
**Parasitism** → most common form of symbiosis

1/4th of all animal families are parasites

20-50% of all animal species are parasitic

**endoparasite**
- parasite lives on the inside of host
- digestive system often very simple or gone altogether
  - eg. tapeworms, flukes, roundworms

**ectoparasites**
- parasite lives on outside of host
- some can use gut for food storage and expand to many times their normal size
  - eg. leeches, ticks, fleas

**Benefits to parasitic lifestyle:**
- gets easy access to food
- protection, esp if endoparasite

**Costs to parasite:**
- host is a small "discontinuous" habitat
- parasite must locate and infect new hosts to propagate its species
- must be able to overcome hosts defenses: inflammation, immune response

**Parasitic Adaptations**

1. **Structures for penetration and attachment to host**
   - hooks, suckers, teeth, enzymes
   - most common point of entry to host is through mouth

2. **Usually have a resistant stage in life cycle**
   - for getting from one host to another which is often in a different kind of environment
   - if endoparasite - needs to survive trip through digestive system

3. **Reduction in “unnecessary” structures**
   - reduced sense organs
   - reduced nervous system
   - reduced locomotion
   - reduced digestive system
   - some endoparasites have lost gut entirely
   - some ectoparasites use gut mainly for food storage (eg. leeches, ticks)

4. **Tendency toward being Hermaphrodite**
   - only need any two, not male and female
   - some can even self fertilize if necessary but usually don’t

5. **Enhancement of reproductive capacity**
   - host is a small "discontinuous" habitat
   - need extraordinary powers of reproduction to insure survival
   - reproductive organs are often the largest, most apparent organ systems present
   - often able to produce of large #’s of eggs
     - Liver fluke (*F. hepatica*) → 20,000 eggs/day
     - Ascaris → 200,000 eggs/day
     - Tapeworm (*Diphyllobothrium*) → 1M eggs/day for 15 years (=5.5 trillion eggs/lifetime)

6. **Use of intermediate larval stages on intermediate hosts**
   - to enhance chances of getting to final host
   - Even with large numbers of eggs chances of success are relatively small:
     - eg. *F. Hepatica* in most favorable situation 3-4 out of 20,000/day will actually hatch
   - simplest life cycle:
     - adult parasite → eggs → ingestion by new host
   - more complex life cycle:
     - adult parasite → eggs → intermediate host → definitive host
   - most complex life cycle:
     - flukes have several intermediate states that reproduce

7. **Behavioral Adaptations**
   - behavior is an important tool for animal survival
   - this is also true for parasites: behavior can be used to enhance their chances for success

**Examples:**

1. **Simple host finding behaviors**
   - eg. *Entobdella* (Monogenea)
     - skin parasite of a stingray
     - eggs are released and settle to bottom
     - larvae emerge from eggs within 3 seconds of sudden darkness
     - then swim vertically upwards

2. **Periodic Behaviors**
   - parasite keys in on cyclic stimulus
   - eg. *Filarial Worms*
     - live in blood transmitted by mosquito or fly
     - larvae (microfilariae) move to peripheral blood on periodic basis
     - corresponds to "biting hours" of local vector (flies & mosquitoes)
   - eg. *Guinea worm* (nematode: *Dracunculus medinensis*)
     - occur in tropical areas; lots of rice fields
     - eggs must be laid in water to be able to get to its intermediate host
     - female may contain up to 1 Million eggs
     - each with a developing larva inside
     - larvae must be released in water to complete life cycle
to do this female moves to part of body likely to be immersed in water → lower legs creates an ulcer at moment limb enters water the female protrudes anus and discharges 1000's of infective larvae

3. Host Modifying Behaviors

an alternative to modifying the parasites own behavior is to alter the hosts behavior to make it more likely to complete parasites life cycle

eg. Echinococcus (Tapeworm)
sheep infected with hydatid cysts lags behind healthier members of heard → more easily caught and eaten by coyote

b. Conspicuous Behavior

eg. Acanthocephalans: adult in birds (ducks); larva in amphipods (small aquatic crustaceans)
Amphipods (fw crustaceans) typically hide in dark vegetation during the day to avoid predation when infected with acanthocephalan worm which as adult infects birds, became highly photophilic and conspicuous
eg. burrowing clams infected with a fluke, rather than burrowing into sediment, remain closer to surface where they are more likely to be preyed upon
eg. Fluke (Leucochloridium)

Some Animals Parasitic on Humans

worldwide, 3 of every 4 people are infected with parasites
bacteria, viruses, protoza, worms, etc kill 17,310,000 people/yr

<table>
<thead>
<tr>
<th>typical #s of parasite species with human hosts:</th>
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<tbody>
<tr>
<td>insects → 8</td>
</tr>
<tr>
<td>mites &amp; ticks → 4</td>
</tr>
<tr>
<td>nematodes → 12</td>
</tr>
<tr>
<td>tapeworms → 4</td>
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<td>flukes → 1</td>
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especially common in developing, tropical countries
the most common kinds of internal human parasites are the "helminthes":
liver and blood flukes tapeworms roundworms

Blood & Liver Flukes (Trematodes)
endoparasites, relatives of the planarians
most relative small, <.5"
leaf shaped body (=fluke)
most are hermaphrodites that produce 1000's of eggs
this group includes some of our most serious parasites
inhibit a wide variety of sites in their hosts:
digestive tract respiratory tract circulatory system urinary system reproductive system
most have fairly complex life cycle with 1 or more intermediate host
eg. Chinese Liver Fluke (Opisthorchis sinensis)
a serious problem in China, Asia and Japan
has one of the most complex life cycles of any parasite
humans are the "final" host but also infects cats, dogs, pigs
**Life Cycle**

**Adult Flukes**
- mature in intestine then move to bile ducts in liver
- light infections (dozens) → no symptoms
- heavy infections (to 20,000) → can cause liver damage
- adults typically live 15-30 years but up to 50 years
- 1000’s of eggs can be released in feces /day

**Intermediate Hosts**
- if eggs reach water they hatch into miracidium and burrow into aquatic snail where they go through 2 more larval stages and reproduce asexually
- polyembryony occurs usually in several larval stages allowing a single egg to develop into 100’s of potential adults
- cercaria emerge from snail and burrow into fish where they develop into metacercaria
- eating infected raw fish (sushi) completes life cycle

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**eg. Sheep Liver Fluke** *(Fasciola)*
- adults live in bile ducts of liver
- eggs passed in feces
- miracidium penetrates land snail and becomes sporocyst the redia then cercaria
- cercaria leave snail and encyst (metacercaria) on vegetation
- when vegetation is eaten by sheep or other ruminant the adult grows
- can infect humans

**eg. Blood Flukes; Schistosomiasis** *(Schistosoma)*
- affects 200 Million worldwide
  esp Africa, S. America, Mid East, Far East
- 3 different species
- aquatic snail is intermediate host, humans are final host
- Adults live in “portal vein” in liver
- separate sexed

**Tapeworms** *(Cestodes)*
- smaller female lives in groove in larger males body
- eggs are passed in feces and/or urine
- in heavy infections many eggs may lodge in liver and cause damage
- if eggs reach water, they hatch and infect a snail
- cercaria are released from snail and burrow into human final host → one of few parasites that can actively bore through skin to get into host
- rice farmers are easily infected
- in N America: some blood flukes of birds may attempt to bore through humans while in water = swimmers itch

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**very different from flukes**
- body consists of a *scolex* for attachment and a long “body” of reproductive sacs (= *proglottids*)
  **scolex** with hooks and suckers
- *proglottids* almost completely made up of male and female reproductive organs
  - any two proglottids can exchange sperm
  - some species may produce a dozen proglottids/day
  - when gravid, a proglottid may contain up to 100,000 fertile eggs
- tapeworms completely lack a digestive system
- human tapeworms grow up to 30’ long (10M)
- can live up to 20 years
- tapeworms require two separate hosts to complete their lifecycle
typically a predator is the host of the adult worm, larvae are found in prey

**Adults** live in intestines of host

eggs or whole proglottids are released in feces

**Larva**

once eggs are shed they must be ingested by **intermediate host**

usually a vertebrate prey of the final host

once eggs are ingested, it hatches and larva bores through intestine of host and into blood

travels to muscles, heart, or other organ

ecysts as the larval stage:

a fluid filled sac = **bladder worm**
(cysticercus)

two of the most common human tapeworms:

**eg. Beef & Pork Tapeworm**

(*Taenia* = *Taeniarhynchus*)

adults in humans

mature adult may reach >30 feet

the adult develops in intestine

when person is infected numerous gravid proglottids are expelled daily

sometimes they crawl out the anus

the pork tapeworm is more dangerous for humans since cysticerci also can develop in humans

→ esp eyes and brain

**eg. Echinococcus**

parasites of dogs and other canines

juvenile develops in >40 species of mammals including humans

ie. Humans can be intermediate host

→ bad for parasite since humans are rarely eaten by dogs

juvenile stage is a special kind of cysticercus = **hydatid cyst**

grows slowly, for long time (up to 20 yrs)

can reach size of basketball

within main cyst are "daughter cysts" that

scolex buries itself in intestinal wall

can produce over 2000 proglottids

gravid proglottids break off and pass out with feces

they crawl out of the feces and onto vegetation

proglottids dry and release eggs

→ eggs can remain viable for up to 5 months

eaten with grass by grazing cattle

but could also be pets, esp dogs and other humans

→ unsanitary conditions

→ kissing pets

when cattle eat the eggs they hatch and larvae burrow through intestine into blood

encyst in muscle tissue of intermediate host as bladder worms

~1% of US cattle are infected

transferred to us when "measly" meat is eaten eg. rare roast beef, steaks, eg. poorly cooked barbecue

bud off, each contains 1000's of scolices

only treatment is surgical removal

→ very dangerous
**Roundworms**  
(Nematodes)

a very large group of animals  
**most** are free living in soil and water  
→ called threadworms  
but many are important plant and animal parasites:  
plant parasites cause billions of dollars in damage  
to crops each year  
livestock also suffer heavy losses  
common parasites of pets  
eg. heartworms in dogs and cats  
a few roundworms are important human parasites  
virtually every human being is host to some  
parasitic nematode at some time in their lives  
compared to the other parasites we’ve discussed they  
have fairly well developed tissues and organs and  
organ systems  
elongated worm-like body  
most <2.5” (5 cm) long  
tube within a tube =complete digestive tract  

**Symptoms:**  
local inflammation if juveniles get in "wrong"  
tissue  
if high #’s in lungs can get severe pneumonia  
if a few adults in intestine → minor effects  
many may cause blockage  
adults also have a tendency to "wander"; particularly if  
living conditions become unfavorable  
eg. fever, anaesthetics, worming tablets  
they may exit the anus or out the mouth  
occasionally may perforate intestine or enter bile ducts  

**eg. Toxocara**  
common roundworm of puppies and kittens  
virtually ALL puppies and 20% of kittens are  
infected until “wormed”  
esp in SE US  
smaller but similar life cycle  
**Toxocara** can infect children  

nerve system with ganglia  
excretory system  
dioecious (separate sexed)  
most produce eggs, a few give birth to live young  

**eg. Ascaris**  
one of the largest roundworm parasites ~1 ft long  
1 Billion people in the world are infected  
even in US infections are not uncommon  
eggs or larvae are ingested fecally contaminated  
food  
→ larvae can survive up to 7 years in soil  
(long after any trace of feces remains)  
larva burrows into blood and circulates to lungs as  
it develops and matures  
ascends trachea or is coughed up and reswallowed  
arrives again in intestine ~ 2 months after initial  
infection  
if another worm of opposite sex is there they mate  
female can release ~200,000 eggs/day  

but won’t complete life cycle  
→ usually killed in liver or lungs  
it can wander through various tissues and  
organs before it dies and cause  
inflammation  

**eg. Pinworms (Enterobius)**  
one of the most common human nematode  
infections  
small worm: 1/2 –3/4” long  
humans are the only hosts  
THE most common helminth infection in US  
→1 in 3 children (30%); 1 in 10 adults are  
infected  
is seldom a health problem  
→ feeds on bacteria and wastes, not on  
“hosts” tissues  

**Life Cycle:**  
after copulation male dies,  
female crawls to anus to deposit 1500 eggs and  
dies
this can cause intense itching
   → eggs are spread on bed sheets, air, fingers, etc

eggs are highly contagious:
not dependent on fecal contamination of food or soil

eggs are very resistant and spread directly on skin and in air, etc

infections easily spread to all family members
larvae may hatch and can also reenter intestine to reinfect

**eg. Trichinella (trichina worm; trichinosis)**
probably the most *dangerous* roundworm disease of humans
smaller than pinworm → barely visible to naked eye
causes *trichinosis*: a potentially lethal disease
in US an estimated 2.5% of the population is infected each year; ~750,000/yr
infections are also common in other parts of world

each worm requires **two separate hosts** to complete its life cycle:
   adult can live in several hosts: humans, pigs, rats, many wild animals
the adults and larvae can develop in same hosts but each worm requires two hosts to complete its life cycle
adults live in the intestine
in low numbers produce very few symptoms
after mating, the female burrows into the wall of the intestine and releases juveniles into the blood
juveniles circulate to all parts of body
but coil up and encyst only in skeletal muscle cells
eg. diaphragm, chest & abdominal wall, tongue, biceps, deltoid
humans are infected by eating poorly cooked infected meat
   often due to undercooked pork, bear, sausage

**Symptoms of infection:**

**Beneficial Effects of Endoparasites**

1. **weight loss**
   light infections of adult tapeworms cause little damage and may cause a loss in weight
   → larvae sold as weight loss pills
2. **dampen an overactive immune system**
   helminths are able to survive in hosts because they can suppress the host’s immune system
   light infections of flukes and other helminths are used to control allergies and some autoimmune diseases

human infections often appear in small, sporadic outbreaks due to:
   undercooked pork, bear, sausage
range from mild to life threatening
as larvae move around in body they may cause local inflammation
as they encyst in muscle tissue may cause soreness and achy muscles
larvae are viable for up to 2 years → are slowly killed and calcified
 heavy infections may be fatal
Ectoparasites

live or feed on the outside of the host
usually only temporarily attach to host
eg. leeches, mites, ticks, lice, flies, mosquitoes, etc

Leeches

small group of only ~500 species
mainly freshwater, a few marine
most are carnivorous predators
a few are ectoparasites
have an anterior and posterior suckers to attach to host while feeding
protrusible pharynx with 3 toothed jaws to pierce skin of host
as they feed they secrete:
a local anesthetic
a histamine-like substance to dilate blood vessels
an anticoagulants (=hirudin)
are able to consume blood meal several x’s their own weight
(eg. Hirudo takes up to 15 ml)

have very slow digestion
eg Hirudo can take up to 200 days to digest one meal
and can live another 100 days on the energy gained
in some their guts secrete no enzymes and relies on bacterial symbions for digestion of proteins

Medicinal Leech (Hirudo)
in past centuries medicinal leech, Hirudo, was used to suck out “bad blood”
ownce believed many bodily disorders were the result of bad blood or too much blood
→ were collected almost to extinction in Europe
now a protected species

Arthropods

mites, ticks, lice, fleas, mosquitoes, flies, etc
many are more dangerous for the diseases they transmit than for the direct damage they do to host

eg. Mites >30,000 species, probably lots more
usually very tiny; <1mm
→ some mites are so small they can only be identified with electron microscope
many mites are free living and feed on decaying vegetation; some are predators
some are blood sucking parasites during all or part of their life cycles
some mites have become adapted to live as internal parasites in the lungs and air sacs of snakes, birds and mammals
eg. follicle mites
usually commensal, NOT parasitic
found in hairs of face especially around nose, and in ear wax
~ 1 in 5 people harbor them, proportion increases in older folks
usually symptomless
in a few may cause redness or irritation
same mite in dogs causes mange

eg. chiggers (redbugs)
“there is probably no creature on earth that can cause more torment for its size than a redbug”
minute, reddish; 0.2x0.15”; barely visible to eye
feed on skin of many vertebrates including humans
red bugs are mite larvae that are very small and can easily go through clothing and burrow in skin
adults are not parasites
chiggers don’t actually burrow into skin but secrete saliva to dissolve skin cells for food

the irritation is largely due to sensitization to saliva and its enzymes that the chigger injects to liquify the skin cells
12-24 hrs after infection itching is at its worst

eg Ticks

much larger than mites
all ticks are parasites during some part of their life cycle
some lay up to 12,000 eggs
most infest mammals, many attack birds, a few attack cold blooded vertebrates
some show host preference; others are nonselective
attracted by animal smells from a distance of up to 50’
→ tend to collect on game trails
wounds made by ticks are very likely to become infected, sometimes seriously
especially if “head” is torn off
anticoagulants are sometimes toxic
may cause fever and inflammation
may even result in blood poisoning
most ticks will not let go even if touched or prodded by chemicals or heat
best removed by gentle pulling
ticks surpass all other arthropods in the numbers and variety of diseases that they can carry
eg. Rocky Mountain Spotted Fever
eg. Lyme Disease
also other viral, fungal and bacterial diseases

eg. Lice
looked on today with disgust and loathing but: high proportion of some populations (50%)
common in jails, camps, etc
in some countries lice are believed to be an indication of robust health and fertility
can suck on blood intermittently for hours at a time
eg. head lice prefer fine hair of head
eg. body lice generally live on clothing when not feeding
a female can lay 80-100 eggs at a time
head and body lice can spread:
typhus
french fever
eg. crab louse
mainly in coarse hairs of body:
public area, armpits, beard, eyebrow, eyelashes
almost exclusively confined to caucasians
almost always venereally transmitted
each female can lay 25 eggs at a time

eg. Fleas
over 1000 species of fleas
have compressed bodies and backward spines and bristles to help them move through fur piercing, sucking mouthparts
long powerful legs → enormous jumping power
eg. human flea (Pulex irritans; really a pig flea)
can jump:
13" horizontally
7.75" vertically
equivalent jump for human: 450' broad jump
275' high jump
most breed and lay eggs in nests of hosts
cat and dog fleas lay eggs in fur of host

Human Benefits of Ectoparasites
1. leeches used today in medicine to speed healing of reattached fingers and limbs
2. leeches have become leading research models for understanding how the nervous system works
3. some chemicals used by the leech in obtaining and digesting blood are being studied for treating circulatory diseases
4. leeches have also affected history:
eg. land leeches of India
live in extremely large numbers in humid forests of India
live in trees and shrubs and fall like "drops of dew" onto any humans passing underneath
their mass attack caused the retreat of a British regiment during the Sikh rebellion in India in mid 1850's!
5. some blood sucking insects are used to assess the health of wildlife populations
eg. Dipetalogaster maximus (hemiptera) is used as a high tech syringe
can take up to 4 ml in one meal
donor doesn't feel a thing

most fleas suck blood wherever they can find it
fleas are fairly indiscriminant in host choice → since they change hosts easily they easily transmit diseases: typhus, plague, etc
David Harum: "A reasonable amount of fleas is good for a dog, they keep him from broodin' on bein' a dog"

eg. bed bug
4-5mm nocturnal
feed on blood
in day, hide in bedding and cracks and crevices anywhere in room
in large infestations produces distinctive "bedbuggy smell"
can live up to a year even without food

eg. mosquitoes
besides being blood parasites are also vectors for malaria, yellow fever, dengue fever, elephantiasis, etc
mosquitoes indirectly kill more people each year than any other cause (infec up to 1 Billion each year and kill up to 3 million)
used as a way to get blood samples from wild animals that are difficult to sample in other ways

eg. can measure stress hormone levels in nesting terns without having to capture them

eg. used to survey rabies infections in bats removes blood sample using a needle; they recover quickly