



## THE BIOLOGY OF SPONGES

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(THUMBNAIL IMAGES IN THIS GUIDE ARE FROM THE VIDEO PROGRAM)

Sponges are one of the more colorful and abundant groups of animals, yet they are generally poorly known by students of biology. One reason for this is the difficulty of observing anatomy and behavior in these animals -- features that exist at the microscopic level, and processes that take place over extended periods of time. This program reveals many of the difficult conceptual aspects of sponge biology through microscopy, animation, and time-lapse microscope photography.

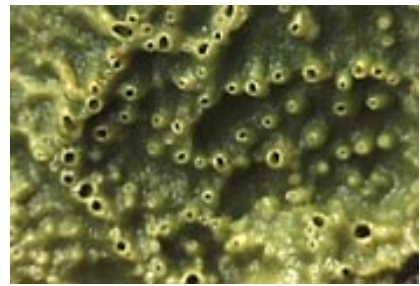
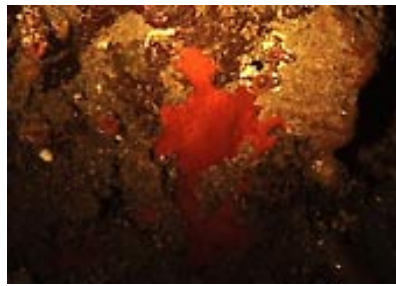
The phylum of sponges, Phylum Porifera, is entirely aquatic, with well over 98% of all sponge species found in marine environments, and a small percentage found in freshwater lakes and streams. Over 8000 species of sponges have been scientifically described, and sponge taxonomists estimate that there are probably about 15,000 species in total. With this level of diversity, sponges rank among the 'big eight' animal phyla that includes arthropods, molluscs, annelids, chordates, echinoderms, cnidarians and platyhelminths.



Sponges play an important roll in aquatic ecosystems, acting to filter particles out of the water (especially bacteria), and forming a fairly substantial portion of the coral reef biomass. Sponges are clearly the simplest of the conspicuous animal phyla, and thus are important subjects for considering the evolution of the animals. Recent studies using the tools of molecular genetics indicate that the animal kingdom evolved only once, and that the Phylum Porifera is at the base of the animal tree of life. In this sense, sponges represent a key group for understanding relationships among the other animal phyla.

This program is divided into ten modules that together give a fairly comprehensive overview of sponge biology:

- Introduction and Characteristic Features
- Sponge Cell Types and Organization
- How Sponges Feed
- The Sponge Skeleton
- Class Calcerea
- Class Hexactinellida
- Class Demospongia
- Sponge Ecology: Avoiding Predation
- Sponge Reproduction
- Sponge Evolution



### Introduction and Characteristics of Phylum Porifera

One exciting place (that is accessible for some coastal biology classes) to observe living sponges is in intertidal sea caves found along rocky ocean shores. Biology students who investigate these geological features are likely to find 'living paintings' on the cave walls, formed by sponges or groups of sponges. In high wave-shock areas, these sponges are usually only a centimeter or two in thickness.

Another good place for biology classes to find living sponges is attached to submerged wood in lakes or streams. Sponges are the simplest living animals, but they are often brightly-colored and spectacular.

The name "Porifera" means "pore-bearing". All sponges have pores over their surfaces that allow water to enter and leave the sponge body. In general, the most conspicuous pores seen on the sponge surface are the outflow pores, or oscula.

The members of phylum Porifera have four main characteristic features.

They feed by filtration.

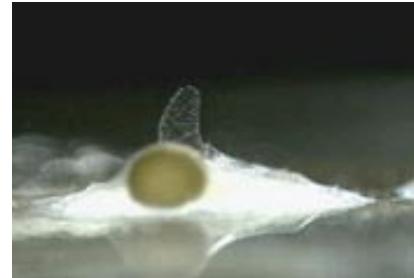
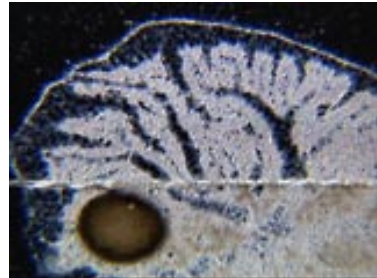
They have a unique type of cell not found in other animal phyla - the choanocyte, or collar cell.

Their tissues are loosely organized, and they have no internal organs.

Most sponges have an internal meshwork made of microscopic crystals (spicules) or fibers (collagen) that serves as an internal skeleton.

#### Discussion Questions:

- What makes an organism an animal? . . . why should sponges be considered animals?
- What distinguishes sponges from plants? . . . from fungi? . . . from colonies of protists?



### Cell Types found in sponges

A freshwater sponge is an excellent subject for examining cells in the sponge body. In this section, viewers see microscope timelapse footage of sponge growth (reconstitution) from a dormant, over-wintering gemmule -- yielding a small transparent sponge that can be observed under the microscope. Several days of growth are compressed into a few short clips.

From the onset of this reconstitution (a form of asexual reproduction) amoeboid cells can be seen emerging and moving around the gemmule as though testing the surrounding environment. These archeocytes, or 'ancient cells', eventually give rise to all of the cells in the sponge.



A top view shows the movement of cells inside the sponge body. (It appears rapid in these scenes sped up to thousands of times normal speed.) Canals also appear, and these are lined with choanocytes, the cells

that create currents in the sponge. Eventually, a new sponge grows, complete with an outflow pore, or osculum.

Although not pointed out directly in the program, other sponge cell types can be seen in the footage through careful frame-by-frame analysis: the pore-forming cells, or porocytes (observation of the microscope feeding footage may reveal these); the spicule-forming cells, or scleroblasts (these can be seen in the section on spicules); the epithelial cells, or pinacocytes (can be revealed by stop-frame); and the contractile cells (around large pore openings), or myocytes (revealed in shots showing the osculum).

Like human stem cells, archeocytes can literally transform themselves into any other type of cell in the animal. All other cell types, in turn, can return to archeocytes when they are needed to perform some other function. Archeocytes are known as 'omnipotent cells'.

**Discussion Questions:**

- What advantages might omnipotent archeocytes provide for a sponge? .. what might be the disadvantages of this?
- Does the behavior of archeocytes and other cells in the sponge suggest communication between the cells? If so, how might this communication be mediated?
- How would you define the 'tissue' of a sponge, and how is it different from the tissues of other animals?

How Sponges Feed



Feeding currents created by a sponge can be investigated using a dye (food color or other soluble dye) dissolved in sea water. Water currents bring food into small pores on the body wall, through the internal canal system, and out the osculum. The microscope shot shows tiny bacteria-sized beads being pulled into the canal system through microscopic pores.

Water flow is created by collar cells lining the canals. An animation shows the collar cell structure and function as well as the mechanism of food entrapment. Sponges have been shown to be capable of pumping as much as 1200 times their body volume in a single day. Studies of water flow on coral reefs show that tall sponges interrupt the prevailing currents, providing a better food supply directly around the sponge.

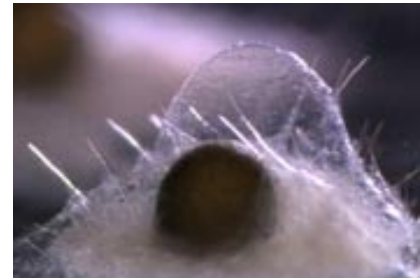
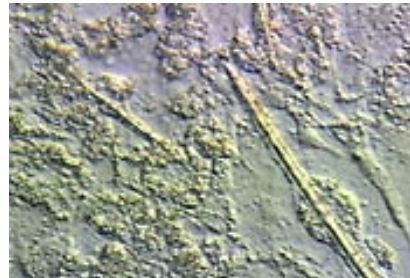
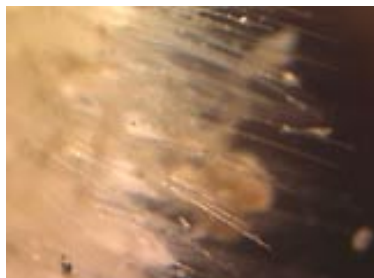
**Discussion Questions:**

- For what size range of food is the sponge system best adapted? É what are the most likely types of food in this range?
- Using drawings from textbooks, compare the three main types of canal system structures in sponges (ascon, sycon, leucon).
- What internal type of structure would you guess fits each of several example sponges seen in the video?

The Sponge Skeleton

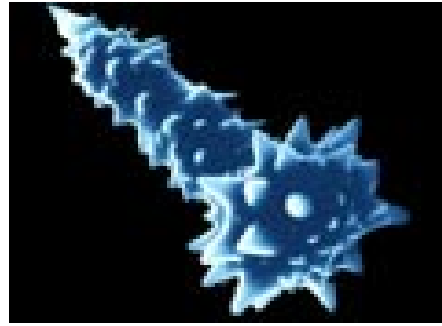
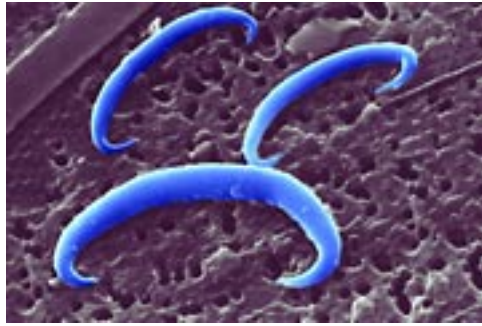
An internal 'skeleton' is present in almost all sponges. There are two basic components - spicules and collagen fibers. This section deals with spicules.

Spicules are elaborate crystals produced from compounds precipitated by scleroblast cells in the sponge tissue. Spicules are either calcereous (precipitated from calcium ions and carbonate ions) or siliceous (precipitated from silicate salts). The ions are extracted from the solution around the sponge. The spicules serve at least two roles in the sponge: a kind of mesh-work internal skeleton, and, in some cases, as a protective device against predation.



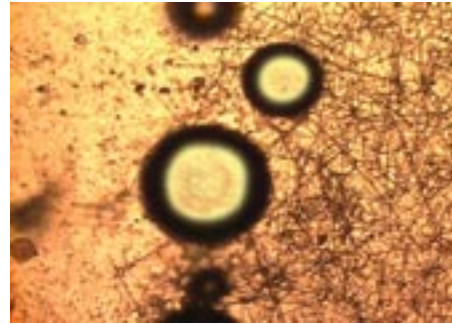


Spicules are highly varied, and to some extent, are distinct for each species of sponge. Thus, microscopic examination of spicule preparations can be used as a means to identify sponges to species level. Indeed, this method is the only way to identify most sponges precisely. To prepare spicules for microscope examination, a small chunk of the sponge tissue is treated with full-strength bleach solution, and then carefully washed with water. This section finishes with a short montage of spicule SEM images to show their variety.



**Discussion Questions:**

- What chemical test might be used to distinguish between calcereous spicules and siliceous spicules?
- How is it possible for sponge cells to create crystalline spicules from ions dissolved in the surrounding water?



**Class Calcerea**

Sponges of Class Calcerea are usually small, dull in color, and they are entirely marine. One 'textbook' example of the class is *Scypha* which is frequently found on ropes hanging from floating docks. This section demonstrates the characteristic of the class by showing spicules from *Scypha* as they dissolve on a microscope slide upon treatment with HCl solution, releasing carbon dioxide gas. Class Calcerea has about 200 different species.

**Discussion Questions:**

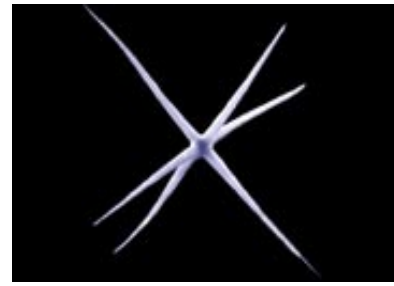
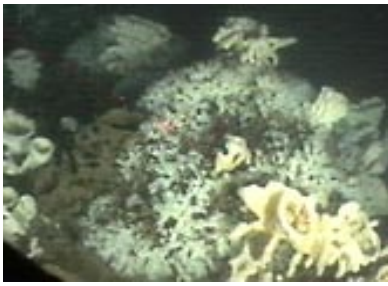
- Why might calcereous sponges be absent from deep ocean environments, while sponges with siliceous spicules inhabit these habitats?
- Why are calcereous sponges absent from fresh water?

**Class Hexactinellida**

Class Hexactinellida is a relatively small group of sponges in terms of diversity, but they are important members of the benthic fauna, especially below about 50 meters. Hexactinellids are entirely marine, and they have been dredged from depths of up to 3000 meters and more.

The footage in this module shows extensive hexactinellid reefs found in Hecate Strait off the Northern tip of Vancouver Island. These sponge reefs lie on top of glacial moraine features left after the last ice ages, and are about 9000 years old. Although sedimentation on the reef slowly covers the sponges, core samples indicate there may be a places where continuous growth of a sponge may outpace sedimentation. Many biologists consider that deep water glass sponges are the oldest living animals.

A key characteristic of hexactinellids is their syncytial tissue structure; the entire animal is generally a mixture of single cells and blocks of syncytial tissue. Another Hexactinellid distinguishing feature is the presence of 6-pointed siliceous spicules, often with very long points.

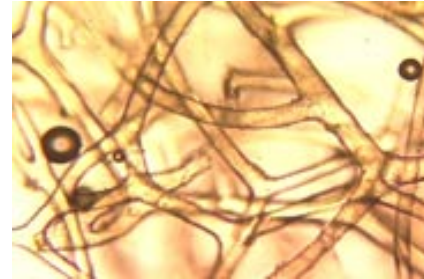


**Discussion Questions:**

- What are the implications of the syncytial nature of Hexactinellids for evolution?
- What advantage might syncytial tissues have in terms of spicule formation?

**Class Demospongia**

Class Demospongia is by far the most diverse class of sponges, with over 95% of the known species. Most Demospongia have siliceous spicules, although none of these are the 6-pointed type found in hexactinellids.



A number of species in class Demospongia have a skeleton made of interlocking, flexible fibers of collagen. Bath sponges have been made from these types for many centuries, by clearing the tissue with chemical agents and washing. There are over 7000 known species of Demospongia, and it is estimated that there may be just as many species yet to be described.

**Discussion Question:**

- Why is Class Demospongia the most abundant and diverse class of sponges?

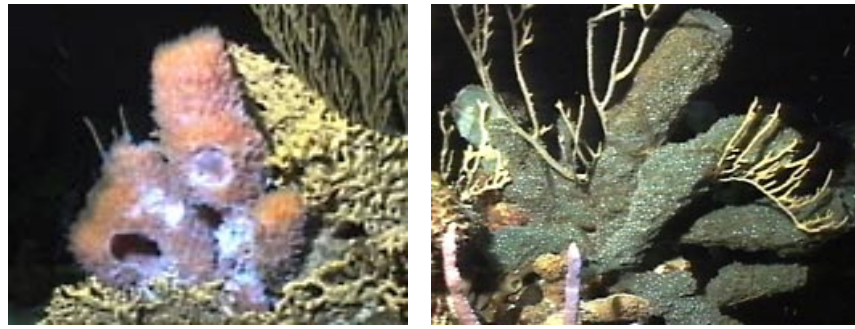
**Sponge Ecology: Avoiding Predation**

Being sedentary animals, sponges cannot swim away from a predator, and they have little in the way of structural armament (some sponges have large defensive spicules). Instead, sponges secrete poisons as their main weapon of defense. It is thought that defensive chemicals in the sponge may taste or smell bad to potential predators. In the last two decades, these poisons and other biochemicals inside sponges have received special attention as potentially useful drugs for treatment of cancer and other diseases. Several promising drugs now on the market are derived from sponge biochemicals.

One group of seemingly unassuming predators is well-adapted to sponge predation - the dorid nudibranchs. These 'sea slugs' (opisthobranch molluscs) are generally dome-shaped with a floret of posterior gills and a pair of chemical-detecting rhinophores on the head region. Some of these nudibranchs are cryptic, especially on their sponge prey, while others seem gaudy, possibly a warning coloration recognized by predators as an indication that the nudibranch carries poisons it has acquired from its sponge prey. The fact that there are many instances of Mullerian mimicry, where flatworms or other animals mimic the poison-carrying nudibranchs, suggest that fish avoid these potential prey through visual recognition.

**Discussion Question:**

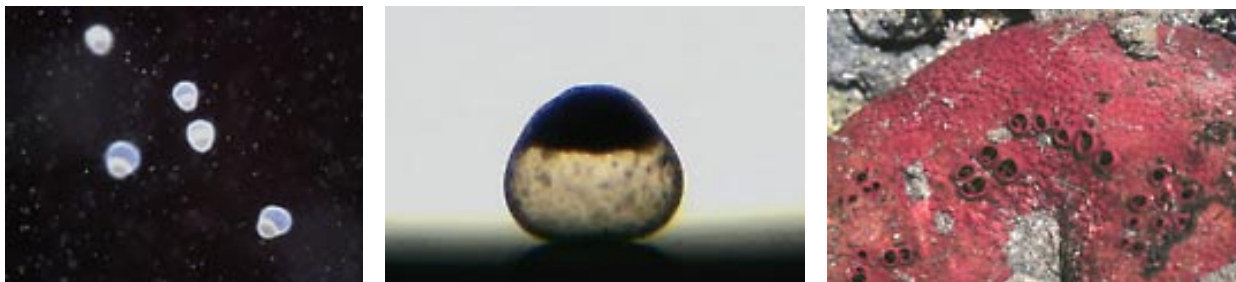
- What is the consequence to a sponge if it relies entirely on 'taste' to deter predators?
- If sponge-eating nudibranchs are cryptic on a brightly-colored sponges, what does this suggest about their vulnerability during times of transit while looking for new prey? What strategies for defense might be used at these times?
- Discuss Mullerian mimicry. How might Mullerian mimics evolve?



### Sponge Reproduction

Sponges have strong powers of regeneration, probably due to the interchangeability of their cells, and to their lack of special tissues. Wounded sponges can regenerate tissue and skeleton to replace the wounded part. These same abilities enable some species to reproduce asexually by fragmenting. The fragments can break off, drift away, and then settle to start new colonies.

The formation of gemmules is another form of asexual reproduction. This strategy is common for freshwater sponges, but rare in marine species. The gemmule is a densely-matted, hardened ball containing archeocytes protected by collagen and special spicules. In freshwater sponges, these balls survive through the winter and then form a new clone in the spring.



Occasionally, sponges reproduce sexually. When the stimulus is right, cells in the sponge become sperm, which are shed into the water. Sperm enter a different sponge body where they are captured and transferred to cells which then travel through the tissue to an embedded egg. The fertilized egg develops into a simple larva - a ball of cells with cilia on the outside. The larvae eventually break out and swim for a few hours before they settle to the bottom where they begin a new sponge.

#### Discussion Questions:

- What advantage do gemmules present for life in fresh water?
- Few types of animals can grow an entirely new adult animal from a small fragment broken off of an individual. What factors enable sponges to do this?
- Although the experiments are not shown in this program, discuss laboratory experiments where sponges put through a nylon mesh will reconstitute a sponge colony, and relate this to the questions about asexual reproduction.
- If a sponge can reproduce asexually, why would it also use sexual reproduction (i.e., what advantage would there be to sex)?

### Sponge Evolution

Since sponges are the simplest living animals, it is reasonable to expect that they may have evolved early in animal evolution. Indeed, sponge fossils dated at 600 million years ago are among the oldest known animals. However, fossil evidence from such old rocks (and generally soft-bodied animals) has not so far provided a clear picture about early animal evolution.

#### Once or Many times? - Theories of Animal Origins

Ideas about the origins of the animal kingdom have long been debated by biologists. Based on many aspects of cellular structure and chemistry, some biologists have favored the multiple origins of animals from two or three different single-cell ancestors. Others theorized that the entire animal kingdom is monophyletic, with only one ancestor. Recent molecular genetics studies strongly support the one-ancestor theory, with ancient sponges at the base of the animal tree of life.



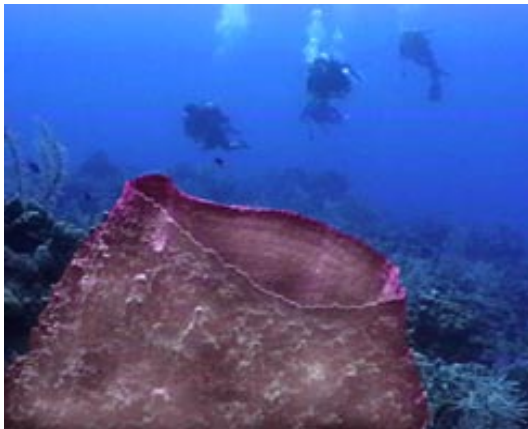
Studies of living animals using the tools of molecular genetics provide a more definitive understanding of how animals evolved. Molecular sequences of genes for ribosomal RNA and for several other ancient molecules fundamental to all cells, show that an ancient sponge-like ancestor was the first animal, and that all other animal groups descended from this ancestor.



When the molecular sequences of a variety of protist groups were also compared to animal sequences, the data showed clearly that one group - choanoflagellates - was also in the same line of evolution. In other words, ancestors of modern choanoflagellates were most likely also the ancestors of sponges. This makes choanoflagellates our nearest living protist relatives. The program shows dramatic microscope footage of colonial Choanoflagellates, elusive members of the fauna of ponds seldom seen by biology classes. Animation is used to show the similarities between choanoflagellates and the choanocytes of sponges, providing a strong visual connection to the evolutionary story.

**Discussion Questions:**

- Discuss differences between multicellular organisms and colonial organisms.
- What factors in the biology of simple animals point to multiple origins of the animal kingdom?
- Find published molecular evolutionary trees (on the internet) and discuss their implications for, and level of support for, a monophyletic grouping of the animal kingdom. What do these trees suggest for the inclusion of choanocytes in this clade?



The Phylum Porifera is an important group to introduce to students of biology. Our goal with this program is to provide a colorful overview of sponge biology with a special emphasis on ecology and evolution. It should inspire students to be more curious about this fascinating group, and should ably complement studies from texts and preserved specimens. We also highly recommend laboratory studies of freshwater sponges as a hands-on approach to this group.