Zooplankton Diversity

OCN 621

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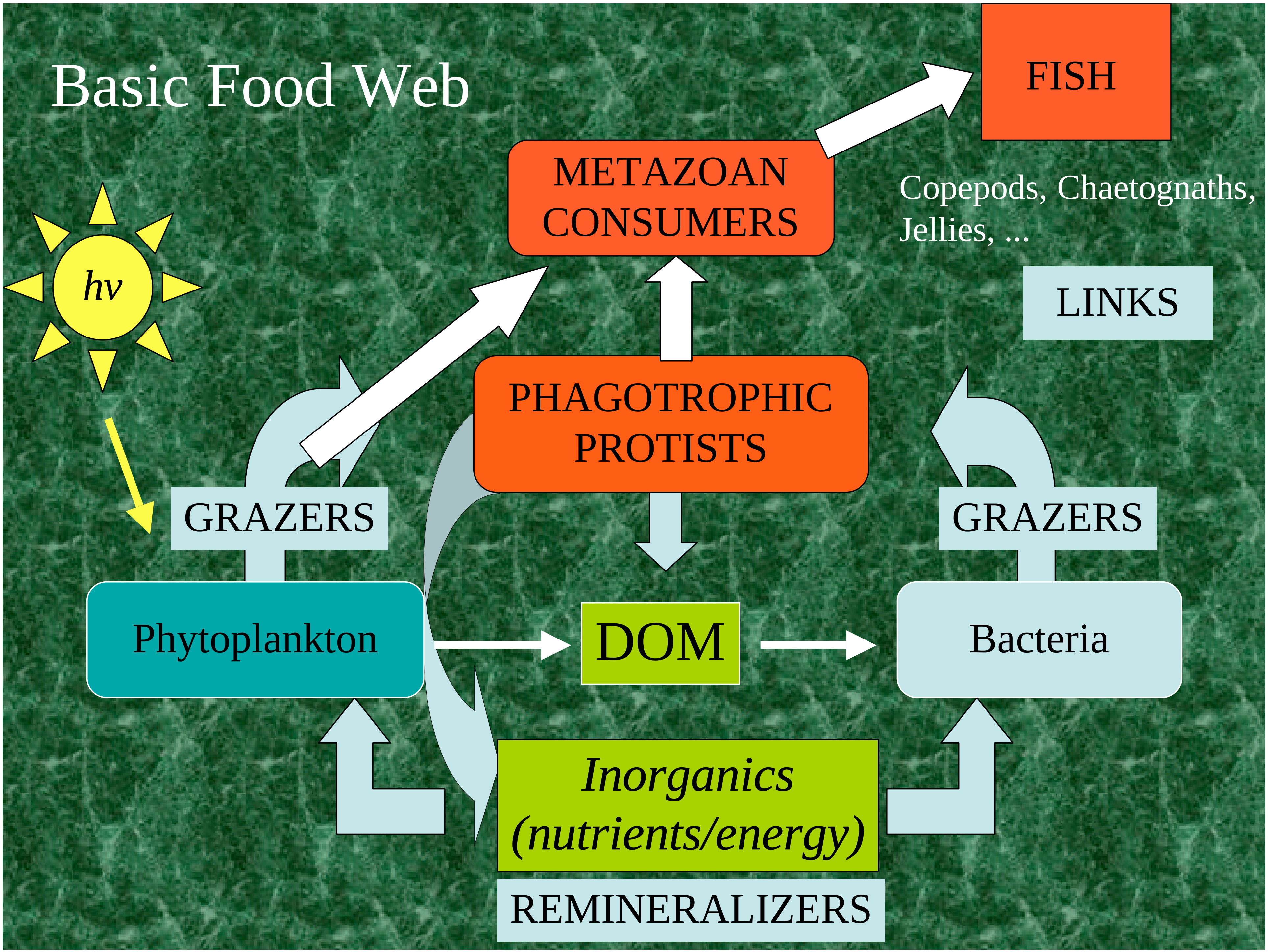
Topics Covered This Week

- Introduction to Planktonic Consumers
  - Who are they?
  - What do they eat?
  - Models of Feeding
  - Selective Feeding
  - Measuring Feeding Rates

Basic Food Web



Feeding

- What do feeding rates tell us about marine ecosystems?
  - Death rates of organisms consumed (“top down controls”): mortality rates
  - Transfer of biomass to higher trophic levels
    - implications for ultimate yield of biomass

      or
    - downward flux of fixed carbon
  - Implications for nutrient remineralization

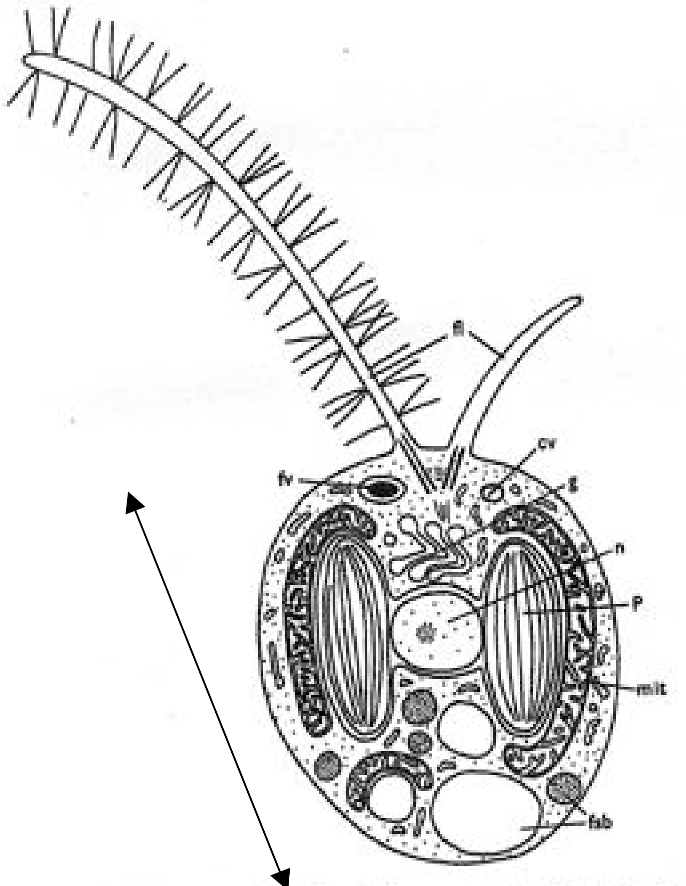
Who are the microzooplankton?

Characteristics and feeding modes of pelagic planktonic consumers

- **Protists: diffusion feeding, direct interception, filter feeding, dinoflagellate feeding diversity, mixotrophy**
- Crustacea: filter and raptorial feeding
- Chaetognaths: raptorial feeding (ambush predators)
- Gelatinous Zooplankton: tentacles, sticky cells and filter feeders
- Larval Fish: mainly raptorial feeders

What are Protists?

Example: *Ochromonas* (flagellate)



Sleigh 1989

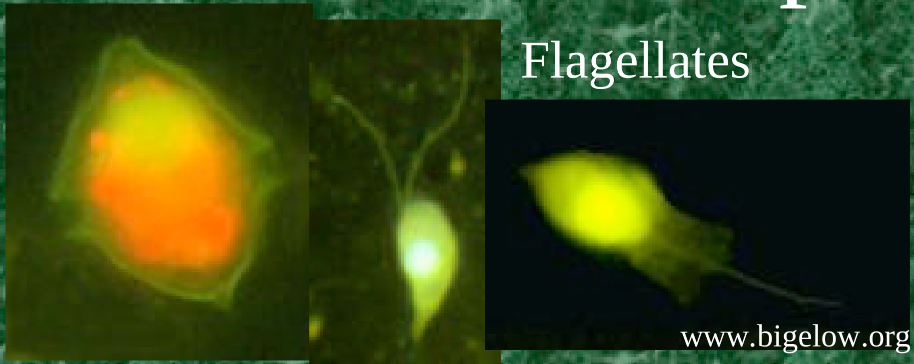
Fig. 1.2 Diagram of structures found in *Ochromonas*, a flagellate member of the Chrysophyta, showing the contractile vacuole *cv*, flagella *fl*, food storage bodies *fsb*, food vacuole *fv*, Golgi body *g*, mitochondion *mit*, nucleus *n* and plastid *p*; length of cell body about 10 μm.

Protists are many of the phytoplankton (e.g., diatoms, coccolithophorids, dino-flagellates, "picoeukaryotes", etc.)

Microheterotroph grazers are also protists (e.g., flagellates, ciliates, dinoflagellates, etc.)

NOT PROTISTS: *Prochlorococcus*, *Synechococcus*, other bacteria

Common Groups

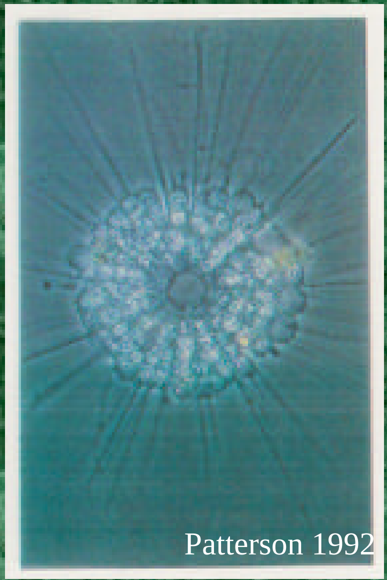


Sarcodina (pseudopodia): Amoeba, Foramininfera, Actinopoda

www.ucmp.berkeley.edu

Radiolarian (Si)

Acantharian ($SrSO_4$)



Heliozoan (Si)

Who do they feed on?
Regional Comparisons of Microzooplankton Grazing Impact

60 - 75% of daily production consumed by microzooplankton

Table 1. Regional comparisons of system characteristics from dilution experiments. Data are distinguished among *Oceanic*, *Coastal* (overlying the continental shelf), and *Estuarine* (including coastal bays) habitats in the upper table and among *Tropical/Subtropical*, *Temperate/Sub-polar*, and *Polar* regions in the lower table. Mean values (± standard errors) are given for initial Chl *a*, phytoplankton growth rate (μ), grazing mortality (m), and percentage primary production grazed d^{-1}. Exp = number of experimental estimates averaged for the region, out of a total of 788.

	Exp (% total)	Chl *a* ($\mu g\ l^{-1}$)	μ (d^{-1})	m (d^{-1})	% PP grazed
Oceanic	510 (65%)	0.58 ± 0.03	0.59 ± 0.02	0.39 ± 0.01	69.6 ± 1.5
Coastal	142 (18%)	3.06 ± 0.53	0.67 ± 0.05	0.40 ± 0.04	59.9 ± 3.3
Estuarine	136 (17%)	13.0 ± 1.8	0.97 ± 0.07	0.53 ± 0.04	59.7 ± 2.7
Tropical	259 (33%)	1.01 ± 0.21	0.72 ± 0.02	0.50 ± 0.02	74.5 ± 2.0
Temperate	435 (55%)	5.18 ± 0.66	0.69 ± 0.03	0.41 ± 0.02	60.8 ± 1.8
Polar	94 (12%)	0.62 ± 0.06	0.44 ± 0.05	0.16 ± 0.01	59.2 ± 3.3

Landry & Calbet 2004, Microplankton production in the oceans, ICES J. of Mar. Science 61:501-507

Food Vacuoles

Intracellular vacuoles digest the food (no gut as in metazoans)

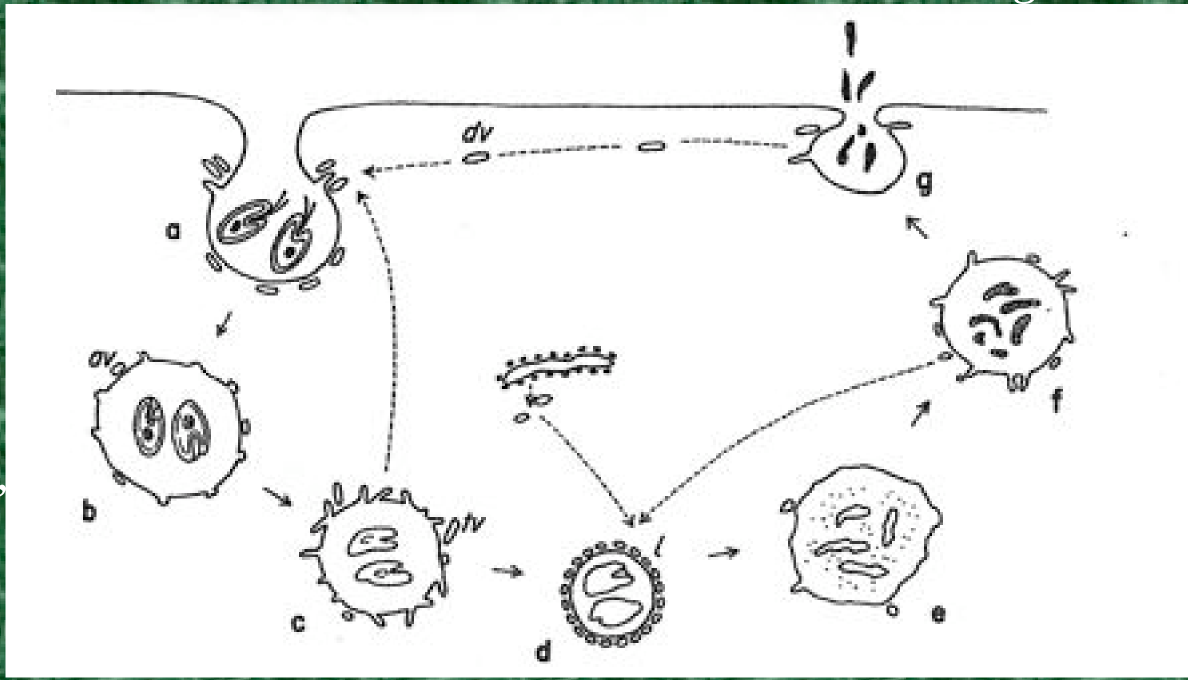
Example of a food vacuole cycle in a protist:

Sleigh 1989

a: food vacuole "pinching off" from outer membrane, enclosing food items (phagocytosis)

b: it fuses with acid-containing vesicles (av)

c & d: it shrinks as liquid is removed, then merges with lytic (lysosomal) enzymes (digestion)



e & f: after food digestion, digested vacuolar contents are pinched off into cytoplasm, as are the enzymes for re-use

g: undigested material may be released to the "outside" environment (remineralization) and the membrane retrieved to be re-used for another cycle

Protist Feeding Modes

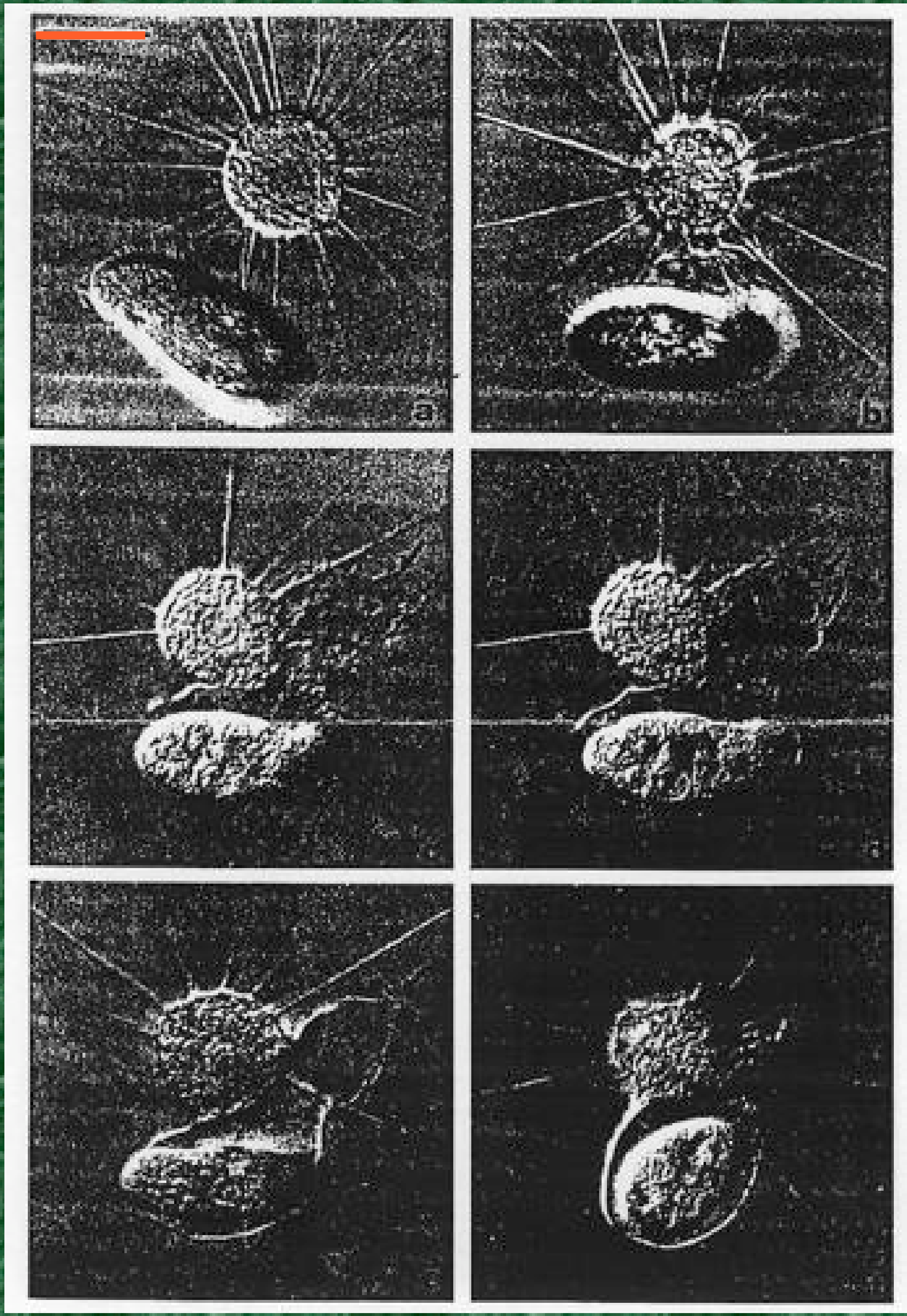
 

- Sarcodines: Diffusion feeding (except amoebae)
- Flagellates: Direct interception
- Ciliates, some flagellates: Filter (suspension) feeding
- Dinoflagellates: peduncle and pallium feeding

Protist Motility: pseudopods

- Sarcodines: e.g., amoebae

http://www.isengrim.com/lasaterd43.html



Diffusion Feeding

Actinophry sol (heliozoan) capturing the ciliate *Colpidium*.

a) adhesion
b) pseudopod extension
c/d) pseudopod wrapping around prey
e/f) prey completely enclosed

scale bar = 50 µm

Hausmann & Patterson 1982

Movie of Diffusion feeding

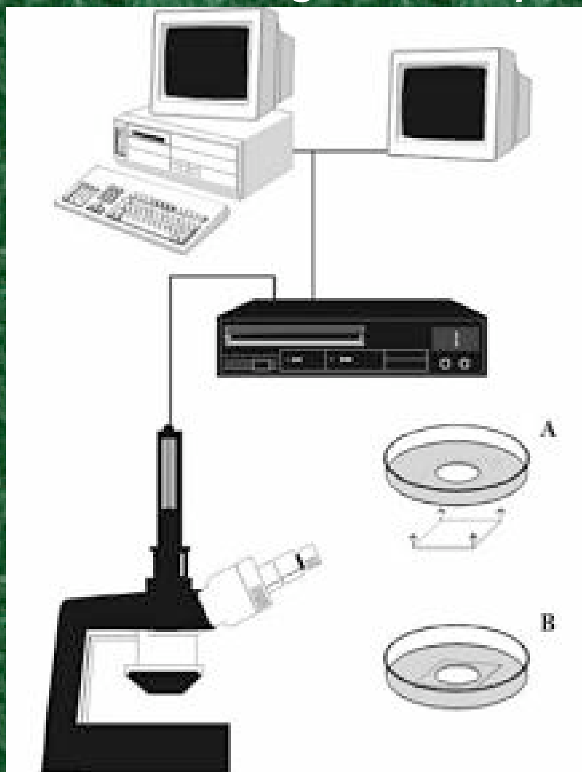
Direct Interception Feeding

- Performed by the smallest protists (flagellates)
- Results in "bacterivory"
- Ubiquitous in aquatic ecosystems

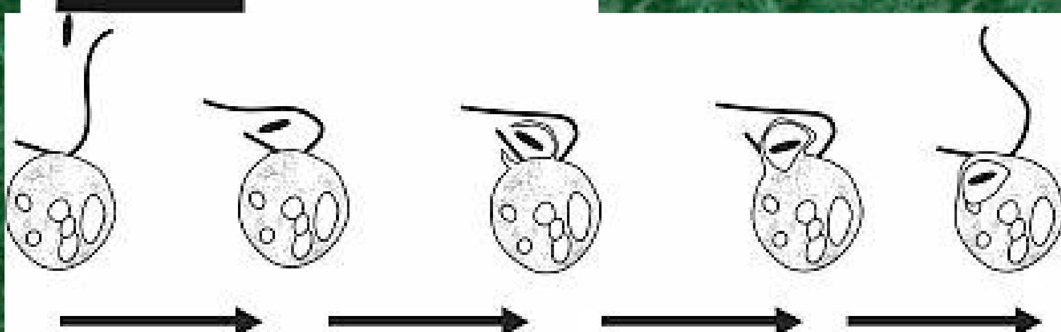
Images courtesy of Bay Paul Center
http://starcentral.mbl.edu/microscope/portal.php,

On the use of video-microscopy for the analysis of protist feeding behavior

J. Boenigk, ***Institute for Limnology, Austrian Academy of Sciences, Mondsee, Austria***



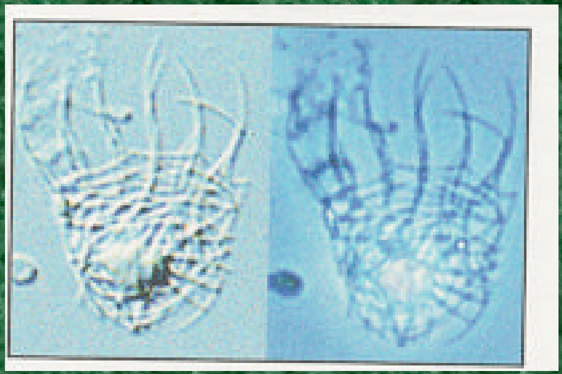
The mechanisms of food selection were the focus of the study. Food selectivity of heterotrophic nanoflagellates can be subdivided into: (1) passive food selection (contact probability and morphological properties of the feeding structures are responsible for a particle-specific response); and (2) active food selection (flagellates may actively select food during food uptake). These experiments revealed a high variability between species, and also high intraspecific variability. Advantages and disadvantages of the technique will be discussed. These include photochemical effects, experimental artifacts and the general suitability of the method for investigating behavioral patterns in microbial populations.



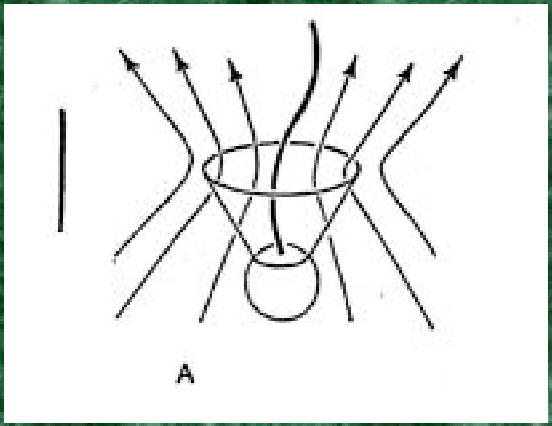
Feeding steps of a flagellate.

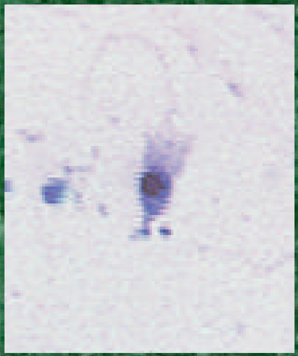
Paper presented at Measuring Behavior 2002, 4th International Conference on Methods and Techniques in Behavioral Research, 27-30 August 2002, Amsterdam, The Netherlands

Filter feeding - choanoflagellates

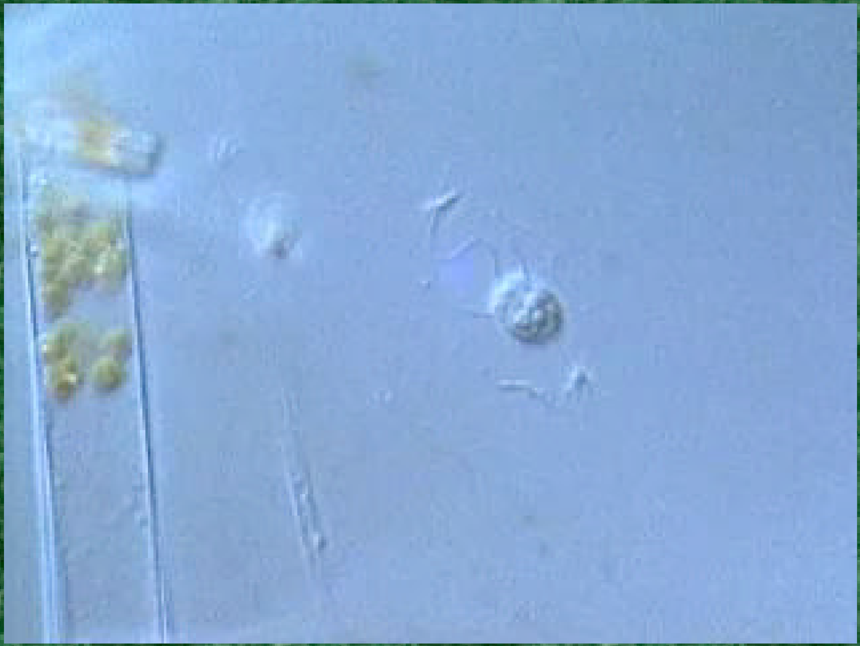


Acanthocorbis unguiculata (dry prep)





Parvicorbicula quadricostata
(Southern Ocean)



http://www.aad.gov.au/

Ciliate filter feeding

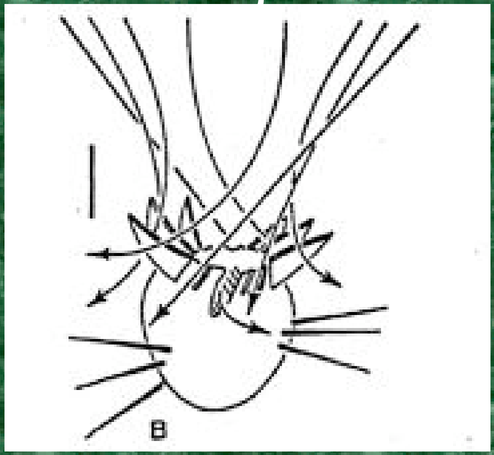
Video by Harvey Marchant

http://www.aad.gov.au/

http://www.aad.gov.au/

More filter feeding: ciliates

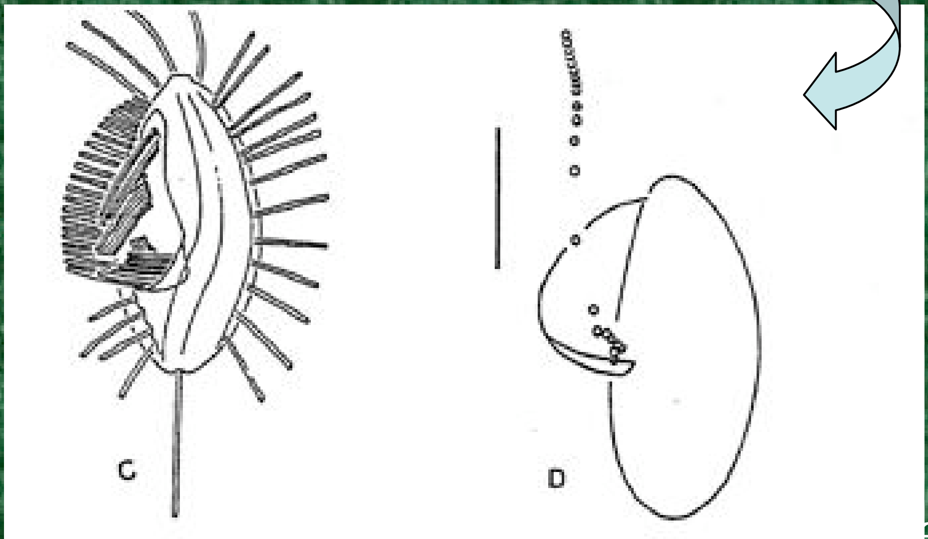
scale bar = 10 µm



Ciliate (oligotrich, *Haltheria*): particles intercepted on inside of membranelle zone

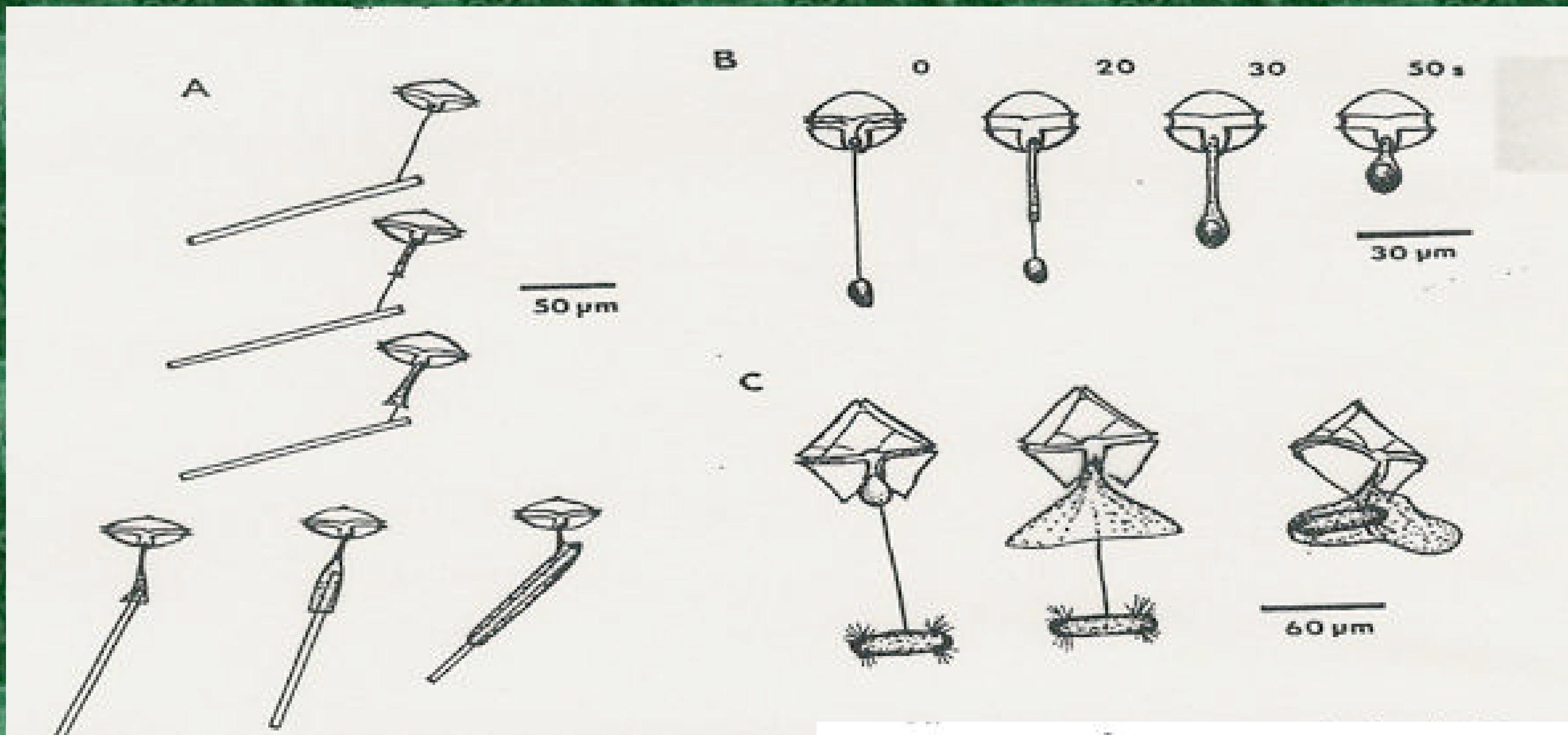
Position of a latex bead at 20 µs intervals, showing acceleration of water into the membrane.

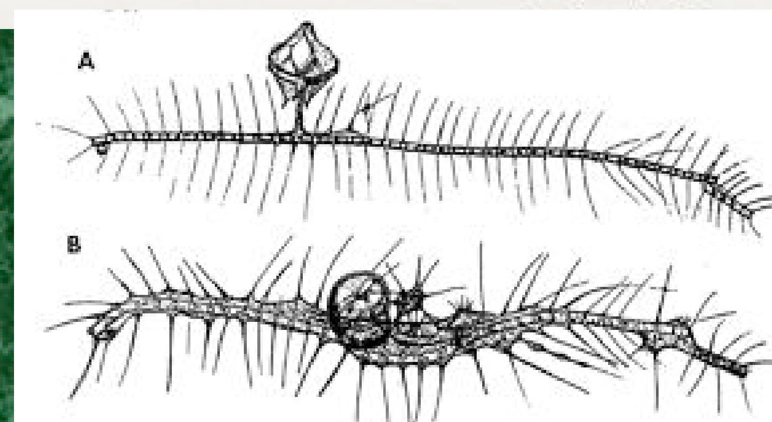
Ciliate (scuticociliate, *Cyclidium*): particles intercepted on a paroral membrane of parallel immovable cilia.



Fenchel 1986

Pallium Feeding by Dinoflagellates





figures from Jacobsen & Anderson 1986

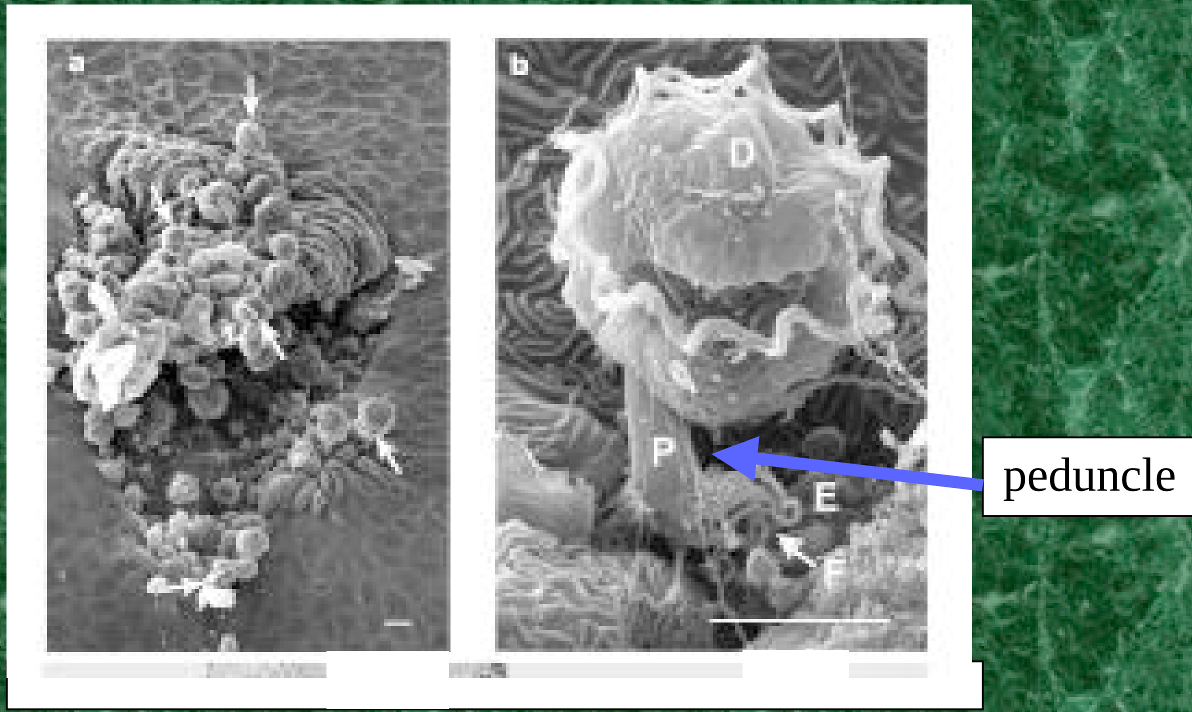
Pallium Feeding by Dinoflagellates

movie shown in class

Peduncle Feeding by Dinoflagellates (Myzocytosis)

e.g., Pfiesteria spp.: fish killed by dinoflagellate predation

A larval sheepshead minnow (*Cyprinodon*) being fed upon by *Pfiesteria*



fish skin lesion w/dinos attached

Vogelbein et al. 2002

Gymnodinium feeding

- Peduncle feeding of *Gymnodinium fungiforme* extending into unidentified food particle

  (Spero & Spero 1982)

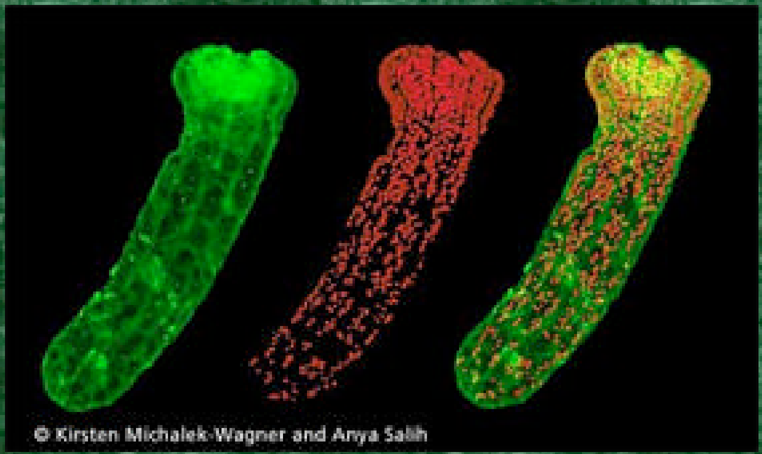
Mixotrophy

- Mixed mode of nutrition, definition broad enough to include symbiotic relationships
- Widespread amongst protistan groups
- Diverse: manifests in many ways

Advantages & Functions of Mixotrophy

- ✎ Gas exchange--oxygenation of large cells
- ✎ Source of nutrients/organics for basically autotrophic cell in an oligotrophic environment
- ✎ Protection, advantage to symbionts

For corals, symbionts supply the added nutrition required for secretion of $CaCO_3$ skeletons



http://www.reefed.edu.au/home/explorer/plants/

Three General Types of Mixotrophy

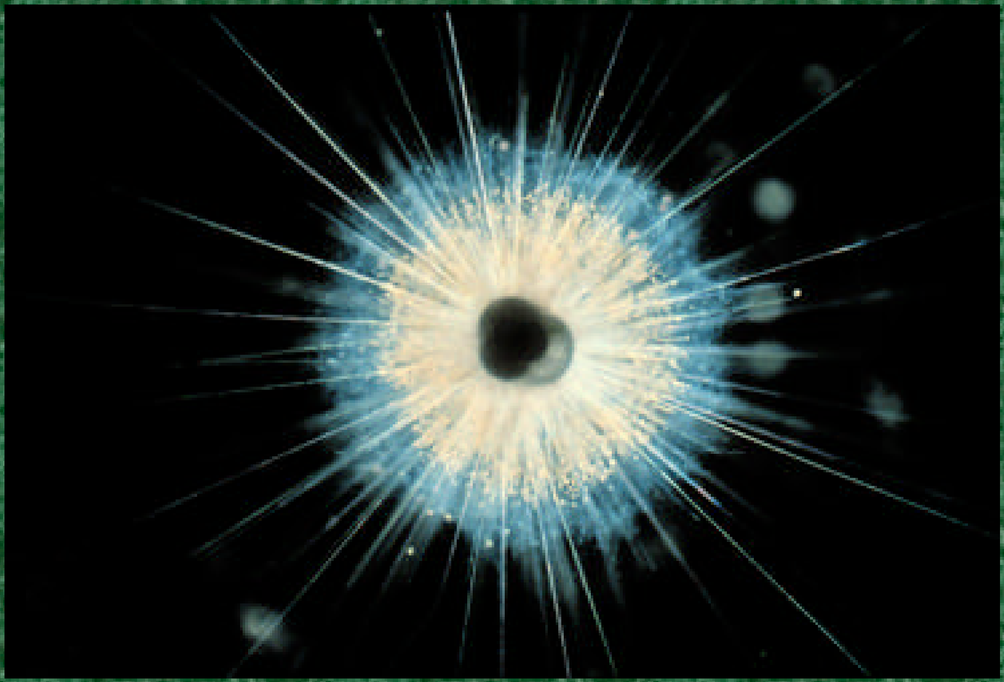
1. Endosymbiotic relationships: true symbiotic relationships, like algae in corals

• *mostly associated with Sarcodines -- symbionts are often dinoflagellates, monads, diatoms, red algae*

• *usually only one symbiont type per host species*

• *enclosed in vacuolar membrane, "respectful distance"*

Globigerinoides ruber
with dinoflagellate symbionts



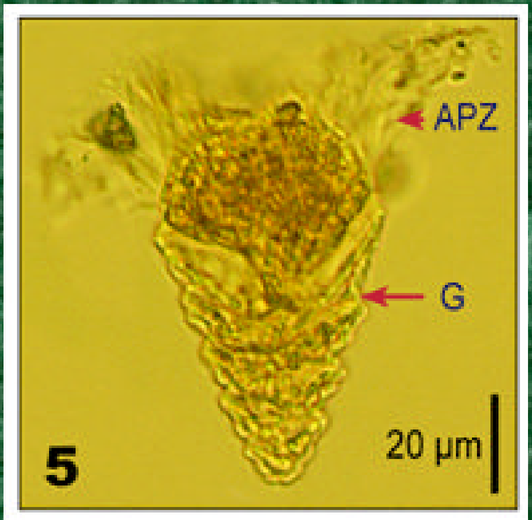
2 mm

image courtesy of D. Lea, UCSB

2. Borrowed chloroplasts

Example: Laboea strobila, a tintinnid ciliate, borrows chloroplasts, it may eat some at night -- gets mainly polysaccharide sugars and LMW molecules from chloroplasts

- Implication: since “prey” may continue to produce organics for predator after ingestion, efficiency of growth might be higher than predicted simply from ingestion of prey biomass

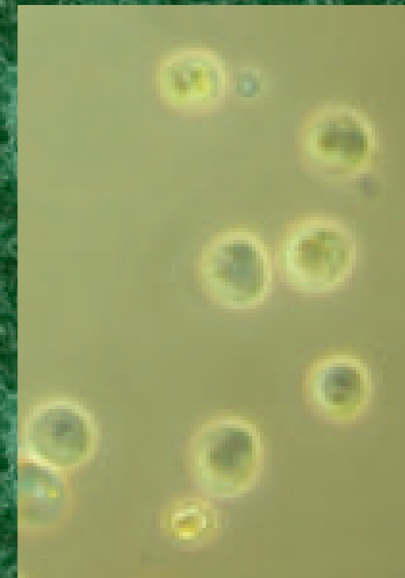


http://www.liv.ac.uk/ciliate

3. Inherent part of Organism's Structure (genome)

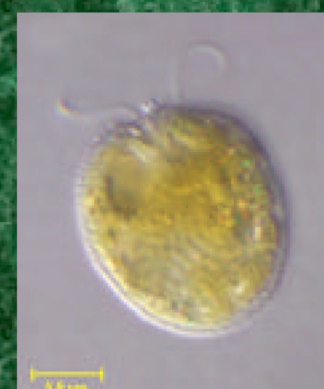
Example: Mixotrophic flagellate (chrysophyte) P. malhamensis, phagotrophy dominates if bacteria are present, phototrophy only when bacterial abundance becomes limiting.

- Other organisms may show the opposite preference for trophic mode.



Carina Pålsson
www.limnol.lu.se/limnologen

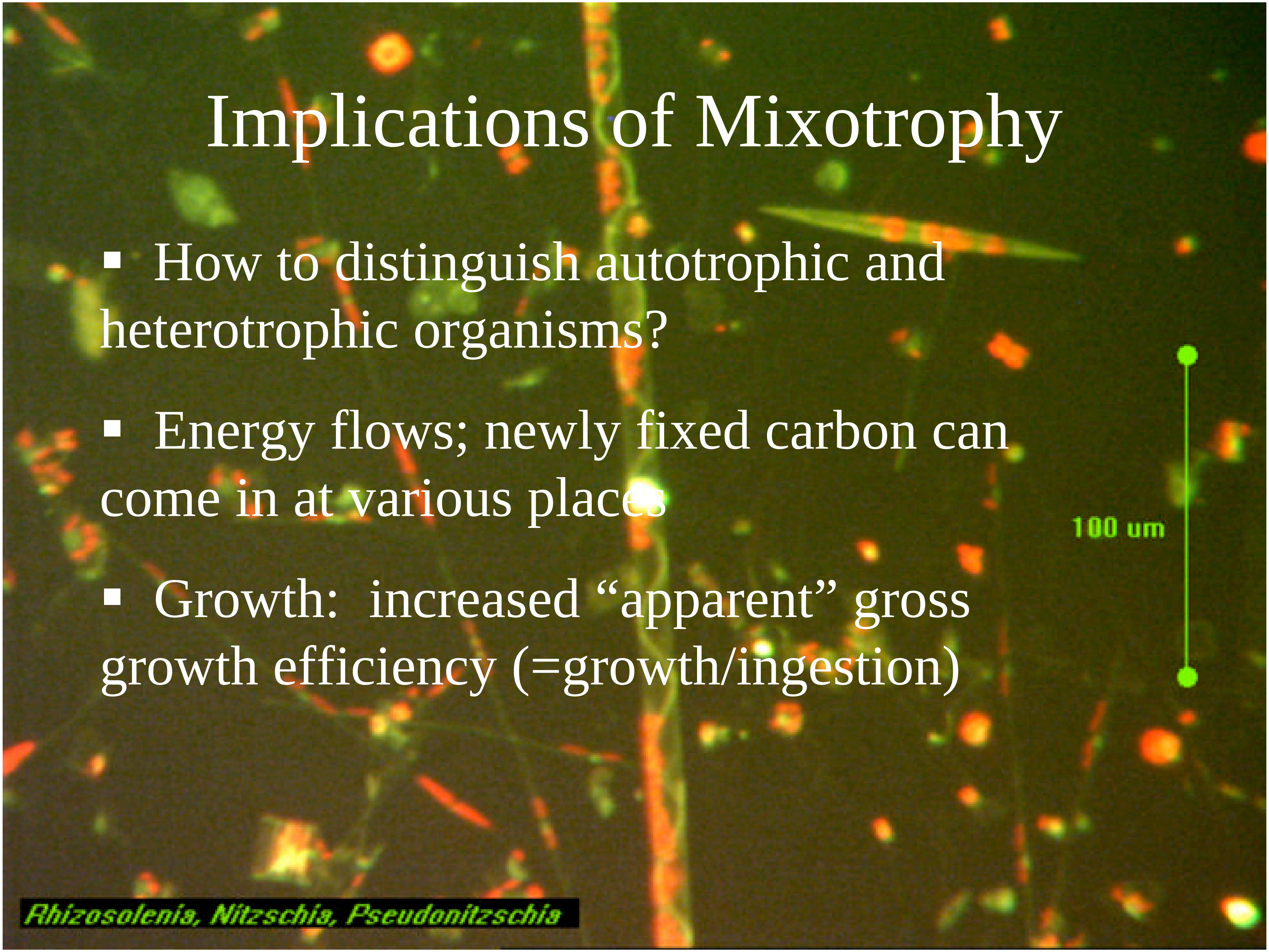
Prorocentrum minimum



www.sb-roscoff.fr/Phyto/gallery/

Implications of Mixotrophy

- How to distinguish autotrophic and heterotrophic organisms?
- Energy flows; newly fixed carbon can come in at various places
- Growth: increased "apparent" gross growth efficiency (=growth/ingestion)



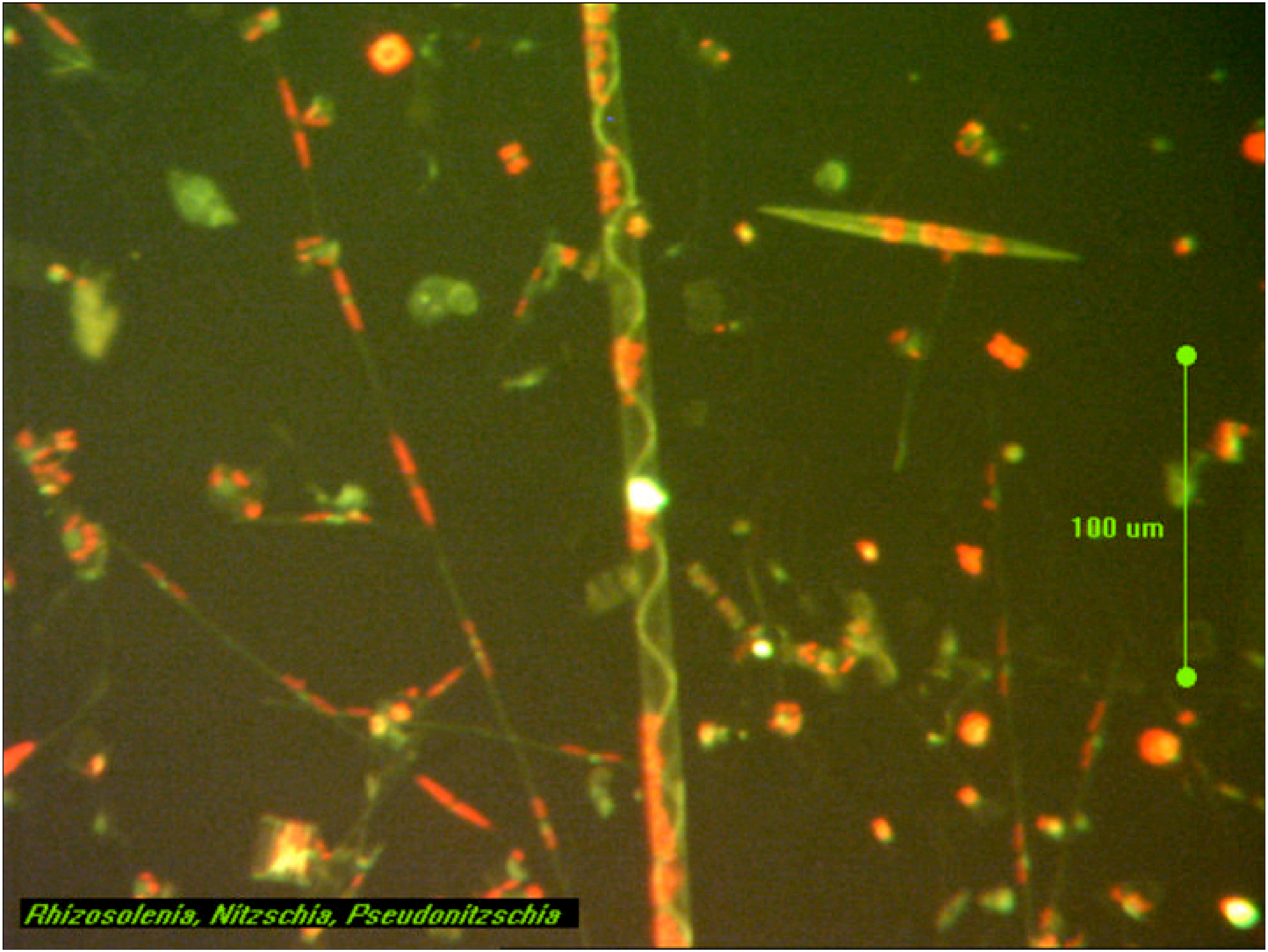
Summary of Feeding Modes

Feeding mechanisms: 4 main types

- *Filter or suspension feeding*
- *Diffusion feeding*
- *Pallium and peduncle feeding*
- *Direct interception (raptorial) feeding*

Mixotrophy: 3 main types

- *Endosymbiosis (true partnership)*
- *Kleptochloroplasts ("borrowed" chloroplasts)*
- *Genetically capable of switching ("autonomous" mixotrophs)*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Rhizosolenia, Nitzschia, Pseudonitzschia