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 known species of every kingdom of life include 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

- 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
  - 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

- 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

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

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 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

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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 pairs 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 pair antennae
  - body consists of head, thorax and abdomen
  - 3 pairs of legs, most with 2 pairs of wings