The phylum **Arthropoda** contains about 78% of all known species of animals. Over a million species have been identified.

They live on land, in the sea and air, and make up over three-fourths of all currently known living and fossil organisms.

They have been called the dominant animals on earth.

**Major Characteristics**

1. **Arthropoda** means jointed foot. Members of this phylum have jointed appendages.
   - These appendages may be modified in a number of ways to form antennae, mouthparts, and reproductive organs.

2. Arthropods are bilaterally symmetrical

3. They are triploblastic

4. Like mollusks, arthropods possess a much reduced coelom. However, there are larger cavities around the alimentary canal but these are not true coelomic cavities. They are filled by blood and are called hemoeoles.

5. Arthropods have a hardened exoskeleton made of chitin that may be further stiffened by calcium carbonate (CaCO3)
   - The exoskeleton is non-expandable and as an individual grows, it must shed the exoskeleton and replace it with a new larger exoskeleton. This process is called molting

6. They have segmented bodies, like the annelids.
   - Some species show various patterns of segment fusing to form integrated units. An example is the fusion of the head and thorax to form the cephalothorax of crayfish.

7. Many have diverse and specialized mouth parts.

8. Arthropods have a well developed ventral nervous system

9. Most possess a dorsal circulatory system.
Classification

We will quickly look at the two subphyla and six classes of Arthropods. These are:

SUB-PHYLUM Mandibulata (There are 4 classes that possess jaws).

- Class *Crustacea*
  
  1. includes crayfish, lobsters, shrimp crabs, Daphnia (water fleas), copepods, and sow bugs

- Class *Insecta*
  
  1. includes insects

- Class *Chilopoda*
  
  1. the centipedes

- Class *Diplopoda*
  
  1. the millipedes

SUBPHYLUM Chelicerata. (There are 2 classes that lack jaws).

- Class *Arachnida*
  
  1. includes spiders, scorpions, mites, and ticks

- Class *Xiphosura*
  
  1. the horseshoe crab

We will look at two classes, the *Crustacea* and *Insecta* in more detail.
Class Crustacea

- Characteristics
  1. Crustaceans are named for their hard shells.
  2. They possess gills for breathing
  3. Have two pairs of antennae
  4. One pair of mandibles
  5. And their appendages are modified for various functions

- Anatomy and Physiology (The crayfish as representative example)

We will discuss the anatomy and physiology of crustaceans using the crayfish as our example. To follow along with this discussion use the handout from page 187 of our lab manual.

Crayfish are common in freshwater streams, ponds and lakes.

External Anatomy

1. The outside is covered by a hard cuticle called chitin

2. The exoskeleton is flexible at the joints to allow movement of body regions.

3. There are two distinct body regions.

- The anterior region is called the cephalothorax (A10)

  1. The cephalothorax is enclosed by a cuticular shield called the carapace.

  2. The cervical groove (A4) runs across the mid-dorsal region of the carapace.

  3. The anterior pointed extension of the carapace is called the rostrum (A3)

  4. Beneath the rostrum on either side of the body is an eye that is at the end of a movable stalk

  5. The antenna(A1) and antennule(A17) are also part of the cephalothorax
• The **posterior** region is a **series of segments** and is called the **abdomen** (A11)

1. The **abdomen** is composed of **6 segments**, the **last** of which is a terminal segment called the **telson** (A7,B11). The **anus** (A22,B12) can be found on the **ventral** surface of the **telson**.

2. **(Draw this on board using a cross section view)** Each abdominal segment that possesses swimmerets has a dorsal plate
   - a **dorsal plate** called the **tergum**(A12)
   - a **ventral plate** or bar called the **sternum**
   - and **lateral plates** called the **pleurons** (A13)

3. Each **swimmeret** is composed of a
   - **Protopodite** (A14)
   - **Exopodite** (A15)
   - And **endopodite** (A16)

4. Going from **anterior** to **posterior** the **paired appendages** are as follows.
   - **1** pair of **stalked eyes**
   - **1** pair of **antennae** (A1)
   - **1** pair of **antennules** (A17)
   - **1** pair of **mandibles** (part of mouth - A9)
   - **2** pair of **maxillae** (part of mouth - A9)
   - **3** pair of **maxillipeds** (part of thorax - A18)
   - **1** pair of **chelipeds** (part of thorax - A2)
   - **4** pair of **walking legs** (part of thorax - A20)
• 5 pair of swimmerets (part of abdomen - A21)

• 1 pair of flattened uropods (part of abdomen - A6,B11)

Internal Anatomy

1. The crayfish possesses all the important systems of organs that are characteristic of higher animals.

Digestive System

1. Crayfish eat snails, tadpoles, insect larvae, decaying organic matter, and may even eat each other.

2. They feed primarily at night.

3. Digestive pathway is as follows:

   Mouth  Esophagus  Cardiac Stomach  Pyloric Stomach  Midgut  Intestine  Anus

   Digestive gland (liver)

4. In the cardiac stomach there are 3 teeth that grind food. This is called the gastric mill.

5. There are two large digestive glands or liver below the stomach that produce digestive enzymes that enter the midgut through ducts.

Circulatory System

1. The crayfish has a circulatory system that is similar to the earthworm, but the crayfish system is an open system and veins are absent. Remember the earthworm had a closed system.

2. The system includes
   
   • a muscular heart
   
   • seven arteries which carry blood to the body
   
   • sinuses which return the blood to
   
   • the large mid-dorsal pericardial sinus surrounding the heart.
3. Blood is almost colorless and contains hemocyanin, a copper containing respiratory pigment.

4. Crayfish blood has the capability of forming clots to prevent excessive blood loss.

Respiratory System

1. The gills are very prominent during dissection

2. Crayfish breath by means of a pair of gills which are delicate feather-like projections located on either side of the thorax.

Excretory System

1. The excretory organs are a pair of green glands

2. The green gland consists of a glandular portion, a thin walled bladder, and a duct leading to the renal pore that opens to outside and is located just behind the eye.

Nervous System

1. The central nervous system consists of (draw on board)
   - A brain which supplies nerves to the eyes, antennules, and antennae
   - A pair of circumesophageal connectives which encircle the esophagus and connect to the
   - Ventral nerve cord

Reproductive System

1. The crayfish is dioecious and there is some sexual dimorphism
   - Females have a broader abdomen and lack the specialized swimmerets that are used as copulatory organs by males

2. The male organs consist of a pair of testes, two long coiled vas deferens (sperm ducts) that lead to genital pores located at the base of the 5th walking legs.
3. The **female organs** are **paired ovaries** and **short oviducts** that lead to **genital pores** at the base of the 3rd **walking legs**.

**Autotomy**

1. Crayfish have the power to **regenerate** lost **body parts**.

2. The power of **self-amputation** is called **autotomy**. If a body part, such as a cheliped is injured, it is cast off and a new one grows in its place.

**Class Insecta**

- **Characteristics**

  1. Insect **bodies** are divided into **three regions**. *(draw diagram below on blackboard)*

     - **Head** - bears the **sense organs** (eyes, etc) and **mouth parts**
     - **Thorax** - bears 3 **pairs** of **legs** and 1 or 2 **pair** of **wings**
     - **Abdomen** - bears or contains most of the **internal organs**

  2. Like crustaceans, they have a hard **exoskeleton** made of **chitin**.

     - Like crustaceans the **exoskeleton** serves to **protect** the organism and insects must **molt** to **grow**.

     - During **molting** insects are **vulnerable** to predators

  3. They are air breathing and **respire** by **trachea** through holes in the body called **spiracles**.

  4. There are **three pair** of **jointed legs**.
5. The *sexes* are *separate* or insects are *dioecious*

6. Insects usually have 1 or 2 *pair* of *wings* in the *adult* stage

7. Insects have both *simple* (called *ocelli*) and *compound eyes*

8. *Coelom* very much *reduced*

9. The *circulatory system* is an *open* system and like crustaceans includes a *hemocoel*.

- **Classification**

  In total, there are 25 *Orders* *(review where Order fit in the hierarchical classification system)* of insects. We will discuss the 10 more *common Orders*.

  1. *Order Thysanura* - silverfish

  2. *Order Isoptera* - termites

  3. *Order Orthoptera* - grasshoppers, crickets

  4. *Order Lepidoptera* - butterflies, moths

  5. *Order Hemiptera* - stink bugs (the true bugs)

  6. *Order Diptera* - flies, gnats

  7. *Order Odonata* - dragonflies, damselflies

  8. *Order Hymenoptera* - wasps, bees, ants

  9. *Order Coleoptera* - beetles

  10. *Order Homoptera* - lacewings, plant lice

- **Metamorphosis**

  1. Before we proceed further we need to introduce a *new term* and discuss a *phenomenon* that is very *common* and *widespread* in insects. We need to talk about *metamorphosis*. 
2. Metamorphosis can be defined as - a change in shape and form that some animals, like insects, undergo during development.

3. Although this phenomenon is not restricted to insects, they illustrate this biological principle better than any other animal group.

4. An example of metamorphosis is the live stages of the mosquito. In summary the cycle is as follow.

- Eggs are layed in water and hatch into
- Larvae that are commonly called wiggles that transform into
- Pupae that mature and change to form
- Young adults that leave the water to become adult mosquitoes

5. With regard to their growth and development, insects can be divided into 4 groups. These are:

- No metamorphosis
  1. These insects have no metamorphosis at all.
  2. The young hatch from the egg as the same form as the adult and merely grow larger.
  3. Stages of development are EGG ADULT

- Incomplete metamorphosis
  1. Some insects like dragonflies, mayflies, and stone flies have a distinctive stage between the egg and adult called a naiad. The naiad bears no resemblance to the adult.
  2. Eggs are laid in water and hatch into aquatic naiads.
  3. Naiads grow by successive molts and after the last molt emerge form the water as adults.
  4. Stages of development are EGG NAIAD ADULT
• **Gradual metamorphosis**

  1. For insects with this type of metamorphosis the *stage* between the *egg* and *adult* is called a *nymph*.

  2. The *nymph* usually *resembles* the *adult* in general body features, but it usually *lacks* wings and genital appendages. *(contrast this with the naiad not resembling the adult)*

  3. *Insects* with this *type* of metamorphosis include the *grasshopper* and *true bugs*

  4. Stages of development are *EGG  NYMPH  ADULT*

• **Complete metamorphosis**

  1. Many insects undergo *complete metamorphosis* during their development.

  2. The *mosquito* was our earlier example and it represents a *complete metamorphosis*.

  3. Stages of development are *EGG  LARVAE  PUPAE  ADULT*

  4. Each *stage* is very *distinctive* and usually very *unlike* any other *stage*.

  5. Perhaps the *best example* of insects that have complete metamorphosis are the *butterflies*.

• **Anatomy and Physiology** *(The grasshopper as representative example)*

  Refer to the handout of the grasshopper from page 193 of our lab manual.

  **External Anatomy**

  1. **The exoskeleton** of *grasshoppers* is made of *chitin* with *softer regions* called *sutures* that allow body *movement*
2. There are 3 body regions

- **Head** (A5)
- **Thorax** (A2)
- **Abdomen** (A3)

3. Head

- The head consists of the following regions

  1. The vertex (B1) - *top*
  2. The *frons* (B6) - *front*
  3. The *genae* (B5) - *sides*
  4. The *clypeus* (B7) - a *plate* below the *frons*

- The head *bears*

  1. 2 *compound eyes* (A17)
  2. 3 *simple eyes* or ocelli (A2)
  3. 2 *antennae* (A4,B8)
  4. *Mouthparts*

    - 1 *labrum* (B3,C1,D24)
    - 2 *mandibles* or jaws (C2)
    - 2 *maxilla* (B4,C3)
    - 1 *labium* (C-4)

4. Thorax

- The *thorax* is divided into 3 regions. These are

  1. **Prothorax** bears 1 pr legs
  2. **Mesothorax** bears 1 pr legs, 1 pr wings, 1 pr spiracles
  3. **Metathorax** bears 1 pr legs, 1 pr wings, 1 pr spiracles

- Each leg is made up of the following parts (draw this on blackboard).

  1. **Coxa** (A12) - attaches leg to body
  2. **Trochanter** (A11)
  3. **Femur** (A8)
  4. **Tibia** (A16)
  5. **Tarsus** (A15)
• The 1st pair of wings are called the mesothoracic wings
  1. these are the forewings
  2. are narrow and leathery

• The 2nd pair of wings are called the metathoracic wings
  1. these are the hindwings
  2. are beneath the mesothoracic wings, are folded, and thin

5. Abdomen

• abdomen is elongated and consists of 11 segments
• at the posterior end the last segment is modified to form the ovipositor (A9) in females used to lay eggs
• there are 8 pr of spiracles (A14) - used for breathing
• there is 1 pr of oval tympanic membranes (A7) used for hearing

Digestive System

1. The most conspicuous organ system in the grasshopper is the digestive system. Grasshoppers are vegetarians.

2. The digestive system can be divided into three regions.

   • Foregut
   • Midgut
   • Hindgut

3. Foregut includes

   • Mouth (including salivary gland (A22) and duct (A23)) salivary gland produces a tobacco-like substance
   • Esophagus (A2) - short and tubular
   • Crop (A5) - a thin walled storage organ
   • Gizzard (A6) - used for grinding food

4. Midgut includes

   • Stomach (A20) - because most of the foregut and hindgut is lined with chitin, most absorption occurs in stomach
   • Gastric ceca (A7) - organ that open into the stomach and secretes enzymes
5. **Hindgut** includes
   - *Ileum* (A11)
   - *Colon* (A12)
   - *Rectum* (A13)
   - *Anus* (A14)

Circulatory System

1. The circulatory system is much *reduced* when compared to other arthropods.

2. As in other Arthropods it is an *open system*. There are *no capillaries or veins*.

3. The elongated *heart* (D9) consists of a *row of chambers*

4. Blood *enters the heart* thru openings called *ostia* in the chambers

5. Blood is *forced* in an *anterior direction* through the *aorta* (D8) into the *hemocoel* (D21) where it *bathes* the internal organs.

Respiratory System

1. Respiration is taken care of by an *extensive network* of *tubes* called *trachae* that communicate with all parts of the body.

2. This network *opens* to the *outside* through *openings* in the body wall called *spiracles* (A14).

Excretory System

1. The excretory system consists of *Malpighian tubules* (D18) which are *joined* to the anterior end of the *hindgut*

2. They *remove wastes* from the blood in the *hemocoel* and pass it into the *hindgut*

3. They *rid* the body of *uric acid* and solid *nitrogenous wastes*. 
Nervous System

1. The nervous system includes
   
   - **brain** (D4)
   - pair of **circumpharyngeal connectives** (D1)
   - **subesophageal ganglion** (D3)
   - **ventral nerve cord** (D19)

Reproductive System

1. Sexes are **separate** and show **sexual dimorphism**
   
   - The **male** has a **round** posterior end while the **female** posterior end is **pointed** because if its **ovipositor**.

2. The **male** reproductive system **consists** of
   
   - 2 **testes** - above the intestine
   - 2 **vas deferens**
   - 2 **Seminal vesicles**
   - 1 common **ejaculatory duct**
   - a **penis**

3. The **female** reproductive system **consists** of
   
   - 2 **ovaries** (D10)
   - 2 **oviducts**
   - a **single vagina** (D17)
   - a single **seminal receptacle** (D15) - stores sperm
   - a **genital opening** (16) in ovipositor

4. **Fertilization is internal** and female grasshoppers use their ovipositor to lay eggs in the ground

5. Grasshoppers undergo **gradual metamorphosis**. The egg hatches into a form that is similar to the adult called a **nymph**.

6. Remember **EGG NYMPH ADULT**
• Social Insects

1. Another interesting feature of insects is the development of societies and social systems by some species. Examples include honeybees and ants.

2. These form colonies that may include many thousands of individuals.

3. Some, like the honeybee have developed a complex social structure that includes divisions of labor. A typical honeybee hive or colony usually includes:

   • A single large female queen that is fertile
     1. the only reproductive female in the hive
     2. can store sperm for many years
   
   • A few hundred male drones that are fertile
     1. Their only role in life is to fertilize the queen.
     2. Usually dies from exhaustion from mating or are drive out by workers
   
   • And thousands of female workers that are sterile
     1. Actually do all the work in the hive
     2. They gather nectar, manufacture honey, and care for young
     3. Usually live only a few weeks.

• Economic Importance

1. Recall that I said that the phylum Arthropoda contains about 78% of all known species of animals and they can be called the dominant animals on earth.

   • This is due to insects being members of this phylum
• Insects make up 97% of all members of the phylum *Arthropoda*. *Crustaceans*, *Chilopods*, *Diplopods*, and *Arachnids* make up only 3%. (Draw the following diagram on the blackboard)

• There are more species of insects than species of all other animals combined.

• Insects live in all kinds of environments.

• Thus they impact man and have an important economic impact on man's activities.

2. The study of insects is called entomology and a person that specializes in entomology is called an entomologist.

3. Two important branches or specialized fields of entomology are

   • Medical Entomology - Study of insects that impact the health and physical well-being of humans

   • Economic Entomology - Study of insects that impact the business activities of humans, especially those dealing with agriculture, forestry, and other natural resource management activities.

4. The *U. S. Department of Agriculture* estimates that annually, insects are responsible for several billion dollars in damage to crops, forests, stored foods, and domesticated animals.

5. However there are many beneficial insects that prey on harmful insects and others that produce useful products like honey, bees wax, silk.

6. Without insects as pollinators, many important plants would vanish from the face of the earth.
**Taxonomy**

Phylum - Arthropoda

- Sub Phylum - Chelicerata (lack jaws)
  1. Class - Arachnida (spiders, scorpions, mites, ticks)
  2. Class - Xiphosura (horseshoe crab)

- Sub Phylum - Mandibulata (with jaws)
  1. Class - Crustacea (crayfish, lobsters, shrimp)
  2. Class - Chilopoda (centipedes)
  3. Class - Diplopoda (millipedes)
  4. Class - Insecta (insects)

**Characteristics**

1. Contains about 78% of all known species of animals.
2. Jointed footed
3. Bilaterally symmetrical
4. Jointed exoskeleton (tagmosis)
5. Hemocoel (filled with blood)
6. Triploblastic

7. Dorsal circulatory system
8. Ventral nervous system
9. Hardened exoskeleton (chitin) may be further stiffened by CaCO3
10. Diverse + specialized mouthparts
11. Many species form trochophore larva
12. Autotomy + self regeneration
PHYLUM - Arthropoda
CLASS - Insecta

I Characteristics

II Classification

III Entomology

IV Metamorphosis

V The Grasshopper
   A. External Anatomy
      1. Head
      2. Thorax
      3. Abdomen
   B. Systems
      1. Digestive
      2. Respiratory
      3. Circulatory
      4. Excretory
      5. Nervous
      6. Reproductive

VII Economic Importance

P. 193

1. Colonies
2. Division of labor
I INSECT CHARACTERISTICS

* 1. Body divided into 5 regions: head, thorax, abdomen
* 2. Exoskeleton of Chitin
* 3. Respire by tracheae from spiracles
* 4. Three pairs of legs
* 5. Direcious
* 6. 1 or 2 pairs of wings in adult stage
* 7. Compound eye; simple eyes—ocelli
* 8. Hemocoel

II CLASSIFICATION [25 orders - 10 or more common ones
Examples

III Entomology [Medical
[ Economic

IV Metamorphosis
(1) Without egg—adult
(2) Incomplete egg—naiad—adult
(3) Gradual egg—nymph—adult
(4) Complete egg—larva—pupa—adult
Grasshopper External Anatomy

**HEAD; THORAX; ABDOMEN**

**HEAD** (A5)
- Clypeus (B7)
- Labrum (B8 C1)
- Mandible (C2)
- Maxilla (B4 C3)
- Labium (C4)
- Frons (B6)
- Genae (B5)

**THORAX** (A2)
1. Prothorax — 1 pr. legs
2. Mesothorax — 1 pr. legs; 1 pr. wings; 1 pr. spiracles
3. Metathorax; 1 pr. legs; 1 pr. wings; 1 pr. spiracles

**EACH LEG**
- Coxa (A12)
- Femur (A5)
- Tibia (A16)
- Tarsus (A18)

**ABDOMEN** (3)
- 11 segments?
- 8 pr. spiracles (A14)
- Tympanic membrane (A7)
- Ovipositor (♀) (A9)

**WINGS**
- 1. Mesothoracic
- 2. Metathoracic
References (Textbook - pages 544-554, Lab Manual pages 184-193)

Major Characteristics

Classification

- Class Crustacea
- Class Insecta
- Class Chilopoda
- Class Diplopoda
- Class Arachnida
- Class Xiphosura

Class Crustacea

- Characteristics
- Anatomy and Physiology (The crayfish as representative example)

  Anatomy
  Digestive System
  Circulatory System
  Respiratory System
  Excretory System
  Nervous System
  Reproductive System
  Autotomy

Class Insecta

- Characteristics
- Classification
- Metamorphosis
- Anatomy and Physiology (The grasshopper as representative example)

  Anatomy
  Digestive System
  Circulatory System
  Respiratory System
  Excretory System
  Nervous System
  Reproductive System

- Social Insects