THE

ELEMENTS

OF

INSECT ANATOMY

AN OUTLINE FOR THE USE OF STUDENTS IN THE ENTOMOLOGICAL LABORATORIES OF CORNELL UNIVERSITY AND LELAND STANFORD JUNIOR UNIVERSITY

BY

JOHN HENRY COMSTOCK

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PREFACE.

The course of study outlined in the following pages is designed to enable students to learn the more general features of the structure of insects. It has been prepared especially for students who devote only a short time to entomology; it may serve, however, as an introduction to a more extended study of the morphology of insects. Students making a special study of entomology will be assigned more advanced work after they have completed this elementary course.

While the more obvious object of this course is the learning of certain facts, a much more important thing to be gained is a training in methods of careful observation. The student is urged, therefore, to do the work with great care.

Chapters IV, V, and VI have been written by Professor Kellogg; the remainder of the work, by the senior author.

CONTENTS.

CHAPTER I.

TERMS DENOTING POSITION AND DIRECTION OF PARTS.

Need of a technical nomenclature.—It has been found that the use of the terms upper, lower, inner, outer, before, behind, anterior, posterior, and similar expressions in the technical descriptions of animals or their parts frequently leads to ambiguity. A great part of the confusion doubtless arises from the fact that the natural position of man differs from that of the lower animals in being erect. Thus, for example, when applied to man, *before* means in the direction indicated by a line drawn from the center of the body to the ventral surface; in the lower animals it means in the direction indicated by a line drawn from the center of the body to the head. The same difficulty attends the use of the term anterior; and of the opposite of these terms, behind and posterior.

Another source of confusion in the use of this class of terms is the fact that they are very commonly applied with reference to the plane of the horizom. Thus *above* means towards the zenith; *below*, towards the nadir; and *before* and *behind* indicate directions parallel to the plane of the horizon. Consequently whenever the position of an object is changed the terms denoting the relation of its parts must be changed.

In order to avoid these difficulties a special set of terms for designating the position and direction of the parts of animals has been adopted by many writers; and it is the object of this chapter to define such of these terms as are used in entomology.

Construction of the terms used.—Excepting the nouns *meson*, *dorsimeson*, and *ventrimeson*, the terms used in this work for denoting the position and direction of parts are either adjectives or adverbs.

The adjectives end in *al*, as dorsal, ventral, and mesal. The adjectives cephalic and intermediate are exceptions to this rule.

The adverbs are formed by substituting for the adjective ending the ending *ad*, the Latin equivalent of the English suffix *ward*. Thus from the adjectives dorsal, ventral, and mesal, are formed the adverbs dorsad, ventrad, and mesad.

In forming compound words indicating position or direction, the vowel *o* is substituted for the termination of the first member of the compound, as dorso-ventral, caudo-cephalic, and dextro-sinistral.

The six cardinal directions.—There are six principal directions to which the position and direction of the parts of a bilaterally symmetrical animal, like an insect, are commonly referred; these are as follows:—

The *cephalic direction* or headward; this is the direction indicated by a line drawn from the center of the animal to the head.

The *caudal direction* or tailward; this is the opposite of the cephalic direction.

The *dextral direction* or towards the right.

The *sinistral direction* or towards the left.

The *ventral direction* or bellyward; this is the direction indicated by a line drawn from the center of the body to the ventral surface and forming a right angle with each of the preceding directions.

The *dorsal direction* or backward; this is the opposite of the ventral direction.

The adverbial forms of the adjectives *cephalic*, *caudal*, *dextral*, *sinistral*, *ventral*, and *dorsal* are *cephalad*, *caudad*,

dextrad, *sinistrad*, *ventrad*, and *dorsad*. Thus a part which extends in a cephalic direction may be said to extend cephalad.

Lateral and laterad — The terms dextral, dextrad, sinistral, and sinistrad, are seldom used in the following pages, as it is rarely necessary to specify one side as distinguished from the other. Instead of these terms *lateral* and *laterad* are used.

EXAMPLE.—The wings are *lateral* appendages of the body; and in most dragon-flies they extend *laterad* when the insect is at rest.

It is important here to define more definitely the directions indicated by these six sets of terms.

When we say that a certain part extends dextrad, we do not mean necessarily that it extends towards the right side of the animal or even towards a plane tangent to the right side of the animal; but that it extends towards a point which is in a certain well understood direction* *and which is at an infinite distance in that direction*. We are thus able to indicate the position of an object which may be far exterior to the body of the animal with whose position we are comparing it. This is perfectly in accordance with the popular use of the terms right and left.

According to this definition, all lines extending right and left across the body of an animal are parallel.

The same may be said respecting ventro-dorsal lines. Dorsad being eqdivalent to *behind* in the sense in which it is applied to the body of man, or *above* as applied to the body of a quadruped when in its natural attitude.

It is also true that all caudo-cephalic lines are parallel. This is a point to which careful attention must be paid, else there is liability to error. It is quite natural to think that cephalad means towards the head or towards the head end of the body axis, and that caudad means toward the tail. The fact is that cephalad means towards a point which is in a di-

* Indicated by a line drawn at right-angles to the cephalo-caudal and dorso-ventral axes and towards the right side.

rection indicated by a line drawn from the center of the animal to the head, *but at an infinite distance in that direction*. In other words, these terms must be used in a way analogous to that in which we use right and left.

EXAMPLES.—Take a figure of a Dragon-fly with its wings extended as when at rest. Draw a line from the distal extremity of one of the wings to the head. Although this line extends directly towards the head it does not extend cephalad; but more or less nearly mesad.* A line extending cephalad from the distal extremity of a wing (or from any other part) is parallel to the cephalo-caudal axis of the body.

Differences between the technical and popular uses of cephalic and caudal.—It has just been shown that in the use of these terms it is not the head and tail to which the position and direction of parts are referred, but to two of the cardinal directions which are at right angles to right and left. Thus when an insect extends its antennæ cephalad, the most cephalic segments of these organs are those *farthest* from the head. For the same reason we can speak of the caudal part of the head or of the cephalic portion of the tail. It will be seen that this does not accord with the popular uses of these terms (as defined in the dictionaries) according to which no part of the body is cephalic except the head; and of the different parts of the head one is just as much cephalic as another.

Oblique lines.—The position or direction of a part towards a point between two of the cardinal points, or toward a point between one of the cardinal points and a line connecting two other cardinal points can be designated by a compound term.

EXAMPLES.—A part which extends in a direction between those directions which are indicated by dextrad and caudad is said to extend *dextro-caudad*. A part which extends in a direction between those directions which are indicated by dorsad and dextro-caudad is said to extend *dorso-dextro-caudad*. This last direction would be indicated in popular terms by saying: *Towards the back and to the right and towards the tail.*

* Mesad is defined on a later page.

Meson, mesal, and mesad.—Frequently the position or direction of parts is referred to an imaginary plane dividing the body into approximately equal right and left halves. This middle plane is called the *meson* (μέσον, middle). From meson are derived the adjective *mesal* and the adverb *mesad*.

Dorsimeson and ventrimeson.—If it is necessary to refer to the lines constituting the dorsal and ventral borders of the meson, these are designated as the *dorsimeson* and *ventrimeson* respectively.

EXAMPLE.—The wing-covers of a beetle meet without overlapping on the dorsimeson.

Ectal, ectad, ental, and entad.—It is often necessary, especially in the study of internal anatomy, to compare parts with relation to their nearness to or remoteness from the surface of the body. For this purpose the terms *ectal* (ἐκτός, without) and *ental* (ἐντός, within) are used. The adverbial forms of these terms are *ectad* and *entad*.

EXAMPLES.—The principal muscles of an insect are attached to the *ental* surface of the body-wall, or to parts of the body-wall which project *entad*.

Aspects of the body.—In describing animals it is often desirable to specify that part of the body which looks in a certain direction. For this purpose the term *aspect* is used combined with an adjective indicating the direction in which the surface in question looks.

EXAMPLES.—Dorsal aspect, ventral aspect.

Six aspects of the body are recognized; these are the two lateral (dextral and sinistral), dorsal, ventral, cephalic, and caudal.* The fact that the outlines of the body of an animal are more or less curved does not interfere with the practical application of the above terms.

Proximal, distal, proximad, and distad.—In describing

* Cases occur where it is desirable to speak of an aspect which looks in a direction between two of the cardinal directions. Thus we speak of the lines or spots on the latero-dorsal aspect of a larva.

appendages of the body (legs, wings, etc.) the position of parts may be referred to the two ends of the appendage by use of the terms *proximal* and *distal*. *Proximal* indicates nearness to the end of the appendage which is attached to the body; *distal*, to the end which is free. From these adjectives the adverbs *proximad* (towards the proximal end) and *distad* (towards the distal end) are formed.

EXAMPLES.—The *proximal* segment of the leg of an insect is the coxa. The segments of the leg *distad* of the tibia constitute the tarsus.

Aspects of appendages.—In addition to the two ends of an appendage four aspects are recognized. To these the same terms are applied as to the corresponding aspects of the body: *viz.*, dorsal, ventral, cephalic, and caudal. It is therefore necessary to have a rule by which the correspondence between the aspects of the body and of appendages can be determined. In other words, a definite position must be chosen as the normal position of an appendage. Naturalists are quite well agreed as to what is the normal position of the limbs of the Vertebrates. The following are what I believe to be the analogous positions for the legs and wings of insects.*

(*a.*) *Wings.*—Extended horizontally at right angles to the body as are the wings of a dragon-fly (*Libellula*) when at rest.

(*b.*) *Legs.*—Extended horizontally at right angles to the body so that the convexity of the articulation between the two principal segments of the leg (femur and tibia) shall look dorsad; and so that the surface of the tarsus ("foot") which is usually applied to the ground when walking shall look ventrad.

The dorsal, ventral, cephalic, or caudal aspect of a wing

* The necessity for referring to the aspects of other appendages than the legs and wings will so seldom arise that it does not seem worth while to attempt to determine the normal positions of such appendages.

or leg is that aspect which, when the wing or leg is in its normal position, looks in the same direction as does the aspect of the body which bears the same name.

First, second, third, etc.—When the individuals of a a series of parts forming a portion or the whole of the body are indicated by the terms first, second, third, etc., the cephalic member of the series is the first.

EXAMPLE.—The *first* abdominal segment is the one nearest the head.

When the series forms a part or the whole of an appendage of the body, the first member of that series is the proximal one.

EXAMPLE.—The *first* segment of a leg is the one which is articulated to the body.

The direction of an appendage does *not* modify the above rule.

EXAMPLE.—The *first* segment of an antenna is the one which is articulated with the head; notwithstanding that when the antennæ are directed cephalad, as is usually the case, this segment is the one nearest the caudal end of the body.

Intermediate.—In order to avoid ambiguity the word mesal and its derivatives are used only with reference to the *meson*. The second member of a series of three similar parts is designated as the *intermediate*.

Limitations to accuracy.—As the body of an animal presents but few plane surfaces or straight lines it is often impossible to describe the position or direction of a part with absolute accuracy. Practically, however, one will meet with but few serious difficulties. Thus in describing the direction of a curved or undulating line on the surface of the body it will rarely be necessary to do more than to give the general direction of that line; the reader will understand that it follows the sinuosities of the surface of the body.

CHAPTER II.

THE EXTERNAL ANATOMY OF A LOCUST.

(*Melanoplus femur-rubrum.*)

Locusts or short-horned grasshoppers are excellent subjects to use in beginning the study of the external anatomy of insects. They are very common and are comparatively large; and the parts of the external skeleton in these insects are, as a rule, remarkably distinct.

The species which has been selected as the basis of this outline is the red-legged locust, *Melanoplus femur-rubrum*, which is found in nearly all parts of the United States. Specimens of this insect, preserved in alcohol, will be furnished the student, who will be expected to verify carefully or to correct each statement made in the text.

DIVISION OF THE BODY INTO REGIONS.

The body of a locust is composed of a series of more or less ring-like segments. In the caudal part of the body the ring-like nature of the segments is obvious; in the cephalic part it is less so. These segments are grouped into three regions: *head*, *thorax*, and *abdomen*.

Head.—The head is the first or cephalic of the three regions of the body. Apparently it consists of a single segment.

Thorax.—The thorax is the second or intermediate region of the body. It is readily distinguished by its appendages; which are three pairs of legs and two pairs of wings. It consists of three segments; but as each segment is composed of several distinct pieces, it requires considerable study to

trace the outlines of each segment. We will return to this subject later.

Abdomen.—The abdomen is the third or caudal region of the body. The segments of which it is composed are more simple, distinct, and ring-like than those of the other regions.

STRUCTURE OF THE BODY-WALL.

Chitine.—In studying the anatomy of insects it is found that in the adult state the greater portion of the body-wall, that part of the insect which corresponds in position to the skin of higher animals, is hard.

This hardness is due to the deposition of a horny substance, called *chitine*, in the membrane which constitutes the body-wall.

Sclerites.—The chitine is not evenly distributed throughout this membrane. Pull the head of a locust so as to separate it from the thorax as far as possible without breaking the insect. Note that the head is joined to the thorax by a soft flexible membrane, in which but little, if any, chitine has been deposited.

Examine the sides of the thorax with a lens and observe that the body-wall appears to be made up of many distinct pieces. The integument is, however, really continuous; and in each case what appears as a distinct piece is simply a portion of the body-wall in which considerable chitine has been deposited. Such a portion of the body-wall is called a *sclerite*.*

Sutures.—The sclerites constitute the greater part of the body-wall, the soft membranous portions separating them being in most cases narrow. Usually these narrow portions are mere lines; they are then called *sutures*.

Frequently the sutures become entirely effaced. We are

* The sclerites are analogous to the centers of ossification in the bones of the higher animals.

therefore often unable to distinguish certain sclerites in one species of insect which we know to exist in another.

In such cases the effaced suture is said to be *obsolete*.

PARTS OF THE HEAD.

The principal portion of the chitinized parts of the head are firmly joined together so as to constitute a box which contains what may be called by analogy the brain of the insect and certain other important organs. To this are articulated a number of movable appendages. The parts of the head may be classed, therefore, under two divisions ; first, the fixed parts ; second, the movable parts.

THE FIXED PARTS OF THE HEAD.

Compound eyes.—The most striking in appearance of the fixed parts of the head are the *eyes*. These are two large nearly hemispherical objects ; one on each side, forming a considerable portion of the latero-dorsal part of the head.

Study one of the eyes with a compound microscope, using a low power. Note the honey-comb-like structure of the eye. If you have difficulty in seeing this, remove a part of one eye with fine-pointed scissors and mount it on a glass slip. Each of the hexagonal divisions of the eye is a cornea of a distinct eye. These large eyes are therefore *compound*, and each of the small eyes of which they are composed is termed an *ocellus* (plural *ocelli*).

Make a drawing showing the honey-comb-like structure of the cornea of a compound eye.

NOTE.—The drawings illustrating this course should be made with great care, on good paper. Outline drawings are better than those that are shaded, as shading tends to obscure lines indicating sutures. The drawings should be made first with a pencil, then, after they have been criticized, the lines should be inked.

Simple eyes.—Cephalad of the dorsal half of each com-

pound eye there is a small transparent hemispherical body. These are the *simple eyes.* There is a third simple eye situated in a depression near the center of the cephalic aspect of the head. The simple eyes are usually termed *ocelli;* sometimes, *stemmata* (singular *stemma*).

When the term ocelli is used in descriptive works, if there is nothing in the context to indicate the contrary, it is almost invariably applied to the simple eyes, and not to the elements of the compound eyes. In the same way the term eyes usually refers to the compound eyes unless otherwise indicated by the context.

Epicranium.—The simple eyes are situated in, and the compound eyes surrounded by a large sclerite which constitutes the greater portion of the fixed parts of the head or cranial box. This sclerite is the *epicranium.* The cephalic and lateral parts of the epicranium are separated on each side by a suture which extends ventrad from the eye. The ventral ends of these sutures are joined by a very prominent suture which forms the cephalic boundary of the cephalic portion of the epicranium.

Remove the head from the thorax and mount it on a slender pin, inserting the pin in the center of the cephalic aspect of the head. The pin will now serve as a handle.

Note the slightly elevated narrow ridge which separates the lateral from the caudal aspect of the head. This ridge marks the position of the suture which constitutes the caudal border of the epicranium. Upon the dorsal aspect of the head this suture is obsolete.

Upon each side joining the ventral end of the suture just described and the ventral end of the one which extends ventrad from the compound eye is a well marked suture, which forms the ventral border of the lateral part of the epicranium.

(*a.*) *Vertex.*—The dorsal part of the epicranium is called the *vertex.*

(*b.*) *Front.*—That part of the epicranium which is upon the cephalic aspect of the head is termed the *front.*

(*c.*) *Genæ.*—The lateral parts of the epicranium are known as the *genæ* or cheeks.*

Clypeus.—Examine again the ventral border of that part of the epicranium which is upon the cephalic aspect of the head. Note that the prominent suture bounding this part separates it from a very broad, but short sclerite. This is the *clypeus.*

Although in a locust the clypeus appears like the basal segment of an appendage of the head; from its form and position in other insects it is classed with the fixed part of the head.

Make a drawing of the cephalic aspect of the head; and name the fixed parts.

Occiput.—Examine again the narrow ridge which separates the lateral from the caudal aspect of the head, and forms the caudal border of the epicranium. Note that it may be easily traced on each side through the broad black stripe which extends caudad from the eye; and that dorsad of that stripe it is obsolete. On each side of the head from a point on this ridge a short distance ventrad of the black stripe a suture extends across the caudal aspect of the head to the membrane connecting the head with the thorax. This suture constitutes the ventral border of the sclerite which forms the caudal part of the dorsal portion of the fixed parts of the head. This sclerite is the *occiput.* As already indicated, the suture between the occiput and the epicranium is well marked on the lateral aspects of the head; but on the dorsal aspect it is obsolete. Hence on this aspect there is no indication of the line where the occiput ends and the epicranium begins.†

*If the student finds it difficult to trace the sutures described here, he should boil the head of the locust in a solution of caustic potash. This will destroy the soft parts and bleach the walls of the head so that the sutures may be easily traced.

†There is upon each gena a depressed line which appears like a suture but is not one.

Postgenæ.—On each side ventrad of the occiput and caudad of the gena is a large sclerite. These form the chief portion of the caudal aspect of the fixed parts of the head and may be termed the *postgenæ*.

The postgenæ and occiput form the boundary of the large opening which connects the cavity of the head with that of the thorax. The postgenæ are separated from the epicranium by the narrow ridge described above.

Tentorium.—Carefully remove the appendages of the ventral part of the caudal aspect of the head. This may be done by lightly scraping with a knife. It will be seen that the postgenæ are connected by a strong part extending from side to side, within the head. This is the *tentorium*.

Make a drawing of the caudal aspect of the head just prepared; and name the parts.

Gula.—When all the parts of the skeleton of the head are present there exists a single sclerite which forms, typically, the ventral part of the cranial box; this is the *gula*. In locusts the gula is not well developed, being represented by merely a membrane to which the lower lip is attached.

Review.—The fixed parts of the head of a locust consist of five sclerites; three of these, the *occiput* and the two *postgenæ* pertain to the caudal aspect, one, the *epicranium*, constitutes the greater part of the dorsal, lateral, and cephalic aspects, and one, the *clypeus*, forms the ventral portion of the cephalic aspect. The epicranium consists of the *vertex*, the *front* and the *genæ*. The gula is not chitinized.

It should be observed that the head of a locust is bent ventrad so that the mouth is not in the typical position for the mouth of an insect, *i. e.*, at the cephalic end of the head.

Imagine the head to be straightened so that the mouth is at the cephalic end of the longitudinal axis of the body and state upon what aspect of the head the clypeus is situated in this case.

THE MOVABLE PARTS OF THE HEAD.

Under this category are classed a pair of jointed appendages termed the *antennæ* and the organs known collectively as the *mouth-parts*.

Antennæ.—Just cephalad of each compound eye there is attached to the head a long, thread-like, many-jointed appendage. These are the *antennæ*. Each antenna is situated in a depression which is known as the *antennary fossa*.

Mouth-Parts.

Labrum —Articulated to the ventral border of the clypeus is a broad, freely movable flap. This is the upper lip or *labrum*.

Letter this part in the drawing of the cephalic aspect of the head.

Mandibles.—Carefully remove the labrum. By doing this there is exposed a pair of jaws which open by a meso-lateral motion of each jaw. These are the *mandibles*. Each mandible consists of a single short and thick piece, the distal extremity of which is notched so as to form a series of teeth.

Remove the mandibles. This may be done by separating them with a pin and turning each one laterad until it breaks from the head.

Make a drawing of one mandible.

Maxillæ.—By the removal of the mandibles there is exposed a second pair of jaws which, like the mandibles, open by a meso-lateral motion. These are the *maxillæ*. Unlike the mandibles the maxillæ are very complicated organs. We will return to them later.

Labium.—Remove the head of the locust and pin it with the caudal aspect uppermost to a piece of cork.

Note the freely movable flap which is the caudal part of the mouth-parts. This and the crescent shaped piece to which it is attached form the lower lip or *labium*.

The labium consists of the following parts :—

Submentum.—The submentum is the proximal part of the labium. It is nearly crescent-shaped, and is joined to the membrane which connects the head with the thorax.

NOTE.—It is believed by some writers that this crescent-shaped part is composed of two fused sclerites, and that the caudal portion of it represents the *gula.*

Mentum.—This is the central portion of the labium ; and is the principal part of that organ. It is articulated to the distal margin of the submentum. To the distal margin of the mentum are joined two movable flaps ; and to each lateral margin is joined an organ consisting of three segments.

Labial Palpi.—These are the three-jointed organs of which one is joined to each lateral margin of the mentum.

Palpiger.—The labial palpi are not joined directly to the mentum. There is on each side of the mentum a sclerite which bears the palpus of that side and which is called the *palpiger.* The suture between the palpiger of each side and the mentum is almost obsolete. Its position is indicated by a slight groove which causes the palpiger to appear somewhat like a segment of the palpus.

Ligula.—This is the distal portion of the labium. It consists of two large movable flaps.

Hypopharynx.—If the specimen has become dry so as to be brittle, it should be softened with a little water.

With the specimen pinned as in last section, carefully lift the ligula so as to expose the maxillæ. Note the tongue-like organ which arises from the labium and from between the maxillæ. This is the *hypopharynx.*

Remove the labium and place it on a glass slip in a drop of Canada balsam or glycerine and cover it with a cover glass. Examine it with a microscope using a low power. Make a drawing of the caudal aspect of the labium, and letter the parts.

Study the distal end of the distal segment of a labial palpus

with a higher objective. Observe the sense papillæ with which it is furnished. Make a drawing of this part.

Parts of the Maxillæ.—After the removal of the labium it is easy to distinguish the maxillæ, of which there is one on each side between the labium and the mandibles.

Remove a maxilla and mount it in Canada balsam or glycerine, with the caudal aspect uppermost. Examine with a microscope using a low objective.

Make a drawing of a maxilla, and name the parts, which are as follows :—

Cardo.—The cardo or hinge is the proximal segment of maxilla. It is triangular in outline in this insect.

Stipes.—The stipes or footstalk is the second segment of the maxilla; it is the large, quadrangular sclerite which forms the central part of the maxilla.

Lacinia.—Articulated to the distal end of the stipes is a large sclerite, which tapers distad, is curved, and is terminated by strong teeth ; this is the part known as the *lacinia.*

Galea.—Joined to the distal end of the stipes, laterad of the lacinia, is a part consisting of two segments. This is the *galea.* The distal segment of the galea is large, spoon-shaped, and covers the inner lobe like a hood ; the proximal segment is constricted in the middle so as to slightly resemble a dumb-bell in outline. The galea is known as the *outer lobe*, *upper lobe,* or *superior lobe.*

Palpifer.—Joined to the lateral border of the stipes and between the cardo and the proximal segment of the galea is a narrow sclerite ; this is the *palpifer.*

Maxillary Palpus.—Articulated to the distal end of the palpifer is a long, slender organ consisting of five segments ; this is the *maxillary palpus.*

After completing the drawing of the maxilla as a whole, study the distal end of the distal segment of the maxillary palpus with a higher objective, and make a drawing of this part.

Review.—The mouth-parts consist of an upper-lip, *labrum;* and under-lip, *labium;* two pairs of jaws acting laterally between these lips; and a tongue-like organ, *hypopharynx.* The cephalic pair of jaws is called the *mandibles;* the caudal pair, the *maxillæ.*

NOTE.—The natural attitude of the head of a locust is such that the *labrum* and *labium* appear to be fore and hind lips respectively; and the *mandibles* and *maxillæ*, fore and hind pairs of jaws. But when the mouth is in its typical position, at the cephalic end of the body-axis, the labrum is an upper-lip, the labium an under-lip, the mandibles, the upper jaws, and the maxillæ the lower jaws.

Each maxilla consists of four primary and two secondary parts. The primary parts are the *cardo*, *stipes*, *lacinia*, and *palpifer;* the secondary parts are the *galea* and *maxillary palpus.*

The labium consists of the *submentum*, *mentum*, *ligula*, two *palpigers*, and two *labial palpi.*

PARTS OF THE THORAX.

Division into segments.—The thorax consists of three segments. The cephalic or first segment is named the *prothorax;* the second or intermediate, the *mesothorax;* and the third or caudal, the *metathorax.*

These divisions of the thorax can be easily recognized by the appendages they bear. To the prothorax is articulated the first pair of legs; to the mesothorax are joined the second pair of legs and the first pair of wings; and to the metathorax, the third pair of legs and the second pair of wings.

PROTHORAX.

Dorsal Part (Pronotum).—That which may be properly termed the dorsal part of the prothorax is a large sunbonnet-shaped piece which covers the greater portion of the sides as well as the dorsal surface of this segment. This piece is called the *pronotum.*

It is believed that the dorsal part of each thoracic segment consists typically of four sclerites. These are named, beginning with the cephalic, *praescutum*, *scutum*, *scutellum*, and *postscutellum*. These sclerites may be distinguished in the dorsal parts of the mesothorax and metathorax (*mesonotum* and *metanotum*) of many insects; but the pronotum consists usually of a single piece. In the insect which we are studying, although the pronotum consists of a single piece, it is crossed by three well marked sutures, indicating the division into four sclerites, which may be named as indicated above.

On the latero-dorsal aspect of the pronotum the suture between the praescutum and the scutum extends cephalad for a short distance and is then interrupted; the lateral portions of this suture is parallel with and quite near to the cephalic margin of the pronotum. Near the center of each lateral aspect of the pronotum there is a short cephalo-caudo-dorsal suture which separates the lateral fourth of the scutellum from the mesal part of that sclerite. None of the sutures extend to the lateral margin of the pronotum.

Make a drawing of the lateral aspect of the pronotum.

Ventral Part (Prosternum).—On the ventral surface of this segment between the legs there is a sclerite which bears a large tubercle; this is the sternum of the prothorax or *prosternum*.

Lateral Parts.—Owing to the great development of the pronotum, which covers the larger portion of the sides as well as the dorsal surface of the prothorax, the lateral parts of this segment are rudimentary. The following named sclerites, however, may be distinguished.

Episternum.—Between the pronotum and the end of the lateral prolongation of the prosternum, which extends on each side of the segment cephalad of the leg, is a conspicuous triangular sclerite; this is the *episternum*.

Jugular Sclerites.—In the membrane connecting the prothorax with the head there is on each side, just cephalad of the dorsal corner of the episternum, a pair of sclerites. These were named by a French entomologist *pièces jugulaires.** They may be called the *jugular sclerites.*

NOTE I.—The homology of these sclerites is not well understood. They were supposed by Straus-Durckheim to represent the remains of two distinct segments. But Newport† believed that they were detached portions of the prothorax; and suggested that they represent the paraptera of this segment.

NOTE II.—It is believed that each lateral part of each thoracic segment consists of three sclerites. These are named the *episternum*, the *epimeron*, and the *parapteron*. In many cases not all of these parts can be distinguished. This may be due to the non-development of a part, or to the effacing of a suture between two parts. In the prothorax, paraptera have never been found unless, as suggested by Newport, the jugular sclerites represent these parts. In many insects the epimera of the prothorax cannot be distinguished from the episterna, the suture on each side between these sclerites being obsolete. In the insect which we are studying, either this is the case or the epimera of this segment are not developed.

Add the episternum and the jugular sclerites to the drawing of the lateral aspect of the pronotum.

MESOTHORAX AND METATHORAX.

Union of these segments.—The second and third thoracic segments are firmly joined together, forming a box to which the two pairs of wings and the second and third pairs of legs are joined. Owing to the intimate union of these two segments it will be easier to describe them together than separately.

With fine pointed scissors cut away the caudal border of the pronotum, that part which overlaps the mesonotum; be careful not to break the membrane connecting the prothorax and mesothorax.

*Straus-Durckheim, Considération Générales sur l'Antaomie Comparée des Animaux Articulés, p. 75.

† Article Insecta, Todd's Cycl. Anat. and Phys., p. 911.

Dorsal Part (Mesonotum and Metanotum).—The dorsal part of the mesothorax is termed the *mesonotum*, that of the metathorax, the *metanotum*. Unlike the pronotum these parts are confined to the dorsal aspect of the body. By cutting away the caudal part of the pronotum as indicated above and spreading the wings laterad, these parts are exposed. Each consists of a nearly square area. To the lateral margins of the mesonotum is articulated the first pair of wings; and to the lateral margins of the metanotum, the second pair of wings.

The sutures indicating the outlines of the sclerites, of which the mesonotum and metanotum are composed, are not all well defined; there is consequently some difficulty in determining the limits of the sclerites.

In each of these segments only two of the four dorsal sclerites are well developed; these are the *scutum* and the *scutellum*. The scutum occupies the cephalic half of the segment, the scutellum the caudal half. The scutellum consists of three parts: a central, shield-shaped part, which in this species is closely united to the scutum; and on each side a part extending to the base of the wing. The caudal border of the scutellum is thickened and is connected on each side with the caudal border of the base of the wing by a cord-like structure.

Make a drawing of the mesonotum and metanotum.

NOTE.—In those insects where the præscutum and postscutellum are well developed, they usually extend entad and are often concealed within the thorax. The connection of the scutellum on each side with the caudal border of the base of the wing, is an excellent guide in tracing the homology of the parts of the mesonotum and the metanotum.

Ventral Part (Mesosternum and Metasternum).—On the ventral surface of the body between the legs of the second thoracic segment is a large sclerite; this is the sternum of the mesothorax or *mesosternum*. The cephalic

margin of the mesosternum is nearly straight; the caudal margin, deeply notched by a large, nearly square incision.

Caudad of the mesosternum there is a large sclerite, the mesal part of which is prolonged cephalad so as to accurately fit the notch in the caudal border of the mesosternum; this is the sternum of the metathorax or *metasternum*.

The caudal border of the metasternum is also notched, and the first abdominal segment is dove-tailed into it.

Make a drawing of these parts.

Lateral Parts (Episterna, Epimera, and Paraptera).—Examine one side of the second and third thoracic segments. Note that it is chiefly composed of four large sclerites, which extend from the fossæ of the legs dorso-cephalad. These sclerites are named as follows:—

Episternum of the mesothorax.—The first or cephalic of these four sclerites is the *episternum of the mesothorax*. The sutures between the episterna and the mesosternum are only faintly indicated in this species.

Epimeron of the mesothorax.—This is the second of this series of sclerites.

Episternum of the metathorax.—This is the third of this series of sclerites; it is the one which bears the oblique yellow band characteristic of this species.

Epimeron of the metathorax.—This is the caudal member of this series of sclerites.

In addition to the four large sclerites just described, observe the following named parts:—

Parapteron of the mesothorax.—Articulated to the dorsal extremity of the episternum of the mesothorax and cephalad of the base of the first wing is a small, inconspicuous, triangular sclerite; this is the *parapteron of the mesothorax*.

NOTE.—This sclerite can be seen more easily in the Carolina locust, *Dissosteira carolina*, a specimen of which will be shown the student on request.

Parapteron of the metathorax.—Articulated to the dorsal

extremity of the episternum of the metathorax and cephalad of the base of the second wing is also a small, inconspicuous sclerite ; this is the *parapteron of the metathorax*. It is even less well-developed than the parapteron of the mesothorax.

Spiracles and Peritremes.—Between the ventro-caudal angle of the epimeron of the mesothorax and the fossa of the leg is an organ which consists of a slit-like opening guarded by two fleshy lips ; this is one of the openings of the respiratory system ; these openings are called *spiracles*. When, as in this case, a spiracle is surrounded by a circular sclerite, such a sclerite is termed a *peritreme*.

In the membrane connecting the mesothorax with the prothorax there is on each side a spiracle. This spiracle is covered by the free margin of the pronotum. In this case the peritreme is developed on the ventral side of the spiracle into a prominent papilla.

Make a drawing of the lateral parts of the mesothorax and metathorax.

Review.—The thorax consists of three segments, which are named, beginning with the cephalic, *prothorax*, *mesothorax*, and *metathorax*.

The body wall of each of these segments is believed to consist typically of *eleven* sclerites. Of these, *four* pertain to the dorsal part of the segment ; *three*, to *each* lateral part ; and *one* to the ventral part.

The dorsal sclerites are named, beginning with the cephalic, *praescutum*, *scutum*, *scutellum*, and *postscutellum*.

Of the two principal lateral sclerlites, the cephalo-ventral one is the *episternum*, the caudo-dorsal one, the *epimeron*. The third lateral sclerite is small, is articulated to the episternum near the base of the wing, and is called the *parapteron*. Paraptera have not been found in the prothorax ; but there has been found on each side, in the membrane connecting this segment with the head, a pair of sclerites termed the *jugular sclerites*.

The ventral sclerite is known as the *sternum*. The sterna of the three thoracic segments are designated as the *prosternum*, *mesosternum*, and *metasternum* respectively.

The dorsal part of the body-wall of each segment is called the *tergum*. This name is also applied to the dorsal part of the three thoracic segments collectively.

The tergum of the prothorax is frequently called the *pronotum*; the tergum of the mesothorax, the *mesonotum*; and that of the metathorax, the *metanotum*.

There are in this insect two pairs of thoracic spiracles.

APPENDAGES OF THE THORAX.

The appendages of the thorax are the legs and wings; the number and distribution of these have already been given.

Legs.—Examine the ventral aspect of the first pair of legs. Each leg will be found to consist of the following named parts:—

Coxa.—This is the proximal segment of the leg. It is subglobular in outline. Examine the cephalic aspect of the coxa, and note the longitudinal suture which traverses this side of it; this is shown better on the mesothoracic legs.

Trochanter.—This is the second segment of the leg, and is much smaller than the coxa. The ventral aspect of it is much longer than the dorsal.

Femur.—This is the third and principal segment of the leg.

Tibia.—This is the fourth segment of the leg. It nearly equals the femur in length, but is more slender.

Tarsus.—The tarsus includes all of that part of the leg distad of the tibia. It consists in locusts of three segments.

The last segment of the tarsus bears a pair of claws.

On the ventral surface of the tarsus there is a series of cushions; these are called *pulvilli*. The distal segment of the tarsus bears a single pulvillus which projects between

the claws ; this is often referred to in descriptive works as *the* pulvillus.

NOTE. —In the membrane connecting the coxa with the thorax, just cephalad of the coxa, is a sclerite ; this I believe to be the *trochantin*. The trochantin is a sclerite which is considered to be an appendage of the coxa ; and its normal position is between the coxa and the episternum.

Make a drawing of one of the cephalic legs.

The same parts may be traced on each of the other legs.

Wings.—The wings are plate-like or membraneous expansions of the body-wall. Each wing is traversed by many linear thickened portions ; these are termed *veins*, or *nerves*. The principal veins extend proximo-distad. These are joined together by many smaller veins or *veinlets*. The thin parts circumscribed by the veins and veinlets are called *cells*.

The two pairs of wings of a locust differ remarkably in form and texture.

Mesothoracic Wings (*Tegmina*).—The mesothoracic wings are long, narrow, and of a parchment-like texture. They are termed *tegmina*.

Metathoracic Wings.—The metathoracic wings are much larger and of more delicate texture than the first pair of wings. When not in use they are folded in plaits like a fan and concealed by the tegmina. Some writers who designate the mesothoracic wings as tegmina or wing-covers, describe the metathoracic wings simply as *the* wings.

Make diagrams showing the *outline* of one of the wings of each pair. Do not attempt to represent the veins and veinlets ; a special study of wing-venation will be made later in the course.

PARTS OF THE ABDOMEN.

Number of segments.—There is a difference of opinion as to the number of segments in the body of a locust. The difficulty arises from the complexity of the caudal end of

this region, and the fact that some authors have considered the first abdominal sternum as a part of the metathorax. Eight abdominal segments can be readily distinguished in the female ; and nine, in the male.* Caudad of the eighth abdominal segment of the female and the ninth of the male are a number of sclerites which are considered by some writers to be merely appendages of the abdomen ; other writers hold that certain of these sclerites represent sterna, and certain others, terga.

It is not within the scope of this work to enter into any discussion of the matter. I shall describe the parts as if there were eleven segments ; but wish the student to understand that the so-called eleventh segment may be merely an appendage of the tenth ; and that what is described here as the ninth and tenth segments have not been considered as such by certain very high authorities.

First Abdominal Segment.—The dorsal and ventral parts of the first abdominal segment are widely separated by the caudal part of the cavities for the insertion of the third pair of legs.

The ventral part of this segment is dove-tailed into the metasternum, and at first sight would be taken for a part of the thorax.

On each side in the dorso-lateral part of this segment, there is a large opening which is closed by a very delicate membrane ; these are the *auditory organs* ; the membrane is the *tympanum*.

Just cephalad of each auditory organ there is a small opening ; these are the first pair of abdominal spiracles.

Second to Eighth Abdominal Segments.—Each of the

*If a sufficiently large series of specimens of the red legged locusts be examined, it will be seen that there are two kinds : one, in which the caudal part of the body tapers to the end, and bears four, pointed and curved, horny pieces ; and another, in which the caudal part of the body increases in size caudad and is terminated by a single, large, hood-shaped plate. The former is the female ; the latter, the male.

abdominal segments, from the second to the eighth inclusive, is ring-like in form, and without appendages.

In each of these segments the lateral margins of the tergum join the pleura* without any suture. Near the cephalo-ventral angle of each pleurum there is a spiracle. The sterna are well developed and are separated from the pleura by a narrow, involuted, membraneous part.

Caudal Part of Abdomen of Female.—The most prominent portion of the caudal part of the abdomen of the female is the *ovipositor*. This is an organ consisting of four, strong, curved, and pointed pieces, which form the most caudal part of the body. With this organ the insect makes a hole in the ground in which she lays her eggs. This is done by alternately bringing together and separating the two pairs of pieces, and at the same time pushing the body into the ground. Examine carefully these pieces, and note how well they are adapted to this purpose.

Between the ventral pieces is the *opening of the oviduct*.

Ventrad of this opening and also between the ventral pieces of the ovipositor is a pointed prolongation of the eighth abdominal sternum; this has been termed the *egg-guide*. Dorsad of the egg-guide there is a forked organ which also is used in placing the eggs.

The ventral pieces of the ovipositor are supported by two pairs of sclerites; there being a sclerite closely applied to the ventral surface of each pair, and one to the lateral surface of each.

The ninth and tenth abdominal terga are shorter than any of the preceding abdominal terga and are joined together on each side, the lateral parts of the suture separating them being obsolete.

*The lateral part of a segment is termed the *pleurum*; in the same way that the ventral part is called the *sternum*; and the dorsal part, the *tergum*. By some writers the entire dorsal part of an insect is called the tergum; the lateral part, the pleurum; and the ventral part, the sternum. These writers apply the terms *tergite*, *pleurite*, and *sternite* respectively to the dorsal, lateral, and sternal regions of each segment.

Caudad of the tenth tergum there is on the dorsimeson a shield-shaped piece ; this is believed to represent an eleventh segment. It consists of two sclerites ; as is indicated by a transverse suture.

On each side, projecting from beneath the caudal border of the tenth tergum, is a pointed appendage ; these are the *cerci*.

Entad of each cercus there is a much larger, triangular sclerite which extends from the lateral border of the tenth tergum to the caudal apex of the eleventh tergum ; these are termed by Brooks* the *podical plates ;* by Packard† the *uropatagium*.

By lifting the free end of the eleventh segment, the caudal opening of the alimentary canal, the *anus*, is exposed ; it is situated between the podical plates.

Caudad of the podical plate is the dorsal pair of pieces of the ovipositor.

Make drawings of the dorsal and the lateral aspects of this part of the body.

Caudal Part of the Abdomen of the Male.—In the male ten abdominal sterna are present ; the tenth is a hood-shaped sclerite on the caudal aspect of the body.

As in the female, the ninth and tenth abdominal terga are united on their lateral margins.

Projecting from the caudal margin of the tenth tergum there is on the dorsimeson a forked appendage, the *furcula*.

The eleventh tergum is furrowed by three deep longitudinal grooves.

The *cerci* are situated as in the female, but are longer.

The podical plates are nearly as in the female.

Make drawings of the dorsal and the lateral aspects of this part of the body.

*Handbook of Invertebrate Zoology, p. 253.

†Zoology, Advanced course, p. 309.

CHAPTER III.

THE INTERNAL ANATOMY OF AN INSECT.

(*Corydalis cornuta.*)

The insect chosen for the study of internal anatomy in this course is the larva of *Corydalis cornuta*. This larva lives under stones in the beds of swiftly flowing streams; it is well known to sportsmen under the name of "dobson," and is used extensively as bait for black bass.

As the larval state of *Corydalis* lasts nearly three years, larvæ which are at least two years old may be found at any time. They are most abundant where the water flows swiftest. A good way to obtain them is to hold a dip-net or a wire screen in the stream below some stones, and, lifting the stones with a hoe or garden rake, cause the current to sweep into the net the insects which were under the stones.

This larva is probably the most desirable subject for an elementary study of the internal anatomy of insects that can be found in this country. The species is a large one, being one of our largest insects; there is a coarseness in its structure, which enables one to study the different viscera with comparative ease; it is furnished with well-developed organs for aquatic respiration, and at the same time with equally well-developed organs for aerial respiration; and, as already stated, fresh specimens can be easily obtained at any season, even in mid-winter.

Unfortunately, however, the appearance of the insect is very disagreeable to most people. But after a specimen has been opened and pinned upon cork, as is necessary in the study of the viscera, the disagreeable features are not visible; and the ease with which the internal organs can be ex-

amined more than counterbalances the unpleasant part of the preparation of the specimen.

PRESERVATION OF SPECIMENS.

Specimens that are to be used for the study of internal anatomy should be preserved in an aqueous solution of chloral hydrate; this is made by dissolving one part by weight of chloral hydrate in twenty parts of water. This liquid preserves the organs and at the same time leaves them flexible. After the specimens have been in the solution for one day, a short, longitudinal slit must be made through the wall of the abdomen, so as to allow the solution to enter the perivisceral cavity; otherwise the viscera will decay. The delay of one day before making the slit in the body is important; if the slit is made too soon, the muscles will contract in such a way as to distort the specimen and render it worthless. One-half of the specimens should be slit on the dorsimeson, the others, on the ventrimeson; for if the specimens are all cut in the same manner, it will be impracticable to study certain organs.

If a very careful study is to be made of the external anatomy of this larva, one or more specimens should be left for several days in a warm place, in the chloral hydrate solution, without being cut. The parts bathed by the solution will be well-preserved; the viscera will decay; and the gases of decomposition will so distend the body that the different sclerites will be spread apart.

EXTERNAL CHARACTERISTICS.

In order to understand the internal anatomy of this insect it is necessary to know the more general features of its external anatomy. We will not stop to trace out the homologies of the different sclerites which enter into the composition of the body wall, but will merely examine the more important external structures.

Pin a larva to the cork or beeswax lining of a dissecting dish, with its ventral aspect uppermost, and cover it with water. Make a drawing of the ventral surface. Name the regions and the appendages of the body shown in this view. The long, tapering appendages on the margins of the abdomen may be termed the *lateral filaments* ; the tufts of hair-like appendages near the bases of the lateral filaments are *tracheal gills* ; and caudad of the ninth abdominal segment is a pair of *prolegs*. These may be termed the *anal prolegs*.*

Make a drawing of each of the following parts : —

1. The dorsal aspect of the head, showing the mandibles, the antennæ, and the labrum.

2. The ventral aspect of the head, showing the labium and the maxillæ.

3. The lateral aspect of the head, showing the number and position of the eyes.

4. One of the true legs ; name the parts of the leg.

5. The anal prolegs.

6. One of the tufts of tracheal gills. First remove the tuft with a pair of small scissors. Cut close to the ventral surface of the body, so that the entire tuft will remain together. Examine the tuft with a lense or with a compound microscope using a low power. The tuft is separated into two parts by a deep fissure. The mesal part is the larger, and is again divided into two parts. Each of these three primary divisions is composed of several bundles of tracheal gills. These are each composed of from two to twelve hair-like branches.

7. One of the tracheal gills. Cut off several of the hair-like branches and mount them in glycerine, using a thin

*Many larvæ bear upon the abdomen locomotive appendages, which resemble legs, and are termed prolegs. This is especially true of caterpillars, which bear from one to five pairs of these appendages. The prolegs are temporary organs, being shed with the skin when the larva transforms to a pupa.

cover-glass. Examine them with a compound microscope, using a high power. The surface of each hair is marked with numerous ridges, which resemble in appearance the fine ridges on the skin of the palm of the human hand. In the center of each hair, and extending nearly its entire length, is a large tube. This is a trachea or air vessel. Tracheæ can be distinguished from other vessels by being marked with transverse lines, which occur at regular and very short intervals. The intimate structure of the tracheæ will be studied later; but at this point the student should become familiar with the appearance of tracheæ, so that when he dissects the insect he can readily distinguish them from other vessels. Branching from this large central trachea are numerous very small tracheæ. Carefully trace out the courses of the small tracheæ and represent them in your drawing.

8. A spiracle. State number of spiracles and the position of each pair. Describe a spiracle. Do you observe any differences between the different spiracles of this insect?

INTERNAL ANATOMY.

Preliminary work.—Take from the chloral hydrate solution a specimen which was slit on the ventral surface. Immerse the insect in water, with its dorsal surface downwards. With fine scissors extend the slit on the ventrimeson the whole length of the thorax and abdomen; in making this slit cut through the wall of the body into the perivisceral cavity; the body-wall consists of two parts, the external crust of the insect, and, entad of this a wall of muscles; it requires considerable care to cut into the perivisceral cavity and not injure the viscera. Make, on each side, in that part of the body-wall connecting the prothorax with the head, an incision extending from the longitudinal incision to the side of the body.

On the meson just entad of the ventral wall of the body, there are two white cords, extending nearly the whole length of the body. At intervals, which approximate the segments in length, these cords are united ; at the points of union they are greatly enlarged ; from these enlargements there arise numerous, small, white cords, which extend in various directions. The two longitudinal cords, the enlargements upon them, and the numerous cords branching from these enlargements constitute the *nervous system ;* the cords are *nerves* and the enlargements are *ganglia*. The nervous system will be studied later in a specimen which has been opened on the dorsal side.

Cut away from the ganglia the nerves that extend to one side ; do this with the scissors, first placing one blade under the nerves and lifting them away from the other viscera.

Take a strip of sheet-cork a little longer than the insect and twice as wide, and pin it to the beeswax lining of the dissecting dish, and cover it deeply with water. Place the specimen on the cork and fasten with a pin at each end. Turn laterad each half of the ventral wall and pin it down to the cork, using ribbon-pins.

NOTE.—At the close of the day's work on this subject the student should remove the strip of cork from the dissecting dish and place it with the specimen still spread out upon it in a wide-mouthed bottle of chloral hydrate solution. By doing this the work can be resumed without the necessity of making a new dissection.

Ramifying through all parts of the body are numerous *tracheæ ;* the larger tracheæ are of a dusky color ; but many of the smaller ones contain air, which renders them silvery white. On each side of the body, extending the entire length of the thorax, are two very large tracheæ ; from each side of each abdominal segment except the last there arises a large trachea, which divides and subdivides into numerous branches. Cut a short piece from one of the large abdominal tracheæ, examine it with a compound microscope, and note

its characteristic appearance, so as to be able to distinguish tracheæ.

In the dissection of this specimen, the student may cut tracheæ and nerves freely; but great care should be used not to cut other vessels unless specially directed to do so.

In the center of the perivisceral cavity and extending the whole length of the body, there is a large tube; this is the *alimentary canal.*

Adipose tissue.—Surrounding the caudal half of the alimentary canal and attached to the lateral and dorsal walls of the abdomen and thorax, there are large, flocculent masses of a white substance; this is the *adipose tissue* or *fat.*

Make a drawing of a piece of adipose tissue showing the general form of the masses.

Examine a bit of adipose tissue with a compound microscope, using a high power, and make a drawing showing the minute structure of the tissue; in preparing the specimen care must be taken to avoid crushing the fat cells by pressure on the cover-glass.

In the farther dissection of this specimen the adipose tissue may be cut away when necessary to see the parts studied.

Form of the Alimentary Canal.—Remove the ventral wall of the head so as to expose the alimentary canal throughout its entire length.

Make a drawing of the alimentary canal and label the following parts:—

Pharynx.—The somewhat trumpet-shaped part of the alimentary canal immediately caudad of the mouth is the *pharynx.*

Œsophagus.—That part of the alimentary canal which is immediately caudad of the pharynx and which traverses the caudal part of the head and the cephalic part of the thorax is the *œsophagus.* It is a straight tube of nearly uniform diameter except when some portion of it is distended by food.

Proventriculus.—In the caudal part of the thorax the alimentary canal begins to enlarge. This enlargement increase gradually caudad until, in the first or second abdominal segment, its diameter is twice that of the œsophagus; then it contracts quite suddenly until its diameter is less than that of the œsophagus; this enlarged portion is the *proventriculus*. It corresponds in function with the gizzard of birds and is very complicated in structure internally.

Ventriculus.—Caudad of the constriction following the proventriculus, there is a slightly enlarged portion, from the cephalic end of which, there project cephalad, four large pouches; this enlargement is the *ventriculus* or *stomach* and the pouches are the *gastric cæca*. The two cæca of each side are quite closely united.

Malpighian vessels.—Emptying into the caudal end of the ventriculus are several, small, very long, and much convoluted tubes; these are the *Malpighian vessels*; they were named in honor of Malpighi, one of the early anatomists. As uric acid is found in the Malpighian vessels, they are supposed to correspond to the kidneys in function.

Determine the number of Malpighian vessels.

Intestine.—The part of the alimentary canal extending from the ventriculus to the caudal end of the body is the *intestine*; the part immediately caudad of the ventriculus is the *small intestine*; following the small intestine is the *large intestine*; there are two bends in the cephalic part of the large intestine; the first extends dorsad and cephalad; the second, dorsad and caudad; the *rectum* is not a well-defined part of the intestine in this insect.

Attachments of the Alimentary Canal.—The alimentary canal is attached to the body-wall and thus held in place in various ways. The most obvious attachments are those of the ends of this organ. In addition to these direct connections, the alimentary canal is indirectly connected to the body-wall as follows:—

By tracheæ.—From the lateral wall of each abdominal segment, large tracheæ arise ; many of the minute branches of some of these extend to the walls of the alimentary canal and thus tend to hold it in place.

In connection with the tracheæ, the action of the masses of adipose tissue should be observed. These large masses, which to a great extent are held in place by the tracheæ that extend to the alimentary canal, serve as cushions which tend to keep the organ in place.

By muscles.—A large number of very delicate muscles extend from the ventral wall of the head to the œsophagus. In the specimen which the student is now studying, only the ends of these muscles which are attached to the œsophagus can be observed, as the attachments of these muscles to wall of the head were cut away in the preparation of the specimen. Large muscles extend caudo-ventrad to the intestine from the line on the dorsal wall of the body between the eighth and ninth abdominal segments. From within the anal prolegs, muscles extend cephalad into the ninth abdominal segment and are attached to the intestine. Other muscles are described in the next section.

By the suspensoria of the viscera.—There are several, long, fine threads that are so attached as to tend to hold the alimentary canal and other viscera in place. These may be termed collectively the *suspensoria of the viscera*. In *Corydalis* four pairs of suspensoria can be distinguished. These are two pairs of suspensory muscles, a pair of ligaments, and a pair of suspensory nerves.

The suspensory muscles arise from the body-wall in the thorax, and extend caudad into the abdomen, where both pairs are attached to the alimentary canal, and one pair to other viscera also. It is rather difficult to trace out the origins of these threads upon the body-wall ; but the threads can be easily seen extending parallel with the œsophagus

and proventriculus, after they emerge from the layer of muscles and fat.

Study first the suspensoria of one side of the specimen, leaving those of the other side for study when the final drawing is made. In the following notes a single member of each pair of suspensoria is described.

The two suspensory muscles may be designated as the simple suspensory muscle and the branched suspensory muscle, respectively.

The *simple suspensory muscle* arises from near the middle of the ental surface of the pronotum, and extends caudad to the gastric cæca, where the fibres of which it is composed spread apart, some going to one cæcum and some to the other.

Make a provisional sketch of this.

With fine-pointed scissors, cut off the tips of the two gastric cæca of this side, and remove them with as long a piece of the suspensory muscle as is practicable, and mount them in glycerine for study with a high power of the microscope. Note the transversely striated appearance of the fibres of this suspensorium. This indicates that it is composed of striated muscular tissue.

Make a careful drawing showing the minute structure of this suspensorium.

The *branched suspensory muscle* arises from the ental surface of the body-wall, on the dorsal side, between the mesothoracic and metathoracic shields, near the lateral margin of the body and extends caudad into the cavity of the abdomen; here it divides into several branches. One branch extends to the ventriculus; one or more to the masses of fat and to the Malpighian vessels; and one joins a suspensorium which extends from a large trachea in the third abdominal segment to the intestine.

Trace out the course of the branches of the branched suspensory muscle, and make a provisional sketch showing their connections.

The *ligament of the viscera* is not attached to the body-wall, but is supported by a large trachea in the third abdominal segment, about which it forms a collar. This suspensorium has three branches; one of these extends caudad to the testis or ovary; one, cephalad, to the heart; and the third, to the intestine. This last branch receives the tendon of one of the branches of the branched suspensory muscle.

Make a drawing representing the alimentary canal in the center, a testis or ovary on each side (these are described in the next section), and the three pairs of suspensoria. While doing this the provisional sketches already made can be utilized, but the observations should be confirmed by a study of the suspensoria of the other side of the specimen.

Cut the trachea supporting the ligament of the viscera, and slip the ligament off from it; cut the ligament extending to the heart as near to the heart as practicable; cut the ligament extending to the intestine, between the intestine and the tendon of the branched suspensory muscle; cut the branched suspensory muscle as far cephalad as practicable; cut off the tip of the testis or ovary, leaving it attached to the ligament; mount the preparation thus made in glycerine for study with the microscope, carefully spreading apart the branches of the ligament and the end of the suspensory muscle with a needle before putting on the cover-glass. Study this preparation with a high power of the microscope and note the difference in structure between the suspensory muscle and the ligament of the viscera. Make a drawing showing this.

The *suspensory nerves of the alimentary canal* extend from the small intestine to the last abdominal ganglion. They can be best seen in a specimen opened on the dorsimeson, and will be described later.

The Reproductive Organs.—Although there appears to be no external characteristic by which the sexes of the larva of *Corydalis* can be distinguished, the internal reproductive

organs differ greatly in appearance ; the testes in this species are long and narrow, while the ovaries are short and broad. These organs are situated one on each side, between the layer of adipose tissue which surrounds the alimentary canal and the layer of the same tissue which is attached to the sides of the wall of the abdomen. The testes extend from near the middle of the third abdominal segment to near the posterior border of the sixth abdominal segment. The ovaries extend from near the middle of the fourth abdominal segment to near the middle of the fifth abdominal segment.

Determine the sex of the specimen that you are studying and do the work indicated below for that sex.

Reproductive Organs of the Male.—Note the shape of a testis, the connection of it with the respiratory system, the groove in the middle of its mesal aspect, and the vessel in the bottom of this groove. This vessel is the *vas deferens* (plural, *vasa deferentia*) and is the outlet of the testis ; it extends caudad to near the caudal end of the body. The cephalic end of the testis is supported by the ligament of the viscera already described.

Make drawings showing the external form of a testis.

Trace out the course of the vas deferens. This will require very careful dissection, especially in the ninth abdominal segment, where the vas deferens passes under a muscle.

The triangular organ into which the two vasa deferentia empty is the *vesiculæ seminales*. If the specimen has been opened on the ventral side, the visculæ seminales will lie on the alimentary canal, but if it has been opened on the dorsal side it will be necessary to cut the intestine and turn back the caudal part of it in order to see the visculæ seminales.

The tube extending from the vesiculæ seminales to the external opening of the reproductive organs is the *ejaculatory duct*.

Make a drawing showing the relations of the testes, vasa deferentia, vesiculæ seminales, and ejaculatory duct.

If the student has been trained in making histologic preparations, the structure of the testis may be studied at this point.

Reproductive Organs of the Female.—Note the shape of an ovary, the connection of it with the respiratory system, the position of the *oviduct* (which is the vessel extending caudad from the ovary), and the attachment of the ligament of the viscera.

Make drawings showing these things.

Each oviduct extends caudad from the caudal end of the ovary through masses of fat to the seventh abdominal segment, where, at a point opposite the last ganglion of the nervous system, it passes under the ventral muscles, and terminates in a disc-like enlargement, on the body wall.

Make a dissection showing this.

NOTE.—In the adult the two oviducts extend caudad to near the caudal end of the body where they empty into a short uterus.

Take one ovary and make longitudinal sections parallel with the broader sides of the organ and make a drawing of one of these sections, showing the ovarian tubes and the ova.

Take the other ovary and make longitudinal sections at right angles to the broader sides of the organ and make a drawing of one of these sections.

The Masticatory Organs of the Proventriculus.—Remove the alimentary canal, and carefully open the proventriculus by a longitudinal slit. Cover a piece of cork with white paper, spread out the opened proventriculus upon the paper ental side uppermost, and fasten it in place with ribbon-pins. Fasten the cork bearing the preparation to the beeswax in a dissecting dish, and cover the preparation with water. Study it with a lens and with a compound microscope, using a low power. Write a description of the masticatory organs, and make drawings illustrating them.

The Respiratory System.—Make a diagram showing

the arrangement of the larger tracheæ, and write a description of the same.

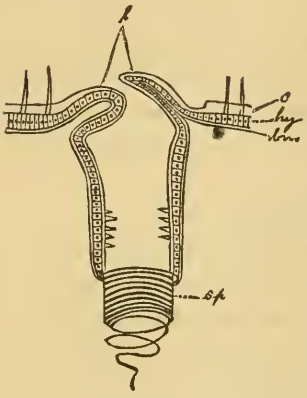

FIG. 1.—Section of trachea and body-wall. *c* cuticle; *hy*, hypodermis; *bm*, basal membrane; *sp*, spiral thickening of the intima.

The walls of the tracheæ are composed of three layers, which correspond to the layers of the body-wall; in fact the tracheæ are believed to be invaginations of the body-wall. The continuity of the membranes of the tracheæ and body-wall is shown diagrammatically in Figure 1. It should be observed that it is the inner layer of the wall of the trachea that corresponds with the outer layer of the wall of the body.

This inner layer of the wall of the trachea, the *intima*, like the cuticle is chitinous, and is shed from the tracheæ with the cuticle when the insect molts. This layer of the trachea is furnished with thickenings, which extend spirally and give to tracheæ their characteristic, transversely striated appearance. If a piece of one of the larger tracheæ be pulled apart the intima will tear between the folds of the spiral thickening, and the latter will uncoil from within the trachea like a thread. In some insects there are several, parallel thickenings of the intima, so that, when an attempt is made to uncoil the thread, a ribbon-like band is produced, which is composed of several parallel threads.

Make preparations and drawings illustrating the structure of the tracheæ of *Corydalis*.

The Circulatory System.—Read the account of the blood-vessels given in "*Comstock's Manual for the Study of Insects.*"

Make a drawing of the heart and the wings of the heart of *Corydalis*. Note especially the number and arrangement

of the *wings of the heart*, and the structure of the cephalic end of the *aorta*. Usually it is very difficult to determine the number and arrangement of the chambers of the heart in *Corydalis*; this point may be omitted, therefore, in this elementary course. Sometimes, however, some of the valves can be easily seen. They occur near the middle of each abdominal segment just opposite the point where the cephalic edges of the larger wing-muscles join the heart.

Review.—Take a specimen that has been slit on the *dorsal* surface and make a preparation similar to the one just studied except that it is opened along the dorsimeson. Review the work on internal anatomy indicated above excepting those parts referring to the nervous system, which will be concealed by the alimentary canal in this specimen, and to the circulatory system, which will be destroyed in the preparation of the specimen.

Note especially the form of the reproductive organs, and determine if the specimen is of the same sex as the one previously studied. If it is not, complete the work on the reproductive organs indicated above; if it is of the same sex other specimens should be examined after the work on this one is completed.

The Suspensory Nerves of the Alimentary Canal.—Gently push the intestine to one side and note the two fine threads extending caudad from the small intestine. Trace out the connection of these threads or nerves with the nervous system. Note the fine branches of these nerves that extend to the caudal part of the intestine.

Make a diagram representing a side view of that part of the alimentary canal caudad of the proventriculus, the last three gangalia of the nervous system, and the nerves just described.

The Peritoneum.—Cut the alimentary canal in two between the ventriculus and the first bend in the intestine. Remove that part of the alimentary canal caudad of this

point. Cut the tracheæ of one side extending to the remaining part of the alimentary canal, so that it can be pushed away to the other side. Be careful not to injure this part of the alimentary canal till after the vagus nerve has been studied, as indicated in a later paragraph. Take the specimen out of the water, and put a few drops of carmine solution on the muscles and nerves in the abdomen. Return the specimen to the dissecting dish and try to observe the peritoneum. This is a transparent, apparently structureless membrane, stretched over the floor of the abdominal cavity in such a way as to protect the central part of the nervous system. Owing to the transparency of this membrane, it is very difficult to see it; but when a specimen is treated as indicated above, the fine particles of carmine that become lodged beneath the peritoneum render it visible, especially when the carmine is washed off from the muscles that are not covered by the membrane. The peritoneum is attached along each side of the body just laterad of the great ventral muscles; the points of attachment are on the lines separating the segments of the body. Between the points of attachment, the margins of the membrane curve mesad, giving the membrane the appearance of being strongly stretched at the points of attachment.

The Nervous System.—After removing the alimentary canal from the specimen opened along the dorsimeson, the central nervous system will be exposed.

Make a diagram showing the disposition of the ganglia and of the principal nerves of the thorax and abdomen.

Make careful dissections of the ganglia and nerves found in the head, and make diagrams showing their arrangement.

The following parts should be observed and figured: —

The supraœsophageal ganglia.—These are two, large, ovoid ganglia, lying above the œsophagus, and connected by a short, thick commisure.

The antennal nerves.—These arise from the latero-cephalic angles of the supraœsophageal ganglia.

The optic nerves.—These arise caudad of the origins of the antennal nerves. Determine the number of divisions of each optic nerve.

The crura cerebri.—These are the two, large cords, one on each side, connecting the supraœsophageal ganglia with the subœsophageal ganglion, and forming with these ganglia the nervous collar of the œsophagus. (The singular form of *crura* is *crus.*)

The vagus nerve.—Just cephalad of the supraœsophageal ganglia there is a minute ganglion, the *frontal ganglion* ; this is connected by an arching nerve on each side with the crura cerebri ; from the frontal ganglion there extends cephalad a small, branching nerve ; from the frontal ganglion there also extends a nerve which passes caudad, between the supraœsophageal ganglia and the œsophagus, and ventrad of the aorta (which is usually turned to one side in opening the specimen as this one is opened), to a minute ganglion on the middle line of the œsophagus, caudad of the supraœsophageal ganglia. From this minute ganglion two nerves extend, one on each side, to the sides of the alimentary canal, which they follow to the proventriculus, where they divide into many branches. This system of nerves and ganglia are termed the *vagus nerve.*

The subœsophageal ganglion.—This is the large ganglion on the meson, ventrad of œsophagus. From it two large cords pass caudad to the first thoracic ganglia.

From the subœsophageal ganglia nerves extend to the labium, the maxillæ, the mandibles, and to other parts of the head. The beginning students who are taking a short course in entomology need not trace out these nerves. Other students may use as a work of reference a paper on this subject by Dr. William C. Krauss, published in "*Psyche*," vol. IV, pp. 179–184.

The Muscular System.—In a fresh specimen the muscles appear soft and translucent; but in specimens that have been kept for a considerable time in a preservative fluid, they are firm and opaque. The greater number of the muscles are attached to the ental surface of the body-wall, where they form several layers. This is well shown in the abdomen, where most of the muscles are for moving the segments of the body. In the head and thorax, there are numerous muscles for moving the appendages of the body, and their arrangement is much more complicated.

To attempt to make a detailed study of the muscular system would require much more time than can be devoted to this system in this elementary course. Only the more general features of the structure of the muscles and of their arrangement will be noticed.

Note that the muscular system is composed of an immense number of distinct, isolated, straight fibers, which are not enclosed in tendinous sheaths as they are with vertebrates.

Mount a few of these fibers in glycerine, and study them with a high power of the microscope. Note that the fibers present numerous, traverse striations, like the striped muscles of vertebrates.

Make a figure of a muscular fiber.

In this outline each series or layer of closely parallel fibers is considered as a separate muscle rather than an aggregation of muscles. It complicates the subject unduly to consider each distinct fiber a distinct muscle as has been done by some writers. Thus Lyonet in his "*Traité Anatomique de la Chenille, que range le bois de saule*" describes 1647 muscles without including the muscles contained in the viscera or those contained in the head.

Take a larva of *Corydalis*, which has been opened on the ventrimeson and from which the alimentary canal and the larger masses of fat have been removed, and study the ental layer of muscles of the dorsal wall of the abdomen.

On each side of the heart and ectad of the wings of the heart, there are great bands of longitudinal muscles, occupying the space between the heart and the prominent muscles that extend dorso-ventrad on the sides of the body. Of the longitudinal, dorsal muscles there are two sets on each side. The wider set, which lie near the heart, may be termed the *great-dorsal-recti-muscles*; the narrower set, which lie between the great-dorsal-recti-muscles and the dorso-ventral muscles of the sides of the body, may be termed the *small-dorsal-recti-muscles*.

Of the dorso-ventral muscles of the sides of the body, referred to above, there are two large bundles on each side of each segment; they are situated near the union of the segments.

Between the lateral muscles and the cut edge of the specimen (the dorsimeson) lie the *great-ventral-recti-muscles*. These differ from the great-dorsal-recti-muscles in being somewhat oblique (this is shown better in specimens opened on the dorsimeson).

Make a drawing of the third, fourth, and fifth abdominal segments respresenting the muscles mentioned above and the heart and its wing-muscles.

Carefully remove the recti muscles in one or two abdominal segments and note that ectad of them are many muscles extending obliquely in various directions. The study of these oblique muscles will be omitted in this course.

Examine Plates VI, VII, VIII, XV, XVI, and XVII, of the "*Traité Anatomique de la Chenille*" of Lyonet and Plates III and IV of the "*Considérations Générales sur l'Anatomie Comparée des Animaux Articulés*" by Straus-Durckheim.

CHAPTER IV.

THE EXTERNAL ANATOMY OF A BEETLE.

(*Pterostichus californicus.*)

With the knowledge of the external anatomy of the locust as a basis we may attempt to examine comparatively some of the various conditions of the body exhibited among different orders of insects. With the varied habits of insects there are necessarily correlated various modifications of structure, internal and external. The modifications of the external structure are those taken special cognizance of and used in the present analytical tables and keys for insect classification, and must be studied to some degree before determination of insect forms can be done intelligently. The study of insect anatomy in a comparative way will also give the student some understanding of the significance of homology and specialization.

The peculiarly flattened form of many insects, by which the lateral aspects of thorax and abdomen are reduced to a mere ridge or margin, is accompanied by a change in the position of many of the body sclerites, in particular the pleural sclerites of the thorax. This condition is well exemplified among the predaceous ground-beetles (*Carabidae*) and almost any species may be selected for illustration. We have chosen the species *Pterostichus californicus*, as the representative of a widely spread genus, and the description following applies especially to this form ; however, the notes will serve as a guide for the examination of any member of the genus.

The meso- and metathoracic segments are closely joined

to each other and to the abdomen. The prothorax is freely movable and is constricted at its articulation with the mesothorax, so that it appears to form all of the second or thoracic region of the body. The insertion of the hinder two pairs of legs, however, shows that part of what at first glance appears to belong entirely to the abdominal region of the body really belongs to the thorax. The body-wall is very strongly chitinized, the body being enclosed in a veritable coat of armor. The head projects horizontally from the body instead of hanging vertically across the front, as with the locust, and the flattening of the body is evident in all regions, head, thorax, and abdomen.

PARTS OF THE HEAD.

THE FIXED PARTS OF THE HEAD.

The fixed parts of the head are fused so as to form a strong and rigid box, which is elongated and flattened.

Epicranium.—The *epicranium* bears on its cephalic portion two impressed lines which run cephalad until they meet the transversal *clypeal suture*, the suture separating the clypeus from the epicranium. Laterad of each of the impressed lines on the epicranium there is, forming the dorsolateral margin of the head, a sharp ridge called the *frontal ridge*, which runs cephalad from the dorsal margin of the eye. The antennæ arise just below the cephalic end of this frontal ridge in a short, rounding groove running cephalad from the eye. On the epicranium just above each compound eye are two, long hairs arising from distinct pits, these pits are called *setigerous punctures*. Similar punctures and hairs are found also near the lateral margins of the clypeus.

Clypeus.—The *clypeus* is broader than long, and projects cephalad between the bases of the mandibles. Projecting

cephalad from the cephalic margin of the clypeus, is the subquadrangular *labrum*.

Compound eyes.—The *compound eyes*, on the lateral margins of the head, are comparatively small.

Ocelli.—There are no *ocelli*.

Genæ.—The portions of the epicranium ventrad of the eyes and antennæ are the *genæ* and each projects cephalad, latero-ventrad of the base of the mandibles, as a thin tapering tongue curving slightly mesad at its tip. Ventrad of this projecting process, the gena presents a rounded emargination, and, filling in the emargination, may be seen the basal portion of the maxillæ. The genæ form, with portions of the occiput, the lateral portions of the ventral surface of the head.

Occiput.—The *occiput*, although fused with the epicranium to form the firm head-box, is plainly separated from the epicranium on the dorsal and lateral portions of the head by an impressed line, which fades out on the lateral portions of the ventral surface of the head, so that the genal and occipital regions cannot here be distinguished.

Gula.—Forming the mesal third of the ventral aspect of the head, slightly widening caudad, and expanding at its cephalic extremity to a narrow, transversal bar, which projects laterad to the genal emargination, is the *gula*, one of the head sclerites, which is wanting or is fused with the submentum in the head of the locust. The gula is usually a well developed sclerite among beetles. The sutures separating it on either side from the contiguous portions of occiput and epicranium (gena) are called the *gular sutures*.

Make a drawing of the ventral aspect of the head, showing the skeletal parts described, and also what may be seen of the mouth parts *in situ*.

Antennæ.—The *antennæ* are filiform, and 11-segmented; the third segment is the longest one. The proximal three segments are glabrous, and the second and third bear each two or three longish hairs near their distal end. The remaining eight segments are finely pubescent. In addition each of these eight bears a few longer hairs at its distal end.

Mouth-Parts.

The *mouth-parts* are fitted for biting and are in general similar to the mouth-parts of the locust.

Labrum.—The *labrum* is conspicuous, with the distal margin slightly concave outwardly; along this margin there are a few, rather long hairs.

Mandibles.—The *mandibles* are rather long, and taper distad to a sharp, curving tooth. They bear on their sharp, cutting, inner margin, near the base, a few, small, blunt teeth, and their outer face presents a broad, shallow groove or furrow called the *mandibular scrobe*. Make a drawing of a mandible.

Maxillæ.—The *maxillæ* differ especially from those of the locust by the presence of an additional sclerite, the subgalea, by the side of the stipes, as if the stipes were divided by a longitudinal suture. The *cardo* is large, and broadly club-shaped; the median portion of the maxilla is composed of three sclerites, the *stipes*, *palpiger* and *subgalea*. These three sclerites may be distinguished when the maxilla is viewed from the dorsal aspect by the following characters: the palpiger lies above the distal two-thirds of the stipes, and also overlaps part of the subgalea. It is elongate, subtriangular in outline with apex directed toward the maxilla. From it arises the four-segmented palpus, and it also bears near the origin of the palpus a single, conspicuous, long

bristle. The stipes as seen from above is elongate and rather slender, with the basal extremity widened. It lies laterad of the large subgalea, which forms the inner or mesal half of the portion of the maxilla. From the subgalea the two lobes, *galea* and *lacinia*, of the maxilla arise. The *galea* is slender, elongate, distinctly two-segmented, and palpiform in character. The lacinia is strongly chitinized, and is strongly beset on its inner face with strong and long, curved spines, and on its dorsal aspects with many, weaker hairs. It bears on its distal end a strong tooth or curved tip, known as the *digitus*.

Make a drawing of the dorsal aspect of a maxilla.

Labium.—The *labium* is separated from the cephalic transverse portion of the gula by a straight, transverse suture. The *submentum* is large, strongly chitinized, and with its lateral portions appearing as broad, expanded lobes, separated by a broad and deep, cephalic emargination. Bordering this emargination is the narrow curving *mentum*, with a mesal, cephalad-projecting, two-pointed tongue. From the elongated, subcylindrical, cephalad-projecting palpigers arise the three-segmented *labial palpi*, the first segments of which are very short. Also projecting cephalad from the mentum is the *ligula*, composed of a dorsal or inner, delicate, transparent, membraneous part, which divides distad into two, slender, tapering projections, the *paraglossæ*, and a ventral or outer, chitinized, undivided portion, the *glossa*. The tip of the glossa is truncate, and bears two, long, strong hairs. The paraglossæ lie slightly laterad of the distal half of the glossa. The entire ligula arises, not from the cephalic margin of the mentum, but from its inner or dorsal face, and it may be that its parts are not homologous with the terminal lobe (ligula) of the locust's labium, but that one or perhaps both parts are continuous with the lining of the mouth cavity; in which case they would be homologous with the hypopharynx of the locust's mouth.

Make a drawing of the ventral (outer) aspect of the labium.

PARTS OF THE THORAX.

PROTHORAX.

Dorsal aspect.—The *pronotum* is not divided into different sclerites, but appears as a single, firm convex plate, bearing a median impressed line, and, laterad of this line, on each side near the caudal margin, a short, linear depression. At the acute lateral margins, the pronotum is inflexed, extending a little distance ventro-mesad on the ventral (pleural *s. str.*) aspect of the body. This inflexed portion is often called the *prothoracic epipleura*.

Ventral aspect.—The *sternum* and the true pleural sclerites or "side pieces," together form the ventral aspect of the prothorax.

Sternum.—The *sternum*, constituting the median region of this aspect, is irregularly-saddle-shaped, with a caudad-projecting tongue between the *coxal cavities*. This tongue after reaching the caudal margins of the coxæ bends at right angles and projects dorsad, the end expanding slightly into two, dorso-laterad projecting points, which meet a ventro-mesad projectingpoint of the epimeron on each side, and thus form part of the enclosing, caudal boundaries of the coxal, cavities.

Episternum.—The *episternum*, a large rhomboidal sclerite, constitutes most of the body wall between the sternum and the epipleurae.

Epimeron.—Separated from the caudal extremity of the episternum by a distinct suture, is the narrow, curving *epimeron*, whose expanded mesal extremity presents two, pointed, curving processes, which enclose the coxal cavity laterad and caudad. The meeting of the epimeron and sternum caudad of the coxal cavity technically *closes* it, or

makes it *entire*; if these two sclerites do not meet, as is often the case among beetles, and the cavity is bounded caudad simply by membrane, the cavity is said to be *open*. If there is no caudal tongue projecting between the cavities, they are said to be *confluent*; when separated, as in the specimen in hand, by this tongue, they are technically *separate*.

MESOTHORAX.

Dorsal aspect.—When the wing-covers are folded the only part of the mesonotum visible is the small, median, triangular or shield-shaped portion of the *scutellum*. By spreading apart or breaking away the wing-covers, the lateral membraneous portions of the scutellum may be seen, as well as the *scutum*; the median part of the scutum is strongly chitinized and the lateral parts, weakly chitinized. The *postscutellum* also may be distinguished as a narrow, weakly-chitinized, curving bar, running laterad on each side just in front of the caudal apex of the scutellum. The *praescutum* is represented merely by a thin, transversal strip of membrane.

Ventral aspect.—As with the prothorax the ventral aspect of this segment is composed of the sternum and the pleural sclerites.

Mesosternum.—The *mesosternum* is plainly set off by sutures. Its caudal margin has a broad, median tongue, which projects caudad between the coxal cavities, and is angularly emarginated at its tip. Laterad of this tongue are two, rounding emarginations, for the reception of the coxæ. Bounding each coxal cavity laterad is a caudad-projecting portion of the sternum. Cephalad the sternal sclerite tapers somewhat, and the cephalic margin is narrowly truncate. A narrow, collar-like cephalic margin which fits into the prothorax, is separated from the rest of the sternum by a slight carina or elevated line.

Episternum.—The pleural sclerites are distinct ; the *episternum* is large, angularly concave, and does not reach the coxa. It bears near its cephalic margin two, transversal, raised lines or carinae, one of which is a continuation of the collar-making carina of the sternum. Like the sternum, the cephalic margin of the episternum fits into the prothorax. The lateral margin is angularly inflexed along its entire length, as is the case with all the pleural sclerites. The narrow, inflexed portion is covered when the wing-covers are closed by the inflexed, lateral margin of the wing-covers.

Epimeron.—The *epimeron*, lying along the caudal margin of the episternum, is a narrow, transversal sclerite. Its mesal extremity does not reach the coxal cavity, but lies contiguous to the lateral margin of the metasternum.

Paraptera or Elytra.—The *paraptera* are remarkably developed into strongly chitinized, wing-like structures, called the *elytra* or wing-covers. When the beetle is at rest, the elytra fit closely over the dorsal aspect of the meso- and metathorax and abdomen, protecting the abdomen and wings, which (when present, as in most beetles) lie folded over the metathorax and abdomen and beneath the wing-covers. The elytra are articulated with the body so as to be freely movable, being outspread when the beetle is in flight. The basal or articulating parts of the elytra lie just ventro-laterad of the lateral margins of the scutellum. The expanded flap or wing-like parts present a series of sub-parallel, longitudinal, impressed lines, and the lateral margins, termed *epipleuræ*, are inflexed over the dorso-lateral margins of the body. This inflexed condition of the margins does not extend quite to the tips of the elytra, but disappears at a point where the margin appears to be *interrupted*. On the inner surface of each elytron near the lateral margin there is a distinct longitudinal fold or *plica*. The fore or mesothoracic wings are wanting or are rudimentary in beetles, although the elytra

(paraptera) are popularly considered to be the modified* forewings.

METATHORAX.

Dorsal aspect.—When the elytra are closed the metanotum is completely covered and invisible. By removal of the elytra, the metanotum is revealed as a narrow transversal bar, on the surface of which a number of sutures and elevated and depressed lines are to be seen. The work of distinguishing the various component sclerites of the metanotum cannot be done satisfactorily by the elementary student. There is a conspicuous depression or groove extending caudo-cephalad along the dorsimeson, with strongly chitinized margins, which project slightly mesad over the depression. On the inner surface of the elytra, near the base of the mesal margins, there are two, slight, projecting processes. These small processes have strong, acute margins, which project slightly laterad. When the elytra are closed, the raised processes fit into the groove of the metanotum, and the laterad-projecting margins of the processes lie under the mesad-projecting margins of the groove, the whole structure forming a means for the firm holding of the elytra over the dorsum of the body. The firm holding of the elytra is further aided by the inflexed lateral margins and by the close dovetailing of the mesal margins along the dorsimeson.

Ventral aspect.—As in the other thoracic segments this includes both the sternum and the pleural sclerites.

Metasternum.—The *metasternum* is, as the mesosternum, best described as saddle-shaped. It has a rather broad, blunt tongue, projecting cephalad between the mesocoxæ to meet the caudad-projecting tongue of the mesosternum. It presents, also, an acute-angled process, projecting caudad between the

*The homology of the elytra with the paraptera and not with the fore wings of other insects was first pointed out by F. Meinert in 1880. In *Dytiscus* and in many other beetles rudiments of the forewing exist beneath the elytra.

cephalic halves of the metacoxæ. The "saddle-flaps," or lateral lobes of the metasternum expand laterad, and their cephalic margins, concavely rounded, form the caudal boundaries of the mesocoxal cavities. There is a line or suture running transversely across the metasternum near the caudal margin which does not reach the lateral margins. That portion of the metasternum caudad of this suture is called the *antecoxal piece* of the metasternum.

Episternum.—The rhomboidal *episternum* is the largest of the pleural sclerites.

Epimeron.—The trapezoidal *epimeron*, though smaller than the episternum, is broader, and more conspicuous than that of either of the other thoracic segments.

Paraptera.—The *paraptera*, lying on the dorsal aspect of the body beneath the elytra, are small and weakly chitinized, and may not be determined satisfactorily by the student.

Make a drawing of the ventral aspect of the entire thorax.

APPENDAGES OF THE THORAX.

Both fore and hind wings are wanting in this beetle. This is exceptional, however, among beetles, the hind wings, membraneous and with a few strong veins, being usually well-developed, and differing from the wings of most insects in being folded transversely as well as longitudinally when the insect is at rest.

The legs are adapted for running, being long and slender. The pro- and mesocoxæ are globular, and the trochanters distinct, but small. In the hind legs the coxæ are large and greatly expanded transversely, extending laterad as far as the lateral margins of the metasternum. The coxæ become narrower laterad, tapering to an acute point. The trochanters of the hind legs are very large and lobe-like. They project along the basal half of the femur. The tarsi of all the legs are distinctly 5-segmented.

PARTS OF THE ABDOMEN.

The abdomen is composed of a number of very much flattened segments ; and its dorsal surface or *tergum* is completely covered by the elytra when they are closed. On the ventral surface, six strongly-chitinized *sterna* may be counted. The first (basal) sternum is completely divided by the coxal cavities, so that it appears as two triangular pieces, lying laterad of the coxæ. The cephalic margin of the second sternum is emarginated on each side of the meson by the coxal cavities, so that the mesal part of the cephalic margin appears as an acute, cephalad-projecting process. The third, fourth and fifth sterna are of about equal length (caudo-cephalic), the sixth being longer and having its caudal margin roundly pointed. The first, second and third sterna are connate (firmly united, not movable on each other), although the sutural lines are distinct. All of the sterna have strongly chitinized, lateral margins, which project somewhat dorsad, and then are narrowly inflexed over the dorso-lateral margin of the abdomen. There are seven *terga*, the tergal aspect corresponding to the sixth sternum being unequally divided by a transversal suture, producing thus an additional small tergum. All of the terga are membranous except the sixth and seventh, which are chitinized, and are known respectively as the *propygidium* and *pygidium*. The propygidium is coarsely punctulated, but the surface of the pygidium is smooth. Each tergum except the seventh bears a pair of *spiracles*, located near the cephalo-lateral angles of the terga. Between the lip-like caudal margin of the pygidium and the sixth sternum there is a transversal fissure, in which lie the anal and genital openings.

CHAPTER V.

THE EXTERNAL ANATOMY OF A BUTTERFLY.

(*Anosia plexippus.*)

As a representative of the large order Lepidoptera, including the moths and butterflies, the familiar "milkweed" or "monarch" butterfly, *Anosia plexippus*, has been selected. It is commonly distributed all over the United States.

PARTS OF THE HEAD.

THE FIXED PARTS OF THE HEAD.

In order to study the head of *Anosia*, it is necessary to remove the scales which almost completely cover it. Rubbing with a soft, pointed brush, assisted by gentle manipulation with a needle or delicate forceps, will soon denude the head.* The antennæ may be broken off if in the way. A large part of the denuding may be done while the head is still attached to the body of the specimen; the denuding of the caudal aspects must be done after removal. If the proboscis is tightly coiled, as is probable, the head may be conveniently held by thrusting a dissecting needle through the center of the coil.

Compound eyes.—The *compound eyes* are striking for their large size, each one appearing to constitute about one-third of the head. Examine a portion of the cornea under

*In addition to the denuded head used for examination it will be advisable for the student to soften and bleach another head; in the bleached or cleared head certain of the sutures can be more readily seen than in the merely denuded specimen. The bleaching should be done as follows: A denuded head should be boiled for a few minutes in dilute potassium hydrate until the eyes become light-brown; then wash in water and transfer to *eau de Labarraque*, in which bleaching fluid the head will soon reach the desired clearness.

high magnification. (Cut out a piece and mount in glycerine, or dry, on a glass slide.) Notice the hexagonal shape of the facets.

Simple eyes.—There are no *simple eyes* ; assure yourself of their absence by examination.

Clypeus.—The cephalic aspect of the head is made up chiefly of the rounding, tumid, shield-shaped *clypeus*. It extends dorsad to the antennary fossæ, and as a short, broad tongue between them to a distinct suture extending transversely from fossa to fossa. Ventrad the clypeus is bounded by a subtransversely-running suture curving slightly dorsad in its lateral portions. Ventrad of the mesal part of the suture is the *labrum* ; and latero-ventrad of the lateral parts of the suture are triangular expansions of the *genæ*. The part of this suture lying between the latero-ventral angles of the clypeus and the triangular expansions of the genæ is especially distinct, and in bleached specimens shows a noticeable expansion at a point from which the suture running dorsad is represented only by a raised line or sutural ridge. Laterad the clypeus is separated from the genæ (those narrow portions of the genæ which form the mesal orbits of the eyes) by the sutural ridge just mentioned.

Epicranium.—The *épicranium* comprises a much smaller proportion of the front of the head than in the locust. It composes most of the dorso-cephalic, dorsal, and dorso-caudal aspects of the head. It is a suboblongate sclerite with its bounding sutures largely obsolete. A short, broad tongue projects cephalad between the antennæ meeting the dorso-caudad-projecting tongue of the clypeus, but separated from it by the short transversal suture. The epicranium presents a tumid transverse space on the caudal aspect of the head, ending in two, tumid, whitish spots.

Between the clypeus and the eyes are the narrow elongated *genæ*. They compose the cephalic and part of the

dorsal and ventral orbits of the eyes. Each gena presents a triangular expanded portion lying between the base of the maxillary proboscis and the caudo-mesal angle of the eye.

Postgenæ.—The *postgenæ* are two important sclerites, constituting the caudal portions of the orbits of the eyes, and also the lateral portions of the caudal aspect of the head. The chief portion of the postgena are the broad surfaces caudad of the eye.

On account of the obliteration of certain sutures, a more detailed study of the fixed * parts of the head is not feasible for the elementary student.

THE MOVABLE PARTS.

Certain parts of the head plainly movable in the locust and in the beetle are immovable in *Anosia*, but their homology with the movable parts heretofore studied, and their homologous distinctness from the "fixed parts" of the head, justify reference to these immovable but homologous equivalents of the movable parts of the head in other insects as "movable parts."

Antennæ.—The rather long, knobbed *antennæ*, have their insertions cephalo-mesad of the dorsal margins of the compound eyes. Note the ringed or jointed structure of the antennæ, and the swelling club of the tip.

Labrum.—Immovably joined to the cephalo-ventral margin of the clypeus is a very narrow, mostly transversal sclerite, the *labrum*. It bears two, tapering, cephalad-projecting points, the *pilifers*, rising from the ends of the transverse portion of the sclerite. Each pilifer bears on its mesal margin a row of short, bristly hairs, light brown in color. There is also to be made out a very small, triangular piece

* For a determination of the sclerites of the head of *Anosia plexippus*, based on a comparative study of various lepidopterous heads, see article by the junior author of these notes entitled "The Sclerites of the Head of Danais archippus Fab." [=*Ansoia plexippus*], in Kansas University Quarterly, Vol. II, No. 2, Oct., 1893.

projecting cephalad from the meson of the transverse portion of the labrum. This is the *epipharynx*, a process rising from the upper wall of the pharynx.

Mandibles.—The *mandibles* are wanting in *Anosia*. (They are present in an aborted condition in many Lepidoptera; and in one genus of small moths, *Micropteryx*, are present and functional, constituting, with the maxillæ which are not produced into a sucking tube, true biting mouth-parts.)

Maxillæ.—The long, coiling, sucking tube of *Anosia* (as of all the Lepidoptera possessing functional sucking mouth parts) is composed of the greatly extended, opposed, terminal portions of the *maxillæ*. In addition there is a fixed basal part of each maxilla, which cannot be divided into *cardo* and *stipes*. This basal part, shining brown, extends caudad and ventrad, partially bounding a cavity lying between it and the labium. The sucking tube consists of two lateral portions, each portion representing a maxilla. These parts are convex laterad and concave mesad. By the opposition of the two concave aspects, a complete central tube is formed. The *maxillary palpi* are wanting in *Anosia*, and in most of the butterflies, although present in a one- or two- or even several-segmented condition among most of the moths.

Labium.—The *labium* is a fixed, semi-membranous sclerite, triangular in outline, with its apex projecting cephalad and joining the maxillar proboscis at its base. The *labial palpi* are large, three-jointed, and covered with scales, and normally project cephalo-dorsad. They are inserted on tumid spaces on the base of the triangular labium, and the first joint is pedicellate.

Make a drawing of the cephalic aspect of the head showing the fixed and movable parts.

PARTS OF THE THORAX.

The three divisions or segments of the thorax vary much in size and shape. It is interesting to note the coördinated specialization of wings and corresponding thoracic segments. The great development of the forewings in *Anosia* is attended by a corresponding marked development of the mesothorax; and the reduction of the flight value of the hindwings is paralleled by the reduction in size and importance of the metathorax. The prothorax is altogether much reduced in size and function. Its legs are small and weak.

PROTHORAX.

The *prothorax* is visible as a narrow ring or collar immediately caudad of the head. On the dorsum may be noted two prominent tumid portions, the "*prothoracic lobes*" of Scudder, and caudad of these, and mesad, a small triangular plate; the tumid lobes constitute the *scutum* and the triangular plate is the *scutellum*. Just caudad of the scutellum are two lobes (smaller than the Scudderian lobes) connected by a transverse piece. These lobes and transverse bar are the *postscutellum*. The *præscutum* is obsolete. The *pleura* and *sternum* are united without visible sutures, forming a "continuous ossified collar" encircling the prothorax beneath.

MESOTHORAX.

The greatly developed *mesothorax* forms fully five-sixths of the mass of the thorax. The prothorax is distinctly separate from the other thoracic segments, and is movable; but the meso- and metathoracic segments are much more intimately united.

Dorsal aspect.—The dorsum of the mesothorax quite overshadows the metadorsum, and plainly shows two sclerites, the *scutum* and *scutellum*. (A third, the *postscutellum*, is hidden beneath the metathoracic scutum.)

Scutum.—The *scutum* is much the larger of the two, constituting, in fact, about two-thirds of the whole thoracic dorsum. It appears to be irregularly oblong in shape, sloping dorso-caudad from its cephalic margin. Its latero-cephalic angles are covered by broad flat leaves or plates, the *patagia* (see below). A slight longitudinal mesal ridge, fading away cephalad, is to be noted. A laterad projecting angulated swelling occurs on each ventro-lateral border about one-third of the caudo-cephalic length of the sclerite from the ventro-caudal corner.

Scutellum.—The *scutellum* is a rather small, subquadrangular plate, just caudad of the scutum. A narrow process projects cephalo-ventrad from each lateral angle of the plate (the processes thus lying ventro-caudad of the ventro-caudal angles of the scutum).

Lateral aspect.—The insertions of the forewings set off the pleura from the dorsum. The three sclerites of each pleura are easily made out; and in addition, the large, divided coxa and a portion of the sternum which runs latero-cephalo-dorsad to meet the episternum give the appearance of three additional pleural sclerites.

Episternum.—The *episternum* lies cephalad of the epimeron and is roughly trapezoidal in outline.

Epimeron.—The *epimeron* is very oddly shaped, being rather hour-glass-like in form with its long axis in an approximately caudo-cephalic direction. The broad portions of the hour-glass are exaggerated by projecting, horn-like processes. The cephalo-ventrad-projecting horn lies between the coxa and the episternum.

Parapteron.—The third pleural sclerite, the *parapteron* is conspicuous because of its remarkable development into a broad, flat lobe, overlying and protecting the costal insertions of the forewing and to a considerable degree the dorso-cephalic aspect of the mesothorax. This lobe is called the *patagium*, by writers on the Lepidoptera.

Ventral aspect.— The *sternum* of the mesothorax is a saddle-like, six-sided piece. Cephalad the bounding suture runs transversely, but caudad the sternum projects by an acute-angled process between the mesothoracic coxæ. It chiefly forms the *pectus* or chest of the insect. It bears a median, impressed, longitudinal line.

METATHORAX.

The metathorax is much smaller than the mesothorax; its dorsum, especially so.

Dorsal aspect —The dorsum comprises but two sclerites: the *scutum* and the *scutellum*. The scutum is divided into two triangular pieces by the triangular, cephalad-projecting scutellum. Neither the præscutum nor the postscutellum is visible.

Lateral aspect.—The *episternum* is irregularly trapezodial, uniting with the sternum by a narrow dorso-ventral neck or bar. Just cephalo-dorsad of its cephalo-dorsal corner, lies the small hemispherical *parapteron*. Caudad of the dorsal half of the episternum lies the *epimeron*, a rather large, irregularly-square sclerite, with a long, caudo-mesad-projecting tongue running from its ventro-caudal corner.

Ventral aspect.—The metathoracic *sternum* is not easily bounded. The suture between the episternum and the sternum is obsolete. The connecting bands running ventro-mesad on either side from the episterna meet and expand on the ventrimeson, forming a subquadrangular space.

Make a semidiagrammatic drawing showing the dorsal aspect of the thorax.

Make a semidiagrammatic drawing showing the lateral aspect of the meso- and metathoracic segments, including the coxæ of the legs.

APPENDAGES OF THE THORAX.

There are three pairs of legs and two pairs of wings in *Anosia*. Note the small size of the first pair of legs. Make out *coxa*, *trochanter*, *femur*, *tibia*, and *tarsi* in the legs. Note the great development of the meso- and metacoxæ, and note they are each divided longitudinally by a distinct suture. They form a considerable part of the lateral aspect of the meso- and metathoracic segments.

The forewings are larger and of more use in flight than the hindwings, which is in contrast to the case with the locust. The wings, like those of the locust, are membraneous plates supported by a framework of strong, hollow veins with strongly chitinized walls. The venation of the wings affords important characters for classification, but we cannot consider the subject here. Note that the upper and lower surfaces of both fore and hindwings are covered with fine scales. Rub off some of these scales upon a glass slide, and examine with a high power. Note that each scale consists of a little stem and a broad flat blade. This blade is longitudinally striated. The scale is simply a flattened membraneous sac, and the striæ are fine ridges running along the upper membrane. Examine a small bit of the wing from which some of the scales have been rubbed off, note the little pits or sockets in which the pedicel of the scales fits, and note the regular arrangement of the scales into rows, each row consisting of two tiers.

Make a drawing showing a part of the wing partly covered by scales and partly denuded.

PARTS OF THE ABDOMEN.

The abdomen is composed of nine segments ; the first or basal one is depressed, while the others are more or less compressed. The second and third are the largest two seg-

ments in both male and female; the fourth, fifth, sixth, and seventh are of nearly equal size and shape in the male; and the fourth, fifth, and sixth are similar in the female. The tergum of the first segment is broad, flattened and cushion-like, projecting slightly caudad over the second tergum. The sternum of the first segment is unchitinized, appearing as a narrow, membraneous space between the metasternum and the well-chitinized sternum of the second abdominal segment. This second sternum is traversed by a transversal, elevated line or carina, which lies almost midway between the cephalic and caudal margins of the sternum. This carina does not, however, represent a suture. The terga of the first seven segments in both sexes are separated from the sterna by a pleural membraneous fold. In this pleural membrane the *spiracles*, which occur only on the first seven segments, are located. The terminal segments differ in the sexes, and they must be considered separately.

In the * female the tergum of the seventh segment is longer than the sternum, and bends somewhat ventrad, forming, with the much reduced eight and ninth segments, a sort of hood over a space partly enclosed by this hood, partly by a bluntly pointed, caudad-projecting process of the narrow sternum of the seventh segment, and partly by the margins of this segment. This space is called the *vaginal vestibule*; in it lies the *vaginal opening*. The eight segment is much reduced and compressed. Its sternum, with the outer aspect facing cephalo-ventrad, forms the roof of the vaginal vestibule, and is bordered by a thin, distinct margin. The ninth segment is much more reduced than the eight, and it usually lies retracted between and almost concealed by the slightly projecting lateral margins of the eight segment. It presents two, small, lateral lobes or flaps, and a narrow sternal connecting piece.

* The sclerites of the caudal segments of the female can be much better studied in fresh specimens than in dry specimens.

In the male the seventh segment does not differ especially from the sixth segment. The tergum of the eighth segment is subtriangular, with curving sides, and the pleural membrane is especially broad. The lateral portions of the sternum project caudad much beyond the caudal tip of the tergum, as two, horny, double-pointed, thin, plate-like processes, called the "*false claspers.*" These processes are not articulated with the sternite, and are not movable as are the true claspers of the ninth segment, but are projecting parts of the sternum, and thus are not homologous with the body appendages. The tergal, lateral, and sternal walls of the ninth segment are concealed within the eighth segment, but certain processes or appendages belonging to the ninth segment are conspicuous. From the tergum a conspicuous, caudad-projecting, tongue-like process arises, whose distal half is divided longitudinally into two, lateral flaps or lobes, whose tips are diagonally truncate. This dorsal process with divided, distal portions is called the *tegumen* or *sicula*. Between the false claspers, there may be seen a pair of dark pointed processes. These are the tips of the *true claspers* or *harpagones*. Break away one of the false claspers, and the true clasper of that side will be mostly exposed to view. It consists of a subquadrate, plate-like part, with a median, thickened and ridged portion lying on its mesal or inner aspect; projecting caudad from the caudo-ventral angle of the subquadrate part and continuous with the ridge of the mesal face, there is a slender, but strong-pointed process, concave outwardly, and bearing on its outer surface near the tip a number of fine, transverse lines. Projecting caudad from the dorso-caudal angle of the subquadrate part of the true clasper there is a smaller and rather triangular process.

CHAPTER VI.

SPECIALIZED MOUTH-PARTS OF INSECTS.

The mouth-parts of the locust and beetle have already been studied; they represent, as a type, the generalized biting mouth-parts of insects; (biting mouth-parts of general identity with this type are found in the Neuroptera and in the pseudo-neuropterous groups (the bird-lice, white-ants, dragon flies, stone flies and others). The student has already become acquainted with the specialized, sucking mouth-parts of the butterfly. Another type of sucking mouth-parts, one in which all the parts of the mouth are represented, is presented by the Hemiptera, for an easily obtained and easily studied example of which we have chosen the Dog-day Cicada, *Cicada dorsata*. As typical of the piercing and sucking (or lapping) mouth-parts of the Diptera we have described the mouth-parts of the horse-fly, *Tabanus sp.*, and of a house-fly, *Musca domestica*, specimens of which are easily obtainable. Finally for that interesting type of combined biting and sucking (or lapping) mouth-parts presented by the Hymenoptera, we have selected, as example, the common honey-bee, *Apis mellifica*. The homologies of the variously appearing parts constituting these different types should be always held in mind.

THE MOUTH PARTS OF THE DOG-DAY CICADA.

(*Cicada dorsata.*)

The sucking beak, tapering from base to tip, arising from the caudo-ventral part of the head, will be found in dried specimens usually appressed to the ventral surface of the body of the Cicada. The mouth-parts may be examined

and dissected in the dry specimen, or the head and mouth-parts may be softened and bleached * before dissection.

Remove the head with the beak from the dried specimen, and examine the beak before dissection. The long, three-jointed *labium*, forming all of the beak as seen superficially, is specially chitinized (brown) near its distal end. The distal joint is the longest, and its surface is sparsely covered with fine, whitish hairs. The tip is rather blunt than acute. A narrow channel, widest at its proximal end runs along the upper face of the labium. In this channel, but concealed by the approaching edges of it, lie the mandibles and maxillæ. A glimpse of the mandibles and maxillæ just at the base of the labium can often be had. Above the base of the labium is the minute, acute-angled *labrum* lying just over the entering mandibles and maxillæ.

With a dissecting needle carefully break away the head-wall and muscle near the base of the beak, especially dorsad and laterad. The bases of the *mandibles* and *maxillæ* will be discovered as small, strongly chitinized (brown), terminal dilations of slender, chitin rods, which run forward into the channel of the labium. Note the relative position of the two rods with dilated bases on either side, and decide which is mandible and which maxilla. (The rod lying slightly dorsad and laterad of the other is the mandible ; the mandible is also thicker and larger than the maxilla.) Trace the slender chitin rods or stylets (the mandibles and maxillæ) into the channel of the labium. Here they are all closely appressed, the two maxillæ specially so, so that they can be separated only with difficulty.

In the softened and clarified specimen, the mandibles and

* As in the bleaching of the locust and butterfly heads, the head with the beak of the Cicada should be gently boiled in K O H until the parts are thoroughly soft and clarified. If the clarifying proceeds too slowly, the head may be removed from the K O H, washed in water, and placed in Labbaraque's solution when the bleaching will proceed rapidly.

maxillæ are more easily separable. Removing them from the labium note the channel in which they naturally lie. The labium is more strongly chitinized along the walls of the channel than elsewhere, except at its tip.

Make a drawing of the mouth-parts from dorsal view, with mandibles and maxillæ removed from channel of labium and spread apart.

THE MOUTH PARTS OF THE HORSE-FLY.

(*Tabanus sp.*)

Select a female horse-fly (distinguished from the males by the narrow space between the eyes; in the males the eyes touch for a greater or lesser distance along the dorsimeson of the head). The projecting mouth-parts are conspicuous. On superficial examination there may be noted two, thickened, slightly-curving, horn- or club-like processes (the maxilliary palpi) projecting above a black, thickened stalk or trunk (the labium), lying on the dorsal surface of which a number of light-brown, slender, pointed stylets may be seen.

For more detailed examination of the mouth-parts the head of the fly should be removed from the body, a considerable part of the head, laterad and caudad, broken away and the remainder, with mouth-parts attached, boiled in K O H to soften and bleach.

The large *maxillary palpi* are two-segmented; the distal segment is longer than the basal one, and compressed. The proximal one is subcylindrical, and projects dorso-cephalad, so that the large distal segment is carried above the rest of the mouth-parts.

Lying along the dorsal surface of the large labial trunk are six, long, slender, pointed pieces or *stylets*. The uppermost, unpaired, flat piece is the *labrum* (or perhaps labrum

and *epipharynx* fused). It is rather bluntly tipped and is the broadest of the stylets. The flat, smooth, sharply pointed *mandibles* lie just above the less strongly chitinized, narrower, and finely-marked *maxillæ*. Corresponding somewhat to the labrum but less broad and strong, is the sixth stylet, an unpaired slender piece lying below the maxillæ. This is the greatly developed *hypopharynx*.* These six stylets, labrum, mandibles, maxillæ, and hypopharynx are the instruments with which the female horse-fly pierces the skin of animals to get at the blood; the male has no piercing stylets, and feeds on flower-pollen.

Beneath the grouped stylets, is the long trunk- or proboscis-like *labium*, presenting on its upper surface a shallow furrow in which the stylets may be partially enclosed, and presenting at its distal extremity a conspicuous, expanded, disk-like part called the *labella*. This terminal disk is believed to be composed of the greatly modified *labial palpi*. It is made up of two, fleshy lobes or leaves, bearing on the outer or under surface many, fine, transversal, subparallel lines or ridges. The two lobes can be closed together like the leaves of a book.

Make a drawing showing all of the mouth-parts from the dorsal view. The stylets can be spread apart laterad, so as to expose the under ones.

In only a few families of Diptera are free mandibles present, and when present they are possessed only by the females. In many flies there are no piercing stylets, and as representative of these flies without piercing mouth-parts the common house-fly may be studied.

*The hypopharynx is merely an outgrowth from the lower wall of the pharynx, and is not, as are the other mouth-parts, a true appendage of the head homologous with the body appendages (legs). The hypopharynx and epipharynx (outgrowth from the upper wall of the pharynx) are in most insects small, fleshy, and inconspicuous.

MOUTH-PARTS OF THE HOUSE-FLY.

(*Musca domestica.*)

In the house-fly, we find only the maxillary palpi and the proboscis-like labium, with well developed labella. The maxillary palpi are prominent, but are only one-segmented. The labial trunk or proboscis may be described as being made up of three portions, a basal third, the *basiproboscis*, from which arise the maxillary palpi, and in which are imbedded two slender chitinous rods, the "*maxillary tendons*," probably representing the greatly reduced maxillæ; a middle third, the *mediproboscis*, strongly chitinized; and a distal third, the *distiproboscis*, including the disk-like, metamorphosed, fleshy, labial palpi, the *labella*. The labella is like that of the horse-fly, but in the house-fly it is the only organ for obtaining food. With it, traversed as it is by transverse, horny, chitinous ridges, the "*pseudotracheæ*," hard food substances may be rasped so that fine particles of food mixed with, or sometimes dissolved in, a salivary secretion, which issues from the ridges, can flow into the mouth, along the dorsal furrow of the labial proboscis.

Make a drawing of the mouth-parts from a lateral view; and also of a portion of the labella, highly magnified, to show disposition of the pseudotracheæ.

THE MOUTH-PARTS OF THE HONEY BEE.

(*Apis mellifica.*)

Most of the bees in alcohol, from among which the student selects a specimen, will be found to have certain of the mouth-parts protruding. These parts are the maxillæ and labium, united at base and associated to form a proboscis. Before the detailed examination of these parts is begun, the student should discover the labrum and mandibles.

Labrum.—The *labrum* is small and oblong in shape with its latero-cephalic corners rounded. The breadth (dextro-sinstral) is about three times its length (caudo-cephalic).

Mandibles.—Partially concealed beneath the labrum are the spoon-shaped *mandibles*. With forceps or needle, press the mandibles apart at their tips (press laterad). Note that the mandibles are not toothed, but are rather paddle- or spoon-like at the tips. Remove and make a drawing of a mandible.

Remove both mandibles and labrum, and grasp the remaining protruding parts with forceps and carefully pull them loose from the head. Wash while still held in the forceps, and mount in glycerine on a glass slide. Before reading further the student should endeavor to name the various parts presented before him on the slide. He should refresh his memory as to the relations of the various sclerites of the labium and maxillæ, by reference to his drawings of these parts in the insects already studied.

Make a drawing of the maxillæ and labium, and name the parts, tentatively. Compare the result with the notes following :—

Maxillæ.—The parts of each maxilla present are the cardo, stipes, galea (or lacinia ; one of the two is probably wanting), maxillary palpi, and possibly the palpifer.

Cardo.—The *cardo*, or proximal part of the maxilla is a rather long, slender, strongly-chitinized sclerite, somewhat resembling a human femur or thigh-bone in shape. At its proximal end it terminates in two unequal prongs, the point of the larger being bluntly rounded. At its distal end (articulating with the stipes) it expands club-like.

Stipes.—The *stipes* is an irregular, elongate sclerite, strongly chitinized. Its proximal end is bluntly rounded and swollen. The stipes articulates with the proximal segment of the galea (see below) by a long diagonal face.

Galea.—The *galea* (we incline to believe this part homolo-

gous with the galea of the locust's maxilla, rather than with the lacinia, because of its two-segmented condition), extends distad from the stipes as a tapering blade-shaped piece. It is composed of two segments. The proximal one is small and triangular, articulating by the entire length of one of its margins with the stipes. The distal segment or sclerite constitutes the real blade-like portion of the maxilla, and nearly equals in length the ligula and labial palpi (see below). Its surface is unequally divided into two portions by a submedian, dark-brown, longitudinal line. (This line may indicate a coalescence of galea and lacinia into this one blade-like compound sclerite.) This line bears several hairs, and there are scattering hairs elsewhere on the sclerite, especially towards the distal end. Near the proximal end of this distal segment of the maxilla, and between the longitudinal line and the outer margin, many, two-jointed papillæ (taste organs?) can be seen with a high power.

Maxillary palpi.—The *maxillary palpi* are minute, exarticulate, outward-projecting pieces, arising from near the outer end of the suture separating the proximal from the distal segment of the galea.

Labium.—The parts of the labium present are the submentum, mentum, glossa, paraglossæ, palpifer, and palpi.

Submentum.—The *submentum* is a small, shield-like piece; its proximal end is connected by two chitinous bands, the *lora*, with the cardo of each maxilla; its distal end articulates with the mentum. The submentum is rather feebly chitinized.

Mentum.—The *mentum* is rather oblong in shape with rounding corners and strongly chitinized.

Glossa.—Rising from the distal end of the mentum is the long *glossa*, which terminates in a small transparent lobe or *flabellum*. The glossa should be carefully examined under low and high magnification. Note the reticulated and hairy

surface. The visible surface is that of a sheath which encloses a slender, flexible rod, the rod being probably concerned with the movements of the organ.

Paraglossæ.—At each side of the glossa, and rising from near its proximal end are two subtransparent lobes or flaps, extending about one-fifth the length of the glossa. These are the *paraglossæ* and are probably homologous with those of the beetle's labium.

Palpifers.—Lying just laterad of the paraglossæ, and rising from the distal end of the mentum, are the *palpifers*, extending forward for about one-half the length of the ligula.

Labial palpi.—At the distal end of each palpifer is a 3-segmented *labial palpus*, the proximal joint being longer than the other two combined. The palpifers and palpi bear a few long hairs, especially on the distal ends.

Make a corrected drawing, if necessary, showing details of labium and maxillæ.

CHAPTER VII.

THE VENATION OF THE WINGS OF INSECTS.

In form an insect's wing is a large, membranous appendage, which is thickened along certain lines. These thickened lines are termed the *veins* or *nerves* of the wing; and their arrangement is described as the *venation* or *neuration* of the wings.

It has been found that the venation of the wings of closely allied insects is very similar, and that great differences in this respect exist between insects remotely connected. Hence, the wings afford excellent characters for use in the classification of insects. In fact, as slight differences in venation are easily observed, the wings being spread out like an open page, these differences are probably the most available characteristics of insects for taxonomic work. It is important, therefore, that the student of entomology should learn early in his course the more important facts regarding this subject.

A careful study of the wings of many insects has shown that the fundamental type of venation is the same in all of the orders of winged insects. But this fact is evident only when the more primitive or generalized members of different orders are compared with each other. In most of the orders of insects the greater number of species have become so modified or specialized as regards the structure of their wings that it is difficult at first to trace out the primitive type.

The specimens indicated for the student to study in the following part of this course have been selected with care to illustrate gradually increasing degrees of divergence from the primitive type. In the case of each order studied the work begins with a comparatively generalized form, and passes step by step to those that are more specialized.

NOTE.—The student should have a clear idea of the significance of the terms *generalized* and *specialized*, which are now much used in biology. Generalized indicates a primitive condition, a nearness to ancestral forms. Thus the most generalized member of a group (as a family or an order) is that member which most clearly resembles the ancient progenitor of that group. Specialized, on the other hand, indicates remoteness from the primitive type, an adaptation to more special conditions of existence. Thus the most specialized member of a group is the one that departs most widely from the ancient progenitor of that group.

These terms are used in a comparative sense; thus, a highly specialized form may be regarded as generalized when compared with forms that are still more highly specialized.

A TYPICAL WING.

The flies of the genus *Rhyphus* afford good examples of comparatively generalized wings. By studying the accompanying figure (Fig. 2) of one of these, the student can

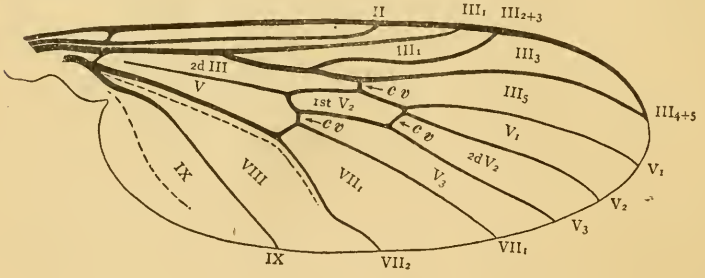

FIG. 2.—Wing of *Rhyphus*.

gain a good idea of the type of the wings of insects belonging to the order Diptera, and have a standard with which to compare wings of insects of other orders.

Longitudinal veins and cross-veins.—The veins can be grouped under two heads: first, *longitudinal veins*, those that normally extend proximo-distad; and second, *cross-veins*, those that normally extend more or less nearly cephalo-caudad. In Figure 2, three of the cross-veins are

indicated by the letters *c v*; two other cross-veins are represented near the base of the wing, but are not lettered. All other veins represented in this figure are longitudinal veins.

The insertion of the word *normally* in the above definitions is important; for it is only in comparatively generalized wings that the direction of a vein can be depended upon for determining to which of these two classes a vein belongs. A little later the student will study wings in which the direction of some of the longitudinal veins has been so modified in the course of specialization that the veins extend transversely (*i. e.*, cephalo-caudad), and some cross-veins extend in a longitudinal direction (*i. e.*, proximo-distad).

Simple veins and branched veins —Veins are either simple or branched. The veins numbered II and IX in Figure 2 are simple veins; between these there are three branched veins.

In the case of branched veins the entire vein including all of its branches is often referred to as a single vein. Thus the third vein in the wing of *Rhyphus*, counting the thickened cephalic margin of the wing as the first vein, is termed vein III; and by this expression we include both the main stem of the vein and its three divisions. On the other hand, each division of a branched vein is often termed a vein. Thus the first division of vein III, counting from the cephalic margin of the wing, is termed vein III_1, and the second division, vein III_2, and so on till all are numbered.

NOTE.—In the most generalized flies known to us vein III is five-branched. But in most flies some of the branches of this vein coalesce so that the number of apparent branches is less than five. In *Rhyphus*, veins III_2 and III_3 coalesce so as to appear as a single vein. In order to indicate that this apparently simple vein is composed of two veins, *and in order that homologous veins in different insects shall bear the same number*, this compound vein is numbered vein III_{2+3}. In the same way, what appears to be the third branch

of vein III in *Rhyphus*, is really the fourth and fifth coalesced, and is numbered vein III_{4+5}. The tracing out of the homologies of the branches of veins, or *veinlets* as they are sometimes termed, is often very difficult, but it is of the greatest importance in determining the relationships of different genera or of families.

Names of wing-veins.—There have been many different sets of names applied to the veins of wings. Not only have the students of each order of insects had a peculiar nomenclature, but in many cases different writers on the same order have used different sets of terms. This condition of affairs was incident to the beginning of the science, the period before the correspondence of the veins in the different orders had been worked out. But now the time has come when it seems practicable to apply a uniform nomenclature to the wing-veins of all orders; and the following set of terms has been proposed for that purpose:—

Costa.—The vein extending along the cephalic or costal margin of the wing is the *costa*.

Subcosta.—Immediately caudad of the costa and extending parallel with it, is a vein, which is simple in flies; this is the *subcosta* (Fig. 2, II).

Radius.—Immediately caudad of the subcosta there is a vein which in generalized insects is always branched; this is the *radius*. In *Rhyphus*, radius is three-branched (Fig. 2, III_1, III_{2+3}, and III_{4+5}).

Media.—Traversing the middle of the wing, there is a longitudinal vein which is always branched in generalized insects; this is the *media*. In *Rhyphus* media is three-branched (Fig. 2, V_1, V_2, and V_3,).

Cubitus.—The third and last of the branched veins in flies is the *cubitus*. This vein is two-branched in *Rhyphus* (Fig. 2, VII_1, and VII_2,).

Anal furrow or first anal vein.—Immediately caudad of the cubitus and closely parallel with it, there is in most flies a prominent furrow in the wing; this is the anal furrow or

the first anal vein. It is represented in Figure 2 by a dotted line.

If this structure were always of the form that it bears in flies it would not be termed a vein, but in many moths it is thickened and appears like the true veins; it is, therefore, termed a vein.

NOTE.—The anal furrow is of very great use in determining the homologies of wing-veins. Except in very highly specialized insects it is easily observed and makes a good starting point in working out the structure of a difficult wing.

Anal veins.—The anal furrow divides the wing into two areas, which may be termed the *preanal area* and the *anal area*. The anal area, that part of the wing caudad of the anal furrow, is usually transversed by one or more simple veins; these are termed the *anal veins*. The anal veins are often designated as *the first anal vein*, *the second anal vein*, *etc.* It should be remembered that in numbering the anal veins the anal furrow is counted as *the first anal vein*.

Premedia and postmedia.—In the May-flies there appears to be a distinct, branched vein between radius and media; this has been termed the *premedia* (Fig. 3, IV). There also appears to be in May-flies a distinct, branched vein between media and cubitus; this has been termed the *postmedia* (Fig. 3, VI).

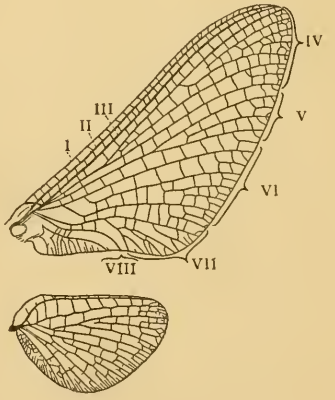

FIG. 3.—Wings of a May-fly, *Hexagenia*.

Numbering of wing-veins.—It is often more convenient to refer to the wing-veins by numbers than by the names that have been applied to them. The system of numbering the veins that we have adopted is illustrated by

the numbering of the veins in Figure 2. By this system the principal veins are numbered with Roman numerals, and the branches of a vein are designated by Arabic subnumbers. Thus the branches of vein III are designated as III_1, III_2, III_3, III_4, and III_5, respectively.

The correspondence of the numbers and the names applied to the wing-veins by the writer is shown in the following table :—

Costa = vein I.
Subcosta = vein II.
Radius = vein III.
Premedia = vein IV.
Media = vein V.
Postmedia = vein VI.
Cubitus = vein VII.
Anal furrow = vein VIII.
Other anal veins = veins IX, X, *et al.*

In most of the orders of insects there is obviously no longitudinal vein between radius and media, and none between media and cubitus. In numbering the veins of the wings of such insects, the numbers IV and VI, which have been applied to the premedia and postmedia of May-flies, are omitted. This is done in order that homologous veins shall bear the same numbers in all orders of insects.

It is often necessary to refer to particular cross-veins ; this can be done by using the numbers of the two veins connected by the cross-vein ; thus a cross-vein extending from vein I to vein II may be designated as vein I—II ; and one extending from vein III to vein V, as vein III—V. In reading these expressions the word *to* is substituted for the dash, as "vein III to V."

When there is more than one cross-vein between two longitudinal veins they may be numbered as follows : 1st vein III—V, 2d vein III—V, etc. In lettering a figure the

word vein would be omitted and the legends would read 1st III—V, 2d III—V, etc.

NOTE.—The above statement will serve the needs of the beginning student. But the advanced student will find in using the works of certain writers that important modifications of this system of numbering the wing-veins have been proposed. For such students it seems desirable to make the following statement, which may be omitted by the beginner.

There have been several attempts to establish a uniform nomenclature for the wing-veins of insects. Of these that of Redtenbacher* is the most important, being based on a much more extended study of the subject than that made by any other author. He was the first author to work out a system and apply it to all orders of insects.

The names and numbers of the wing-veins given above are those adopted by Redtenbacher, except the names premedia, postmedia and anal furrow, which were proposed by the writer.† These veins were recognized and numbered, as above, by Redtenbacher, but not named.

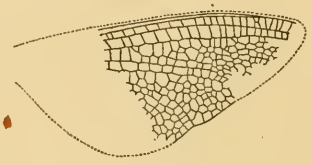

FIG. 4.—Wing of *Platephemera*.

Redtenbacher, however, took the wing of a May-fly as the typical insect's wing, and endeavored to find all the principal veins of this wing in the wings of insects of each of the other orders. Later it was shown by Spuler‡ and by the writer§ that in several orders of insects at least there is no longitudinal vein between radius and media and none between media and cubitus. The writer also pointed out the fact that the veins premedia and postmedia were also wanting in the wings of paleozoic insects,‖ and suggested that these veins had been developed secondarily in the May-flies, as a result of the corrugation of the wings of those insects.¶ In support of this view, attention was called to the fact that in the oldest May-fly known, *Platephemera antiqua* of the Devonian age (Fig. 4), the cells of the wing are polygonal in the areas traversed by these veins, while in the modern May-

* JOSEF REDTENBACHER, *Vergleichende studien über das Flügelgeäder der Insecten. Ann. des k. k. naturhistorischen Hofmuseums, Wein.* Bd. I. s. 153–232, t. IX–XX.

† J. H. COMSTOCK, *Evolution and Taxonomy, The Wilder Quarter-Century Book*, pp. 37–114, Pl. I–III.

‡ A. SPULER, *Zur Phylogenie und Ontogenie des Flügelgeäders der Schmetterlinge, Zeitschrift fur wissenschaftliche Zoologie.* Bd. LIII, s. 597–646, t. XXV, XXVI.

§ J. H. COMSTOCK, *Evolution and Taxonomy.* ‖ *l. c.*, pp. 66, 67.

¶ It may be, however, that these veins are detached branches of media.

flies they are quadrangular (Fig. 5). This indicates that the longitudinal, concave veins IV and VI were developed by a straightening out of the zigzag lines between two series of cells in each case. In the wings of modern May-flies, not only have longitudinal, concave veins been formed from zigzag lines, but the cross-veins extending between these concave veins and the adjacent convex veins have become strictly transverse; this is an arrangement which insures the preservation of the corrugations.

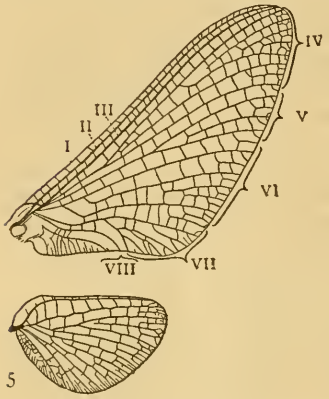

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FIG. 5.—Wings of a May-fly.

Although it was shown that the wing of a modern May-fly differs essentially from the primitive type of an insect's wing, and that the veins premedia and postmedia are absent in most of the orders of insects it seemed desirable to base our nomenclature on the type containing the maximum number of veins. The nomenclature of Redtenbacher was retained, therefore, with only such modifications as were necessary. The most important of these modifications was the omission of the numbers IV and VI in those cases where premedia and postmedia are wanting.

Spuler, however, failed to recognize the veins premedia and postmedia at all. In fact there is no evidence in his paper that he has studied the wings of May-flies. He therefore numbers the veins as they occur in the Lepidoptera without omitting numbers for premedia and postmedia.

In a recent paper* Dr. Packard has adopted the views of Spuler in this respect. And I have come to feel that perhaps it would be better for the sake of simplicity to refer to premedia and postmedia by name only when speaking of the wings of May-flies, and to take no account of them in numbering the wing-veins of other insects.

A similar course has been taken already in the case of the *humeral veins* of the Lasiocampidæ.† In this family of moths, longitudinal veins have been developed secondarily in the greatly expanded humeral angle of the hind wings (Fig. 6, h.v.). These veins are referred to merely by name, no account being taken of them in numbering the principal veins.

*A. S. PACKARD, *On a Rational Nomenclature of the Veins of Insects, especially those of Lepidoptera*, *Psyche*, May, 1895.

†*Evolution and Taxonomy*, p. 89.

I regret that this conclusion was not reached before the figures and descriptions of wings in "*Comstock's Manual for the Study of Insects*" were prepared. Should a second edition of this work be needed, it is quite probable that a revised system of numbering the wing-veins will be adopted in it. The beginning student, however, is advised to use in this course the system given on page 80, in order to avoid confusion when using the "*Manual.*" It should be remembered that, although it is exceedingly desirable that all entomologists should use the same system of numbering the wing-veins, the adoption of any particular system is of much less importance than a clear knowledge of the homologies of the wing-veins.

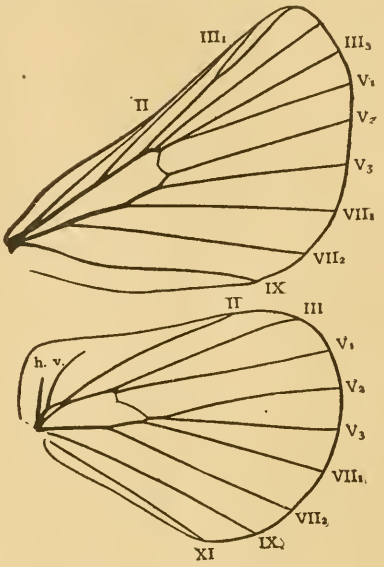

FIG. 6.—Wings of *Clisiocampa*.

The following table shows what seems to the writer to be the most simple and hence the most desirable system of numbering the wing-veins :—

Costa = vein I.
Subcosta = vein II.
Radius = vein III.
Media = vein IV.
Cubitus = vein V.
Anal furrow = vein VI.
Other anal veins = veins VII, VIII, *et al.*

The above system agrees with that proposed by Spuler and adopted by Packard, in not numbering premedia and postmedia. But it differs in a very important particular from the system of these writers. They do not number costa, but begin with subcosta, which they term vein I.

In defense of this, Dr. Packard says :* "Spuler shares the opinion of Fritz Müller (Termitidæ), Brauer and Redtenbacher (Libellulidæ), and Haase (Papilionidæ), that costa is only a hypodermal structure, a thickening of the edge, which does not have a trachea as its origin (*anlage*), and which, therefore, has nothing to do with the veins."

It may be that the costa does not originate in the same way as other

l. c., p. 236.

veins,* but, if we except the Lepidoptera, it is usually present and indistinguishable in structure from the other principal veins; and except by writers on the Lepidoptera, it has been generally recognized and named as one of the principal veins of the wing. It seems desirable, therefore, to include it in numbering the wing-veins.

In fact, there are much stronger reasons for counting costa a vein than there is for including the anal furrow in the list of veins, as is done by these very writers who exclude costa. The anal furrow arose in an entirely different way than did the wing-veins,† and except in the Lepidoptera it almost never resembles a vein in structure. But, as the anal furrow becomes a well-developed vein in the Lepidoptera, and is present, though in a different form, in nearly all winged insects, it simplifies the nomenclature to include it in the list of veins.

There is one other point which the student should clearly understand in order to avoid confusion when he comes to use the special works treating of the Lepidoptera. Although costa is present in the wings of many of the more generalized moths, it is wanting, as a rule, in the Lepidoptera. This fact being overlooked by the writers on this order, they have applied the term costa to the vein that is called subcosta in other orders of insects, and have applied the term subcosta to the vein that bears the name radius in other orders. It is to be hoped that writers on the Lepidoptera will soon conform to the usage of writers on all other orders of insects. The change need necessitate little if any confusion, as the use of the term radius will indicate that the writer using it has adopted the uniform nomenclature for all orders.

Convex veins and concave veins.—In most insects, except Lepidoptera, the wings are more or less corrugated. This is very well shown in the wings of dragon-flies, one of which should be examined at this point in the course. Note that as a result of this corrugation some of the wing-veins extend along the summits of ridges; such wing-veins are termed *convex veins*. Other wing-veins of a corrugated wing extend along the bottoms of furrows; such veins are termed *concave veins*.

Note that a corrugated wing is much stiffer than it would be otherwise.

Numbering of the cells of the wings.—In numbering

*See *Evolution and Taxonomy*, p. 59.
†*Evolution and Taxonomy*, p. 60.

the cells of the wings, according to the system proposed by the writer,* each cell is designated by the name or number of the longitudinal vein that normally forms its front (cephalic) margin. This is illustrated by Figure 7, in which

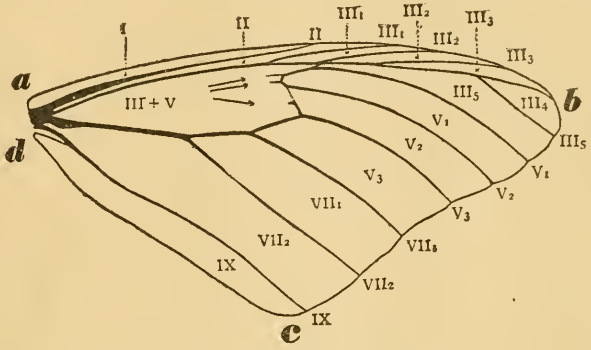

FIG. 7.—Wing of a butterfly.

the numbers placed opposite the ends of the veins refer to the veins; the others, to the cells.

When a cell is divided by cross-veins into two or more parts, the parts are numbered, beginning with the proximal one. Thus in the wing of *Leptis* (Fig. 8) cell I is divided

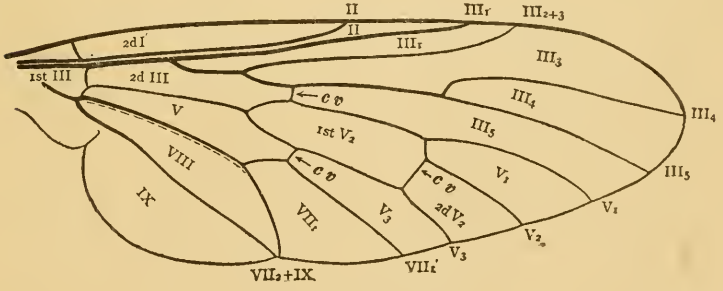

FIG. 8.—Wing of *Leptis*.

by a cross-vein. In this case the first part (not numbered in the figure) is 1st cell I; and the second part is 2d cell I

* *Evolution and Taxonomy*, p. 93.

(lettered 2d I). In this wing also cell III is divided into 1st III and 2d III; and cell V_2, into 1st V_2, and 2d V_2.

Margins of wings.—An insect's wing is more or less triangular in outline; it, therefore, presents three margins; the *costal margin* (Fig. 7, a-b); the *outer margin* (Fig. 7, b-c), and the *inner margin* (Fig. 7, c-d).

Angles of wings.—The angle at the base of the costal margin (Fig. 7, a) is the *humeral angle;* that between the costal margin and the outer margin (Fig. 7, b) is the *apex of the wing;* and the angle between the outer margin and the inner margin (Fig. 7, c) is the *anal angle.*

THE WING-VEINS OF DIPTERA.

As the chief object of the following work is to give the student training in tracing the homologies of wing-veins, comparatively little information will be given directly. The student will be furnished in each case with the wing to be studied, and his studies should take the following course :—

Directions for the study of wings.—Make a drawing of the wing, based upon a careful study of it with a compound microscope, using a low power. The drawing should be first made with a pencil; after it has been criticised by the teacher, the lines should be inked. Make the drawing on a sufficiently large scale so that each vein can be represented distinctly; in most cases the drawings should be somewhat larger than Figures 7 and 8.

Number each vein and cell of the wing.

Write a description of the wing, noting the more important features of its venation, and especially the more important departures from the primitive type of the order as indicated by the generalized form first studied. In the Diptera the wing of *Rhyphus* (Fig. 2) may be used as a generalized type, although in certain respects other wings will be found to be more generalized.

The following are some of the more important points to be noted in the descriptions: The extent of vein I. The extent of vein II. The number of branches of vein III; in this connection determine which of the radical cells has been obliterated by the coalescence of branches of vein III. The position of the cross-vein III–V; the number of branches of vein V; the division or not of cell V_2; the presence or absence of cell V_3; the courses of the branches of vein VII_2; and the course of vein IX.

Wing of Protoplasa.—Study the figure of the wing of *Protoplasa fitchii* (Fig. 9) as an illustration of a wing in which radius is five-branched. Do not be confused by the spur at the base of vein III_{2+5} (marked *s* in the figure); this is a secondary development.

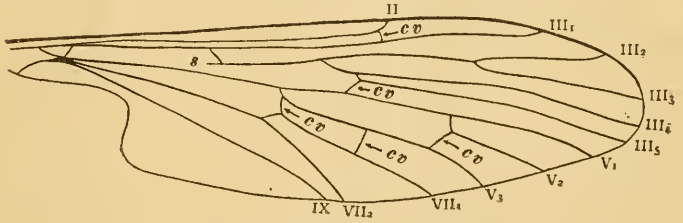

FIG. 9.—Wing of *Protoplasa fitchii*.

Wing of a Leptid.—A specimen of one of the snipe-flies, *Leptidæ*, will be given the student for examination with a hand lens. Note the deep furrow between veins I and III; along the bottom of this furrow vein II extends. Vein II, therefore, is a concave vein. Note that this corrugation stiffens the wing. It is along the costal edge that the wing needs to be strongest, and correlated with this fact we find that vein II is usually a concave vein.

Make a drawing of a mounted wing of one of the *Leptidæ*. Note that in the mounted specimen vein II is more or less concealed by vein III, although the two veins are distinct, as was seen on the unmounted specimen, studied with a

hand lens. Represent these two veins as slightly separated in your drawing.

In the description of this wing, state in what respect it is more generalized than that of *Rhyphus*, and in what respect it more specialized.

Wing of an Asilid.—In the description of this wing note a method of coalescence of veins not exhibited by *Rhyphus*, and call attention to each case in which this method of coalescence occurs in this wing.

Wing of a Bombylliid.—In the study of this wing especial attention should be paid to the branches of media and cubitus.

Wing of an Empidid.—The most striking feature in the venation of this wing is the courses of the branches of cubitus.

Wing of a Dolichopodid.—This wing will afford the student excellent training if he will work over it carefully.

WINGS OF LEPIDOPTERA.

As the wing of Lepidoptera are covered with scales, it is difficult to determine the nature of their venation without specially preparing them for this purpose. After a student has become familiar with the type of venation characteristic of the order, he can usually determine the nature of any particular structure by putting a drop of chloroform on the part of the wing to be examined ; this will render the veins more distinct for a few seconds. Or the scales can be removed from a small part of the wing with a small, artist's, sable brush. But when a very careful study of the venation of a wing is to be made, it should be bleached and mounted on a card or on a glass slip, in order that it may be studied with a compound microscope. The following is the method of bleaching wings :—

1. Remove the wings carefully so as not to break the

frenulum if there be one ;* it is well to remove the patagium first.†

2. Dip the wings in alcohol in order to wet them.

3. Immerse them for an instant in hydrochloric acid (muriatic acid). Use for this purpose dilute acid, one part acid to nine parts water.

4. Put them in Labaraque solution with the upper surface of the wings down, and leave them there till the color has been removed from the scales. If a wing bleaches slowly, the process can be hastened by dipping it in the dilute acid and returning it to the Labaraque solution from time to time. This solution can be procured of most druggists. It deteriorates if left exposed in strong sunlight. If it cannot be obtained, use an aqueous solution of chloride of lime.

5. When a wing is bleached, put it in alcohol and leave it there till after it floats. This is to wash off the Labaraque solution. The wing can then be mounted on a card. But it is better to mount it as described below.

6. Transfer the wing to a clearing mixture, if it is to be mounted in balsam, and leave it there five or ten minutes. This is to remove any water there may be on it. A good clearing mixture can be made by mixing two parts by measure of carbolic acid crystals and three parts of rectified oil of turpentine.

7. Put the wing on a glass slip with considerable clearing mixture under it to avoid bubbles ; put Canada balsam on top, and cover with thin glass. In the case of small wings, it is best to transfer them from one solution to another, and to the glass slip by means of a camel's-hair brush.‡

* The *frenulum* is a strong spine or bunch of bristles borne by the hind wing at the humeral angle in most moths.

† The *patagia* are the paraptera of the mesothorax, they are scale-like appendages at the bases of the fore wings.

‡ In the case of very small wings, as those of Tineids, the very fine veins are more distinct when mounted in glycerine than when mounted in Canada balsam.

Wings bleached and mounted in this way make an important addition to a collection. The slides should be carefully labelled; and the insect from which the wings were take should be kept with the slide. It is our practice to remove always the wings from the right side, and then to mount the slide in the collection at the right of the insect from which the wings were taken. Uniformity in this respect adds greatly to the appearance of the collection.

Wings of Hepialus.—Mounted specimens of the two wings of one side of a moth belonging to the genus *Hepialus* will be furnished the student for study. Be very careful of the specimens, as moths of this genus are rare in this country.

In the description of these wings, note especially a striking difference between them and the wings of Diptera as regards the nature of vein II.

The membraneous lobe near the base of the inner margin of the fore wing is the *jugum*. This extends under the costal margin of the hind wing, while the greater part of the inner margin of the fore wing overlaps the hind wing. This arrangement assures the acting together of the two wings.

Wings of a Cossid.—Mounted wings of one of the *Cossidæ* will be furnished the student for study.

In the description, state the most important differences between these wings and those of *Hepialus*, and make a comparison between the structure of vein VIII in the Lepidoptera and in the Diptera.

Wings of the Monarch Butterfly.—The student will be furnished with specimens of the two wings of one side of the monarch butterfly, *Anosia plexippus*.

Study the fore wing first. In the description of this wing explain the significance of the three short spurs that project into the distal end of the large cell near the middle of the wing.

In the description of the hind wing, discuss the changes that have taken place in media.

Wings of Frenate Moths.—Specimens of moths belonging to the family *Noctuidæ* will be furnished as illustrations of Lepidoptera in which the frenulum is well developed. Two specimens, a male and a female of the same species, will be given the student.

Remove the wings of the right side of the female, and bleach and mount them.

Figure and describe these wings.

Remove the wings of the right side of the male, and bleach and mount them.

Figure and describe these wings.

Describe the secondary sexual distinction exhibited by the wings of this species.

How could one of these types have been derived from the other?

Study the wings of the male that have not been bleached and note the *frenulum hook* on the fore wing, which receives the tip of the frenulum. It may be necessary to remove some of the hairs from the base of the wing. Use a small sable brush for this.

Study the unbleached wings of the female and note the absence of a frenulum hook.

Compare the hind wing of the monarch butterfly with the hind wings of these moths and discuss the differences between them.

INDEX AND GLOSSARY.