

Biol 206 - Zoology
Lecture Handout - Arthropods

Phylum Arthropoda Overview: Most abundant and diverse of any group of animals on Earth; over 1,000,000 spp. known. Eucoelomate protostomes, organ-system level of development. Exoskeleton of chitin (nitrogenous polysaccharide). Segmented, in somites, with jointed appendages.

1. Review:

Recall characteristics of annelids:	Compare to the characteristics of arthropods:
segmented	segmented
bilateral	bilateral
lack jointed appendages	highly modified jointed appendages
lack chitinous exoskeleton	modified chitinous exoskeleton
closed circulatory system	open circulatory system
nephridia	malpighian tubules (or green gland)
lack tracheal system	trachea and spiracles
lack striated muscle	striated muscle
monoecious (usually)	dioecious
	metamorphosis

2. How to tell the subphyla and classes apart:

- a. Number and arrangement of body divisions, tagmata, possible arrangements:
 - Head + trunk
 - Head + thorax + abdomen
 - Cephalothorax + abdomen
 - Single piece with no clear distinctions
- b. Number of legs
- c. Number of antennae: 3 options - 0 pairs, 2 pairs, 4 pairs
- d. Mean of respiration:
 - Gills - aquatic
 - Tracheae (spiracles) - insects and Onychophora
 - Book lungs - spiders

3. Why the success?

- a. Exoskeleton: Versatile, protects, cuticle. Secreted by epidermis. Protects against dehydration. Permits flexibility. Calcium salts for durability.
 - Procuticle: inner, thick, chitinous
 - exocuticle - secreted before a molt
 - endocuticle - secreted after a molt
 - Epicuticle: Outer, thin
 - Ecdysis, molting: Shed, then grow larger exoskeleton
- b. Segmentation and appendages for locomotion: Generally, pair of jointed appendages per segment or somite. Muscles connect for movement. Fused and modified segments.
- c. Air piped to cells: Terrestrial species, therefore efficient O₂ delivery. Tracheal system of air tubes. Supports active metabolism. Aquatic species generally have gills.
- d. Sensory organs and nervous system well-developed
- e. Complex behavior patterns
- f. Competition with others reduced due to metamorphosis, i.e., larval forms very different from adults. Or, division of labor in the life cycle.

4. Four subphyla of Arthropoda:

- SP Trilobita
- SP Chelicerata
- SP Crustacea
- SP Uniramia

5. SP Trilobita

- Primitive marine arthropods
- 3 body divisions
- 1 pair of antennae
- Biramous appendages
- All extinct

6. **SP Crustacea** Shrimps, lobsters, crabs, barnacles, pillbugs, etc. Hard and flexible crust. Mostly marine, few terrestrial, freshwater. Approximately 35,000 spp. Many have 16 - 20 segments, others up to 60. 2 pairs of antennae (or 1 antenna pair and 1 antennule pair), mandibles, 2 pairs maxillae on head (as accessory mouth parts), 1 pair appendages on each body segment. Most appendages biramous (2 branches primitively). Gills for respiration. No Malpighian tubules. 16 - 20 segments and fuse as tagmata; head, thorax, abdomen. Dorsal carapace is dorsal cuticle of head extending posteriorly over thorax and part of abdomen. Cephalothorax + abdomen. Hard exoskeleton of chitin

a. Appendages:

- Maxillipeds: First 3 pairs of thoracic appendages + 2 pairs of maxillae used for handling food.
- Chelipeds: First pairs of walking legs, on thorax. Chela is enlarged claw, defense.
- 4 More pairs walking legs: On thorax.
- Swimmerets: Abdominal appendages, biramous with endopod, exopod.
- Uropods: Last pair appendages, for paddling and rapid backwards movement.

b. Ecdysis: Shedding of cuticle and formation of new one. Frequent as larvae, less so as adult. Preparation is long and continuous process during the life of the individual, shedding is brief. Hormonal and nervous system control. Nervous stimulus decreases production of molt-inhibiting hormone from X-organ neurosecretory cells, then Y-organ produces molting hormone. Now, premolt.

- Premolt: Cuticle thins, salts removed from it and stored in tissue. Epidermis grows by cell division and new cuticle secreted.
- Postmolt: Cuticle thickens, salts added.

c. Feeding Habits:

- Suspension feeders: Feed on plankton, detritus, bacteria.
- Scavengers: Dead organic (plant, animal) matter.
- Predators: Animal prey.

d. Respiration:

- Gills: Variable shape, but blood vessels and sinuses provide ample surface area for O₂/CO₂ exchange.

e. Excretion: Organs for excretion and osmoregulation are located in head; excretory pores open to outside.

- Antennal glands:
- Maxillary glands:

f. Circulation: Open system. Heart (not in all), arteries deliver to body.

g. Nervous and Sensory Systems:

- Cerebral ganglion: Connects to subesophageal ganglion, then from a double ventral nerve cord, nerves penetrate each segment, viscera, appendages, muscles.
- Sensory organs:
 - median/nauplius eye - usually in nauplius larvae, some adults. Retinal cells in pigment cups.
 - compound eye - on movable eye stalks.

h. Reproduction:

- Most have separate sexes. Barnacles are monoecious (hermaphroditic), but cross-fertilize. Some crustaceans exhibit parthenogenesis.
- Most brood eggs, some attach to underside of abdomen.
- Most crustaceans produce larvae and change via molts.

7. **Class Branchiopoda (of SP Crustacea)** Very important component of freshwater zooplankton. - Fresh water (mainly) filter feeders

- Ex: *Daphnia*, water fleas - we fed them to *Hydra* earlier in the semester.

8. **Class Cirripedia (of SP Crustacea)** Barnacles. In calcareous plates, secreted by carapace. Sessile as adults. Reduced head, no abdomen, thoracic legs extended, cirri, with hairlike setae for filtering food particles from water.

- Sessile as adult
- Can be parasitic
- Carapace covered with calcareous plates
- 6 pairs of thoracic appendages for feeding
- All marine
 - Ex: barnacles, mantis shrimp
 - These look like a shrimp stuffed into a volcano shaped shell and only the feet are sticking out.

9. **Class Malacostraca (of SP Crustacea)**

- Large crustaceans with 14 segments on trunk
- Thorax of 8 segments
- Abdomen of 6 segments
- Posterior telson
- All segments have appendages
 - Ex: shrimp, lobsters, crayfish

Phylum Arthropoda (continued) Subphylum Uniramia Class Insecta Unbranched appendages (uniramous). Insects in this subphylum. Most numerous and diverse arthropods. Have 3 tagmata (fused somites for a particular function); head, thorax, abdomen (each comprised of 3 somites).

1. **Characteristics:**

- a. Head with Appendages: One pair of antennae, mouth with labrum, pair of mandibles and pair of maxillae, labium, hypopharynx. Compound eyes, 3 ocelli.
- b. Thorax with appendages, prothorax, mesothorax, metathorax. Usually 2 pairs of wings.

c. Abdomen with no or reduced appendages.

d. Respiration by:

- Gaseous exchange across body surface, and;
- Tracheal system.

e. Segments of 4 Plates (Sclerites):

- Tergum - dorsal notum.
- Ventral sternum
- Lateral pleura

f. Wings and Flight: Formed from outgrowth from body wall of mesothoracic and metathoracic segments. Cuticle (non-cellular organic layer secreted by epidermis). Generally 2 pairs (true flies have 1 pair).

- Flight muscles:

- direct flight muscles - attached to wing.
- indirect flight muscles - not attached to wing, rather alter shape of thorax. Wing upstroke controlled by contraction of these, because the dorsal plate (of the segment) is pulled down toward the ventral plate. Downstroke accomplished either by:
 - contraction of direct muscles on lateral plates (dragonflies, cockroaches), or;
 - contraction by only indirect muscles (Hymenoptera, Diptera). Stenotergal muscles relax and longitudinal muscles of thorax arch the dorsal plate. Pulls up.
 - direct and indirect muscles involved in beetles and grasshoppers.

- Neural control over flight:

- synchronous - nerve impulses stimulate muscle contraction and effect one wing stroke, as in butterflies. Few beats/second.
- asynchronous - dependent on potential energy in thoracic cuticle. Muscles and their antagonists (other set of muscles) move wing in opposite directions and not directly related to nervous stimulation, therefore not dependent on one nerve impulse/wing movement. Therefore, extremely rapid wing beats are possible, as in flies and bees. Hundreds beats/second.

- Flight direction: Direct flight muscles change wing angle, figure 8 movement.

g. Internal Form:

- Nutrition: The order is: foregut, esophagus, crop (storage), gizzard (grinding), midgut (stomach and cecum), and hindgut (intestine to anus).

- herbivores - feed on plants, mainly;
- saprophagous - feed on dead animals;

- predators - catch and eat prey;
- parasitic - i.e., fleas suck blood from host.
- biting and chewing mouthparts in some;
- sucking mouthparts in some with or without mandibles (jaw appendages);
- piercing - i.e., mosquitos.

- Gas exchange: Tracheal system functions for efficient O₂-CO₂ exchange without blood and O₂-carrying pigments. Network of tubes throughout body and open to outside via spiracles on thorax and abdomen. Spiracle may have cover “valve” to prevent water loss, thus survive in dry habitats. Tracheae have cuticle covering and thin walls. System is so extensive that some extensions touch mitochondria (supply O₂ efficiently).

- For aquatic insects:
 - gaseous exchange via diffusion across body wall to a tracheal system under integument.
 - gaseous exchange via gills, extensions of body wall.

- Excretion and water balance: Malpighian tubules, excrete waste water and conserve water. In drier habitats, most water recycled, from rectum, such that waste is solid.

- in dry habitat - need to conserve water and excrete salts;
- in aquatic habitat - need to excrete water and conserve salts (recall hypo- and hypertonicity).

- Nervous system: Consists of fused ganglia, a giant fiber in some insects, a visceral nervous system similar to the autonomic nervous system in vertebrates, neurosecretory cells in brain have endocrine function with role in molting and metamorphosis.

- Sense organs: React to mechanical, auditory, chemical, visual stimuli; spread throughout the body.

- photoreceptors - compound eyes, ocelli.
- sound - hairlike organs or tympanic organs.

- Reproduction: Dioecious, separate sexes, fertilization internal. Attract opposite sex by:

- pheromone release - chemical, detected at great distances;
- light - fireflies;
- color;
- courtship displays.
- sperm deposited in female vagina during copulation; exceptions occur such as sperm packets (spermatophores) deposited outside male and picked up by female.

- sperm stored in female can fertilize successive eggs batches.
- lots of eggs laid, species specific behavior re: where eggs are deposited, i.e., monarch butterfly deposits on milkweed plant.

h. Metamorphosis and Growth: Most dramatic in insects. Early development occurs in eggshell, later, changes in form occur → Metamorphosis. Instar - growth stage between molts. Most insects undergo complete metamorphosis, distinct physiological processes. Metamorphosis is under hormonal control:

- Holometabolous (complete) metamorphosis:

- egg
- growth - larva, feeding via chewing mouthparts
- pupa - differentiation, non-feeding stage, then adult emerges
- adult - reproduction, no more molting
- Habitat may be entirely different for the 4 processes

- Hemimetabolous (incomplete) metamorphosis - i.e., grasshoppers:

- egg
- nymphs - young individuals, several instars and grows into adult
- adults- sexually mature

- Direct development - in some insects, young (juveniles) similar to adults:

- egg
- juvenile
- adult - sexually mature

- Insects may enter state of dormancy during adverse conditions, the time period may be of variable time periods depending on environmental conditions OR

- Diapause: a rather fixed time period, internally programmed (genetic control) and often seasonal. Adaptation to survive regular adverse or changing environmental conditions

Phylum Arthropoda (continued) Subphylum Chelicerata (mouthparts) Example: Spiders, horseshoe crabs. Originated in Paleozoic shallow seas, very ancient. Horsecrabs are one of the few surviving species of those original marine species. More familiar are scorpions, spiders, ticks, chigger mites. These are arachnids, **Class Arachnida**. Scorpions and spiders are predators; sting, bite or subdue prey with venom. Ticks parasitize vertebrates and some may transmit bacterial pathogens. Mites are mostly scavengers (free-living). Arachnids segments are fused into (segments form) a forebody and hindbody.

1. **Subclass Xiphosurida.** Horseshoe crabs. Ancient marine group. *Limulus* lives in shallow waters of N American Atlantic coast. Carapace, dorsal shield, broad abdomen with spike-like telson. Book gills.

2. **Class Arachnida (of SP Chelicerata)** (scorpions, spiders, harvestmen (daddy longlegs), ticks, mites. Drawing of spider showing location of pedicel, 2 rows of 4 eyes and spinnerets. All Arachnida have fangs and all are poisonous - different species are more potent than others, some are too small to bite humans. Over 50,000 - 60,000 species. No visible external segmentation.

a. Mainly terrestrial: No marine but some live in aquatic areas

b. 6 pairs of appendages:

- 1 pair of chelicerae with claw/fang

- pedipalps - may function as sensory, reproductive or grasping function

- 4 pairs of walking legs

- No antennae

c. Forebody:

- Jointed appendages include 4 pairs of walking legs, 1 pair of pedipalps of sensory function, 1 pair of chelicerae for discharging venom or causing a wound

- No mandibles, no antennae

- Pedicel: Connection between cephalothorax and abdomen

d. Hindbody:

- Spinnerets - spin out silk threads from silk glands for webs and egg cases

e. Open circulatory system: Heart pumps blood into tissues, blood returns to heart via openings in heart wall

f. Respiration: "Book" lung, like book pages, or tracheae, great surface area for gaseous exchange. Spiracles are opening to outside.

g. Predators: All are predators

h. Excretion: Malpighian tubules collect solute waste and this drains to intestine. Rectal glands resorb potassium and water, leaving uric acid.

i. Sensory organs: 8 simple eyes, vision is poor; sensory setae used to detect surroundings

j. Web: Spin silk. Spinnerets connect to silk glands, substance is a protein, extremely strong. Function is to trap insects, construct egg sacs, create a pathway for travel (bridge).

k. Reproduction: Genital opening on anterior of abdomen. Male first spins web, deposits sperm on it, picks sperm up and stores it in his pedipalps until needed to deposit into the female genital opening then seminal vesicle. Courtship behavior is common. Female lays fertilized eggs in silk cocoon. Eggs hatch, several molts occur before adult stage reached.

3. **Order Scorpionida:** Scorpions

- Hide during day, feed at night on insects, spiders.
- Seize prey with pedipalps and tear prey with chelicerae.
- 1-6 pairs of eyes
- Segmented abdomen: Preabdomen and postabdomen with stinger to inject venom
- Bear live young and brood on back until after 1st molt

4. **Order Opiliones:** Harvestmen

- Daddy longlegs
- Cephalothorax + abdomen broadly joined (not noticeable pedicel)
- Capable of losing leg appendages
- Feed as scavengers

5. **Order Acari:** Ticks and Mites

- Cephalothorax + abdomen fused
- No visible sign of segmentation
- Capitulum - location of mouthparts
- Ubiquitous
- Parasitic on vertebrates/invertebrates
- Free-living in i.e., house dust, causing allergies
- Some marine and freshwater mites
- Spider mites are agricultural pests
- Chiggers are mite larvae
- Hair-follicle mite, benign
- Ticks are larger than mites, parasitic on vertebrates (suck blood); feed again after
 - molting
 - Disease vectors by transmitting protozoans, viruses, bacteria, fungus disease-causing organisms
 - Rocky Mountain spotted fever
 - Lyme disease

6. **Phylum Onychophora** - Shares characteristics with Arthropods and Annelids. The most common is *Peripatus* (velvet worm). First described in 1826 as mollusc. This phylum seems to be somewhat of a hybrid between the 2 - the fossil and genetic record argues that it was possibly the predecessor of Arthropoda, no final decision made regarding whether Onychophora should be separate phylum or combined with Arthropoda. Slow-moving with 2 openings on head, stream of glue squirted through to entangle prey, prey and glue consumed. Characteristics:

- Chitinous exoskeleton with hard claws

- Open circulation

- Tracheal system

- Jaws

- Ciliated nephridia

- No striated muscles

- Appendages - but not jointed