Arthropods - General

includes: crabs, crawfish, shrimp, spiders, scorpions, mites, ticks, millipedes, centipedes, insects (dragonflies, butterflies, ants, wasps, beetles, etc)

1,100,000 known species;
at least 2-3 M more species

more species in this phylum than in ANY phylum of ANY kingdom of life

half of all know species of every kingdom of life

includes 2/3rds of all known animals

more widely distributed over the earth than any other animal phylum

→live in virtually every habitat on earth

common in all terrestrial, freshwater and marine habitats

Distinctive Characteristics of Arthropods

1. **"jointed legs"**

→ the only invertebrate with this trait

2. **hard (sclerotized) exoskeleton** of **chitin** completely covers body

→excellent for protection

→also **waterproof** → good for life on land

3. **segmented body**

allows infinite possibilities for adaptive modifications

4. **well developed head (cephalization)**

with numerous sense organs

antennae & compound eyes are characteristic sense organs of arthropods

brain (ganglia)

5. several pairs of jointed **feeding appendages**

6. very **active and energetic animals**

→ most active invertebrate group

can walk, jump, burrow, fly

some can fly over 30 mph

some can run up to 10 mph

Arthropods are one of the most ancient phyla with many fossils

→ polychaetes (annelids) and arthropods probably arose from a common ancestor over 600 M years ago

→ one of the few animal phyla that existed before the Cambrian explosion

shortly after the Cambrian explosion arthropods quickly became the dominant lifeforms and have dominated the fossil record since

one of the oldest animal species on earth (has remained unchanged) is *Triops cancriformis*

→ 180 M yrs → requires no males

many unusual forms now long extinct

in terms of numbers of individuals:

200 M individual arthropods for every person on earth

most <6 mm (1/4") long

largest: Japanese crab 12''; largest ever found was 19' (5.79M), 40lbs (18kg)

smallest: mite <0.1 mm

tremendous economic importance to humans

food
pollination
drugs, dyes, silk, honey, wax
crop pests
vectors of disease

were the **first animals to move onto land**
→ Silurian 420 MY ago

spider-like and centipede-like animals appeared shortly after plants moved onto land

(predators; must have been prey around also)

were the **1st animals to fly**
150 MY before flying reptiles, birds, bats

insects	→ 330 MY; Carboniferous
pterosaurs	→ 170 MY;late Jurassic
birds	→ 150 MY; (coexisted with pterosaurs for ~90 MY)
bats	→ ~40 MY; late Eocene

→ opened up a whole new set of ecosystems and habitats

before anything else began to compete for the same resources

allowed wide and rapid distribution and dissemination across the globe

Arthropod Body Plan

segmented body

allows infinite possibilities for adaptive modifications

lots of fusion of segments into a variety of body plans:

head & **trunk**

cephalothorax & **abdomen**

head - **thorax** - **abdomen**

paired jointed appendages

arthropods are the only invertebrates with jointed appendages

appendages are also highly adaptable to suit almost infinite functions:

sensory→ antennae, palps

feeding → mandibles, chelicerae, etc

locomotion → walking, climbing, swimming, flying, walking, swimming,

reproduction

Body Wall

body is completely covered with **hard exoskeleton**

also folds into mouth and anus to form lining of foregut and hindgut

cuticle also lines tracheae

main component is **chitin** (a starch) but much thicker than the thin flexible chitin of previous animal phyla such as segmented worms and roundworms

in some chitin is further hardened with proteins and calcium deposits (eg. crustacea)

exoskeleton is secreted by **epidermis** (hypodermis)

structure:

two major layers each further subdivided into finer layers

outer thin **epicuticle**: hardened (= sclerotized) protein with waxy surface for waterproofing

much thicker, inner **procuticle** (includes exocuticle and endocuticle): thick outer layer of **chitin** above a thinner inner layer that remains thin and flexible

some crustaceans (eg. lobsters & crabs) have a much thicker and stronger procuticle

often impregnated with Calcium salts

greatly increases its strength

exoskeleton is often highly colored:
camoflage
recognition
warning

various microscopic **canals** run through cuticle and open to outside:

pore canals → calcium salts for sclerotization in crustacea

wax canals → secrete waxy covering for water proofing

dermal gland ducts → unknown function

exoskeleton consists of many separate hardened plates with flexible **hinges** between

→ areas where cuticle hasn't been hardened

the exoskeleton also contains various folds (apodemes), flaps and spines:

muscles are attached to fingerlike inner extensions of skeleton (=**apodemes**)

→ when muscle pulls it moves part

eg. lobster closes claws

some parts modified for **feeding**

also structures for **respiration**, **swimming** & **mating**

many spines act as **tactile organs** (touch)

with the advantages of this exoskeleton it has one major drawback:

→animals can't grow without shedding and regrowing a larger exoskeleton

Molting

the problem is solved by **molting**

a complex process requiring environmental factors and the interaction of various hormones

includes actual shedding of old cuticle = **ecdysis**

eg. insects go through a fixed # of molts till adulthood, then they don't molt anymore

eg. spiders & some crustaceans molt indefinite # of times throughout their lives

a. molting is usually initiated by **environmental cues** or a buildup of pressure in the body

→ causes the release of **molting hormone** (=ecdysone)

b. triggers epidermis to secrete enzymes (proteases and chitinases) that digest and dissolve the inner layers of old cuticle (procuticle) and it separates from body wall

c. epidermis secretes new procuticle

d. arthropod inflates itself with air or fluid to crack the old skin (at fracture lines)

e. animal extricates itself from old cuticle

animal is especially vulnerable at this point

eg. soft shell crab must also shed lining of intestine and tracheae at same time

f. animal inflates itself and allows new cuticle to harden

Movement

virtually every form of animal movement is found in arthropods:

walking, running, crawling, burrowing, swimming, flying, etc

arthropods have a very **complex muscular system** the jointed plates of the body and legs provide attachment point for muscles

similar to muscle bundles that move our bones

insects have more muscles than most animals including us

eg. humans have ~700 individual muscles; some insects have 900 or more muscle organs; some caterpillars have 4,000

also, layers of muscles surround internal organs as in segmented worms

both striated and smooth muscle fibers

Feeding & Digestion

virtually every mode of feeding: carnivores, herbivores, omnivores, parasites

arthropods typically have 4-6 pairs of feeding appendages near their mouth

two main types of feeding appendages:

chelicerae → pinchers or fangs

mandibles → jawlike

with numerous accessory feeding appendages

well developed, complete, digestive tract:

mouth: salivary glands

esophagus: tube that brings food to stomach

stomach: often with specialized areas for grinding and storing and absorbing food

eg. crop, gizzard

and accessory glands that secrete enzymes and digestive juices

intestine: efficient areas for absorption of nutrients

anus: discards unused materials

Respiration

need some kind of respiratory system since waxy cuticle is impermeable to air

arthropods use a variety of respiratory systems lots of different kinds depending on habitat

eg. gills in most aquatic species such as crustaeans and aquatic insect larvae and nymphs

thin feathery structures or flat sheets of tissue

eg. book gills in some chelicerates extend from abdomen like pages of a book

eg. lungs protected internal chamber for air breathing arthropods

thin walls of chamber allow exchange of gasses with body fluids

eg. book lungs

several hollow internal folds; reverse of book lungs

able to work in air like book lungs work in water

eg. trachea

all terrestrial arthropods use this system for respiration

is a system of branching tubules that delivers oxygen directly to tissues

O_2 doesn't need to travel in blood

allows for high metabolism if insects

doesn't limit body size

insect tracheal system was an excellent method to get lots of oxygen to muscle tissues

→ preadaptation to flight

Circulation

arthropods have a simple **open circulatory system**

→ coelom becomes **hemocoel** filled with blood as in most molluscs

has dorsal **heart** and only a few blood vessels

dorsal blood vessel with paired **ostia** in each segment

blood flows anteriorly in dorsal vessel

out into segments and circulates around organs and back to dorsal vessel

no capillaries

blood of most arthropods contains pigments to carry oxygen:

eg. **hemocyanin** → bluish pigment with Copper

eg. **hemoglobin** → red pigment containing Iron

Nervous System

similar to annelids:

dorsal brain and double nerve cord with paired ganglia in each segment

still relatively simple, doesn't do a lot of processing

eg. cockroach can survive 30-40 days without a head

but much better developed sense organs

1. Eyes

a. simple eyes = **ocelli**

→ can detect only light vs dark

b. compound eyes

with many individual lenses = facets

provide a wide field of view and particularly good at detecting movement

2. Antennae

tactile & chemical sensations

3. Chemoreceptors

in addition to being on antennae, can be found on almost any body surface

eg. many insects have chemoreceptors on their feet

4. Tactile Hairs & spines

equivalent to our sense of touch

5. Statocysts

for balance

the more elaborate nevous sytem with sense organs allows for some of the more complex invertebrate behaviors

still mostly reflex, but with some learning

second only to cephalopods complexity

Excretion

arthropods have a variety of efficient excretory systems to:

remove excretory wastes

also prevents excessive water loss on land

antennal glands excretory organs at the base of antennae in crustaceans used to regulate salt balance

malpighian tubules are excretory organs unique to Arachnids and Hexapods

→branch from hindgut or rectum

collects salts and wastes and drains into the intestine

coxal glands modified nephridia at base of legs in some chelicerates

in some aquatic species nitrogen wastes are excreted through **skin** or through **gills**

Reproduction and Development

mostly **dioecious**

lots of variation in developmental stages

often quite complex

eg. **larva** → **metamorphosis** → **adult**
larvae = caterpillars, grubs, maggots, nauplius in crustacea

often with complete change in feeding and lifestyles

eg. aquatic larva vs terrestrial adult

eg. **nymph → juvenile → adult**

a few groups reproduce **parthenogenetically**

Origin & Evolution of Arthropods

arthropods show many similarities to certain segmented worms

1. metamerism with tendency for segments to become specialized
2. similar nervous system with paired ganglia in each segment
3. some have same type of excretory system
4. spiral cleavage in primitive members
5. mesoderm derived from 4D blastomere

soft cuticle of a segmented worm was hardened by deposits of additional proteins and calcium

the hard sections of cuticle were still separated from each other by flexible sutures and joints

→ provided protection from predators & environmental hazards

→ provided more secure site for attachment of muscles

parts of hard exoskeleton became pivots and levers for jointed appendages

new jointed appendages provide much more rapid

locomotion than hydrostatic skeleton of past

as coelom became less useful for movement it became more important for circulation

→ became a haemocoel

Classification

because of the diversity of arthropods:
classification is complex and difficult

it is difficult to generalize about various body systems

even taxonomists have not reached consensus on the classification and evolutionary relationships between some group

Major Subphyla:

There are 4 main kinds of **living** Arthropods (plus one extinct group we will discuss)

1. **Trilobites (4,000 species)**

   all extinct
   mostly marine

2. **Myriopods (14,000 species)**

   "many feet"
   centipedes and millipedes
   mostly terrestrial
   distinct head with mandibles & 1 pr antennae
   many similar segments

3. **Chelicerates (74,000 species)**

   spiders, crabs, ticks, mites, scorpions
   ancient group
   mostly terrestrial
   chelicerae and pedipalps for feeding
   no antennae
   cephalothorax

4. Crustacea (67,000 species)

shrimp, crab, barnacles, crayfish
mostly marine
a few freshwater and terrestrial forms
mandibles, 2 prs antennae
many appendages & many different kinds of appendages
cephalothorax

5. Hexapoda (>1,100,000 species)

most successful animal group
- 87% of all arthropods
- 62% of all animals
- 50% of all life on earth

mostly terrestrial
a few freshwater, hardly any marine
distinct head with mandibles & 1 pr antennae
body consist of head, thorax and abdomen
3 prs of legs, most with 2 prs of wings