INTRODUCTION TO THE STUDY OF ENTOMOLOGY

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Contents

Summary

Strictly defined, entomology is the study of insects, but often includes closely related arthropods as well. The work of entomologists, the people who study insects is extremely diverse due to the high abundance, species richness, and ecological and behavioral characteristics of insects. This chapter is intended as an introduction to the study of entomology, giving brief explanations and definitions of some chosen topics such as integrated pest management, Chagas disease caused by triatomine bugs, colony collapse disorder of honey bees, red pigments derived from scale insects, the human consumption of insects, and keeping of insects as pets. Emphasis was particularly given to some important aspects of human association with insects.

Since early times, entomology has been a very broad subject. Oliver Wendell Holmes Sr. (29.viii.1809 – 8.x.1894) in his book “The Poet at the Breakfast Table” (1872) wrote the following quotes that describe the complexities of entomology:

“ ‘*I suppose you are an entomologist?*’ *I said with a note of interrogation*.”

"*Not quite so ambitious as that, sir. I should like to put my eyes on the individual entitled to that name! A society may call itself an Entomological Society, but the man who arrogates such a broad title as that to himself, in the present state of science, is a pretender, sir, a dilettante, an impostor! No man can be truly called an entomologist, sir; the subject is too vast for any single human intelligence to grasp*."

1. Introduction

Entomology is a branch of biology that focuses on the study of insects. The word entomology comes from the French word "entomologie" coined from the Greek word "entomon" meaning "insect" + "logia" meaning the "study of". "Entomon" comes from the word "entomos" which means "having a notch or cut (at the waist)," so called by Aristotle in reference to the segmented division of the insect body, from "en-" meaning "in" + "temnein" meaning "to cut" (Online Etymology Dictionary, 2011).

In the strict sense, entomology is the study of insects, but entomologists often study other arthropods such as arachnids (e.g., spiders, scorpions and mites), myriapods (e.g., millipedes and centipedes) and even crustaceans (e.g., crabs and isopods). Nevertheless, insects (those organisms belonging to the class Insecta) are studied by entomologists, arachnids are studied by arachnologists and acarologists (those who specialize on mites and ticks), myriapods are studied by myriapodologists, and crustaceans are studied by carcinologists (also known as malacostracologists or crustaceologists). Recent phylogenetic studies have placed organisms previously included in the class Insecta, such as diplurans (order Diplura), proturans (order Protura) and springtails (order Collembola) into a sister group called the class Entognatha. Hexapods (six legged organisms) of the class Entognatha have long been treated as insects, and thus are generally studied by entomologists too. The word "entognathology" may be proposed as the study of these non-insect hexapods, and the word "entognathologist" to describe those who study them.

2. What is an Insect?

Insects are small animals with 6 pairs of legs that range from less than 1 mm to about 30 cm long. Within the phylum Arthropoda, the classes Insecta and Entognatha (together forming the superclass Hexapoda) have the most developed tagmosis, that is, their body segments are arranged into well-defined functional body parts known as tagmata (singular tagma). Adult insects and entognathans are characteristic in having three tagmata, the head, thorax and abdomen (Figs 1 & 2, left). Besides bearing the mouthparts, the insect head contains many of the sensory organs that perceive and process external information (e.g., antennae, eyes and ocelli). The thorax bears the locomotory organs (i.e., legs and wings).

The abdomen contains most of the organs associated with metabolism and reproduction. The insect body is protected by a hard external "shell" or integument called the exoskeleton, which is composed of cuticle that is secreted by the epidermis. Cuticle is formed of chitin (an amino-sugar polysaccharide) and protein, and there are several layers that vary in development and composition on different areas of the body to allow flexibility or strength of the body wall.

Figure 1. A colorful eumastacid grasshopper (Insecta: Orthoptera: Eumastacidae). Photo by T. Kondo.

Other arthropods have a more reduced type of body segmentation - for example, arachnids have two tagmata, the cephalothorax (or prosoma) and the abdomen (or opisthosoma) (Fig. 2, right). Insects have different types of metamorphosis, but all entognathans have incomplete metamorphosis (see Section 5.3.). Some morphological differences between the Insecta and the closely related Entognatha are as follows (features of Entognatha in parenthesis): (1) mouthparts exposed or in technical terms ectognathous (mouthparts not exposed, entognathous); (2) adults usually with compound eyes and ocelli (eyes and ocelli usually absent, rudimentary when present); and (3) legs composed of six segments (legs composed of four or five segments). Colloquially, insects are often referred to as “bugs”, however, in entomology; the word “bug” is strictly used for insects belonging to the order Hemiptera. Insects in this order, especially those of the suborder Heteroptera are known as “true bugs”. Although insects of the family Coccinellidae (Fig. 11) are sometimes called ladybirds or ladybugs, these are neither birds nor true bugs, but actually beetles, and thus the names ladybird beetles or lady beetles are preferred by entomologists.

Figure 2. Comparison of an insect and an arachnid. Left. The fruit fly, *Anastrepha striata* (Insecta: Diptera: Tephritidae) showing its three main body parts. Right. The crab spider, *Gasteracantha cancriformis* (Arachnida: Araneae: Araneidae) showing its two main body parts. Photos by T. Kondo.

For common names of true bugs, e.g., assassin bug, leaf-footed bug or giant water bug, the word 'bug' is written separately from its adjective or descriptor. Many insect common names end with the word "fly", e.g., butterfly, dragonfly, mayfly, whitefly, but these are really not flies; butterflies belong to the order Lepidoptera, dragonflies belong to the order Odonata, mayflies belong to the order Ephemeroptera and whiteflies belong to the order Hemiptera. In entomology, "flies" are insects belonging to the order Diptera, and for this group, common names are usually written with the word fly separately, e.g., fruit fly, vinegar fly, deer fly, house fly, etc.

3. Insects and People

The first insects appeared on Earth more than 400 million years ago, in comparison to the modern human species that only came into existence only about 50,000 years ago. Insects have long been associated with humans. A list of some insects and insect products that are associated with human life are summarized in Table 1.

Topic	Associated Insects or Insect Products
Arts and literature	Insects are often a subject in literature works and painting (eg. butterflies, flies, beetles). In some countries in SE Asia and Brazil, art works made of butterfly wings are commonly sold.
Clothing	Plant fiber and leather product pests (e.g., carpet beetles, clothing moths, screw worms), silk clothes (e.g., silk moths).
Cosmetics	Ingredients in cosmetics (e.g., bee wax, cochineal dye, honey).
Educational material	Insects (silk moth, cockroaches, crickets, butterflies, others) are often used for teaching art, biology and other related subjects.
Energy	Caddisfly cases (e.g., *Stenopsyche siamensis*; Stenopsychidae) can foul flumes in hydroelectric generators and reduce generator efficiency.
Food and agriculture	Agricultural, storage and food product pests (e.g., aphids, army worms, bruchid beetles, cigarette beetles, corn borers, fruit flies, fruit borers, inch worms, Indian meal moth, June beetles, leaf beetles, leaf hoppers, rice weevils, scale insects, schaffers, thrips, whiteflies, wireworms); livestock pests (e.g., house fly, stable fly, horn fly, bot flies, deer flies, horse flies, blister beetles, moths); insects and insect products as a food source (e.g., honey, mopane worms, beetle grubs).
Forensic science	The biologies of insects and other arthropods often aid in solving crimes. Insects (e.g., flesh flies, blue bottle flies, various beetles, moths) are often studied in criminal investigations to determine the time of death, original location of a crime, etc.
Forestry	Bark beetles, gypsy moth, woolly adelgids, and other insect pests.
Human health and medicine	Stinging and urticating insects (e.g., bees, carabids, hornets, blister beetles, moths); blood sucking and/or disease vectors (e.g., bed bugs, black flies, ceratopogonid flies, cockroaches, fleas, deer flies, horse flies, house flies, kissing bugs, lice, mosquitoes, sandflies, tsetse flies); insect products use for pharmaceutical purposes (e.g., beeswax, pela scale insect wax, shellac as material for coating pills); aphrodisiacs (Spanish fly).

Jewelry and ornaments	Jewel beetles (buprestid beetles); butterflies; colorful and beautiful insects for display (e.g., butterflies, June beetles, rhinoceros beetles).
Museum	Cleaning flesh and cartilage from bone specimens (e.g., dermestid beetles).
Science	Many species of insects are commonly studied by scientists, but the vinegar fly, *Drosophila melanogaster*, is probably the most studied organism in biological research, particularly in genetics and developmental biology.
Sports	Fishing bait (e.g., caddisflies, stoneflies, chironomid midges).
Transport and communication	Disruption of visibility and slippery road surface conditions (e.g., mayflies, chironomid midges); accidents due to distraction and stings (bees, wasps, others); shellac extracted from the Indian lac insect *Kerria lacca* may be used as an electric insulator in electric wires; damage to electric wires (powderpost beetles).
Wood building and construction	Wood boring pests (e.g., bruchid beetles, carpenter ants, carpenter bees, deathwatch beetles, longhorned beetles, termites).

Table 1. Insects and insect products associated with various aspects of human life.

4. What Subjects are studied in Entomology?

Entomologists may investigate any number of subjects relevant to insects. Some examples include agriculture, anthropology, behavior, biochemistry, biomechanics, developmental biology, ecology, forensic science, insect art (Fig. 3), genetics, molecular biology, morphology, nutrition, paleontology, physiology, robotics, systematics, and various other fields. For example, meteorology is applied to the study of insects as radar technology is used for studying the migratory patterns of insects such as butterflies and dragonflies.

Figure 3. Luna moth. Ceramic plate by unknown American artist. Photo by T. Kondo.

Entomology is divided into basic and applied entomology. The former deals with the basic aspects of insects, whereas the latter deals with the economic aspects of insects in human society. Nevertheless both basic and applied fields are like two wheels of a cart and must go hand in hand.

5. Basic Entomology

Basic entomology (also known as general, pure, fundamental, or theoretical entomology) deals with studies such as biochemistry, biogeography, cytology, ecology, insect development, ethology, genetics, histology, morphology (insect anatomy), paleoentomology, physiology, reproduction, phylogeny and taxonomy.

5.1. Insect Anatomy and Insect Physiology

Insect anatomy is the study of the structures (body parts and organs) of insects. It is often taught in courses in general entomology and insect physiology, and is usually divided into external and internal anatomy. The study of external anatomy is called morphology. Morphology is the branch of biology that deals with the form and structure of organisms. In entomology, morphology is important to understand the functions of the various insect body plans and to allow the classification and identification of insects and their relatives. Internal anatomy deals with the internal organs of the insect body, and is often taught along with insect physiology because of the close association of the various organs with essential chemical and physiological processes.

The study of minute anatomical structures includes histology (the study of the organization of tissues) and cytology (the study of cells).

5.2. Systematic Entomology

Systematic entomology or insect systematics is the study of the diversity of insects and their inter-relationships. Systematics can be subdivided into two fields, i.e., taxonomy and phylogenetics.

Insect taxonomy is the science that deals with recognizing, describing, and naming species and groups of species, and the classification of insects into a ranked and named system (e.g., species, genus, family, order, etc.) that aims to reflect a natural evolutionary history. Phylogenetics is the study of the relatedness of organisms or groups of organisms based on shared ancestry. The study of the distribution of insects based on environmental, geological factors and phylogenetic relationships is termed biogeography. More than half of the known species on Earth are insects, with an estimate of 925,000 species described! Within the currently recognized 29 insect orders, the most species-rich orders are the Coleoptera (the beetles) (e.g., Figs 11 & 25) (38% of species), Lepidoptera (butterflies, moths (e.g., Figs 4, 8 & 26) and skippers) (16%), Hymenoptera (ants, bees (e.g., Figs 18 & 19) and wasps (e.g., Fig. 25)) (13%) and the Diptera (flies (e.g., Figs 2 left & 10), gnats and mosquitoes (e.g., Fig. 14)) (12%). The superorder Paraneoptera, composed of the orders Hemiptera (true bugs (e.g., Fig. 6) and others (e.g., Fig. 21)), Psocoptera (bark lice), Phthiraptera (sucking lice) and Thysanoptera (thrips) make up about 11% of the total known insect species. The rest of

the 10% of insects are composed by the less species-rich orders: Siphonaptera (fleas), Mecoptera (scorpion flies), Trichoptera (caddisflies), Strepsiptera (twisted-winged parasites), Neuroptera (lacewings, mantidflies, antlions, others), Rhapidioptera (snakeflies), Megaloptera (alderflies, dobsonflies, fishflies), Blattodea (cockroaches, termites (e.g., Fig. 16)), Mantodea (praying mantids) (e.g., Fig. 5), Zoraptera (zorapterans), Dermaptera (earwigs), Plecoptera (stoneflies), Orthoptera (crickets, grasshoppers (e.g., Fig. 1), katydids, locusts), Mantophasmatodea (heel-walkers or gladiators), Grylloblattodea (ice-crawlers or rock crawlers), Embioptera (webspinners), Phasmatodea (stick insects, walking sticks, leaf insects), Ephemeroptera (mayflies), Odonata (damselflies, dragonflies), Zygentoma (silverfish), Archaeognatha (jumping bristletails).

Figure 4. Two male geometrid moths. Photo by T. Kondo.

Figure 5. A praying mantis (Mantodea) showing cryptic coloration. Photo by T. Kondo.

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Biographical Sketch

Takumasa Kondo (Demian Takumasa Kondo Rodríguez), born in Colombia in 1968, obtained a B.Sc. degree in International Agricultural Development from Tokyo University of Agriculture (Japan) in 1994 for his thesis entitled: "The scale insect fauna of Okinawa" (In Japanese), and in 1996 he was awarded a M.Sc. degree from the same university for his thesis entitled: "The Scale Insects on Mango in the World" (In English). While studying his undergraduate degree in Japan, he traveled to the USA where he was an exchange student at the Department of Entomology at Michigan State University (1992-1993). In 1997 he moved to the Department of Entomology (now Department of Entomology and Plant Pathology) of Auburn University and obtained his Ph.D. degree in 2003. His dissertation was entitled: "A taxonomic review of the subfamily Myzolecaniinae (Homoptera: Coccoidea: Coccidae)". As soon as he received his doctorate's degree he moved to the University of California, Davis, where he was a postdoctoral researcher until December 2007. Since January 2008 he has been working in the area of integrated pest management at the Corporación Colombiana de Investigación Agropecuaria (Corpoica), in Palmira, Colombia. During his career, he has participated in many field expeditions, traveling to countries such as Argentina, Brazil, Chile, Colombia, Ghana, India, Indonesia, Jamaica, Japan (Okinawa), Mexico, and other regions. He is section editor in the area of systematics for the journal Neotropical Entomology (2007-present), member of the editorial board of the International Journal of Insect Science (2008-present), and topic editor of systematics for the Journal of Insect Science (2010-present). He is member of: The Honor Society of Agriculture: Gamma Sigma Delta, Auburn University Chapter (Inducted May 1, 2003). He is an active member of the Entomological Society of America, The Entomological Society of Japan, The Entomological Society of Colombia (SOCOLEN), The Entomological Society of Brazil, the International Organization for Biological Control (IOBC), Neotropical Regional Section (NTRS) and ASIAVA (Association of Agricultural Engineers of the Valle del Cauca region, Colombia). He has experience supervising or co-supervising Ph.D., M.Sc. and undergraduate students, and has published over 80 research papers. His research has dealt mostly with the systematics of several scale insect groups, including the lac insects (Kerriidae), mealybugs (Pseudococcidae), giant scales (Monophlebidae), ground pearls (Margarodidae), the felt scales (Eriococcidae), and the soft scale insects (Coccidae), especially those species associated with ants and stingless bees. He is also working on a molecular level phylogenetic study of the family Coccidae. At Corpoica, he has lead three research projects, namely, two projects on integrated pest management of two lonchaeid fly species, *Dasiops inedulis* (Steyskal) on passionfruit, and *D. saltans* (Townsend) on yellow pitaya, *Selenicereus megalanthus* (Cactaceae), and a third project on a faunistic survey of mites and scale insects and their natural enemies on avocado in Colombia. Currently he is conducting research on the integrated pest management of the Asian citrus psyllid, *Diaphorina citri* (Psyllidae), with emphasis on biological control, and is involved in a classical biological control program on San Andres Island, Colombia, to control two invasive scale insect species, namely the pink hibiscus mealybug *Maconellicoccus hirsutus* (Pseudococcidae) and the multicicatrices fluted scale *Crypticerya multicicatrices* (Monophlebidae).