INSECTS AND OTHER HEXAPODOUS ARTHROPODS

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Summary

Hexapods (insects and entognathans) comprise about 75% of all animal species, are almost ubiquitous in terrestrial and freshwater habitats, and have profound influences on the functioning of ecosystems, although they are little understood and poorly appreciated. Their success and diversity is a consequence of their body structure and organization, particularly the waterproof malleable integument, the development of wings, complex patterns of metamorphosis with short generation times, and dietary specialization. Although a small proportion of species are of economic importance, destroying crops, parasitizing or transmitting diseases to plants, animals and humans, causing direct damage to structures, or merely being a nuisance, most insects are beneficial, sometimes obviously so, attacking pest plants and animals, pollinating crops or providing desirable products.

This is a general account of the hexapodous arthropods, including information on their basic structure and function, ecology, and economic and other significance. Conservative estimates of the diversity and feeding habits of the orders are tabulated. A basic classification, and descriptions of the morphological and biological characteristics of members of the most important groups (2 classes, 2 subclasses, 2 infraclasses, 2 sections, 5 superorders, 33 orders and their suborders and infraorders), form the bulk of the treatment.

1. Introduction

The hexapodous arthropods, the Superclass Hexapoda, commonly known as insects, comprise the greatest number of species of living organisms. It is often asserted that insects make up at least 75% of all animal species, and 67% of all species of organisms, although it is very difficult to verify the accuracy of these claims. Even if the figures prove to be exaggerated, it is nevertheless clear that the insects are the predominant major group of organisms in their specific diversity. They are almost ubiquitous in terms of terrestrial and freshwater habitats occupied, although there are very few species that are found in the open oceans (where crustaceans are the dominant arthropods). Various estimates of the total number of insect species, based on different ways of extrapolating from samples taken in different habitats, have ranged from about 1 million to about 30 million. The true number is probably somewhere in between, but it is unlikely that it will ever be known, not only because the number of specialists working on insect classification is limited, and the sampling effort in collecting specimens is very uneven, but also because environmental degradation and habitat destruction will ensure that many thousands, if not millions, of species will go extinct before any specimens have been collected and studied. Table 1 includes a conservative summary of the estimated numbers of species already recorded and the total numbers for each of the orders of hexapods.

Order	No. Families					No. Species described	Total No. Species
	Min.	Max.	Predatory	Other	Phytophagous		
Collembola	5	20	0	20	0	6 100	15 000
Protura	4	4	0	4	0	500	1500
Diplura	9	9	2	7	0	800	2500
Archaeognatha	2	2	0	2	0	350	700
Zygentoma	4	4	0	4	0	370	700
Ephemeroptera	19	23	4	19	0	2 200	4 000
Odonata	27	27	27	0	0	5 000	6 000

Grylloblattodea	1	1	0	1	0	25	50
Plecoptera	14	15	5	10	0	2 100	4 000
Blattodea	6	6	0	6	0	5 000	9 000
Isoptera	7	7	0	7	0	2 400	4 000
Mantodea	8	8	8	0	0	1 900	4 000
Orthoptera	27	31	0	4	27	20 500	45 000
Mantophasmatodea	1	1	1	0	0	2	30
Phasmatodea	3	11	0	0	11	2 600	7 000
Dermaptera	8	10	1	8	1	1800	4 000
Embioptera	8	8	0	8	0	200	2 000
Zoraptera	1	1	0	1	0	30	100
Psocoptera	35	35	0	35	0	3 100	9 000
Phthiraptera	25	25	25	0	0	3 300	6 000
Hemiptera	118	140	26	2	112	82 000	200 000
Thysanoptera	7	8	0	1	7	4 500	10 000
Megaloptera	2	2	2	0	0	350	600
Raphidioptera	2	2	2	0	0	200	300

Planipennia	16	18	18	0	0	5 100	10 000
Coleoptera	165	180	20	70	90	350 000	750 000
Strepsiptera	8	8	8	0	0	550	1500
Mecoptera	9	9	9	0	0	500	800
Siphonaptera	16	16	16	0	0	2 400	4000
Diptera	131	140	10	120	10	120 000	300 000
Trichoptera	43	45	5	39	1	11 200	18 000
Lepidoptera	128	135	0	5	130	150 000	275 000
Hymenoptera	84	100	86	0	14	120 000	350 000
32 (29-35)	943-1051		275	373	403	905 077	2 044 780

*Feeding habits: Numbers of families (based on the maximum number for the order) for which the *predominant* habit is predatory (including parasites and parasitoids), phytophagous (feeding on living tissues of higher plants) or other (detritivores; scavengers; microbial, pollen, spore, algal, fungal, moss, fern feeders; etc.). Note that many families contain some species that have different feeding habits; larvae and adults also often differ in feeding habits.

Table 1. Diversity and Feeding Habits* of Modern Insects
(species numbers very approximate and conservatively estimated from various sources).

2. What are Insects?

Insects broadly comprise all groups of Arthropoda (serially segmented invertebrate animals with a hardened exoskeleton and jointed appendages) that have the body of the adult subdivided into three distinct regions or tagmata (head, thorax and abdomen) and three pairs of legs. In addition, adults of most have two (sometimes one) pairs of wings. Each tagma is made up of several segments that may or may not be distinguishable. The head comprises six segments, most indistinguishably fused, and bears the major sensory organs (one pair of compound eyes, three ocelli or simple eyes, and one pair of antennae) and the mouthparts (primitively a single labrum, one pair of mandibles, one pair of maxillae and a single labium). The thorax comprises three segments, all generally distinct, and the locomotory appendages (legs and wings). The abdomen primitively comprises 11 or 12 segments, most generally distinct although some (eespecially the apical ones) may be reduced or not visible externally, and the genitalia which are usually derived from reduced and modified paired appendages; additional reduced jointed or lobe-like appendages may also be present. The external structure of a generalized adult insect is shown in Figures 1 - 3, and common modifications of the generalized type in Figures 4 - 6.

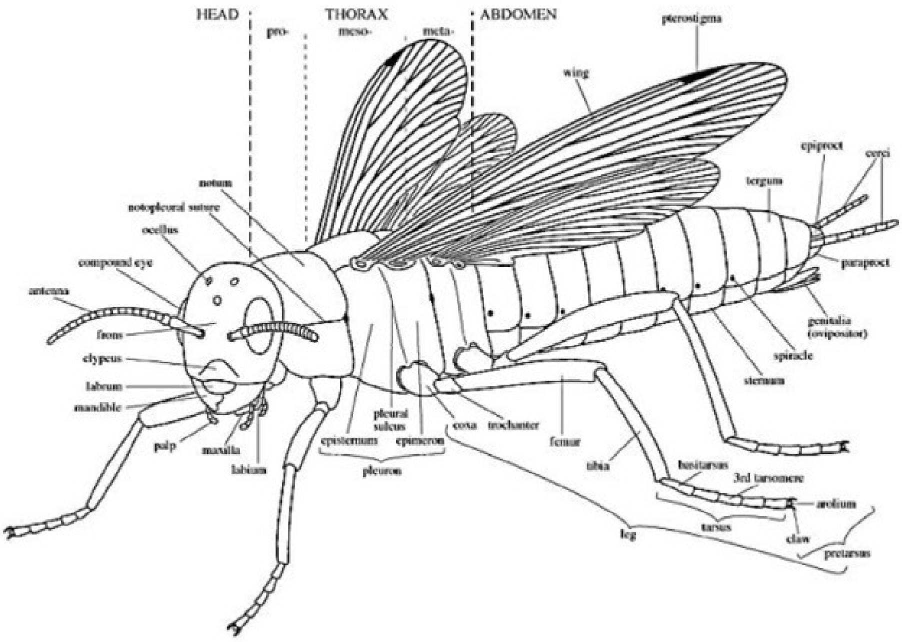

Figure 1. Generalized winged insect, anterolateral view.

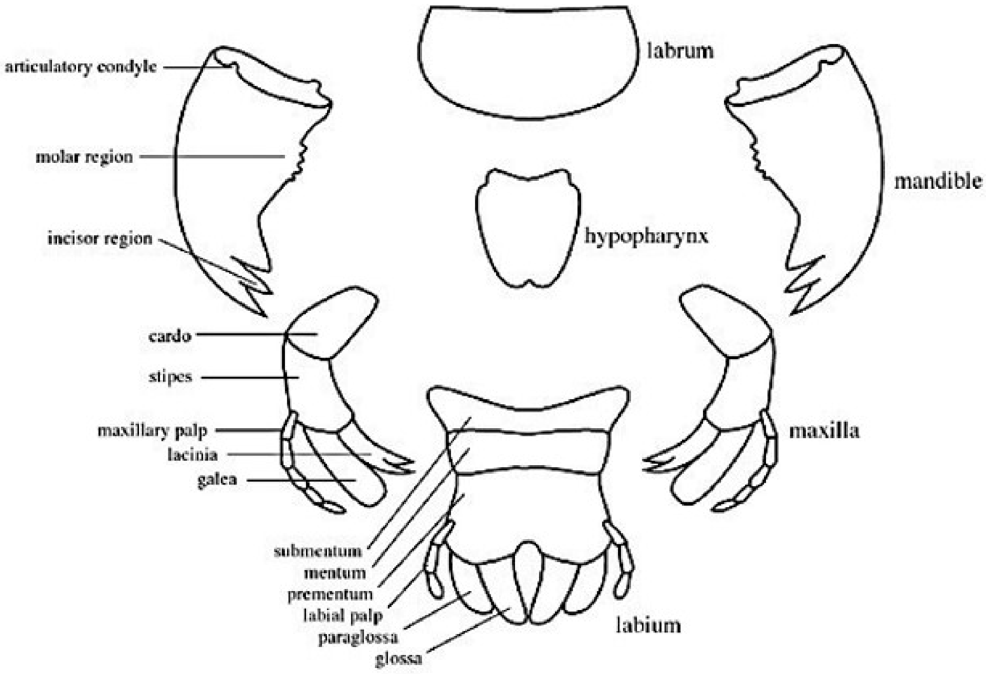

Figure 2. Generalized biting insect mouthparts.

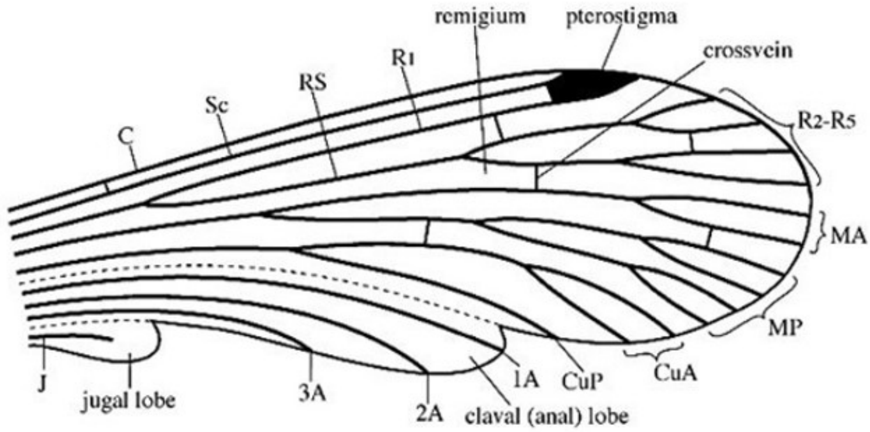

Figure 3. Generalized insect wing.
Veins: A = anal; C = costa; CuA = anterior cubitus; CuP = posterior cubitus; J = jugal bar; MA = anterior media; MP = posterior media; R = radius; RS = radial sector; Sc = subcosta. Dashed lines = folds.

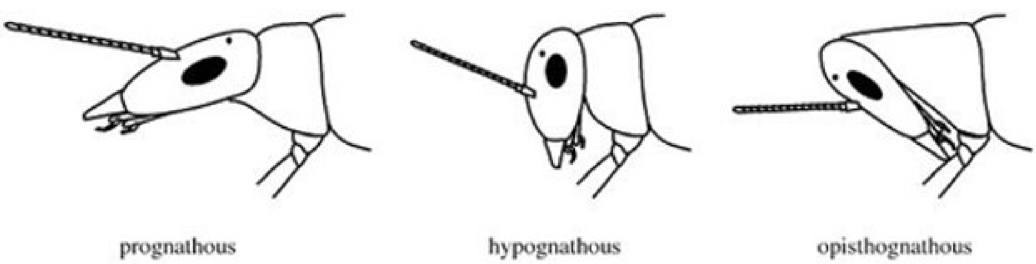

Figure 4. Orientation of the head in insects.

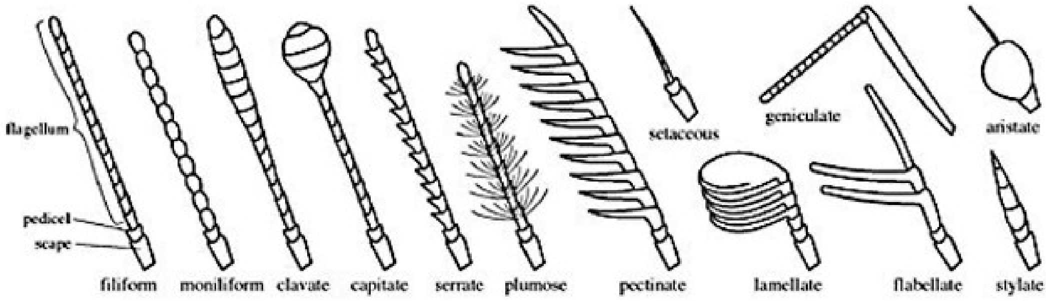

Figure 5. Modifications of insect antennae.

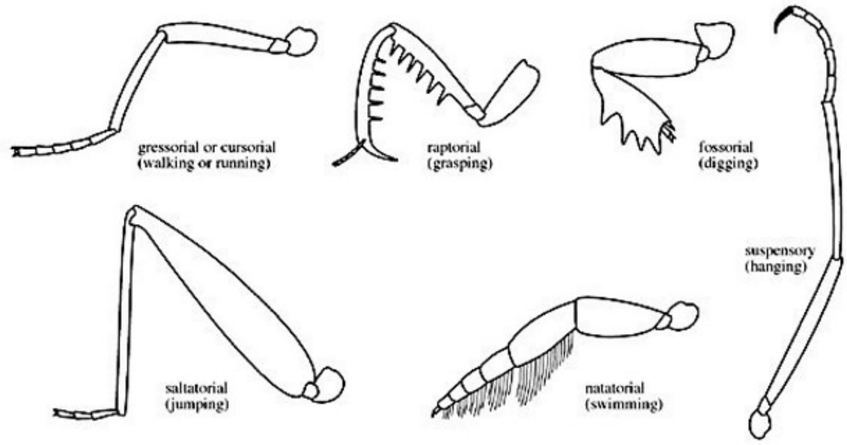

Figure 6. Adaptations of insect legs.

3. Why are Insects so Successful?

The insects owe their success to a few key features that have enabled them to diversify and adapt to almost all possible terrestrial and freshwater habitats, from the tropics to the polar regions and sea level to the tops of high mountains (Figure 7). Most features relate directly to characteristics of the integument: it is hard, resistant to physical damage and water transmission, almost infinitely malleable into complex forms and capable of displaying many colors; it requires ecdysis (molting) for growth and imposes physical limitations on size. Accordingly, most insects are tough, not easily injured, able to chew or pierce hard food or penetrate hard substrates when laying eggs, able to survive under conditions of extremely low humidity (the waterproofing characteristics of the cuticle being supplemented by physiological adaptations enabling the conservation of water, since the major nitrogenous waste product is insoluble uric acid which can be voided without using water as a solvent), adapted morphologically through modification of the basic body plan to perform a wide variety of activities (including flight through the development of specialized flapping wings thus enabling efficient dispersal) and feed on many and varied resources. Molting permits the development of extreme differences in body form and function between instars, thus reducing competition for resources between larvae and adults of the same species and enabling the occupation of different niches, and small size also allows fine differentiation of available resources and permits short reproductive cycles that lead to more rapid evolutionary change and adaptation.

Figure 7. Mating pair of stick insects from the Andes of Argentina; the dark color facilitates quick warming by the sun at high altitudes where the thin atmosphere provides little insulation.

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Biographical Sketch

Denis J. Brothers is a Professor of Entomology and also Deputy Director of the Centre for Environment and Development at the University of Natal, Pietermaritzburg, South Africa, where he teaches courses in insect functional diversity and biological systematics. He is a member of the Council of the International Commission on Zoological Nomenclature. He obtained his PhD in 1974 from the University of Kansas on the phylogeny of the aculeate Hymenoptera and his research interests are mainly in the biology and systematics of various groups of aculeate Hymenoptera (especially Mutillidae, Bradynobaenidae, Plumariidae and Scolebythidae), including fossils, and the principles of systematics. He is a member of the Council of the International Commission on Zoological Nomenclature and the Council of the International Palaeoentomological Society, and is President-Elect of the International Society of Hymenopterists.