ENTOMOLOGY

(MEDICAL AND VETERINARY)

BY

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To

MY WIFE

Whose constant encouragement made this effort possible.

PREFACE

On account of the war scarcity of books particularly of a technical nature has been experienced in India and with a view to easing the situation, the author undertook to write a book on medical entomology with the object of providing medical and veterinary students also public health workers with a treatise containing up-to-date information on the life history and bionomics of disease-carrying insects.

The information embodied in this book has been collected from various sources. A special effort has, however, been made to present the subject matter briefly without in any way affecting the essential details. It is not possible to provide keys which can be used for the identification of different insects. This would require a big volume by itself. However, taking into consideration the importance of *Anopheles* mosquitoes in the tropics, these have been exhaustively dealt with in this book. Keys and tables for the identification of adults and larvæ have been given. The key is mainly based on one salient character whereas in the table more than one distinctive feature has been given for a species. The beginner is advised to proceed with the identification with the help of the key, and where necessary, the identification thus made may be confirmed with the help of supplementary characters given in the table. The illustrations have not been drawn to any particular scale. As it is intended to bring out a short volume on insecticides and their practical application in medicine and public health, a separate chapter dealing with this very useful subject has been omitted.

The llustrations have been executed by Mr. J. K. Mullick. the artist, whose debt is acknowledged. The author is indebted for criticism, useful suggestions and other help to several colleagues among whom special mention should be made of Dr. S. M. Ghosh, his associate in the same department and Dr. N. Bhaduri, Research Worker in Helminthology. Dr. P. Bose of the Microbiology Department in the All-India Institute of Hygiene and Public Health was also kind enough to place at the author's disposal some specimens of mosquitoes and their larvæ from which drawings were made. Dr. A. G. McClymont deserves mention for help in the preparation of the manuscript for the press.

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The 25th January, 1946.

INTRODUCTION

Although it was known as early as 1869 that the embryos of guinea-worm are carried by water-fleas or cyclops, it was not till the discovery by Ronald Ross in 1898 of the relationship between malaria and mosquitoes that sufficient importance came to be attached to that aspect of entomology which is useful in preventive medicine. Entomology is really a branch of zoology but the medical man attaches the least importance to details of morphological or histological characters except those that have a direct bearing on the identification of the disease-producing agents. He pays special attention to their life history, bionomics, and natural enemies, his sole object being to discover a weak point in their life which will enable him to undertake the necessary measures to cope with the nuisance. Such measures should not only be effective but at the same time cheap, and easy to carry out.

It will thus be apparent that medical entomology has now a separate status which has its background in preventive medicine. The present war in the Far East has proved beyond doubt that entomology is the foundation of tropical medicine.

The word "Entomology" is derived from the Greek which signifies the science of insects. Strictly speaking therefore it should include the study of insects alone. Its scope has, however, been extended to comprise all animals in the phylum Arthropoda which in addition to insects also includes ticks, mites, tongue-worms, water-fleas, scorpions, centipedes etc.

On account of the presence of jointed appendages in at least one member of the phylum Annelida, there has been a tendency to include the two phyla, Annelida and Arthropoda, in a single phylum Appendiculata, and to give them the rank of subphyla. We will, however, consider them as separate phyla.

The animal kingdom is broadly divided into two sub-kingdoms, Protozoa or unicellular and Metazoa or multicellular animals. The latter is again subdivided into a large number of groups called phyla, and those of a lower order and which contain the important parasitic species are given below:

(*a*) Platyhelminthes (tapeworms, flukes etc.)
(*b*) Nemathelminthes (roundworms, flukes etc.)
(*c*) Mollusca (snails)
(*d*) Annelida (earthworms and leeches)
(*e*) Arthropoda (insects, ticks, mites etc.)

CONTENTS

PHYLUM ANNELIDA

The body is elongated and divided by a number of rings; the body cavity is a true coelom being lined by layers of mesoderm.

It comprises three different types of worms.

1. OLIGOCHAETA (earthworms): the locomotor appendages consist of chitinous setæ or bristles attached in rows to the sides and ventral surface.

2. POLYCHAETA (bristle worms): the parapodia are highly developed bearing numerous long setæ. There is a definite head with eyes and tentacles.

3. HIRUDINEA (leeches): possess locomotor and adhesive suckers either at both extremities or posteriorly; bristles on the body are absent.

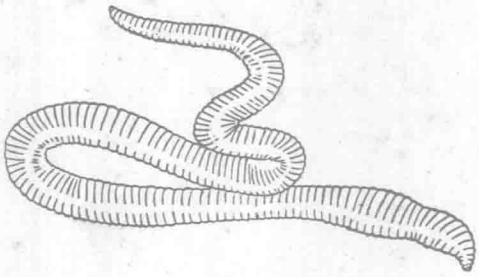

FIG. 1.
An earthworm.

OLIGOCHAETA or earthworms: These have been included by Blanchard among the pseudoparasites of man. Heymons (1926) and Müller (1926) have reported freshwater oligochaeta being passed in living states by patients. The species involved was *Pachydrilus lineatus*.

POLYCHAETA or bristle worms: Though the bristle worms are essentially marine animals they are very adaptable to changes in their environment, such as the salinity of water in which they may find themselves. There are only two instances where their occurrence in the human body has been reported. In the first case a specimen of the genus *Nereis* was evacuated from the nasopharynx of an adult individual who complained of coryza and severe headache. (Biswas and Strickland, 1927). The second case was reported by Strickland and Roy, (1933) where the specimen belonged to *Nereis* (Lycoris) *verille*, Grube, a typical marine species, which was passed in the stool of a child about 2 years old.

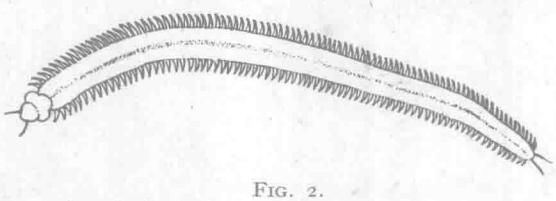

FIG. 2.
A polychæte (after Strickland and Biswas).

HIRUDINEA or leeches: The common leeches which concern us are (*a*) *Hæmadipsa zeylanica*; (*b*) *H. sylvestris*; (*c*) *Limnatis nilotica*; (*d*) *Dinobdella ferox*; (*e*) *Hirudo medicinalis* and (*f*) *H. birmanica*. Their distribution and habitat are as follows.

H. zeylanica Moq-Tand.

This leech has a wide distribution throughout south eastern continental Asia and the Oriental islands. It is the only land-leech in Ceylon and is not found on the Indian mainland. They are extremely small and wiry looking. They are an intolerable pest in Ceylon attacking man and domestic animals.

FIG. 3.
Diagram of a leech.

H. sylvestris Blanchard.

In the living state they are much thinner than they appear in the preserved condition. This is the principal land-leech in Assam, Darjeeling, Sikkim and Burma.

A land-leech bites, and drops down on the ground after it has fed. It crawls up from the foot or shoes. It shows no colour preference. Its olfactory organs are poorly developed ; it is not roused to activity by vibration. It can see objects clearly at a distance of 12 feet, and by sight alone it discerns its prey. This is the reason why people in the rear of a party going along a track through leech infested country are generally attacked.

Human beings and cattle are its favourite hosts ; it shows a distaste for sheep and goats. It abounds in places where cattle graze; where cattle are absent, it is rarely found.

H. medicinalis Lin.

It is the common medicinal leech of Europe. In India this species is represented by *H. birmanica* which are found in tanks. They attack cattle.

L. nilotica Savig.

They are about 3 times as strong as the land-leech and are distributed in Palestine and Persia. They live in springs and similar water courses. They are known as "horse-leeches" on account of their habit of entering the air passages of horses and other domestic animals. The young leech is swallowed with drinking water and usually fastens on the mucous membrane of the mouth, pharynx, or larynx. In this situation it may even cause death of the host. Man is occasionally attacked ; in the last Gallipoli campaign several cases occurred among soldiers.

D. ferox Blanchard.

These are of very large size and are found in tanks, ponds and in marshes. They are essentially cattle leeches and the report of the oozing of blood from the nostrils of domestic animals refers to an invasion of the air passages by this species in India.The parasitic infestation is generally of long duration.

This species is widely distributed in India, Burma and Ceylon. In the dry zones and also in the deserts they are conspicuously absent.

H. birmanica Blanchard.

It is the common medicinal leech of India. It is found in rivers, streams, swamps, tanks or ponds. It is widely distributed in India.

ANTI-LEECH REMEDIES.

The following observations have been made by Roy and Ghosh:

Infusion of tobacco leaves, copper sulphate, and common salt are no doubt toxic to leeches but they do not possess any repellent properties. In this respect nearly all volatile oils such as oil of citronella, lemon grass oil, oil cassia, oil ocimum, are not only toxic to leeches when applied directly on their bodies, but they also possess some repellent properties. Of these oils, those of cassia and citronella seem to be the most powerful either when prepared with vaseline, a drachm to an ounce, and applied on the skin, or mixed with rectified spirit in the same proportion as above and sprayed on socks. When the treated parts are washed with water, the repellent action will still persist for at least six hours. If applied directly to the leather of shoes or boots the repellent is less effective. The spirit preparation should be sprayed with a De Vilbiss sprayer on the socks around the ankle about $2\frac{1}{2}$ inches above and $\frac{1}{2}$ to $\frac{3}{4}$ inch below and also opposite the eyelets of shoes ; complete protection against their bite for the whole day is thereby ensured.

Putties when wetted with infusion of tobacco leaves do not repel leeches but when they have crawled and stayed on the wet parts for about a minute or so, the animals are stupefied and are soon killed or they drop down in a semi-dead condition. Washing nut soaked in water is useful so long as it is wet, but as soon as the soap dries, it ceases to act.

TREATMENT OF INFESTATION OF THE NASOPHARYNX.

For the treatment of infestation of the nasopharynx *aqua aurantii floris* is ideal. When the official preparation (40 per cent strength) is diluted with an equal volume of water and sprayed by means of a De Vilbiss sprayer into the nasopharynx through the nostril in the case of cattle, and preferably through the mouth in the case of human subjects, it at once acts on the leech and causes it to become dislodged. This substance is extremely toxic to leeches. When *aqua aurantii floris* is not available, Eau De Cologne, which contains it, can be used. It is harmless to the mucous membrane.

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PHYLUM ARTHROPODA

The word Arthropoda has been derived from the Greek which signifies animals which possess jointed appendages. Entomology is no longer restricted to insects alone but it includes the study of the whole phylum Arthropoda. Insects form not only the largest group among this phylum but also the largest group of the animal kingdom. At least a quarter of a million different species have already been described. Besides being the largest, they are undoubtedly the most important group of arthropods. Other members of this phylum such as spiders, ticks, mites and centipedes also play some rôle in the well-being of man.

Although the presence of jointed appendages is an important feature of this phylum, it cannot be held as an axiomatic truth that all jointed limbed creatures must belong to this group. The chief characters distinguishing this phylum from others are:

(*a*) Presence of metameric segmentation of the body.

(*b*) Presence of bilateral symmetry of the body.

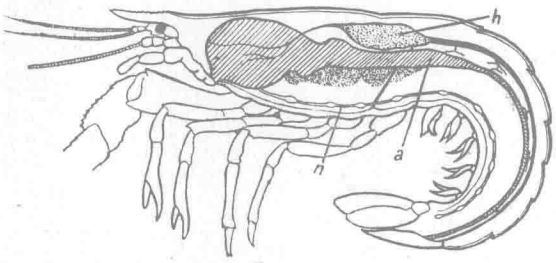

FIG. 4.

Side view of a prawn showing the relative positions of the alimentary canal, heart and nerve chain.

a, alimentary canal; h, heart; n, nerve chain.

(*c*) Central nervous system lies ventrally, the heart dorsally, and the alimentary canal between them.

(*d*) Each typical segment bears a pair of jointed appendages.

(*e*) Muscles are of the striped kind.

(*f*) Body cavity corresponding to hæmocœle which is in free communication with the circulatory system.

ARTHROPODA IN RELATION TO DISEASES AND DISCOMFORTS OF MAN.

(1) They are obnoxious pests, *e.g.*, house-flies, eye-flies etc.

(2) They bite, producing at times a certain amount of unpleasant after effects, *e.g.*, mosquitoes, fleas, ticks, lice etc.

(3) They produce a kind of diseased condition by their presence on the skin, in one of the natural orifices of the body, or in the intestine, *e.g.*, external and internal myiasis, scarabiasis or beetle infestation, etc.

(4) They produce dermatitis by their irritating effects, *e.g.*, spider-lick dermatitis, caterpillar hairs causing conjunctivitis, also dermatitis, etc.

(5) They produce symptoms of local and general toxæmia due to the introduction of a venomous glandular secretion, *e.g.*, centipede, spider, scorpion, wasp, etc.

(6) They carry disease germs mechanically, *e.g.*, house-flies and cholera, tabanid flies and trypanosome of surra, blood-sucking flies and anthrax, etc.

(7) They act as vectors or true intermediate hosts in which the development of the pathogenic organisms always takes place, *e.g.*, mosquitoes and plasmodial parasites of man and birds, mosquitoes and filaria, sandflies and leishmaniasis, tsetse fly and sleeping sickness etc.

How Arthropoda cause harm to animals.

(1) Loss of blood causing reduction of the yield of milk and deterioration of health.

(2) Mechanical carriers of disease germs of anthrax, surra, etc.

(3) True intermediate hosts of disease organisms, *e.g.*, ticks causing piroplasmosis, spirochætosis, etc.

(4) Flies of the family Oestridae cause considerable damage to hides and to meat.

(5) Paralysis and death may be caused due to some toxic action.

Classification:

In order to understand the systematic position of the different members in the animal kingdom, it is necessary to classify them into different groups and sub-groups, proceeding from the higher gradually to the lower grades. This classification is based generally on their external characters, *e.g.*, segmentation of the body, presence of wings ; in addition to these, metamorphosis and habitat are also taken into consideration. The following table represents an outline of the different grades into which Arthropoda is subdivided. Only those which are important to us have been included.

Phylum Arthropoda (jointed-limbed animals).

Class Myriapoda	Class Arachnida
(Centipedes & millipedes).	(Ticks, mites, etc.).
Class Crustacea	Class Hexapoda
(Prawns, crabs, cyclops).	(Insects).

Each class may be subdivided into subclasses, orders, suborders, families, subfamilies, genera and species. To illustrate this point, we take a mosquito.

Class—Hexapoda. Order—Diptera. Suborder—Orthorrapha.

Family—Culicidæ. Subfamily—Culicinæ. Genus—*Culex*. Species—*fatigans*.

All family names end in -idæ ; subfamily names similarly end in -inæ.

Each species represents both the genus and the species, *e.g.*, *Culex fatigans* in which *Culex* is the generic name and *fatigans* the specific name.

The generic name always starts with a capital letter and both are underlined.

Therapeutic uses of Arthropoda and their products.

(1) Use of malaria-infected mosquitoes for inducing malaria in cases of paresis.

(2) The treatment of arthritis with bee venom.

(3) The application of extracts from certain Meloid beetles as counter irritants.

(4) The use of blow-fly larvæ or extracts from them in the treatment of infected wounds.

(5) Leeches are employed for letting out blood.

(6) Hirudin has well-marked physiological properties.

Class Insecta
(Hexapoda)

The study of insects from an economical point of view is very important. It is seldom realised that all insects cannot be styled as pests, as some of them are no doubt beneficial to man. The part they play in the pollination of plants is the least appreciated by the ordinary man. Honey, silk, wax and cochineal dye are the products of insects. On the other hand, the well-being of man is entirely at the mercy of insects. They not only carry human and animal diseases, but also cause considerable harm to crops, plants and trees.

The Class Insecta is divided into many orders, the important among them being the following:

(1) Diptera (Mosquitoes and flies).
(2) Siphonaptera (Fleas).
(3) Hymenoptera (Ants, bees, wasps etc.).
(4) Lepidoptera (Butterflies and moths).
(5) Coleoptera (Beetles).
(6) Anoplura (Sucking lice).
(7) Mallophaga (Biting lice).
(8) Rhynchota or Hemiptera (Bugs).
(9) Orthoptera (Cockroach, locusts etc.).

The chief characters of Class Insecta are: (1) Body regionally divided into head, thorax and abdomen ; (2) Head carries a pair of jointed antennæ ; (3) Mouth parts are adapted either for chewing hard food or for sucking only liquid food ; some have their mouth adapted for piercing the skin and for sucking blood ; (4) Metamorphosis may be either complete or incomplete ; (5) Sexes are separate ; (6) Thorax carries 3 pairs of legs and 2 pairs of wings.

Type: Cockroach
(*Blatta orientalis* or *Periplaneta americana*)

Blatta orientalis: The pronotum is uniformly coloured without any dark markings.

Periplaneta americana: The pronotum has a faint yellowish border.

External structure.

Head: The head does not show any indication of segmentation but is really composed of a pre-antennary and five further segments, ultimately united together.

The head can be separated into the following regions:

(*a*) Epicranium covers the dorsal and posterior surfaces of the head. (*b*) Clypeus is a broad plate covering the front of the head below the epicranium. (*c*) Labrum, which is the upper lip. (*d*) Genæ or cheeks covering the sides of the head. behind and below the eyes. (*e*) Eyes are reniform elevations one on each side of the head. They are compound, being made up of numerous ommatidia.

The head bears: (1) A pair of many-jointed flagella-like antennæ. To the inner sides of the bases of the antennæ are a pair of small white oval patches called the fenestra and which represent a highly primitive ocellus.

(2) Mouth organs: (*a*) Labrum or upper lip overhanging the aperture of the mouth. (*b*) A pair of stout mandibles which lie below the genæ and articulate with the sides both of the epicranium and of the clypeus ; their inner edges are toothed. (*c*) Behind the mandibles are the first pair of maxillæ (jaws). Each maxilla consists of two segments, cardo and stipes, the latter supporting an outer lobe, the galea and an inner lobe, the lacinia. To the maxilla is attached a 5-jointed palp. While with the help of the powerful mandibles solid food is chewed, the maxillæ assist in holding and masticating the food. (*d*) Behind the first maxillæ are the second maxillæ which have the two basal segments united together into a single structure which supports the prementum ; the latter carries two pairs of distal lobes, an outer pair, paraglossæ, and an inner pair, the glossæ ; these two structures collectively form the ligula. The united 2nd maxilla is called the labium or lower lip. A pair of 3-jointed labial palps is attached to the prementum. A soft median process, the tongue (lingua or hypopharynx) is attached to the upper surface of the mentum.

Thorax: The thorax consists of three separate segments, prothorax, mesothorax and metathorax. The dorsal plate of each segment is called the tergum, the ventral plate is the sternum, and the plate which joins the tergum and the sternum laterally on each side is the pleuron.

Attached to the anterior border of the tergum of the mesothorax in the male are the anterior wings or elytra. These are highly chitinised and hard. They take no part in the flight of the insect and their function is merely to protect the more delicate second pair of wings which are membranous. When at rest they are kept folded up longitudinally like a fan under the elytra. The second pair of wings articulate with the tergum of the metathorax. In the female of *Blatta orientalis* the wings are vestigial.

To the ventral surface of each segment of the thorax is attached a pair of legs. On account of the presence of three pairs of legs, insects are often called hexapoda. Each leg is composed of: (1) coxa, (2) trochanter, (3) femur, (4) tibia, (5) 5 tarsal joints ; to the last segment are attached the pulvilli and a pair of claws.

Abdomen: The abdomen consists of 10 segments. Each segment is enclosed by a dorsal tergum and a ventral sternum. In the male the 9th segment bears a kind of rudimentary styles. In the female the sternum of the 7th segment is very much more prominent than in the male. The anus lies below the 10th tergum which is produced backwards into a thin flexible plate, notched at the posterior border.

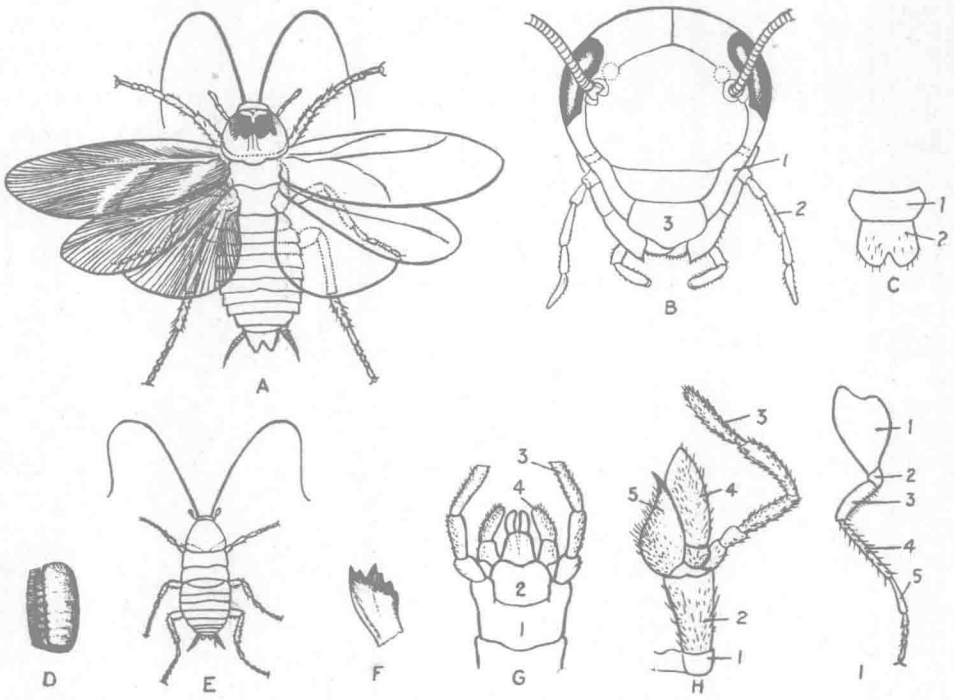

FIG. 5.

A. Diagram of a cockroach (Class Insecta).
B. Front view of head of cockroach. 1. gena ; 2. maxillary palp ; 3. labrum.
C. 1. clypeus ; 2. labrum.
D. Egg capsule of cockroach.
E. Larva.
F. Mandible.
G. 1. submentum ; 2. mentum ; 3. labial palp ; 4. paraglossa.
H. 1. cardo ; 2. stipes ; 3. maxillary palp ; 4. galea ; 5. lacinea.
I. Leg of cockroach. 1. coxa ; 2. trochanter ; 3. femur ; 4. tibia ; 5. first tarsal segment.

INTERNAL ANATOMY.

Digestive system: The digestive system consists of an alimentary canal which is divided into foregut, midgut, and hindgut. The foregut consists of (*a*) mouth ; (*b*) buccal cavity which receives the duct of the salivary glands. Each gland is divided into two lobes. There is a separate salivary receptacle. The duct of the salivary receptacle joins with that of the salivary glands into a common duct and the two common ducts of each side unite to form a single duct ; (*c*) pharynx which is provided with powerful muscles ; (*d*) œsophagus ; (*e*) crop ; (*f*) proventriculus which is lined inside with teeth. The midgut consists of the stomach proper. To it are attached the hepatic cæca. The stomach with the hepatic cæca is the mesenteron ; the regions in front and behind the cæca are the stomodæum and the proctodæum respectively, the two last-named portions being lined by a chitinous cuticle.

The point of junction between the stomach and the intestine is indicated

by the attachment of the Malpighian tubules which are excretory in function. The Malpighian tubules are yellowish, thread-like, and extremely long.

For the digestion of the particular types of food, corresponding enzymes are present in the salivary glands and stomach, according to feeding habits of the insects.

Circulatory system : The fluid blood circulates in the hæmocœle and does not flow in any well-defined tubular structure except in the heart and aorta. The heart is an elongated tube, closed behind and open in front, running along the middle line of the abdomen and thorax immediately behind the terga. The aorta is a narrow tube which is a continuation of the heart anteriorly.

The heart is divided by valves which open forwards into a number of chambers ; its walls are provided with valvular apertures or ostia through which blood enters the heart. The blood is driven forwards by rhythmical contractions.

The blood plasma is called the hæmolymph. It is composed of protein, lutein, metallic salts, and also food absorbed from the midgut, and some cellular elements. It also contains some enzymes.

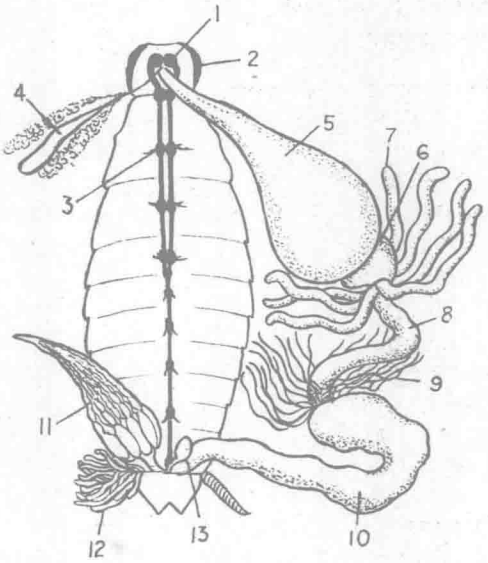

FIG. 6.
Dissection of female cockroach.
1. cerebral ganglion ; 2. eye ; 3. ventral nerve chain with ganglia ; 4. salivary glands with salivary vesicles ; 5. crop ; 6. gizzard ; 7. hepatic cæca ; 8. midgut ; 9. malpighian tubules ; 10. hindgut ; 11. ovary ; 12. colleterial glands ; 13. spermatheca.

Respiration: Respiration takes place through tracheæ which ramify over every organ of the body. They possess a chitinous internal lining. They open on the surface at the stigmata through which the air enters the trachea. One pair of stigmata lies on the side of the thorax between the prothorax and mesothorax and the second pair between the mesothorax and metathorax. Eight are situated on either side of the abdomen between the terga and sterna of the segments. Each spiracle is guarded by a valve.

Air enters the body by diffusion through the wall of the trachea, part of the CO_2 being eliminated through the cuticle. The tracheoles come into play when an excess of oxygen is needed for extra work performed by muscles, *e.g.*, during flying and running. In some animals which have no tracheal system, the air enters through the cuticle which acts as a membrane.

Excretion: Solid excreta are given off in crystalline form or in aqueous solution in which the Malpighian tubules play the most important part. Nephrocytes which are special cells arranged in groups are supposed to possess excretory function as after injection of ammonia carmine into the blood, carmine particles are retained in the cytoplasm of these cells.