What is biodiversity? (Wilson 1991, CBD 1992)

•Biodiversity – variety of organisms at all levels, from genetic variants belong to the same species through arrays of species to arrays of genera, families, and still higher taxonomic levels; includes the variety of ecosystems, which includes communities of organisms within particular habitats and the physical conditions under which they live

•Most common definition: **Number of species**

Biogeographical Local evolution and barriers to dispersal create distinct biotas and species

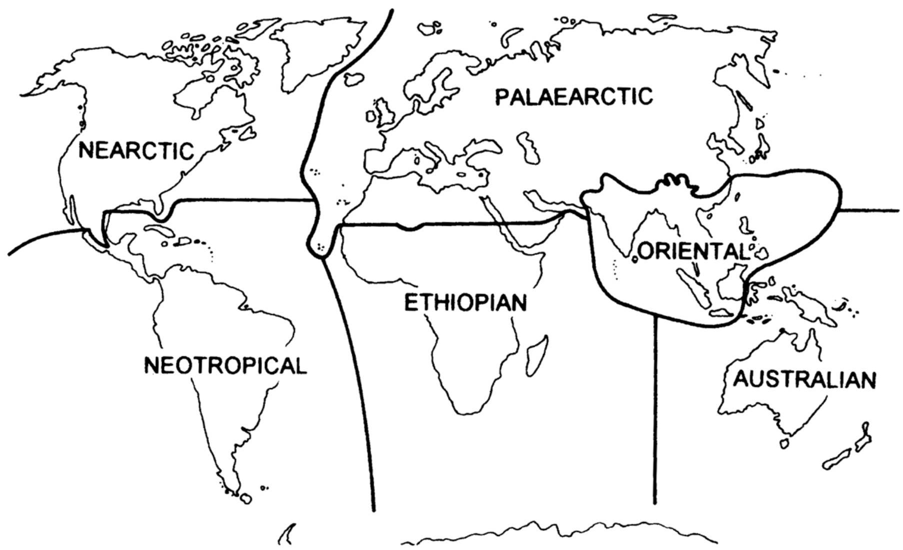
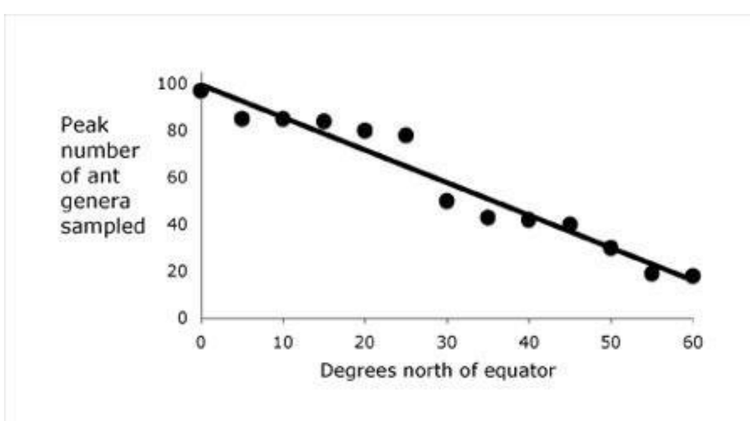


Figure 2.1 Wallace's six realms. Different authors use slightly different boundaries in some places. (From Wallace, 1876; illustration by Mike Hill.)

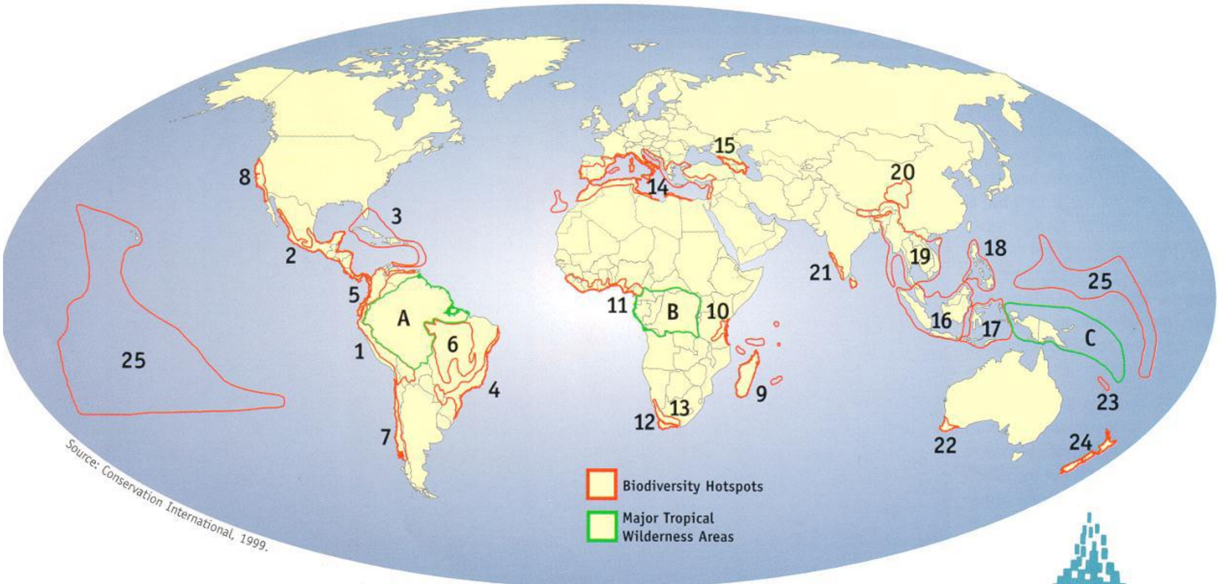
Positive species-energy relationship



Warm tropical regions are more diverse than cold regions

Same patterns along elevational gradients

People and Biological Diversity



Population Action International

The Global Biodiversity Hotspots and Major Tropical Wilderness Areas

Hotspots
1. Tropical Andes
2. Mesoamerica
3. Caribbean
4. Atlantic Forest Region
5. Chocó-Darién-Western Ecuador
6. Brazilian Cerrado
7. Central Chile
8. California Floristic Province
9. Madagascar and Indian Ocean Islands
10. Eastern Arc Mountains and Coastal Forests of Tanzania and Kenya
11. Guinean Forests of West Africa
12. Cape Floristic Province
13. Succulent Karoo
14. Mediterranean Basin
15. Caucasus
16. Sundaland
17. Wallacea
18. Philippines
19. Indo-Burma
20. Mountains of South-Central China
21. Western Ghats and Sri Lanka
22. Southwest Australia
23. New Caledonia
24. New Zealand
25. Polynesia/Micronesia

Major Tropical Wilderness Areas
A. Upper Amazonia and Guyana Shield
B. Congo Basin
C. New Guinea and Melanesian Islands

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Estimating Biodiversity (May 1989)

Numbers of species in relation to body size:

Compensating for the neglect of small organisms by extrapolation

Number of species declines with body size according to a mathematical rule

By extrapolating to the left, conclude many species of small organisms have yet to be discovered and described

World insect species richness 15

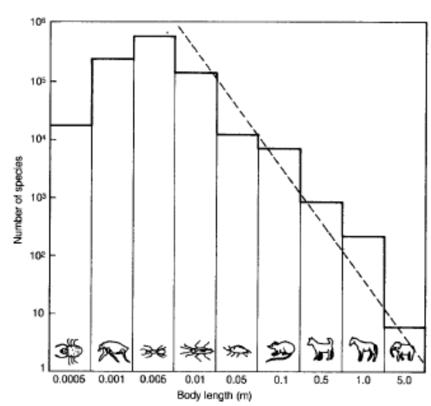
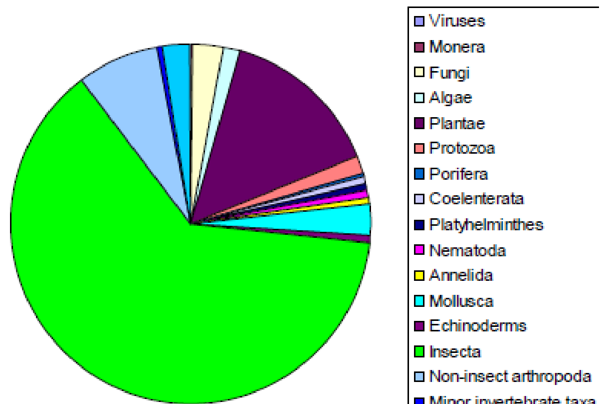


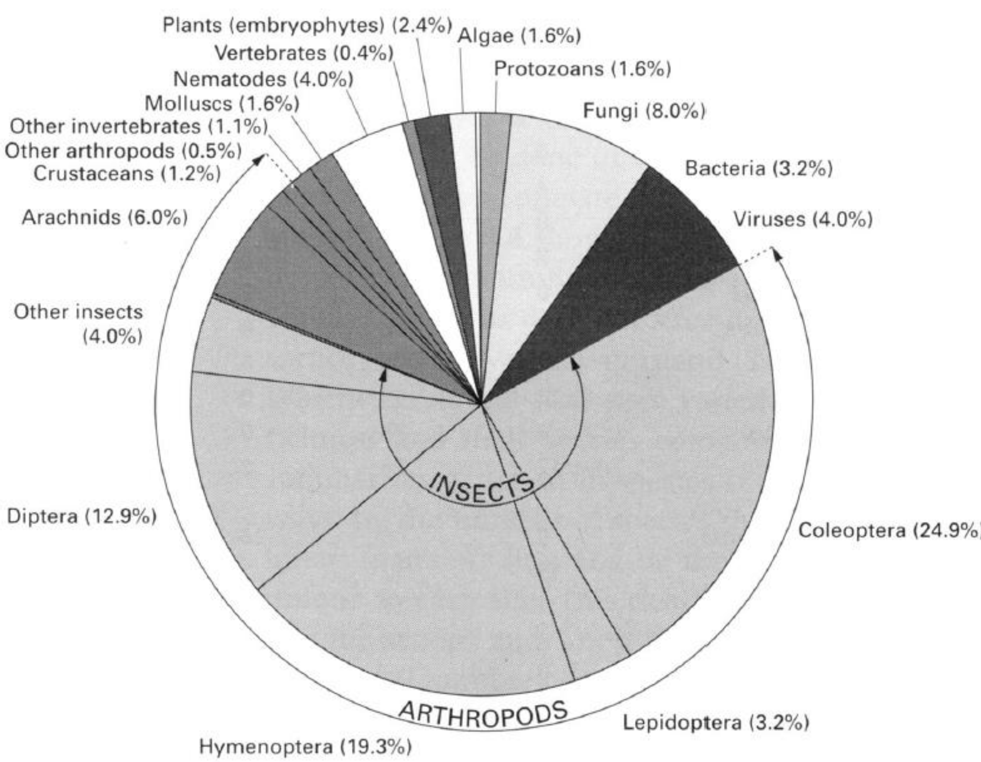
Figure 1.6 An approximation of the numbers of all described (the histogram) terrestrial animals categorized according to body length. The total number of species, undescribed as well as described, would change the shape of the left-hand side of the histogram, and increase the height of the bars. A much greater proportion of the larger animals have been described, with the right-hand side of the histogram having a characteristic slope. (From May, 1989.)

Approximate number of described species

Viruses	1,000
Monera	5,000
Fungi	47,000
Algae	27,000
Plantae	250,000
Protozoa	31,000
Porifera	5,000
Coelenterata	9,000
Platyhelminthes	12,000
Nematoda	12,000
Annelida	12,000
Mollusca	50,000
Echinoderms	6,000
Insecta	***1,112,000***
Non-insect arthropoda	125,000
Minor invertebrate taxa	10,000
Chordata	44,000
Total	1,758,000



Insects alone 64%
With other arthropods 72%



Populations or communities

A **population** is all the organisms that both belong to the same species and live in the same geographical area

A **community** is an assemblage of two or more populations of different species occupying the same geographical area

We need to define what a site is (e.g. a forest, a tree, a meadow, a river…)

Sampling insect communities

Unlike monitoring population of single species, we usually need sampling techniques to maximize the number of species collected

Detection probability should be equal between species

We need to standardize time and space to make diversity measures comparable between sites

Generic trapping systems or direct observation methods

Biodiversity data Community data

	Site 1	Site 2	Site 3
Species A	1	0	0
Species B	2	0	0
Species C	7	0	0
Species D	9	71	0
Species E	23	49	143
Species F	7	0	0
Species G	15	0	0
Species H	76	74	7
…	1	1	42

Presence/absence or abundance

How to measure diversity from this data?

Species richness: Number of species

Abundance: Number of individuals of each species

Diversity: Statistical combination of species richness and relative abundance of each species.

Diversity is measured in terms of different diversity indices

Simpsons index, Shannon-Wiener index, Chao 1 index

Why do we need insect diversity?

- Conservation of single species (populations)
- Conservation of communities
- Ecosystem services delivered by insects (pest control, pollination, nutrient cycling…)

Threats to biodiversity

1. Land-use change
2. Climate change
3. Invasions of exotic organisms

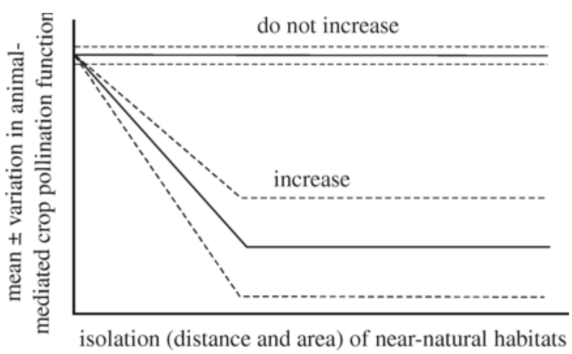
Conservation biology evaluates the impact of these pressures on biodiversity

OR

the effectiveness of mitigation measures

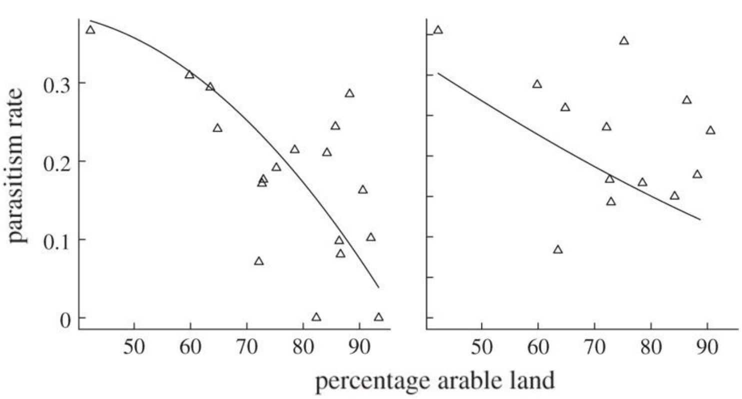
Conservation of single species (populations)
Extinctions of rare species: some species are conserved because rare and endangered
-Saproxylic beetles (Osmoderma eremita, Lucanus cervus…)
-Butterflies (Parnassius apollo, Lycaena phlaes)
-Dragonflies …
Conservation of single species (populations)
Umbrella species: Species used as indicator of high quality habitat and large biodiversity e.g. *Osmoderma eremita*
Conservation of communities
We usually try to conserve communities with large number of species and evenness
More biodiversity = better ecosystem functioning?
Ecosystem Services
•nutrient cycling
•pollination
•pest control

Pollination
The ecological and financial importance of natural pollination by insects to agricultural crops, improving their quality and quantity



The vicinity of a forest or wild grasslands with native pollinators near agricultural crops

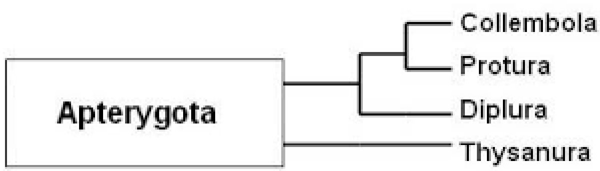
Pest control
Many potential crop pests are controlled by natural enemies, including many spiders, parasitic wasps, flies, and lady bugs. These natural biological control agents save farmers billions of euros annually by protecting crops and reducing the need for chemical control



The cover of semi-natural habitats increase pest control

EVOLUTIONARY TIME EVENTS
Earth 4.5 billion years old
- **Precambrian:** 3.1 billion, single celled organisms, bacteria et alia assorted prokaryotes
- **Cambrian:** 600 mya (million years ago), 1st period of abundant fossils (metazoans)
- **Silurian:** 425 mya, invasion of land by arthropods
- **Devonian:** 405 mya, first true insects
- **Carboniferous:** 345 mya, first great radiation of insects
- **Cretaceous:** 135 mya, second great radiation of insects
- **Tertiary:** 63 mya, dominance of the land by mammals, birds, & insects
- **Quaternary:** 2 mya, first Homo sp.

INSECT MACROEVOLUTION - THE DEFINING EVENTS
1) Appearance of primitive, wingless insects!!! The APTERYGOTES (Devonian Period: ca. 400 million years ago)



2) Development of Wings!!! The PTERYGOTES
(Late Devonian to Lower Carboniferous Period: 350 million years ago)

Primitive Winged Insects or PALEOPTEROUS insects with simple wing articulation - at rest held out from body (Odonata and Ephemeroptera)

3) Development of the WING-FLEXION mechanism!!!! - Allows exploitation of terrestrial habitats (niches) and more efficient escape from predators. NEOPTEROUS – (Lower Carboniferous Period: 300 million years ago).
Today NEOPTEROUS insects comprise the majority of insect orders and 97% of species.

Darwin's Theory of Evolution
Darwin defined **evolution** as species (share a common ancestor) change over time, giving rise to new species (**descents with modifications**). This evolution has occurred through the process of **natural selection** or the **"Survival of the fittest**".

Darwin's theory of evolution by natural section has **five basic premises** which very well fit to insects:
1. Many more individuals are born in each generation than will survive and reproduce **(natality)**
2. There is variation among individuals; they are not identical in all their characteristics. **(variability)**
3. Individuals with certain characteristics have a better chance of surviving and reproducing than individuals with other characteristics **(survivorship)**
4. At least some of the characteristics resulting in differential reproduction (those organisms best adapted to a given environment will be most likely to survive to reproductive age and have offspring of their own) are caused by different genes. **(heritability)**
5. Enormous spans of time available for slow, gradual change. **(Time)**
REMEMBER: Insects, as a taxon, have long inhabited this planet!!!!

Genetic Diversity

Genetic diversity refers to the diversity (or genetic variability) within species. How is diversity created? In the process of inheritance, nucleotides (although not always whole genes) are shuffled and recombined to form new combinations that are different than the parents. Each individual species possesses genes which are the source of its own unique features: In human beings, for example, the huge variety of people's faces reflects each person's genetic individuality. The term genetic diversity also covers distinct populations of a single species, such as the thousands of breeds of different dogs or the numerous varieties of roses.

What is the significance of genetic diversity?

The huge variety of different gene sets also defines an individual or a whole population's ability to tolerate stress from any given environmental factor. While some individuals might be able to tolerate an increased load of pollutants in their environment, others, carrying different genes, might suffer from infertility or even die under the exact same environmental conditions. Whilst the former will continue to live in the environment the latter will either have to leave it or die. This process is called natural selection and it leads to the loss of genetic diversity in certain habitats. However, the individuals that are no longer present might have carried genes for faster growth or for the ability to cope better with other stress factors.

Genetic diversity is important because it helps maintain the health of a population, by including alleles that may be valuable in resisting diseases, pests and other stresses. Maintaining diversity gives the population a buffer against change, providing the flexibility to adapt. If the environment changes, a population that has a higher variability of alleles will be better able to evolve to adapt to the new environment. In extreme situations (e.g. drought, disease epidemics) diversity could even mean the survival of the population.

Why prevent the loss of genetic diversity?

The loss of genetic diversity is difficult to see or measure. In contrast, the reduction and extinction of populations is far easier to see. Extinction is not only the loss of whole species, but is also preceded by a loss of genetic diversity within the species.

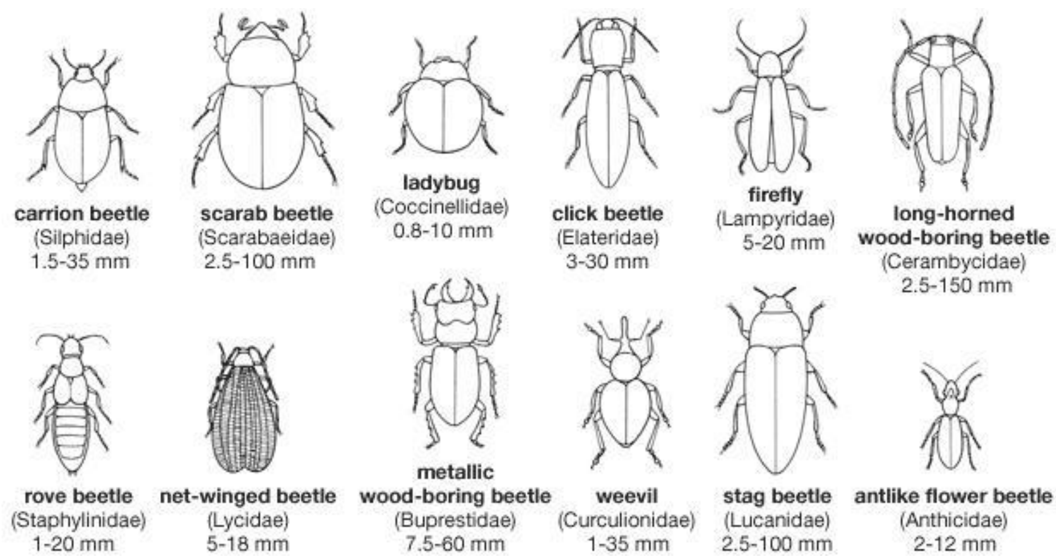
This loss reduces the species ability to perform its inherent role in the whole ecosystem.

Furthermore, the loss of genetic diversity within a species can result in the loss of useful and desirable traits (e.g. resistance to parasites). Reduced diversity may eliminate options to use untapped resources for food production, industry and medicine.

Order Coleoptera

Beetles and weevils (Coleoptera) are one of the most successful groups of insect on the planet, over 400,000 species described worldwide in 166 families. It is the largest order of insects, representing about 40 percent of the known insect species. All super family names end in 'dea' and families end in 'dae', e.g. Curculionoidea and Curculionidae.

Some species are solitary; others occur in aggregations. Coleoptera vary greatly in size, from a fraction of a millimeter to more than 200 mm (almost 8 inches) in length (e.g., rhinoceros beetle). Diversity of structure among adult beetles is as great as range of size.



Beetles larvae are usually called grubs. Pupae of beetles usually have a form similar to that of the adult except that the elytra are represented by pads on the exterior of the body; the colour, generally white, is sometimes pale brown or patterned. Beetles are Holometabola with complete development (egg, larva, pupa, adult).

Immatures:

- Head well-developed with ocelli and chewing mouthparts.
- Three pairs of thoracic legs; no abdominal prolegs
- Body form:
  - Campodeiform -- Slender, active crawlers
  - Scarabaeiform -- Grub-like, fleshy, c-shaped body
  - Elateriform -- Wireworms; elongate, cylindrical, with a hard exoskeleton and tiny legs

Adults:

- Chewing mouthparts (sometimes located at the tip of a beak or snout)
- Front wings (elytra) are hard and serve as covers for the hind wings; meet in a line down the middle of the back
- Hind wings large, membranous, folded beneath the elytra
- Tarsi 2- to 5-segmented

Campodeiform Elateriform Scarabaeiform

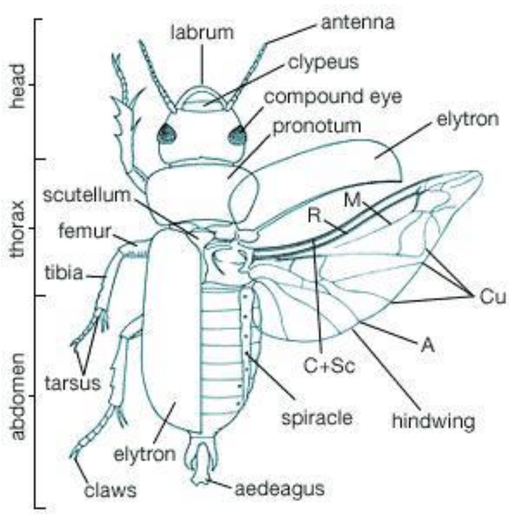
Coleoptera is divided into four suborders

- Adephaga
- Archostemata
- Myxophaga
- Polyphaga

But only two of these, Aedephaga and Polyphaga, include common families:
Aedephaga - the first abdominal sternum is divided by the hind coxae
Polyphaga - the first abdominal sternum is undivided

Economic Importance

Many beetles are regarded as major pests of agricultural plants and stored products. They attack all parts of living plants as well as processed fibers, grains, and wood products. Scavengers and wood boring beetles are useful as decomposers and recyclers of organic nutrients. Predatory species, such as lady beetles, are important biological control agents of aphids and scale insects. Some beetles are vector of diseases in plants like bark beetles.



Family Carabidae

They are found worldwide, with over 40,000, 200 genera and 23 subfamilies, 110 tribes. Their species are distinct from one another in their size, shape, and color. They are night feeders and the majority of them are skilled predaceous. At night, they can be found under stones, logs, or piles of debris.

Many species, (both larvae and adults) feed on slugs and snails, other insects, carrion and some species attack aphids. They can be found all year round and many over winter as adults therefore they are often easy to find.

Key family features:

- Large trochanters
- Forward protruding head and mouthparts
- Tarsi are 5,5,5, mostly simple
- Antennae are filiform

Examples: ground beetles, tiger beetles, bombardier beetles, ant nest beetles



Family Coccinellidae

They are found worldwide, with over 5,000 species, 360 genera and 7 subfamilies. Coccinellids are typically predators on Hemiptera, such as aphids and scale insects, though members of the subfamily Epilachninae are herbivores, and can be very destructive agricultural pests (e.g., the Mexican bean beetle). While they are often used as biological control agents, introduced species of ladybugs (such as *Coccinella septempunctata*).

Ladybird beetle adults are oval and brightly colored. They appear to have three tarsal segments, but actually have four. A small bead-like third segment is nested within the second segment. Larvae are flattened and covered with spines. Both the larvae and adults are predaceous on aphids

Key family features:

- Body oval and convex
- Black with red spots or red/orange with black spots
- Tarsi appear 3-3-3, actually 4-4-4

Examples: seven spotted LBB, six spotted LBB, eleven spotted LLB, Zigzag LBB

Family Curculionidae

Weevils are the largest family with more than 50,000 species in 4600 genera and 12 subfamilies worldwide. They are also called snout beetles (snout is also called the rostrum). The majority of weevils feed exclusively on plants. The fleshy, legless larvae of most species feed only on a certain part of a plant i.e., the flower head, seeds, fleshy fruits, stems, or roots. Many larvae feed either on a single plant species or on closely related ones. Adult weevils tend to be less-specialized in their feeding habits.

Key family features:

Most adults have the characteristic snout with jaws at the end.

Elbowed, clubbed antennae arising near the middle of the proboscis, usually with 11 segments.

Examples: cotton boll weevil, grain weevil, rice weevil

Order Hymenoptera

Overall 150,000 species have been described in 2 sub-orders, 132 families and 8423 genera. Sub-order Apocrita (have narrow junction between thorax and abdomen) includes bees, ants and wasps while sub-order Symphyta (have broad junction between thorax and abdomen) includes sawflies. Many groups are predatory, feeding their young ones with meat, usually of other insects. Some groups feed their young ones with pollen and adults take nectar.

Life cycle has egg, larva, pupa, and adult (holometabola). Some larvae (such as sawflies) are caterpillar-like, most are grub-like, lacking legs. Males usually develop from unfertilized eggs in this order, Young one are fed by the adults, however in many groups the larvae are parasitoids (predatory parasites) of other insects. Larvae of sawflies feed on plants.

Economic importance:

They provide important ecosystem services like biological pest control (predators and parasitoids), pollination (bees), honey, royal jelly etc. (honeybees), environmental cleaning (ants) etc.

Key features of order:

- Typically two pairs of wings, with forewings usually larger than hindwing.
- Wings have few cross-veins, these are angled to form closed cells.
- Triangular stigma in front wings.
- Antennae typically with 10 or more segments
- Females have prominent ovipositor, modified in some groups to be a "stinger", used to paralyze prey and for defense.

- Chewing mouthparts, but some groups have a "tongue" used for lapping up fluids, such as nectar.
- Several groups highly social (eusocial), with separate reproductive and worker castes.
- Tarsi usually 5-segmented.
-

Examples: Honeybees, bumble bees, leaf cutter bees, ants, wasps, hornets, saw flies, egg, larval and pupal parasitoids

Family Apidae

There are 5 subfamilies, with 5,750 species in 200 genera worldwide. The sub-families include Apinae (honey bees), Meliponinae (stingless bees), Euglossinae (solitary orchid bees), Bombinae (bumble bees) and Psithyrinae (cuckoo bumble bees). Bees in Apidae are all long tongued bees. These include a large variety of bee species with interesting traits. Not all have scopa. Those without a scopa cannot collect pollen and are cleptoparasitic. Some are solitary. Some are colonial (eusocial with cast system). Some are burrowers. Most collect pollen and nectar. Some do not and yet still produce honey.

Key Characters:

- Body heavily clothed with branched hairs
- First segment of hind tarsi enlarged and flattened; usually bearing a "pollen basket"

Examples: Honeybees, bumble bees, carpenter bees, blue banded bees, cuckoo bees, long horned bees




Honey bee Bumble bee Blue banded bee Carpenter bee

Family Formicidae

There are 14,000 species in 300 genera of 20 subfamilies. A characteristic of most formicids is the possession of a metapleural gland. This gland produces phenylacetic acid, which fights against fungi and bacteria. Two or more generations coexist, with the adult ants caring for the young. Ants are divided into castes, with reproductive queens and kings, and sterile workers and soldiers (all of which are female). Ants thrive in most ecosystems and may form 15–25% of the terrestrial animal biomass. They play role in improving soil health, cleaning of ecosystem, biological control.

Key Characters:

- Elbowed antennae

- Wingless workers; winged swarmers (reproductives)
- Peduncle located between thorax and abdomen -- first (or first and second) abdominal segments separate from rest of abdomen

Examples: Fire ants, army ants, carpenter ant, bullet ant




Worker ant Soldier ant Alate ant Queen

Family Vespidae:

There are 5,000 species in 270 genera. Most species are usually social and one of the better known families whose paper or mud nest constructions are common in many gardens and under the eaves of houses and other buildings. These wasps vary in colour and size with some species growing to 30 millimetres in length. Most of these wasps provide lepidopteran caterpillars as food for their developing young. Caterpillars are partially broken down by the adults before being given to the larvae. Most species in this family will deliver a painful sting if disturbed. These castes include queens, female workers, and drones. Only the workers are able to sting

Key Characters:

- These insects have a distinct 'U-shape' to the posterior margin of the pronotum.
- Wings folded longitudinally at rest; first discoidal cell of FW greater than half the wing length
- Inner margin of eye usually notched
- Pronotum extending back to the tegulae and thus appearing triangular in lateral view and horseshoe-shaped from above

Examples: Hornets, yellow jackets, paper wasps, mud wasps, potter wasps, paper wasps




Mud wasp/potter wasp Hornet Paper wasp Yellow jacket

Order Diptera

Family Syrphidae

There are >6,000 species in 210 genera worldwide. Like most other flies, Hover Flies have very large eyes and short antenna. They have one pair of wings which are usually transparent. Hover Flies can be recognized by their wing vein patterns. M branches do not reach wing margin but run in parallel with wing margin.

Hover Flies are also known as Flower Flies. Some species are called Drone Flies. Hover Flies may sometimes be confused with stinging bees or wasps. Their mimic colors make them look like bees or wasps. Their bodies are slender. They are from small to medium in size. They are major pollinators of some flower plants e.g. mango, onion etc. They are usually seen hovering or resting on flowers. Beside nectar, they feed on honey dew produced by aphids as well.

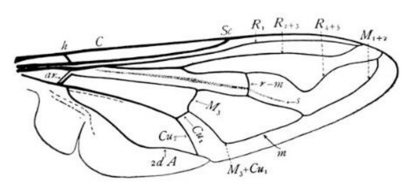
Some species larvae are predators of many soft body insects such as aphids, scale insects, thrips and caterpillars. Some species of Hover Flies lay eggs near the aphid colonies. Their maggot-like larvae are the predators of aphids. Some larvae in this family live in ant or bee nests where they live as scavengers or predators.

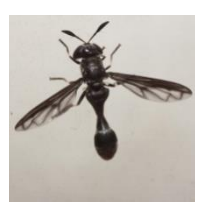
There are three subfamilies of Hoer Flies and they have very different life-histories.

Eristalinae - drone flies
Microdontinae - wasp-mimic hover Flies
Syrphinae - Slender hover Flies

Key Characters:

- Presence of spurious wing vein (S)
- M branches do not reach wing margin but run in parallel with wing margin.





Larva Drone fly wasp mimic Slender hoverflies

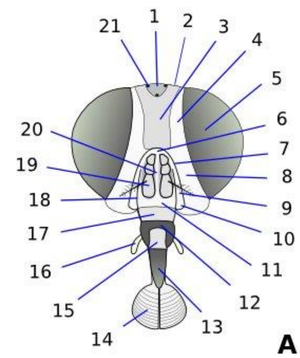
Family Calliphoridae

There are 1,500 species in ~100 genera worldwide. Members are known as blow flies, carrion flies, bluebottles, greenbottles, or cluster flies. Calliphoridae adults are commonly shiny with metallic colouring, often with blue, green, or black thoraces and abdomens.

Adult blow flies are occasional pollinators, being attracted to flowers with strong odors resembling rotting meat. Little doubt remains that these flies use nectar as a source of carbohydrates to fuel flight, but just how and when this happens is unknown. Larvae of most species are scavengers of carrion and dung, and most likely constitute the majority of the maggots found in such material, although they are not uncommonly found in close association with other dipterous larvae from the families Sarcophagidae and Muscidae.

Key characters:

- Antennae are three-segmented and aristate.
- Members of Calliphoridae have branched Rs-2 veins, frontal sutures are present, and calypters are well developed.



/ . Frontal suture

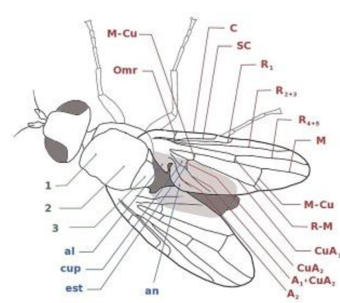
Family Tephritidae

There are 4,700 spp. in almost 500 genera worldwide. The Tephritidae are one of two fly families referred to as fruit flies, the other family being the Drosophilidae. Many species have highly-patterned wings used by males for courtship and may also be defensive.

Larvae feed on fleshy fruits and vegetables of plants in many families. In the subfamily Tephritinae, most species oviposit in flower heads of various plants (primarily, Asteraceae) and have short, stout larva that live in the ovaries. In the other subfamilies of Tephritidae (as well as in some Tephritinae), there are species that mine or form galls in leaves, stems, and roots. Adult fruit flies feed predominantly on liquids such as sap, nectar, honeydew or droppings.

Fruit flies are some of the most economically important species due to the destructive and often secretive feeding nature of their larvae.

Examples are *Bactrocera zonata*, *B. dorsalis*, *B. diversa*. They are pests of Cucurbitaceous plants (melon, gourd, cucumber, pumpkin, etc.), tomato, chilly, brinjal, pepper, papaya, ber, pear, peach, custard apple, jackfruit, apple, guava, mango and several citrus fruits. Some are invasive pests.



Key characters:

These can be recognized by the structure of the subcosta which bends apically forward at almost a right angle and then fades out. In most species the anal cell has an acute distal projection posteriorly.

Family Sarcophagidae

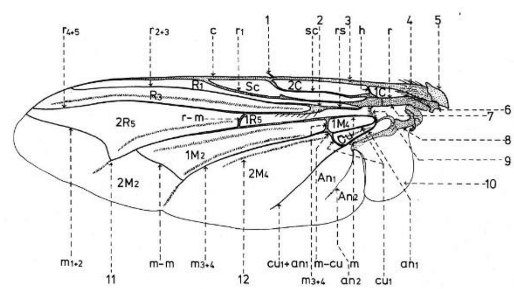
There are 3,100 spp. in >170 genera worldwide. Flies in family Sarcophagidae are from medium to large in size. They are also known as flesh flies. The species in this family look very similar. Larvae develop in carrion or dung. The adult flies are usually black in color with three grey longitudinal stripes on thorax. Their head is relatively small with bright red eyes.

Some females are viviparous, producing live maggots directly onto their food source. They are either breed in rotting vegetation, carrion, decomposing organic matter or parasites of other insects. The adults mostly feed on fluids from animal bodies, nectar, sweet foods, fluids from animal waste and other organic substances.

Forensic entomology could provide valuable data for the minimum postmortem interval estimation and other relevant information, such as causes and circumstances of death. Some representatives of flesh flies are one of the dominant necrophagous insects during early stages of decomposition.

Key characters:

- Similar to blowflies, but generally blackish with gray thoracic stripes (never metallic); 3 black racing stripes on a gray background.
- The Flesh Fly males are dichoptic or with semi-narrow frons, never truly holoptic; females are dichoptic.
- Vein M1 +2 (anterior transverse vein, medial vein 1+2) is always present, and the cubitulus is strongly bent at right angles or acute; vein Rs is dibranched.
- The eyes are smooth and very rarely hairy.
- The arista is plumose in its basal half, or rarely pubescent or glabrous.



Order Lepidoptera

Worldwide there are probably about 300,000 species of Lepidoptera, of which only an estimated 14,500 or about 5% are butterflies.

Common practice is to divide the Lepidoptera into two (or three) groups, though this is not, strictly speaking, a taxonomic division. (Butterflies and skippers are a monophyletic group within the Lepidoptera [Papilionoidea], but "moths" are a paraphyletic group.)

Moths usually have feathery antennae and most are active at night. They generally rest with their wings open, either flat or "tented" over the body. Rarely, the wings are held together vertically above the body as with butterflies.

Monophyletic group: is a term used to describe a group of organisms that are classified in the same taxon and share a most common recent ancestor.

Paraphyletic group: consists of the group's most common ancestor and all descendants of that ancestor excluding a few—typically only one or two—monophyletic subgroups.

Economic importance:

- Many hundreds of Lepidoptera injure plants useful to humans, including some of the most important sources of food, fabrics, fodder, and timber.
- The great majority of the injurious species are moths, and the detrimental life stage is always the larva. However, unlike members of other insect orders, lepidopterans do not act as carriers of plant diseases, nor are any of them parasites of or injurious to humans. However, some species feed on open wounds or bodily secretions of wild or domestic animals.
- The list of valuable plants subject to damage by lepidopterans is a long one, including many grains, sugar beets and sugarcane, cotton, tobacco, some root crops and leaf crops, many fruits, and timber and shade trees.
- The damage may involve the leaves, stems, roots, or fruit. Woolens, furs, silk, and even feathers are eaten by fungus moths (see tineid moths) of several genera (clothes moths).
- The greater wax moth (*Galleria mellonella*) causes considerable damage in beehives.
- A few Lepidoptera are directly beneficial to humans. Nearly all silk is obtained from the domesticated silkworm (*Bombyx mori*), which is originally from China. Other silks such as shantung and tussah are the products of various Asiatic giant silkworm moths (family Saturniidae).
- The larvae and sometimes the adults of a few species are used for food. The larvae of one skipper (*Rhopalocampta libeon*, or *Caeliades libeon*) are collected in large quantities in the Congo, and the 10-cm (4-inch) caterpillars of giant skippers (family Megathymidae), known in Mexico as gusanos de magüey, are both consumed domestically and canned and exported for consumption as hors d'oeuvres.
- The South American cactus moth (*Cactoblastis cactorum*) has been highly beneficial in weedcontrol, clearing more than 150 million ha (60 million acres) in Australiaof

alien prickly pear cactus. Doubtless, humans also benefit from much unrecognized weed eating by caterpillars and flower pollination by adults.

- Many lepidopterans are valuable in biological research, including work in ecology, biogeography, systematics, genetics, and physiology. Much of the present knowledge of endocrine controls of insect development has come from studies of the silkworm moth and its relatives.

Key characters:

- They can be readily identified from other insects by the scales on their wings
- Adults have four membranous wings (rarely wingless)
- hindwings are usually smaller than forewings
- Adult mouthparts adapted for sucking, the proboscis is usually in the form of a coiled tube (adults of some species lack mouthparts and do not feed as adults)

Family Sphingidae

Hawk moths have a thick body that is covered in hairs and is pointed at the posterior and the anterior end. The antenna is thickest at its midpoint and may be bipectinate in nature. The hind wings are much shorter than the forewings. The forewings are elongate and rather pointed with a posterior angle that is at least 120 degrees. Some hawk moths are commonly known as hummingbird moths because they hover in front of flowers as they feed on nectar. There are 1,450 species.

Importance:

The caterpillars are pests of tomato, peppers, eggplant, tobacco, grapes, gardenia, sunflower, lantana and potatoes

Key characters:

1. Body thick, hairy, and spindle-shaped
2. Antennae thickest near midpoint, sometimes bipectinate
3. Long, narrow forewings with a posterior angle greater than 120o
4. Hind wings much shorter than forewings

Family Noctuidae

The Noctuids are members of the Superfamily Noctuoidea. Worldwide in distribution, this family is the largest in the Lepidoptera and has approximately 20,000 species. They have filiform antennae, an unbranched subcosta, and three medio-cubital veins that reach the distal margin of the hind wing. In most species the pattern of the front wings is much more complex than that of the hind wings. Most members of this family are nocturnal. They have tympanal organs (ears) located at the base of the hind wings to help detect and avoid bats.

Importance:

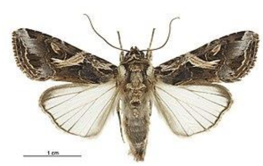
The larvae of other species are voracious feeders that can defoliate entire crop plots within a short period.

Key characters:

1. Antennae filiform
2. Front wings mottled brown in color
3. Hind wings differ from front wings in color and/or pattern
4. Unbranched subcosta (Sc) arises near base of hind wing
5. Three medio-cubital veins reach distal margin of hind wing

Examples: *Spodoptera littoralis*, *Spodoptera exigua*, *Helicoverpa armigera, Earias insulana, Earias vittella*






Order Orthoptera

Over 20,000 species worldwide. Two major taxonomic divisions (sub-orders):
Caelifera - Grasshoppers and allies
Ensifera - Crickets, katydids and allies
Members of both suborders are generally phytophagous but many species are omnivores. Females of most species lay clutches of eggs, either in the ground or in vegetation. Some of the best examples of cryptic coloration are seen in this group, involving mimicry of leaves and other vegetation or other resemblance to the background. Grasshoppers, katydids and crickets are well known for their abilities to jump and particularly for singing by males (females are typically silent).

Key characters:

- Hind legs long, modified for jumping
- Forewings (tegmina) hardened, leathery, spread in flight, covering membranous hindwings at rest
- Cerci (appendages at tip of abdomen) unsegmented
- Pronotum usually with large descending lobes on sides
- Hind coxae small and well-separated
- Hind tibiae with two dorsal rows of teeth

Family Acrididae

Common Name: Grasshoppers

Description: Otherwise known as ‘short horned’ grasshoppers, Acrididae are abundant in meadows where they feed on plants. Characteristic of the Orthoptera order, the males in this family will sing by rubbing a hind femur against the lower edge of their wing. These creatures are easily recognizable by short antennae and a tympanum on each side of the first abdominal segment.

Key Characters:

1. Tarsi three-segmented — often with a conspicuous pad (arolium) between the claws
2. Tympanum on first abdominal segment
3. Antennae shorter than body
4. Pronotum covers the thorax

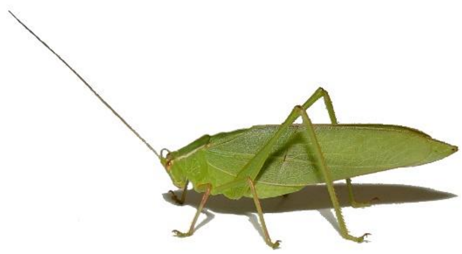
Family Tettigoniidae

Common Name: Katydids

Description: "Long-horned" grasshoppers are characterized by far-reaching antennae. They are usually green or brown in color and tend to be well-camouflaged in the leaves of plants. Similar to other Orthoptera, they feed on plants, but may also prey on other insects. Specific to this family is the four segmented tarsi and the tympanum located on the tibia. These may be evolutionary adaptations used to meet their dietary needs.

Key Characters:

1. Four-segmented tarsi
2. Tympanum located on front tibia
3. Thread-like antennae as long or longer than body



Family Gryllidae

Common Name: House, Field, and Tree Crickets

Description: 'True crickets' are found in a variety of environments, including fields, houses, and trees. With the slight color variation, they are somewhat camouflaged. In contrast to the singing grasshoppers, these crickets are the only family able to hold a constant pitch. By rubbing their wings together, they can create a musical tone that is used to attract or warn another cricket. With a three-segmented tarsi and long antennae, they are a distinctive family of Orthoptera.

Key Characters:

1. Three-segmented tarsi
2. Tympanum located on front tibia
3. Thread-like antennae as long or longer than body

Sample: Sample is a specimen, part or proportion representative of something larger to show nature and quality of the whole.

Sampling Unit: An "entity" is the insect population that is measured, and a "sampling unit" is group of entities that form a single composite or average measure e.g. (individuals/plant)

Sample Size: It is number of sampling units evaluated at each sample site. e.g. the number of plants selected per field.

Sample Point/Site: It is spatial unit for which disease is measured /calculated, e.g., a field within a geographical area. The selection of number of sample points/sites is often determined by the sampling fraction stipulated before actual survey.

Sampling Designs and Procedures: The main purpose of sampling design is to increase the accuracy, precision, scope and speed of a sample for minimum cost, and reduce variation in results. A common technique to assess crop diseases is to sample plants at uniform or random intervals along a line of a predetermined design in a field. The general sampling designs comprises of diagonal, a big V, W, X, Z pattern or a stratified random sampling design.

General Instructions on collecting and handling Samples

Sample collection

- The training and experience of the persons collecting samples is vital. Ensure that everyone involved in the collection process is trained and competent to collect, store and handle samples.
- Complete a sample submission form at the time of sampling (include details such as host, plant parts affected, GPS coordinates, sampling date, collector, property owner, contact details and any other relevant information).
- Choose clean and sunny day with (above 17 °C and 50% sunshine) for the observations and avoid rainy and foggy days and days with strong gusts of wind.
- The collection point must be recorded in the field with its GPS coordinates.
- Disinfect implements (e.g. with 80% v/v ethanol or 0.5% v/v available chlorine solution, as appropriate) prior to and after each sampling.
- If possible, sample the perceived area of high damage within a field/orchard and on the individual plant.
- Damaged parts of plants like leaves, stems or fruits should be wrapped in dry paper towel or newspaper and seal in an air tight plastic bag.
- Keep the collection of specific crop and specific location separate from other crops and locations by putting it in separate plastic pouches. Label each plastic pouch properly to avoid mixing and confusion. Put the entire plastic pouches in portable cool boxes.
- Large and hard bodied insects (e.g. beetles) die slowly and may damage other insects placed in the same killing bottle, so more than one killing bottles are needed.
- Use glass killing jars containing cyanide to kill insects or use mini killing tube containing a cotton swab soaked in ethyl acetate.
- Place the insect samples in a plastic vials, a crush-proof box, or similar containing material to prevent damage.

Specimen preparation

- The training and experience of the persons handling specimens in laboratory is vital. Ensure that persons involved in the handling process are trained and competent to prepare, morphologically sort and store the specimens.
- Before preserving hard bodied insects, cleaning is important. Wash the specimens in a dish first with soapy water, then ethanol and then carbolic acid. Use fine soft forceps and camel hair brush for this purpose.
- Large hard bodied insects having hard exoskeleton should be mounted directly with the help of insect pins (in center of thorax) after removal from storage vials or portable cool boxes on the same day. Smaller hard bodied insects on the other hand, should be doubled mounted either on minute or card point.
- Those insects that have been dried out in the storage vials, it is necessary to 'relax' them in relaxing jar. Prepare a relaxing jar by adding some moist sand and coving it with a blotting paper. Place dry insects on it and keep for few days until specimen is 'relaxed' for pinning.
- While mounting, use stretching board for spreading wings and legs of insects for better display of taxonomic characters.
- Many types of insects, including aphids, springtails, thrips, mayflies or silverfish, immature of insects (larvae of beetles, wasps, flies, butterflies, moths etc.) are soft-bodied and cannot be pinned successfully. Therefore preserve them in glass vials with ethyl alcohol, usually of about 70% concentration (70% absolute ethanol and 30% water).
- Labeling of sample vials must be clear and legible using an alcohol-proof and water-proof marker or led pencils. Computer printed labels may also serve the purpose. Place the labels beneath the pinned insects and aligned parallel to the insect's body. For labeling vials, always place labels inside the vial. The writing needs to be visible from outside.

Sample posting/dispatch/travel

- Most insects and mites submitted to labs or experts for identification should not be shipped alive. Dry pinned specimens can be transported in wooden or card board boxes fitted with cork or thermocol sheet at the bottom and cross-pinned to ensure that they will not swing around or wiggle loose. Never pin a very large specimen, such as a scarab beetle, along with more delicate material. If the large one comes loose in transit it will reduce the rest of the box to dust in short order.
- Soft bodied insects can be transported in polyethylene screw-topped tubes containing 70% ethanol. Wrap them in tissue paper or cotton and place them in postal boxes.
- The lid of the small box should be secured with rubber bands or tape. The small box should now be placed inside a larger box with at least 10cm clearance all round which is filled with polystyrene chips, crumpled newspaper or other packaging. Do not compress the outer packing too tightly as it will lose its shock absorbing qualities. The box should be wrapped in strong paper, if available, secured with string or parcel tape and addressed on several sides.
- For international parcels, secure the label clearly, and triple-bag using tamper-proof bags, disinfecting between layers, and include the completed sample submission form in the outer bag. Also ensure that all necessary customs forms are completed and that the parcel is clearly labelled with the following information

FRAGILE! CUIDADO! VORSICHT! PRECAUTION!
Dead Insects for Scientific Study
Insectes Desseches pour L'etude Scientifique
Getro. Insekten für Wissenschaftliche Zwek
NO COMMERCIAL VALUE - NO VALOR COMMERCIAL

- Minimize the time between sampling and dispatch to the receiving laboratory, and store in a portable cool-box during this time. More than one label can be placed according to the information collected.

Storing specimens/curation at National Museum

- All collections should be stored in secure, environmentally controlled conditions. To minimize deterioration, keep specimens away from light sources. Store rooms should be kept at a stable relative humidity (RH) level of between 45% and 55%. This may require a humidifier or dehumidifier.
- Temperature levels should be as stable as possible, between 10°C and 22°C.
- Store rooms are never completely immune to pests. Most pests will lay eggs inside specimens and the young stages (larvae) will cause the most damage. Pests can be reduced by regular vacuuming and cleaning of the stores and banning food and drink from the area. Pests can be monitored with insect traps (such as the sticky trap). Quarterly checks of the traps will show the types of pests entering store rooms. Inspect your collections at least twice a year to monitor for any pest activity. March and April (in the UK) through to the hot months are the most likely periods to locate pests, especially if RH is high.
- One of the simplest and safest ways to reduce pests in entomology collections is to seal the specimen drawers tightly. This will prevent most pests from crawling inside. Slightly drier environments (a lower RH) can cause wood to shrink, providing gaps for pests. Older collection cabinets were not made to be air tight and may need additional monitoring. Dry material can be stored in clear polystyrene lidded boxes, nested in acid-free tissue paper. These provide protection from dust and allow the specimen to be seen, reducing the need for handling it.
- Taxidermy specimens should be stored in closed cupboards to prevent dust build-up and reduce the risk of pests. Study skins should be stored in sealed cupboards. Both types of collections should be monitored regularly for pest activity.
- Pests can be treated by one of the following methods: Freezing: place the specimen inside a clear polyester bag, push out excess air and heat seal, or place inside polythene bags and use parcel tape to seal. Place the bag in a normal domestic freezer for at least 14 days at a temperature of -18ºC or for 72 hours if freezing at - 30ºC. Insecticide: 'Constrain' is one of the few permitted chemicals to control insect pests in museum collections. Always follow the instructions. Anoxia: this method starves the pests of oxygen. Small anoxic environments are created using sealed barrier films (such as Marvelseal™ or Escal™ or re-usable aluminium laminate) and placing oxygen scavengers and RH buffers inside before sealing.
- Wearing disposable nitrile gloves will eliminate any transfer of skin oils and perspiration to specimens. Taxidermy specimens before 1980 may have been treated with arsenical soap (sometimes noticeable as a fine white powder). Always handle specimens with gloves, and if cleaning them, always use dust extraction/fume cupboard and wear a dust

mask. Pinned entomology specimens are normally handled using specialised curved and gripping forceps. Old specimens can be very dry and brittle and pins may be corroded; remove specimens from their drawer very slowly and carefully.