Two Contrasting Trophic Pathways

- Herbivorous food web & Microbial Food Web

- **Phytoplankton** → **DOM** → **Bacteria**

- **PHAGOTROPHIC PROTISTS**

- **METAZOAN CONSUMERS** → **FISH**
Feeding Modes: Protists
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)

Protists are many of the phytoplankton (e.g., diatoms, coccolithophorids, dinoflagellates, “picoeukaryotes”, etc.)

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

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

Sleigh 1989
Common Groups

Sarcodina (pseudopodia): Amoeba, Foraminifera, Actinopoda

Ciliates

Flagellates

Amoeba

Foraminifera (CaCO$_3$)

Radiolarian (Si)

Acantharian (SrSO$_4$)

Heliozoan (Si)
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

*Actinophrya 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
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

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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.

Filter feeding - choanoflagellates

Acanthocorbis unguiculata (dry prep)

Parvicorbicula quadricostata (Southern Ocean)

Ciliate filter feeding

Video by Harvey Marchant
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
Peduncle Feeding by Dinoflagellates (Myzocytosis)

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

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

Vogelbein et al. 2002

fish skin lesion w/dinos attached
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 CaCO₃ skeletons

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

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.
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)