Phylum Annelida
(segmented worms, bristle worms)

15,000 species

large successful phylum in water & on land

include earthworms, sand worms, bristle worms, clam worms, fan worms, leeches

worldwide distribution:

marine, brackish, freshwater and terrestrial

elongated wormlike body

new body design: hollow **tube-within-a-tube**

true **coelom** present

mesoderm on inside of body wall and outside of digestive system

one of the most successful animal designs

→ room for development of complex organs with muscle layers

→ allows for circulation of body fluids

→ provides hydrostatic skeleton

some live in tubes they secrete or make with sand or shell

Body Form

most are long and wormlike with **head**-**body**-**pygidium**

some with bizzare forms

head (prostomium & peristomium)

most annelids show some degree of **cephalization** with a distinct head (=**prostomium**)

tentacles, **palps** and sensory structures

peristomium behind prostomium contains the mouth

with **pharynx** and chitinous **jaws**

body with well developed **metamerism** (=segmentation)

most prominent distinguishing feature

seen in just a few other phyla: eg arthropods, chordates

segments are separated by tissue = **septae**

allows more efficient **hydrostatic skeleton**

offers a way to achieve greater size:

rather than increasing size of each organ

→ each organ is repeated in each segment

the segmentation is both external and internal

essential features of segmentation:

several systems (eg. nervous, excretory) show serial repetition

segmentation is produced during embryonic development

NOT the same as asexual budding as in tapeworms

most annelids have paired appendages on most segments = **parapodia**

used for locomotion

respiration

in some, parapodia modified into fans and mucous bags for feeding or to create water currents

terminal **pygidium** with anus

Body Wall

epidermis a single layer of cells (columnar epithelium)

epidermis secretes a thin flexible **cuticle** and **setae**

setae → small chitinous bristles

most annelids have **setae**

repeated on each segment (ie. "bristle worms")

used as anchors while burrowing

to prevent capture

some used for swimming

or as protection or camoflage

beneath **epidermis** is two layers of **muscle tissue**

thin layer of **circular muscle**

thick layer of **longitudinal muscle** (obliquely striated)

body cavity of true **coelom**

lined with **peritoneum** (squamous epithelium)

lines inside of body wall & outside of digestive tract

peritoneum also form **mesenteries** that hold

blood vessels and the **septae** between segments

Movement

coelom is filled with fluid (except leeches) which serves as **hydrostatic skeleton**

annelids have 3 general types of movements:

1. **burrowing**:

   waves of **peristaltic contractions** sweep down body

   1st animal elongates →contraction of circular muscle

   2nd animal sortens → contraction of longitudinal muscle

   setae anchor hind end of body while front end pushes foreward

2. **crawling:**

   polychaetes use parapodia alternately to move across surface

3. **swimming:**

   mainly polychaetes and leeches

   undulating body movements

parapodia help in polychaetes

Feeding & Digestion

complete digestive tract "tube within a tube" design

muscle layers allow modification of tract into various structures:

pharynx with **teeth**

esophagus

crop

gizzard

intestine

mouth beneath prostomium

some with eversible pharynx with jaws

in others the pharynx produces a suction to draw food into mouth

crop: food storage area

gizzard: thick and muscular

helps physically break up food

intestine

in some the first part of intestine is used for **digestion**

secretes digestive enzymes

most of intestine is used for **absorption**

on dorsal surface is infolding = **typhlosole**

increases surface area for absorption

lining intestine are yellowish **chloragogue cells**

→ equivalent to our liver: synthesizes glycogen and fats

→ they also travel through coelom to repair wounds

→ function in excretion: convert amino acids to urea & ammonia

Respiration

through body wall

some through parapodia

a few have gills

Circulation

body cavity is filled with coelomic fluid which helps mive food and wastes around

most annelids also have circulatory system that helps in t ransport of materials

closed circulatory system

dorsal and ventral vessel connected by capillary network

dorsal vessel pumps blood anteriorly

ventral vessel pumps blood posteriorly

dorsal vessel is main pump

several pairs of **aortic arches** (="**hearts**") help to keep pressure up in ventral vessel

thus a double transport system for foods, gasses, wastes

fluid filled coelom

circulatory system with heart & vessels

foods, wastes and respiratory gasses are carried both in blood and in coelomic fluid

blood:

most with dissolved blood pigments to carry oxygen:

hemoglobin (Fe) red - most annelids
hemerythrin (Fe) red
chlorocruorin (Fe) green

(only 4 blood pigments known & annelids have 3 of them)

blood also contains amoeboid cells which engulf foreign particles

Nervous System

brain a pair of **cerebral ganglia**

leeches have another pair of ganglia at posterior end

paired **ventral nerve cords**

with pair of ganglia in each segment

ladderlike connections in each segment

Senses:

simple single celled photoreceptors or clusters of cells = eyespots

eyes with retina and rod-like receptors

a few polychaete eyes have cornea, lens, retina → can form images

statocysts in some

nuchal organ → chemoreceptors

tentacles & palps → well devleoped sense of touch

other simple chemoreceptors

free nerve endings → tactile??

Endocrine System

simple endocrine system

neurosecretory cells in ganglia

hormones regulate reproduction and regeneration

Excretion

one pair of **nephrida** (=metanephridia) in each segment

similar to that in molluscs

(a few polychaetes have protonephridia or both)

nephric tubule:

nephrostome = funnel like opening into previous segment

coiled ciliated tubule surrounded by **capillaries**

bladder like structure

nephridipore = opening to outside

function:

wastes from coelom are drawn in

salts and organic wastes from blood are discharged into duct

useful stuff is selectively reabsorbed

in earthworms and leeches chlroagogue cells collect NH4 or urea and deposit in blood or take directly to nephrostome

some nitrogen wastes are also excreted through body wall

excretory organs also help in salt and water balance

in earthworms, **calciferous glands** along esophagus secrete excess calcium from blood into digestive tract

(lots of calcium in soil; lots gets absorbed, excess is secreted)

Reproduction and Development

both asexual and sexual reproduction

quite variable within the phylum

Asexual

most can bud to some degree

other spontaneously fragment

Sexual

monoecious or dioecious

larva, if present = **trochophore**

Classification of Annelida

Class: Polychaeta

mostly marine

distinct head with eyes and tentacles

segments with parapodia and lots of setae

no clitellum

Class: Oligochaeta

mainly terrestrial and freshwater

head absent

fewer setae, no parapodia

Class: Branchiobdellida

commensal on crayfish

no setae

posterior sucker only

Class: Hirudinea

terrestrial, freshwater or marine

no parapodia or setae

fixed # of segments with "false segments"

anterior and posterior suckers

Class: Polychaeta
(Sand Worms)

means "many setae"; also called bristle worms

largest, most diverse and most primitive class of Annelids

10,000 species; 2/3rds of all Annelid species

sand worms, bristle worms, fan worms, clam worms, etc

mostly marine

a few found in freshwater

most 5-10 cm long; some up to 3 m

often brightly colored

deposit feeders, filter feeders, predators, scavengers,

live in crevasses, old shells, burrows or construct tubes

some have elaborate filtering structures

eg feather dusters

a few are pelagic → part of the **plankton**

important in marine food chains

Body Plan

distinct **head** with mouth and sense organs

wormlike body with repeating segments

body segments with flaplike **parapodia**

Head

have distinct **head**

head has retractable pharynx with **jaws** used to capture prey

lots of different kinds of sense organs on head

1. chemoreceptors (nuchal glands) on palps and tentacles
2. touch receptors also on tentacles for locating food and shelter
3. eyes

some can focus an image = esp predators

very similar to cephalopod and vertebrate eyes

Body or Trunk

most body segments have appendages = **parapodia** with **setae**

both parapodia and setae are moved by internal muscle bands

most sand worms and relatives move by **crawling** using appendages (parapodia) as "legs"

other swim using them as paddles for swimming

parapodia also serve as main respiratory organ

in some the anterior parapodia are modified into fan-like structure to filter the water

Feeding & Digestion

free swimming polychaetes are mostly predators

sedentary polychaetes are filter feeders or deposit feeders

foregut: pharynx and jaws, esophagus

lined with cuticle

midgut: secretes digestive enzymes

in posterior section absorbs nutrients

hindgut: anus

Respiration

usually through parapodia

some have paired gills on some segments

some have no special organ and exchange across body surface

Circulation

lots of variation

some open some closed circulatory systems

may have respiratory pigments

eg. hemoglobin, chlorocruorin, hemerythrin

Excretion

protonephridia and in some **metanephridia** or both

1 pair per segment

opens into coelomic compartments

tubule absorbs any useful materials and concentrates wastes as fluid passes to nephridiopore

Nervous System

basic annelid plan

dorsal **ganglia**

double ventral nerve cords with paired ganglia in each segment

Senses:

eyes: simple eyespots to complex organs

esp in free moving (errant) polychaetes

in one group can form image: cornea, lens, retina

nuchal organs: ciliated sensory pits

chemoreceptors used in food gathering

statocysts in burrowers and tube building forms

Reproduction & Development

most are dioecious

simple reproductive system

have no permanent gonads

→ gonads appear as temporary swelling of

peritoneum at certain seasons

gametes are shed either

→ through genital ducts

→ or through nephridiopore

→ or through rupture in body wall

some polychaetes live most of the year as sexually immature individuals = **atokes**

after living 1 or 2 years as benthic organisms they become sexually mature and swollen with gametes = **epitokes**

head shrinks, body enlarges, gonads develop and produce egg or sperm

sometimes only part of the body makes the transformation, breaks off and the rest of the worm lives to repeat next season

eg. palolo worm

males and females gather by the millions in one spot

at night determined by phases of the moon
female releases pheromone

pheromone excites male to circle about female

swarms of epitokes appear at start of moon's last quarter in oct or nov
→ sea is literally thick with epitokes

just before sun rises, epitokes burst to release gametes

anterior portion of worm returns to burrows

=synchronous mating

→ensure most eggs are fertilized

→predator saturation
predators have a field day; but too many prey so some are always left to reproduce

→atokes safely in their burrows to repeat next year

a Samoan holiday to feast on epitokes

Examples of Polychaetes

eg. clam worm or sand worm (*Nereis*)

up to 10" long

live in mucus tubes in or near low tide

males - iridescent bluish-greenish color

females - light green with yellow, orange-red mottling

most active at night

move out onto sand to search for food

can also swim by undulatory movements

they are predators

use their jaws to capture small animals

jaws open as pharynx is everted

jaws close as pharynx is retracted

eg. Tangleworms (Cirratulus grandis)

on east and west coasts of US

yellow to green; 5-6" long

front with great mass of long red hairlike filaments used as gills

eg. Blood Worms (Glycera)

red worms, all marine, several species

eg. Sedentary Polychaetes

many polychaetes burrow or live in tubes rather than crawling around on the sediment

often develop various food gathering structures for filter feeding

leads to tagmosis → fusion and reduction of metamerism

eg. *Sabella* (tubeworm)

eg. *Chaetopterus* (parchment worm)

secretes parchment like tube

tubeworm must maintain a flow of water to get oxygen and get rid of wastes

→ uses modified parapodia as paddles

can emit strong bioluminescent flashes

burrows often shared by commensal crab

eg. Fanworms, tubeworms, featherduster worms)

secrete many kinds of tubes:
firm calcareous tubes

glue sand grains together
bits of shell cemented together
some burrow

may extend long tentacles out of tube to filter particles from the water

eg. Scale Worms

very abundant

flattened and coverd with scales formed by the modified parapodium

most are small; some up to 19 cm

carnivores;

many are commensals with other marine inverts

eg. Beard Worms (pogonophorans) & Giant Tube Worms

once thought to be a separate phylum, now known to be an unusual kind of polychaete

discovered in 1900; today 150 known species

all are marine

most live in bottom ooze of deep ocean

in many the forepart bears long **tentacles** giving it a bearded appearance

thin, transparent, segmented trunk has several pairs of setae and is enclosed in a chitinous tube

the trunk ends in a small segmented opisthosoma

the best known of the group are the giant tubeworms found around deep sea **hydrothermal vents**

some up to 6' long,

a **red plume** that extends from the tube

bright red → hemoglobin in blood

used to absorb nutrients from the water

→ tubeworms have no mouth, stomach

their **trunk** contains a large sac (**trophosome**) that is filled with symbiotic bacteria

Feeding

only non-parasitic animals without a digestive tract

no mouth, anus or digestive tract

they get most of their nutrients from symbiotic bacteria living in an organ (=trophosome) within the trunk of the worm

bacteria harvest energy from H_2S and convert inorganic elements into sugars for the worm

$CO_2 + H_2S + O_2 + H_2O \rightarrow H_2SO_4 +$ sugars

have well developed closed circulatory system containing **hemoglobin**

use hemoglobin to carry oxygen to body cells and to carry oxygen and hydrogen sulfide to bacteria

reproduction

usually sexual

dioecious

male releases packet of sperm into water

females release eggs into the water

fertilization produces a worm shaped embryo

poor swimmer; probably carried by water currents

the larvae will drift through the deep water until they locate a hydrothermal vent

they will then settle to a rocky perch

the young tubeworms do have a mouth and gut and feed

as the worm matures the muth and gut degenerate and the area once holding the digestive systems becomes a bacteria filled sac

tube worms seem to have few predators

although sometimes crab and shrimp will feed on the worm's red plume

Ecological and Economic Impacts of Polychaetes

eg. detritus food chains

eg. prominent in marine food webs

eg. beardworms entire ecosystem not based on photosynthesis

discovered in 1900; today 150 known species

most live in deep ocean
→common in hydrothermal vent communities

no digestive tract

they get most of their nutrients from symbiotic bacteria living in an organ (=trophosome) within the trunk of the worm

bacteria harvest energy from H_2S and convert inorganic elements into sugars for the worm

$CO_2 + H_2S + O_2 + H_2O \rightarrow H_2SO_4 +$ sugars

have well developed circulatory system containing hemoglobin

use hemoglobin to carry oxygen to body cells and to carry oxygen and hydrogen sulfide to bacteria

eg. Major decomposers of deep sea whale carcasses

2001 found red fuzz on whale carcasses in deep ocean

1000's of polychaetes with red plumes up to 6 cm long

new genus and species of polychaete

seem to be unique to "whale fall"

worms have no functional mouth or gut

have symbiotic bacteria that digested oil in bones

→ they degrade hydrocarbons

the bacteria live in rootlike structures of worm that extend in and throughout the bone

worm provides oxygen via blood vessels extending into the roots

eg. human food (samoa)

eg. insecticides

eg. Padan – a powerful insecticide produced from a polychaete worm

eg. anticancer drugs

eg. dolastatins from sea hare (Dolabella auricularia) has potential anticancer properties

Class Oligochaeta
(Earthworms)

means "few setae"

over 3000 species

mostly terrestrial; most abundant 'worms' on land

→burrow in the soil

also many live in freshwaters

and a few marine or brackish

most are less than 30 cm (~1')

some tropical earthworms get up to 3 M long

relatives of sand worms but **no parapodia**

and very **few setae**

most with 4 prs of setae/segment

no distinct head

Body Wall

protective layer of collagenous **cuticle** secreted by **epidermis**

segments contain pores for coelomic fluid to leak out and lubricate outer surface of animal

also has numerous **mucous glands**

Feeding & Digestion

most are **scavengers** on decaying organic matter

mainly burrowers

eat as they burrow then let digestive system extract nutrients

well developed digestive tract:

mouth→ pharynx→esophagus→gizzard→intestine→ anus

pharynx - pumps food in
crop - temporarily stores food
gizzard - muscular, lined with cuticle, grinds food
intestine - most chemical digestion and absorption

allows them to eat soil and then the intestine sorts out the nutrients for absorption

typhlosole in intestine improves absorption of nutrients

chloragogue cells surround outside of intestine

store nutrients

synthesize glycogen and fats

cells break off and deliver fats through coelom to other organs in body

eliminate some metabolic wastes

Respiration

no respiratiory organs or parapodia like polychaetes

breath through skin, no lungs or gills

extensive system of capillaries in epidermis

Circulation

double circulatory system:

coelomic fluid

closed pumping system

have circulatory system with 5 pairs of hearts

and hemoglobin in blood to carry oxygen

Excretion

main excretory organs are **nephridia**

paired nephridia in each body segment

in aquatic forms nephridia release ammonia

in terrestrial forms nephridia release urea (conserves water)

in fw and terrestrial oligochaetes nephridia not only eliminate wastes but also eliminate excess water (osmoregulation)

also, terrestrial worms have **calciferous glands**

worms eat soil; soil has lots of calcium

high levels of calcium in blood

calciferous glands remove excess calcium from blood and deposit it in the intestine for removal

Nervous System

have both CNS and PNS

CNS: cerebral ganglia and ventral nerve cord

with paired fused ganglia in each segment

PNS: nerves branch off fused ganglia to supply body wall and body organs

Sense Organs

rather than concentrated in head they are distributed all over body

numerous sensory cells (chemo- and mechano-receptors) on skin

chemoreceptors esp on prostomium

many free nerve endings → probably tactile

earthworms have no "eyes" but do have numerous photoreceptors in epidermis

Endocrine System

neurosecretory cells in brain and ganglia

secrete hormones that regulate:

reproduction

secondary sex characteristics

regeneration

Earthworm Reproduction

earthworms are **hermaphrodites**

cross fertilize each other

copulation involves a **double exchange** of sperm cells

mucous secreted from **clitellum** holds pair

together with genital pores aligned

can last 2-3 hours

sperm is deposited in seminal receptacle

after copulation worms return to burrows

fertilization and egg laying occur a few days later

each worm secretes a sheath of mucous around **clitellum**

clitellum then secretes nourishment for egg

then envelopes mucous and food in tough chitin-like cocoon

the worm then backs out of the cocoon

as cocoon slips over the genital openings it receives an egg, then sperm

fertilization occurs in the cocoon

cocoon is deposited in soil

in 2-3 weeks a new worm emerges

Examples of Oligochaetes

eg. Aquatic "Earthworms"

smaller, benthic, longer setae, more active

better developed sense organs

some have gills

generally eat algae and detritus

some with great powers of asexual reproduction → budding

eg. tubifex

red worms to 10 cm long

live on bottoms of lakes, ponds and polluted streams

live in very low oxygen concentrations

have large amounts of hemoglobin

keep their heads in tubes while waving bright red tails

in heavily polluted areas banks appear bright red at low water

absorb dissolved nutrients (DOM) across skin

eg. giant Palouse earthworm

in Idaho

thought extinct but recently rediscovered

up to 3 ft long, lives in burrows 15'deep

spits at predators

eg. ice worms

small worms <1" long

only found on surface of glaciers at temperatures below freezing (~7ºC), they die at temperatures of 5ºC or more
can appear by the 100's

eat algae and pollen

Ecological and Economic Impacts

1. Detritus food chain

eg. Night Crawler

burrow within the upper 30 cm of moist soil rich in organic matter

in soft soil earthworms move by peristaltic contractions

setae prevent back sliding

this type of movement only works because segments are separated by septa

mainly active at night

on warm damp nights, forage for leaves and organic debris

up to 54,000 earthworms /acre
→ turn over 18 tons of soil per year

prefer moist soil but if too much water they will move to surface
→ sometimes in great numbers

→ used to think they "rained" down from the sky

important in keeping soil fertile since they are constantly turning over earth and mixing organic matter into it

if all material ever moved through earthworm gut was piled on surface of earth it would rise 30 miles above sea level (5x's height of Mt Everest)

2. Food for birds and other animals

3. Food for Humans

in some parts of Asia, Africa and Latin America people regularly eat worms

usually because there is not much other food available

a few restaurants in the US offer them as novel food fare

4. Fishing bait

worms are commonly used for freshwater fishing

Class Hirudinea
(**Leeches)**

500 sp

probably should be in same class as oligochaetes

mainly freshwater

a few marine and terrestrial

most 2-6 cm long; some to 20 cm

often brightly colored

many are carnivores; some are parasites

body is dorsoventrally flattened

anterior and **posterior suckers**

fixed number of true segments

→ usuall 32 plus prostomium & pygidium

each segment with 2-14 **annuli** (=false segments)

Body Wall

coelom functions as a single large chamber
→ no septae between segments

coelom is filled with connective tissue and muscle

except for a system of spaces (=coelomic sinuses and channels) filled with coelomic fluid

→ acts as secondary circulatory system

Movement

no parapodia
(except 1 genus)

no setae

leeches have poor hydrostatic skeleton

aquatic species use muscle layers to make undulating swimming movements

can also use suckers to move like inchworms

some terrestrial forms are able to "stand up" on hind sucker to search for prey

Feeding & Digestion

most are predators of snails, worms and insect larvae

protrusible pharynx with 3 jaws armed with teeth

some are scavengers

some are blood sucking parasites

adaptations to parasitism by leeches:

attach to host with suckers

pierce skin with sharp teeth on end of proboscis

while cutting, secrete local anesthetic and histamine-like chemical that dilates blood vessels of host

consume large blood meals

→blood is sucked by muscular pharynx

while being swallowed, blood mixes with **hirudin** (anticoagulant) to prevent clotting

very slow digestion

gut secretes very few digestive enzymes

→depend on **bacterial digestion**

can live for almost a year on one meal

may take up to 200 days to digest one meal

can live for another 100 days afterwards

Respiration

most exchange gasses through skin

a few aquatic forms have **gills**

Circulation

many species have no blood vessels

coelomic fluid does the work of blood in open haemocoel

may be hemoglobin in haemocoel fluid

Nervous System

nervous system similar to other annelids

but leeches have two "brains"

→ one composed of paired cerebral ganglia around pharynx as in other annelids

→ the other in posterior of animal consists of 7 pairs of fused ganglia

simple sense organs are much better developed in terrestrial species which tend to be blood suckers

Excretion

10-17 pairs of nephridia

Reproduction

hermaphroditic

→ cross fertilize during copulation

mating process similar to earthworms

do have **clitellum**

→produce coccoon that receives eggs and sperm

Human Impacts

1. **medicinal uses**

in past centuries medicinal leech, *Hirudo*, was used to suck out "bad blood"

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

introduced into US but rare in nature

today leeches used in medicine to speed healing of reattached fingers and limbs

2. commonly used in **biology labs**

3. leeches have become leading **research models** for understanding how the nervous system works

4. some chemicals used by the leech in obtaining and digesting blood are being studied for treating circulatory diseases

5. 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!