INSECTS

Phylum Arthropoda – Subphylum Hexapoda – Class Insecta – Insects

The Earth's most varied organisms, about half of the described species of living things and almost three-quarters of all animals are insects.

The word insect derives from the Latin word *insectum,* meaning "with a notched or divided body," literally "cut into," from the fact that insects' bodies have 3 parts.

The total number of insect orders varies from 29 to 32 depending upon morphological, molecular and/or phylogenetic information.

Homeopathy has representatives – described, listed or available from pharmacies – in 13 insect orders.

Order Blattodea – Cockroaches
Blatta [= Periplaneta] americana – American cockroach. Blattidae.
Blatta orientalis – Oriental cockroach. Blattidae.

Order Coleoptera – Beetles
Adalia bipunctata – Two-spotted ladybird. Coccinellidae.
Cantharis [= Lytta vesicatoria] – Spanish fly. Meloidae.

Cantharis [= Epicauta] strigosa – Strigose blister beetle. Meloidae.
Cetonia aurata – Rose chafer. Scarabaeidae.
Chalcolepidius limbatus – Click beetle. Elateridae.
Coccinella septempunctata – Seven-spot ladybird. Coccinellidae.
Doryphora [= Leptinotarsa] decemlineata – Colorado potato beetle. Chrysomelidae.
Gastrophysa viridula – Green dock leaf beetle. Chrysomelidae.
Geotrupes stercorarius – Dor beetle. Geotrupidae.
Heliocopris antenor – African dung beetle. Scarabaeidae.
Hoplia farinosa – Root beetle. Scarabaeidae.
Lamprohiza splendidula – Firefly. Lampyridae.
Lucanus cervus – Stag beetle. Lucanidae.
Lytta [= Epicauta] vittata – Striped blister beetle. Meloidae.
Meligethes [= Brassicogethes] aeneus – Pollen beetle. Nutidulidae.
Meloe [= Berberomeloe] majalis. Red-striped oil beetle. Meloidae.
Melolontha melolontha – Common cockchafer. Scarabaeidae.
Nicrophorus vespillo – Burying beetle. Silphidae.
Photuris pennsylvanica – Lightning bug. Lampyridae.
Rhynchites cupreus – Plum borer. Attelabidae.
Scarabaeus sacer – Scarab beetle. Scarabaeidae.

Order Diptera – True Flies, Mosquitoes, Gnats, Midges
Anopheles maculipennis – Common malaria mosquito. Culicidae.
Bibio marci – St. Mark's fly. Bibionidae.
Calliphora vicina – Blue bottle fly [larvae]. Calliphoridae.
Culex musca [= Culex pipiens] – Northern house mosquito. Culicidae.
Culex musca, Mosquito – Unspecified mosquito species from Mumbai, India. Culicidae.
Culex pervigilans – Common domestic mosquito. Culicidae.
Culicoides impunctatus – Highland midge. Ceratopogonidae.
Dermatobia hominis – Human botfly [larvae]. Oestridae.
Haematopota pluvialis – Horsefly. Tabanidae.
Lucilia sericata – Green bottle fly [larvae]. Calliphoridae.
Musca domestica – Housefly. Muscidae.
Oestrus cameli [= Cephalopina titillator] – Camel nasal botfly. Oestridae.
Simulium makara – Black fly Finland. Simuliidae.
Simulium posticatum – Blandford fly. Simuliidae.
Tabanus sp. – Horsefly. Tabanidae.
Tipula paludosa – Crane fly. Tipulidae.

Order Ephemeroptera – Mayflies
Ephemera vulgata – Drake mackerel mayfly. Ephemeridae.

Order Hemiptera – True Bugs, Cicadas, Aphids & Allies
Acanthocephala terminalis – Leaf-footed bug. Coreidae.

Aphis chenopodii glauci [= Hayhurstia atriplicis] – Chenopodium aphid. Aphididae.
Cimex lectularius – Bedbug. Cimicidae.
Coccus cacti [= Dactylopius coccus] – Cochineal. Dactylopiidae.
Cryptotympana facialis – Japanese cicada. Cicadidae.
Gerris lacustris – Common water-strider. Gerridae.
Melampsalta [= Cicadetta] montana – New Forest cicada. Cicadidae.
Palomena prasina – Common green shield bug. Pentatomidae.
Periostracum cicadae – cast-off skin of Cryptotympana atrata. Chinese cicada. Cicadidae.
Philaenus spumarius – Meadow spittlebug. Aphrophoridae.
Reduvius personatus. Masked hunter. Reduviidae.
Triatoma infestans – Kissing bug. Reduviidae.
Triatoma protracta – Western conenose. Reduviidae.

Order Hymenoptera – Ants, Bees & Wasps
Acromyrmex octospinosus – Leaf-cutter ant. Formicidae.
Apis mellifera – Western honeybee. Apidae.
Apis regina – Western honeybee queen bee. Apidae.
Bombus pratorum – Early bumblebee. Apidae.
Dinoponera gigantea – Giant Amazonian ant. Formicidae.
Formica rufa – Southern wood ant. Formicidae.
Formica subsericea – Field ant. Formicidae.
Formicum acidum – Formic acid.
Lasius niger – Black garden ant. Formicidae.
Paraponera clavata – Bullet ant. Formicidae.
Polistes fuscatus [synonym: P. pallipes] – Common paper wasp. Vespidae.
Solenopsis invicta – Red imported fire ant. Formicidae.
Vespa [= Vespula] vulgaris – Common wasp. Vespidae.
Vespa crabro – European hornet. Vespidae.
Vespa mandarinia – Asian giant hornet. Vespidae.
Vespa orientalis – Oriental hornet. Vespidae.
Vespula germanica – German wasp. Vespidae.
Vespula [= Dolichovespula] maculata – Bald-faced hornet. Vespidae.
Vespula maculifrons – Eastern yellowjacket. Vespidae.
Vespula squamosa – Southern yellowjacket. Vespidae.

Order Isoptera – Termites
Coptotermes formosanus – Formosan subterranean termite. Rhinotermitidae.
Mastotermes darwiniensis – Giant northern termite. Mastotermitidae.
Reticulitermes flavipes – Eastern subterranean termite. Rhinotermitidae.

Order Lepidoptera – Butterflies & Moths
Acherontia atropos – Death's head hawkmoth. Sphingidae.
Anthocharis cardamines – Orange tip butterfly. Pieridae.
Apeira syringaria – Lilac beauty. Geometridae.

Bombyx [= Euproctis] chrysorrhoea – Brown tailed moth. Lymantriidae.
Bombyx mori – Silkworm. Bombycidae.
Bombyx [= Thaumetopoea] processionea – Oak processionary. Thaumetopoeidae.
Danaus plexippus – Monarch. Nymphalidae.
Euphydryas aurinia – Marsh fritillary. Nymphalidae.
Gonepteryx rhamni – Brimstone butterfly. Pieridae.
Graphium agamemnon – Tailed jay. Papilionidae.
Graphium sarpedon choredon – Common bluebottle. Papilionidae.
Inachis [= Aglais] io – Peacock butterfly. Nymphalidae.
Isia [= Pyrrharctia] isabella – Isabella tiger moth. Erebidae.
Limenitis [= Adelpha] bredowii californica – California sister. Nymphalidae.
Macrothylacia rubi – Fox moth. Lasiocampidae.
Malacosoma disstria – Forest tent caterpillar moth. Lasiocampidae.
Megalopyge opercularis – Southern flannel moth. Megalopygidae.
Morpho menelaus occidentalis – Menelaus blue morpho. Nymphalidae.
Morpho peleides – Blue morpho. Nymphalidae.
Noctua pronuba – Large yellow underwing. Noctuidae.
Papilio lowi – Asian swallowtail. Papilionidae.
Papilio machaon – Swallowtail. Papilionidae.
Papilio paris – Paris peacock. Papilionidae.
Phalera bucephala – Buff tip. Notodontidae.
Pieris brassicae – Large cabbage white. Pieridae.
Pieris rapae – Small white. Pieridae.
Polyommatus icarus – Common blue. Lycaenidae.
Saturnia pavonia – Emperor moth [cocoon]. Saturniidae.
Vanessa atalanta – Red admiral. Nymphalidae.
Vanessa [= Aglais] urticae – Tortoise-shell butterfly. Nymphalidae.
Yponomeuta rorrella – Willow ermine moth. Yponomeutidae.

Order Mantodea – Mantids
Mantis religiosa – Praying mantis. Mantidae.

Order Mecoptera – Scorpionflies
Panorpa communis – Common scorpionfly. Panorpidae.
Panorpa lugubris – Dark scorpionfly. Panorpidae.

Order Odonata – Dragonflies & Damselflies
Anax imperator – Emperor dragonfly. Aeshnidae.
Calopteryx splendens – Banded demoiselle. Calopterygidae.
Enallagma carunculatum – Tule bluet. Coenagrionidae.
Libellula quadrimaculata – Four-spotted skimmer. Libellulidae.
Pyrrhosoma nymphula – Large red damselfly. Coenagrionidae.

Order Orthoptera – Grasshoppers, Locusts, Crickets
Gryllus assimilis – Jamaican field cricket. Gryllidae.
Gryllus campestris – Field cricket. Gryllidae.

Locusta migratoria – Migratory locust. Acrididae.
Schistocerca americana – American grasshopper. Acrididae.
Schistocerca gregaria – Desert locust. Acrididae.
Tettigonia viridissima – Great green bush-cricket. Tettigoniidae.

Order Phthiraptera – Lice
Pediculus capitis – Head louse. Pediculidae.
Pediculus humanus – Body louse. Pediculidae.

Order Siphonaptera – Fleas
Archaeopsylla erinacei – Hedgehog flea. Pulicidae.
Ctenocephalides canis [Pulex canis] – Dog flea. Pulicidae.
Ctenocephalides felis – Cat flea [feline flea]. Pulicidae.
Pulex irritans – Human flea. Pulicidae.

ESSENTIALS & PECULIARS of INSECTS

Factors in the Success of Insects

- Highly adaptable exoskeleton.
- Colonisation of the terrestrial environment.
- Small body size.
- Can do with little; require only limited resources.
- Short life cycles and high reproductive rates.
- Highly efficient flight, allowing insects to *escape* unfavourable habitats and enemies, to *colonise* new habitats, sometimes at great distances, and to find mates, food, and places to lay eggs. Except for the Coleoptera, the many species in the large Endopterygota superorder [winged insects] are strongly dependent on flight for most of the requisites of life.
- Metamorphosis.
- Key roles in the proper functioning of all ecosystems as food for other creatures, pollinators and recyclers of nutrients. [see Importance of Insects]

Abundance

Inhabiting virtually all land surfaces of the globe, insects *tend to dominate* the small fauna wherever they occur, being rivaled only by another group of arthropods, the mites, in some habitats.

Insects are found in Antarctica, the Arctic, at mountain elevations of 6000 m [19,685 ft], in deep caves, hot springs, salt lakes, pools of petroleum, freshwater, marine intertidal zones, and on the surface of the open ocean. They are only missing entirely in the deeper waters of the oceans.

The greatest concentration of insect species lies in tropical areas of the globe. One hectare of Amazonian Forest contains more than 100,000 species of arthropods, of which roughly 80–85% are insects.

Four orders account for more than 80% of all described species of living insects. The largest known order of insects is Coleoptera [beetles], some 390,000 species of beetle have been described to date. The next largest is the Diptera [true flies], followed by the Lepidoptera [butterflies and moths] and then the Hymenoptera [ants, bees and wasps].

Small Body Size

In body size, most insects are 1 to 10 mm in length. Measuring 0.2 mm in body length, some tiny insects are smaller than some protozoa or large one-celled, ciliate animals. At the other extreme, some giant insects are larger than the smallest mammals. Examples are large moths measuring from 24 to 28 cm [9.5 to 11 in] from wingtip to wingtip, scarab beetles up to 16 cm [6.3 in] in body length, and an Australian stick insect with a body length of up to 25 cm [9.8 in].

BODY PLAN

Alimentary Canal

All insects have a complete digestive system, meaning that food processing occurs within a muscular, tube-like enclosure, the alimentary canal, running lengthwise through the body from mouth to anus. Ingested food usually travels in only one direction. In most insects, the alimentary canal is subdivided into 3 functional regions: foregut [stomodaeum], midgut [mesenteron], and hindgut [proctodaeum].

In addition to the alimentary canal, insects also have paired salivary glands and salivary reservoirs. These structures usually reside in the thorax [adjacent to the foregut]. Movements of the mouthparts help mix saliva with food in the buccal cavity for the initial breakdown of food particles. The midgut is where most digestion takes places, through enzymatic action. In the hindgut of solid feeders undigested food particles join uric acid to form faecal pellets, which are eliminated through the anus.

In sap feeders [liquid feeders] the faeces is liquid like. The liquid faeces of homopteran bugs [aphids, mealy bugs, scale insects and psyllids] with soluble sugars and amino acids is known as honeydew, which attracts ants for feeding. [ncsu.edu]

Chewers & Suckers

There are basically 2 kinds of insect mouths. There are chewers and suckers. Some chewers may have a difficult time trying to draw water from a pond, whereas getting their water from chewing a leaf is simple. Chewing insects bite and chew plant parts creating holes and tunnels in leaves, stems, twigs and fruits. Examples of chewing insects are armyworms, cabbageworms, Colorado potato beetles, grasshoppers, Japanese beetles, caterpillars, and fall webworms.

Suckers have a tube-like mouthpart called a proboscis that allows them to get liquid by sucking or lapping, whether from the nectar of flowers or from a soda can. Piercing-sucking mouthparts include one or more appendages that are sharp at the apex and suited for piercing the surface of plant or animal bodies. Saliva is usually injected while feeding. Insects that attack vertebrates often have anticoagulants in the saliva to aid the flow of blood.

Bloodsucking insects can torment humans and animals and can transmit disease. They are all parasites of humans or other host animals and are abundant at certain times of the year. Bloodsucking insects can be grouped as mosquitoes, flies [stable flies, horse flies, deer flies, sand flies, black flies], fleas, lice, and true bugs.

Plant sap-sucking insects include aphids, leafhoppers, scale insects, thrips, and whiteflies. Withdrawal of the sap results in minute white, brown or red spotting on leaves, fruits, or twigs. It may also cause curling leaves, deformed fruit, or general wilting, browning and dying of the entire plant.

Non-piercing sucking insects have mouthparts designed for taking up water or nutrients dissolved in water, such as nectar of flowers or the honeydew [plant sap] excreted by aphids and leafhoppers. These include Lepidoptera [butterflies, moths], Hymenoptera [bees, wasps, etc.], and Diptera [non-bloodsucking flies]. [Daly, 1998]

Circulation & Blood

Unlike the closed circulatory system found in vertebrates, insects have an open system lacking arteries and veins. The haemolymph thus flows freely throughout their bodies, making direct contact with all internal tissues and organs, transporting nutrients and metabolic wastes.

In addition, the system plays several critical roles in defence: it seals off wounds through a clotting reaction, it encapsulates and destroys internal parasites or other invaders, and in some species, it produces [or sequesters] distasteful compounds that provide a degree of protection against predators.

Haemolymph is mostly water, but it also contains ions, carbohydrates, lipids, glycerol, amino acids, hormones, pigments, and only about 10% haemocytes [blood cells].

Haemolymph is usually green or yellow in colour. The insect circulation system does not carry oxygen, so the blood does not contain red blood cells [with the exception of a few aquatic midges].

Gas exchange in insects occurs via the tracheal system, which supplies all internal organs with tracheole tubules from spiracular openings in the body wall of terrestrial insects or from gill structures in aquatic insects.

Insects do not have a long-term immune recognition system, and do not acquire immunity.

Muscles

All muscles of insects are striated. In contrast, vertebrates and many other invertebrates have both striated and smooth muscles. The muscles of insects are inside the skeleton, while those of vertebrates are outside. Due to the tubular construction, which resists bending, and the general absence of calcium salts, the insect skeleton is relatively lighter and stronger than the vertebrate skeleton.

Extraordinary Extensibility & Elasticity

Elastomeric polypeptides are very interesting biopolymers and are characterized by rubber-like elasticity, large extensibility before rupture, reversible deformation without loss of energy, and high resilience upon stretching. Two important elastomeric biopolymers are elastin and resilin.

Elastin is a key extracellular matrix protein that provides structural integrity, resilience and elasticity to tissues and organs. Elastin is roughly 1000 times more flexible than collagens. It exists as fibres in the extracellular spaces of many connective tissues. Elastin derives its name from its ability to act as an elastic band, that is to stretch and recoil with transient force.

It is located throughout many tissues and organs of higher vertebrates and plays an important functional role in maintaining pressures associated with liquid and air flow in the cardiovascular and pulmonary systems. The long-term stability of the elastin fibres makes it a desirable protein for dynamic organ tissue engineering.

The pliable protein resilin is found in many insects. Possessing extraordinary extensibility and elasticity, resilin provides extension and retraction in specialized cuticle region where this is needed millions of times over the lifetime of the insect.

Its role as an elastic spring in insect organs provides clear illustration of its characteristic fatigue resistance and resilience. Resilin also serves an important role in the sound production cicadas and pyralid moths, as well as in the flight systems of locusts, dragonflies, damselflies, beetles and other flying insects.

In flying insects, resilin forms a hinge where the wings attach to the body. Resilin absorbs compression and tension created during each wing stroke, and the stored energy is transferred through an elastic recoil-like effect to assist in the initiation of each successive stroke.

Its presence in the ambulatory systems of cockroaches and houseflies provides elasticity to the joints and facilitates rapid movement. The most notable application of resilin-based rubber-like elasticity in the locomotion of insects is seen in the jumping mechanism of fleas, grasshoppers and other leaping insects.

Aside from rubber-like elasticity, resilin also demonstrates a remarkable capacity for stretching. Capable of being stretched to over 300% of its original length before breaking, the extensibility of resilin can be seen in the ability of some insects to swell their abdomens to many times the original size.

Resilin occurs in the cuticle of physogastric insects, such as the queens of termites, bees and ants, which are capable of increasing the size of the abdomen up to 50 times in order to hold enlarged ovaries.

The outstanding mechanical properties of natural resilin have motivated recent research in the engineering of resilin-like polypeptide-based biomaterials, with a wide range of applications including use as bio-rubbers, nanosprings, elements in biosensors, and tissue engineering scaffolds.

See also below, Biomedical Applications of Resilin.

Nervous System

The easiest way to understand an insect's nervous system is that an insect has many different ganglia or sub-brains in different parts of its body, which feed into and can be controlled by a slightly larger central brain but can actually also operate separately. Even if the central brain of an insect stops working, its legs still have their own sub-brains, and can keep walking.

In comparison to vertebrates, an insect's nervous system is far more decentralized. Most overt behaviour [e.g. feeding, locomotion, mating, etc.] is integrated and controlled by segmental ganglia instead of the brain. Headless insects may survive for days or weeks [until it dies of starvation or dehydration] as long as the neck is sealed to prevent loss of blood.

Like most other arthropods, insects have a relatively simple central nervous system with a dorsal brain [situated above the mouth] linked to a ventral nerve cord [beginning behind the mouth] that consists of paired segmental ganglia running along the ventral midline of the thorax and abdomen.

An insect's brain is a complex of 6 fused ganglia [3 pairs] located dorsally within the head capsule. Each part of the brain controls [innervates] a limited spectrum of activities in the insect's body:

The first pair of ganglia – the protocerebrum – is largely associated with vision; they innervate the compound eyes and ocelli. The second pair – the deutocerebrum – processes sensory information collected by the antennae, whereas the third pair – the tritocerebrum – innervates the labrum [main feeding tube] and integrates sensory inputs from proto- and deutocerebrums.

In the thorax, 3 pairs of thoracic ganglia [sometimes fused] control locomotion by innervating the legs and wings.

Abdominal ganglia control movements of abdominal muscles. A pair of terminal abdominal ganglia [usually fused to form a large caudal ganglion] innervate the anus, internal and external genitalia, and sensory receptors [such as cerci] located on the insect's back end. [ncsu.edu]

Oxygen

The insect tracheal system delivers oxygen directly to respiring cells via diffusion combined [when the insect is active] with convective ventilation. The tracheal system delivers oxygen efficiently even at ambient oxygen levels below 10%.

Sensory Perception

Tactile, touch

Tactile hairs, concentrated on the antennae, palps, legs, and tarsi, cover the entire body surface. The 4 types of mechanoreceptors that insects possess are all 4 designed to transmit nerve impulses to the nervous system that are initiated by movements of parts of the insect's body in response to mechanical stress, touch, wind, or vibrations in air, water, or solid substrate. For example, hairs in the cerci [projections on the end of the abdomen] of cockroaches, respond to low-frequency sound waves as well as to wind currents [puffs of wind].

Sound
Exceedingly sensitive organs called sensilla are concentrated in organs of hearing. These can be found on the bushy antennae of the male mosquito or tympanal organs in the front legs of crickets or in abdominal pits of grasshoppers and many moths. In moths these sensitive organs can perceive the high-pitched sounds emitted by bats as they hunt by echolocation.

Insects complement organs of sound reception with sound-producing organs, which usually are [as in crickets] wing membranes that vibrate in response to movement of a stiff rod across a row of stout teeth. Sometimes [as in cicadas] a timbal [membrane] in the wall of the thorax is set in vibration by a rapidly contracting muscle attached to it. [Enc. Brit.]

Light
Light is detected by specialized photoreceptor cells that are grouped into visual organs on the head or may exist as small, light-sensitive sense organs elsewhere on the body. Insects have either compound eyes or simple eyes. Compound eyes are composed of one to many thousands of closely packed photoreceptive units called ommatidia [singular: ommatidium]. Each unit has its own corneal lens. Simple eyes each have a single round corneal lens with several to many light-sensitive cells beneath.

Unlike humans, most insects can distinguish between polarized light [coming directly from the sun] and unpolarized light [reflected from water vapour and other particles in the atmosphere]. This ability allows them to detect the sun's position in the sky, even on cloudy or overcast days, and use it as an orientation cue.

Studies show that many insects are sensitive to 3 or 4 spectral classes: ultra-violet [340 to 360 nm], violet to blue [420 to 460 nm], blue-green [490 to 550 nm], and, in addition in butterflies, yellow-orange-red [570 to 650 nm].

The visual world of insects differs from ours because the spectrum is shifted toward the shorter wavelengths to include ultraviolet.

Except for butterflies and moths, most insects cannot distinguish differences in wavelengths between 550 and 650 nm [yellow-orange-red].

Movement
Insects cannot form a true [i.e. focused] image of the environment; their visual acuity is relatively poor compared to that of vertebrates. However, their ability to sense movement, by tracking objects from ommatidium to ommatidium, is superior to most other animals. Temporal resolution of flicker is as high as 200 images/second in some bees and flies, whereas in humans, still images blur into constant motion at about 30 images/second.

Sensing movement comes down to sensing changes in the intensity of light generated by motion. This is how insects navigate and avoid obstacles.

The number of ommatidia in insect eyes depends upon the type of insect and ranges from as low as 400 in worker ants, 800 in the fruit fly Drosophila, 2,000 in cockroaches, 4,000 in houseflies, between 6,000 and 8,000 in various bee species, to about 17,000 in swallowtail butterflies and around 30,000 in large dragonflies and some hawk moths.

Temperature
Insects usually have a well-developed temperature sense. The sense organs they use are located all over the body but are more numerous on the antennae and legs.

Common chemical sense
High concentrations of irritant compounds [e.g. ammonia, chlorine, acids, essential oils, etc.] simulate avoidance reactions and cleaning behaviour. Insects can detect these compounds even when all known chemoreceptors have been covered or destroyed. The irritants evidently trigger a generalized response from other types of sensory neurons.

LIFE CYCLE – METAMORPHOSIS

Directed by Programmed Information

"It seems fairly safe to assume that no butterfly 'knows' what it is doing. It seems unlikely that a butterfly thinks through the possible consequences of its action. When carrying out this act of egg-laying, so vital for the survival of their kind, all the females of each species behave in the same way, without first having to learn this proper egg-laying procedure, with its seeming wisdom. Butterflies brought up totally alone and isolated from all of their fellows, with no opportunity to copy this behaviour from others, do not differ in the slightest in the way they carry out this task.

"This means, of course, that the behavioural instinct must be present from birth. The information necessary for such behaviour must already be there in the egg, stored in coded form ready for future decoding and use. After all, the information-bearing substance of heredity, the species-specific DNA, does not change in the slightest during the transformation [meta-morphosis] of this egg to the caterpillar stage, then through the pupa right up to the imago, the finished butterfly. Not one scrap of new information [through learning, for example] is added to the DNA during this entire life-cycle.

"The remarkable thing about this tiny butterfly egg is that it contains the information for all 3 stages stored in its microscopically small nucleus. It must contain the instructions for building and operating a caterpillar; for the pupa that develops from this and for the development and operation of the butterfly. All 3 of these stages arc remarkably different in form, function and behaviour.

"Every one of these radically different programs must be called into play and executed at exactly the right time, cleanly separated from the others.

"When the caterpillar is fully grown, it sheds its skin for the last time. But what now appears – the pupa – has almost no resemblance to a caterpillar. This motionless pupa has neither head nor legs. Before its transformation, the caterpillar [directed again by programmed information] spins a silken 'safety-belt' with which it anchors itself against a twig.

"Its apparent motionlessness is purely an external feature. Under this seemingly lifeless shell, something quite unbelievable is happening. The old caterpillar organs, with the exception of the nervous system, begin to totally dissolve into smaller groups of cells, even to disintegrate into single cells. From this 'cellular soup', new and [in part] quite different organs begin to develop.

"It is precisely when you consider this puzzling rebuilding process – metamorphosis as it is called – that you are struck with the certainty that everything is happening here with the utmost precision according to an extremely cleverly programmed plan. Without central direction towards a pre-programmed goal, a random agitation of these countless millions of cells could never give rise to anything other than a disordered, chaotic, tumour-like heap of cells, which would not be capable of survival.

"What happens instead is that new functional organs are constructed, which then collaborate and complement each other in a purposive and error-free way to form a new and radically different organism – the butterfly.

"This degree of miniaturization of information storage can hardly be imagined.

"In today's computer age, we know that information of this order never arises from unprogrammed matter by itself. While it may be transmitted from one 'machine' [having equal or greater information] to another, the ultimate origin of all such information is only to be found in mind, in an intelligence outside of the system itself." [Kuhn, 1992]

From Young To Adult

Metamorphosis, or change in form during development, is one of the distinctive features of insects. This ability to change allows insects to specialize and fill a wide variety of roles in the environment.

Insects attain maximum size by undergoing a succession of moults or ecdyses. Because of their rigid exoskeleton, insects can only grow by periodically shedding their exoskeleton, called moulting.

Moulting occurs repeatedly during larval development. The number of moults that an insect passes through is quite constant for the species. The form assumed by the insect between any 2 moults is called an instar. At the final moult, the adult emerges.

The insect's existence is thus made up of a succession of instars [growth] during which the insect is immature, followed by the attainment of the final adult instar [metamorphosis].

Both moulting and metamorphosis are under endocrine [hormonal] control.

While most insects begin life as eggs, there are 4 different paths, or types of metamorphosis, that will allow an insect to reach the adult stage.

No metamorphosis – 3 stages [egg, nymph, adult].
Gradual metamorphosis – 3 stages [egg, nymph, adult].
Incomplete metamorphosis – 3 stages [egg, naiad, adult].
Complete metamorphosis – 4 stages [egg, larva, pupa, adult].

Most insects have either gradual or complete metamorphosis.

No Metamorphosis – Little or No Change from Young to Adult

This occurs in the most primitive insects, such as silverfish, bristletails, firebrats, and springtails. The only change that takes place in these insects is an increase in size as the insect develops. The instars resemble one another and only differ from the adult in the absence of wings and the incomplete development of the reproductive system.

Gradual Metamorphosis – Gradual Change

In this form of paurometabolous development, immature stages [nymphs] represent a smaller version of the adult. In addition to being smaller, nymphs do not have wings and are not sexually mature. External wing buds can be seen on late-stage nymphs. They live in the same habitat as adults, have the same type of mouthparts as the adult, feed on the same food, and have the same general behaviour.

Included in this group are insects in the orders Blattodea, Hemiptera, Isoptera, Mantodea, Orthoptera, and Phthiraptera.

Incomplete Metamorphosis – Partial Change

Hemimetabolous or incomplete metamorphosis involves a partial change in appearance from the larva to imago, incl. 3 stages beginning with the egg and ending with the adult. The main difference is the *immature stage, called a naiad, that is found in aquatic environments*, for which it has the necessary adaptations, incl. a streamlined body, specialized mouthparts different from the adult stage, and a respiratory system adapted for oxygen exchange in aquatic environments.

Naiads and adults feed on different foods. These insects have compound eyes throughout their development and gradually grow wing pads. The adults are flying terrestrial insects, so they have some major structural differences, but the changes are accomplished without a pupal stage.

This development occurs in 3 orders of aquatic insects: dragonflies and damselflies [Odonata], mayflies [Ephemeroptera], and stoneflies [Plecoptera].

Complete Metamorphosis – Complete Change

Holometabolous insects undergo complete metamorphosis [or histological reorganisation]. About 75% of all extant insect species have this type of development. The specialized feeding stage, called a larva, is very different in form and habit from the adult. The larval stage typically has simple eyes, reduced antennae, mandibulate mouthparts, and no external evidence of wings. Larvae grow in size and their colouration may change as they mature.

In this type of development, the larva [immature] stage is primarily an eating machine, gathering and storing energy that will be needed in the pupa and adult stages. The most dramatic changes take place during the pupal stage, which is typically a non-feeding, [seemingly] inactive, resting stage where the insect is protected by a cocoon, puparium, or hidden in ground litter. The moult into the pupal instar is called pupation.

During the pupal stage, compound eyes develop [and simple eyes may be retained], larger complex antennae develop, mouthparts change to a form other