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 are **symbiotic** in animals & other organisms

some are **mutualistic**

many are **parasites** of animals

eg. most vertebrates hae protozoan parasites in their intestinal tract or in their blood

eg. a few are ectoparasites of fish (Costia

in aquatic environments they are an important part of **plankton**

= organisms that drift with currents

phytoplankton include autotrophic protists

zooplankton include heterotrophic protists

most protozoa are **motile** by

cilia

usually many short whiplike filaments that beat in unison to move protozoan along

flagella

much longer whiplike filaments; usually only one or a few per cell

amoeboid motion (false feet; pseudopodia)

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 º C (=96.8 – 104º 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

fission = divide in equal halves
(not same as bacterial fission)
eucaryotic fission involves mitosis

some split longitudinally (flagellages)

some split transversely (ciliates)

budding = unequal fission

multiple fission = >2 daughter cells

sexual: involves some exchange of genes

conjugation = exchange of a few genes
(ciliates only)

syngamy = fusion of gametes (egg & sperm)

some have alternation of sexual and asexual generations

Life Cycles

most protozoa exist in a single form which feeds and reproduces

some alternate between two stages in their life cycle:

troph = active vegetative feeding form

cyst = more resistant stage, low metabolic rate

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

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:

radiolaria secrete a silica shell (SiO_2)

found from surface to bottom of ocean

foraminiferans produce calcium carbonate shells ($CaCO_3$)

most live on the ocean floor in incredible numbers

have existed since precambrian 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

Human Impacts:

1. some amoebas are common **human pathogens**:

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 comtaminated 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* (Africal 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 hygeine

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. "<u>Ciliates</u>"

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

<u>Ecological Interactions</u>

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

malaria has probably killed more people than any other disease in history

chronic in some parts of world

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

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**

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 (especiallly 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 mimmic 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

→ 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

1. <u>Slime Molds</u>

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

essentialy 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
→but pieces continued to crawl around
caused local panic:
→must be indestructible **aliens from space**
→ or **mutant bacteria** that might take over the earth
excitement soon dissipated once identified

→ biologists "saved the world!"

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

fruiting bodies can also be produced by absence of food, changes in moisture, pH, temperature

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)

<u>Economic Importance of slime molds:</u>

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 **saprobes** –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 emmigration 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