Animals with a Body Cavity

the animals discussed so far lacked any kind of body cavity

→ organs, when present, were embedded in mesoglea or parenchyma tissue

virtually all other major animal phyla have some kind of body cavity

they are "hollow" with organs packed into this hollow space

'*tube within a tube*' body plan:

→ allows an increase in size

→ allows more elaborate lengthening and coiling of internal organs

→ allows circulation of gasses, food and wastes in the absence of a circulatory system

→ provides hydrostatic skeleton

2 major kinds of body cavities:

pseudocoelom and **true coelom**

both have:

three embryonic tissue layers:

ectoderm → skin, nervous system
mesoderm → muscles, bones, circ sys
endoderm → dig and resp tracts

pseudocoelomates:

body wall is lined with mesodermal tissue ie. muscle layers

body cavity is filled with fluid

intestine has no mesodermal tissue therefore no muscle layers

tends to be simple, thin, collapsed tube

eucoelomates:

layers of mesoderm on the inside of the body wall and the outside of the digestive tract

muscle layers in both places

digestive system much better developed

Phylum Nematoda
(roundworms)

= eel worms; thread worms

~25,000 known species

specialists estimate that only ~20% of existing species have been studied and described so far

→ there may be over 100,000 living species

a few fossils known; some in amber

very common and diverse group but poorly known and difficult to identify

mostly free living but includes many common parasitic species

especially notable for their lack of variation in size and shape: "they all look alike"

species more similar than in any other major phylum

very simple and highly adaptable design:

generally; cylindrical, unsegmented worms, tapered at both ends

externally no distinct head or obvious sense organs

most are very small 0.5-1.0mm (100^{th} of an inch to $1/5^{th}$ inch)

largest is a parasitic species that lives in the placenta of female sperm whales → 18' long

most are colorless and transparent or with whitish or yellowish tint

most abundant of the pseudocoelomate animals

all other pseudocoelomate phyla have relatively few species

nematodes may actually be second only to arthropods in number of species

over two hundred species have been found in a spoonful of beach mud

in terms of sheer numbers, nematodes are probably the most abundant animal on earth

→ 4 of every 5 animals on planet are nematodes

→ 90,000 nematodes were found in a single rotting apple

occur in virtually all habitats from arctic to tropics; marine, freshwaters, and especially in soil

there is virtually no part of the biosphere that **doesn't** harbor nematodes

→ anywhere there is organic matter

have been found in deep ocean trenches and in hot springs & ice

the deepest living animal known is a nematode that lives in fractured rock 0.8 miles deep

→ almost 3 times deeper than any other animal

(its DNA was found >2 miles below ground)

common as **interstitial fauna**

nematodes are especially common in soil

as numerous in soil as arthropods

eg. est 6 M individuals in 1 ft^3 of soil

eg. upper 1" of soil may contain <1 Bill/acre

eg. 3.5M/m^2 in tundra soils to 9M/m^2 in grassland soils

→ virtually *every* soil sample will yield new species

"If all the matter in the universe except the nematodes were swept away, our world would still be dimly recognizable, and if, as disembodied spirits, we could then investigate it, we should find its mountains, hills, vales, rivers, lakes, and oceans represented by a thin film of nematodes. The location of towns would be decipherable, since for every massing of human beings there would be a corresponding massing of certain nematodes. Trees would still stand in ghostly rows representing our streets and highways. The location of the various plants and animals would still be decipherable, and, had we sufficient knowledge, in many cases even their species could be determined by an examination of their erstwhile nematode parasites."

-N. A. Cobb, 1914, Yearbook of the US Dept of Agriculture, p. 472

enormous ecological importance

living species feed on a variety of organic material
→ aerate soil
→ recycle nutrients
→ decompose toxins and wastes

there is no sharp distinction between aquatic and terrestrial species

all nematodes including soil nematodes are essentially **aquatic**

→ live in water film around soil particles

nematodes also parasitize virtually every type of animal and plant

~60% of all known nematode species are parasitic

virtually *every* species of vertebrate and many invertebrate groups are hosts to nematode parasites

human parasites are the best known of the nematodes but make up only a small percentage of total species

a study done in 1947 found 99% of people around the world were infected with nematode parasites

"everyone in the world has either had a threadworm infection, has it now, or will have it in the future"

some of the largest roundworms are parasites,

eg. largest nematode is a parasite of a whale → 27 *feet* long

Body Organization

elongated, wormlike body; mostly small

few external features

difficult at first glance to distinguish front from back end

"tube within tube" design

animals with simple fluid filled body cavity around internal organs=**pseudocoelom**

persistant blastocoel

mesoderm present only on external face of cavity
gut lacks muscle layer

three true tissue layers (=triploblastic)
ectoderm → skin, nervous system
mesoderm → muscles, bones, circ sys
endoderm → dig and resp tracts

eutely is common

→ fixed number of cells in adult of each species

Body Wall

body wall a syncytial epidermis

adhesive glands usually present,

no cilia

secretes tough, flexible **cuticle** containing collagen

→ protects worms from abrasion in soil and sediment

→ protects parasites from digestive enzymes

some have an elaborately sculpted cuticle

probably helps them move through soil or sediment

cuticle is sometimes molted as animal grows

cuticle sometimes shows superficial segmentation

their cuticle is highly resistant to fairly extreme environments and conditions

→ some can survive pH's from 1.5-11.5

→ some can survive mercuric chloride solutions that would kill most other animals

→ only living organisms to survive a space shuttle explosion

eg. 6 canisters of *C. elegans* survived the Columbia disaster

allows them to survive in many unusual habitats including:

eg. as parasites of both plants and animals

eg. in hot springs

eg. **vinegar eel** can live in concentrated mercuric chloride that would kill most other animals

a very common soil animal

feeds on rotting fruit; can thrive in a wide pH range from 1.5 to pH=11.5

before vinegar was pasteurized it was usually found in commercial vinegars (cider vinegar from fermented apples)

eg. a related species is found in pitcher plants

eg. another species has only been found in the felt coasters under beer mugs in German pubs

body wall with **longitudinal muscles** only

fluid filled **pseudocoelom**

→ important as a **transport** medium for oxygen, foods and wastes

→ pressure created by tough cuticle and muscle layer creates **hydrostatic skeleton**

Movement

unlike most wormlike animals they have only **longitudinal muscle** in body wall

hydrostatic pressure in fluid filled pseudocoelom maintains internal pressure and keeps body wall from collapsing

(circular muscle does this in other worm phyla)

produces characteristic whiplike or snake-like thrashing motion; "S"

Feeding and Digestion

nematodes feed on a wide variety of foods:

but almost all nematodes eat living cells

1. some are predatory **carnivores**

eat small or microscopic animals

2. some are **phytophagous**

many marine worms feed on diatoms and other algae

3. many are **parasitic** in plants and animals

roots of practically all plants are attacked by some kind of nematode worm

~20-35% of nematodes found in soil are actually plant parasites

all the root eaters have a syringe-like **stylet** that injects digestive juices into root to liquify meal

4. a very few *may* be **saprobes:**

eat dead or decaying matter

however, more recent studies indicate that most of these "saprobes" are actually feeding on live bacteria and fungi and are typically found on or in dead organic matter such as dung or decomposing bodies

complete digestive tract:

mouth is at front end surrounded by three "lips"

often with retractable piercing **stylet**

muscular pharynx which is able to produce a suction to draw in food

food passes into a **long straight intestine** where it is digested and absorbed

no muscles lining intestine - collapsed thin tube

intestine only 1 cell layer thick

almost all digestion is extracellular

undigested material exits through **anus** near (but not at) posterior end

they have a "**postanal tail**", unusual in inverts

Nervous System

"brain" = nerve ring with **ganglia** around pharynx

dorsal and ventral **nerve cords**

→mainly controls dorsal and ventral muscle layers

muscles send processes to nerve cord

(opposite more common structue where nerve cells extend to muscle cells)

(this also occurs in some flatworms, gastrotrichs, and others)

muscle cells are interconnected so muscles on each side contract together

→ produce whip-like or thrashing contractions characteristic of these organisms

Senses

visible sense organs generally absent

has mainly **chemoreceptors** sometimes in head or tail

Excretion

unique excretory system:

excretory system a series of canals or tubules or interconnected glandular cells (=renette cells)

sometimes with **protonephridia**

tubules form **lateral line** along sides of animal visible from the outside

empties through **excretory pore** near front of animal

no circulatory or respiratory system

pseudocoelom fluids circulate nutrients, oxygen and wastes

Reproduction

all nematode species show incredible reproductive abilities

most species have separate sexes (dioecious)

and show **sexual dimorphism**

most with **internal fertilization**

sperm lack flagella or cilia → they are amoeboid

after mating, females lay 100,000's eggs/day

eggs often extremely resistant to environmental extremes

eg. *Ascaris* eggs remain viable in 5% formalin

development is usually **direct**; no larval stage

usually 4 **juvenile** stages; but resemble adult

juveniles grow by shedding (molting) old cuticle

in some species one of the juvenile stages becomes an inactive, **resistant stage**

→can survive for months or years until conditions improve

cryptobiosis

some nematodes can enter a state of arrested activity

→ makes them successful in seemingly unfavorable environments

eg. some have been dried for several years then rehydrated

eg. some have been placed in liquid air (-194ºC (= -317ºF)) and revived afterwards

Ecological Effects of Nematodes

while rarely studied and relatively unknown, nematodes occur in large numbers in virtually every habitat

1. Nematodes are of enormous ecological importance:

they feed on a variety of organisms and are an important part of all food webs especiall in soil

they are fundamental in recycling nutrients in all ecosystems

eg. they play an important role in the nitrogen cycle by helping to mineralize nitrogen

they also help to decompose toxins and wastes

soil nematodes help to aerate the soil

nematodes help regulate soil bacterial populations and overall community composition

eg. one nematode can eat up to 5000 bacteria /minuite

since many nematodes parasitize plants and animals they play key roles in population and community ecology within most ecosystems

2. Some nematodes play unique roles in the life cycles of some animals

eg. one species of nematode spends its entire life on fig wasps

the wasps spend their entire lives inside the fruit and flower of the fig tree

wasps are essential for fertilization of the fig flower

the worm attaches to the wasp as it is born in the fruit of the fig

it feeds on them until the fig flowers along with the wasp dies

the worms' offspring await the birth of the next generation of wasps as the fruit ripens

eg. the adult of a species of parasitic nematode, *Myrmeconema neotropicum*, is found in 'fruit-eating' birds

its eggs are passed in the birds feces and collected by foraging ants to feed their larvae

the infected ant larvae develop large bright red abdomens as they mature

the ants tend to walk with their abdomens conspicuously elevated

they also walk more slowly than uninfected ants

the birds apparently mistake the ants for berries and eat them completing their life cycle

Human Impacts of Nematodes

while their primary value is their ecological roles, we are most *directly* affected and *aware of* the numerous parasitic species of nematodes:

1. Plant Parasitic Nematodes

cause extensive crop damage (eg potatoes, soybeans, etc.) and billions in food & fiber damage each year

up to 15% of our agricultural crops are damaged by nematodes each year

eg. root knot nematodes alone cause over $100 billion/yr worldwide in crop damage

most plants can tolerate these parasites to some degree

but when the balance is tipped in favor of the parasite large scale damage may ensue

eg. Golden nematode (*Heterodera*)

parasite of potato plants

has caused crop failures worldwide

chemical in soil diffusing from plant stimulates emergence of larva from cyst and attracts it toward plant

also damage ornamental plants, turf grasses and greenhouse plants

other nematodes attack bark and forest trees

eg. pine wood nematode

in Asia, America and recently found in Europe

2. Other predatory nematodes are beneficial to agriculture

eg. kill garden pests like cutworms and corn earworm moths

some of these beneficial nematodes are cultured and sold as an organic form of pest control

3. livestock & pets also suffer heavy losses

eg. Dog Heartworm (*Dirofilaria immitis*)

a major global pest that affects dogs, cats, wolves, coyotes, foxes among others

they can also infect humans

in US common in all 50 states, but especially common in SE US in which ~45% of pets are infected

requires two hosts

mosquito is the intermediate host

ingests juveniles when it bites dog

transfers it to uninfected dog when another is bitten

in final host (dog) the juveniles undergo further development

dogs can have juveniles circulating in their blood and lungs without symptoms

once the number of worms exceeds a certain number based on size of host the adult worms move to the heart (usually 6-7 mo.)

and establish themselves in the right side of the heart

adult worms can reach 12" long and live for several years

after mating, females bear live juveniles (=microfilariae) into the blood

the microfilariae can circulate for up to 3 years "waiting" to be picked up by a mosquito

symptoms begin years after initial infections

begin as soft cough which worsens as the infection increases

leading to congestive heart disease

untreated dogs die; treatment is difficult and takes several weeks of discomfort to the dog to rid it of the parasites

a few human cases are known

eg. *Toxocara canis*

common intestinal helminth infection in dogs and kittens

virtually all puppies and 20% of kittens are infected

untill wormed

relatively mild symptoms in pet

can infect children but wont complete life cycle
→ usually killed in liver or lungs
→ but can wander through various tissues and organs causing inflammation

human infections are fairly common; 3-20% in children,
especially in SE US
especially urban children

similar life cycle to *Ascaris*

may be associated with neuropsychological effects

4. Human Parasites

some species are important human parasites

about 50 species of nematodes are able to parasitize human hosts

virtually *every* human is host to some parasitic nematode at some time in their life

eg. *Ascaris* sp.

the largest human nematode parasites; ~ 10 - 12" (up to 30 cm) long

found exclusively in humans

1-1.4 Billion people in world are infected

20,000 die each year

common in tropics; in some countries over 50% of children are infected

even in US infections are not uncommon

main cause of infection is fecally contaminated food

Ascaris eggs are resistant to concentrated bleach and formalin

they are also coated with an extremely sticky coating to adhere to almost anything

egg can survive >7 yrs after any trace of feces is gone

after ingestion the juvenile burrows into blood/lymph vessels

→ circulates into lungs

arrives in lungs ~2 months after initial infection

→ enters alveoli and ascends trachea or is coughed up and reswallowed

become adults in the intestine

adult worms can survive for 25 years

they are not really parasites, they feed on material in intestine

if another worm of opposite sex is there they mate

female can release ~200,000 eggs/day (~8 Mil/lifetime)

<u>symptoms of infection:</u>

juveniles:

local inflammation if they get into wrong tissue

if large numbers in lungs→ fever, spasms, coughing, severe pneumonia-like symptoms, allergic rxns

adults:

a few adults → minor effects

many adults → if "worm burden" is to great 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. Pinworms (*Enterobius vermicularis*)

one of the most common nematode infections of humans worldwide

500 Million are infected worldwide

small; ~12mm (0.5-.75")

unusually, its more common in temperate areas than in tropical areas

the <u>most</u> common helminth (flukes, tapeworms, roundworms) infection in US

30% children infected
16% adults infected
more common in US in Caucasians than African Americans - don't know why

seldom a health problem

adult feeds on bacteria and wastes; not on hosts tissues

dioecious

after copulation male dies

eggs are not released into feces

instead female crawls to anus to deposit ~1500 eggs when host is asleep

day or night → worm keys on sleep physiology of host

infections not dependent on fecal contamination for spread

→ eggs are spread directly

→ eggs are very resistant

eggs are highly contageous

can cause intense itching

eggs spread on sheets and in the air

infections easily transferred to entire household

eggs can also hatch and reenter the intestine

(not easily detected by fecal exam since female lays eggs on skin outside anus; use 'scotch tape test')

eg. Trichina worm (*Trichinella spiralis*)

probably the most serious roundworm disease of humans

causes **trichinosis**: a potentially lethal disease

smaller than a pinworm → barely visible

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

often appear in small sporadic outbreaks

each worm requires **two separate hosts** to complete its life cycle:

occurs in several hosts: humans, pigs, rats, bears and other carnivores

each may serve as **intermediate** or **final** host

juveniles travel through blood and encyst mainly in muscle tissue of intermediate host

when raw or poorly cooked meat is eaten, juveniles mature into adults in intestine of final host

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 infected meat

often due to undercooked pork, bear, sausage

<u>symptoms of infection</u>

from encysted juvenile

range from mild to life threatening

light → soreness; achy muscles

heavy → esp dangerous if in heart

juveniles can remain viable for up to 2 years, but are slowly calcified

eg. Hookworms (*Necator* sp. & *Ancylostoma*)

named for its hooklike anterior end where the head is bent into a curved shape

up to 11mm long

found in tropics and subtropics

one of the most dangerous roundworm parasites

> 600 Million infected worldwide

adults live in intestine; blood feeders

large plates in mouth cut into intestinal lining to suck blood

often cause excessive blood loss while feeding

eg. a "mild" infection of ~1000 worms can cause a loss of 100 mL/day (3.3 oz)

heavy infections can cause anemia and weakness

in children can cause retarded physical and mental growth

<u>Reproduction & Life Cycle</u>

dioecious: male smaller than female

female can produce 25000-3000 eggs/day for up to 5 yrs

eggs released in feces

juveniles hatch in soil

feed on bacteria, 2-3 days

juveniles climb to the top of a blade of grass and wait for a host to walk by

when juvenile contacts skin it immediately burrows into blood vessels to lungs, then climb up trachea

→swallowed and reattach as adults in intestine

eg. Filarial Worms

8 species (include *Wuchereria bancrofti*, *Loa loa*, river blindness (=onchocercosis))

females up to 10 cm (4") long

250 Million humans are infected

common in tropical countries

highest rates of infection are in Sri Lanka

female worms release live young (=**microfilariae**) into blood

mosquito or fly is an intermediate host and vector of spread

microfilariae move to peripheral blood on periodic basis corresponds to "biting hours" of local vector

eg. *Loa loa* → diurnal vector

eg. *Wulcheria* → nocturnal vector = mosquito but in S Pacific vector bite in

day so are diurnal here

eg. in some places, no cycling of vector so no cycling of movement to peripheral blood

eg. several species of filarial worms, including *Wuchereria* sp., cause **Elephantiasis**

infects 120 Million/yr in Africa & Asia

the juvenile worm is carried by mosquitoes

in host adult worms live in lymphatic system

symptoms associated with inflammation (fever & skin lesions) and obstruction of the lymphatic ducts causing swelling

results in excessive enlargement of affected parts

esp in arms, legs, scrotum

eg. *Onchocerca* (causes river blindness)

occurs in 38 countries worldwide especially in Africa, South America, and the Middle East

the worm migrates through the body to victims' eyes

is a major cause of blindness

18 Million infected worldwide

of those 270,000 are blind

500,000 have severe visual impairment

some villages have 100% infection rate

eg. Human Whipworm (*Trichuris*)

500 Million are infected worldwide; esp subsaharan Africa

a medium sized worm (3-4cm)

1st 2/3rds of animal is thin and hairlike, last one third is thick; animal resembles a whip

found throughout the world, especially tropics

almosts 1 Billion humans infected

other species infect many other kinds of vertebrates

lives in large intestine

after mating eggs are passes with feces

can release 7000 eggs/day

eggs must lie for 3 weeks in soil before becoming infective

eggs swallowed

juveniles in intestine mature into adult

new data shows the eggs are triggered to hatch by gut bacteria
→ prevents them hatching in stomach

adults feed on living tissue resulting in more severe symptoms:

normal: diarrhoea, abdominal pain, nausea

heavy infection may lead to intestinal bleeding and anemia

or rectal prolapse (protrusion of the rectum out through the anus

treatment is difficult since *Trichuris* is resistant to commonly used drugs

eg. Guinea Worm *(Dracunculus medinensis)*

an ancient disease

a water borne parasite

the juvenile lives in small aquatic crustaceans (*Cyclops*)

the adult only lives in humans

drinking water with infected crustaceans or juvenile worms in it

lives beneath skin

up to 3' long

lives under the skin and creates ulcerations

the worm creates ulcerations and emerges painfully through the skin to release its eggs into the water (up to 1.5 M eggs/day

providing clean drinking water has greatly reduced incidence of the disease

the disease has almost been eliminated throughout the world except for Southern Sudan

in 1986 there were 3.5 M cases of the disease in Africa and Asia in 2012 only 542 cases were reported

on track to become only the 2nd human disease after smallpox to be completely eliminated from the planet

5. Other Human Impacts

a. evidence is mounting that some parasitic infections may have benefit in decreasing allergies and asthma

→ it dampens an overactive immune system

proteins secreted by some parasites dampen our immunity

eg. 2007-a study of 1600 vietnamese children infected with hookworm only 60% were allergic to dust mites

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

nematodes are often able to suppress the immune system of the host to produce a more favorable environment

b. some parasitic nematodes show promise as biological controls against insect crop pests

c. *Caenorhabditis elegans* important biological "model" in research (one of a handful; eg. lab rat, fruit fly, E. coli, etc

used to study: genetics, nervous physiology, cell physiology, aging, etc.

we know:

its complete wiring diagram of nervous system

origin and embryological lineage of all 959 cells making up its body

entire genome of 19,820 genes has been mapped