Protists – General

Protists were the earliest and simplest of eukaryotic organisms. They were the second major form of life to appear on the earth after the prokaryotes (bacteria).

Mostly single celled organisms.

Very efficient cells compared to procaryotic cells.

Protists are not a natural grouping, some divide protists into 5 or 6 separate kingdoms and 50 or so phyla.

Very diverse group of organisms; algae, seaweeds, protozoa, slime molds & water molds.

We will concentrate on those that have some affinities to the Animal Kingdom.

Most of the "animal-like" protists are collectively called the Protozoa.

Common name for an unrelated group of protists that share at least some characteristics with the animal kingdom.

The Animal-like Protists: The Protozoa

Most are unicellular; a few are colonial.

Protozoa share several animal-like traits:

- Lack cell wall
- Most are motile
- Heterotrophic nutrition

→ Protozoa gave rise to animals.

Most are microscopic (3-300μm).

But some are relatively large cells than can be seen with the unaided eye.

One species of amoeba (foraminiferan) is 2.5" long.

Some colonial.

Diverse group of organelles with highly developed division of labor.

Protozoa are found in all aquatic environments anywhere there is water or moisture:

- Freshwater ponds, lakes, creeks, rivers
- Marine environments

Some found in terrestrial habitats where moisture is abundant:

- Sand
- Soil
- Decaying organic matter

Some can send extensions outward, then "ooze" into them (eg. "the blob") or they can even actually "walk" on these false feet.

Some protozoa are nonmotile (=sessile) but use cilia or flagella to create water currents for feeding.

Most have optimum temperature range of 36 – 40 °C (=96.8 – 104°F).

Most protozoa are heterotrophs → must eat organic food:

They have many ways to take in organic food:

1. Absorbing dissolved organic nutrients through cell membrane
2. Ingest solid particles through a mouth-like opening (=cytostome) eg. eat bacteria
3. Some are herbivores eat algae
4. Some are saprophytic eat decaying organic matter in water or sediment eg. scavengers, detritus feeders
5. many are **predators**
   some can eat prey larger than themselves
   (eg. didinium takes 1 min & digests for 2 hrs)
   some have long hollow "tentacles" and pierce other
   protozoa to suck contents out (suctoria)

6. some are **parasites**
   once inside the cell:
   food becomes enclosed in **vacuole** which
   travels through cytoplasm (endocytosis)
   **digestive enzymes** are injected into the
   vacuole to digest the food
   undigested material is expelled by a reverse
   process (exocytosis) or through an "anal
   pore"

   a few protozoa are **autotrophs** and have
   **chloroplasts**
   do photosynthesis to make organic molecules

**Reproduction and Life Cycles**

protozoa reproduce both asexually and sexually:

   **asexual:** main form of reproduction

   allows them to be successful even in
   harsh environments
   → cilia or flagella are reabsorbed
   → metabolism slows or stops
   → hard resistant outer covering is secreted
   the resistant stage can withstand harsh conditions
   and become an active feeding stage again
   when conditions improve
   some cysts have survived for 38 yrs and 49 yrs in
   dried soil

**Reproduction**

protozoa, like all protists, reproduce both **asexually**
and **sexually**:

   **asexual:** identical copies
   this is their main form of reproduction
   most protozoa divide several times per
day
   by: **fission**
   **budding**
   **multiple fission**

   **sexual:** involves some exchange of genes
   between 2 cells
   produces genetically unique individuals

   **conjugation**
   two individuals come together and one
   gives a few of its genes to the other
   they separate as genetically different
   individuals and usually then reproduce
   asexually
   (ciliates only)

   **syngamy**
   two separate cells, acting and male and
   female actually join and fuse together
   like egg and sperm in a zygote
   (fertilized egg)
   combine their genetic material and then
   divide asexually as a genetically
   distinct individual

   most protists alternate between asexual and sexual
   reproduction

   a few parasitic forms also have several different **developmental
   stages** in more than one host
Some major kinds of Protozoa:
these are just convenient groupings of a considerably larger number of actual phyla and does not follow current classification schemes

1. “Amoebas”
protozoa that move primarily by amoeboid motion
44,000 living and extinct species

2. “Flagellates”
protozoa that move mainly with flagella
~1,500 species

3. “Ciliates”
protozoa that use cilia for movement or for feeding
~8,000 species

4. Apicomplexans
nonmotile, parasitic protozoa with complex life cycles
~ 5,000 species

Human Impacts:
1. some amoebas are common human pathogens:

1. “Amoebas”
amoeba = “to change form”
includes protozoa that move by pseudopodia (=false feet)
organism can alternate between solid gel-like and liquid cytoplasm to produce pseudopodia
→ false feet used for locomotion
→ false feet used to engulf food
→ some are long thin tentacle-like for grabbing food and drawing it in

simplest protozoans → relatively few organelles
also, some of the largest single celled organisms
→ some amoebas are up to 4” long (forams)

the life cycle of some amoebas involve the alternation between amoeba and flagellate forms
found in all aquatic environments
many are symbiotic in animals
amoebas are the only group of protozoa that have an extensive fossil record

over 20,000 fossil species
some member of the group secrete or construct protective shells
→ the shell may be composed of calcium carbonate or silica secreted by cytoplasm
→ foreign material such as sand grains embedded in cement like secretion
two most important shelled forms:
radiolarians secrete a silica shell (SiO₂)
found from surface to bottom of ocean
foraminiferans produce calcium carbonate shells (CaCO₃)
most live on the ocean floor in incredible numbers
have existed since pre cambrian times
form thick “oozes” that cover a third of the deep ocean floor
both have an extensive fossil record are are valuable to geologists as “index fossils”

amoebas reproduce mostly asexually
a few also reproduce sexually

a. Entamoeba gingivalis
found in the mouth near base of teeth
found in 95% of people with gum disease and 50% of people with healthy gums
parasitic → feeds on RBC’s and WBC’s at sites of infection and gum disease
does not form cysts
→ requires direct transmission by kissing, shared utensils

b. Entamoeba hystolytica (amoebic dysentery)
intestinal parasite
infects 400 Million worldwide
esp tropics and areas of poor sanitation
10% of world population is infected
up to 10 Million in US
kills >10,000/yr
90% hosts are asymptomatic
humans only reservoir
spread by fecal/oral route
cysts passed in feces
→ ingested with contaminated water
invade intestinal lining and feed on RBC’s
can cause ulcerations and profuse bleeding in acute cases
may spread to liver, lungs, brain, etc

2. *Naegleria fowleri*

members of the genus are found in almost all freshwater lakes, rivers, hot springs
but extremely rare in them
feeds as an amoeba on bacteria
once most of the food is gone they transform into a flagellated cell (<90 minutes) which is better able
to go in search of food
one species, *Naegleria fowleri*, is a human pathogen
35 cases reported in Texas (2007) including a few in central Texas have died from infections of this amoeba parasite
usually infects from getting contaminated water into nose
makes its way to the brain
causes always-fatal primary amoebic meningoencephalitis or PAM
most die within 2 weeks
mature adults seem to be immune
the parasite prefers warm waters with a high iron content
especially warm stagnant water
usually cannot survive highly chlorinated water of swimming pools but does seem to survive in low numbers even in treated water supplies
may prefer areas where other organisms have been wiped out by natural or man made disasters (eg Mt. St. Helens)

3. *Acanthamoeba*

one of the most common amoebas in soil
also found in freshwaters
though free living it can occasionally cause severe infections of eyes, skin and brain especially in patients with compromised immune systems
spread by improperly disinfected contact lens solutions
can damage cells of the cornea

2. “Flagellates”

includes several major phyla
cell membrane surrounded by *pellicle* that “stiffens” the cell membrane
move using one or a few long *flagella*
some have “sail-like” *undulating membrane*
used for food gathering and locomotion
reproduce by binary fission
a few are *free living*

eg. *Euglena* is common in stagnant ponds and creeks
it usually has chloroplasts and does photosynthesis
when sunlight is not available it gets rid of its chloroplasts and becomes a heterotroph
eg. *Volvox* is a colonial flagellate that is thought to resemble what the first truly multicellular animals might have looked like.
Each hollow spherical colony is made up of 50,000 individual cells embedded in a gelatinous ball
each cell is similar to *Euglena* cells and are interconnected by cytoplasmic strands
they are autotrophic
within the colony there is a division of labor with some cells specializing in feeding and locomotion and larger germ cells in specialized for sexual and asexual reproduction
asexual reproduction includes the formation of daughter colonies inside the “adult” colony
most flagellates are *symbiotic*
one cellulose digesting group has a mutualistic symbiosis with animals
animals are not able to produce the enzymes to break down cellulose or lignin
*eg. cellulose digesting flagellates in the gut of termites*
1/3rd to 1/2 of a termites weight is these symbiotic protozoa
*eg. cellulose digesting flagellates in cow rumen*
contains 1 M protozoa/ml (100 l of fluid total
they provide cow with ~20% of its protein needs
some are *parasitic* in humans and other animals
one group of flagellates, the “*Choanoflagellates*”
are believed to be the protists group most closely related to the protozoa that gave rise to animals and fungi
resemble feeding cells (collar cells) of sponges
common in freshwaters and salt water
many species are **colonial**

**Human Impacts**

many protozoan flagellates are important human **pathogens** throughout the world

*eg. Giardia* (one cause of “traveler’s diarrhea”)

- first observed by von Leeuwenhoek in his own feces
- worldwide distribution: one of most common intestinal parasites in the world
  - → up to 20% of all humans are infected (7% US)
- also occurs in cattle, cats, bears, coyotes, bird & amphibians
- transmitted by contaminated food or water:
  - cysts shed in feces; fecal/oral transmission
  - epidemics associated with contaminated water
- especially common in poor overcrowded areas with poor sanitation and lack of clean water
- can also be transmitted in ponds and pools
  - → cysts can survive up to 2 months in water
  - → chlorine doesn’t always kill cysts
- once ingested *Giardia* infects small intestine

- it is not usually a parasite: it usually feeds on dead organic material; no invasive ability
- usually **asymptomatic**
  - in large #’s can cause chronic diarrhea, cramping, dehydration
- incidence is increasing in US where it affects 3x’s more children than adults; esp daycare centers & public places

*eg. Trypanosoma (African Sleeping Sickness)*

- some of the most important protozoan parasites are in this genus
- trypanosomes are blood parasites and occur in all vertebrate groups
- human parasites occur mainly in the tropics of Africa and the Americas
- African Sleeping Sickness occurs in old world tropics; esp in Africa
- about 10,000 new cases occur each year; kills ~5,000 people/yr (2007); many of the rest suffer permanent brain damage
- requires two hosts:
  - the tse-tse fly is the **final host** for the sexual stage of the parasite
  - humans and other animals are **intermediate hosts**
- humans become infected when fly bites for blood meal
  - parasite moves into blood and lymphatic system

- begins with aching joints, headache and fever
- affects CNS: personality changes, headaches, apathy, sleepiness, emaciation
- usually results in death from coma, malnutrition, secondary infections
- so far, no safe and effective treatment

*eg. Chagas disease (T. cruzi)*

- new world tropics; eg Mexico, Central America, So. America
- 40-50% of population in So. America; 2-3 Million are chronically infected
  - → 45,000 die each year
- the most serious cases occur in children <5 yrs old
  - only a few cases in extreme SW US
- also requires 2 hosts in its life cycle:
  - kissing bug and humans
    - in kissing bug its an intestinal parasite
    - in humans it’s a blood parasite
  - other mammals serve as **reservoirs**: rodents, possums, armadillos
- contracted when "kissing bug" bites (usually on lips)
  - bug usually defecates after feeding
  - when the bite is scratch some of the infected feces is rubbed into the wound

- symptoms somewhat similar to sleeping sickness
- chronic and hard to treat
- may also affects many organs; eg. brain, heart, intestines
- most dangerous to children
  - → can affect many organs

*eg. Trichomonas*

- several species; commensal or parasitic
- **T. tenax**
  - lives in mouth, is not a pathogen
  - 5-10% oral infections, esp with poor oral hygiene
- **T. vaginalis**
  - 20-40% infection rate worldwide
    - one of most common infections in US
      - (2.5 M inf/yr: 3-15% US infected)
  - lives in human urogenital tract: likes acidity of female tract
  - ~50% are **asymptomatic carriers**
    - no cyst form → usually requires personal contact (STD)
    - occasionally spread in communal baths
    - and mother to child
  - if acid balance is disturbed, eg. by other infections, can become more virulent
esp common in promiscuous young women who are already infected with other STD's

in some women infection may produce a frothy, smelly green discharge & painful urination

not often virulent in men

3. “Ciliates”

the most diverse group of single celled ‘protozoan’ protists

they also tend to be larger than most protozoans and some can even be seen without magnification

most are freeliving and solitary

in a wide variety of aquatic habitats, especially in freshwaters

most are motile by means of cilia

= 1000’s oarlike projections produce coordinated movements

fastest of all the protozoans

in some bundles of cilia are fused to form rigid spines (=cirri) that the organism uses to crawl on substrates

a few are nonmotile, and some of these are colonial

live attached to substrate by stalk

use cilia for filter feeding, not for movement

ciliates have the greatest variety of organelles and internal structures of all the protists:

eg. more than one nucleus

all ciliates have more than one nucleus and usually two different kinds of nuclei

macronucleus → vegetative chores

micronuclei (up to 80) → sexual reproduction

eg. “mouth” (=cytostome) and throatlike area called a gullet

most feed on microorganisms

have mouthlike cytostome; opens into a throat; food vacuole forms at end of throat

an unusual group are called the suctoria

which paralyze their prey (other protozoa) and suck out the cell’s contents with tubelike “tentacles”

eg. food vacuoles

contain digestive enzymes for processing organic food

eg. contractile vacuoles

freshwater species tend to take on water

must constantly pump out excess; like a bilge pump on a boat

eg. trichocysts

long thread like proteins that the protozoan is able to shoot out to anchor the cell or to capture prey

eg. myonemes

muscle-like fibers that allow stalked forms (eg. Vorticella) to rapidly contract from danger

“eg. chloroplasts!”

ciliates are heterotrophs but ...

some ciliates can steal chloroplasts from the algae they eat and then use them for photosynthesis

Reproduction:

asexual: binary fission

sexual: conjugation: portion of micronuclei are exchanged between + and – forms

Ecological Interactions

ciliates play a vital role in food webs, particularly of freshwater ecosystems

many are part of the zooplankton

others are benthic - spending their lives crawling about the substrate for food
4. "*Apicomplexans*"
All members of this group are **nonmotile**
all are **endoparasites**
most have fairly **complex life cycles**
   ➔ same species exists in lots of different forms
      alternating between forms that reproduce sexually and those that reproduce asexually
   sometimes in two hosts

**Human Impacts:**

Human parasites include:

- **eg. Texas fever** (*Babesia*)
  killed 1000's of cattle in US in late 1800's and early 1900's
  spread by tick
  destroy RBC's ➔ causes red urine ➔ "red water fever"
  today almost completely eliminated by dipping cattle to kill ticks
- **eg. Plasmodium (malaria);** several species
  generally a nonhuman parasite that can occasionally infect humans
  humans can become intermediate hosts
  humans contract by contaminated soil, cat feces (litter box), infected meat
  generally no human-human transfer
  ➔ 16% of US adults are infected
  often asymptomatic in adults; children sometimes get rash ("macropapular rash")
  in humans can invade blood and multiply in WBC's and various organs
  if contracted by pregnant woman (especially in the first trimester) the parasite can cross placenta and cause retardation blindness and convulsions in embryo, fetus or newborn
  ➔ 2% of all mental retardation in US may be due to prenatal *Toxoplasma* exposure
  new info indicates that though there are usually no symptoms in most infected adults there seems to be a correlation with more risky behaviors in humans the mimic the results of the parasite in rodents
  ➔ 1000's of years ago would increase the chances of humans falling prey to large cats
  in another study 3900 drivers were monitored for 18 months
  those who were infected with *Toxoplasma* were 2.5X's more likely to have an accident

- **Plasmodium**
  kills 1000's of people each year and kills 1-3 M/yr
  worldwide infects 300 - 5000M each year and kills 1-3 M/yr
  (90% of cases in Africa, also in Asia & Latin America)
  every 12 seconds someone dies from malaria
  unlike many other parasitic diseases it is NOT a disease of poor sanitation and contamination
  its distribution and incidences is closely correlated with its mosquito host
  relatively rare in US (usually travelers)
  single most important disease hazard for people traveling to foreign lands
  requires two hosts to complete life cycle:
      *Anopheles* mosquito has sexual stages in its salivary glands
      humans harbor the asexual stages in blood, especially vessels in liver
  transmitted by mosquito bite
  symptoms of infection:
      7-14 days after infection cold chills and shaking begin
      uncontrollable deep tremors take over the body (can propel a bed across a room)
      next comes fever (up to 106º F) with profuse sweating
      cyclic chills/fever, headache every 3-4 days

- **Toxoplasma**
  generally a nonhuman parasite that can occasionally infect humans
  humans can become intermediate hosts
  infected cats release cysts in feces
  rodents, cattle, sheep are intermediate hosts
  toxoplasma is an example of a zoonosis
  new info indicates that though there are usually no symptoms in most infected adults there seems to be a correlation with more risky behaviors in humans the mimic the results of the parasite in rodents
  ➔ 1000's of years ago would increase the chances of humans falling prey to large cats
  in another study 3900 drivers were monitored for 18 months
  those who were infected with *Toxoplasma* were 2.5X's more likely to have an accident

   - can produce irreversible damage to liver, spleen, kidneys and brain
   - many succumb by way of delerium and coma
   - if not treated may be self limiting but host may be a reservoir for up to 3 years
   - most effective prevention is elimination of mosquito
   - WHO has been trying to eliminate it but with little success
   - mosquitoes have developed resistance to insecticides
   - the parasite has developed antibiotic resistance
   - experimental vaccines are being tested
   - some living in endemic areas have developed genetic resistance to disease (sickle cell)
   - **eg. Toxoplasma**
     requires two hosts to complete life cycle:
     - cats are primary host,
     - prey species such as rodents serve as intermediate hosts
     - infected cats release cysts in feces
     - rodents, cattle, sheep are intermediate hosts
     - to spread toxoplasma manipulates rodents brains making them reckless and more likely to be caught by cats
     - toxoplasma is an example of a zoonosis
based on current rate of world infections, 0.4-1 million of world’s annual road deaths might be due to toxo infections

Toxoplasma has also been implicated in the mental disorder; obsessive-compulsive disorder, but results are not yet conclusive

eg. Cryptosporidium sp.

first reported in people in 1976

is now recognized as a major cause of diarrheal disease worldwide

especially in children in tropical countries

occasional outbreaks occur in US

can be life threatening in AIDS patients

Protists - Slime Molds & Water Molds

~1100 species

two distinct groups of fungus-like protists:

slime molds and water molds

both superficially resemble fungi at some stage in life cycle

heterotrophs

some produce chitinous cell walls at some stage in their life cycle

body of threadlike filaments = hyphae

many produce a fruiting body with spores for reproduction

but differ from fungi:

most are motile by false feet or flagella at some point during life cycle; fungi are NEVER motile

produce flagellate reproductive cells; fungi produce nonmotile spore

some have cellulose cell walls or no cell walls; all fungi have cell walls, usually made of chitin

Protists - Slime Molds

this group is probably more closely related to amoebas than to fungi

sometimes referred to as “social amoebas”

common in cool, moist shady places

most easily found in summer and early fall

eg. crevasses of rotting wood

two basic stages to its life cycle:

a. a relatively large motile feeding stage

b. the reproductive stage in the form of a fungus-like fruiting body that produces spores

a. feeding stage (‘plasmodium’):

for most of a slime molds life it exists as a thin, free-living amoeba-like mass of protoplasm

especially a large single cell up to several inches across that

can cover an area of several square yards

(to 30 g = ~ 1oz)
creep along in **amoeboid** fashion and feeds on decaying organic matter, bacteria and protozoa

it is thick and slimy to the touch

feeds and grows as long as there is food and moisture

some species form extensive growths on lawns, croplands
  → do little, if any, damage
  → may appear in the same locations, year after year as patches of purple, gray, white & cream

some species found on lawn are mistaken for dog vomit
  some pet owners find them then rush their dogs to the vet to find out why their pet is sick

eg. **Fuligo septica** plasmodium (shades of war of the worlds)
  1973 found in Dallas suburb & reported in paper appeared on lawns as bright yellow masses spread over large areas described in paper as a "pulsating yellow blob" blobs broke apart when sprayed with hose
  → must be indestructible **aliens from space**
  or **mutant bacteria** that might take over the earth
  excitement soon dissipated once identified

b. **reproductive stage:**

when food supply dwindles reproduction is initiated

it moves out of its normal habitat and goes to a drier, more exposed location to produce a fruiting body
  → often seen crossing roads, lawns, climbing trees, etc
  plasmodium divides into numerous mounds
  each mound forms cells surrounded by cell walls
  at this stage the slime mold more closely resembles fungi than amoebas

produces multicellular **fruiting body** (= sporangium)
  → very small (~1-2mm); look like tiny mushrooms
  → goblets, globes, plumules
  → with or without a stalk
  → often colored yellow, orange, red
  → produces very resistant reproductive spores

some slime molds can produced a hardened resistant **sclerotium** to survive adverse condition

new (2010) research indicates that some slime molds show traits usually encountered in more complex organisms:
  eg. slime molds can be taught to "run mazes for food"
  eg. some slime molds "farm" the bacteria they eat
  they stop grazing on bacterial while there is still some left
  then mix uneaten bacteria into the spores they produce to make a "starter kit" for the next generation

fossils of this group has the distinction of being the first true fossil that actually shows an organism caught in the act of sexual reproduction (65MY)

**Economic Importance of slime molds:**

1. slime molds are eaten in Veracruz Mexico:
   some are collected, fried and eaten by indigenous peoples
   called "caca de luna"

2. **Water Molds**

1000 species (~100 genera) described
most primitive group of fungi

molecular evidence suggests that they are a direct link between protists and fungi

some are **unicellular**, some **multicellular**

have **chitin** in cell wall

mostly aquatic, a few are terrestrial

extremely abundant
  a teaspoon of water from virtually any freshwater habitat should yield samples

most are **saprobic** –absorptive

others are **parasites** of plants, animals and other fungi

most commonly seen as the fuzzy filaments growing on skin or eggs of fish & amphibians
  eg. Saprolegnia is common parasite of aquarium fish;
    causes lesions
    sometimes becomes a problem in fish farms
  other species infect rotifers, nematodes, arthropods and diatoms
**Economic Impacts of Water Molds:**

1. *some (chytrids)* are part of the microorganism community in the stomachs of most farm animals and grazing animals

   they are anaerobic and produces cellulases to help digest plant material along with other protists and bacteria

   therefore all products coming from these animals (beef, milk, dairy products, leather, wool, etc) are in part a product of these protists

2. *some are serious plant pathogens*

   eg. root rotting fungi, blister rusts, white rusts and downy mildews

   **eg. Downy Mildews**

   - infect grapes, lettuce, corn, cabbage and many other crop plants
   - introduced into France in late 1800’s
   - almost destroyed the wine industry
   - problem was accidentally solved using copper sulfate and lime

   **eg. Potato Blight (Phytophthora infestans)**

   - Cause of Irish Potato Famine (1845-7) in Ireland

   - virtually the entire Irish potato crop was wiped out in one week

   - > 1 million deaths from starvation

   - began large scale emigration of Irish to US

   - within a decade the population of Ireland dropped 50%: 8M -> 4M

   **eg. other Phytophthora species**

   - have caused widespread destruction of many crops throughout the world:
     - pineapples, tomatoes, rubber, onions, strawberries, apples, soybeans, tobacco, citrus

3. **Animal Pathogens**

   a primitive water mold pathogen *(Batrachochytrium dendrobatidis (chytrid))* is at least partly responsible for current decline in amphibians around the world

   today one third of the worlds 6,000 amphibian species are threatened

   - one of largest extinction spasms in vertebrate history

   - unsure of exact causes of declines:
     - possibly caused by acid precip, deforestation, urbanization, climate change

   - more recently noted deformities pollutants in water

   - most recently has been tied to worldwide spread of (including in and around central Texas)

   - the fungus spreads very rapidly;

   - don’t know how it kills frogs

   - Barton springs salamander and some other amphibians have natural antibiotics in its skin that seem to protect it from the pathogen)

   - 2008-probiotic treatment with normal amphibian skin bacterium, *Janthinobacterium lividum*, seems to protect frogs from the chytrid.

   - It apparently produces an antibiotic that is deadly to the chytrid.

   - Treatment is now being tested on wild populations