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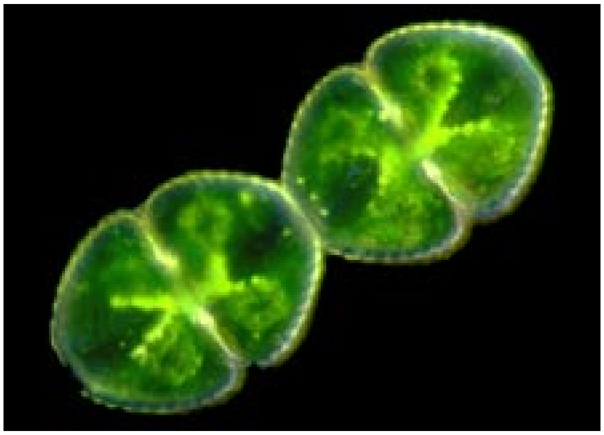
Branches on the Tree of Life: PROTISTS

Written, produced and photographed by Bruce Russell

All photos in this guide are from the DVD

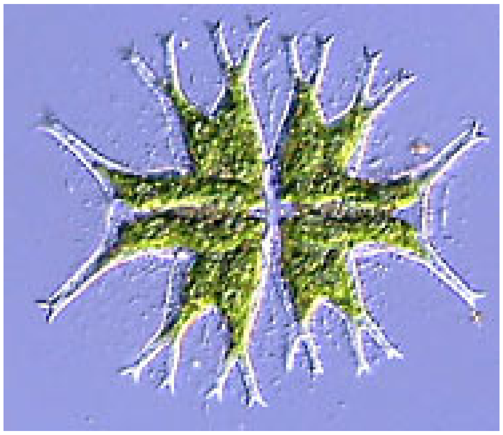


Cosmerium, a green alga

Arcella

The goal of this program is to show a representative sample of the great diversity of protists, and to show why they need a new classification reflecting our growing understanding of their long evolutionary history. The protists shown can be found in habitats such as: roadside puddles, park duck ponds, aquariums, birdbaths and in the gut of termites. We hope that these observations will encourage students to collect pond water samples and see for themselves this amazing hidden world.

The live photography was accomplished using a variety microscope techniques, including dark field (good for showing the natural color of subjects) and the most advanced forms of differential interference contrast (DIC gives contrast to transparent structures that would be invisible in normal bright field microscopy). While these forms of imaging living protists are particularly revealing for some aspects of micro-organism biology, all of the organisms seen here can be studied



Micrasterias

successfully with student microscopes.

IMPORTANT NOTE: This program packs a lot of information and a wealth of observational data into nine different modules. We recommend that the material be viewed module by module, stopping for discussion and replay as needed. "Discussion starters" for the various modules are provided in this guide.

Chapters on this DVD:

CHAPTER CONTENTS

What is a Protist

Cells with a nucleus, are known as "eukaryotic cells". Single cell eukaryotes are called Protists. One of the problems in biology is how to classify protists. Analysis of their DNA and RNA shows that some lines of protists separated very far back in time, diverging from the earliest eukaryotes. Also, some lines of single cell life (green algae) are more closely related to multicellular organisms (plants) than to other lines of protists.

The lesson here is that single celled eukaryotes show such extreme evolutionary divergence, and that the old idea of lumping them into a single kingdom needs correcting. Biologists are now attempting to create a protist classification that looks more closely at their genetic material. The ultimate goal is to understand how the various lines of protists diverged from each other, and how these independently living cells and multicellular organisms are related.

Campanella, a colonial ciliate

Questions for Discussion:

Should biological classification reflect genetic relationships?

Why did biologists lump all single cell eukaryotes (and their near multicellular relatives) into a single kingdom Protista?

What should be the criteria for grouping organisms into a kingdom?

Euglena rubra

The Euglenids

In green euglenids, the red eyespot and corresponding photosensitive region near the base of the flagellum create a guidance system that allows *Euglena* to home in on a light source and swim in that direction until it reaches a light level suitable for photosynthesis. The euglenid shown is *E. rubra*, which can live at the surface in full sunlight, a niche unavailable to other euglenids due to the high levels of ultra violet radiation. *E. rubra* survives the radiation using a shield of red pigment. The pigment can be withdrawn when the sun isn't shining, giving the chloroplasts more light for photosynthesis. A swimming *E. rubra* shows the red pigment as a concentrated core in the middle of the cell. Several other species are shown hinting at the diversity of green euglenids.

Non-green euglenids include *Astasia*, which evolved from a green euglenid that lost its chloroplasts. Without photosynthesis, *Astasia* obtains its nutrition by absorbing nutrient molecules directly from its surroundings. In another relative, *Peranema*, the exceptionally robust flagellum works like a propeller, pulling the cell through the water. *Peranema* is a predator, capturing and engulfing smaller euglenids. Two rods, located in the mouth area, are used to hold prey during engulfment.

In the euglenid line, as in most other flagellated protists, individuals divide longitudinally. Division begins with duplication of the basal body at the base of the flagellum creating a cell with two flagella that then splits right down the middle. Today's euglenids are modern representative of an ancient line of life, so different from other protists that some biologists have suggested placing them in a kingdom of their own.

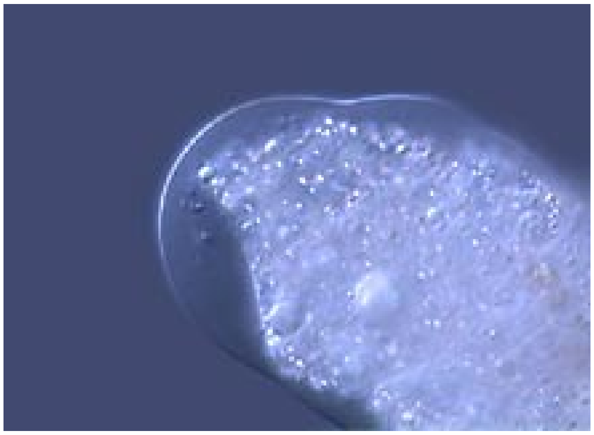
Questions for Discussion:
How might a euglenid loose its chloroplasts?
How could such a cell, deprived of photosynthesis, obtain nutrition?
What are the dangers to a single cell exposed to full sunlight?
How many kinds of euglenids can be found in accessible habitats near your school?

Diatoms and Their Unlikely Relatives

Diatoms are important producers in aquatic food chains. In diatoms, the photosynthetic pigment is yellow, not green. Diatoms convert the products of photosynthesis into oil droplets--an energy reserve the cell can draw on when the sun isn't shining. But the unique thing about a diatom is its house. These cells remove dissolved silica from the water and use it to construct finely sculptured glass cases.

Diatoms are not alone on their evolutionary branch. The lesson here is that even though organisms my look very different (diatoms and water molds), their genetic material may indicate that they occupy the same branch on the tree of life. Regrouping organisms on this branch is such a new game that biologists are yet to agree upon a name. One proposal for a branch name is "Chromista," considered by some to be a phylum and by others, a kingdom.

Questions for Discussion:
How do diatoms move?
What advantage might oil droplets be to a planktonic diatom?
In the intricately patterned glass houses of diatoms what function might the sculpturing serve?
Should evolutionary relationships be used as a basis for classification, even though the relatives look nothing alike?



Amoeba, extending pseudopod

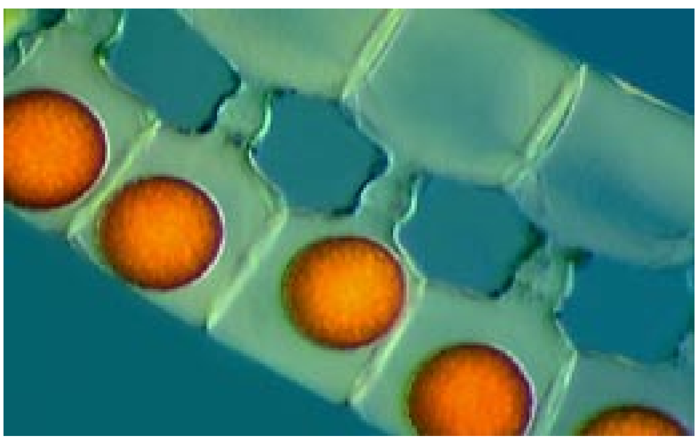
Actinosphaerium, a heliozoan

Amoebas and Heliozoans

This observational module shows amoeboid protists moving and feeding by the extension of pseudopodia. All of the amoeba observations are in real time. Shell-building amoebas such as *Difflugia* are common in pond water samples.

Heliozoans have long been classified with the amoebas, but genetic analysis places them on their own limb of the eukaryote tree. Their spines, made of microtubules, are often broken by a thrashing prey, but are quickly rebuilt.

Question for Discussion:
Does it appear that the diatoms ingested by the amoeba have undergone digestion, or do their glass cases protect them from digestive enzymes.
How do amoebas move?
Is there more than a single method of amoeba movement?
How does a heliozoan's spines actually trap prey?



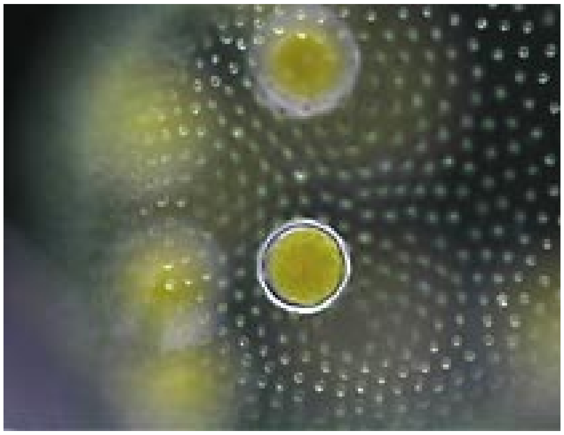
Spirogyra zygotes

Green Protists

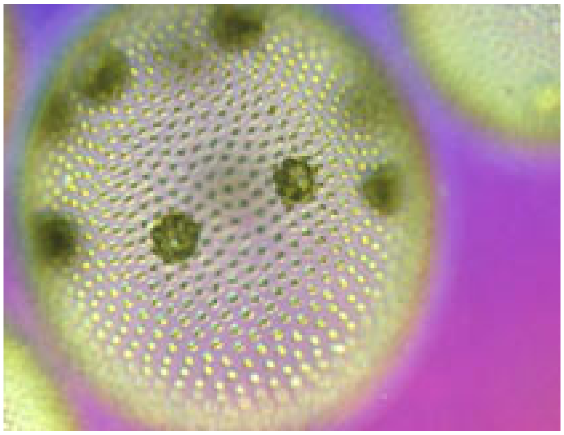
In unpolluted habitats it is common to find a diversity of unicellular green algae including crescent-shaped *Closterium*, a brilliant green cell with dancing crystals of gypsum in vacuoles at its tips.

Spirogyra is a filamentous alga composed of barrel-shaped cells with a band shaped chloroplast that spirals around the cell. Conjugation in *Spirogyra* usually occurs before seasonal disruption of the habitat. Conjugation results in zygotes that will assure a new population of Spirogyra when conditions improve.

Questions for Discussion:
What is causing the gypsum crystals to dance?
Are there male and female strands of *Spirogyra*?
What environmental factors might trigger conjugation in *Spirogyra*?



Volvox eggs



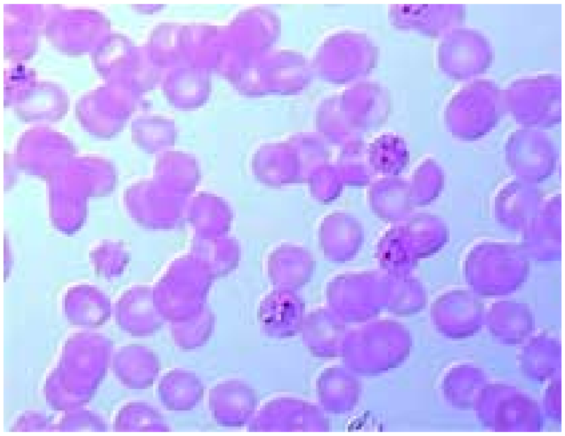
Volvox, daughter colony development

Colonial Protists

Colonial green protists let us imagine how simple plants evolved from single-celled green protists. In the same drop of pond water you can find: small colonies such as *Gonium*--usually with 16 cells; *Eudorina*--a 32 cells colony; and the queen of colonial protists--*Volvox*, with thousands of flagellated cells lining the sphere.

Volvox shows the beginnings of cellular differentiation, a key event in embryology of multicellular organisms. Within the *Volvox* colony germinal cells divide, producing daughter colonies that break out in an asexual cycle that repeats generation after generation. As winter comes on some daughters will produce packets of sperm, others eggs. The result of fertilization is a thick walled zygote that will carry *Volvox* through freezing and drying.

Questions for Discussion:
How would you explain the appearance of *Volvox* in temporary rain pools (vernal pools)?
Aside from difference in size and number of cells how does *Volvox* differ from *Gonium*?
What survival advantage might have driven the evolution of colonies from single cells?



Plasmodium, in field of red blood cells

Trychonympha, from a termite gut

Insiders

There are probably at least as many kinds if protists living inside animals as there are living in ponds, puddles, and oceans.

Plasmodium (three are seen in a stained blood smear) is a parasite of the red blood cells multiplying and breaking out in a daily cycle that produces the alternating chills and fever of malaria.

Another blood parasite, *Trypanosoma* (shown live in a drop of blood) produces an often fatal disease--sleeping sickness. Certain amoeboid protists colonize mammalian intestines, causing tissue damage and diarrhea. But not all insiders are harmful.

A termite's gut is packed solid with flagellated protists (*Trichonympha*) that aid in breaking down wood. Without its helpers, a termite would continue to eat wood, but die of starvation. A variety of protists live in the termite gut, but not all of them digest wood. The relationships among the various species are still being worked out.

Questions for Discussion:
How might blood parasites, such as *Plasmodium* and *Trypanosoma* evolve from free living protist ancestors?
At some point were their ancestors parasites of insects?
How do newly hatched termites become "infected" with their wood digesting symbionts?

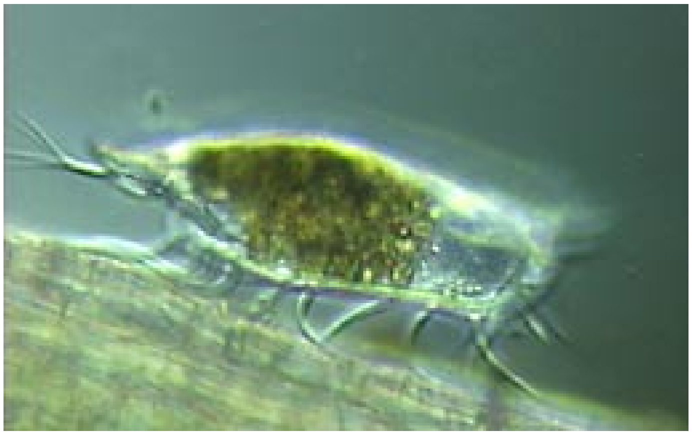
Ciliated Protists

In our view, ciliates are the dinosaurs of micro-space. *Colpidium* is representative of a large line of ciliated protists in which the cilia are uniformly distributed in rows. Lying just below the cilia rows are the mitochondria that supply the ATP that fuels the ciliary beat.

Animation shows cilia structure and explains how the power stroke is produced. The next section shows eight organisms (common in pond water samples) that demonstrate the diversity of ciliates.

Lacrymaria
Lacrymaria hides in the bushes, extending its neck to feed. This remarkable behavior is made possible by myonemes--muscle-like fibers that spiral around the cell. (***Q. -*** In what ways might the highly extendible neck be advantageous for *Lacrymaria*?)

Euplotes
Euplotes, has tendril-like locomotor structures called “cirri.” The cirri can be used to walk over surfaces. (***Q. -*** How might “walking” benefit a protist?)



Euplotes taking a stroll

Vorticella
In *Vorticella*, a band of cilia-stiffened membrane is used to generate feeding currents. *Vorticella* is a bacteria feeder, bringing in food from a distance. The bacteria selected are engulfed in a food vacuole that pinches off and circulates through the cell while the bacteria digest. If disturbed, *Vorticella* can snap in--the advantages of living on a contractile stalk. When it's time to divide, one daughter retains the stalk while the other develops a band of swimming cilia and breaks free. The swimmer is attracted to the stalks of other vorticellids where it will settle down, grow a new stalk, and join the group. (***Q. -*** What advantages might Vorticella enjoy by living in groups?)

Vorticella, contractile stalk

Vorticella group on duckweed rootlet

Urocentrum
Urocentrum turbo, has a unique method for remaining in choice feeding areas. *Urocentrum*’s trick is an invisible tether line that it attaches to some nearby object.
(***Q. -*** How is *Urocentrum* able to compete with other bacteria feeders such as *Vorticella* and *Paramecium*?)


Urocentrum, linked by tethers


Stentor

Stentor
There are many *Stentor* species (several are shown). Like other ciliates, stentors join at their mouths and exchange micronuclei in a form of sexual behavior known as conjugation.
Q. - In large *Stentor* species the macronucleus appears as a string of beads. Can this configuration be functional?

Trichodina
Trichodina lives as a commensal on *Hydra*, feeding on the bacteria that collect around hydra's regurgitated meals. *Trichodina* hangs on by means of an amazing adaptation--a multi-toothed basal disc.
Q. - What advantages might Trichodina derive by living on *Hydra*? Could *Hydra* derive any benefits from its guests? How might the protist be harmful to its host?


Trichodina attachment disk


Coleps feeding on Paramecium carcass

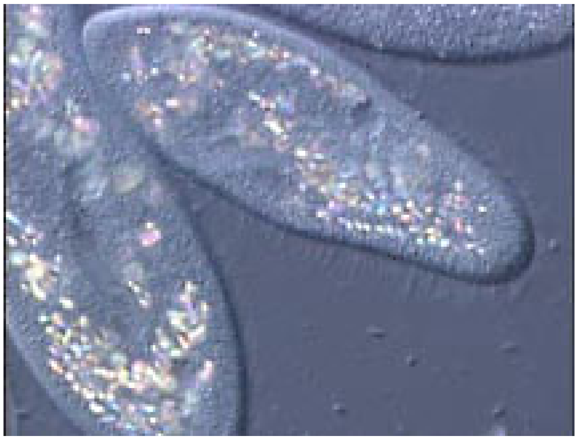
Coleps
No community would exist for long without scavengers, and in the microworld *Coleps* is the Jackal. These are feasting on a paramecium carcass.
Q. - How does *Coleps* attach in order to ingest food?

Suctorians
Looking in pond water you may find a ciliate that has no ciliaÑa suctorian. Upon contact, the suctorian’s tentacle tips fuses with the prey’s membrane and with some pressure adjustments, the suctorian sucks in its meal. Suctorians exhibit the very unprotist-like behavior of giving birth. As the ciliated larva emerges from the birth pore, it turns on the power--a response that helps it avoid touching its mother's tentacles.
Q. - Why do biologist place suctorians (organisms without cilia) on the ciliate line of evolution?

Didinium
Didinium has an appetite for just one type of prey--*Paramecium*. It takes *Didinium* approximately 40 seconds to swallow a *Paramecium*. In a laboratory dish, the feeding frenzy will continue until nearly all the paramecia have been eaten. With no more food, the didinia form cysts, lying dormant while they wait for a new population of paramecia to build up.
Q. - In a pond, how can *Paramecium*, which normally does not encyst, avoid being wiped out by a *Didinium* attack? What might signal an encysted *Didinium* that it is time to excyst and go hunting?

Paramecium

Paramecium can be cultured by adding some boiled hay (or dry grass clippings) to pond, or aquarium water.



Paramecium, excretory crystals

Didinium attacks a *Paramecium*

With plenty of organisms to examine one can observe:

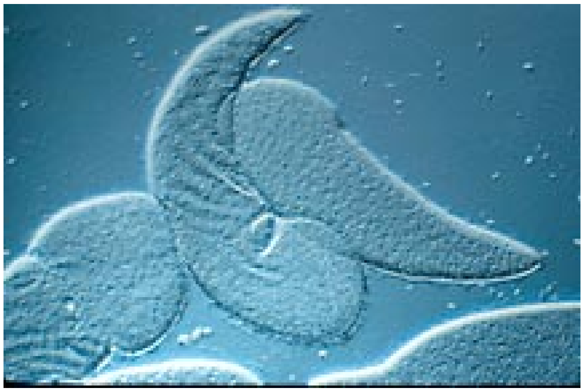
- How *Paramecium* feeds on bacteria by phagocytosis and digests them in food vacuoles.
- How the cell gets rid of water entering by osmosis by means of its contractile vacuoles.
- How it eliminates undigested material through its anal pore.
- How it deals with metabolic wastes by crystalizing them.
- How it avoids getting trapped in microscopic mazes.
- How it reproduces asexually, with division of its macronucleus and the duplication of its various organelles. Periodically, *Paramecium* enters into a sexual process, whereby individuals fuse together at their oral grooves and exchange micronuclei. This mixing of genes revitalizes the Paramecium population which can then continue on reproducing asexually for hundred of generations.

Paramecium dividing by fission

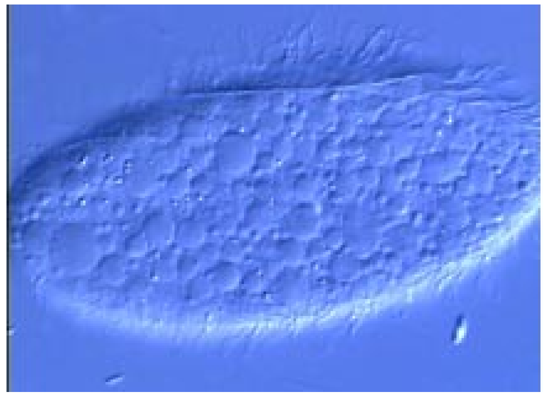
Additional Observations

The remaining sections on this DVD show a variety of protists with background music but with no narration. This exciting state-of-the-art microscope footage is provided for teachers who would like to involve students in observing living protists, an activity that leads to discussion and research. These can be used as an introduction to the study of protists (and the narrated portion of this DVD), or played as “ambiance” (to inspire student interest and questioning) during laboratory work with protists. One thing everyone agrees upon is that observing this remarkable footage of living microorganisms has tremendous learning benefits.

Flagellated Protists



Opalina



Opalina showing many nucleii

Opalina: 100-200µ Although *Opalina* appears to be a ciliate, it is more closely related to certain flagellated organisms. Opalinids are intestinal parasite of amphibians. The species shown was taken from a tree frog tadpole. Note that *Opalina* is a multinucleated cell with hundreds of nuclei, a rare phenomenon in protists. Because most of the opalinid population occurs in the host's rectum, *Opalina* is considered to be more commensal than a parasite.

To obtain opalinids for microscope study, without killing their host, use a glass eyedropper filled with 0.7% saline solution. The fire-polished end of the dropper can be gently inserted in the host’s cloaca. The idea is to provide a saline enema while sucking back a sample of the rectal content including any commensals it may contain. For a frog, the procedure may be a little unsettling, but certainly better than a postmortem extraction.

> ***Questions for Discussion:*** How might a multinucleated cell evolve? What kinds of nutrients are available to *Opalina*? How do tadpoles become infected?

Hexamita: around 20µ Hexamita is a diplomonad, related to *Giardia*, the notorious intestinal parasite known to travelers who indulge in untreated drinking water and spend the remainder of their trip in hospital bathrooms. The dark-field shot shows the typical rapid dancing behavior of unrestrained *Hexamita*. These came from a jar of putrid pond water in which a large freshwater bryozoan colony was decomposing (note the abundance of large spiral bacteria). *Hexamita* species are also common in the large intestine of frogs and salmonid fish.

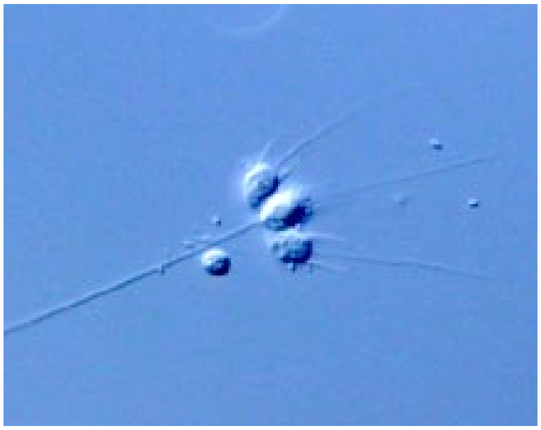
> ***Questions for Discussion:*** How might the transition from a free-living Hexamita to a parasite be accomplished? Might free living *Hexamita* have evolved the other way around--from parasite to free-living?

Dinobryon

Dinobryon: cells around 40µ *Dinobryon* colonies are found in the plankton of lakes. Colonial life may provide several advantages over living as a single isolated cell. Larger size may help prevent predation. Branching may help orient and stabilize the colony in the open water. Each new individual, resulting from division, builds on the rim of their sister and so derives all the benefits of colonial life.

Questions for Discussion: Based on the video observation, in what group of protists would you place *Dinobryon*?

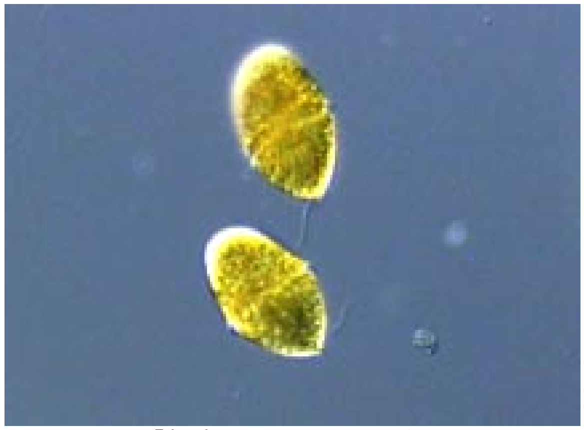
Codosiga on duckweed rootlet



Codosiga, collar and flagellum

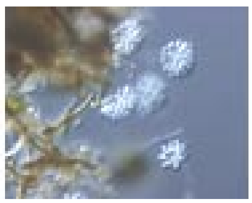
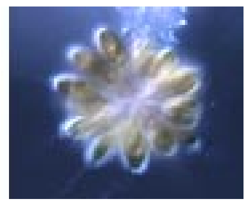
Codosiga: cells around 20µ Choanoflagellates such as *Codosiga* live attached to other objects. The first scene shows a colony of *Codosiga* attached to a duckweed rootlet. These cells have transparent collars (seen in optical section). A long flagellum emerges from the collar where it creates food-trapping currents. Choanoflagellates are virtually identical to the collar cells of sponges, suggesting a close relationship. In fact, these little cells may be our closest living protistan relative.

Questions for Discussion: What steps might a colonial choanoflagellate have undergone in becoming a sponge-like organism?



Gymnodinium, a dinoflagellate

Gymnodinium: around 40µ *Gymnodinium* is a common dinoflagellate found in lakes and ponds. The cells have a thin cellulose shell and two flagella. One flagellum is contained in a groove that circles the cell and produces rotation. The other flagellum projects posteriorly and provides forward locomotion. A surprising new finding, based on genetic analysis, is that dinoflagellates are more closely related to ciliates than to other flagellated protists.

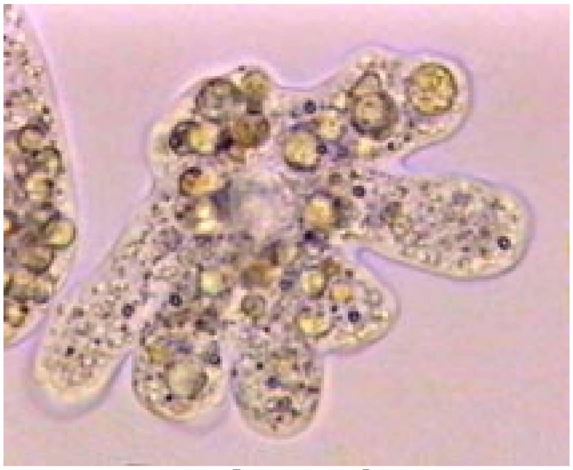
Four “Unknowns” to identify:

#1 ***Ceratium*** is a dinoflagellate common in the plankton of lake, ponds and oceans. How might Ceratium's structure be adaptive for planktonic life?
#2 ***Actinocystis*** is a colonial flagellate that produces a branching extension tube. The colonies break off and sheds individual cells which may start up new colonies. What advantages might gained by producing an extension?
#3 ***Phacus*** is a green flagellate with many species, some twisted, some flat. To what group of flagellates might *Phacus* be related?
#4 ***Synura*** is a colonial flagellate. Spherical colonies of flagellated cells are common in both the green and yellow-brown lines of life--and there are a few clear ones as well such as *Actinocystis*, #2 above.

Amoeboid Protists

Pelomyxa: 100-600µ These giant amoebas seldom put out pseudopods, creeping along by means of cytoplasmic waves. The one shown does indeed extend a broad pseudopod, but this may be in response to the coverglass pressing down on the organism. *Pelomyxa* is one of the few eukaryotic organisms lacking mitochondria, the ATP producing organelles that supply energy for cell use. *Pelomyxa*’s energy needs are met by symbiotic bacteria living in its cytoplasm. Some of these aerobic symbionts can be seen in the clear zone at *Pelomyxa*’s advancing surface.

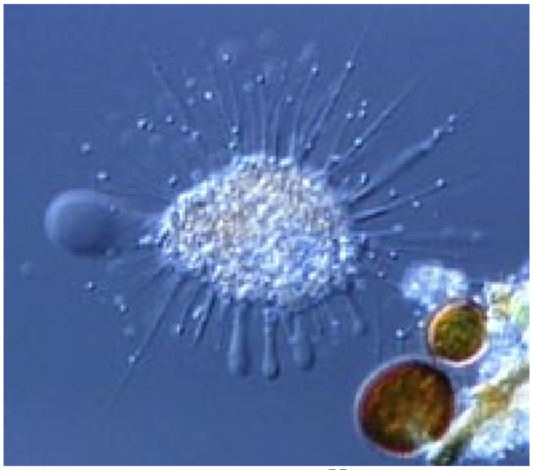
Question for Discussion: In what ways might *Pelomyxa* be a model for the evolution of mitochondria?



Hydramoeba

Hydramoeba: around 150µ We had been filming Hydra's feeding and reproductive behavior. Our subjects, which numbered in the hundreds, suddenly went into an obvious decline. They stopped eating the copepods we sent their way and their tentacles withered to nubs. The day after we first noticed the decline all but a few had simply vanished. Examining the remaining sickly Hydras showed them to be stuffed with parasitic amoebas which oozed out when the Hydra was pressed by the coverglass. Other amoebas clung to the sickly hydraÕs tentacles and body wall. Higher magnification showed that in addition to feeding on endothelial cells, the amoebas were ingesting the hydraÕs nematocystsÑthe stinging cells used to capture prey.

> ***Questions for Discussion:*** At what stage in the evolution of multicellular organisms did they become hosts for unicellular parasites? How might such relationships begin? How can a parasite benefit by killing its host?



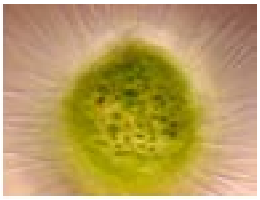
Vampyrella

Vampyrella: Named for its ability to enter and absorb the cytoplasm of algae cells, *Vampyrella* is an amazing find. Entering and emptying one cell in an algal filament, *Vampyrella* then moves to next and on down the line.

> ***Questions for Discussion:*** Many filamentous algas (*Spirogyra*, *Zygonema*) produce a jelly-like coating. What evolutionary pressures might account for these jelly sheaths?

Raphidocystis: This small heliozoan is easily recognized by its two types of axiopodia, long axiopods with beads that move up and down the axiopod, and shorter processes with wineglass tips.

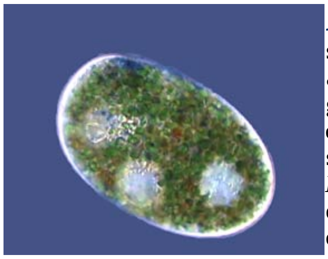
Choanocystis: This delicate heliozoan demonstrates the amazing ability of axiopods to repair themselves. The real-time observation shows how the microtubules that make up the axiopod quickly reassemble and repair the broken structure.

Two "unknowns" to identify.

#5 ***Acanthocystis***, a heliozoan filled with symbiotic algae (*Chlorella*). The fork-tipped processes are distinctive for this genus.
#6 ***Thecamoeba***, an amoeba with a thick pellicle that forms folds. These slow moving amoebas ingest filaments of cyanobacteria.

Ciliated Protists



Nassula: 200µ Jellybean shaped *Nassula* is from an ancient line of ciliates, possibly going back to a time when cyanobacteria were a major food source for early eukaryotic cells. *Nassula* continues this ancient diet today by engulfing strands of *Oscillatoria*. Its food habits make it one of the most colorful ciliates, due to *Oscillatoria* fragments in various stages of digestion. When food runs low, or when the pond dries up, *Nassula* encysts, awaiting better times.

Questions for Discussion:Does it appear that *Nassula* is restricted in its diet? Most ciliates engulf their food by phagocytosis, a process of surrounding the food with plasma membrane as it is taken into the cell. How then does *Nassula*, which engulfs its meal en toto break up the cyanobacteria strands and surround them with membrane?

Homalozoon: 400µ These large ciliates have a “nose” filled with toxicysts used to stun and kill small ciliate prey. In the dark-field observation, the “nose” touches a small ciliate which immediately disintegrates. *Homalozoon* then expands its anterior end and engulfs the prey. Homalozoon is adapted for living on, and moving slowly over, surfaces. In a petri dish it is often difficult to dislodge the cell, which adheres to the glass surface.

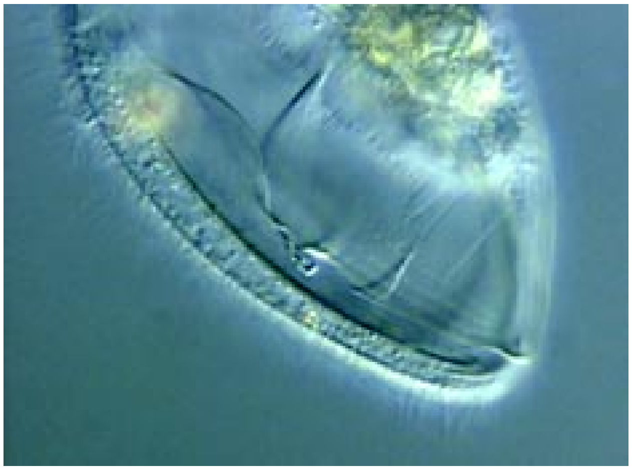
Questions for Discussion: How would you describe Homalozoon's ecological niche? How does it “stick” to surfaces?

Loxodes: two species are shown, *Loxodes magnus* (500-700µ) and *Loxodes vorax* (150µ). After several hours of observation, we have yet to see *Loxodes* actually engulf food. The cytostome is located in the in-curved region and appears to have an extension that may "unzip" to engulf large items. *Loxodes* has an unusual featureÑa row of pinkish bodies known as Mullerʼs vesicles. The pink bodies are barium salt crystals.

Questions for Discussion: What function might the Muller's vesicles serve?

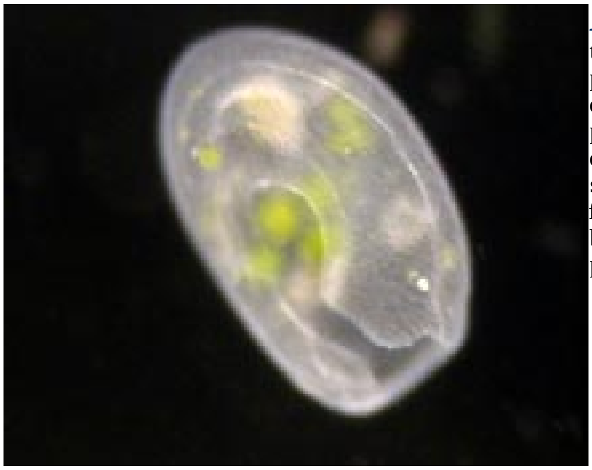
Trachelius: ovum 200µ. *Trachelius* ovum has a balloon-like cell body filled with large vacuoles. The curved proboscis contains a slit that moves suspended food items to a cytostome at its base. Look for *Trachelius* in plankton collections taken near weed beds. It hovers in the water using cilia to create a current from which it constantly filters out microorganisms, a feeding style practiced on a somewhat larger scale by the baleen whales.

Question for Discussion: In what way might the shape of these large cells be adaptive for living in the open water?

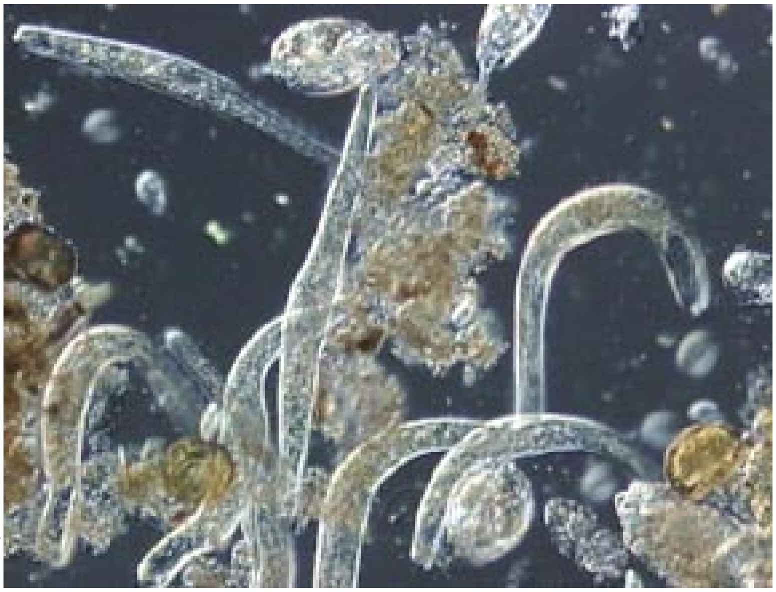


Lembadion: 120µ Common in pond vegetation, *Lembadion* is a specialist at capturing small rapidly swimming ciliates such as Halteria. The cell is cupped, forming a large open cavity. On either side of the cavity are membrane flaps. When feeding, the flaps repeatedly open and close. Upon a chance encounter with a small ciliate, the flaps stay closed, preventing the prey from escaping.

Questions for Discussion: How might *Lembadion*'s unique feeding structure have evolved? Which organisms in this collection would you guess to be its closest relatives?



Bursaria trunkatella 500-1000µ, *Bursaria* swims through the water with its cavernous food trap sweeping up protists in its path. The actual cell mouth is at the rear of the cavity. Rows of cilia lining the narrowing food channel prevent prey from escaping. The macronucleus is long, curving around the cell interior. Contractile vacuoles are small and numerous lying near the surface. Bursaria is often found after seasonal rains fill temporary pools or catch basins, where it survives drying and freezing within the protection of thick walled cysts.



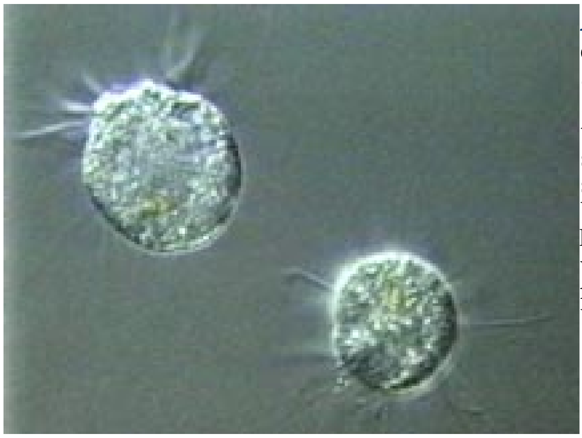
Spirostomum: The species shown here is a small one, extending to around 300µ. Some species of *Spiostomum* reach a length of 4mm. The species shown has a single macronucleus, but its longer relatives have multiple macronuclei strung together like a string of beads. A feeding groove, with associated cilia, extends part way down the elongated cell with a cytostome at its end. A collecting tube runs the length of the cell emptying into a contractile vacuole that fills the posterior of the cell. Myonemes (muscle-like contractile fibers visible in the observation) run the length of these long cells. *Spirostomum*'s worm-like shape seems well suited for living in the tangle of bottom debris where bacteria and small protists are usually plentiful. A thick population of *Spirostomum* resembles a plate of animated spaghetti. When disturbed *Spirostomum* suddenly contracts to about a quarter of its extended length. Find the place in the observation where the cells contract.

Questions for Discussion: How might the ability to contract benefit these extremely long cells?

Blepharisma: 130-200µ common in pond water. Two species are shown. Most ciliates are colorless, except for the colored food items they have ingested. Blepharisma is the rare exception. Cultured in bright sunlight it may appear colorless, but most individuals found in the shady aquatic jungles of ponds are pink. *Blepharisma* has a feeding channel, lined on one side by a membranous veil that traps small organisms and direct them to its mouth. On the other side of the channel, tufts of long cilia, beating in waves, help steer small food organisms into the cytostome. The second species shown in the observation cultures algae in its cytoplasm, a kind of symbiosis practice by a number of other large ciliates.

Strobilidium gyrans: 40µ Think of it as an escaped airplane motor running at full throttle. A ring of extremely powerful fused cilia create a feeding current that brings bacteria and small algae cells to Strobilidium's centrally located cytostome. *Strobilidium* secretes a tether, allowing it to remain in choice feeding zones. The tether is produced from a “tail” projection covered with “teeth” that appear to be used to snip the tether, allowing the cell go shooting away should danger threaten or local conditions deteriorate. In terms of body length traveled over time *Strobilidium* may well be world’s fastest protist. Under full power it can exceed 150 body lengths per second, not bad for a cell 40 micrometers in length moving through a viscous medium. *Strobilidium* is commonly found in aquatic plant infusions and seems more at home in well oxygenated water than in putrid cultures. This may be due to the high oxygen demands imposed by its powerful ciliature--the propellers that create its long-reaching feeding currents, and its remarkable speed.

Questions for Discussion: What is the advantage of living on a tether?



Halteria: 25-40µ, Common in stagnant pond water cultures. *Halteria* is shaped like a fat flower vase. The anterior is surrounded by cirri that produce a smooth gliding motion. Around the mid-section are groups of long stiff cirri that produce an entirely different form of locomotion--the sudden jumps for which this ciliate is noted. Bacteria and small algae cells are taken in through a curved slit bordered by a row of cirri that sweep in the food. These entertaining little cells go bouncing through their environment--but to what purpose? Filming several caught up in *Stentor*'s feeding currents we discovered once again how structure, behavior, and function are inevitably related.

Campanella: cells 200µ, colonies up to 4 cm, *Campanella* colonies are by far the largest we have seen in nature. In our lab's outdoor fish pond, they often form blobs several centimeters in diameter. The cells are extremely robust, with rings of cilia-stiffened membrane that create a lot of local turbulence. The branching stalks (which began from a single individual) contain no myonemes and so can not contract. The individual cells, however, contain contractile proteins and jerk into tight balls if disturbed.

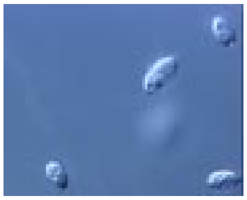
Epistylis: cells 100µ, Members of this genus are often found living on other organisms ranging from turtles to copepods. Like *Campanella*, the stalk does not contract and functions as a pedestal that holds the feeding individuals above their attachment site.

Six "unknowns" to identify.

Lionotus 100-200µ. *Lionotus* can be distinguished from other elongated ciliates by having cilia restricted to the outer curve of its "neck". The inside curve lacks cilia but is equipped with trichites distributed along the length of the cytostome--a long slit running along the slender neck. If you find a population of *Lionotus*, try to determine how it feeds and the kinds of food it goes after.

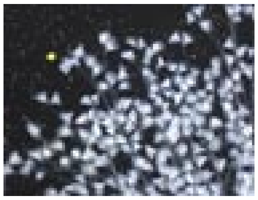
Dileptus 250-300µ One of the stealthy predators of the microworld, *Dileptus* hides in the bushes, extending its neck to snare passing rotifers and large protists. Once brought to the cytostome located at the base of the neck, the prey is engulfed with the aid of trichites.

Glacoma 50µ A number of small ciliates have cytostomes containing flapping membranes. See *Colpidium* in the narrated section of this program, and for an extreme case, *Lembadion* seen in the additional ciliates section



Cyclidium 25-30µ These tiny ciliates, almost always seen in masses, remind one of a cage of mice, all scampering about in total confusion. The illusion is enhanced by a particularly long cilium at the posterior end of the cell. Stop on clear frames to see *Cyclidium*'s structures, particularly the undulating membrane that channels food to its mouth and the long stiff cilia that produce the jumping locomotion characteristic of these small cells.

Metopus Two species are shown. Sizes vary from 100µ to 200µ . The anterior of *Metopus* is folded over, causing these cells to spiral when free swimming. The twist creates a trap for food organisms that are then transported to the mouth. *Metopus* thrives in low oxygen environments.



Carchesium cells 120µ, colonies up to 6mm *Carchesium* forms a branching colony in which the various branches contract independently. The observation shows a newly formed colony with just a few individuals. Over the next month, the colony grew to approximately a centimeter in diameter with thousands of individuals distributed on five main branches. Touching a few individuals on one branch caused a chain reaction with all members of that branch contracting causing the sub-branch to snap back into a ball. Occasionally the response would spread to the other branches and the grape sized colony would snap down to pea size before returning to feeding.

To learn more about these fascinating organisms, collect water from local sources. Jars of pond water that contain some decaying vegetation and kept at room temperature for several days will often teem with populations of protists.

To identify organisms found in natural collections we recommend the classic ***How to Know the Protozoa*** by T. L. Jahn, and ***Guide to Microlife*** by Rainis and Russell.

To further explore the lives of these fascinating organisms see The MicroNaturalists Notebook, a monthly feature on our web site eBioMEDIA.com.

A full listing of the Biology of--- series video and DVD programs (18 topics, from Viruses to Chordates) can be found at eBioMEDIA.com.