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 19’ (5.79 M), 40lbs (18kg)

smallest: mite <0.1 mm

tremendous economic importance to humans

food

pollination
drugs, dyes, silk, honey, wax
crop pests

were the first animals to move onto land

→ Silurian 420 MY ago

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

most with head, thorax and abdomen
lots of fusion of segments into a variety of body plans:
- cephalothorax & abdomen
- head & trunk
- head - thorax - abdomen

**paired jointed appendages**

arthropods are the only invertebrates with jointed appendages
also highly adaptable to suit animals lifestyle:
- sensory → antennae, palps
- locomotion → walking, climbing, swimming, flying, walking, swimming,
- feeding → mandibles, chelicerae, etc
- 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

chitin is further hardened with proteins and calcium deposits

exoskeleton is secreted by **epidermis** (=hypodermis in arthropods)

**structure:**
- **epicuticle:** hardened (= sclerotized) protein with waxy surface for waterproofing
- **procuticle:** 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:
- camouflage
- 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

the exoskeleton also contains various folds, flaps and spines:

- exoskeleton consists of many hardened plates with flexible **hinges** between
  - areas where cuticle hasn't been hardened
- 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)
Animals: Arthropods

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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
   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 \rightarrow pinchers or fangs
   mandibles \rightarrow jawlike
   with numerous accessory structures
   well developed complete digestive tract:

mouth - esophagus - stomach - intestine - anus
   with specialized areas for grinding and storing and absorbing food
accessory glands that secrete enzymes and digestive juices
   efficient areas for absorption of nutrients

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 crustaceans 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
   \( \rightarrow \) preadaptation to flight

Circulation

arthropods have a simple open circulatory system
   \( \rightarrow \) coelom becomes haemocoel filled with blood
as in most molluscs has dorsal heart and 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 nervous system 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
eg. nymph → juvenile → adult
eg. some aquatic forms with free swimming larval stage = nauplius
often with complete change in feeding and lifestyles
eg. aquatic larva vs terrestrial adult
a few groups reproduce **parthenogenetically**

**Origin & Evolution of Arthropods**

arthropods show many similarities to certain segmented worms

most believe annelids, molluscs and arthropods are related

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 appendages provided 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
t   - mostly terrestrial
   - distant 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