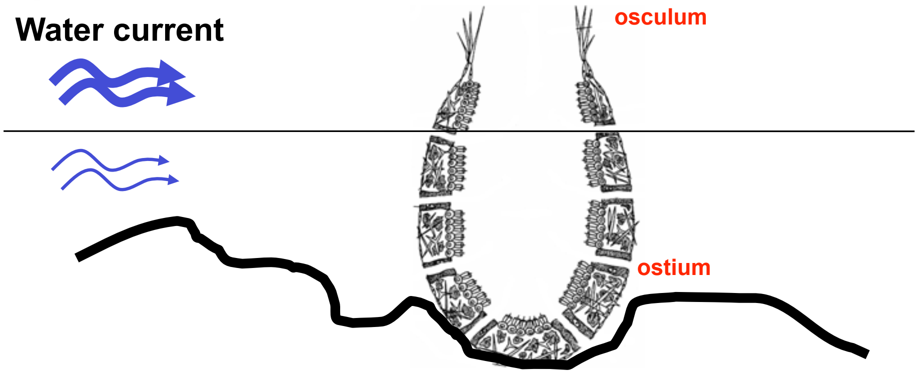


II. **Passive pumping mechanism**: design principle that capitalizes on ambient currents (Bernoulli's principle)



Passive Pumping

- **Bernoulli principle:** the pressure exerted by a moving fluid is inversely proportional to the velocity of the fluid
- Osculum is higher in water column than the ostia
- Current is generally greater higher in the water column
- Pressure is lower outside osculum than outside ostia.



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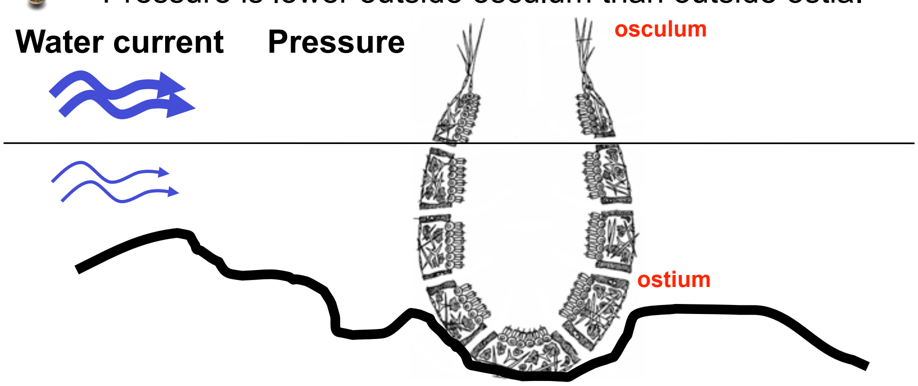
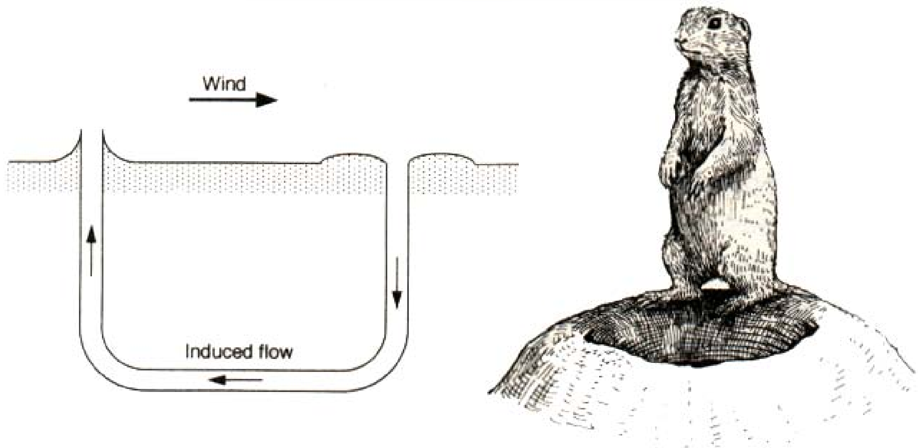
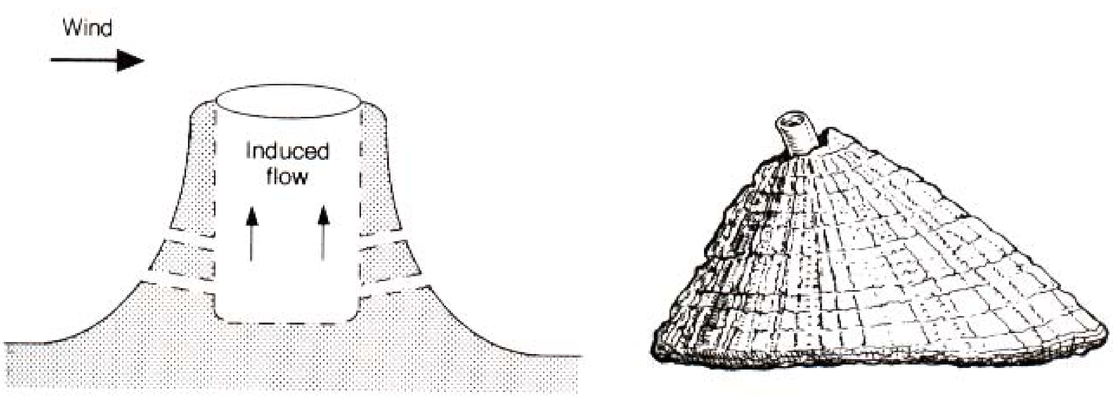


Fluid flow through a praire dog burrow



from ***Cat's Paws and Catapults***, Vogel (1998)
Figure 8.5. "A scheme for using ambient flows of air or water to induce a secondary flow in a burrow or other passage through the substratum, and a prairie dog viewing the world from the crater-shaped opening on one end of a burrow that uses the scheme for ventilation."

Fluid flow through a termite mound and a limpet



from ***Cat's Paws and Catapults***, Vogel (1998)
Figure 8.6. "Another scheme for using ambient flow to induce a secondary flow, this one through some elevated structure; and a keyhole limpet, which uses the scheme to draw water in beneath the edge of its shell, over its gills, and out the apical hole."

Carnivory (Macrophagy) in Sponges

“Extremely food-poor environments, such as the deep sea, place extraordinary demands on organisms with respect to feeding strategies found in shallow waters. A general rule is that macrophagy becomes a better strategy than microphagous suspension-feeding. The characteristics by which phyla are defined, nonetheless, remain unchanged in these adaptations. We present here an apparently unique example of a fundamentally different body plan, derived from a pre-existing phylum, occurring in deep-sea sponges. We demonstrate that the Cladorhizidae have evolved carnivory and capture small crustaceans by means of filaments provided with raised hook-shaped spicules. This adaptation to a food-poor deep-sea environment has resulted in the loss of the diagnostic characteristics of the phylum Porifera: an aquiferous system and choanocytes.” —Vacelet and Boury-Esnault. 1995. Carnivorous sponges. *Nature* 373: 333-335

Carnivory (Macrophagy) in Sponges

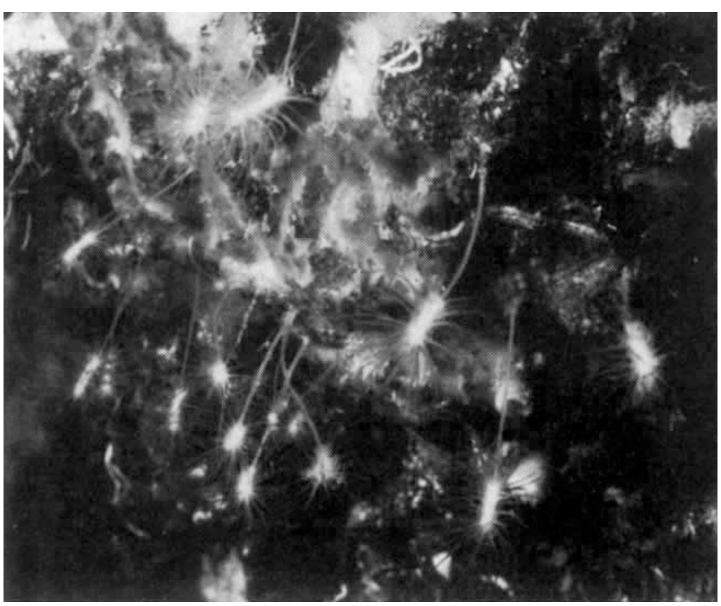
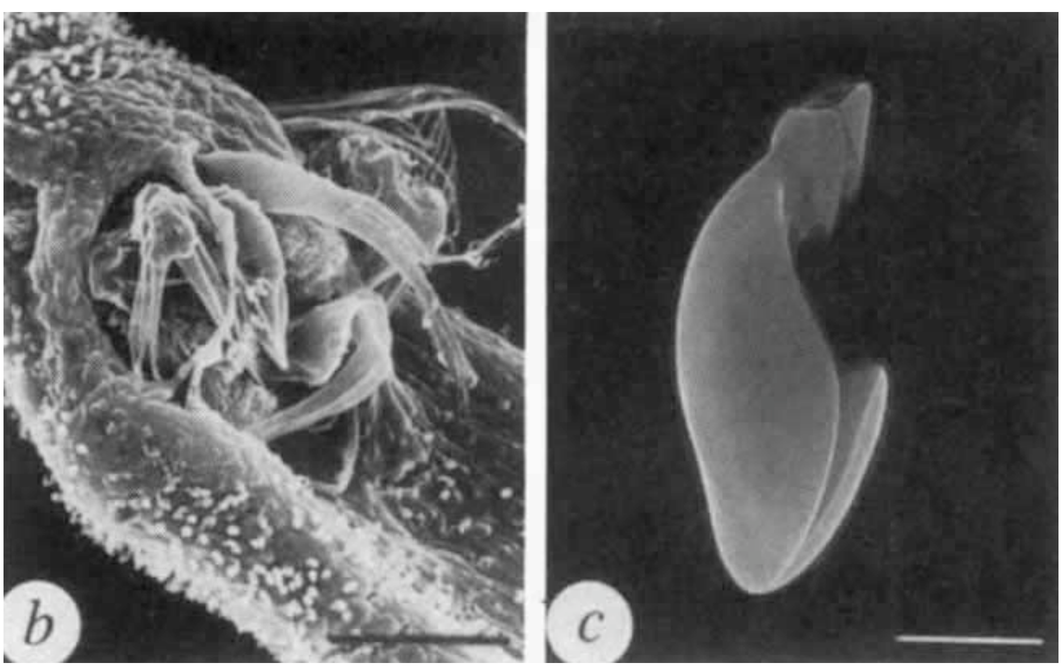


FIG 1. Clustered specimens, no more than 15 mm high, of an undescribed species of *Asbestopluma*, the otherwise deepest known genus of Porifera, in a Mediterranean cave at a depth of 18 m. The sponge body is anchored by a spicule peduncle and bears long, thin filaments. Unlike other poriferans, this sponge has neither aperture nor canal system, but feeds mainlhy on swimming prey captured passively by the filaments.

Carnivory (Macrophagy) in Sponges

Carnivory (Macrophagy) in Sponges



Close-up of captured *Artemia*. Close-up of modified spicule.