Introduction to Agricultural Entomology

Prof John H. Nderitu
Department of Plant Science &Crop Protection
Email: huria@uonbi.ac.ke
Tel: 2722308581

Course description

Biology of arthropod pests: morphology, and physiology of insects and mites, life history; introduction to insect classification; insect damage to crops; insect sampling techniques; insect population dynamics: ecology, surveillance and monitoring of insect in crop fields, economic threshold and crop loss assessment

Course topics

1. Insects
2. Economic importance of insects
3. External anatomy
4. Internal anatomy
5. Insect physiology
6. Life cycle
7. Insect ecology
8. Classification of insects and their relatives
9. Orders of insects
10. Sampling of insects
11. Major pests and damage on crops

Practical sessions

1. External structure of insects
2. Collection, preservation and identification of insects
3. Demonstration of types of insect traps
4. A field study of insect pests (2 sessions)

List of references

1. Ros, H.H., Toss, C. P. Rose , Rose J. R. A text book of entomology
2. Imms. Textbook of entomology Volume 1 and 2
3. Robert E. Pfadt. Fundamentals of applied entomology (Reserve collection)
4. Hill, D. Agricultural insect pests of the tropics and their control (Reserve collection)
5. Hill, D. and Waller. Pests and diseases of tropical crops Volume 1 and 2 (Researve collection)
6. Borror, D. An introduction to the study of insects (reserve collection)

What is entomology?

Entomology is the study of insects. Although entomology in the strict sense is the concerned solely with insects the practicing entomologist is expected to deal with related animals such as mites and spiders, slugs and snails where these are of economic Significance

Agricultural entomology: Practical importance of insects in agriculture. The aim of agricultural entomology is the manipulation of insects (both harmful and beneficial) to man's advantage. Successful manipulation of any insects depends on adequate biology and ecology

INSECTS

- Over 80% of all living organisms are insects
- About one million species of insects are known
- Terrestrial animals most adaptable to changing food and climatic conditions and to competition with other animals
- Insects are found in every conceivable habitat

Reasons for their success are :

- Ability to live and adapt to adverse habitats
- High reproductive capacity
- Ability to consume different kinds and quantities of food
- Ability to escape quickly from their enemies

Biological success of insects

1. Large numbers of species: there are more species of insects than all other animal species put together
2. Large number of individuals : Individual species often occur in vast numbers
3. Great variety of habitats: occur in great variety of habitats and are found almost everywhere that life can exist , other than the sea
4. Long geological history

Reasons for insects' success

1. Power of flight: This enables to colonize new sources of food also facilities rapid escape from unfavorable conditions
2. Adaptability: Insects have adapted to all environments capable of supporting life (other than marine) and also can utilize any organic material as food
3. Possession of external skeleton: an external skeleton provides a small animal with a valuable protective casing, provides a barrier against water loss
4. Small size: The advantage of low food requirement per individual and ease of concealment
5. Rapid reproduction: Multiply rapidly due to short life cycles and many offspring per fame. They can quickly exploit food sources as they become available and have rapid evolutionary change (shown by development of pesticide resistance)

(Continue)

Insects are more important in the tropics than temperate regions because of:

- Rapid multiplication in the tropics
- Many pests and of importance per crop
- Vectors and pests account for a heavy financial human and livestock problem eg tsetse flies, mosquitoes, locusts and armyworms, termites
- Heavy losses of food due to pests > 30%
- Few agricultural entomologists

Economic importance of insects

Harmful effects:

- Insect pests of field and storage pests
- Vectors of plant pathogens
- Wood
- Fabrics and clothing

Beneficial effects :

1. Natural enemies of pest species: i.e parasites and predators
2. Pollinators of cultivated crops for effective crop production
3. Producers of useful products:

- Honey
- Beeswax
- Natural silk

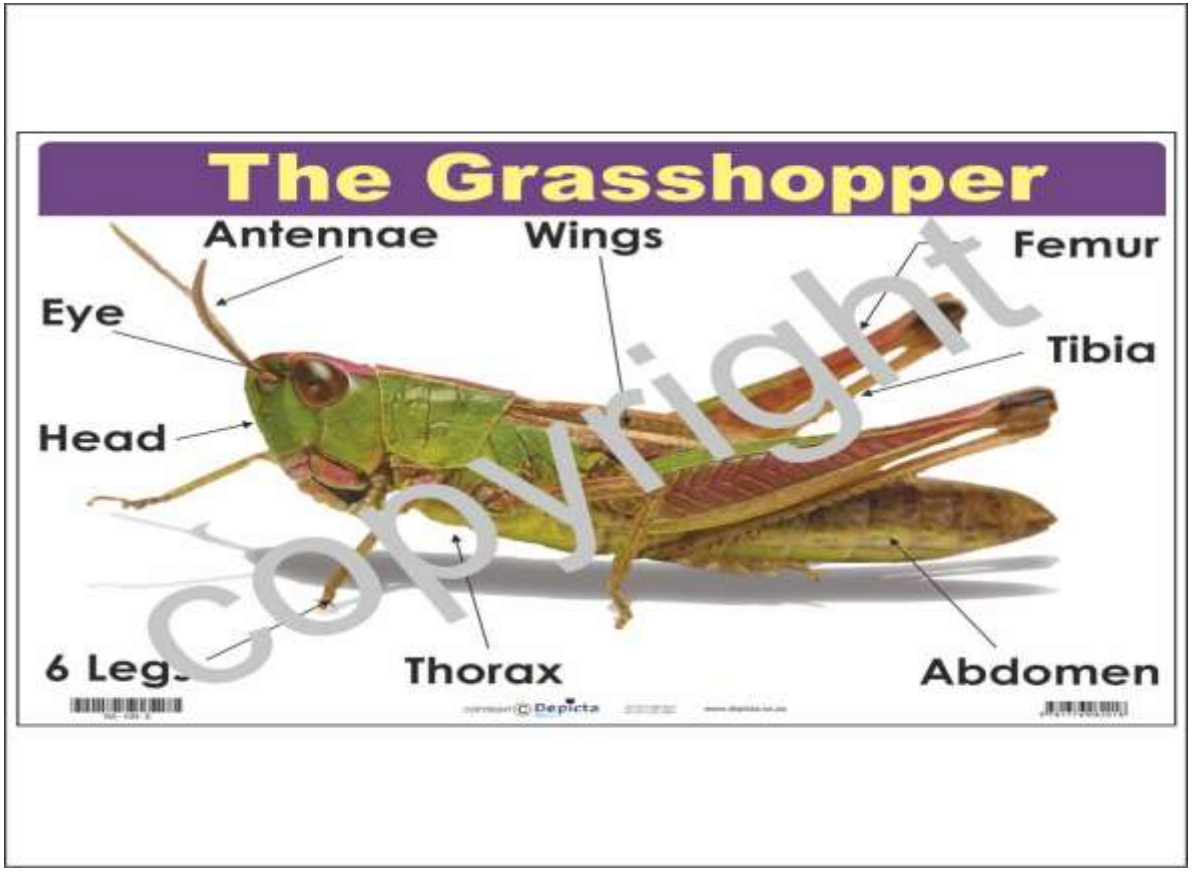
(Continue)

4. **Human food**: High fat and protein content eg termites, caterpillars, locusts, grasshoppers
5. **Subjects for scientific study** eg studies of fruit fly, Drosophila has contributed to the development of field of genetics, ideas of speciation and evolution theory> Other insects have contributed to the field of phylogeny, ecology, population dynamics , endocrinology, biochemistry, physiology and biogeography
6. **Recreational and aesthetic values**: Food for birds and other animals, pollinating plants, aesthetic value on their own right

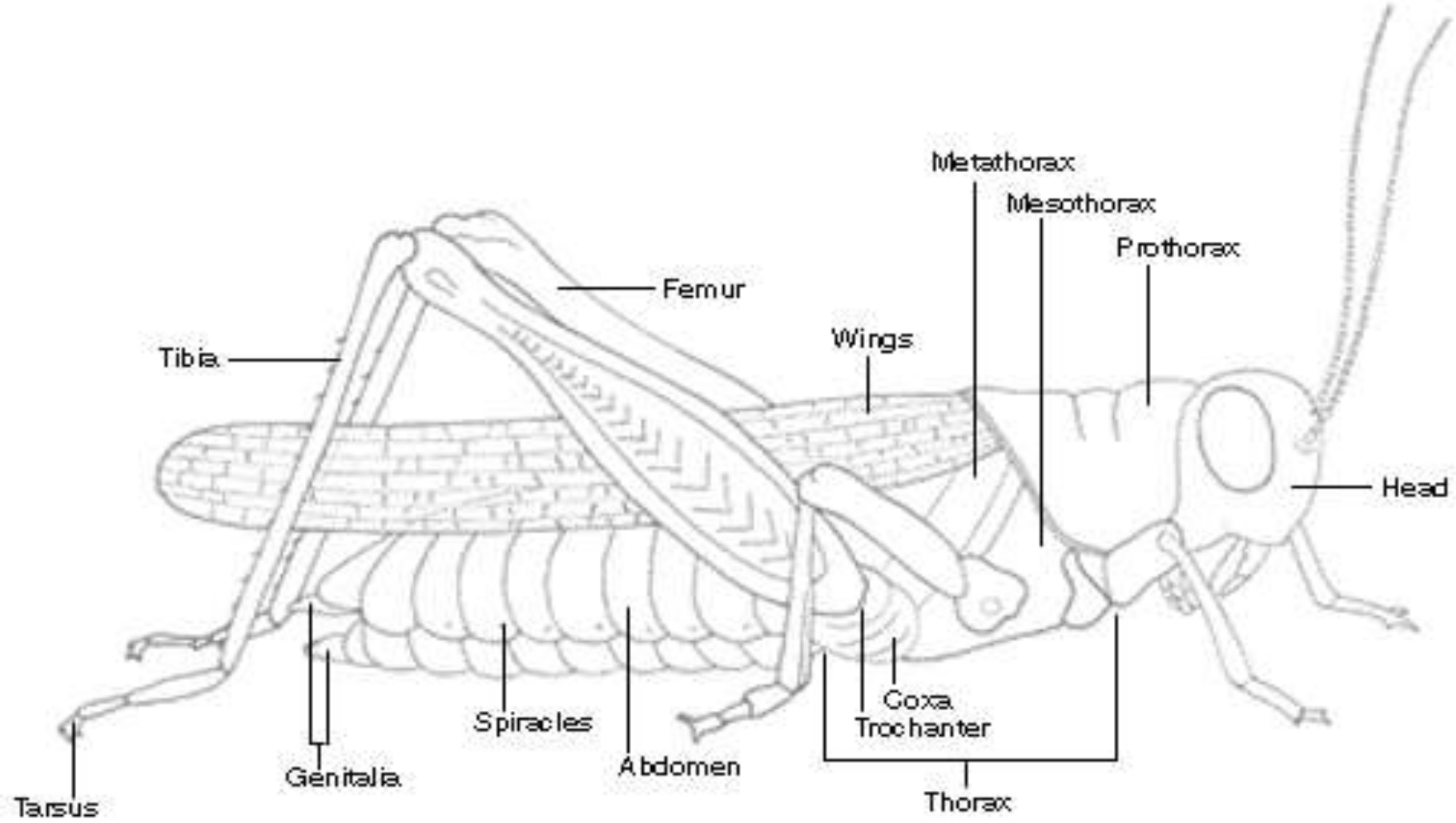
(Continue)

7. **Decomposers and nutrient recycling**: turnover of key elements in an ecosystem eg millipedes, termites, boring beetle larvae; direct feeding on plant materials, degradation and consumption of plant materials in water
8. Weed management : Control of water plants eg Salvinia by use of Salvinia beetle and use of a beetle water hyacinth

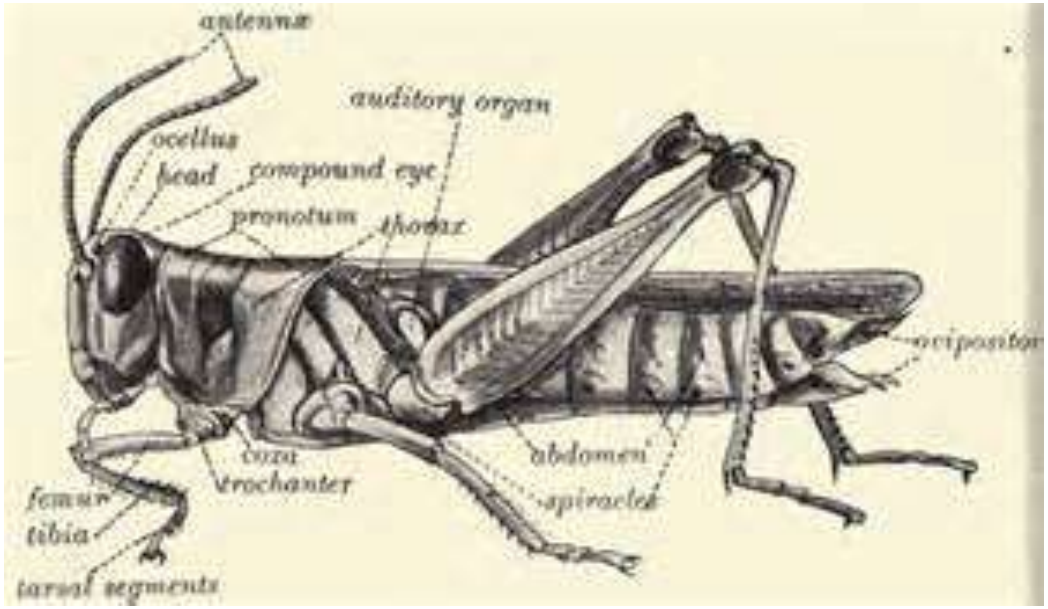
External structure of an insect



External structure



External features of a locust



External anatomy of an insect

Head: The anterior part of an insect body with eyes, antennae, and mouthparts.

Thorax: The body section after the head, with the legs and wings attached. There are three sections of the thorax: the prothorax, the mesothorax, and the metathorax.

Abdomen: The posterior section of the body containing the reproductive and digestive organs.

Spiracles: Breathing pores.

Coxa: The section of a leg that is attached to the body.

Trochanter: The second segment of a leg, between the coxa and the femur.

(Continue)

Femur: The third segment of a leg, between the trochanter and the tibia.

Tibia: The fourth segment of a leg, between the femur and the tarsus.

Tarsus: The leg segment after the tibia, often subdivided into several sections.

Genitalia: The sexual organs.

Wings: Outgrowths of the body wall that enable insects to fly. The first pair of wings is sometimes modified into a protective covering for the hind wings.

(Continue)

1. **Body wall and exoskeleton**: The body wall of insects secretes an exoskeleton that serves as a framework for internal attachment of muscles. The functions of the exoskeleton are:-

- Acts as a skeleton for bodily support
- Protective covering to the soft internal organs
- The waxy layer on the surface (cuticle) is highly impermeable to water which minimizes loss of water from the body

(Continue)

2. **The head:** A typical insect head consists of a pair of compound eyes, three ocelli, a pair of antennae and mouth parts

i. Compound eyes:- 2 large, many- faceted structures on the head

ii. Ocelli:- three faceted organs situated on the face and usually between the compound eyes. In some insects they are missing or not aparent

iii. Antennae:- a pair of movable segmented appendages that arise from the face, usually between the eyes. The antennae varies in shape in different insects

(Continue)

iv. Mouthparts: Comprises of the mandibles, maxillae and labium

v. Types of mouth parts: Insect mouthparts have become modified in various groups to perform the ingestion of different types of food and by different methods:-

i. Chewing type: Mabibles cut off and grind solid food. examples are coleoptera, grasshoppers and lepidoptera larvae

ii. Cutting –sponging type eg Diptera

iii. Sponging type :- take food which is either liquid or readily soluble in saliva. eg houseflies

iv. Chewing –lapping type: Type of mouthparts for taking up liquid food. bees, wasps

(Continue)

v. Piercing-sucking type: Mouth piece tissues and suck juices from them. Aphids, leafhoppers, scale insects, predators

vi. Siphoning type: Long Proboscis which sucks the nectar and other liquid food eg adult lepidoptera

Thorax: The thorax is the body region between the head and abdomen. It has three segments: prothorax, mesothorax and metathorax

(Continue)

Legs: The typical thoracic insect leg consists of the coxa, trochanter, femur, tibia, tarsus and pretarsus. Insects have simple legs designed for walking or running. However there are a number of modifications:-

i. Jumping types with greatly enlarged femora eg grasshoper
ii. Grasping types – armed with sharp opposing spurs and spines. E.g praying mantis
iii. Swimming types- having long brushes of hair and flattened parts eg water boatmen
iv. Digging types- with long, scraperlike parts e.g mole crickets

(Continue)

Wings: Wings are the most important reason for the success of the insect group as a whole. Flight is a characteristic of insects. Winged insects have two pairs of wings, the mesothorax and metathorax each bearing a pair. The prothorax is always wingless. Insect wings exhibit innumerable differences in venation that are of great value in the classification of orders, families and genera

Abdomen: Consists of 10 or 11 segments. The appendages in the abdomen are non-reproductive (Tergum, sternum, spiracles) and reproductive appendages (ovipositor, claspers)

Internal organ system

The main internal organ systems are :

1. Digestive system
2. Excretory system
3. Circulatory system
4. Tracheal system
5. Nervous system
6. Reproductive system

The nature of these systems in the insects is very much different from those of higher animals

Digestive system

- The digestive system is the food tract and its accessory parts. It is composed of the alimentary canal (digestive tract) and various glands connected with it either directly or indirectly (salivary glands, gastric caeca, salivary glands)
- The alimentary canal is divided into three parts:- foregut, midgut and hindgut
- Most digestion and absorption of food takes place in the midgut region
- Hindgut absorbs moisture from digested food

Draw and label a generalized structure of a insect digestive systems

Excretory system

Most insects possess a group of long, slender tubules branching From the alimentary canal near the junction of the midgut with the hindgut. These are the malpigian tubules which are for Excretion. The collect waste products from the body and discharge not the gut

Tracheal system (respiratory system)

- Insects breath by a system of air tubes (tracheae) which takes oxygen directly to body tissues from the outside
- The spiracles are the external openings of the system which lead into a network of air tubes (tracheae). They have an important control of air intake and have closing device
- Respiration of most insects is a passive process of diffusion

Draw and label a basic layout of the tracheal system of an insect

Circulatory system

- The circulatory system comprises chiefly the blood and tissues and organs which cause its circulatory through the body.
- The blood (hemolymph) flows through the body cavity, irrigating the various tissues and organs (open system)
- The pumping organ or heart is situated dorsally in the insect body and it pumps the blood from the posterior portion of the body and empties it into the internal cavity of the head. It is pumped forward and back

Draw and label a basic layout of the circulatory system of an insect

Nervous system

- The basic layout of the central nervous system consists of a double nerve cord running the ventral (lower) side of the insect close to the body wall
- There is a swelling (ganglion) in each segment from which branches arise to adjacent parts of the body
- In the head region three ganglia are fused together to form a large nerve mass immediately below the esophagus (sub-esophageal ganglion)
- In the upper part of head (brain) three ganglia make up another large nerve mass

Draw the basic layout of the central nervous system of an insect

Reproductive system

- Normally only one sex is represented in any one individual. A few rare instances are know of hermaphroditic insects eg cottony-cushion scale
- The female system consists of: i) a group of ovarioles in which the eggs are produced; ii) a spermatheca in which sperms are stored, and iii) a duct arrangement through the eggs are discharged outside the body. Insects will produce large numbers of eggs per female
- In general the male system is similar to the female. It consists primarily of testes, associated ducts and sperm reservoirs and outlets to the outside world
- Draw a generalized female and male reproductive system of an insect

INSECT PHYSIOLOGY

1. Body wall
2. Digestion and nutrition
3. Respiration
4. Blood and circulation
5. Excretion
6. The senses
7. Reproduction
8. Locomotion
9. Flight
10. Coordination: Nervous system and endocrine system
11. Insect behavior

Insect physiology

An understanding of insect physiology is essential to an understanding of how these insects live, and how they can be controlled . The major peculiarities of insect physiology from other animals have to do with the possession of an exoskeleton, which affects the way the grow and the way they carry on various physiological processes

1. **Body wall**: The body of an insect has three major functions: i) protection, ii) reception of external stimuli, iii) service as an exoskeleton

(Continue)

ii. **Digestion and nutrition**: Insects feed on a great variety of living , dead and decomposing animals and plants, on plants and plant products, on blood or plant juices. The food habits may vary greatly in a given order: larvae and adults usually have entirely different food habits and different types of digestive systems. The nutritional requirements of insects include the same ten amino acids essential for man, a number of B vitamins , sterols, nucleic acid derivatives and several minerals. The water requirements are very different in different types of insects

(Continue)

iii. **Respiration**:

- Gas transport in insects is a function of the tracheal system: the circulatory system usually plays no significant role in this process
- In insects with a tracheal system (one having the spiracles functional) air enters the body through the spiracles, passes through the tracheae to the tracheoles, and oxygen ultimately enters the cells of the body by diffusion; carbon

  Dioxide leaves the body in a similar fashion
- In insects with a closed tracheal system, the gases enter and leave the body by diffusion through the body wall between the tracheae and the environments, and the movement of gases through the tracheal system is by diffusion

(Continue)

iv. **The blood and circulation:** The blood of insects has four known functions:-

- The blood or hemolymph of insects is the tissue fluid comprising body fluid that bathes the internal organs
- The blood effects the distribution of food products to the tissues and carries waste products from them
- The blood has also maintenance of the water and salt balance in the body
- The blood plays a role in molting (in enabling the insect to get out of the old xoskeleton0 and in the expansion of the wings after the last molt
- Blood is also important as a storage tissue (eg, for proteins and water during metarmorphosis)

(Continue)

V. **Excretion**:

- This is the process of removing waste products of metabolism eg excess water, salts, nitrogenous wastes such as uric acid and various undesirable organic compounds
- In insects the malphigian tubules are the chief organ of excretion
- The waste products pass from the tubules to the hindgut and out of the body through anus

(Continue)

vi. The senses:

- **Hearing**- the ability to detect sound (vibrations) in the substrate or the surrounding medium) is developed in many insects, and sound plays a role in many types of insects; and the sense of hearing is best developed in insects that produce sound
- Air bone sound is detected in many insects by means of sensory hairs
- The principal roles played by sound in insect behior are to alert the insect to an environmental condition, to enable it locate something in the environment, and to allow communication. Many insects respond to sound by reduced or increased activity

(Continue)

Vision: Visual organs or eyes occur in most insects and consists of aggregations of photoreceptive cells

- insects eyes are divided into simple eyes (ocelli) and compound eyes
- In adult insects the ocelli are simple eyes and the large eyes are compound eyes. Larvae have only simple eyes. Both eyes connect as a unit directly with the brain

(Continue)

VII. Reproduction: In insects reproduction is the function of the sexual reproductive system. Normally insect reproduction is bisexual, in that the egg produced by the female will not develop unless fertilized by spermatozoa produced by the male. Except in a few species, only one sex is represented in any individual. In most insect species, the physiology of reproduction deals with the development and maturation of spermatozoa in the male and of eggs or ova in the female

VIII. Oviposition: Insect eggs are laid singly or in batches and most insects lay more than one egg at a time. Many insects have their eggs enclosed in a n egg case or ootheca, which is se creted by the accessory glands

(Continue)

ix. Flight: The flight is a distinctive attribute of most insects

- Flight has been responsible for the success of the insects
- Flight is involved in an insect's search for food, a mate, oviposition sites, escape from an insect threatened by a predator
- Many insects have powers of flight that exceed those of all other flying animals

(Locomotion)

x. **Locomotion:** Insects are basically terrestrial animals, but many live in water and many are capable of flight

- Insects have developed effective mechanisms of locomotion on land, in water and in the air
- The basic equipment of insects for locomotion on land consists of the legs
- The legs may be used for creeping, walking, jumping or swimming

(Continue)

xi. Nervous system and endocrine system:

- The nervous system and endocrine system coordinate the activities of the various parts
- The nervous system is concerned principally with rapid adjustments to environmental change
- The endocrine system regulates slower and longer-lasting changes (growth, development)
- The functional units of the nervous system are the nerve cells, of which there are three principal types: sensory, internuncial, and motor
- The endocrine system consists of glands that produce hormones

(Continue)

- The endocrine system consists of glands that produce hormones.
- Hormones are chemical substances that are introduced into the blood which carries them to other parts of the body where they produce some effect on physiology
- Several organs in an insect are known to produce **hormones**
- The principal functions of hormones are to control reproductive processes, molting and metamorphosis
- **Pheromones** are substances that are secreted to the outside of the body, where they cause specific reactions by other individuals of the same species eg sex attractants, alarm substances, aggregation-promoting substances, territorial markers, trail substances

(Continue)

xii) Insect behavior

- Insects have evolved ways of responding to their environment that tend to insure their successful propagation
- Examples of behaviors: acoustic behavior, sound producing mechanisms, bioluminescence, social behavior

Life cycle of insects

- **The egg:** Insects develop from eggs, which are usually deposited by the female in sites favoring survival
- Bisexual reproduction occurs in most insects, mites and ticks, but there are exceptions
- Following fertilization, and when embryonic development is finished, various hatching mechanisms aid a new individual to emerge from the egg
- There is a wide variation in the external structures of insects at the time of hatching
- Molting and growth are controlled by hormones

(continue)

- Hormones causing molting (ecdysones) are produced by prothoracic glands
- Juvenile hormones maintains the immature form of an insect during early molts
- Upon hatching, insects grow by a series of molts, shedding the old cuticle and expanding into a new and larger one
- When the adult stage is reached, molting in most insects ceases
- This type of growth is called metamorphosis
- **Ametabola**: are insects which do not undergo metamorphosis
- **Paurometabola**: These insects undergo simple metamorphosis . There are relatively gradual change in external appearance in molting steps from egg to adult. The immature forms are called nymphs and have feeding habits similar to those of the adult

- **Holometabola** under complex metamorphosis: Great external and internal structural changes take place among insects. The have egg, larvae , pupa and adult

Insect ecology

- The most important environmental factors concerning the distribution and abundance of insects are weather, physical and chemical conditions of the medium, food, enemies and competition

1. **Weather** i.e light, temperature, relative humidity, precipitation and wind are the most important ecological components

- **Light:** Light is an important factor in insect behavior
- **Temperature:** In most insects their body temperature is within narrow limits the same as that of the surrounding medium . They are cold-blooded animals. Temperature has an effect on development and mortality

- **Precipitation**: Insects are indirectly affected by normal precipitation through the effect of precipitation on humidity, soil moisture, and plant food supply
- **Humidity**: In general humidity is important but not so critical a factor as is temperature, and that each species has an optimum, which may be different for various stages of the life cycle. Temperature and humidity have a marked effect on both general development and distribution of insect species

2. **Physical and chemical condition of the medium:**

- Three media are important: terrestrial (land and aerial) surface , subterranean (soil and sand), and aquatic

3. **Food :**

- Food is one of the most important factors influencing the distribution and abundance of insects

4. **Enemies** :

- Insects are attacked by internal parasites namely insects, parasitic worms, bacteria, viruses and fungi
- Predators: other insects, vertebrates (birds, fish, reptiles, bats, man)
- Insect protect against enemies by building protective structures; poisons, bites and stings; Noxious secretions; protective mimicry

4. **Competition:**

- Among insects competition is chiefly for food
- The competition is either individuals of the same species or individuals of different species

Methods of assessing insect pest populations

Various sampling techniques can be used to quantify pest population in the field:

List of methods of measuring insect populations:-

1. Crop inspection
2. Shaking and beating
3. Knock down sampling
4. Bait sprays
5. Mite sampling
6. Sweep net catches
7. Malaise trap
8. Impaction traps
9. Water traps
10. Suction traps: i) mobile traps; ii)fixed traps

(Continue)

11. Light traps
12. Pheromone traps
13. Soil samplers
14. Sticky Traps
15. Pitfall traps
16. Phenological monitoring

1. check images of the traps in the internet
2. Term paper: write a concise summary of advantages and disadvantages of each of these sampling techniques

- Why is sampling for pest and beneficial insects so important?
- Because it is of importance for farmers and pest managers to understand insect activity in their crops and fields before they can make cost-effective and environmentally sound pest management decisions.
- The main objectives of insect sampling (pest and beneficial) are to: Detect species that are present; Determine their population density; Determine how they are distributed in the field
- There are many different insect sampling techniques and sampling equipment that can be used to detect insects in the air, on plants, and even on and beneath soil