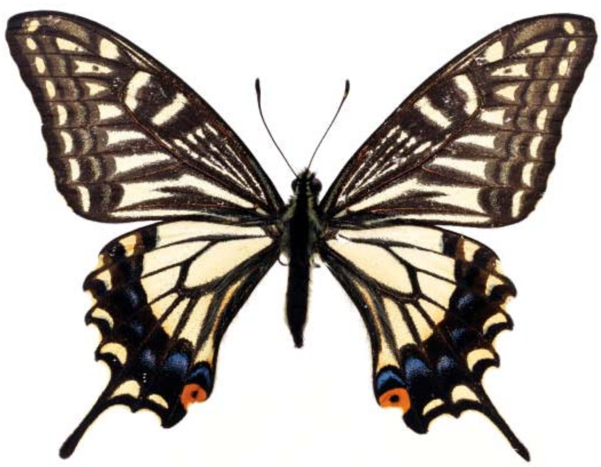
Bragina T. M.

INTRODUCTION TO ENTOMOLOGY PART 1:THE EXTERNAL STRUCTURE OF INSECTS

Textbook



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The textbook is devoted to the most diverse and numerous group of the animal world - insects.It provides theoretical data and practical recommendations for the study of the first part of the entomology course - the external structure of insects, tasks for testing and consolidating the knowledge gained. The textbook is intended for the assimilation of material on the discipline and improve the efficiency of independent work of students. There is also a glossary and dictionary of technical terms and names of animals and certain taxa.

The textbook intended for students and teachers of universities and, other educational organizations.

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TABLE OF CONTENTS

INTRODUCTION

General Entomology studies the main features of insects – the structure of their bodies, the lifestyles, the diversity of forms and the relationship with the environment. In accordance with this, general entomology can be divided into morphology (with its division into external morphology, and internal morphology – anatomy), physiology, biology (in the narrow sense of the word), systematics and classification, and ecology of insects.

The textbook on the discipline "Introduction to Entomology" is a tool of theoretical and applied nature. It includes both theoretical materials and practical recommendations for the formation of students' skills and abilities to apply acquired knowledge of the discipline.

The textbook includes methodological development of practical works, and their titles can be used as the titles of seminars in accordance with the programs of different courses when studying this discipline. The above materials serve to consolidate and deepen the knowledge gained by students during lectures, they provide the basis for the formation of the scientific worldview, the mastery of the experimental skills and methods of conducting experiments.

The textbookincludes the drawings and other illustrative material with links to published sources.

A special feature of the use of the textbook is its theoretical and practical orientation, corresponding to the main goal of the discipline "Introduction to Entomology" on study insects as the most diverse and numerous animals of the world. The workshop presents the main studied objects in universities and secondary schools, as well as recommendations on the use of collections and the animal preparations of the collections of the region.

The textbook offers a glossary of specific terms along with explanations of their meanings, in English as well as in Russian. Recommendations for the assimilation of the material and its study are also set out in the preface to the topics. The textbook is divided into educational sections in accordance with the systematics of the studied groups of insects.

The textbook provides the necessary theoretical material and recommendations on how to train students to consolidate the material. The textbook encourages the use of effective methods of active learning, including practical problem-based communicative, intensive training and modeling with using the collection material, specimens and information and communication technologies.

The textbook reviews the history of Entomology and external structure of insects using different printed and electronic resources named in the List of References. This is the first part of the planning textbooks for the course “Introduction to Entomology”.

Some illustrations in the tables are used from internet-resource “General Entomology” (source: https://projects.ncsu.edu/cals/course/ent425 library/tutorials/).

The publications used to write this textbook and recommended literature are given in the List of references.

SUMMARY OF THE COURSE

The aimof the courseis to obtain knowledge in the professional biology teacher training at bachelor´s level on the diversity of insects, the features of their origin, development, the current status in the animal world, the role in the biosphere and human life.

Course Objectives:

- to appreciate the value and importance of insects;
- to obtain the knowledge about the external structure and anatomy of insects;
- to learn about the classification, diversity, biology, ecology, behavior, and characteristic features of the structure of the main insect orders;
- to study vital processes, peculiarities of reproduction and ontogeny of the main groups of insects;
- to study of the distribution and significance of the main representatives of the most important orders of insects;
- to obtain practical skills in recognition of the basic orders of insects, and the ability to apply these skills in professional activities;
- to acquire skills for collecting and preserving insects.

Forming competences

- obtaining systematic knowledge in the field of entomology;
- studying features of morphology and vital activity of insects;
- studying insect taxonomy;
- the ability to apply the acquired knowledge in professional work.

As a result of studying this discipline, students ***should know***:

- the entomology as a science and history of Entomology;
- the external structure of insects, their mouthparts, legs, wings etc.;

- the internal structure and features of vital activity, metamorphosis, lifestyles;

- the classification of insects to explain which order an insect belongs to, the main characteristics of major insect orders;

- a variety of insects and basic methods of entomological research;

- phylogeny of insects.

Students will be able to...

- explain the importance of insects;

- describe basic insect structure and functions, compare the morphophysiological features of different systematic groups of insects;

- work with the determinants of insects;

- work with preparations and collections, determinants, schemes of the structure of insects to determine their systematic position;

- conduct observations of insects in natural and laboratory conditions by modern methods of researches;

- acquire new knowledge, using modern information technology education;

- ***develop such skills as****:*

- observation, description, and identification of insects, their preparation, work with drugs, collections, animal structure schemes.

The study of the course involves the following types of classes: lectures, practical, SRSP, CDS.

Pre-requisites: Zoology of invertebrates, general ecology, cytology

Post-requisites: Physiology of animals, histology, the biology of individual development and comparative embryology, comparative anatomy, ecology, ethology, zoogeography, biophysics, evolutionary theory, and others, evolutionary teaching.

The topics of lectures deal with the above mentioned issues. For each lecture, there are checklists – questions to serve for students´self-check. To get answers to these questions, mandatory work with literature is required.

THEMATIC PLAN OF THE COURSE

THE HISTORY OF ENTOMOLOGY. EXTERNAL STRUCTURE OF INSECTS

1. The subject and objectives of Entomology. History of Entomology. Diversity of insects.
2. The body of insects, skin and its derivatives.
3. The head of an insect and its appendages. The thoracic part and itsstructure.
4. Types of legs of insects, a structure of wings.
5. The abdominal part of insects and its appendages.

INNER STRUCTURE AND DEVELOPMENT OF INSECTS. EVOLUTION OF INSECTS

6. Body cavity. Digestive and excretory systems. Respiratory and circulatory systems.
7. The structure of the nervous system, sense organs.
8. Reproductive system, reproduction and development. Life cycles, types of metamorphosis.
9. The origin and evolution of arthropods. Primitive insects.

CLASSIFICATION AND DIVERSITY OF INSECTS

10. Classification of insects. Basic units. Protura (proturans), Collembola (springtails), Diplurans (diplurans), Thysanura (silverfish, bristletails).
11. Infra-class Ancient-winged insects: Ephemeroptera (mayflies), Odonata (damselflies, dragonflies). Infraclass new-winged Suborder orthopteroid: Blattodea (cockroaches, Infraorder: Isoptera – termites), Mantoidea (mantises), Orthoptera.
12. Suborder Hemiptera (Suborder Coleorrhyncha -beetle bugs or moss bugs; Suborder Auchenorrhyncha – cicadas, and leafhoppers; Suborder Heteroptera – true bugs; Suborder Sternorrhyncha, Order Homoptera – whiteflies, aphids, scale insects; Thrips.
13. Suborder Coleopteroides (Carabidae, Scarabaeidae, Tenebrionidae, Chrysomelidae, Coccinellidae, and others). Suborder Neuropteroides. Lacewings, Raphidioptera.
14. Suborder Mecopteroid: Caddisflies, Butterflies. Hymenoptera, Diptera.
15. Life forms. Environmental groups of insects.

1 ENTOMOLOGY AS A SCIENCE. IMPORTANCE OF INSECTS

1. Entomology as a science.
2. Subject of Entomology.
3. Entomology sections.
4. Importance of insects.

Entomology as a science is a branch of zoology.It studies insects and their interactions with other species,humans and environment.

Earlier (until the middle of the 19 century), all arthropods (Arthropoda) were the object of study for entomology. Later, only insectshave become the object of Entomology. By the number of species, insects predominate over all animals.

Insects body is divided into threeparts (tagmas): head, thorax and abdomen;one pair of antennae and compound eyes on the head; three pairs of jointed legs;one or two pairs of wings.They have a chitinous exoskeleton.

Entomology has three branches – General Entomology, Private Entomology and Applied Entomology.

General Entomology studies the main features of structure, development, and evolution of insects.It includes morphology, anatomy, physiology, systematics, zoogeography, ecology (relationships with the environment), genetics, paleontology, and phylogeny of insects.General entomology is a theoretical basic scientific discipline for the private and applied entomologies.It is of the great importance for the knowledge of the laws of nature in applied entomology and for using the discovered principles in engineering and bionics (the science of using the principles of operation of various organs of animals and plants in the industries).

Private entomology considers separate systematic groups of insects, for example, Lepidopterology – Order of Lepidoptera (butterflyes), Order of Diptera (dipterans), and Coleopterology – Order of Coleoptera (beetles).

Applied entomology studies insects of practical importance and includes medical, agricultural, forest, and veterinary entomology.

*Agricultural entomology*studies insects as pests of agricultural crops and develops methods to combat them, and also studies domestic and other useful insects for humans,such as pollinators of plants, and insects of practical importance (bees etc.).

Forest entomology studies the most importantinsects for forests and bushes and their harmfulness. Studing the life styles of such insects we could to develope the effective methods to combat them.

*Medical and veterinary entomology*deals with insects dangerous for life of people and domestic animals.

There are some subspecialties which named below: Apiology (or melittology) studies bees, Coleopterology studies beetles, Dipterology studies flies, Hemipterology studies true bugs, Lepidopterology studies butterflies and moths, Myrmecology studies ants, Odonatology studies dragonflies, Orthopterology studies locusta, grasshoppers, crickets, etc., Vespology studies wasps.

Insects have animportant role in nature and human life. In nature ecosystems, they regulate the population densities of many species, including potential pests; play a vital role in the biogeochemical cycling of nutrients (as scavengers, consumers, and decomposers). They dispose of wastes and dead organisms and recycle organic nutrients. Insects redistribute nutrients within the soil, help aerate and retention of rainwater. Flies and dung beetles decompose the manure from large animals and support a clean environment. The decomposition speed by insects is more effective than bybacteria and fungi.

A number of animals feed on insects (invertebrate species, fish, amphibians, reptiles, birds, mammals) – they are considered an important element of the food pyramids.

Some species of insects are parasites and predators of other organisms.

From another point of view, insectshave a great role as pollinators of flowering plants.These plants (angiosperms) cannot reproduce without insectswhich carry pollen (the male gametophyte) from flower to flower, and it is a clear example of a close symbiotic relationship and co-evolution.

For a long time, human population have used some insect species and their products and even keep them as domesticated animals.

Since ancient times**,** honey bees (*Apis mellifera*) have been valued for the **honey** and **beeswax** they produce as well as propolis and other products.

Another of the wideknown domesticated species is silkworm (*Bombyx mori*). These insects produce a natural fiber – the **silk** thread used to make silk cloth and other things.

In some tropical countries, a tiny scale insect (*Laccifer lacca*) produce a lac, a sticky resin (the ingredient of commercial **shellac**). This insect grows on soapberry and acacia tree in India and Burma. Shellac used as a protective coating for furniture, floors, photographs, etc.

Another useful insect is *Dactylopius coccus* (a scale insect). It lives on prickly pear cacti in Central America and Mexico. People use **cochi-neal** as a scarlet pigment extracted from these insects. In the 17th century, this pigment became a staple of trade with Europe for itsintensity and permanence color.

Many valuable products are produced by other insects: the varnish chervets produce a wax-like substance used in electrical engineering; caterpillars of an oak cocoon trimmer produce silk thread; carmine chervets produce red paint – carmine; blister beetles produce cantharidin, etc.

Some insects carry fungal bacteria, microbes, and other harmful microorganisms, and they are dangerous pathogens of various diseases. Some insects debug the larvae in food.

Other insects are the pests of agriculture and forestry, parasites of humans and animals, carriers of diseases. Many insects have a big direct impact on agricultural food production. They feed the leaves of crop plants, lives within the roots, sucking out plant juices. They spread plant pathogens. They destroy wooden materials, transmit diseases.

In nature, herbivorous insects feed on plants, and thereby regulate their plant growth, eating the main part. And parasitic and predatory insects are considered regulators of the number of representatives of animals, which they also feed on. Thus, insects are of great importance as consumers of animal and plant debris.

Questions for self-check:

1. What is Entomology?
2. What does entomology study apply?
3. What are the negative values of insects?
4. List domesticated insects.
5. Describe some negative rolesof insects in human life.

2 HISTORY OF ENTOMOLOGY. CLASS INSECTA IN THE SYSTEM OF ARTHROPODS

1. Development of Entomology during the antiquity period and middle ages.
2. The development of Entomology in the XVII – XVIII centuries.
3. The development of Entomology in the XVII – XVIII centuries.
4. The development of Entomology in the XIX century and up to modern times.
5. Class Insecta in the system of arthropods.

The very first people have their observation of animals, incuding insects and their life, so Entomology is rooted in cultures from ancient time.People have long been confronted with the harm caused by insects, from one side, and used beneficial insects in human life. In Assyrian cuneiform tablets and Egyptian papyrus of the 3rd millennium BC devastating locust attacks are mentioned; in ancient Chinese manuscripts of the same period, there are indications of the silkworm breeding and the control of insects, the pests of vegetable gardens. In the rock painting of bees were registered from approximately 13,000 B.C.E. Some images and jewelrywere founded about 1800 to 1700 B.C.E. with insect pictures (a painting of a Scarab beetle on a wall of Rameses IX tomb around 1000 B.C.E) or insect forms (for examples, two golden bees with a drop of honey from Crete). Some Roman writers Virgil, Gaius Julius Hyginus, Varro, and Columella had discussionsabout Ancient Egyptian beekeeping.

Development of Entomology duringthe antiquity period and middle ages.The history of biology hasstartedin the Greek civilization with Aristotle's observations of the natural world, especially animals. Aristotle (384 – 322 B.C.) is founder of Zoology, his classification of species was the greatest contribution to the biology development. His description and classification almost 500 species was the first known attempt to animals into groups and species according to their construction, the similarities and differences between their physiologies. Aristotle wrote a number of tractates for zoology science: “The History of Animals”, “The Parts of Animals”, “The Movement of Animals” and others. He created a hierarchy of animals, where he arranged the species from simple to complex species with a man on the top.

In the 13th-century Albert Magnus studied Aristotle’s manuscripts and enlarged this knowledge about the animal world.

Fragmentary information about insects in various manuscripts has reached our days, but the first volume on the history of animals ("Historia animalium") was published in 1551 by Konrad Gesner. This date can be considered the beginning of the scientific study of animals, but there were only some references to insects.

The development of Entomology in the XVII – XVIII centuries. Only at the beginning of the 17th century were published works devoted to insects. Ulisse Aldrovandi’s “Animalibus insectis libri septem, cum singulorum iconibus AD vivum expressis”, published in 1602, was devoted to insects and other invertebrates.

Jan Goedart published “Metamorphosis and historia naturalis” between 1662 and 1667 with images of the metamorphosis of insects.

The use of a microscope made it possible to study in detail the reproductive organs of insects and the transformations of insects during metamorphosis. These data were summarized and published in 1669 by Jan Swammerdam in “History of Insects”.

Marcello Malpighi studied the silkworm and published the description of its anatomy and the development in 1669. It was a very detailed description of this species.

A number of detailed investigations of insects Anton van Leeuwenhoek (1632 – 1723) did with using the microscope. He studied some specialized organs and the morphology of insects. He used insects as a convenient object of scientific study.

In the 18th century, interest in insects was attracted by the wonderful aesthetic illustrations, e.g.the detail colorful images of the metamorphosis of exotic Surinam butterflies and moths and description of the full life cycle of them.prepared by Maria von Merian (Metamorphosis Insectorum Surinamenis – “Transformations of the insects of Surinam,” 1705).

In the 18th century, there was great interest in the description and systematics of insects. John Ray published in 1710 a work on the systematic classification of insects "Historia insectorum", which attracted the attention of the scientific world.

In 1758, the fundamental work “Systema Naturae” was prepared and published by Carolus Linnaeus (1707 – 1778) who introduced the binominal nomenclature in Latin as a universal mechanism and means for understanding scientific descriptions of species.He personally described and gave names to a huge number of plant and animal species, including insects.

In the same period, descriptions of the insect fauna of vast territories appeared, including the fauna of Sweden (Carolus Linnaeus, 1746, 1761), some data about entomofauna of Russia (P.S. Pallas, 1771–1776), Italy (P. Rossi, 1790), Austria (F. Shrank, 1781), Great

Britain (Moses Harris book “The Aurelian or Natural History of English Insects, namely Moths and Butterflies”, 1976), American insects fauna (J.R. Forster., 1771), world lepidopterans (J. Hübner, 1761–1826).

In the 18th century, significant work was carried out in the field of the physiology of insects, the biology of their development. Important labor was published such as the “Book of Nature” (“Biblia Naturae” by Jan Swammerdam, 1737) and “Memoires pour Servir a L’Historie des Insectes” (René Antoine Ferchault de Reaumur).

The development of Entomology in the XIX century and up to modern times.In the early 19th century, the biological sciences were booming. The "System of invertebrate animals or general table of classes, orders and genera of these animals" ("Système des Animaux sans Vertèbres ou Tableau Généraldes Classes des Ordres et des Genres de ces Animaux") by Jean Baptiste Pierre Antoine de Monet de Lamarck was published in 1801.

In the field of morphology and taxonomy of insects, Johann Christian Fabricius worked and published a series of important works in 1801.

The first professor of entomology in the world was Pietro Rossi as a professor in Pisa.

The most significant work in the field of entomology in the 19th century was the book of William Kirby and William Spens “Introduction to Entomology or Elements of the Natural History of Insects”, which was prepared from 1815 to 1826 and published in four volumes in London. This work has become an outstanding contribution to the science and study of insects. ***William Kirby***was recognized in the scientific world as ***the father of entomology***.

The **first Entomological Society in the world** was founded **in 1832 in France by Pierre André Latreille.**

In **1833** the Royal Entomological Society was founded in London with help from **William Kirby**and **Jean Guillaume Audinet Serville**(in the 1740s the Aurelian society was established on the basis of which some scientific societies of Great Britain were created), but earlier the Entomological Club was established in 1826 in London.

The **Russian Entomological Society** was founded **in 1859** by Karl Ernst von Baer, Johann Friedrich von Brandt **in St. Petersburg** (Appendix A).

The **American Entomological Society** was established in **1867** (it was renamed from the Entomological Society of Philadelphia which was established in 1859).

The greatest achievement in biological science of the 19th century was the work of Charles Darwin "On the origin of species", which substantiated evolutionary theory. This theory explained how life evolved in the past and is currently evolving on the planet.

From the 19th century to the present, entomology has developed rapidly. In addition to scientific interest, it is in demand in the system of control over the harvest of crops, the production of silk, honey, forest resources, protection from dangerous diseases and in other spheres of human activity.

Among the outstanding researchers – entomologists we can name Jean-Henri Fabre, Karl von Frisch, E. O. Wilson and some famous Russian scientists – V.F. Dogel, M.S Ghilyarov, G.Ya. Bey-Bienko, O.L. Kryzhanovskiy, G.S. Medvedev and many others.

Class Insecta in the system of arthropods.

The appearance of the first arthropods belongs to the Cambrian period of the Paleozoic era (about 600 million years ago). They inhabited the warm, shallow seas, dominated by bacteria and algae.

Insects make up a special superclass (Latin name Insecta; previously the name Hexapoda, i.e. six-legged) was also used in the type of arthropods (Phyllum Arthropoda), and they appeared about 480 million years ago (in the Ordovician).

Scientistsusually use the classification system created by Carolous Linneas – Kingdom, Phylum, Class, Order, Family, Genus, Species as the actual groups of the modern classification system, or eight levels of classification: Domain, Kingdom, Phylum, Class, Order, Family, Genus, Species.

Insects are in the Subphylum Tracheata as the insect respiratory system is the tracheal system.

Dominion Eukaryota Moore, 1974 – Доминион Эукариоты
Kingdom Animalia – Царство Животные
SubkingdomEumetazoa – Подцарство Настоящие многоклеточные
Section Triploblastica
Subsection Prostomia
Bilateria – Двусторонне-симметричные
Group Coelomata – Целомические
Ecdysozoa Aguinaldo et al., 1997 – Экзувиальные (линяющие)
Phylum Тип Arthropoda – Членистоногие
Subphylum Tracheata (= Antennata) – Трахейнодышащие
Superclassis Hexapoda Latreille, 1825 – Шестиногие
Classis Insecta Linnaeus, 1758 – Класс Насекомые
(Ectognatha, насекомые, открыточелюстные)
Subclassis Apterygota (wingless insects) – Подкласс Низшие,
или первичнобескрылые
Infraclassis Entognatha (hidden-jaw) – Инфракласс Энтогнатные
Infraclassis Thysanura – Инфракласс Щетинохвостки (тизануровые)

Subclass Pterygota (winged insects), or Ectognatha(higher insects, or open-jaw) – Подкласс Высшие, или крылатые, или эктогнатные

All insects have a general appearance: exoskeleton (a hard outer covering) that is non-living; it must be shed periodically. Theyhave body with three sections (tagma) – head, thorax, and segmented abdomen; one pair of antennae and pair of compound eyes; mouthparts perfected for licking, piercing, crushing, or sucking; 6 jointed legs (3 pairs) all found on the thoraxand one or two pairs of wings.

Phylogenetically, insects are closest to the classes of millipedes (Myriapoda) and crustaceans (Crustacea).

Questions for self-check:

1. Where was the first entomological society organized?
2. When did the scientific study of insectsbegin?
3. Diversity and abundance of insects.
4. When was the Russian Entomological Society formed?
5. Who laid the foundations of the modern classification of higher insect groups?

3 DIVERSITY OF INSECTS

1. The appearance of insects.
2. Diversity of insects.
3. The reasons for the high diversity and abundance of insects.

Insects are the largest class of the Phylum Arthropoda, most diverse and abundant group of animals. They appeared about 480 million years ago (in the Ordovician). Scientific evidence shows that insects evolved from a group of crustaceans. About 400 million years ago (in the Devonian period) one lineage of insects evolved flight.

Scientists have identified and named over a million species of insect, but in total an estimated 6-10 million species. It is known that up to 7-7, 5 thousand new species are described annually.

One of the features of insects is the numerous varieties of their forms. Insects live in different habitats and may be found nearly everywhere.

There are some reasons for the high diversity of species and life forms of insects:

1) they have small body size;

2) they need minimal resources for their life and reproduction;

3) they have an exoskeleton which protects insects from physical and chemical exposure andsupportsmuscles, soft tissues;

4) they have wings – effective protection from predators, to find new habitats and food resources;

5) can live in various forms – they are found in every environment;

6) they have reproduction success – they often produce large numbers of eggs (sometimes numbers in the thousands). For example,

the queen of an African termite lives 20 - 25 year and may produce of more than 10 million eggs;

7) they have relatively short life cycle (often 2 - 4 weeks);

8) they develop with metamorphosis – from immatures (larva) to adults, and immatures and adults often consume different food, use different environmental resources, and different habitats.

9) insects adapt quickly in the changing environment with their genetic resources. Populations of insects must continually change as new resources appear and old ones disappear. From the last century, pest populations of insects have rapidly developed resistance to chemical and biological insecticides.

Questions for self-check:

1. When did insects appear?
2. Why are the insects the predominant group of terrestrial invertebrates?
3. Who founded the modern system of nomenclature?
4. What is the diversity of insect species?
5. What is the importance of short life cycle of insects?

4 INSECT’S BODY SEGMENTATION. SKELETON AND MUSCULAR SYSTEM

1. Parts (tagmata) of the body of insects.
2. Sceleton and general principles of its construction.
3. Muscular system.

Insects have segmented bodies. The segments of the body of insect are organized into three parts **(tagmata) –** head, thorax, and abdomen (Figure 1).

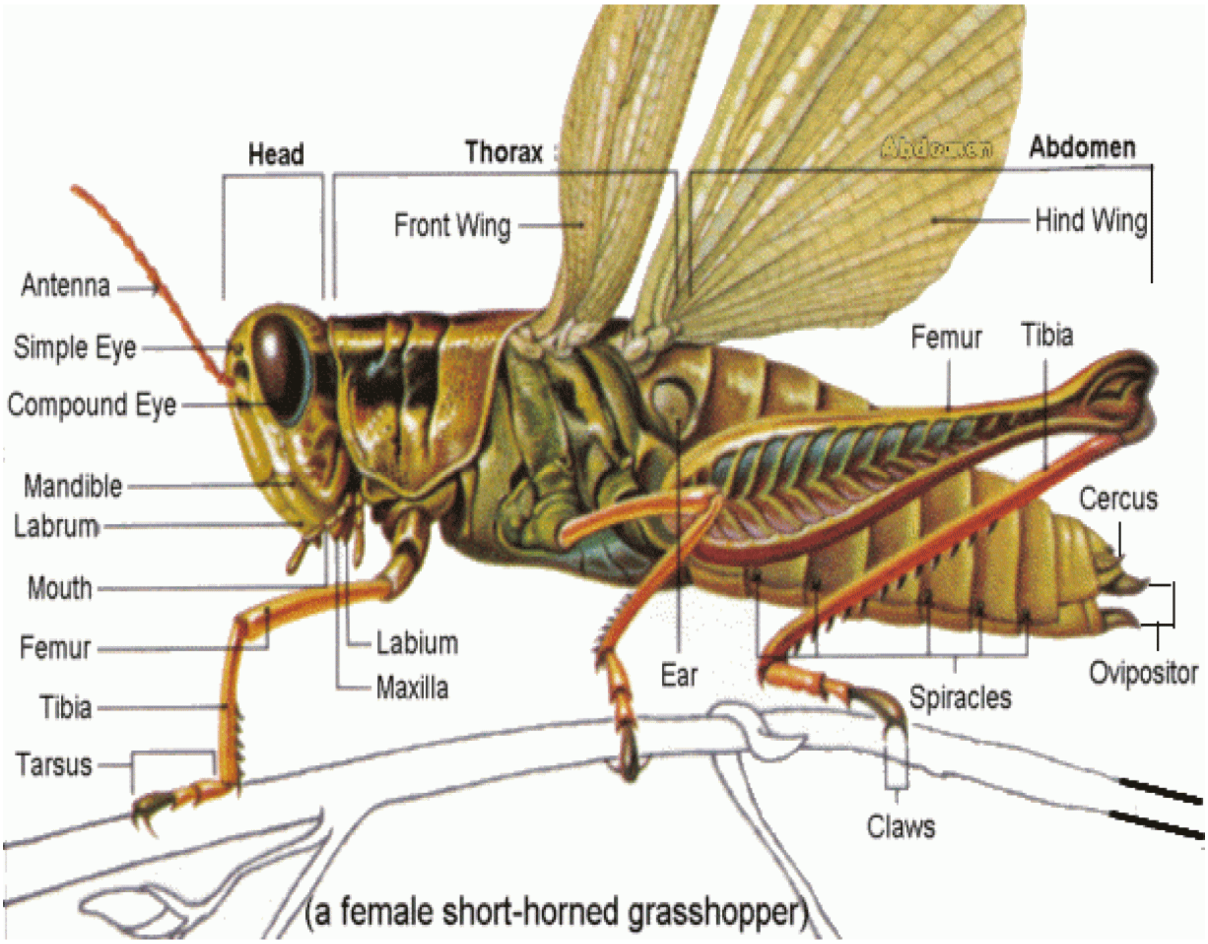


Figure 1. Insect body parts
(source:https://i.pinimg.com/originals/35/f8/18/35f818de621fc27f68d7d4e16a541140.gif)
Рисунок 1. Части тела насекомого

The role of heads of insects is orientation, ingestion food and sensory. On the head of an imago of insects, there are two sensory antennae, two compound eyes, and, usually, one to three ocelli (simple eyes) and mouthparts.A hard outer coveringof the head of an insect is heavily sclerotized and unsegmented, – it is withouta distinguishable border between the segments.The exoskeletal head capsule named **epicranium**.

The second part of the body is thorax. Itsupports six segmented (jointed) legs and wings and specializes for locomotion. The first pair of legs is on the first segment of the thorax – prothorax. The second segment of the thorax – mesothorax has the second pair of legs and first pair of wings (forewings). The third segment of the thorax (metathorax) has the third pairof legs and second pair of wings. The second and third segments of the thorax with wings named **pterothorax**. In winged forms, on the thorax, there is sclerotized inner fold of the cuticle named **fragma**. It penetrates deep into the body as an internal plate (invagination of the dorsal wall) for the attachment of muscles.

The **abdomen** of insects consists of eleven segments in most orders but in many others the number of segments is reduced, and only six or seven segments are visible. In the adult form of insects, the abdomen has not any legs. Each segment of the abdomen consists of two semiring – **tergite** (upper) and **sternite** (lower), between them there is a thin elastic **pleural membrane**.

Sceleton of insects

Insects have an external skeleton or exoskeleton (hard outer covering) made mostly of chitin (a polysaccharide that binds with various protein molecules to form a body wall). Chitin exosceleton may be flexible and elastic or hard and rigid. An insect's skeleton provides protection from any chemical and other attacks and minimizes the loss of fluids and water. Exosceleton gives shape and serve as a mechanical structure to muscles. Above skin layers exockeleton covers by an impervious layer of wax that prevents desiccation. Some freedom of movement is ensured by membranes and joints in the exoskeleton.

The **endoskeleton** (an internal frame of the body) has internal outgrowths of the cuticle to attach muscles and support some internal organs. The elements of an endoskeleton are called apodemes.

The most developed endoskeleton is in the head and thorax. It ensures the strength of them for reliable fixation of the mouthparts and wings. The endoskeleton of the head of insects is called the **tentory.**

Musculoskeletal system

All skeletal muscles attach to the inner surface of the integument. Muscles that attach directly to the body wall combine maximum strength with optimal mechanical advantage (leverage) (for example, an ant can lift up to fifty times its own body weight).

In total insects have more muscles than vertebrates for a larger surface area of an exoskeleton for muscle attachment than an endoskeleton.

Questions for self-check:

1. Explain the terms of "tagma", "fragma".
2. Explain the term “exoskeleton”.
3. Segmentation of an abdomen of insects.
4. What is “tentory”?

5 SKIN (INTEGUMENT) OF INSECTS.APPENDAGES AND DERIVATIVES OF THE SKIN. SKIN GLANDS OF INSECTS

1. Integument (scin) of insects.
2. Cuticle formation and its sclerotization.
3. The colour of the covers.
4. Appendages and derivatives of the skin.
5. Types of sensilla.
6. Classification of skin glands, their main types.

The insect outer skeleton is named as an exoskeleton (integument) or the cuticle. The exoskeleton (integument) is a protective covering over the body, a water-tight barrier against desiccation, a surface for muscle attachment, and it has a lot of sensory organs.

Exosceleton consists of two layers and **epidermis** (Figure 2). The surface layer is called the **epicuticle**, the layer under it called the **procuticle**.

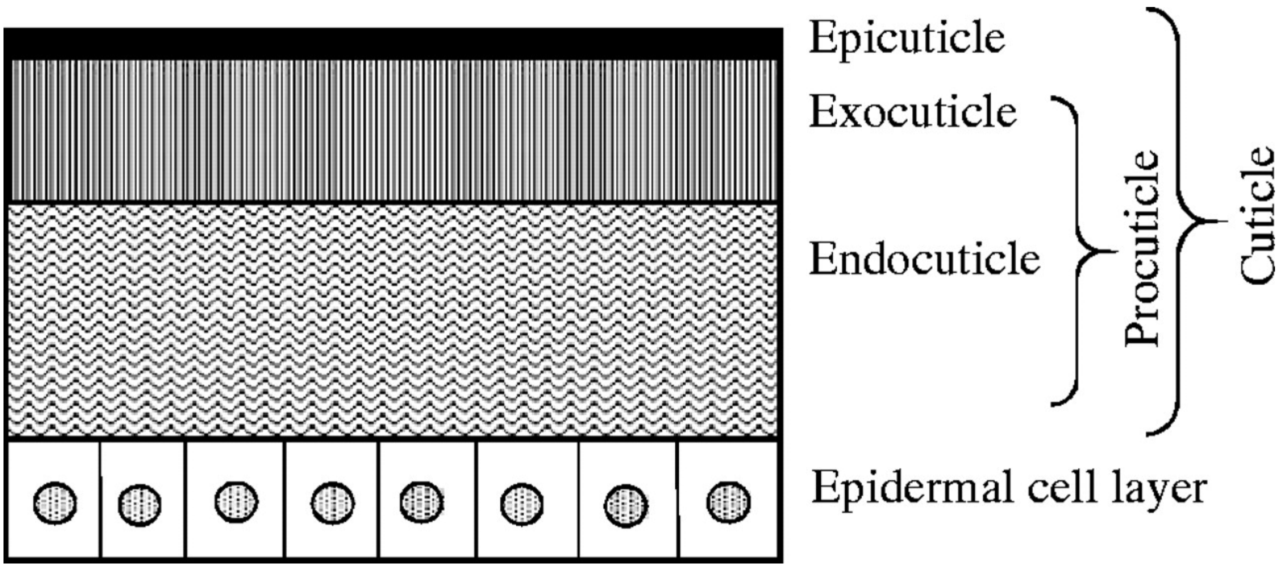


Figure 2. Skin (integument) of insects
(source: http://d3e3jwjal5zk9x.cloudfront.net/content/jexbio/209/4/722/F1.large.jpg)
Рисунок 2. Кожа (интегумент) насекомых

The **epicuticle** is a thin, waxy, water-resistant outer layer without chitin. It reduces water loss and blocks the invasion of matter from outside.The innermost layer of epicuticle is called the ***cuticulin layer***. It composed of lipoproteins and chains of fatty acids embedded in a protein-polyphenol complex. Above the cuticulin layer, a ***layer of wax*** molecules lies as the barrier to movement of water into or out of the body. Some insects have ***a cement layer*** above the wax layer which protects it from abrasion.

The chitinous thick **procuticle** lies between epicuticle and the epidermis. Procuticle composes of thin lamellae with chitin microfibers which oriented at a different angle in each subsequent layer. Procuticula has numerous fine pore channels. They stretch from each cell of the hypodermis to the epicuticle and include processes of plasma cells. For 1 $mm^2$of skin they account for about 15 thousand to 1200 thousand and more. Substances from the hypodermis to the epicuticle and procutikule enter through these channels.

In some parts of the body of insects, procuticle divides into two layers – the outer hard ***exocuticle*** and the inner ***endocuticle***. The endocuticle consists of microfibers of chitin surrounded by a protein.

The **epidermis** consists of a single layer of epithelial cells. It produces all layers of cuticle and part of the basement membrane.

Under the epidermis is the **basement membrane**which separates the insect's body cavity (hemocoel) from the scin (integument). The basement membrane consists of ***basal lamina*** from mucopolysaccharides and ***reticular layer*** from collagen fibers. It is very thin and does not have a cellular structure.

The colour of the covers

Body colour in insects is diverse, and can be two types – pigment, or chemical, and structural, or physical. The coloring substance may be located in the cuticle, in the hypodermis, or in the blood and fat body.

The integument colours are produced by pigment molecules of the cuticle (the pterines, melanins, carotenoids, and mesobiliverdin), or by physical effects of the skin (scattering, interference, or diffraction of light).

Cuticular colouring is stable and practically does not change after the death of the insect, due to the fact that the cuticle itself almost does not change; and, conversely, the hypodermal coloration changes very much posthumously due to the decomposition of the hypodermis.

The colour of insects can change under the influence of daily and seasonal changes in the environment, behavioral reactions, hormonal influence.

Often, the actual colour of the insect is combined, that is, the result of a combination of pigment and structural coloration.

Appendages and derivatives of the skin. Types of sensilla

The appendages of the scin of insects are diverse. They divided into **sculptural** and **structural**.

Sculptural appendages include those appendages that have no connection with the hypoderm. These include a variety of *depresses points and grooves on the cuticle, spines, tubercles.*

Structural formations have a connection with the hypoderm. These include *hairs, thorns, bristles, spikes,scales, and spurs.*

The hairs and bristles are most common and united under the name heta (**chaetae, or seta**) (Figure 3). They are secreted by trichogenic cells and its base by another specialized hypodermis cell. The chaetae become sensitive if the nerve cell comes to the base of the hair.

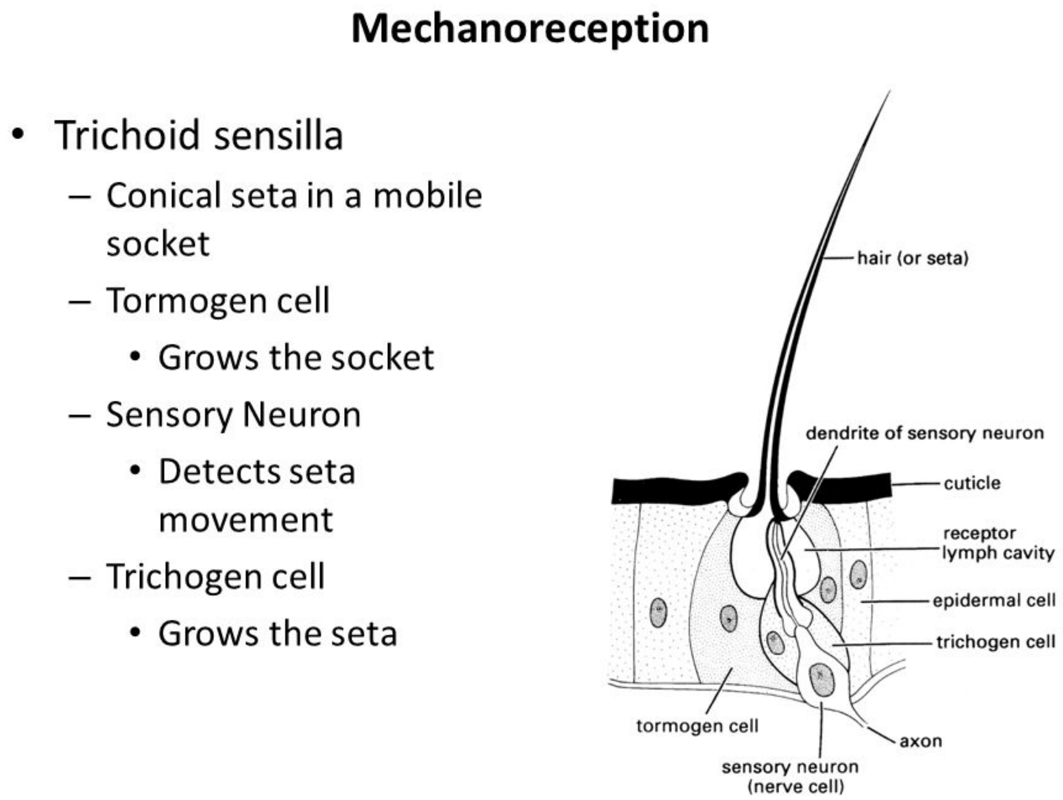


Figure 3. Chaetae or seta of insects for mechanoreception (source: http://slideplayer.com/slide/1738570/7/images/14/Mechanoreception+Trichoid+sensilla+Conical+seta+in+a+mobile+socket.jpg)
Рисунок 3. Волосок, или щетинка насекомых для механорецепции

Spines are multicellular appendages of the exoskeleton. They are called **spurs**, if movable. They contain of procuticle and epicuticle.

Sensilla are the basis of the sense organs.They are neuro-sensitive units consisting of two components: the skin structure and the nerve sensory cells adjacent to it, often among the one in each sensillum.There are dividedinto two types – immersed and non-immersed sensilla. The mmersed sensilla protrude above the surface of the skin in the form of a hair, bristle, cone or other formation. The non-immersed sensilla are located under the cuticle or in the skin.

The ***hordotonal organs***, as an aggregate of sensilla, are located on the antennae, abdomen, legs, wings or another parts of the body of insects. They are usually distributed symmetrically and metameric and are found in large numbers.

A special form of the hordotonal organs is the ***Johnston organ*** (Figure 4).

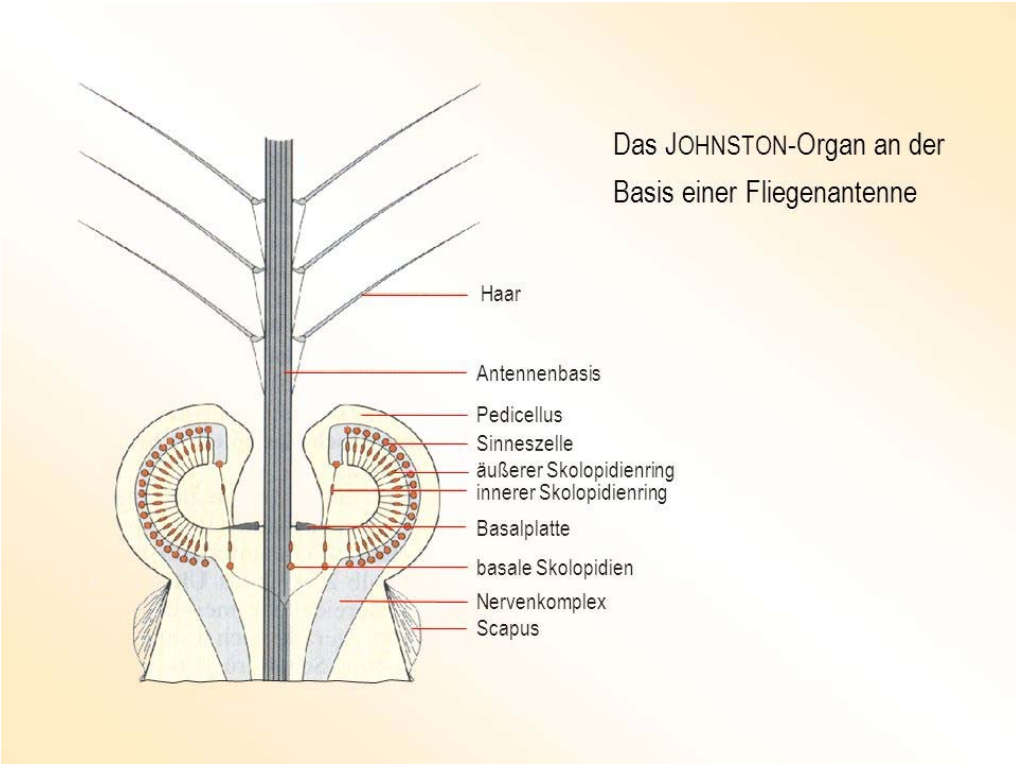


Figure 4. Johnston organ (source: http://slideplayer.org/slide/666115/1/images/9/Das+JOHNSTON-Organ+an+der+Basis+einer+Fliegenantenne.jpg
Рисунок 4. Джонстонов орган

It is located on the second segment of the antennae and is considered an organ that perceives the movement and shaking of air or water, as well as contact with a solid substrate.

Skin glands of insects

Many insects have large, epidermal secretory cells which specialized as exocrine glands. They produce pheromones, repellants and other compounds. They are released on the surface of the skin through microscopic ducts.

The main types of glands of insects are below:

a) allotrophic,

b) molar and lubricant,

c) odorous and poisonous,

d) salivary and silk-separating,

e) wax and lacquer.

Questions for self-check:

1. Describe the layers of the skin of insects.
2. What is a “cuticle”?
3. What are the main types of insect skin appendages?
4. What is the “Johnston organ”?
5. What are the “chordotonal organs”?
6. Explain the function of the hypodermis.

6 STRUCTURE OF THE INSECT HEAD AND ITS APPENDAGES

1. Setting of the head (direction of the mouth parts).
2. Terminology of head capsule parts.
3. Tentorium and its mechanical meaning.
4. Types of heads.

3 Segmental composition of the head and the origin of the head capsule.

4 Types and functions of insect antennas.

The head capsule named epicranium. On the head of insects are eyes, antennas, mouthparts, mouth opening. It contains the brain.

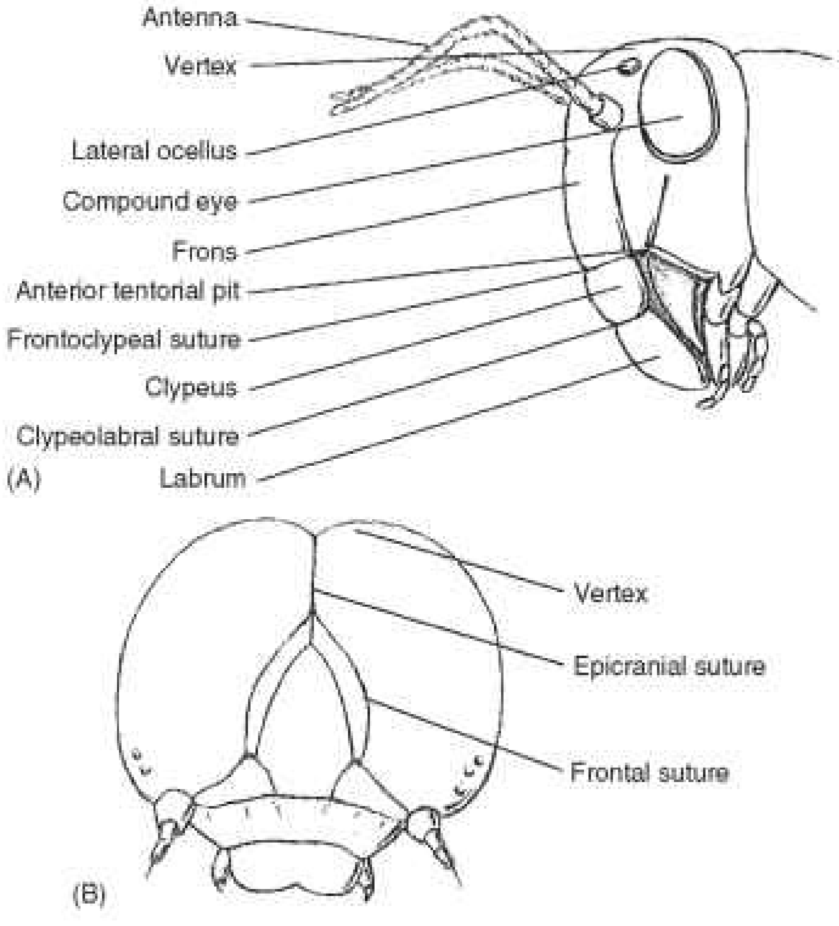


Figure 5. (A) - The head of a grasshopper (Orthoptera: Acrididae) - (B) - Larval pterygote head showing epicra-nial and frontal sutures (Lepidoptera: Noctuidae) (source: http://what-when-how.com/insects/anatomy-head-thorax-abdomen-and-genitalia-insects/)
Голова гусеницы с эпикраниальным и лобным швом (Lepidoptera: Noctuidae)
Рисунок 5. Голова кузнечика (Orthoptera: Acrididae).

According the embryological evidence the head capsule of the present-day insects was formed from the fused first six body segments of primitive worm-like ancestory insects (three pre-oral and three post-oral segments).

The surface of the head is divided into separate sections (regions, or sclerites), sometime separated by *sutures*.

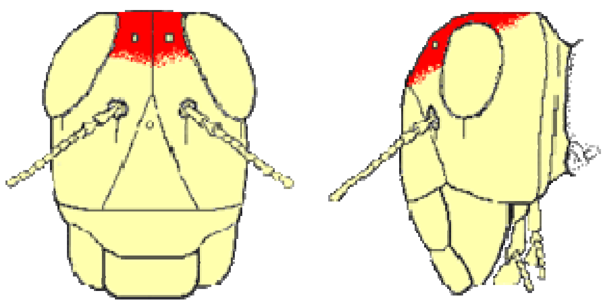
The uppermost part of the epicranium is represented by the **vertex**, divided by the middle *coronal suture* into the right and left halves.

Going down to the front face of the head, the epicranial suture forks into the *frontal sutures*, limiting the triangular forehead (**frons**) – it lies between these frontal sutures.

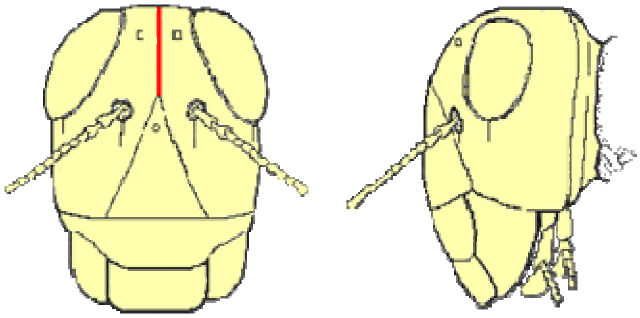
The base of the frons separates from the clypeus by the epistomal suture.

An occipital suture circumscribes the head capsule near the back of the head. Behind the occipital suture, tiny sclerites lie. Maybe they are the remnants of the fifth primitive segment form the head construction, and the sixth primitive segment of the head capsule is located at the posterior-most margin of the head and marked by a postoccipital suture and a thin sclerite (the postocciput) that connects with the neck membrane.

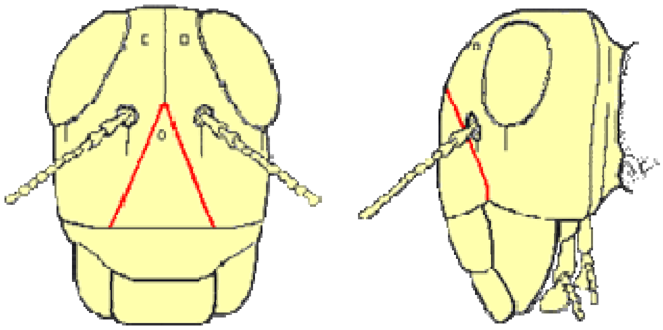
Vertex – темя



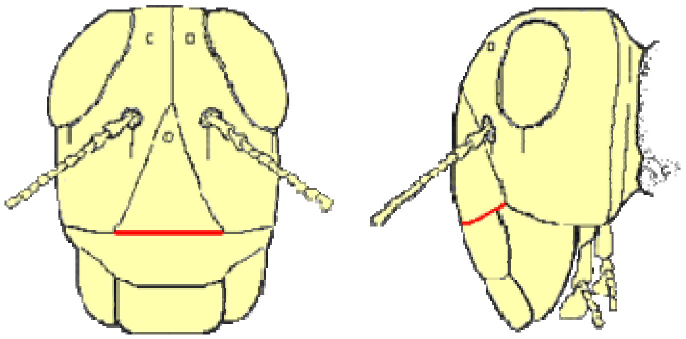
Coronalsature –
теменной
(эпикраниальный)
шов



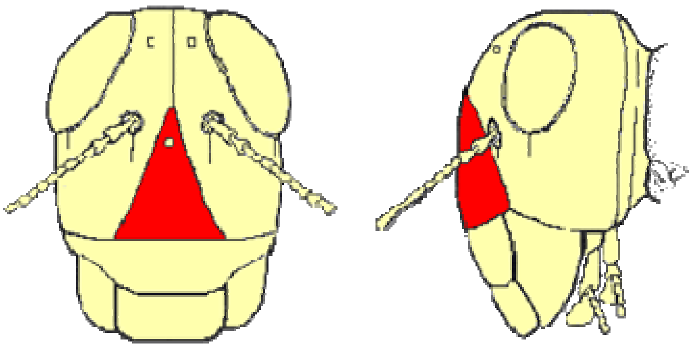
Frontal satures –
лобные
(фронтальные)
швы



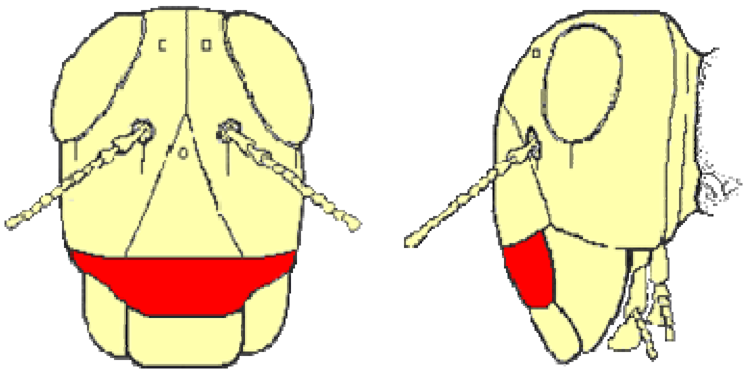
Epistomal sature –
эпистомальный
шов



Frons – лоб



Clypeus –
наличник

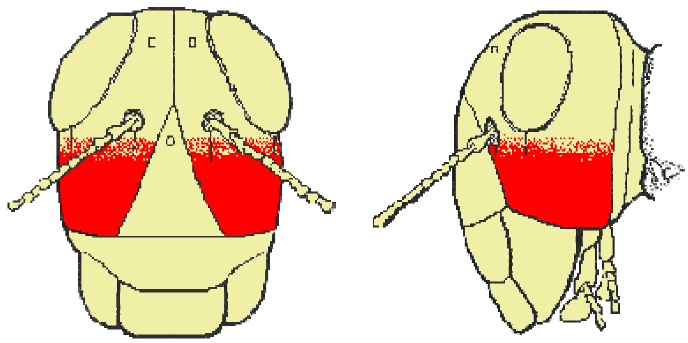


The lateral sclerites are genae. They lie behind the frontal sutures on each side of the head.

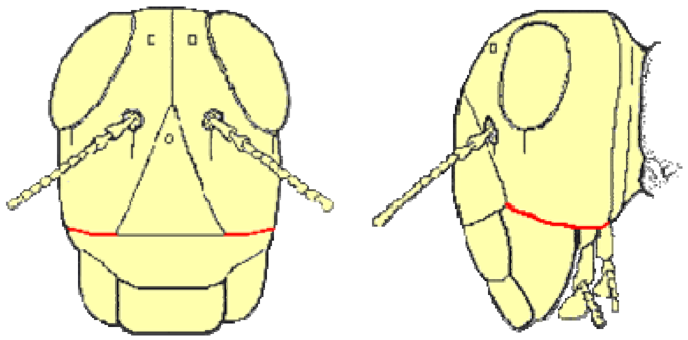
Below genae there are the subgenae, separated from the gena by a subgenal suture.

A pair of compound eyes, one – three ocelli (simple eyes), two antennae may be found on the top, front, or sides of the head.

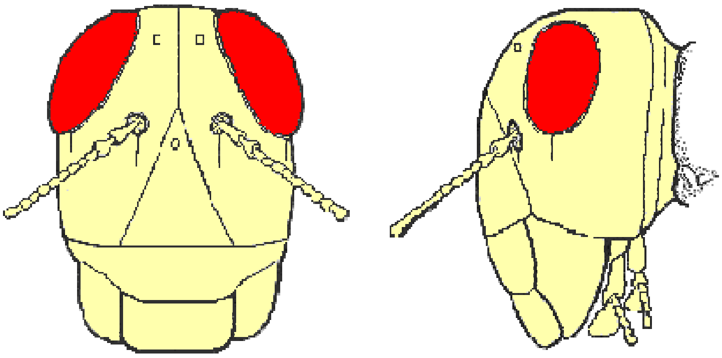
Genas ("cheeks")
щеки



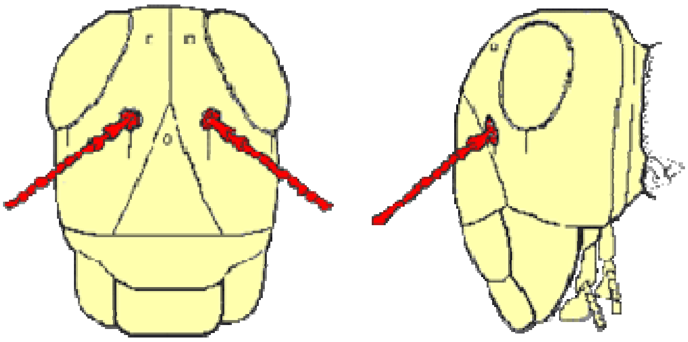
Subgenal suture –
субгенный
(подщечный) шов



Compound eyes – сложные глаза



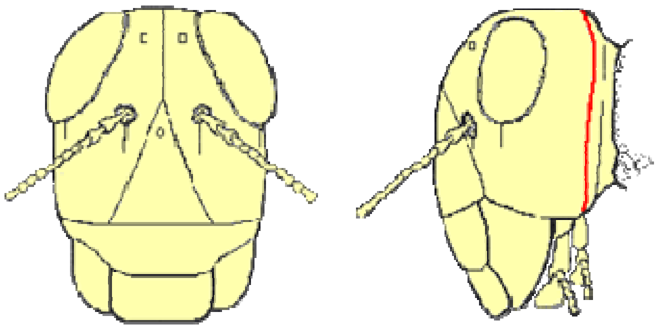
Antennae – антенны



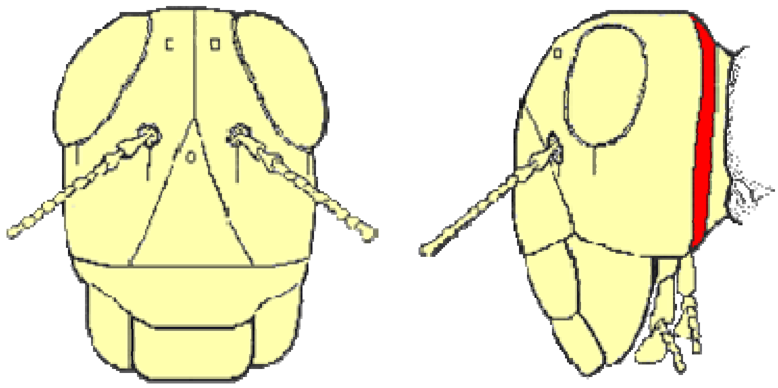
An *occipital suture* circumscribes the head capsule near the back of the head at the posterior margin of the genae and vertex, and marks the internal sclerotized ridge (apodeme) that strengthens the head capsule here.

The **occipu**t and **postgenae** are located behind the occipital suture.

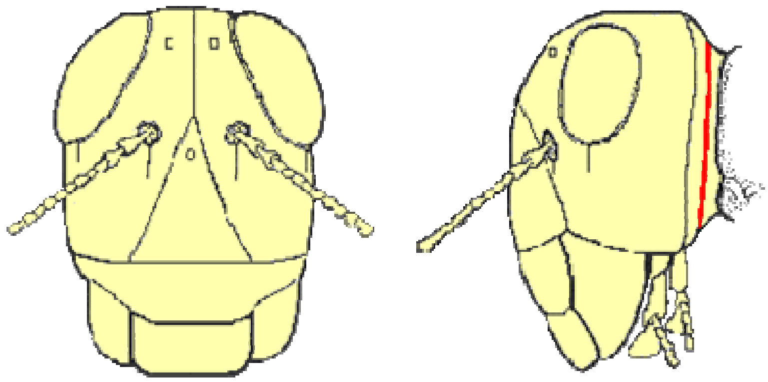
Occipital suture – затылочный шов



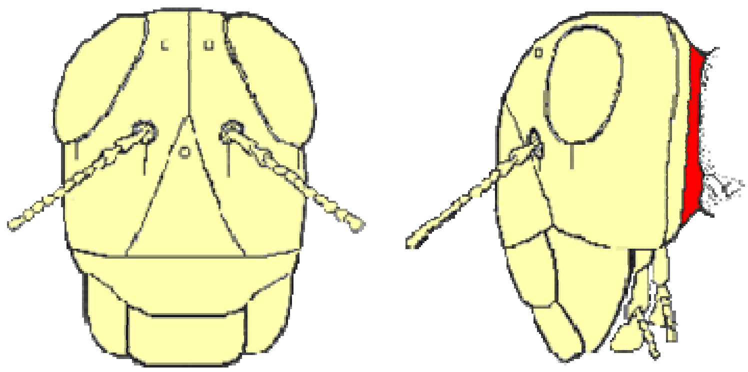
Occiput – затылок



Postoccipital suture
заднезатылочный шов

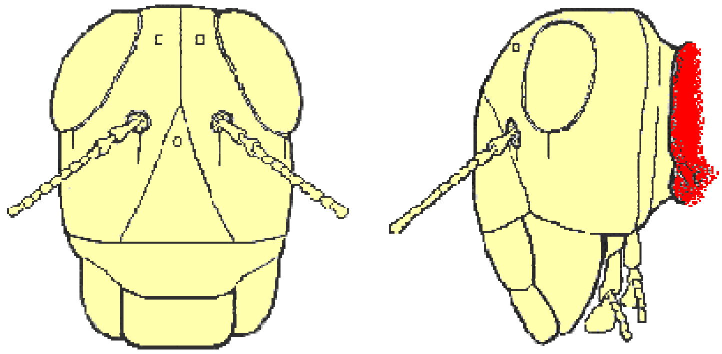


Postocciput
заднезатылок

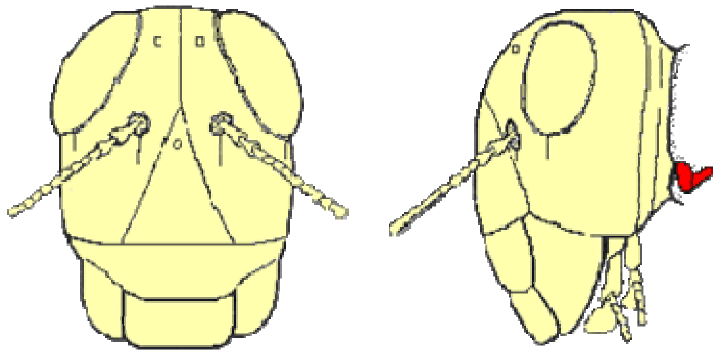


The cervix is the neck of insects.It is a membranous area that allows protraction and retraction of the head. After that, there is the cervical membrane which extends from the posterior part of the postocciput to the prothorax.It represents a transitional zone between the head and thorax. Some points of attachment for muscles for the control of head movements are small cervical sclerites.

Cervix – шея



Cervical sclerites – шейные склериты



The inside structure of the insect's head is the **tentorium**. It cradles the brain and provides a rigid origin for muscles of the mouthparts.

The origin of the tentorium is from pairs of apophyses (finger-like invaginations of exoskeleton) which fuse internally to create a bridge.

The shape and setting (orientation) of the head

The shape of the head of insects is diverse: rounded (flies), compressed laterally (locusts, grasshopper), elongated in the form of a tube (weevils).

Different types of the head of insects setting and the orientation of the mouthparts on the head are named as prognathic, hypognathic and opistognathic (Figure 6).

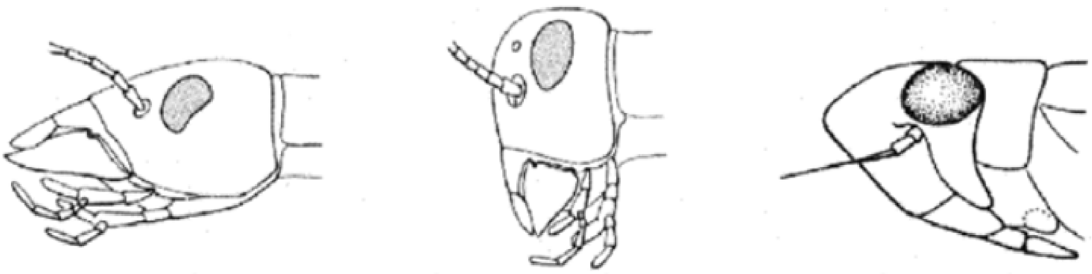


Figure 6. Types of thesetting and orientation of the mouthparts of the insect head (source: https://jscienceclass.blogspot.com /2011/06/orientation-of-insect-head-prognathous.html
Рисунок 6. Типы прикрепления и ориентации ротовых частей головы насекомых

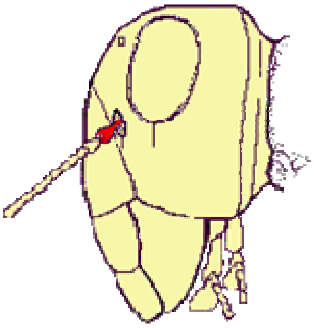
With the prognathic type of head, the mouthparts of insects are projecting forward (horizontal). It is characteristic of predatory insects (ground beetles, stafillins).

With hypognathic type of head, the mouthparts of insects projecting downward at right angles. It is characteristic of the herbivorous insects (locust, many species of bugs, beetles).

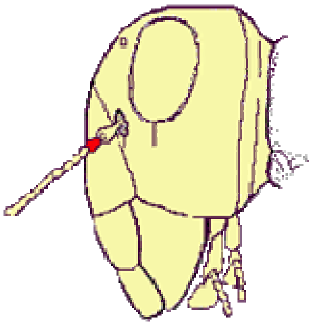
With opisthognathic type of head, the mouthparts of insects are projecting at an acute angle down and back, approaching the front legs - obliquely or posteriorly. It is characteristic of cicadas, thrips.

Antennae of the insects and their types

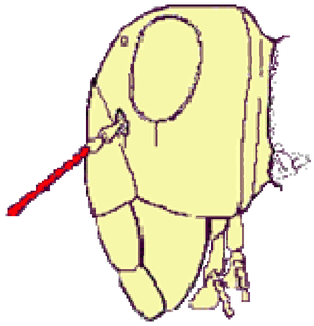
Antennae of insects are paired segmented mobile and well-developed appendages of various forms, but their composition is of the same type – they have three basic parts. Antennae are located in a shallow antennal fossa on the vertex, close to the eyes or mandibles of the insect and consist of the main basal segment that articulates with the head capsule segment (**scapus**), the second antennal segment (**pedicle or pedicellum**) and multi-segmented remaining cord (flagellum).



Scape – основной членик



Pedicel – ножка



Flagellum – жгутик

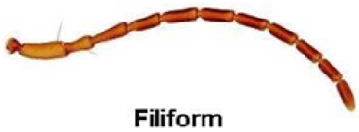
The antennae of insects are a pair of sense organs located on the heads. The antennae are much more than just tactile receptors, they covered with olfactory receptors and have the role of the smell sense organs.

The antennae are the humidity sensors too because they detect the concentration of water vapor. The antennae of mosquitoes detect sounds. Some insects (e.g. flies) use the antennae to gauge airspeed during their flight.

Types of antennae of insects

The antennae of insects have a different shape, length, thickness, hairiness, etc.They have multiple functions and specialization – sensory receptors, detecting sound vibrations, wind speed, air fluctuations, or detection of humidity.

There are some common antennal types of insects:



Filiform
Examples: Ground beetles and cockroaches

Filiform = thread-like.
Нитевидные.
Filiform antennae have a simple, thread-like shape. They are common among many groups of insects.

Moniliform
Example: Termites

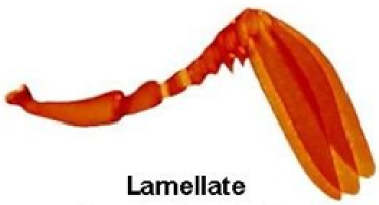
Moniliform = beaded.
Четковидные.
Moniliform antennae have round segments and shape as a string of beads (e.g. many Coleoptera).

Serrate
Example: Click beetles

Serrate = sawtoothed.
Пиловидные.
Serrate antennae have segments that are angled on one side as in the saw (in some species of Coleoptera)

Setaceous
Examples: Dragonflies and cicadas

Setaceous antennae
Щетинковидыные.
Setaceous antennae taper gradually from the base to the tip (e.g Plecoptera, Thysanura, Trichoptera, Ephemeroptera, Blattodea)

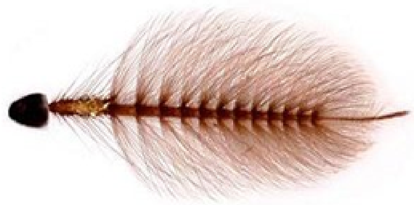


Lamellate
Example: Scarab beetles

Lamellate = nested plates.
Пластинчатые.
Lamellate antennae have segments that have flattened and like-plate-segments (e.g. Scarabaeidae sp.).

Pectinate
Examples: Sawflies and dobsonflies

Pectinate = comb-like.
Гребневидные.
Pectinate antennae have are longer segments on one side as a comb (Hemynoptera – Symphyta sp. and some Coleoptera).

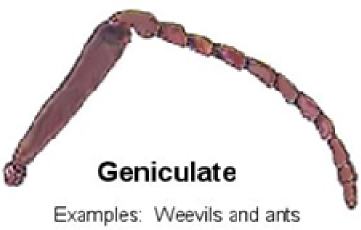


Plumose
Example: Mosquitoes

Plumose = long hairs.
Перистые.
Plumose antennae have a number of fine, thread-like branches on each segment, and the antenna is as a feather (some Diptera – Mosquitoes)

Clavate
Example: Carrion beetles

Clavate = gradually clubbed.
Булавовидные.
Clavate antennae are wider towards the tip by gradual along its length, or a sudden increase (capitate), giving the appearance of a club (e.g. Lepidoptera and some Coleoptera),



Geniculate
Examples: Weevils and ants

Geniculate = elbowed.
Коленчатые.
Geniculate antennae have an elbow part of the antenna – with a long main segment to which the pedicle and flagellum is attached at an angle (e.g. Hymenoptera – Formicidae sp. and some Coleoptera – Weevils).

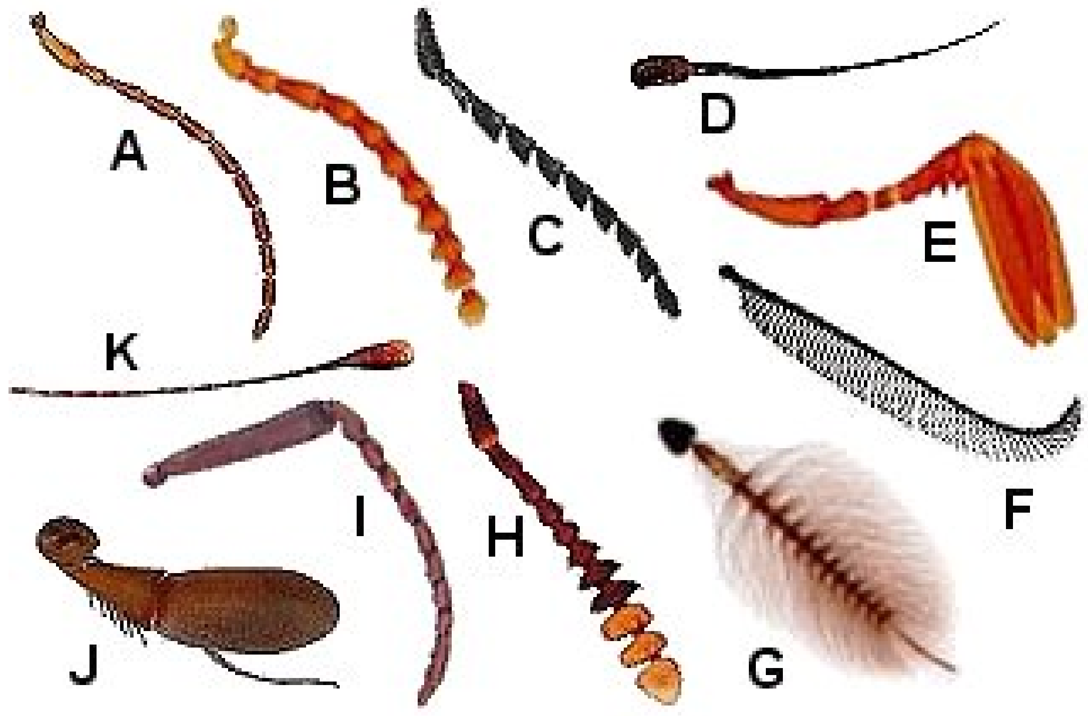
Aristate
Example: House flies

Aristate = pouch-like
Щетинконосные.
Aristate antennae have a lateral bristle (e.g. flies).

Capitate
Example: Butterflies

Capitate = abruptly clubbed
Головчатые.
Capitateantennae have a head at the end of a thin antenna (Butterflies

All of these antennae types are below.



Questions for self-check:

1. What kind of insect has a prognathic type of head?
2. What are main appendages of head of insects?
3. Explain the name of "tentorium".
4. How many types of head setting and orientation do insects have?
5. How many dorsal eyes are on the crown of many insects?
6. Why do some males have antennas larger than females?
7. List the types of antennae of insects.
8. Name antennae E and J.

7 TYPES OF MOUTHPARTS OF INSECTS

1. Main types of mouthparts of insects.
2. Chewing mouthparts.
3. Modified mandibulate mouthparts.
4. Haustellate mouthparts.

Insect's mouthparts are adapted to their modes of feeding (Figure 7). At the base of the insect mouthparts is chewing, or gnawing. The evolutionary transformations associated with adaptations to one or another type of food and the method of its consumption led to the transformation of the original chewing (gnawing) type to the variety of oral devices.

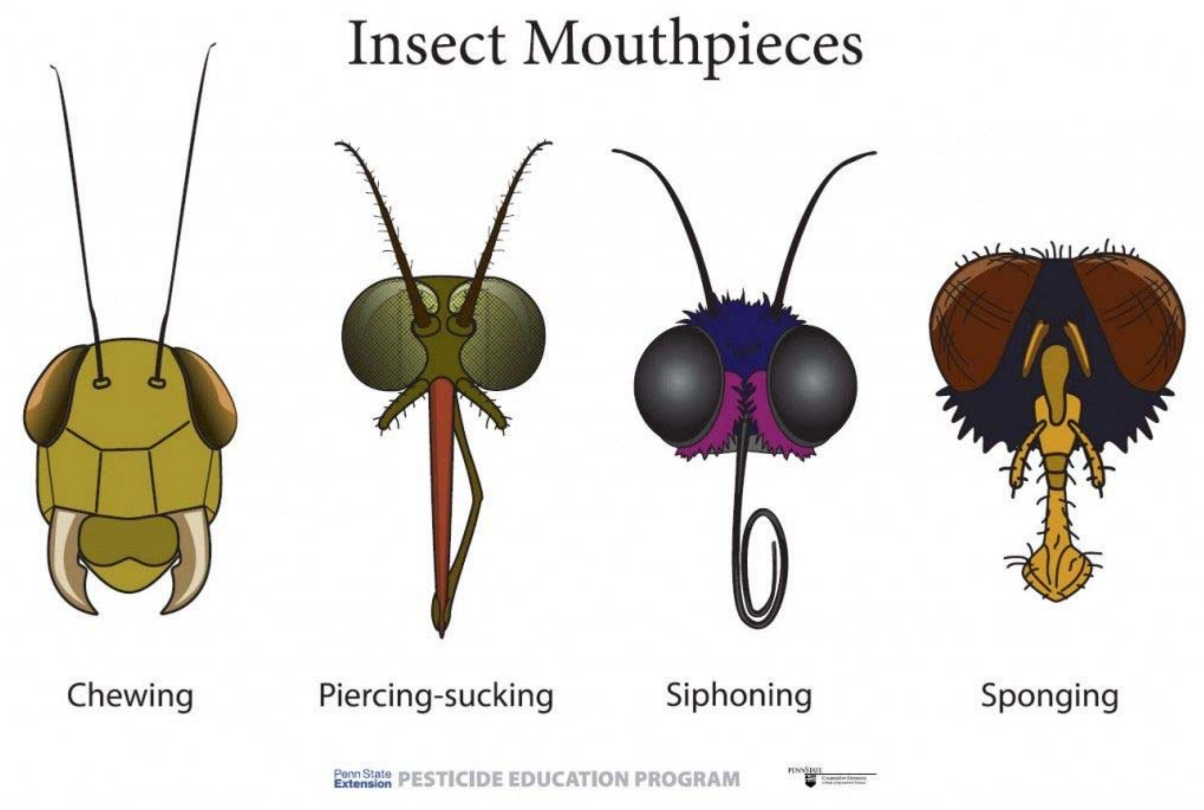


Figure 7. Main types of insect mourthparts (source: https://i.pinimg.com/originals/f6/88/c0/f688c0a9341e1c6d26b45185e70015b9.jpg
Рисунок 7. Основные типы ротовых аппаратов насекомых

According to some scientific data the ancestors of present-day insects were worm-like arthropods. They had a simple mouth opening near the front part of a body. Over many millions of years, the appendages near the mouth opening have changed into mouthparts for the feeding of solid food, gathering and manipulating its parts and adapted to new resources of food.

According to such adaptations and morphological changes, the structure of mouthparts allows using solid or liquid, dead or alive food.

Gnawing and chewing mouthparts
(Грызущий ротовой аппарат)

The mouthparts in "primitive" insects are adapted for pinching, grinding, chewing, or crushing particles of solid food. Such kind of mouthparts is known as chewing (mandibulate) mouthparts because they have chewing mandibles (Figure 8).

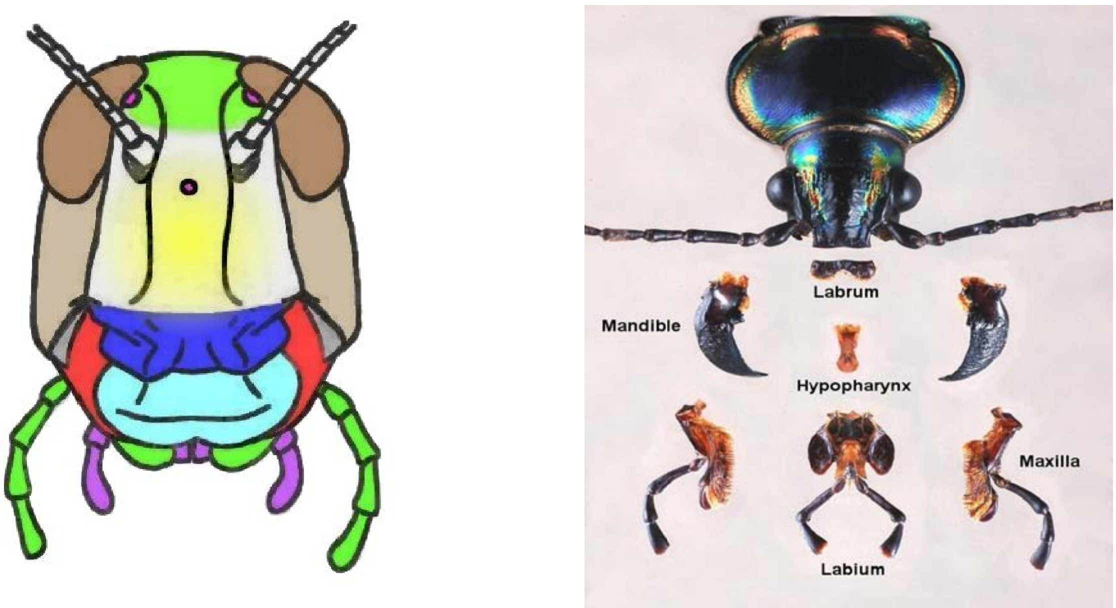
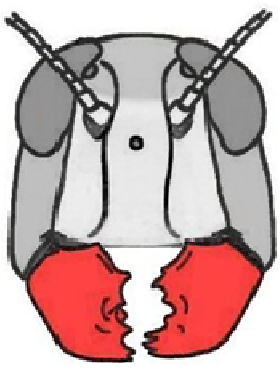


Figure 8. Head of an insect with chewing (gnawing, mandibulate) mouthparts(source: https://genent.cals.ncsu.edu/bug-bytes/mouthparts/)
Рисунок 8. Голова насекомого с грызущим ротовым аппаратом

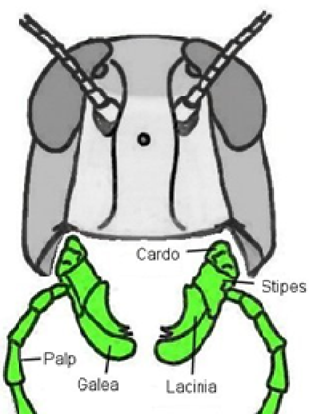
The gnawing and chewing mouthparts of insects have five basic components:


Labrum

1. **Labrum** – a front lip, simple plate-like sclerite. It helps to contain the food.
Лабрум – верхняя губа, простой пластинчатый склерит. Она помогает удерживать пищу.

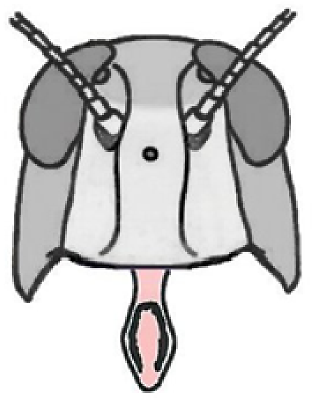

Mandibles

2. **Mandibles** – upper jaws. They crush or grind the food moving from side to side.
Мандибулы – верхние челюсти. Они раздавливают или перемалывают пищу, перемещаясь из стороны в сторону.



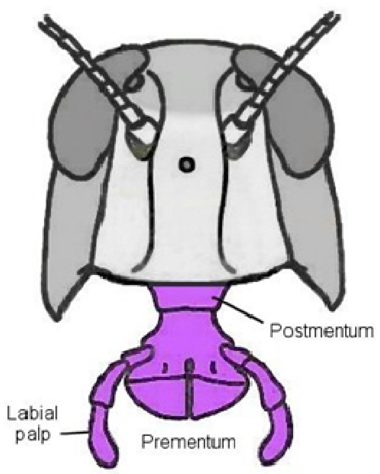
Maxillae

3. **Maxillae** – lower jaw. They consist of the following parts:
a) **Cardo** – basal sclerite connected with the head capsule; b) **Stipes**(stem) – medial sclerite with a sensory palp (organ of taste);
c) **Galea** and **Lacinia** – distal sclerites to manipulate the food.
Максиллы – нижние челюсти. Они состоят из следующих частей:
а) кардо – базальный склерит, связанный с головной капсулой; б) стипес (стволик) – медиальный склерит с чувствительным щупиком (органом вкуса);
в) галея и лациния – дистальные склериты для манипулирования пищей



Hypopharynx

4. **Hypopharynx –** it protrudes into the pre-oral cavity in the form of a thick and soft tongue. It divides the pre-oral cavity into the anterior (cybarium) with the oral opening and the posterior (salvary), where the ducts of the salivary glands flow and food is mixed with saliva.
Гипофаринкс (подглоточник) – он выступает в предральную полость в виде толстого и мягкого языка. Он делит предротовую полость на переднюю (цибарий) с ротовым отверстием и заднюю (сальварий), куда впадают протоки слюнных желез и пища смешивается со слюной.



Labium

5. **Labium** – a back lip.The lower lip originnates from the second pair of lower jaws, merged together at the base. The labium is consists of basal plates – **submentum**, **mentum**, and **palpiger**. The palpiger carries the segmented **labium palp** as a chemoreceptor. On the tip of the labium, there are paired **glossa** and **paraglossa** with the function like a tongue (but the true tongue is hypopharynx).
Нижняя губа. Нижняя губа происходит от второй пары нижних челюстей, слитых вместе у основания. Нижняя губа состоит из базальных пластинок – субментума, ментума и пальпигера. Пальпигер несет сегментированный губной щупик – хеморецептор. На кончике нижней губы имеются парные глосса и параглосса с функцией, подобной языку (но истинный язык – это гипофарингс).

A numberof insects have the mandibulate (gnawing and chewing) mouthparts (e.g. cockroaches, grasshoppers, ground beetles, lepidopteran caterpillars, and beetle larvae have chewing mouthparts). All of them have two mandibles, one on each side of the head. They open to the sides of the head and come together medially.

Modified mouthparts of insects

The mouthparts can be modified. During evolution, insects evolved and feed on a wider variety of food resources (e. g. nectar of flowered plants or blood of animals). Mouthparts were adapted (Figure 9, Appendix A)to new food resources.

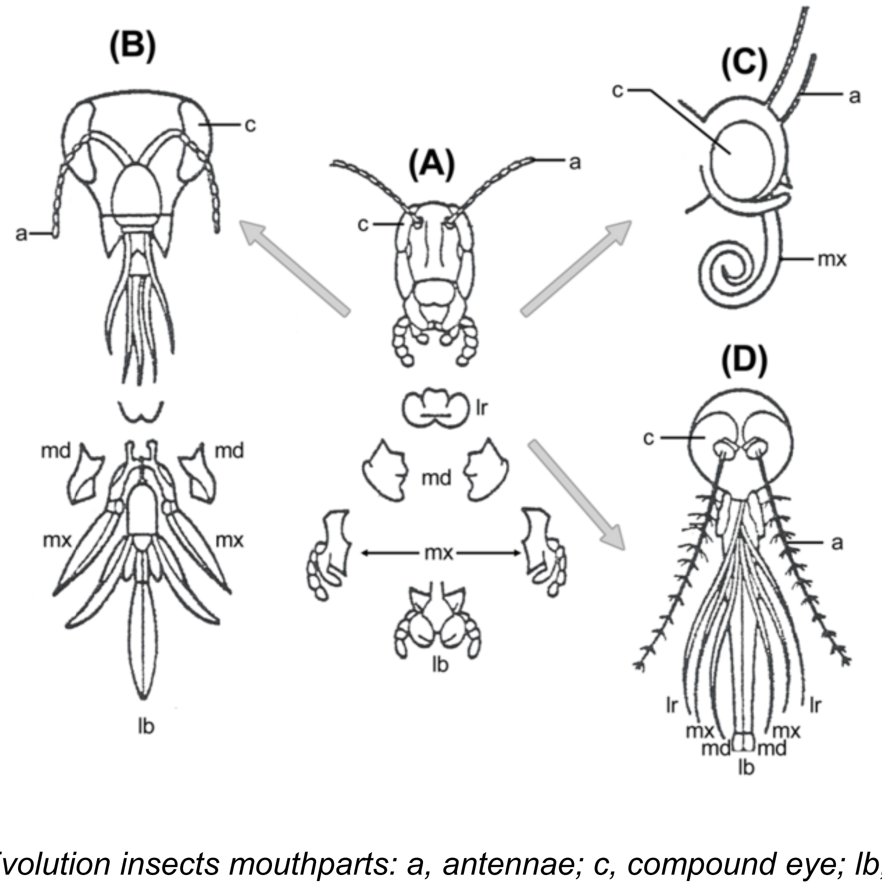


Figure 9. Evolution insects mouthparts: a, antennae; c, compound eye; lb, labium; lr, labrum; md, mandibles; mx, maxillae. (A) biting and chewing. (B) Ticking and biting. (C) Sucking. (D) Piercing and sucking: (source: http://www.newworldencyclopedia.org /entry/File:Evolution_ insect_ mouthparts.png)
Рисунок 9. Эволюция ротовых органов насекомых

The carnivorous chewing insects have knife-like mandibles, but herbivorous chewing insects have the broad and flat mandibles. In some species of beetles, the mandibles of males do not serve to feed but used to defend mating sites, or the mandibles in ants also serve a defensive function (soldier castes).selection and specialized for new food and function.

Chewing and lapping type of mouthparts

(грызуще-лижущий тип ротовых органов)

In these mouthparts (Figure 10), the upper lip and jaw, forming mandibles did not change principally but mandibles are well developed with teeth for biting and chewing pollen and wax.

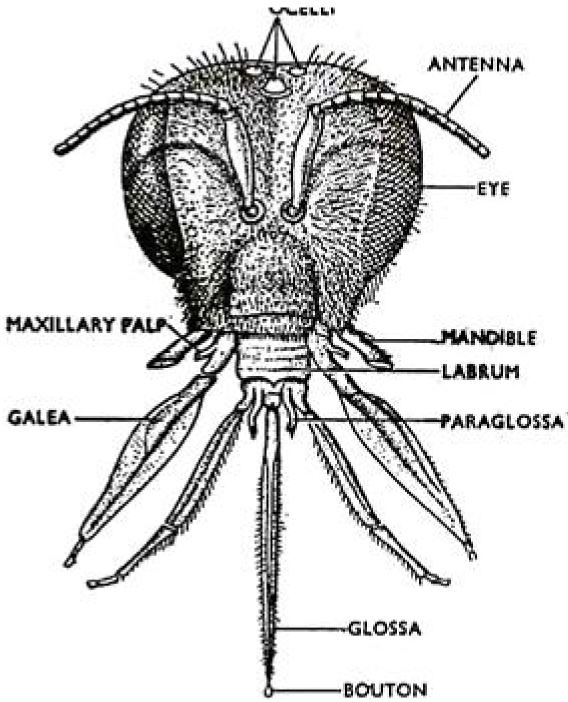


Figure 10. Chewing and lapping type of mouthparts (honeybee, source: http://cdn.biologydiscussion.com/wp-content/uploads/2016/08/ image_thumb1_thumb-2.png)
Рисунок 10. Грызуще-лижущий ротовой аппарат (пчела)

The labium is elongated to form a tube and retractile tongue–like structure with a small labellum (or honey spoon) at its tip and elongated labial palps; the glossa is an organ of touch and taste and used for gathering honey.

The galea and labial palps form a tube enclosing the glossae. It moves up and down to collect nectar which is sucked up through the tube by the pumping action of the pharynx.

Chewing and lapping type of mouthparts is available in bees, wasps and appeared with the connection of the evolution of pollinated plants.

Mouthparts adapted for ingesting liquid food

Mouthparts adapted for ingesting liquid food realize different function such as sponging, piercing and sucking, probing and sipping. Such mouthparts are found in dipteran insects (mosquitoes), hemipteran insects (bugs, aphids), butterfly, moths, fleas etc.

Siphoning insects – sucking insects, which not pierce prior to sucking (most of moths and butterflies; some moths have no mouthparts, but few species have fully developed mandibles).

All Lepidoptera (but a few adults' forms) lack mandibles, heavily modified maxillae (specifically the galea) formed an elongated sucking tube (the proboscis) (Figure 11).

The proboscis is held coiled under the head when not in use, but during the feeding, it is extended to reach the nectar of flowers.

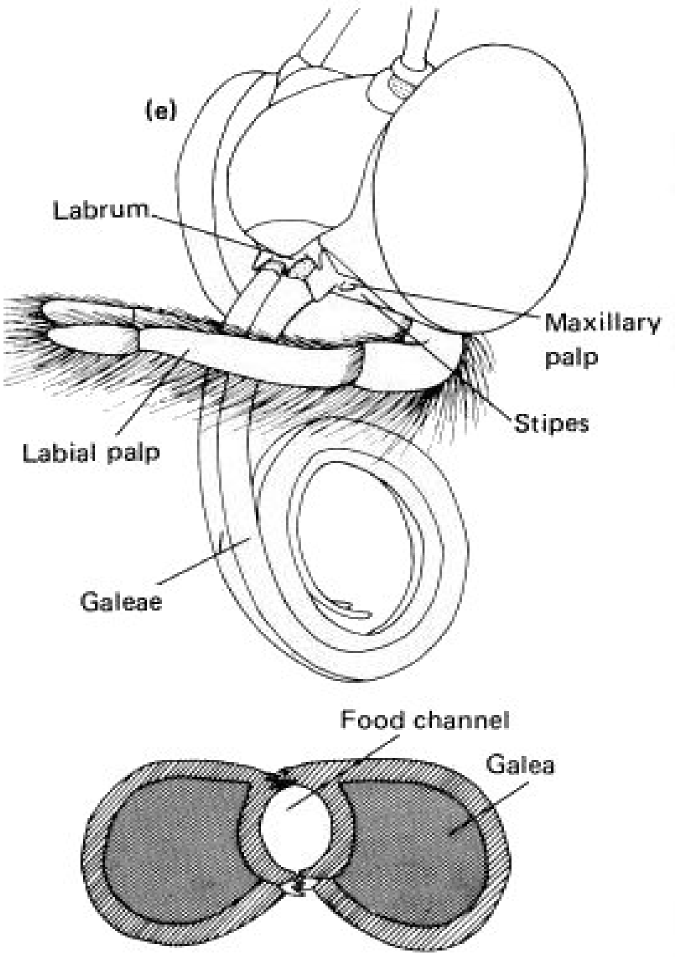


Figure 11. Siphoning mouthparts of Butterflies
(source: https://genent.cals.ncsu.edu/bug-bytes/mouthparts/)
Рисунок 11. Сосущий ротовой аппарат бабочек

*Piercing and necking insects*pierce food items (the tissues of animals and plants) to sucking of internal fluids – the blood or plant juice. Such mouthparts are found in mosquitoes and some herbivorous insects like bugs, aphids or some insectivorous, like assassin bugs.

Hemiptera's mouthparts have the mandibles and maxillae modified into a straight, fleshy proboscis sheathed within a modified labium; it piercing tissues and sucking out the liquids.

The labial palps form two conical lobes at the tip of the proboscis, called labella which bear tactile bristles.

The labrum is long needle-like, and the epipharynx is fused with the labrum thus, covers the labial groove dorsally from inside.

The bedbug has a three-jointed proboscis where the mandibles and maxillae are modified to form stylets; the mandibular stylets possess blade-like tips, and maxillary stylets possess saw-like tips. The labrum covers the labial groove at the base only.

*Piercing and sucking mouthparts.*The female mosquitoes have a stylet (Figure 12). Their mandibles and maxillae form the stylet, which are used to pierce the skin.

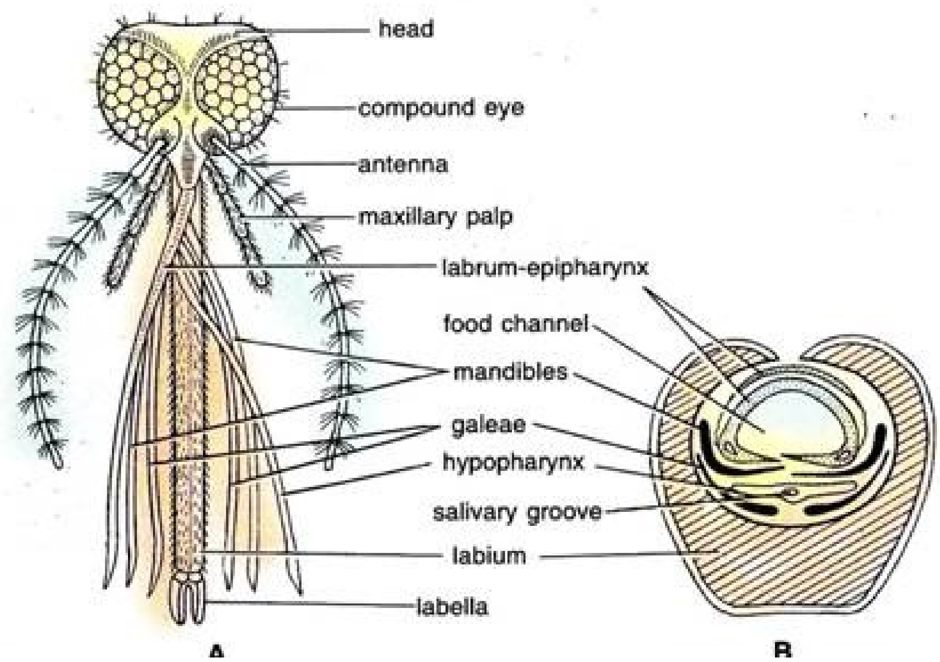


Figure 12. Piercing and sucking mouthparts of mosquitous, female (source: http://cdn.biologydiscussion.com/wp-content/uploads /2016/03/ clip_ image006-77.jpg)
Рисунок 12. Колюще-сосущий ротовой аппарат комара, самка

When piercing, the labium remains outside the skin of food animals, folding away from the stylet. When the insect starts to feed, it sits on the substrate, touches it with the tip of the proboscis; presses it, making a forward movement of the head. In this time the outer part of the mouthparts, the proboscis, is slightly bent and it may slightly stretch and shrink as a corrugated hose. The ends of the needles move forward and pierce the integument, penetrating into the food items – plants tissue or animal skin.

The labium encloses all other mouthparts like a sheath. Ithas such way: the connected two lower jaws have two longitudinalgrooves on the inner surface (each of which) and form two channels in a contiguous position. The lower lip surrounds the needles and plays the role of a durable case that does not allow the needle to bend. Saliva is introduced into the substrate (at the bottom).It contains digestive enzymes that partially digest food. Also saliva contains anticoagulants which inject into the food animals and blood sucked out. The upper channel absorbs of a liquid substrate saliva-primed. The labrum is reduced – it is a part of the base of the proboscis.

Muscoid (licking) type of mouthparts are typical for insects feeding on liquid food (e.g. houseflies) (Figure 13). Mandibles and maxillae are much reduced and non-functional. The labium forms a long proboscis-like structure which is used to channel liquid food to the esophagus. The rostrum is the basal part of the proboscis and is proximally articulated with the head capsule and distally articulated with the haustellum by a hinge joint. The rostrum encloses pharynx and salivary duct and pharynx communicated with the food canal. The middle part of the proboscis and the proximal part of labium is haustellum. The apical part of labium forms a broad bilobed sponge-like apparatus called labellum. When the proboscis is unfolded, labelums have the special mobility, having the form of two semicircular suckers with a food opening located in the center. Pseudo-trachea submerged beneath the surface of the labellum – thin tubules with small pores, reinforced by semicircular sclerites. When housefly eats solid food, it secrets saliva which dissolves the solid food (e.g. sugar), the solution is drawn up into the mouth as a liquid food.

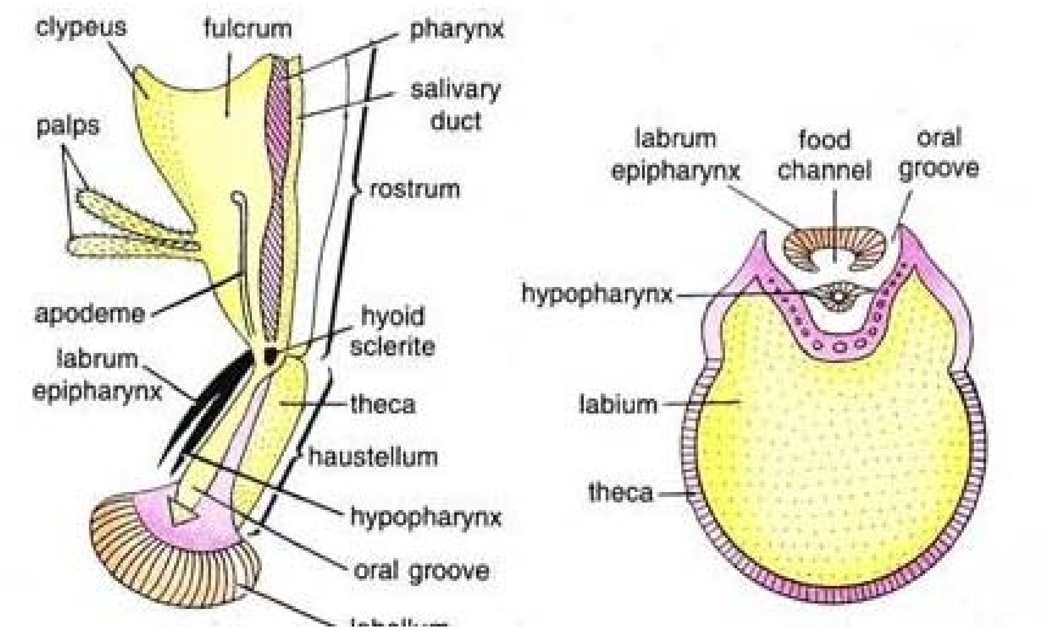


Figure 13. Muscoid (licking) type of mouthparts (housefly, source: http://cdn. biologydiscussion.com/wp-content/uploads/2016/03/ clip_image009_thumb-20.jpg)
Рисунок 13. Мускоидный тип ротового аппарата (домовая муха)

The labellum's surface is covered by small food channels, formed by the interlocking elongate hypopharynx and epipharynx, which form a tube leading to the esophagus. This food channel draws liquid and liquified food to the esophagus by capillary action that quickly absorbs fluid.

Questions for self-check:

1. Which type of mouthparts do “primitive” insects have?
2. What are chewing mouthparts adapted for?
3. Name insects with chewing mouthparts and their main parts.
4. Describe the structure and role of hypopharynx.
5. Which structure of chewing mouthparts do sensory palps have?
6. Describe the mouthparts of mosquitoes female.
7. Describe the mouthparts of housefly and butterfly.

8 THE THORACIC PART AND ITS STRUCTURE. LEGS OF INSECTS, STRUCTURE AND MAIN TYPES

1. Torax and its structure
2. The legs of insects and their structure.
3. Types of legs of insects and their functions.

The thorax is the second (middle) tagma of an insect's body adapted for locomotion. It consists of three body segments (**prothorax**, **mesothorax**, and **metathorax**) and contains six walking legs and one or two pairs of wings in many adult insects (Figure 14).

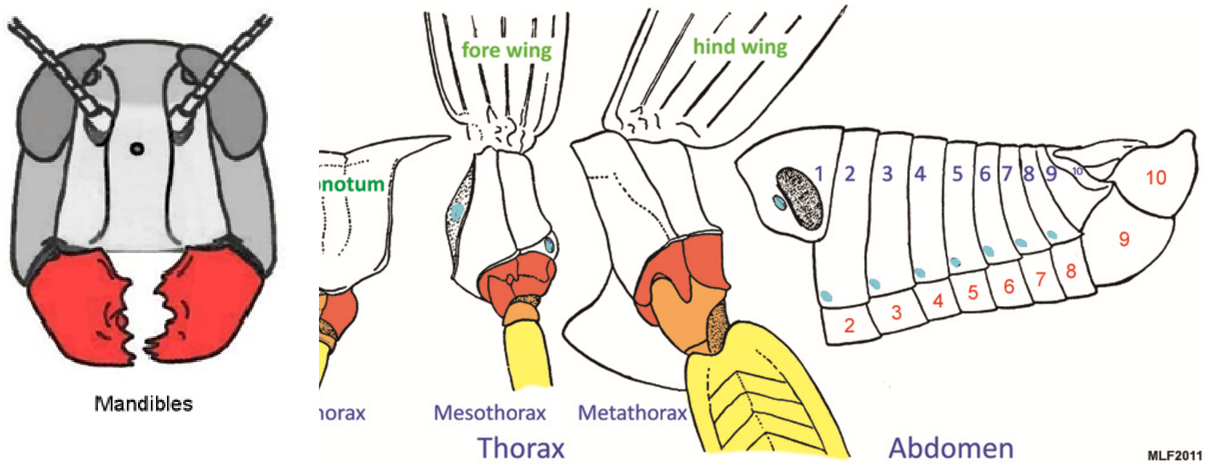


Figure 14. The thorax of insects
(source: https://wiki.bugwood.org/uploads/Grasshopper_anatomy.jpg)
Рисунок 14. Грудь насекомых

The thoracic three segments are joined together rigidly and contain the musculature for the legs and wings.

The dorsal sclerite of the thorax segments named the notum (pronotum, mesonotum, and metanotum) may be subdivided into an anterior scutum and a posterior scutellum (Figure 15). The ventral sclerite of thorax segments named the sternum (prosternum, mesosternum, and metasternum).

The side of thorax segments are called the pleurons (usually theyare divided by a pleural suture into at an anterior episternum and a posterior epimeron).

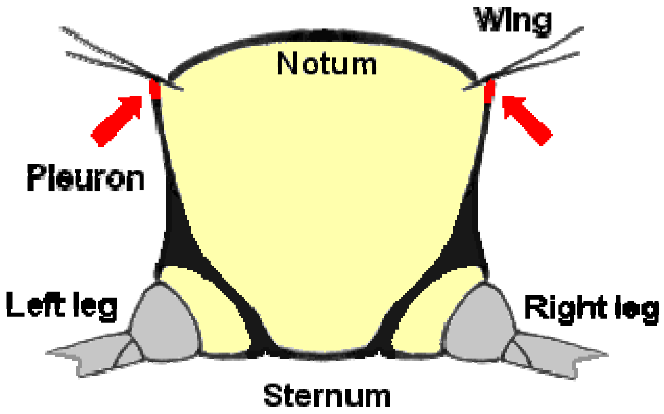
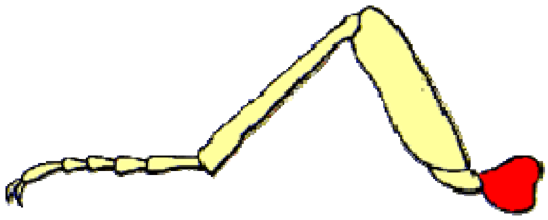


Figure15. Sclerites of the torax (source: https://projects.ncsu.edu/cals/course/ent425/images/tutorials/external/thorax/furca01.gif)
Рисунок 15. Склериты груди

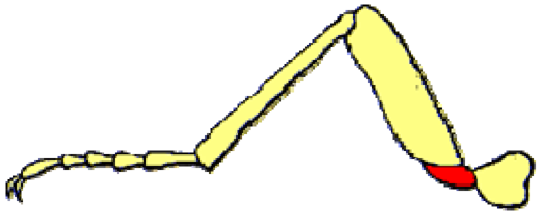
An internal ridge of exoskeleton (an apodeme) strengthens the sides of the thorax and forms a point of articulation with the basal segment of legs of insects – the coxa. In segments that bear wings, the pleural apodeme runs dorsally into the pleural wing process (a finger-like sclerite) that serves as a pivot or fulcrum for the base of the wing.

The ventral corners of each thoracic segment are reinforced as a rigid site for attachment of leg muscles and ventral longitudinal muscles. This structure is called the **furca** which similar in structure to the tentorium which serves a related function inside the head capsule.

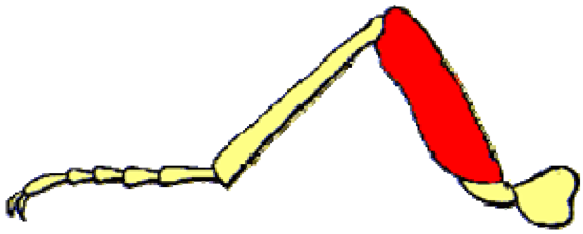
Legs of insects. Insects have six walking legs (three pairs). Each thoracic segment has one pair of legs consist of five segments that articulate with one another by hinge joints (jointed legs) named below.



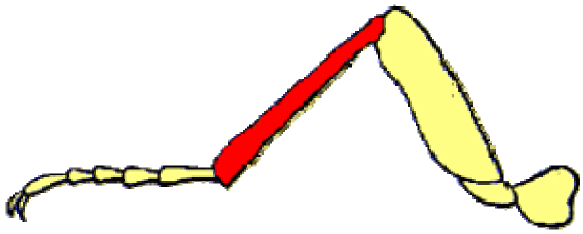
1. Coxa (тазик)



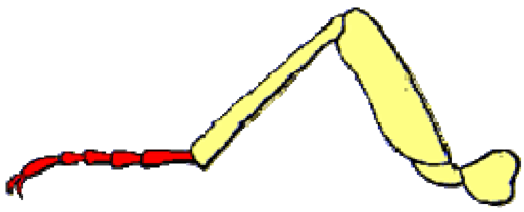
2. Trochanter (вертлуг)



3. Femur (бедро)



4. Tibia (голень)



5. Tarsus (лапка)

Tarsus is markedly different in structure in various insect species. It may consists of a different number of segments (their number is usually from two to five, but sometimes there is one, like in caterpillars) and have special appendages (Figure 16).

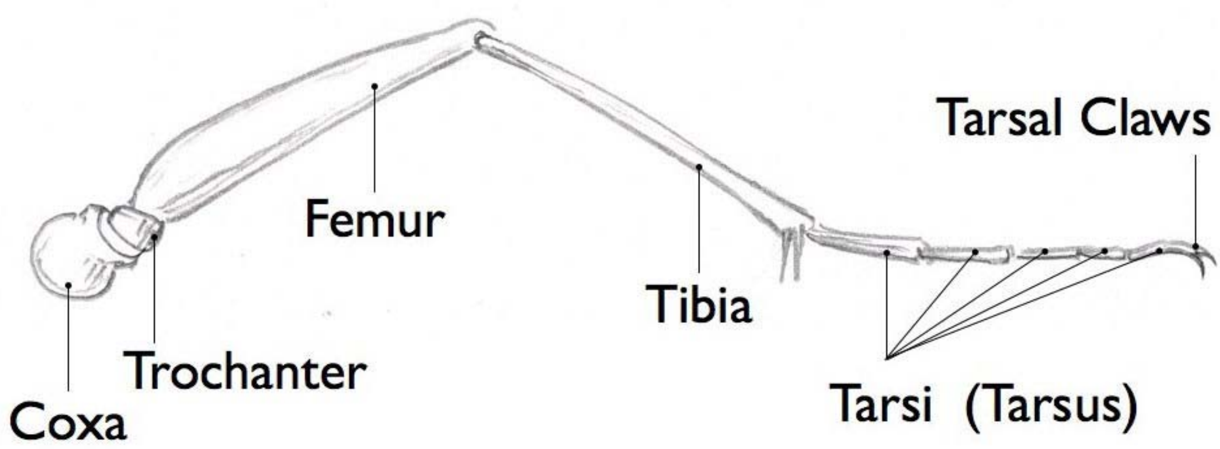


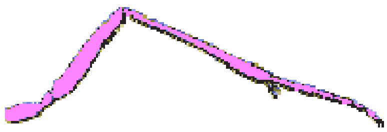
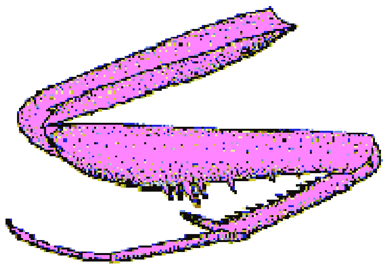
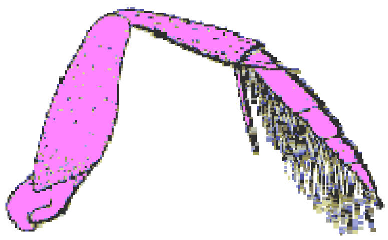
Figure 16. Leg of insect (source: .wp.com/www.johnmuirlaws.com/wp-content/uploads/2014/06/insect-leg-parts.003.jpg)
Рисунок 16. Нога насекомого

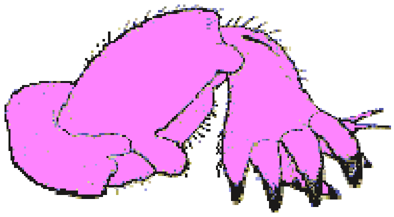
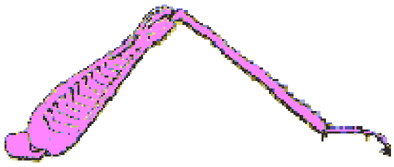
The terminal segment of the tarsus is **pretarsus**. On the last segment of the leg there are **claws** and a special sucker – **arolium**. Instead of a wide sucker on the leg, there may be another, narrower one, which is called **anempody**. Some insects at the tips of the legs have located pads – **pulvilly**. Some insects, for example, flies on their legs have special glandular hairs that secrete a sticky secret that helps them to hold onto objects even in the "upside down" position.

Insects have different kinds of legs and different types of movement: many beetles are running, moths are flying, diving beetles are swimming, fleas are jumping, etc.

Walking and Running (Cursorial) legs. This is the two most common types of insect legs – they have the usual structure. The running legs are distinguished by a longer femur and tibia, an elongated, narrow tarsus. Parts of the walking leg are somewhat shorter and wider, at the end of the foot, the extension is the sole. Running legs are characteristic of fast insects (ground beetles, ants). Lot of insects have walking legs.

Some adapations and modifications of insect's legs:

Names and characteristic	Constructions	Examples
Cursoriallegs – they are adapted for running		Ground beetles Cockroaches Ants
Raptoriallegs – they are adapted for catching and holding their prey		Praying insects – mantids
Natatoriallegs – they are adapted for swimming		Diving bugs Water beetles

Fossoriallegs – they are adapted for digging in soil		Mole crickets Dung beetles
Saltatoriallegs – they are adapted for jumping		Grasshoppers Cricket

Raptorial legs. Usually, it is the front pair of grasping legs of some predatory insects such as mantis. They have elongated and powerful femur and tibia for capturing prey.

Swimming (Natatorial) and Skating legs. Many aquatic insects (beetles, bugs) swimming or diving by using their middle and hind legs as oars which are usually flattened or equipped with a fringe of long, stiff hairs to improve their efficiency in the water. Some aquatic insects (e.g. water striders) have a whorl of hydrophobic hairs on the tips of their legs and it allows them to skate on the surface of the water.

Digging (Fossorial) legs. The first pair of digging legs are transformed into short, thickened limbs, equipped with powerful muscles and ending with a rounded, flattened tibia with serrations; the tarsus may be underdeveloped.

Jumping (Saltatorial) legs. These legs have powerful, markedly thickened femur, containing the main muscles acting when jumping.This construction allows a grasshopper to jump vertically 10 times its body length and I horizontally 20 times its body length.

Questions for self-check:

1. List the parts of insect legs.
2. What is the name of the insect leg between the tarsus and the femur?
3. What are the most powerful parts of an insect leg?
4. Explain the name "tarsus".
5. Give a name to a pair of lobe-shaped pads for some dipterans, located under the claws.
6. What type of legs do ground beetles have?
7. What type of legs do grasshoppers have?

9 THE STRUCTURE OF THE WINGS OF INSECTS. TYPES OF WINGS. LOCOMOTION

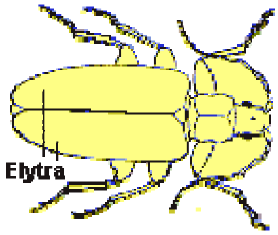
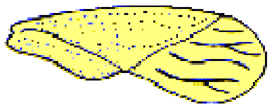
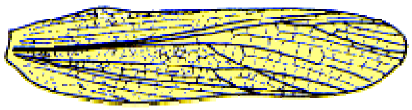
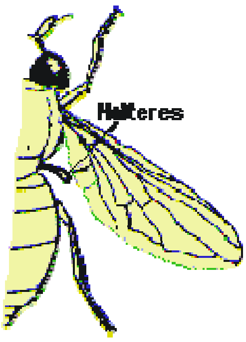
1. Origin of wings.
2. Wing morphology.
3. Kinds of wings.
4. Number and design of wings.
5. Adapations and modifications of wings.
6. Wing venation.
7. Principales of fly of insects.

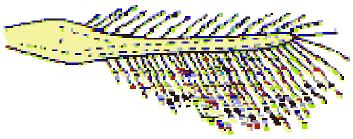
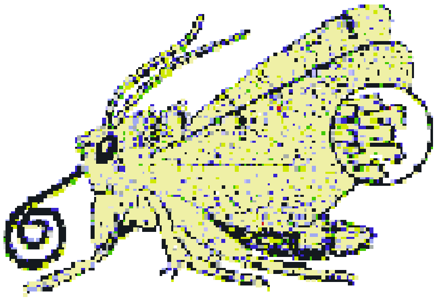
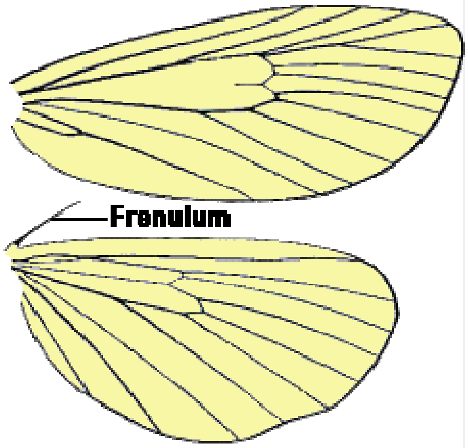
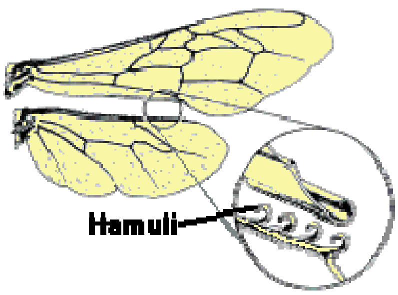
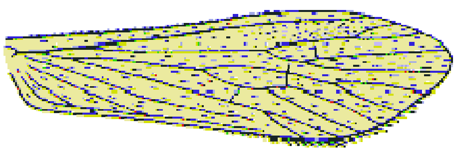
Insects have active flight, and they are only invertebrates with such ability. It is one of the most important factors have played an important role in their life success. Most insects have two pairs of wings. Forewings are located on the mesothorax and hindwings on the metathorax. Wings play a different role but first of all, they are organs of flight. In addition, they have some other additional functions in some insects such as the protective heavily sclerotized covers (Coleoptera and Dermaptera), gyroscopic stabilizers (Diptera), thermal covered collectors with scales and visual cues for species recognition and sexual contact (Lepidoptera), sound producers (some Orthoptera). The wings have fully functions only in the adult stage.

The wings of the insects are a two-layer fold of the integument, which come together, harden and form a thin elastic lamina and develop as evaginations of the exoskeleton during morphogenesis. Between the folds are tubular nodules (veins), which form the supporting skeleton of the wing. Their muscles can contract multiple times for each single nerve impulse, and the wings to beat very fast.

All wings of insects are classified according to three characteristics: by consistency, density, venation and pubescence.

Wing adapations and modifications

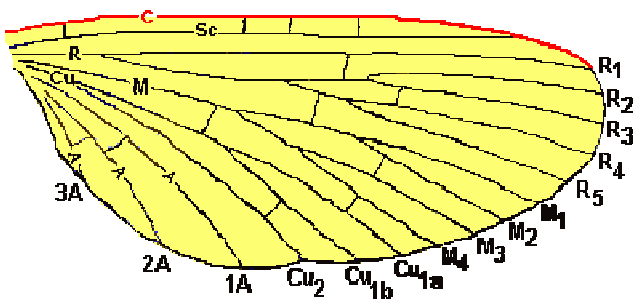
Names	Constructions	Examples (Orders)
Elytra		**Coleoptera, Dermaptera** They have hard, sclera-tized front wings. They are the protective covers for membranous hind wings
Hemelytra		**Heteroptera** They have leathery or parchment-like at the base of front wings and membranous near the tip
Tegmina		**Orthoptera, Blattodea, Mantodea** They have leathery or parchment-like front wings
Halteres		**Diptera** They have small, club-like hind wings as gyroscopic stabilizers during flight

Fringed wings		**Thysanoptera** They have slender front and hind wings with long fringes of hair
Scaly wings		**Lepidoptera** They have covered with flattened setae (scales) front and hind wings
Frenulum		**Lepidoptera** They have bristle near base of hind wing that holds front and hind wings together
Hamuli		**Hymenoptera** They have tiny hooks on hind wing that hold front and hind wings together
Hairy wings		**Trichoptera** They have front and hind wings clothed with setae

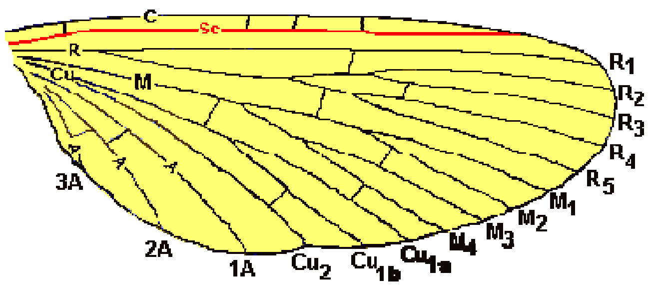
Wing Venation

According to scientific hypotheses, all winged insects have evolved from a common ancestor, and wing venation can represent the "template" that has been modified by natural selection for 200 million years. The venation is diverse in different groups of insects and is an important feature in their determination. The main sign of the structure of the wings are the number and characteristics of the location of the veins, or venation.

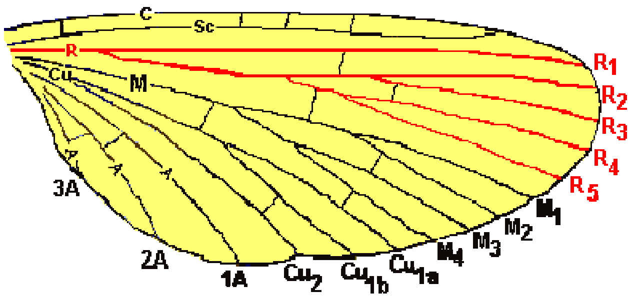
There are three angles on the wing plate: the base, the back angle, the top. The sides of the triangle formed by the edges of the wing also have their names. The anterior, or costal, edge is located between the base and the top of the wing, the outer edge is between the apex and the posterior angle, the posterior, or inner, edge is between the base and the anterior angle of the wing such below:



Costa (C) – runs along the front edge of the wing
Костальная жилка (C) – проходит вдоль переднего края крыла, переднего края крыла

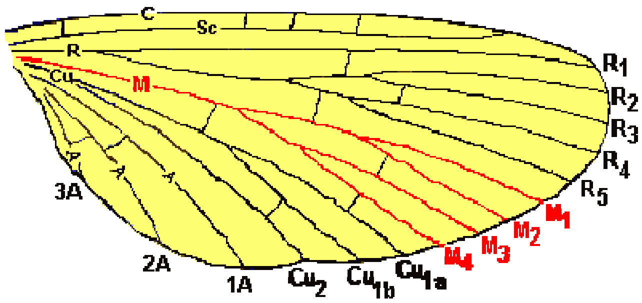


Subcosta (Sc) – leaves the root of the wing and merge with the costal beyond the middle of the front edge of the wing, second longitudinal vein behind the costa.
Субкостальная (Sc) – выходит из кореня крыла и сливается с костальной жилкой за серединой переднего края крыла, вторая продольная жилка после костальной



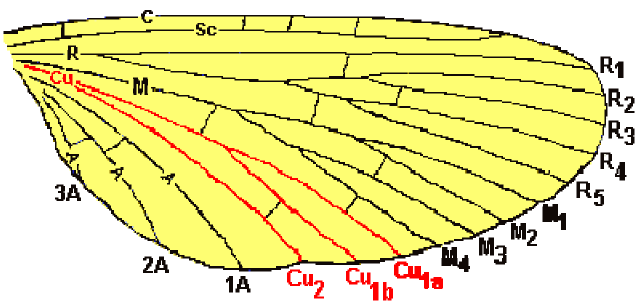
Radius (R) – third longitudinal vein extends from the wing root, restricts the central cell from the top, one to five branches reach the wing margin

Радиальная (R) – третья продольная жилка выходит из корня крыла, ограничивает центральную ячейку сверху, от одной до пяти ветвей достигают края крыла



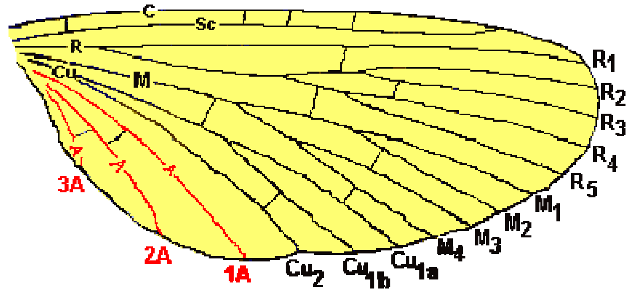
Media (M) – fourth longitudinal vein starts from the middle of the wing and gives one to four branches reach the wing margin

Медиальная (M) – четвертая продольная жилка начинается от середины крыла и дает от одной до четырех достигающих края крыла ветвей



Cubitus (Cu) – fifth longitudinal vein extends from the wing root, restricts the central cell to the bottom and gives one to three branches reach the wing margin

Кубитальная (Cu) – пятая продольная жилка простирается от корня крыла, ограничивает центральную ячейку снизу и дает от одной до трех достигающих края крыла ветвей



Anal veins (A1, A2, A3) – unbranched veins behind the cubitus extending from the wing root
Анальные (A1, A2, A3) – неразветвленные жилки за кубитальной, идущие от корня крыла

There are some crossveins named according to their position relative to longitudinal veins (e.g.crossveins run between the costa and subcostal are c-sc; bewteen adjacent branches of the radius - r; between the radius and media - r-m; between the media and cubitus - m-cu).

Flight

The insect's wings have the freedom to move up and down through an arc of more than 120 degrees by a complex hinge joint. The wings move up and by contraction of dorsal-ventral muscles, but they have not direct contact with the wings (Figure 17).

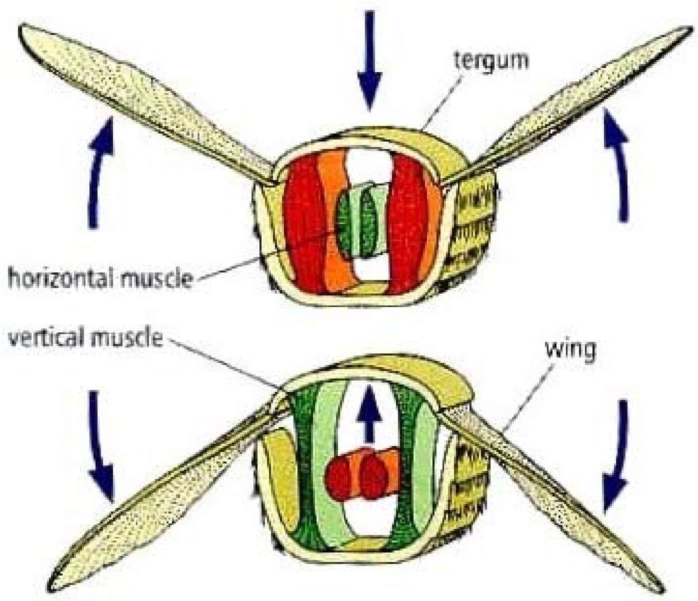


Figure17. Horisontal and vertical muscles for moving the wings of insects (source: https://i.pinimg.com/736x/55/3b/67/ 553b67746fe 180293be349626f154272--wind-power-sustainable-living.jpg)
Рисунок 17. Горизонтальные и вертикальные мышцы, обеспечивающие движения крыльев насекомых

The elasticity of the thoracic sclerites and hinge mechanism conserve 85% of the energy involved in the upstroke of the wings as potential energy during force down of the wing.

Insects of the orders Odonata and Blattodea (and some another primitive insects) have another principle of the downstroke which initiated by basalar muscles that attach directly to the wing's axillary sclerites and the contraction of these flight muscles pulls the wings down. Other insects have dorsal-longitudinal muscles attached to apodemes at the front and back of thoracic segments and by their contraction the wings to snap down.

During flight, upstroke and downstroke muscles must contract in alternating sequence. There are different mechanisms controlling for upstroke and downstroke muscles during flight: 1) neurogenic (synchronous) when each contraction is triggered by a separate nerve impulse 10-50 beats per second; 2) myogenic (asynchronous), when flight muscles for upstroke (dorsal-ventrals) and downstroke (dorsal-longitudinals) contract spontaneously if stretched beyond a certain threshhold, each in response to stretching by the other, after the signal of the nervous system, in some insects (e.g. flies and bees) it may be 500-1000 beats per second.

Questions for self-check:

1. What is the origin of wings?
2. To which segments of the thorax of insects are the elytra attached?
3. Characterize the wings of the bug.
4. Characterize the wings of the grasshopper.
5. Describe the flight of insects.

10 ABDOMINAL PART OF INSECTS AND ITS APPENDAGES

1. Abdominal part of the insects.
2. The segmental composition of the abdomen.
3. Types of abdomen of insects.

An abdomen of insects is located just behind the thorax. The maximum number of abdominal segments is 12, including the tail component – telson, which carries the anus and is devoid of appendages. However, in this form, the abdomen was preserved only in representatives of the order Protura. Due to abdominal oligomerization, the number of visible segments in other insects is reduced to 9–10 (orthopterans), and in the higher groups (some hymenopterans, two-winged) even 4–6.

Often the correspondence between the numbers of tergites is lost in the abdomen, and it is not uniform, for example, the male black cockroach has 10 tergites and 9 sternites, and the female has 8 and 7, respectively.

In some of the hymenopterans (wasps, bees, horsemen), the first segment of the abdomen is included in the thorax, forming an intermediate segment, or propodeum. Ants include the 2nd and the 3rd segment.

By the nature of the articulation with the thorax, there are three types of abdomen (Figure 18):

- sessile (attached to the metathorax with all its base, without forming constriction – typical of most insects);
- hanging (has a short constriction due to the propodeum – bees);
- hanging (has a long constriction – ants, wasps, horsemen).

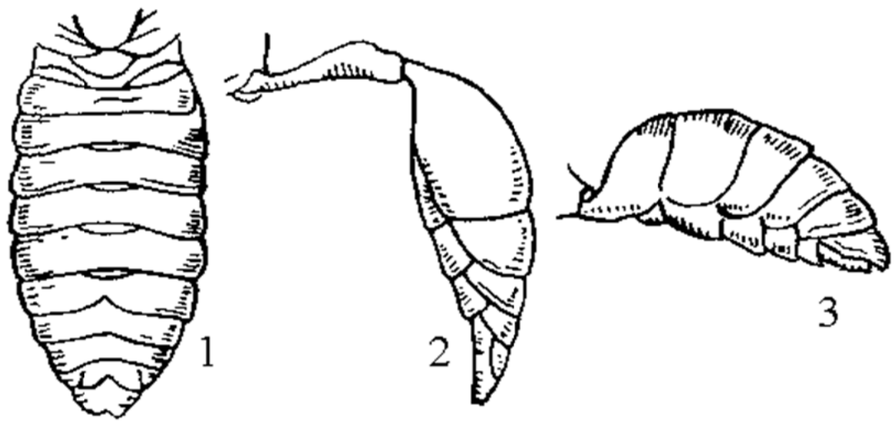
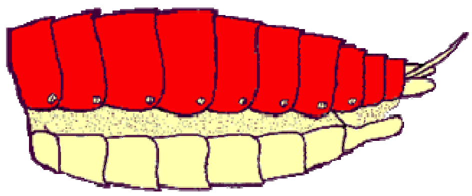


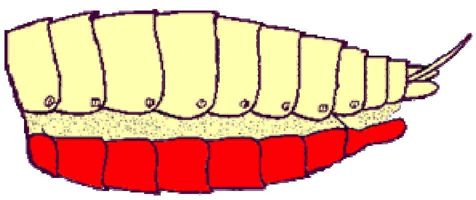
Figure 18. Insect abdomen attachment types: 1 - sessile; 2 - stalked; 3 – hanging (source: http://biofile.ru/pic/bio170b-023.png)
Рисунок 18. Типы прикрепления брюшка у насекомых:
1 – сидячее; 2 – стебельчатое; 3 – висячее

Each segment consists of a dorsal sclerite (tergum), and a ventral sclerite (sternum), joined by a lateral pleural membranes.On side of the first eight abdominal segments there are openings to the respiratory system (spiracles).

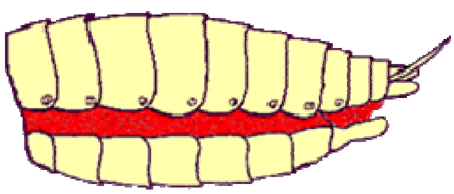
Tergum
Тергит



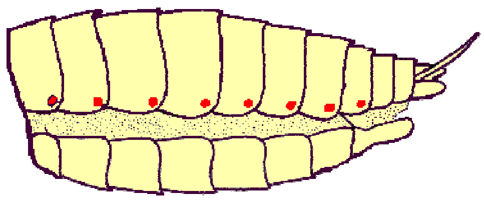
Sternum
Стернит



Pleural membrane
Превральная
мембрана



Spiracles
Дыхальца



On the 8th and 9th abdominal segments, the external genitalia, or **genitals**, are located. In this regard, these segments are called genital, the preceding 1–7th segments are **pregenital**, and the last two segments, the 10th and 11th, are **postgenital**.

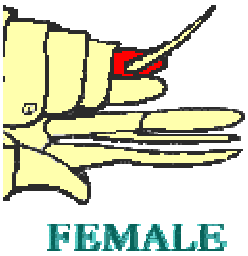
In the pregenital abdominal segments, the appendages are found only in the most primitive Insecta-Entognata. Thus, in the case of proturans (Protura), rudimentary legs remained on the 1–3 segments of the abdomen. Some of the springtails (Collembola) have a **collophore** (abdominal tube**)** on the 1st segment, on the 3rd segment there are **retinaculum** and on the 4th one **– furcula** ("jumping forks"). Many diplurans (Diplura), and bristletails (Tizanura) on various segments of the abdomen including postgenital, there are **retractable sacs** and elongated non-segmented appendages – **stylus**.

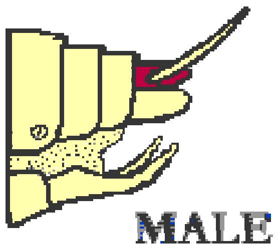
Among the appendages of post-genital segments of Insects-Entognatha, one can find a pair of **cerci** on the 10th and 11th segments of the abdomen. The representatives of the Family Campodeidae from the Order Diplura, they are long and articulate, in the Family Japygidae - short, non-jointed, mite-like. Many Tyzanura, in addition to the long segmented cerci, have multi-segmented **caudal filaments**.

Among the appendages of the post-genital segments, there are **styles** and **cerci**. The one pair of styles are preserved in male of cockroaches and grasshoppers. Long articulate cerci are present in mayflies, short ones in cockroaches. In earwigs, cerci turned into large, unsegmented mites.

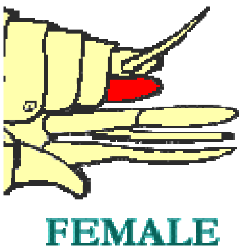
The tergite of the 11th segment forms the **anal plate**, or **epiprokt**, lying above the anus, and the sternite residues – a pair of plates on its sides – **paraprocts**. In cockroaches, however, the epiproct is called the **anal plate**.

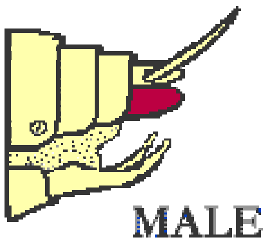
Dorsal epiproct
Спинной эпипрокт



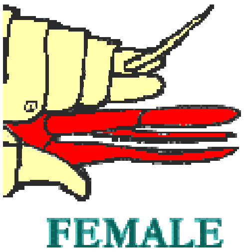


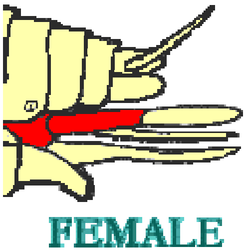
Lateral paraproct
Боковой парапрокт

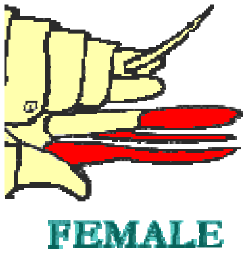




Insects have external genital appendages (genitalia). The copulatory organ in the male has name aedeagus, located on the eighth and nine segments of the abdomen. The genital opening of insects is located just below the anus. The paired external appendages of the eighth and ninth segments of the abdomen of females joined together and form the ovipositor – the egg-laying structure.







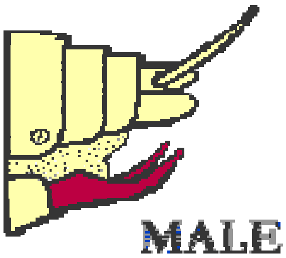
Ovipositor
Яйцеклад

Valvifers
Генитальные
лопасти

Valvulae

These appendages consist of four valvifers (basal sclerites with muscle attachments) and six valvulae (apical sclerites which guide the egg as it emerges from the female's body).

Aedeagus (claspers)
Эдиагус



In **males**, the genital opening is usually enclosed in a tube-like **aedeagus** which enters the female's body during copulation (like a penis). The external genitalia may also include other sclerites (e.g. subgenital plate, claspers, styli, etc.) that facilitate mating or egg-laying. The structure of these genital sclerites differs from species to species to the extent that it usually prevents inter-species hybridization and also serves as a valuable identification tool for insect taxonomists.

Other abdominal structures presented in some insects are below:

Abdominal gills – respiratory organs of the naiads (nymphs) of some aquatic insects (paired gills along the sides of each abdominal segment in mayflies (Ephemeroptera); the gills attached to the end of the abdomen in damselflies (Odonata),

Abdominal prolegs – fleshy, locomotory appendages found only in the larvae of some orders (Lepidoptera, Mecoptera and some Hymenoptera).

Collophore – a fleshy, peg-like structure on the ventral side of the 1st abdominal segment in Collembola to maintain homeostasis by regulating the absorption of water from the environment (Figure 19).

Furcula – the jumping organ ("springtail") on the ventral side of the fifth abdominal segment in Collembola(Figure 19).

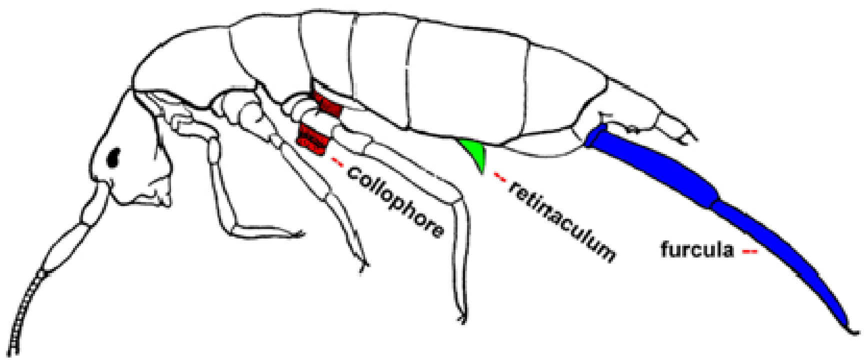


Figure 19. Collophore, furcula and retinaculum in Collembola (source: https://bugwoodcloud.org/bugwoodwiki/thumb/Collembola.jpg/350px-Collembola.jpg)
Рисунок 19. Брюшная трубка (коллофор), прыгательная вилочка (фуркула) и зацепка (тенакулум) у коллембол

The **tenaculum (a clasp)** on the third abdominal segment which holds the springtail in its "cocked" position (Figure 19).

Median caudal filament – some "primitive" orders Diplura, Thysanura, Ephemeroptera (Figure20) have a thread-like projection arising from the center of the last abdominal segment between the cerci.

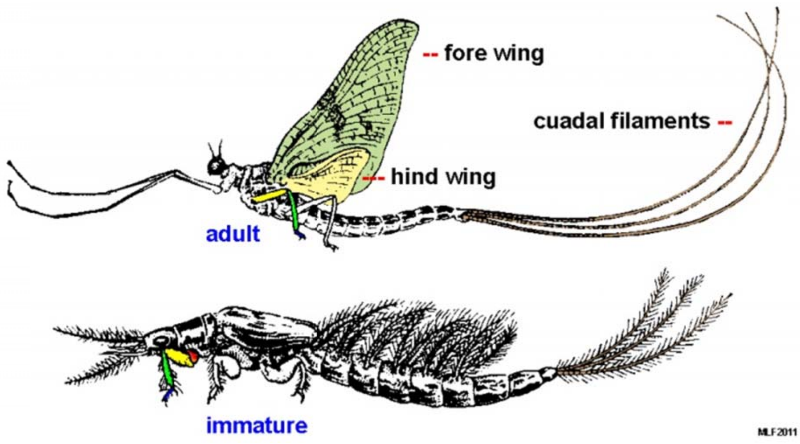


Figure 20. Median caudal filament of mayfly (Ephemeroptera) (source: http://bugwoodcloud.org/bugwoodwiki/thumb/Ephemeroptera.jpg/350px-Ephemeroptera.jpg)
Рисунок 20. Срединная хвостовая нить поденки (Ephemeroptera)

Pincers-representatives of order Dermaptera (earwigs) have heavily sclerotized and forceps-like cerci, which used for defense. (Figure 21).

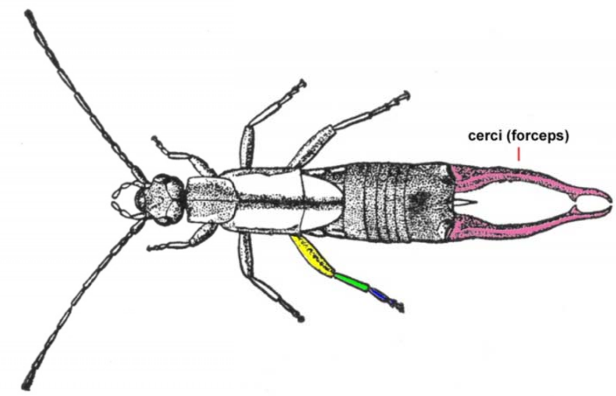


Figure 21. Pincers (cerci) on the abdomen of insects (earwigs) (source: https://bugwoodcloud.org/bugwoodwiki/thumb/Dermaptera.jpg/350px-Dermaptera.jpg)
Рисунок 21. Клещи (церки) на брюшке насекомых (уховертка)

Sometimes they help in folding the wings or during courtship.

Sting – a modified ovipositor in the females of **aculeate** Hymenoptera (bees, predatory wasps, and ants) (Figure 18).

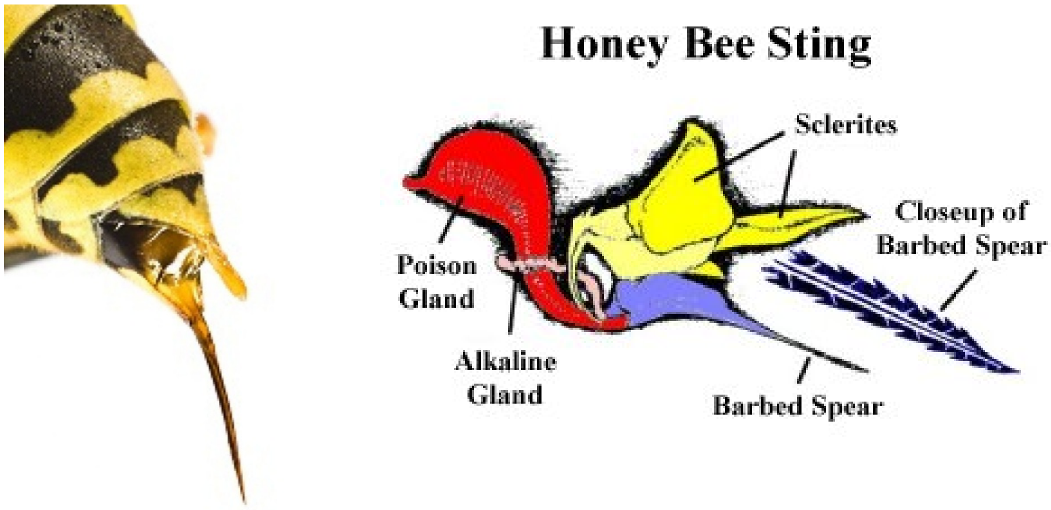


Figure 22. Sting in insect (source: http://lclawyers.com.au/wp-content/uploads/2016/08/1405313696585-1892-768x1149.jpg
Рисунок 22. Жало у насекомых (перепончатокрылые)

Cornicles – paired of the secretory structures located dorsally on the abdomen of aphids. They produce substances repeled predators or for stimalation the care-giving behavior of symbiotic ants.

The ovipositor of the representatives of the Order Orthoptera consists of three pairs of differently developed valves: the first pair departs from the first paired egg-laying plate of the 8th abdominal segment, the second and third pairs from the base and the top of the second paired egg-laying plate of the 9th abdomen. All three pairs of valves, folding together, form different ovipositors. In the grasshopper females, it has a saber-shaped form, in crickets it is spear-shaped, etc. (Figure 23).

In other insects (Coleoptera, Diptera), a secondary, or false, ovipositors. It is formed from reduced in diameter of the last segments of the abdomen, moving into each other, for what is sometimes called telescopic.

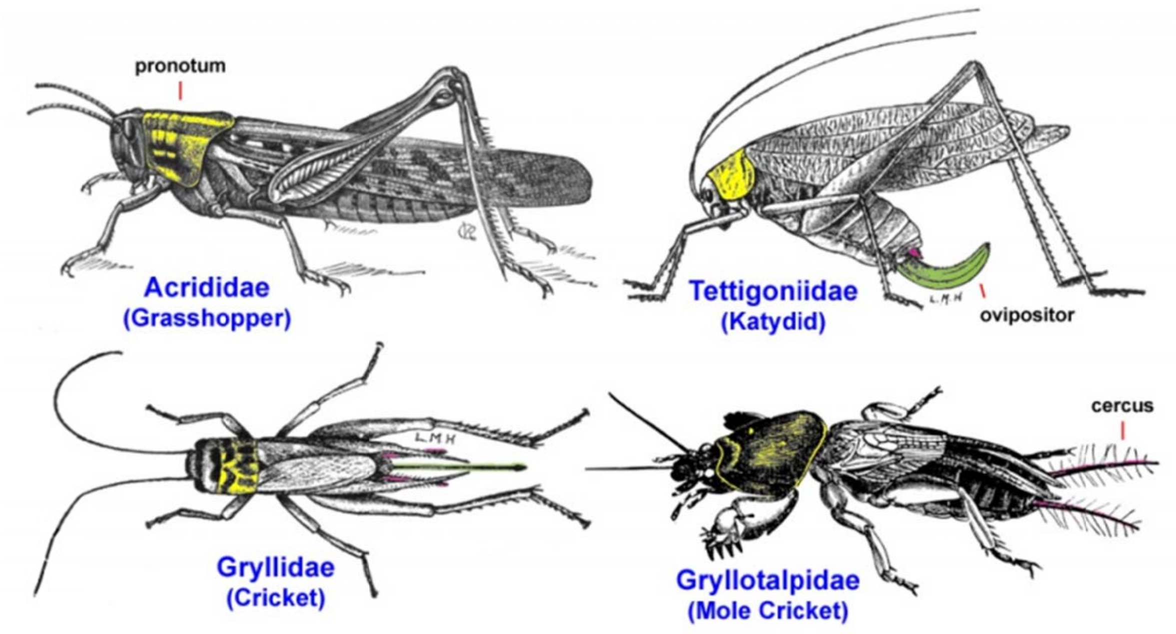


Figure 23, Ovipositors in some Orthoptera (source: https://s3.amazonaws.com/classconnection/592/flashcards/1859592/jpg/450px-orthoptera-14C2FD6DCF634FCAE8E.jpg)
Рисунок 23. Яйцеклады некоторых прямокрылых

Questions for self-check:

1. What is the origin of ovipositors?
2. Which insects have the median caudal filament?
3. Characterize the wings of the bug.
4. Characterize the wings of the grasshopper.
5. Describe the flight of insects.

CONCLUSION

This textbook includes materials on the external structure of insects – the most diverse class of the animal world. The covers of insects (integument, or exoskeleton) and their structure, the main parts of the body of insects and their appendages are considered step by step.

In addition, the students could learn a brief history of entomology – an important branch of zoology and its main division. For more detailed study, at the end of each section, questions and tasks are set. The students can check how much they have understood and may be motivated to learn more about the topic. A glossary at the end of the textbook could be found useful by students as well as a list of references and recommended literature, appendices and illustrations.

This textbook is the first part of a series about the structure and diversity of insects, which is planned to continue.

List of References and Recommended Literature

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16.*Systema Nature, 2000* / Brands Sheila J., (comp.). 1989 – 2008. URL: http: //sn2000.taxonomy.nl/

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18. *Clow.ru: Biology for schoolchildren*. URL: http://bio.clow.ru

GLOSSARY

Abdominal filaments – thread-like processes located at the end of the abdomen ofsome insects (Ephemeroptera).
Брюшные филаменты – нитевидные отростки, расположенные на конце брюшка некоторых насекомых (Ephemeroptera – поденки).

Aedeagus – male copulatory organ of insects.
Эдеагус – копулятивный орган у самцов насекомых

Analogous - structures with similar functions but different evolutionary origins, such as the wings in birds versus insects
Аналогичные - структуры со схожими функциями, но различного эволюционного происхождения, такие как крылья у птиц и насекомых.

Cerci – paired sensory projections from the terminal abdominal segment.
Церки – парные сенсорные придатки конечного брюшного сегмента

Elytra (Elytron) – Hardened, protective forewings of Coleoptera.
Надкрылья – твердые, защитные передние крылья жестко-крылых (Coleoptera).

Halteres (Halter) – knob-like reduced hindwings of Diptera and forewings in Strepsiptera, its function is as gyroscopic instruments in flight:

Жужжальца – уменьшенные задние крылья двукрылых или передние крылья у веерокрылых, их функция как гироскопических приборов в полете.

Hemelytra – half-hardened, half-membranous forewings of Hemiptera (Heteroptera)

Гемелитра – полутвердые, полуперепончатые передние крылья перепончатокрылых Hemiptera (Heteroptera).

Homologous – structures with similar evolutionary origin but different function, such as the different forms of mandibles in insects.

Гомологичные – структуры с похожим эволюционным происхождением, но разной функцией, такие как различные формы мандибул у насекомых.

Hypopharynx – tongue-like, bears openings of salivary ducts.

Гипофаринкс – языкоподобный, несет отверстия слюнных протоков.

Labium – lower lip.

Нижняя губа.

Labrum – upper lip, a flap-like structure that lies immediately in front of the mouth.

Верхняя губа – похожая на пластику структура, которая лежит непосредственно перед ртом.

Mandibles – jaws. Their function is typically to grasp, crush, or cut the insect's food, or to defend against predators.

Мандибулы – верхние челюсти. Их функция, как правило, заключается в том, чтобы схватить, раздавить или порезать пищу насекомого или защитить от хищников.

Mandibulate mouthparts – used for biting and grinding solid foods.

Мандибулярные ротовые части – используются для кусания и измельчения твердой пищи.

Maxillae – situated caudal to the mandibles, paired maxillae manipulate and, in chewing insects, partly masticate, food. Each maxilla consists of two parts, the proximal *cardo*, and distal *stipes*. At the apex of each stipes are two *lobes*, the inner l*acinia* and outer *galea* more jaws.

Нижние челюсти – парные челюсти манипулируют и, при жевании насекомых, частично жуют, пищу. Каждая верхняя челюсть состоит из двух частей: проксимального кардо и дистальных ножек. На вершине каждой ножки по две доли, внутренняя лациния и внешняя галея больше челюстей.

Forewing.

Переднее крыло

Hindwing.

Заднее крыло.

Notum – dorsal plate or sclerite, dorsal portion of an insect's thoracic segment.

Notum – дорсальная пластинка или склерит, дорсальная часть грудного сегмента насекомого.

Ovipositor – egg-laying apparatus (may be modified for other purposes)

Яйцеклад.

Piercing-sucking mouthparts – have stylets, and are used to penetrate solid tissue and then suck up liquid food.

Колюще-осущий ротовой аппарат – имеет стилеты и используется для проникновения в твердые ткани, а затем всасывания жидкой пищи.

Pleuron – a lateral sclerite of thoracic segment of an insect between the tergum and the sternum, often membranous.

Плейрон – латеральный склерит грудного сегмента насекомого между тергитом и стернитом, часто перепончатый (мембранный).

Pronotum – the dorsal sclerite on the prothorax**.**

Переднеспинка – дорсальный склерит на переднегруди.

Sclerotization – hardening of insect exoskeleton to make a strong, armor-like 'skin'.

Склеротизация – отвердение экзоскелета насекомых с образованием прочной бронеподобной «кожи».

Siphoning mouthparts lack stylets and are used to suck liquids, and are commonly found among species of Lepidoptera.
Сосущий ротовой аппарат – отсутствуют стилеты, используется для всасывания жидкостей и обычно встречается среди видов чешуекрылых.

Sternum – the ventral portion of a segment of an arthropod thorax or abdomen
Стернум – вентральная часть сегмента членистоногого грудного отдела или брюшной полости

Tarsus (pl. tarsi) – last section of insect legs. It consists of several segments (tarsomeres).
Тарсус (лапка) – последний участок ножек насекомого. Он состоит из нескольких сегментов (tarsomeres).

Thorax – middle section of the insect's body,
Торакс (грудь) – средняя часть тела насекомого.

List of figures:

APPENDIX A

The labeles of some Entomological Societies

APPENDIX B

Mouthparts of insects (source: http://cdn.biologydiscussion.com/wp-content/uploads/2016/03/clip_image002_thumb-146.jpg)

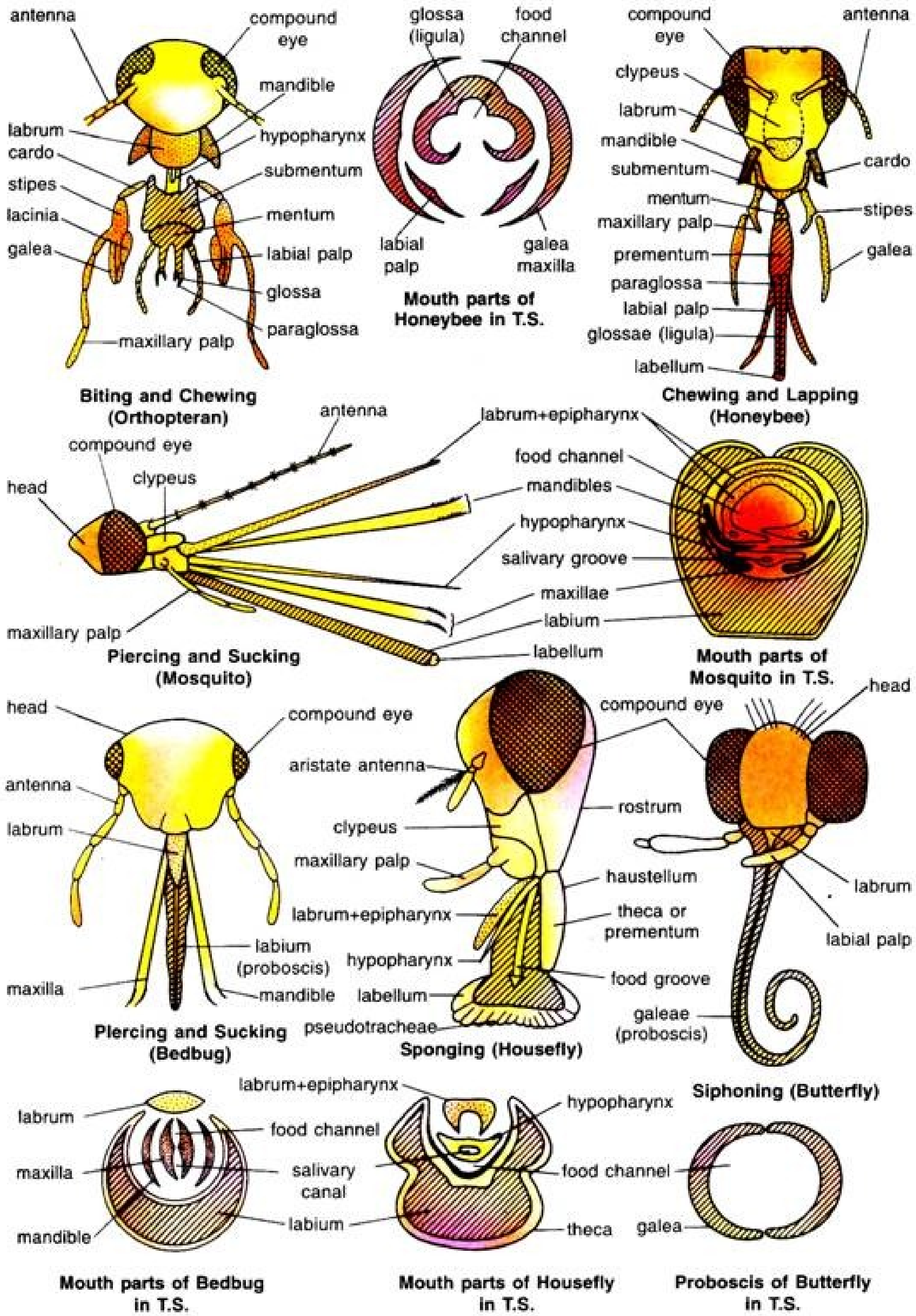
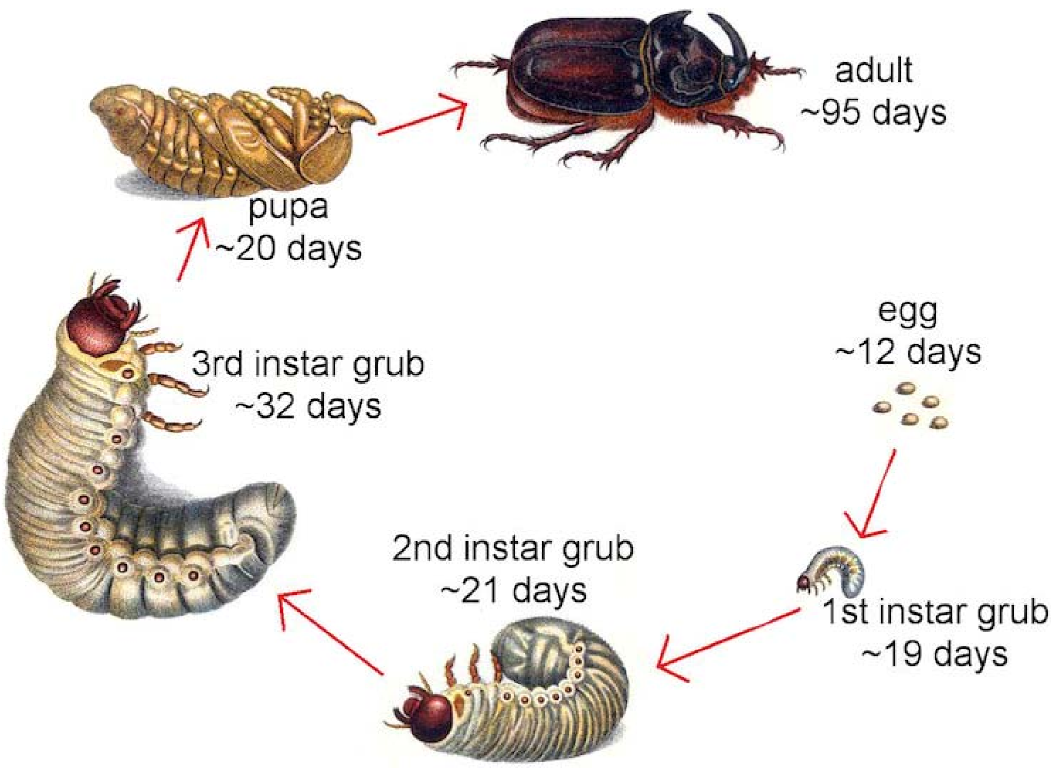


Fig. 82.3. Mouth parts of insects.

APPENDIX C

Lifecycles of some insects

Source: http://modernservantleader.com/wp-content/uploads/2013/04/butterfly-lifecycle-w.jpg



Source: https://plantheroes.org/sites/default/files/coconut_rhinoceros_beetle_life_cycle_small_1.jpeg