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Insect Morphology

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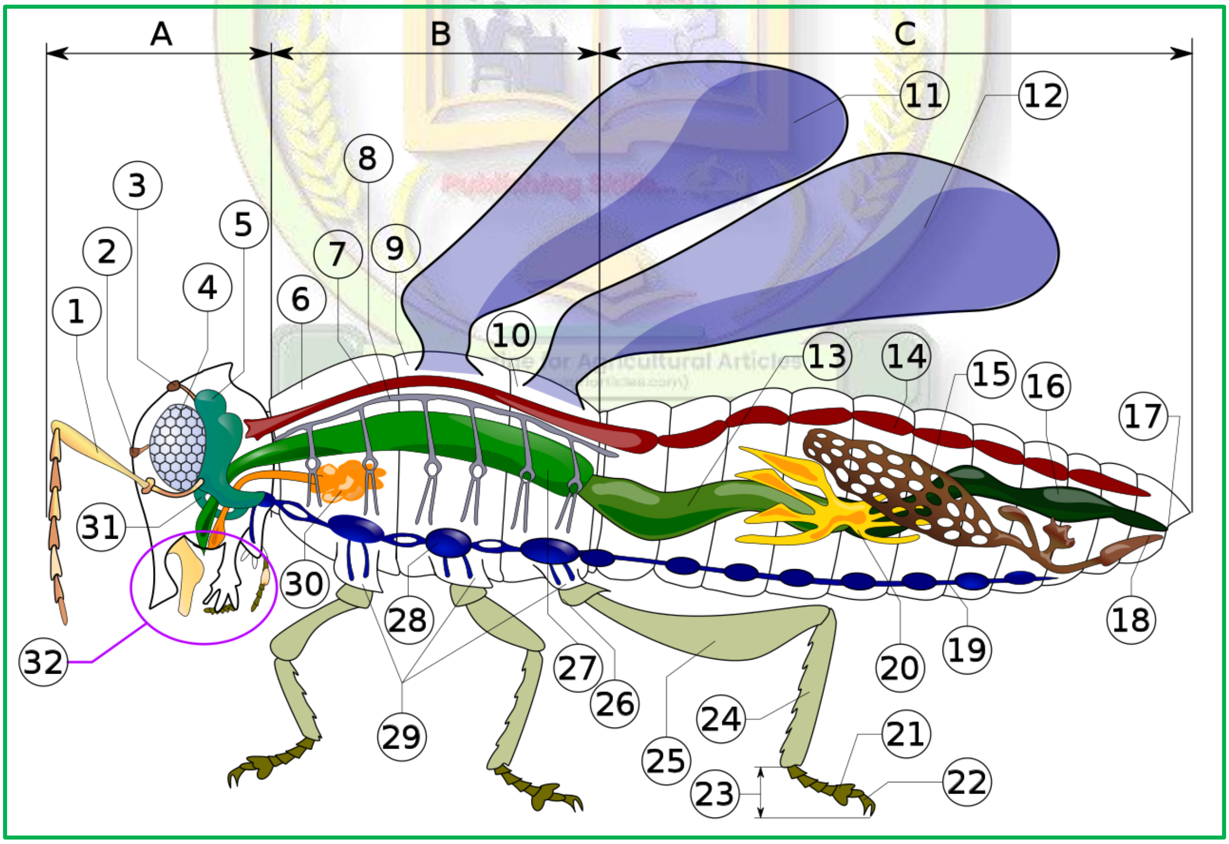
Insect morphology is the study and description of the physical form of insects. The terminology used to describe insects is similar to that used for other arthropods due to their shared evolutionary history. Three physical features separate insects from other arthropods: they have a body divided into three regions (called tagmata) (head, thorax, and abdomen), have three pairs of legs, and mouthparts located *outside* of the head capsule. It is this position of the mouthparts which divides them from their closest relatives, the non-insect hexapods, which includes Protura, Diplura, and Collembola.

There is enormous variation in body structure amongst insect species. Individuals can range from 0.3 mm (fairyflies) to 30 cm across (great owlet moth), have no eyes or many; well-developed wings or none; and legs modified for running, jumping, swimming, or even digging. These modifications allow insects to occupy almost every ecological niche on the planet, except the deep ocean. This article describes the basic insect body and some of the major variations of the different body parts; in the process it defines many of the technical terms used to describe insect bodies.



1. Antenna	17. Anus
2. Lower ocelli	18. Oviduct
3. Upper ocelli	19. Nerve cord
4. Compound eyes	20. Malpighan tubes
5. Brain	21. Tarsal peds
6. Prothorex	22. Claws
7. Dorsal blood vessel	23. Tarsus
8. Tracheal tubes	24. Tibia
9. Mesothorex	25. Femur
10. Metathorex	26. Trochanter
11. Forewing	27. Fore-gut
12. Hindwing	28. Thoracic gnglion
13. Mid-gut	29. Coxa
14. Dorsal tube	30. Salivary gland
15. Ovary	31. Subesophageal ganglion
16. Hind-gut	32. Mouthparts

Insects, like all arthropods, have no interior skeleton; instead, they have an exoskeleton, a hard outer layer made mostly of chitin which protects and supports the body. The insect body is divided into three parts: the head, thorax, and abdomen. The head is specialized for sensory input and food intake; the thorax, which is the anchor point for the legs and wings (if present), is specialized for locomotion; and the abdomen for digestion, respiration, excretion, and reproduction. Although the general function of the three body regions is the same across all insect species, there are major differences in basic structure, with wings, legs, antennae, and mouthparts being highly variable from group to group.

Exoskeleton

The insect outer skeleton, the cuticle, is made up of two layers; the epicuticle, which is a thin, waxy, water-resistant outer layer and contains no chitin, and the layer under it called the procuticle. This is chitinous and much thicker than the epicuticle and has two layers; the outer is the exocuticle while the inner is the endocuticle. The tough and flexible endocuticle is built from numerous layers of fibrous chitin and proteins, criss-crossing each other in a sandwich pattern, while the exocuticle is rigid and sclerotized. The exocuticle is greatly reduced in many soft-bodied insects, especially the larval stages (e.g., caterpillars). Chemically, chitin is a long-chain polymer of N-acetylglucosamine, a derivative of glucose. In its unmodified form, chitin is translucent, pliable, resilient and quite tough. In arthropods, however, it is often modified, becoming embedded in a hardened proteinaceous matrix, which forms much of the exoskeleton. In its pure form, it is leathery, but when encrusted in calcium carbonate, it becomes much harder. The difference between the unmodified and modified forms can be seen by comparing the body wall of a caterpillar (unmodified) to a beetle (modified).

From the embryonic stages itself, a layer of columnar or cuboidal epithelial cells gives rise to the external cuticle and an internal basement membrane. The majority of insect material is held in the endocuticle. The cuticle provides muscular support and acts as a protective shield as the insect develops. However, since it cannot grow, the external sclerotised part of the cuticle is periodically shed in a process called "moulting". As the time for moulting approaches, most of the exocuticle material is reabsorbed. In moulting, first the old cuticle separates from the epidermis (apolysis). Enzymatic moulting fluid is released between the old cuticle and epidermis, which separates the exocuticle by digesting the endocuticle and sequestering its material for the new cuticle. When the new cuticle has formed sufficiently, the epicuticle and reduced exocuticle are shed in ecdysis.

The four principal regions of an insect body segment are: tergum or dorsal, sternum or ventral and the two pleura or laterals. Hardened plates in the exoskeleton are called sclerites, which are subdivisions of the major regions – tergites, sternites and pleurites, for the respective regions tergum, sternum, and pleuron.

Head

The head in most insects is enclosed in a hard, heavily sclerotized, exoskeletal head capsule'. The main exception is in those species whose larvae are not fully sclerotised, mainly some holometabola; but even most unsclerotised or weakly sclerotised larvae tend to have well sclerotised head capsules, for example the larvae of Coleoptera and Hymenoptera. The larvae of Cyclorrhapha however, tend to have hardly any head capsule at all.

The head capsule bears most of the main sensory organs, including the antennae, ocelli, and the compound eyes. It also bears the mouthparts. In the adult insect the head capsule is apparently unsegmented, though embryological studies show it to consist of six segments that bear the paired head appendages, including the mouthparts, each pair on a specific segment. Each such pair occupies one segment, though not all segments in modern insects bear any visible appendages.

All the insect orders, Orthoptera most conveniently display the greatest variety of features found in the heads of insects, including the sutures and sclerites. Here, the vertex, or the apex (dorsal region), is situated between the compound eyes for insects with hypognathous and opisthognathous heads. In prognathous insects, the vertex is not found between the compound eyes, but rather, where the ocelli are normally found. This is because the primary axis of the head is rotated 90° to become parallel to the primary axis of the body. In some species, this region is modified and assumes a different name.

The ecdysial suture is made of the coronal, frontal, and epicranial sutures plus the ecdysial and cleavage lines, which vary among different species of insects. The ecdysial suture is longitudinally placed on the vertex and separates the epicranial halves of the head to the left and right sides. Depending on the insect, the suture may come in different shapes: like either a Y, U, or V. Those diverging lines that make up the ecdysial suture are called the frontal or frontogenal sutures. Not all species of insects have frontal sutures, but in those that do, the sutures split open during ecdysis, which helps provide an opening for the new instar to emerge from the integument.

Compound eyes and ocelli

Most insects have one pair of large, prominent compound eyes composed of units called ommatidia (ommatidium, singular), possibly up to 30,000 in a single compound eye of, for example, large dragonflies. This type of eye gives less resolution than eyes found in vertebrates, but it gives acute perception of movement and usually possesses UV- and green sensitivity and may have additional sensitivity peaks in other regions of the visual spectrum. Often an ability to detect the E-vector of polarized light exists polarization of light. There can also be an additional two or three ocelli, which help detect low light or small changes in light intensity. The image perceived is a combination of inputs from the numerous ommatidia, located on a convex surface, thus pointing in slightly different directions. Compared with simple eyes, compound eyes possess very large view angles and better acuity than the insect's dorsal ocelli, but some stemmatal (= larval eyes), for example those of sawfly larvae (Tenthredinidae) with an acuity 4 degrees and very high polarization sensitivity, match the performance of compound eyes.

Antenna

Antennae, sometimes called "feelers", are flexible appendages located on the insect's head which are used for sensing the environment. Insects *are* able to feel with their antennae because of the fine hairs (setae) that cover them. However, touch is not the only thing that antennae can detect; numerous tiny sensory structures on the antennae allow insects to sense smells, temperature, humidity, pressure, and even potentially sense themselves in space. Some insects, including bees and some groups of flies can also detect sound with their antennae.

The number of segments in an antenna varies considerably amongst insects, with higher flies having only 3-6 segments, while adult cockroaches can have over 140. The general shape of the antennae is also quite variable, but the first segment (the one attached to the head) is always called the scape, and the second segment is called the pedicel. The remaining antennal segments or flagellomeres are called the flagellum.

Thorax

The insect thorax has three segments: the prothorax, mesothorax, and metathorax. The anterior segment, closest to the head, is the prothorax; its major features are the first pair of legs and the pronotum. The middle segment is the mesothorax; its major features are the second pair of legs and the anterior wings, if any. The third, the posterior, thoracic segment, abutting the abdomen, is the metathorax, which bears the third pair of legs and the posterior wings. Each segment is delineated by an intersegmental suture. Each segment has four basic regions. The dorsal surface is called the tergum (or notum, to distinguish it from the abdominal terga). The two lateral regions are called the pleura (singular: pleuron), and the ventral aspect is called the sternum. In turn, the notum of the prothorax is called the pronotum, the notum for the mesothorax is called the mesonotum and the notum for the metathorax is called the metanotum. Continuing with this logic, there is also the mesopleura and metapleura, as well as the mesosternum and metasternum.

The tergal plates of the thorax are simple structures in apterygotes and in many immature insects, but are variously modified in winged adults. The pterothoracic nota each have two main divisions: the anterior, wing-bearing alinotum and the posterior, phragma-bearing postnotum. Phragmata (singular: phragma) are plate-like apodemes that extend inwards below the antecostal sutures, marking the primary intersegmental folds between segments; phragmata provide attachment for the longitudinal flight muscles. Each alinotum (sometimes confusingly referred to as a "notum") may be traversed by sutures that mark the position of internal strengthening ridges, and commonly divides the plate into three areas: the anterior prescutum, the scutum, and the smaller posterior scutellum. The lateral pleural sclerites are believed to be derived from the subcoxal segment of the ancestral insect leg. These sclerites may be separate, as in silverfish, or fused into an almost continuous sclerotic area, as in most winged insects.

Abdomen

The ground plan of the abdomen of an adult insect typically consists of 11–12 segments and is less strongly sclerotized than the head or thorax. Each segment of the abdomen is represented by a sclerotized tergum, sternum, and perhaps a pleurite. Terga are separated from each other and from the adjacent sterna or pleura by a membrane. Spiracles are located in the pleural area. Variation of this ground plan includes the fusion of terga or terga and sterna to form continuous dorsal or ventral shields or a conical tube. Some insects bear a sclerite in the pleural area called a laterotergite. Ventral sclerites are sometimes called laterosternites. During the embryonic stage of many insects and the postembryonic stage of primitive insects, 11 abdominal segments are present. In modern insects there is a tendency toward reduction in the number of the abdominal segments, but the primitive number of 11 is maintained during embryogenesis. Variation in abdominal segment number is considerable. If the Apterygota are considered to be indicative of the ground plan for pterygotes, confusion reigns: adult Protura have 12 segments, Collembola have 6. The orthopteran family Acrididae has 11 segments, and a fossil specimen of Zoraptera has a 10-segmented abdomen.

Generally, the first seven abdominal segments of adults (the pregenital segments) are similar in structure and lack appendages. However, apterygotes (bristletails and silverfish) and many immature aquatic insects have abdominal appendages. Apterygotes possess a pair of styles; rudimentary appendages that are serially homologous with the distal part of the thoracic legs. And, mesally, one or two pairs of protrusible (or exsertile) vesicles on at least some abdominal segments. These vesicles are derived from the coxal and trochanteral endites (inner annulated lobes) of the ancestral abdominal appendages. Aquatic larvae and nymphs may have gills laterally on some to most abdominal segments. The rest of the abdominal segments consist of the reproductive and anal parts.

The organs concerned specifically with mating and the deposition of eggs are known collectively as the external genitalia, although they may be largely internal. The components of the external genitalia of insects are very diverse in form and often have considerable taxonomic value, particularly among species that appear structurally similar in other respects. The male external genitalia have been used widely to aid in distinguishing species, whereas the female external genitalia may be simpler and less varied.

The terminalia of adult female insects include internal structures for receiving the male copulatory organ and his spermatozoa and external structures used for oviposition (egg-laying; section 5.8). Segments 8 and 9 bear the genitalia; segment 10 is visible as a complete segment in many "lower" insects but always lacks appendages. Most female insects have an egg-laying tube, or ovipositor; it is absent in termites, parasitic lice, many Plecoptera, and most Ephemeroptera. Ovipositors take two forms:

- The anal-genital part of the abdomen. which consists generally of segments 8 or 9 to the abdominal apex
- substitutional, composed of extensible posterior abdominal segments.