INSECTS – DIVERSITY AND ALLERGY

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ABSTRACT

The class Insecta belongs to the superclass Hexapoda (six-legged arthropods) of the phylum Arthropoda (joint-legged animals). Approximately 50 000 of the 800 000 - 1 000 000 currently described species occur in South Africa, belonging to 28 of 30 insect orders. This huge biodiversity is a natural treasure to South Africa as many species are important pollinators or provide useful compounds (honey, silk). However, some insects have a negative impact on human health because they are vectors of diseases that affect millions of people. In addition, insects can cause allergic or adverse reactions in humans. Reactions have been noted in the following insect orders Zygentoma (silverfish), Blattodea (cockroaches), Phasmatodea (stick insects), Orthoptera (locusts, crickets), Phthiraptera (lice), Hemiptera (true bugs, cicadas), Coleoptera (beetles), Diptera (flies, mosquitoes), Siphonaptera (fleas), Lepidoptera (butterflies, moths) and Hymenoptera (bees, wasps, ants). Specific IgE responses can be quantified using the UniCAP System (Pharmacia Diagnostics AB, Uppsala, Sweden).

INTRODUCTION

With approximately 800 000 – 1 000 000 described species, insects represent about 55% of all known species on earth. Roughly 50 000 named insect species from 28 of the current 30 insect orders occur in southern Africa (for classification see below).[1] This huge insect biodiversity is a treasure of the region. Certain insects or their products are useful for human consumption or use, such as dried mopane worms or honey and royal jelly from honeybees. Others are essential for economic activities because they are important pollinators in agriculture, for example in fruit orchards.[1,2]

Many species, however, have a negative impact on human life. Some, such as mosquitoes and ants, are just regarded as a nuisance by most people. More seriously, some insects are important agricultural pests and cause damage to crops (for example aphids, locusts, flies) whereas others impact more directly on human health. Such insects can be vectors of diseases, e.g. malaria. Another important way in which insects impact on human health is by causing allergies and other adverse reactions. This article presents an overview of the insects that can cause such reactions, particularly discussing those relevant to southern Africa.

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PHYLOGENY OF INSECTS

Most people would say that they know what insects are. However, detailed questioning reveals that even scientists confuse insects and other invertebrates. Scientifically, the term 'Insecta' is clear-cut, so it is important to clarify this.

Because of the consistently increasing body of information available for interpreting the phylogeny of arthropods in general and of 'insects' in particular, there have been some changes in scientific opinion as to how these animals are related to each other. The 'classic' phylogeny was established mainly by comparison of morpho-anatomical features. Recent advances in molecular biology, especially on information from proteins and nucleotide sequences (i.e. RNA, DNA), have confirmed some established relationships whereas they have questioned others.[3] The current phylogeny cannot be considered final and some details will probably change in the future.

The following paragraph is therefore an attempt to summarise and simplify the current understanding of insects and how they are related to other arthropods.

Arthropoda (joint-legged animals) consist of four **superclasses**: the Myriopoda (millipedes, centipedes, etc.), the Chelicerata (horseshoe crabs, spiders, mites, ticks, scorpions, etc.), the Crustacea (crabs, lobsters, shrimps, prawns, etc.) and Hexapoda (six-legged animals) (Fig. 1A). The latter group includes the insects as one of four classes. There are indications that crustaceans and hexapods (or at least major taxa of each group) are so closely related that they can be grouped together. Some authors have termed this comined group 'Pancrustacea'. Interestingly, crustaceans are sometimes referred to as 'insects of the sea' and in the light of the close relationship of the two sister groups, this term carries some truth.

As mentioned above, not all hexapods are insects. The more basic classes (each containing only one order) of proturans (Protura), springtails (Collembola) and diplurans (Diplura) are entognathous (for their mouthpart morphology) hexapods. The class of true insects comprises 30 orders (Fig. 1B, not all orders depicted). The Archaegnatha (bristletails) and Zygentoma (silverfish) are the most basic (i.e. 'primitive') and wingless insect orders (termed 'Apterygota' for their winglessness). All other orders are winged or secondarily wingless (therefore termed 'Pterygota'). The 'Pterygota' are further subdivided into 'Palaeoptera', meaning 'old wings' that cannot be folded against the body at rest, and the 'Neoptera' ('new wings' that can be folded).

INSECT ALLERGY

The following is a summary of insect orders containing members whose body parts or secretions are known to cause allergic or adverse reactions in humans.

Zygentoma: Members of this primitive order are commonly known as silverfish or fish moths and are found in almost every home. Of the 370 species worldwide, 40 species occur in South Africa, but we are concerned with the domestic species. Scales from their bodies are an important component of house dust which makes avoidance in the living environment almost impossible. To date there are only a few reports of their allergenicity.[4,5]

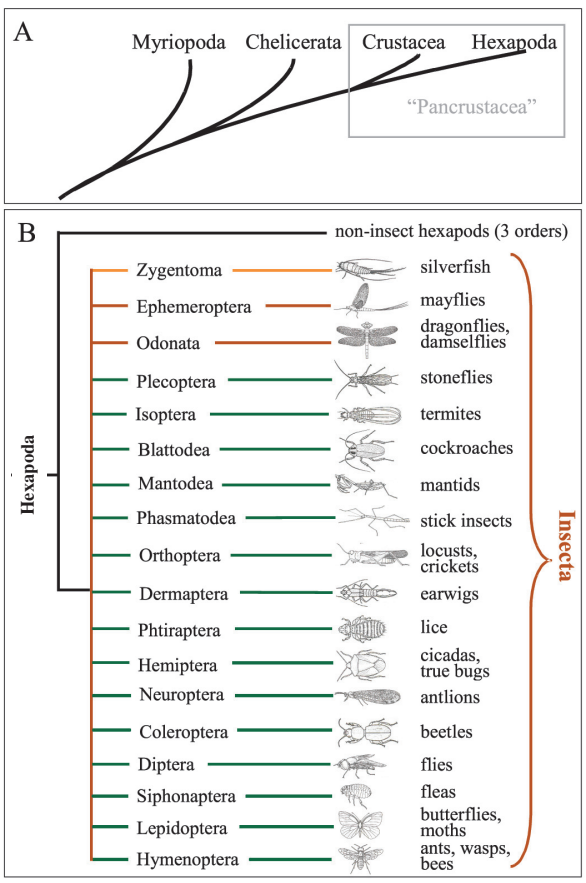

Fig.1. Systematic position of insects in the phylum of arthropods modified and simplified from Gullan and Cranston.[3] (A) Hexapods as one of the four superclasses of the phylum Arthropoda (joint-legged animals). Large parts of the two superclasses Crustacea and Hexapoda are hypothetically grouped into 'Pancrustacea' (indicated by grey frame) by some authors because of their close relationship. (B) Selected, more commonly known, extant orders of the class of insects inside the superclass of Hexapoda (six-legged arthropods). Twelve of the current 30 orders have been omitted for simplicity. Informal sub-groupings of Insecta: Apterygota – orange line; Pterygota: Palaeoptera – red line and Neoptera – green line (for more details see text).

Blattodea: Cockroaches are well known and some species share almost every environment with humans. There are more than 100 known endemic species in South Africa alone. The problematic ones, however, are alien species, namely the American (*Periplaneta americana*) and the German cockroach (*Blatella germanica*). These cockroaches can feed on almost any organic matter and are therefore attracted by human settlements. Allergens are found in faecal material, saliva, secretions (body washes), exoskeletons and dead bodies of cockroaches, and are the cause of widespread sensitisation.[6] (See a detailed article on this topic by Lopata *et al.*[7] in this issue).

Phasmatodea: There are about 50 endemic species of stick insects in the region. Stick insects are not normally in close contact with humans but Indian stick insects, *Carausius morosus*, are often kept in dense colonies for demonstrations in schools or for scientific use. This species was introduced some years ago and now lives in almost every ivy hedge in the wider Cape Town area.[1] Sensitisation has been recently reported.[8]

Orthoptera: This order is comprised of grasshoppers, locusts, crickets and their relatives. Approximately 1 000 species of this diverse order occur in South Africa alone. Some species live close to humans, such as certain cricket species, whereas contact with others, such as locusts, is often made in southern Africa when large swarms form during outbreaks, often causing asthmatic symptoms in sensitised individuals.[8] Some locusts are also used as a food source and some people, in fact, have proposed diminishing swarms by eating the locusts. Nevertheless, sensitised individuals can also react to ingested locusts (author's own observation!).

Phthiraptera: More than 1 000 of the 3 000 worldwide species of lice are present in Africa. Lice are very diverse and highly modified to suit their parasitic lifestyle. They have mouthparts that are adapted to either chew on their prey or suck their blood, frequently causing pruritus.[9]

Hemiptera: This order is divided into two suborders, each containing more than 1 000 species in southern Africa. The Homoptera include terrestrial plant feeders such as cicadas, leaf hoppers and plant lice (aphids). Members of the suborder Heteroptera (true bugs) are aquatic and terrestrial bugs that are mainly carnivorous (often bloodsucking). They are well known for the release of stinking secretions. The latter group impacts on human health – allergens are found in the saliva, often causing severe generalised and acute allergic reactions.[10,11]

Coleoptera: This is the largest and most diverse insect order, commonly known as beetles. Of the 370 000 species worldwide an estimated 18 000 live in our region. Some species are storage pests and this is how they come into close contact with humans. Beetles such as mealworms and weevils are often implicated in sensitisation, particularly in the working environment.[12] (See article by Jeebhay *et al.*[13] in this issue).

Diptera: The order of flies, mosquitoes and midges has a vast number of representatives in the Afro-tropical region with some 16 000 species. Some species, like the tsetse fly, *Glossina* spp., or the Malaria mosquito, *Anopheles* spp., are important vectors of parasitic diseases. Allergic and even anaphylactic reactions to mosquitoes and flies are documented, often associated with saliva proteins.[14,15] However, even non-biting diptera, such as the chironomid midges can cause severe allergic reactions to the haemoglobin of these insects.[16] These so-called blood worms are utilised for dry fish-food and can sensitise exposed workers. **Siphonaptera**: Over 100 of the worldwide 2 800 species of fleas are found in this region. All fleas feed on blood and have sucking and piercing mouthparts. Fleas are important vectors of diseases and are associated with domestic animals such as cats and dogs. Salivary allergens cause allergic reactions such as the so-called papular urticaria.[17,18]

Lepidoptera: This order is divided into butterflies and moths. In our region, there are about 850 butterfly and several hundred species of moth. Some species are important agricultural pests. There are over 100 reported species that cause irritant and allergenic reactions through their hairs.[19] Even the important *Bombyx mori*, which produces valuable silk, can cause severe sensitisation.[20]

Hymenoptera: There are 198 000 species of bees, wasps and ants worldwide of which about 6 000 live in southern Africa. Some wasps and bees and all ants are social, meaning several thousand insects can be found in or near a nest. Many species are important pollinators of the local flora. Allergic reactions are mainly caused by the venom of the sting.[21] A detailed article by Potter[22] in this issue deals with the allergic reactions and possible immunotherapy.

Table I. Available ImmunoCAP tests for the quantification of specific IgE responses to different insect species

Common name	Scientific name	Immuno-CAP Code
Blattodea		
German cockroach	*Blatella germanica*	i 6
Oriental cockroach	*Blatta orientalis*	Ri 207
American cockroach	*Periplaneta americana*	Ri 206
Diptera		
Horse bot fly	*Gasterophilus intestinalis*	i 201
Horse fly	*Tabanus spp.*	i 204
Mosquito	*Aedes communis*	i 71
Blood worm	*Chironomus thummi*	i 73
Green nimitti midge	*Cladotanytarsus lewisi*	i 72
Coleoptera		
Grain weevil	*Sitophilus granaries*	Ri 202
Mealworm	*Tenebrio molitor*	Ro 211
Berlin beetle	*Trogoderma angustum*	i 76
Hymenoptera		
Honeybee	*Apis mellifera*	i 1
Common wasp	*Vespula* spp.	i 3
Paper wasp	*Polistes* spp.	i 4
European hornet	*Vespa crabro*	i 75
White-faced hornet	*Dolichovespula maculata*	i 2
Yellow hornet	*Dolichovespula arenaria*	i 5
Bumblebee	*Bombus terrestris*	Ri 205
Fire ant	*Solenopsis invicta*	i 70
Orthoptera		
Migratory locust	*Locusta migratoria*	Research preparation
Lepidoptera		
Silk moth	*Bombyx mori*	i 8
Mediterranean flour moth	*Ephestia kuehniella*	Ri 203

Many different allergens are characterised from different allergen sources and insect species. Some allergens seem to be present in different insect species; however, many allergens appear to be species-specific as demonstrated for cockroaches. Subsequently commercial ImmunoCAP tests (UniCAP System; Pharmacia Diagnostics AB, Uppsala, Sweden) have been developed in recent years for the quantification of specific IgE responses to some insect species. The currently available ImmunoCAP tests are listed in Table I.

ALLERGY TO NON-INSECT ARTHROPODS

Insecta is not the only taxon within the phylum Arthropoda whose members can cause allergies or adverse reactions. Such species can be found in all three sister-superclasses of Hexapoda. In the superclass **Myriopoda**, the venom released during centipede bites and the toxin secreted by certain millipedes as a chemical defence causes adverse reactions (such as swelling, irritation etc.).[10] Several mites (superclass **Chelicerata**) such as house-dust-, spider- and certain storage mites are well known to cause asthma and other allergic reactions.[23] (see article on this topic by Jeebhay *et al.*[13] in this issue). The venom injected into the human body during spider bites and scorpion stings can also cause adverse reactions.[10] Many species of **Crustacea**, such as lobsters, crabs, prawns and shrimps can cause severe allergies when consumed, and are also a source of occupational allergies in the fishing and processing industries.[24-26] It is interesting to note that cross-reactivity seen frequently between crustacean and insect allergens supports the grouping of 'pancrustacea' as detailed in Figure 1.

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