[Template:Taxobox](/wiki/Template:Taxobox" \o "Template:Taxobox) An **arthropod** (from Greek *arthro-*, joint + *podos*, foot) is an [invertebrate](/wiki/Invertebrate) [animal](/wiki/Animal) having an [exoskeleton](/wiki/Exoskeleton) (external [skeleton](/wiki/Skeleton)), a [segmented](/wiki/Segmentation_(biology)) body, and jointed [appendages](/wiki/Appendage) (paired appendages). Arthropods form the [phylum](/wiki/Phylum) **Arthropoda**, which includes the [insects](/wiki/Insect), [arachnids](/wiki/Arachnid), [myriapods](/wiki/Myriapod), and [crustaceans](/wiki/Crustacean). Arthropods are characterized by their jointed limbs and [cuticle](/wiki/Arthropod_cuticle) made of [chitin](/wiki/Chitin), often mineralised with [calcium carbonate](/wiki/Calcium_carbonate). The arthropod [body plan](/wiki/Body_plan) consists of [segments](/wiki/Segment_(biology)), each with a pair of [appendages](/wiki/Appendage). The rigid cuticle inhibits growth, so arthropods replace it periodically by [moulting](/wiki/Moulting). Their versatility has enabled them to become the most species-rich members of all [ecological guilds](/wiki/Guild_(ecology)) in most environments. They have over a million described species, making up more than 80% of all described living animal species, some of which, unlike most animals, are very successful in dry environments.

Arthropods range in size from the microscopic [crustacean](/wiki/Crustacean) [*Stygotantulus*](/wiki/Stygotantulus) up to the [Japanese spider crab](/wiki/Japanese_spider_crab). Arthropods' primary internal cavity is a [hemocoel](/wiki/Hemocoel), which accommodates their internal [organs](/wiki/Organ_(anatomy)), and through which their [haemolymph](/wiki/Haemolymph) - analogue of [blood](/wiki/Blood) - circulates; they have [open circulatory systems](/wiki/Circulatory_system#Open_circulatory_system). Like their exteriors, the internal organs of arthropods are generally built of repeated segments. Their [nervous system](/wiki/Nervous_system) is "ladder-like", with paired [ventral](/wiki/Anatomical_terms_of_location#Dorsal_and_ventral) [nerve cords](/wiki/Ventral_nerve_cord) running through all segments and forming paired [ganglia](/wiki/Ganglia) in each segment. Their heads are formed by fusion of varying numbers of segments, and their [brains](/wiki/Brain) are formed by fusion of the ganglia of these segments and encircle the [esophagus](/wiki/Esophagus). The [respiratory](/wiki/Respiratory_system) and [excretory](/wiki/Excretion) systems of arthropods vary, depending as much on their environment as on the [subphylum](/wiki/Subphylum) to which they belong.

Their vision relies on various combinations of [compound eyes](/wiki/Compound_eye) and pigment-pit [ocelli](/wiki/Ocelli): in most species the ocelli can only detect the direction from which light is coming, and the compound eyes are the main source of information, but the main eyes of [spiders](/wiki/Spider) are ocelli that can form images and, in a few cases, can swivel to track prey. Arthropods also have a wide range of chemical and mechanical sensors, mostly based on modifications of the many [setae](/wiki/Seta) (bristles) that project through their cuticles. Arthropods' methods of reproduction and development are diverse; all terrestrial species use [internal fertilization](/wiki/Internal_fertilization), but this is often by indirect transfer of the sperm via an appendage or the ground, rather than by direct injection. Aquatic species use either internal or [external fertilization](/wiki/External_fertilization). Almost all arthropods lay eggs, but [scorpions](/wiki/Scorpion) give birth to live young after the eggs have hatched inside the mother. Arthropod hatchlings vary from miniature adults to grubs and [caterpillars](/wiki/Caterpillar) that lack jointed limbs and eventually undergo a total [metamorphosis](/wiki/Metamorphosis) to produce the adult form. The level of maternal care for hatchlings varies from nonexistent to the prolonged care provided by scorpions.

The evolutionary ancestry of arthropods dates back to the [Cambrian](/wiki/Cambrian) period. The group is generally regarded as [monophyletic](/wiki/Monophyletic), and many analyses support the placement of arthropods with [cycloneuralians](/wiki/Cycloneuralia) (or their constituent clades) in a superphylum [Ecdysozoa](/wiki/Ecdysozoa). Overall however, the [basal](/wiki/Basal_(evolution)) relationships of Metazoa are not yet well resolved. Likewise, the relationships between various arthropod groups are still actively debated.

Arthropods contribute to the human food supply both directly as food, and more importantly as [pollinators](/wiki/Pollination) of crops. Some specific species are known to spread severe disease to humans, [livestock](/wiki/Livestock), and crops.

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## Etymology[[edit](/index.php?title=(none)&action=edit&section=1)]

The word *arthropod* comes from the [Greek](/wiki/Greek_language) [Template:Lang](/wiki/Template:Lang) [*Template:Lang*](/wiki/Template:Lang), "[joint](/wiki/Joint)", and [Template:Lang](/wiki/Template:Lang) *pous* ([gen.](/wiki/Genitive) *podos*), i.e. "foot" or "[leg](/wiki/Leg)", which together mean "jointed leg".<ref name=OnlineEtDict>[Template:Cite web](/wiki/Template:Cite_web)</ref>

## Description[[edit](/index.php?title=(none)&action=edit&section=2)]

Arthropods are [invertebrates](/wiki/Invertebrate) with [segmented](/wiki/Segmentation_(biology)) bodies and jointed limbs.[[1]](#cite_note-1) The [exoskeleton](/wiki/Exoskeleton) or [cuticles](/wiki/Arthropod_cuticle) consists of [chitin](/wiki/Chitin), a polymer of [glucosamine](/wiki/Glucosamine).[[2]](#cite_note-2) The cuticle of crustaceans are also [biomineralized](/wiki/Biomineralization) with [calcium carbonate](/wiki/Calcium_carbonate).

### Diversity[[edit](/index.php?title=(none)&action=edit&section=3)]

Estimates of the number of arthropod species vary between 1,170,000 and 5 to 10 million and account for over 80% of all known living animal species.[[3]](#cite_note-3)[[4]](#cite_note-4) The number of species remains difficult to determine. This is due to the census modeling assumptions projected onto other regions in order to scale up from counts at specific locations applied to the whole world. A study in 1992 estimated that there were 500,000 species of animals and plants in Costa Rica alone, of which 365,000 were arthropods.[[5]](#cite_note-5) They are important members of marine, freshwater, land and air [ecosystems](/wiki/Ecosystem), and are one of only two major animal groups that have adapted to life in dry environments; the other is [amniotes](/wiki/Amniote), whose living members are [reptiles](/wiki/Reptile), [birds](/wiki/Bird) and [mammals](/wiki/Mammal).[[6]](#cite_note-6) One arthropod sub-group, [insects](/wiki/Insect), is the most species-rich member of all [ecological guilds](/wiki/Guild_(ecology)) in land and fresh-water environments.[[5]](#cite_note-5) The lightest insects weigh less than 25 micrograms (millionths of a gram),[[7]](#cite_note-7) while the heaviest weigh over [Template:Convert](/wiki/Template:Convert).[[8]](#cite_note-8) Some living [crustaceans](/wiki/Crustacean) are much larger; for example, the legs of the [Japanese spider crab](/wiki/Japanese_spider_crab) may span up to [Template:Convert](/wiki/Template:Convert),[[7]](#cite_note-7) with the heaviest of all living arthropods being the [American lobster](/wiki/American_lobster), topping out at over 20 kg (44 lbs).

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### Segmentation[[edit](/index.php?title=(none)&action=edit&section=4)]

[Template:Annotated image](/wiki/Template:Annotated_image) [Template:Annotated image](/wiki/Template:Annotated_image) The [embryos](/wiki/Embryo) of all arthropods are segmented, built from a series of repeated modules. The [last common ancestor](/wiki/Most_recent_common_ancestor) of living arthropods probably consisted of a series of undifferentiated segments, each with a pair of appendages that functioned as limbs. However, all known living and fossil arthropods have grouped segments into [tagmata](/wiki/Tagma_(biology)) in which segments and their limbs are specialized in various ways;[[6]](#cite_note-6) The three-part appearance of many [insect](/wiki/Insect) bodies and the two-part appearance of [spiders](/wiki/Spider) is a result of this grouping;[[9]](#cite_note-9) in fact there are no external signs of segmentation in [mites](/wiki/Mite).[[6]](#cite_note-6) Arthropods also have two body elements that are not part of this serially repeated pattern of segments, an [acron](/wiki/Prostomium) at the front, ahead of the mouth, and a [telson](/wiki/Telson) at the rear, behind the [anus](/wiki/Anus). The eyes are mounted on the acron.[[6]](#cite_note-6) The original structure of arthropod appendages was probably [biramous](/wiki/Biramous), with the upper branch acting as a [gill](/wiki/Gill) while the lower branch was used for walking. In some segments of all known arthropods the appendages have been modified, for example to form gills, mouth-parts, [antennae](/wiki/Antenna_(biology)) for collecting information,[[9]](#cite_note-9) or claws for grasping;[[10]](#cite_note-10) arthropods are "like [Swiss Army knives](/wiki/Swiss_Army_knife), each equipped with a unique set of specialized tools."[[6]](#cite_note-6) In many arthropods, appendages have vanished from some regions of the body, and it is particularly common for abdominal appendages to have disappeared or be highly modified.[[6]](#cite_note-6)[Template:Clear](/wiki/Template:Clear) [Template:Annotated image/Arthropod head problem](/wiki/Template:Annotated_image/Arthropod_head_problem) The most conspicuous specialization of segments is in the head. The four major groups of arthropods – [Chelicerata](/wiki/Chelicerata) (includes [spiders](/wiki/Spider) and [scorpions](/wiki/Scorpion)), [Crustacea](/wiki/Crustacean) ([shrimps](/wiki/Shrimp), [lobsters](/wiki/Lobster), [crabs](/wiki/Crab), etc.), [Tracheata](/wiki/Tracheata) (arthropods that breathe via channels into their bodies; includes [insects](/wiki/Insect) and [myriapods](/wiki/Myriapod)), and the extinct [trilobites](/wiki/Trilobite) – have heads formed of various combinations of segments, with appendages that are missing or specialized in different ways.[[6]](#cite_note-6) In addition some extinct arthropods, such as [*Marrella*](/wiki/Marrella), belong to none of these groups, as their heads are formed by their own particular combinations of segments and specialized appendages.[[11]](#cite_note-11) Working out the evolutionary stages by which all these different combinations could have appeared is so difficult that it has long been known as "the [arthropod head problem](/wiki/Arthropod_head_problem)".[[12]](#cite_note-12) In 1960 R. E. Snodgrass even hoped it would not be solved, as trying to work out solutions was so much fun.[Template:Refn](/wiki/Template:Refn) [Template:Clear](/wiki/Template:Clear)

### Exoskeleton[[edit](/index.php?title=(none)&action=edit&section=5)]

[Template:Main](/wiki/Template:Main) [thumb|Illustration of an idealized arthropod exoskeleton.](/wiki/File:Arthropod_cuticle_based_upon_Xvazquez_edited_to_include_english_legend.PNG) Arthropod exoskeletons are made of [cuticle](/wiki/Arthropod_cuticle), a non-cellular material secreted by the [epidermis](/wiki/Epidermis_(zoology)).[[6]](#cite_note-6) Their cuticles vary in the details of their structure, but generally consist of three main layers: the [epicuticle](/wiki/Epicuticle), a thin outer [waxy](/wiki/Wax) coat that moisture-proofs the other layers and gives them some protection; the [exocuticle](/wiki/Exocuticle), which consists of [chitin](/wiki/Chitin) and chemically hardened [proteins](/wiki/Protein); and the [endocuticle](/wiki/Endocuticle), which consists of chitin and unhardened proteins. The exocuticle and endocuticle together are known as the [procuticle](/wiki/Procuticle).[[13]](#cite_note-13) Each body segment and limb section is encased in hardened cuticle. The joints between body segments and between limb sections are covered by flexible cuticle.[[6]](#cite_note-6) The exoskeletons of most aquatic [crustaceans](/wiki/Crustacean) are [biomineralized](/wiki/Biomineralization) with [calcium carbonate](/wiki/Calcium_carbonate) extracted from the water. Some terrestrial crustaceans have developed means of storing the mineral, since on land they cannot rely on a steady supply of dissolved calcium carbonate.[[14]](#cite_note-14) Biomineralization generally affects the exocuticle and the outer part of the endocuticle.[[13]](#cite_note-13) Two recent hypotheses about the evolution of biomineralization in arthropods and other groups of animals propose that it provides tougher defensive armor,[[15]](#cite_note-15) and that it allows animals to grow larger and stronger by providing more rigid skeletons;[[16]](#cite_note-16) and in either case a mineral-organic [composite](/wiki/Composite_material) exoskeleton is cheaper to build than an all-organic one of comparable strength.[[16]](#cite_note-16)[[17]](#cite_note-17) The cuticle may have [setae](/wiki/Seta) (bristles) growing from special cells in the epidermis. Setae are as varied in form and function as appendages. For example, they are often used as sensors to detect air or water currents, or contact with objects; aquatic arthropods use [feather](/wiki/Feather)-like setae to increase the surface area of swimming appendages and to [filter](/wiki/Filter_feeding) food particles out of water; aquatic insects, which are air-breathers, use thick [felt](/wiki/Felt)-like coats of setae to trap air, extending the time they can spend under water; heavy, rigid setae serve as defensive spines.[[6]](#cite_note-6) Although all arthropods use muscles attached to the inside of the exoskeleton to flex their limbs, some still use [hydraulic](/wiki/Hydraulic) pressure to extend them, a system inherited from their pre-arthropod ancestors;[[18]](#cite_note-18) for example, all spiders extend their legs hydraulically and can generate pressures up to eight times their resting level.[[19]](#cite_note-19)

### Moulting[[edit](/index.php?title=(none)&action=edit&section=6)]

[Template:Main](/wiki/Template:Main) [thumb|Cicada climbing out of its exoskeleton while attached to tree](/wiki/File:Cicada_climbing_out_of_its_exoskeleton_while_attached_to_tree.jpg)

The exoskeleton cannot stretch and thus restricts growth. Arthropods therefore replace their exoskeletons by [moulting](/wiki/Moult), or shedding the old exoskeleton after growing a new one that is not yet hardened. Moulting cycles run nearly continuously until an arthropod reaches full size.[[20]](#cite_note-20) In the initial phase of moulting, the animal stops feeding and its epidermis releases [moulting fluid](/wiki/Moulting_fluid), a mixture of [enzymes](/wiki/Enzyme) that digests the [endocuticle](/wiki/Endocuticle) and thus detaches the old cuticle. This phase begins when the [epidermis](/wiki/Epidermis_(zoology)) has secreted a new [epicuticle](/wiki/Epicuticle) to protect it from the enzymes, and the epidermis secretes the new exocuticle while the old cuticle is detaching. When this stage is complete, the animal makes its body swell by taking in a large quantity of water or air, and this makes the old cuticle split along predefined weaknesses where the old exocuticle was thinnest. It commonly takes several minutes for the animal to struggle out of the old cuticle. At this point the new one is wrinkled and so soft that the animal cannot support itself and finds it very difficult to move, and the new endocuticle has not yet formed. The animal continues to pump itself up to stretch the new cuticle as much as possible, then hardens the new exocuticle and eliminates the excess air or water. By the end of this phase the new endocuticle has formed. Many arthropods then eat the discarded cuticle to reclaim its materials.[[20]](#cite_note-20) Because arthropods are unprotected and nearly immobilized until the new cuticle has hardened, they are in danger both of being trapped in the old cuticle and of being attacked by predators. Moulting may be responsible for 80 to 90% of all arthropod deaths.[[20]](#cite_note-20)

### Internal organs[[edit](/index.php?title=(none)&action=edit&section=7)]

[Template:Annotated image/Basic arthropod internal structure](/wiki/Template:Annotated_image/Basic_arthropod_internal_structure) Arthropod bodies are also segmented internally, and the nervous, muscular, circulatory, and excretory systems have repeated components.[[6]](#cite_note-6) Arthropods come from a lineage of animals that have a [coelom](/wiki/Coelom), a membrane-lined cavity between the gut and the body wall that accommodates the internal organs. The strong, segmented limbs of arthropods eliminate the need for one of the coelom's main ancestral functions, as a [hydrostatic skeleton](/wiki/Hydrostatic_skeleton), which muscles compress in order to change the animal's shape and thus enable it to move. Hence the coelom of the arthropod is reduced to small areas around the reproductive and excretory systems. Its place is largely taken by a [hemocoel](/wiki/Hemocoel), a cavity that runs most of the length of the body and through which [blood](/wiki/Blood) flows.[[21]](#cite_note-21) [Template:See also](/wiki/Template:See_also) [Template:See also](/wiki/Template:See_also)

Arthropods have open [circulatory systems](/wiki/Circulatory_system), although most have a few short, open-ended [arteries](/wiki/Artery). In chelicerates and crustaceans, the blood carries [oxygen](/wiki/Oxygen) to the tissues, while [hexapods](/wiki/Hexapoda) use a separate system of [tracheae](/wiki/Invertebrate_trachea). Many crustaceans, but few chelicerates and [tracheates](/wiki/Tracheata), use [respiratory pigments](/wiki/Respiratory_pigment) to assist oxygen transport. The most common respiratory pigment in arthropods is [copper](/wiki/Copper)-based [hemocyanin](/wiki/Hemocyanin); this is used by many crustaceans and a few [centipedes](/wiki/Centipede). A few crustaceans and insects use iron-based [hemoglobin](/wiki/Hemoglobin), the respiratory pigment used by [vertebrates](/wiki/Vertebrate). As with other invertebrates the respiratory pigments of those arthropods that have them are generally dissolved in the blood and rarely enclosed in [corpuscles](/wiki/Blood_cell) as they are in vertebrates.[[21]](#cite_note-21) The heart is typically a muscular tube that runs just under the back and for most of the length of the hemocoel. It contracts in ripples that run from rear to front, pushing blood forwards. Sections not being squeezed by the heart muscle are expanded either by elastic [ligaments](/wiki/Ligament) or by small [muscles](/wiki/Muscle), in either case connecting the heart to the body wall. Along the heart run a series of paired ostia, non-return valves that allow blood to enter the heart but prevent it from leaving before it reaches the front.[[21]](#cite_note-21) Arthropods have a wide variety of respiratory systems. Small species often do not have any, since their high ratio of surface area to volume enables simple diffusion through the body surface to supply enough oxygen. Crustacea usually have gills that are modified appendages. Many arachnids have [book lungs](/wiki/Book_lung).[[22]](#cite_note-22) Tracheae, systems of branching tunnels that run from the openings in the body walls, deliver oxygen directly to individual cells in many insects, myriapods and [arachnids](/wiki/Arachnid).[[23]](#cite_note-23) Living arthropods have paired main nerve cords running along their bodies below the gut, and in each segment the cords form a pair of [ganglia](/wiki/Ganglia) from which [sensory](/wiki/Sensory_nerve) and [motor](/wiki/Motor_nerve) nerves run to other parts of the segment. Although the pairs of ganglia in each segment often appear physically fused, they are connected by [commissures](/wiki/Commissure) (relatively large bundles of nerves), which give arthropod nervous systems a characteristic "ladder-like" appearance. The brain is in the head, encircling and mainly *above* the [esophagus](/wiki/Esophagus). It consists of the fused ganglia of the acron and one or two of the foremost segments that form the head – a total of three pairs of ganglia in most arthropods, but only two in chelicerates, which do not have antennae or the ganglion connected to them. The ganglia of other head segments are often close to the brain and function as part of it. In insects these other head ganglia combine into a pair of [subesophageal ganglia](/wiki/Subesophageal_ganglia), under and behind the esophagus. Spiders take this process a step further, as *all* the [segmental ganglia](/wiki/Segmental_ganglia) are incorporated into the subesophageal ganglia, which occupy most of the space in the cephalothorax (front "super-segment").[[24]](#cite_note-24) There are two different types of arthropod excretory systems. In aquatic arthropods, the end-product of biochemical reactions that [metabolise](/wiki/Metabolism) [nitrogen](/wiki/Nitrogen) is [ammonia](/wiki/Ammonia), which is so toxic that it needs to be diluted as much as possible with water. The ammonia is then eliminated via any permeable membrane, mainly through the gills.[[22]](#cite_note-22) All crustaceans use this system, and its high consumption of water may be responsible for the relative lack of success of crustaceans as land animals.[[25]](#cite_note-25) Various groups of terrestrial arthropods have independently developed a different system: the end-product of nitrogen metabolism is [uric acid](/wiki/Uric_acid), which can be excreted as dry material; the [Malpighian tubule system](/wiki/Malpighian_tubule_system) filters the uric acid and other nitrogenous waste out of the blood in the hemocoel, and dumps these materials into the hindgut, from which they are expelled as [feces](/wiki/Feces).[[25]](#cite_note-25) Most aquatic arthropods and some terrestrial ones also have organs called [nephridia](/wiki/Nephridia) ("little [kidneys](/wiki/Kidney)"), which extract other wastes for excretion as [urine](/wiki/Urine).[[25]](#cite_note-25)

### Senses[[edit](/index.php?title=(none)&action=edit&section=8)]

#### Optical[[edit](/index.php?title=(none)&action=edit&section=9)]

[Template:Main](/wiki/Template:Main) The stiff [cuticles](/wiki/Cuticle) of arthropods would block out information about the outside world, except that they are penetrated by many sensors or connections from sensors to the nervous system. In fact, arthropods have modified their cuticles into elaborate arrays of sensors. Various touch sensors, mostly [setae](/wiki/Seta), respond to different levels of force, from strong contact to very weak air currents. Chemical sensors provide equivalents of [taste](/wiki/Taste) and [smell](/wiki/Olfaction), often by means of setae. Pressure sensors often take the form of membranes that function as [eardrums](/wiki/Eardrum), but are connected directly to nerves rather than to [auditory ossicles](/wiki/Auditory_ossicle). The [antennae](/wiki/Antenna_(biology)) of most hexapods include sensor packages that monitor [humidity](/wiki/Humidity), moisture and temperature.[[26]](#cite_note-26) [240px|thumb|right|Head of a](/wiki/File:Wasp_ocelli.JPG) [wasp](/wiki/Wasp) with three ocelli (centre), and [compound eyes](/wiki/Compound_eye) at the left and right Most arthropods have sophisticated visual systems that include one or more usually both of [compound eyes](/wiki/Compound_eye) and pigment-cup [ocelli](/wiki/Ocelli) ("little eyes"). In most cases ocelli are only capable of detecting the direction from which light is coming, using the shadow cast by the walls of the cup. However, the main eyes of [spiders](/wiki/Spider) are pigment-cup ocelli that are capable of forming images,[[26]](#cite_note-26) and those of [jumping spiders](/wiki/Jumping_spider) can rotate to track prey.[[27]](#cite_note-27) Compound eyes consist of fifteen to several thousand independent [ommatidia](/wiki/Ommatidia), columns that are usually [hexagonal](/wiki/Hexagon) in [cross section](/wiki/Cross_section_(geometry)). Each ommatidium is an independent sensor, with its own light-sensitive cells and often with its own [lens](/wiki/Lens_(anatomy)) and [cornea](/wiki/Cornea).[[26]](#cite_note-26) Compound eyes have a wide field of view, and can detect fast movement and, in some cases, the [polarization of light](/wiki/Light_polarization).[[28]](#cite_note-28) On the other hand, the relatively large size of ommatidia makes the images rather coarse, and compound eyes are shorter-sighted than those of birds and mammals – although this is not a severe disadvantage, as objects and events within [Template:Convert](/wiki/Template:Convert) are most important to most arthropods.[[26]](#cite_note-26) Several arthropods have color vision, and that of some insects has been studied in detail; for example, the ommatidia of bees contain receptors for both green and [ultra-violet](/wiki/Ultra-violet).[[26]](#cite_note-26) Most arthropods lack balance and [acceleration](/wiki/Acceleration) sensors, and rely on their eyes to tell them which way is up. The self-righting behavior of [cockroaches](/wiki/Cockroach) is triggered when pressure sensors on the underside of the feet report no pressure. However, many [malacostracan](/wiki/Malacostracan) [crustaceans](/wiki/Crustacean) have [statocysts](/wiki/Statocyst), which provide the same sort of information as the balance and motion sensors of the vertebrate [inner ear](/wiki/Inner_ear).[[26]](#cite_note-26) The [proprioceptors](/wiki/Proprioceptor) of arthropods, sensors that report the force exerted by muscles and the degree of bending in the body and joints, are well understood. However, little is known about what other internal sensors arthropods may have.[[26]](#cite_note-26)

#### Olfaction[[edit](/index.php?title=(none)&action=edit&section=10)]

[Template:Further](/wiki/Template:Further)

## Reproduction and development[[edit](/index.php?title=(none)&action=edit&section=11)]

[200px|right|thumb|*Compsobuthus werneri* female with young (white)](/wiki/File:scorpionwithyoung.JPG)

A few arthropods, such as [barnacles](/wiki/Barnacle), are [hermaphroditic](/wiki/Hermaphroditic), that is, each can have the organs of both [sexes](/wiki/Sex). However, individuals of most species remain of one sex their entire lives.[[29]](#cite_note-29) A few species of [insects](/wiki/Insect) and [crustaceans](/wiki/Crustacean) can reproduce by [parthenogenesis](/wiki/Parthenogenesis), for example, without mating, especially if conditions favor a "population explosion". However, most arthropods rely on [sexual reproduction](/wiki/Sexual_reproduction), and parthenogenetic species often revert to sexual reproduction when conditions become less favorable.[[30]](#cite_note-30) [Aquatic](/wiki/Aquatic_animal) arthropods may breed by [external fertilization](/wiki/External_fertilization), as for example [frogs](/wiki/Frog) also do, or by [internal fertilization](/wiki/Internal_fertilization), where the [ova](/wiki/Ovum) remain in the female's body and the [sperm](/wiki/Sperm) must somehow be inserted. All known terrestrial arthropods use internal fertilization. [Opiliones](/wiki/Opiliones) (harvestmen), [millipedes](/wiki/Millipede), and some crustaceans use modified appendages such as [gonopods](/wiki/Gonopod) or [penises](/wiki/Opiliones_penis) to transfer the sperm directly to the female. However, most male [terrestrial](/wiki/Terrestrial_animal) arthropods produce [spermatophores](/wiki/Spermatophore), waterproof packets of sperm, which the females take into their bodies. A few such species rely on females to find spermatophores that have already been deposited on the ground, but in most cases males only deposit spermatophores when complex [courtship](/wiki/Courtship) rituals look likely to be successful.[[29]](#cite_note-29) [200px|thumb|right|The nauplius larva of a](/wiki/File:Shrimp_nauplius.jpg) [prawn](/wiki/Dendrobranchiata) Most arthropods lay eggs,[[29]](#cite_note-29) but scorpions are [viviparous](/wiki/Viviparous): they produce live young after the eggs have hatched inside the mother, and are noted for prolonged maternal care.[[31]](#cite_note-31) Newly born arthropods have diverse forms, and insects alone cover the range of extremes. Some hatch as apparently miniature adults (direct development), and in some cases, such as [silverfish](/wiki/Silverfish), the hatchlings do not feed and may be helpless until after their first moult. Many insects hatch as grubs or [caterpillars](/wiki/Caterpillar), which do not have segmented limbs or hardened cuticles, and [metamorphose](/wiki/Metamorphosis) into adult forms by entering an inactive phase in which the larval tissues are broken down and re-used to build the adult body.[[32]](#cite_note-32) [Dragonfly](/wiki/Dragonfly) larvae have the typical cuticles and jointed limbs of arthropods but are flightless water-breathers with extendable jaws.[[33]](#cite_note-33) Crustaceans commonly hatch as tiny [nauplius](/wiki/Nauplius_(larva)) larvae that have only three segments and pairs of appendages.[[29]](#cite_note-29)

## Evolution[[edit](/index.php?title=(none)&action=edit&section=12)]

[Template:See also](/wiki/Template:See_also)

### Last common ancestor[[edit](/index.php?title=(none)&action=edit&section=13)]

The [last common ancestor](/wiki/Last_common_ancestor) of all arthropods is reconstructed as a modular organism with each module covered by its own [sclerite](/wiki/Sclerite) (armor plate) and bearing a pair of [biramous](/wiki/Biramous) limbs.[[34]](#cite_note-34) Whether the ancestral limb was uniramous or biramous is far from a settled debate, though. This Ur-arthropod had a [ventral](/wiki/Ventral#Dorsal_and_ventral) mouth, pre-oral antennae and [dorsal](/wiki/Ventral#Dorsal_and_ventral) eyes at the front of the body. It was a non-discriminatory [sediment](/wiki/Sediment) feeder, processing whatever sediment came its way for food.[[34]](#cite_note-34)

### Fossil record[[edit](/index.php?title=(none)&action=edit&section=14)]

[thumb |right |120px|](/wiki/File:Marrella.jpg)[*Marrella*](/wiki/Marrella), one of the puzzling arthropods from the [Burgess Shale](/wiki/Burgess_Shale)

It has been proposed that the [Ediacaran](/wiki/Ediacaran) animals [*Parvancorina*](/wiki/Parvancorina) and [*Spriggina*](/wiki/Spriggina), from around 555 million years ago, were arthropods.[[35]](#cite_note-35)[[36]](#cite_note-36)[[37]](#cite_note-37) Small arthropods with bivalve-like shells have been found in Early Cambrian fossil beds dating [Template:Ma](/wiki/Template:Ma) in China.[[38]](#cite_note-38)[[39]](#cite_note-39) The earliest Cambrian [trilobite](/wiki/Trilobite) fossils are about 530 million years old, but the class was already quite diverse and worldwide, suggesting that they had been around for quite some time.[[40]](#cite_note-40) Re-examination in the 1970s of the [Burgess Shale](/wiki/Burgess_Shale) fossils from about [Template:Ma](/wiki/Template:Ma) identified many arthropods, some of which could not be assigned to any of the well-known groups, and thus intensified the debate about the [Cambrian explosion](/wiki/Cambrian_explosion).[[41]](#cite_note-41)[[42]](#cite_note-42)[[43]](#cite_note-43) A fossil of [*Marrella*](/wiki/Marrella) from the Burgess Shale has provided the earliest clear evidence of [moulting](/wiki/Moulting).[[44]](#cite_note-44) The earliest fossil [crustaceans](/wiki/Crustacean) date from about [Template:Ma](/wiki/Template:Ma) in the [Cambrian](/wiki/Cambrian),[[45]](#cite_note-45) and fossil [shrimp](/wiki/Shrimp) from about [Template:Ma](/wiki/Template:Ma) apparently formed a tight-knit procession across the seabed.[[46]](#cite_note-46) Crustacean fossils are common from the [Ordovician](/wiki/Ordovician) period onwards.[[47]](#cite_note-47) They have remained almost entirely aquatic, possibly because they never developed [excretory systems](/wiki/Excretory_system) that conserve water.[[25]](#cite_note-25) Arthropods provide the earliest identifiable fossils of land animals, from about [Template:Ma](/wiki/Template:Ma) in the Late [Silurian](/wiki/Silurian),[[22]](#cite_note-22) and terrestrial tracks from about [Template:Ma](/wiki/Template:Ma) appear to have been made by arthropods.[[48]](#cite_note-48) Arthropods were well [pre-adapted](/wiki/Preadaptation) to colonize land, because their existing jointed exoskeletons provided protection against desiccation, support against gravity and a means of locomotion that was not dependent on water.[[49]](#cite_note-49) Around the same time the aquatic, scorpion-like [eurypterids](/wiki/Eurypterid) became the largest ever arthropods, some as long as [Template:Convert](/wiki/Template:Convert).[[50]](#cite_note-50) The oldest known [arachnid](/wiki/Arachnid) is the [trigonotarbid](/wiki/Trigonotarbid) [*Palaeotarbus*](/wiki/Palaeotarbus) *jerami*, from about [Template:Ma](/wiki/Template:Ma) in the [Silurian](/wiki/Silurian) period.[[51]](#cite_note-51)[Template:Refn](/wiki/Template:Refn) [*Attercopus*](/wiki/Attercopus) *fimbriunguis*, from [Template:Ma](/wiki/Template:Ma) in the [Devonian](/wiki/Devonian) period, bears the earliest known silk-producing spigots, but its lack of [spinnerets](/wiki/Spinneret_(spider)) means it was not one of the true [spiders](/wiki/Spider),[[52]](#cite_note-52) which first appear in the Late [Carboniferous](/wiki/Carboniferous) over [Template:Ma](/wiki/Template:Ma).[[53]](#cite_note-53) The [Jurassic](/wiki/Jurassic) and [Cretaceous](/wiki/Cretaceous) periods provide a large number of fossil spiders, including representatives of many modern families.[[54]](#cite_note-54) Fossils of aquatic [scorpions](/wiki/Scorpion) with [gills](/wiki/Gill) appear in the Silurian and [Devonian](/wiki/Devonian) periods, and the earliest fossil of an air-breathing scorpion with [book lungs](/wiki/Book_lung) dates from the Early Carboniferous period.[[55]](#cite_note-55) The oldest definitive insect fossil is the [Devonian](/wiki/Devonian) [*Rhyniognatha hirsti*](/wiki/Rhyniognatha_hirsti), dated at [Template:Ma](/wiki/Template:Ma), but its [mandibles](/wiki/Mandible_(insect_mouthpart)) are of a type found only in winged insects, which suggests that the earliest insects appeared in the Silurian period.[[56]](#cite_note-56) The [Mazon Creek lagerstätten](/wiki/Mazon_Creek_fossils) from the Late Carboniferous, about [Template:Ma](/wiki/Template:Ma), include about 200 species, some gigantic by modern standards, and indicate that insects had occupied their main modern [ecological niches](/wiki/Ecological_niche) as [herbivores](/wiki/Herbivore), [detritivores](/wiki/Detritivore) and [insectivores](/wiki/Insectivore). Social termites and ants first appear in the Early [Cretaceous](/wiki/Cretaceous), and advanced social bees have been found in Late Cretaceous rocks but did not become abundant until the Middle [Cenozoic](/wiki/Cenozoic).[[57]](#cite_note-57)

### Evolutionary family tree[[edit](/index.php?title=(none)&action=edit&section=15)]

[thumb|left|The](/wiki/File:Onycophora.jpg) [velvet worm (Onychophora)](/wiki/Velvet_worm) is closely related to arthropods[[58]](#cite_note-58) From 1952 to 1977, zoologist [Sidnie Manton](/wiki/Sidnie_Manton) and others argued that arthropods are [polyphyletic](/wiki/Polyphyletic), in other words, that they do not share a common ancestor that was itself an arthropod. Instead, they proposed that three separate groups of "arthropods" evolved separately from common worm-like ancestors: the [chelicerates](/wiki/Chelicerate), including [spiders](/wiki/Spider) and [scorpions](/wiki/Scorpion); the [crustaceans](/wiki/Crustacean); and the [uniramia](/wiki/Uniramia), consisting of [onychophorans](/wiki/Onychophoran), [myriapods](/wiki/Myriapod) and [hexapods](/wiki/Hexapoda). These arguments usually bypassed [trilobites](/wiki/Trilobite), as the evolutionary relationships of this class were unclear. Proponents of polyphyly argued the following: that the similarities between these groups are the results of [convergent evolution](/wiki/Convergent_evolution), as natural consequences of having rigid, segmented [exoskeletons](/wiki/Exoskeleton); that the three groups use different chemical means of hardening the cuticle; that there were significant differences in the construction of their [compound eyes](/wiki/Compound_eye); that it is hard to see how such different configurations of segments and appendages in the head could have evolved from the same ancestor; and that crustaceans have [biramous](/wiki/Biramous) limbs with separate gill and leg branches, while the other two groups have [uniramous](/wiki/Uniramous) limbs in which the single branch serves as a leg.[[59]](#cite_note-59)

[Template:Clade](/wiki/Template:Clade)

Simplified summary of Budd's "broad-scale" cladogram (1996)[[58]](#cite_note-58)

Further analysis and discoveries in the 1990s reversed this view, and led to acceptance that arthropods are [monophyletic](/wiki/Monophyletic), in other words they do share a common ancestor that was itself an arthropod.[[60]](#cite_note-60)[[61]](#cite_note-61) For example, [Graham Budd's](/wiki/Graham_Budd) analyses of [*Kerygmachela*](/wiki/Kerygmachela) in 1993 and of [*Opabinia*](/wiki/Opabinia) in 1996 convinced him that these animals were similar to onychophorans and to various Early [Cambrian](/wiki/Cambrian) "[lobopods](/wiki/Lobopod)", and he presented an "evolutionary family tree" that showed these as "aunts" and "cousins" of all arthropods.[[58]](#cite_note-58)[[62]](#cite_note-62) These changes made the scope of the term "arthropod" unclear, and Claus Nielsen proposed that the wider group should be labelled "[Panarthropoda](/wiki/Panarthropoda)" ("all the arthropods") while the animals with jointed limbs and hardened cuticles should be called "Euarthropoda" ("true arthropods").[[63]](#cite_note-63) A contrary view was presented in 2003, when Jan Bergström and Xian-Guang Hou argued that, if arthropods were a "sister-group" to any of the anomalocarids, they must have lost and then re-evolved features that were well-developed in the anomalocarids. The earliest known arthropods ate mud in order to extract food particles from it, and possessed variable numbers of segments with unspecialized appendages that functioned as both gills and legs. Anomalocarids were, by the standards of the time, huge and sophisticated predators with specialized mouths and grasping appendages, fixed numbers of segments some of which were specialized, tail fins, and gills that were very different from those of arthropods. This reasoning implies that [*Parapeytoia*](/wiki/Parapeytoia), which has legs and a backward-pointing mouth like that of the earliest arthropods, is a more credible closest relative of arthropods than is [*Anomalocaris*](/wiki/Anomalocaris).[[64]](#cite_note-64) In 2006, they suggested that arthropods were more closely related to [lobopods](/wiki/Lobopod) and [tardigrades](/wiki/Tardigrade) than to anomalocarids.[[65]](#cite_note-65)[Template:Clear](/wiki/Template:Clear)

[Template:Clade](/wiki/Template:Clade)

Relationships of [Ecdysozoa](/wiki/Ecdysozoa) to each other and to [annelids](/wiki/Annelid), etc.,[[66]](#cite_note-66) including [euthycarcinoids](/wiki/Euthycarcinoid)[[67]](#cite_note-67)

Higher up the "family tree", the [Annelida](/wiki/Annelida) have traditionally been considered the closest relatives of the Panarthropoda, since both groups have segmented bodies, and the combination of these groups was labelled [Articulata](/wiki/Articulata_Hypothesis). There had been competing proposals that arthropods were closely related to other groups such as [nematodes](/wiki/Nematode), [priapulids](/wiki/Priapulid) and [tardigrades](/wiki/Tardigrade), but these remained minority views because it was difficult to specify in detail the relationships between these groups.

In the 1990s, [molecular phylogenetic](/wiki/Molecular_phylogenetics) analyses of [DNA](/wiki/DNA) sequences produced a coherent scheme showing arthropods as members of a [superphylum](/wiki/Superphylum) labelled [Ecdysozoa](/wiki/Ecdysozoa) ("animals that moult"), which contained nematodes, priapulids and tardigrades but excluded annelids. This was backed up by studies of the anatomy and development of these animals, which showed that many of the features that supported the Articulata hypothesis showed significant differences between annelids and the earliest Panarthropods in their details, and some were hardly present at all in arthropods. This hypothesis groups annelids with [molluscs](/wiki/Mollusc) and [brachiopods](/wiki/Brachiopod) in another superphylum, [Lophotrochozoa](/wiki/Lophotrochozoa).

If the Ecdysozoa hypothesis is correct, then segmentation of arthropods and annelids either has evolved [convergently](/wiki/Convergent_evolution) or has been inherited from a much older ancestor and subsequently lost in several other lineages, such as the non-arthropod members of the Ecdysozoa.[[68]](#cite_note-68)[[66]](#cite_note-66)[Template:Clear](/wiki/Template:Clear)

## Classification[[edit](/index.php?title=(none)&action=edit&section=16)]

[Template:See also](/wiki/Template:See_also)

Arthropods are typically [classified](/wiki/Scientific_classification) into five [subphyla](/wiki/Subphylum), of which one is extinct:[[69]](#cite_note-69)

1. [**Trilobites**](/wiki/Trilobite) are a group of formerly numerous marine animals that disappeared in the [Permian–Triassic extinction event](/wiki/Permian–Triassic_extinction_event), though they were in decline prior to this killing blow, having been reduced to one order in the [Late Devonian extinction](/wiki/Late_Devonian_extinction).
2. [**Chelicerates**](/wiki/Chelicerata) include [horseshoe crabs](/wiki/Horseshoe_crab), [spiders](/wiki/Spider), [mites](/wiki/Mite), [scorpions](/wiki/Scorpion) and related organisms. They are characterised by the presence of [chelicerae](/wiki/Chelicerae), appendages just above / in front of the mouth. Chelicerae appear in scorpions and horseshoe crabs as tiny claws that they use in feeding, but those of spiders have developed as fangs that inject venom.
3. [**Myriapods**](/wiki/Myriapoda) comprise [millipedes](/wiki/Millipede), [centipedes](/wiki/Centipede), and their relatives and have many body segments, each bearing one or two pairs of legs. They are sometimes grouped with the hexapods.
4. [**Crustaceans**](/wiki/Crustacean) are primarily aquatic (a notable exception being [woodlice](/wiki/Woodlouse)) and are characterised by having [biramous](/wiki/Arthropod_leg#Biramous_and_uniramous) appendages. They include [lobsters](/wiki/Lobster), [crabs](/wiki/Crab), [barnacles](/wiki/Barnacle), [crayfish](/wiki/Crayfish), [shrimp](/wiki/Shrimp) and many others.
5. [**Hexapods**](/wiki/Hexapoda) comprise [insects](/wiki/Insect) and three small orders of insect-like animals with six thoracic legs. They are sometimes grouped with the myriapods, in a group called [Uniramia](/wiki/Uniramia), though genetic evidence tends to support a closer relationship between hexapods and crustaceans.

Aside from these major groups, there are also a number of fossil forms, mostly from the Early [Cambrian](/wiki/Cambrian), which are difficult to place, either from lack of obvious affinity to any of the main groups or from clear affinity to several of them. [*Marrella*](/wiki/Marrella) was the first one to be recognized as significantly different from the well-known groups.[[11]](#cite_note-11) The [phylogeny](/wiki/Phylogenetics) of the major extant arthropod groups has been an area of considerable interest and dispute.[[70]](#cite_note-70) Recent studies strongly suggest that Crustacea, as traditionally defined, is [paraphyletic](/wiki/Paraphyly), with Hexapoda having evolved from within it,<ref name=Regi10/><ref name=vonJennWillDell11>[Template:Citation](/wiki/Template:Citation)</ref> so that Crustacea and Hexapoda form a clade, Pancrustacea. The position of [Myriapoda](/wiki/Myriapoda), [Chelicerata](/wiki/Chelicerata) and Pancrustacea remains unclear [Template:As of](/wiki/Template:As_of). In some studies, Myriapoda is grouped with Chelicerata (forming [Myriochelata](/wiki/Myriochelata));[[71]](#cite_note-71)[[72]](#cite_note-72) in other studies, Myriapoda is grouped with Pancrustacea (forming [Mandibulata](/wiki/Mandibulata)),<ref name=Regi10>[Template:Citation](/wiki/Template:Citation)</ref> or Myriapoda may be sister to Chelicerata plus Pancrustacea.<ref name=vonJennWillDell11/>

[Template:Barlabel](/wiki/Template:Barlabel)

Phylogenetic relationships of the major extant arthropod groups according to Regier et al. (2010);<ref name=Regi10/> traditional subphyla in bold

[Template:Clear](/wiki/Template:Clear)

The placement of the extinct [trilobites](/wiki/Trilobite) is also a frequent subject of dispute.[[73]](#cite_note-73) One of the newer hypotheses is that the chelicerae have originated from the same pair of appendages that evolved into antennae in the ancestors of [Mandibulata](/wiki/Mandibulata), which would place trilobites, which had antennae, closer to Mandibulata than Chelicerata.[[74]](#cite_note-74) Since the [International Code of Zoological Nomenclature](/wiki/International_Code_of_Zoological_Nomenclature) recognises no priority above the rank of family, many of the higher-level groups can be referred to by a variety of different names.[[75]](#cite_note-75)

## Interaction with humans[[edit](/index.php?title=(none)&action=edit&section=17)]

[thumb|right|Insects and scorpions on sale in a food stall in](/wiki/File:Insect_food_stall.JPG) [Bangkok](/wiki/Bangkok)

[Template:See also](/wiki/Template:See_also)

[Crustaceans](/wiki/Crustacean) such as [crabs](/wiki/Crab), [lobsters](/wiki/Lobster), [crayfish](/wiki/Crayfish), [shrimp and prawns](/wiki/Shrimp_and_prawn) have long been part of human [cuisine](/wiki/Cuisine), and are now raised commercially.[[76]](#cite_note-76) Insects and their grubs are at least as nutritious as meat, and are eaten both raw and cooked in many cultures, excluding most European, Hindu and Islamic cultures.[[77]](#cite_note-77)[[78]](#cite_note-78) Cooked [tarantulas](/wiki/Tarantula) are considered a delicacy in [Cambodia](/wiki/Cambodia),[[79]](#cite_note-79)[[80]](#cite_note-80)[[81]](#cite_note-81) and by the [Piaroa](/wiki/Piaroa) Indians of southern Venezuela, after the highly irritant hairs – the spider's main defense system – are removed.[[82]](#cite_note-82) Humans also [unintentionally eat](/wiki/Entomophagy#Unintentional_ingestion) arthropods in other foods,[[83]](#cite_note-83) and food safety regulations lay down acceptable contamination levels for different kinds of food material.[Template:RefnTemplate:Refn](/wiki/Template:Refn) The intentional cultivation of arthropods and other small animals for human food, referred to as [minilivestock](/wiki/Minilivestock), is now emerging in [animal husbandry](/wiki/Animal_husbandry) as an ecologically sound concept.[[84]](#cite_note-84) [Commercial butterfly breeding](/wiki/Commercial_butterfly_breeding) provides Lepidoptera stock to [butterfly conservatories, educational exhibits](/wiki/Butterfly_house_(conservatory)) , schools, research facilities and cultural events.

However, the greatest contribution of arthropods to human food supply is by [pollination](/wiki/Pollination): a 2008 study examined the 100 crops that [FAO](/wiki/FAO) lists as grown for food, and estimated pollination's economic value as €153 billion, or 9.5% of the value of world agricultural production used for human food in 2005.[[85]](#cite_note-85) Besides pollinating, [bees](/wiki/Bee) produce [honey](/wiki/Honey), which is the basis of a rapidly growing industry and international trade.[[86]](#cite_note-86) The red dye [cochineal](/wiki/Cochineal), produced from a Central American species of insect, was economically important to the [Aztecs](/wiki/Aztec) and [Mayans](/wiki/Maya_civilization),[[87]](#cite_note-87) and while the region was under [Spanish](/wiki/Spain) control, becoming [Mexico's](/wiki/Mexico) second most-lucrative export;[[88]](#cite_note-88) and it is now regaining some of the ground it lost to synthetic competitors.[[89]](#cite_note-89) The blood of horseshoe crabs contains a clotting agent [Limulus Amebocyte Lysate](/wiki/Limulus_Amebocyte_Lysate) which is now used to test that antibiotics and kidney machines are free of dangerous [bacteria](/wiki/Bacteria), and to detect [spinal meningitis](/wiki/Spinal_meningitis) and some [cancers](/wiki/Cancer).[[90]](#cite_note-90) [Forensic entomology](/wiki/Forensic_entomology) uses evidence provided by arthropods to establish the time and sometimes the place of death of a human, and in some cases the cause.[[91]](#cite_note-91) Recently insects have also gained attention as potential sources of drugs and other medicinal substances.[[92]](#cite_note-92) The relative simplicity of the arthropods' body plan, allowing them to move on a variety of surfaces both on land and in water, have made them useful as models for [robotics](/wiki/Robot). The redundancy provided by segments allows arthropods and [biomimetic](/wiki/Biomimesis) robots to move normally even with damaged or lost appendages.[[93]](#cite_note-93)[[94]](#cite_note-94)

|  |  |  |  |
| --- | --- | --- | --- |
| Diseases transmitted by insects | | | |
| **Disease**[**[95]**](#cite_note-95) | **Insect** | **Cases per year** | **Deaths per year** |
| [Malaria](/wiki/Malaria) | [*Anopheles*](/wiki/Anopheles) mosquito | 267 M | 1 to 2 M |
| [Yellow fever](/wiki/Yellow_fever) | [*Aedes*](/wiki/Aedes) mosquito | 4,432 | 1,177 |
| [Filariasis](/wiki/Filariasis) | [*Culex*](/wiki/Culex) mosquito | 250 M | unknown |

Although arthropods are the most numerous phylum on Earth, and thousands of arthropod species are venomous, they inflict relatively few serious bites and stings on humans. Far more serious are the effects on humans of diseases carried by blood-sucking insects. Other blood-sucking insects infect [livestock](/wiki/Livestock) with diseases that kill many animals and greatly reduce the usefulness of others.[[95]](#cite_note-95) [Ticks](/wiki/Tick) can cause [tick paralysis](/wiki/Tick_paralysis) and several [parasite](/wiki/Parasite)-borne diseases in humans.[[96]](#cite_note-96) A few of the closely related [mites](/wiki/Mite) also infest humans, causing intense itching,[[97]](#cite_note-97) and others cause [allergic](/wiki/Allergy) diseases, including [hay fever](/wiki/Hay_fever), [asthma](/wiki/Asthma) and [eczema](/wiki/Eczema).[[98]](#cite_note-98) Many species of arthropods, principally insects but also mites, are agricultural and forest pests.[[99]](#cite_note-99)[[100]](#cite_note-100) The mite [*Varroa destructor*](/wiki/Varroa_destructor) has become the largest single problem faced by [beekeepers](/wiki/Beekeeper) worldwide.[[101]](#cite_note-101) Efforts to control arthropod pests by large-scale use of [pesticides](/wiki/Pesticide) have caused long-term effects on human health and on [biodiversity](/wiki/Biodiversity).[[102]](#cite_note-102) Increasing arthropod [resistance](/wiki/Pesticide_resistance) to pesticides has led to the development of [integrated pest management](/wiki/Integrated_pest_management) using a wide range of measures including [biological control](/wiki/Biological_control).[[99]](#cite_note-99) [Predatory](/wiki/Predator) mites may be useful in controlling some mite pests.[[103]](#cite_note-103)[[104]](#cite_note-104)[Template:Clear](/wiki/Template:Clear)

## See also[[edit](/index.php?title=(none)&action=edit&section=18)]

* [Invertebrate paleontology](/wiki/Invertebrate_paleontology)

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## Notes[[edit](/index.php?title=(none)&action=edit&section=19)]

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## References[[edit](/index.php?title=(none)&action=edit&section=20)]

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### Bibliography[[edit](/index.php?title=(none)&action=edit&section=21)]

* [Template:Citation](/wiki/Template:Citation)
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## External links[[edit](/index.php?title=(none)&action=edit&section=22)]

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* [Template:Eol](/wiki/Template:Eol)
* [Venomous Arthropods](http://entomology.ifas.ufl.edu/fasulo/vector/chapter_07.htm) chapter in [United States Environmental Protection Agency](/wiki/United_States_Environmental_Protection_Agency) and [University of Florida](/wiki/University_of_Florida)/[Institute of Food and Agricultural Sciences](/wiki/Institute_of_Food_and_Agricultural_Sciences) National Public Health Pesticide Applicator Training Manual
* [Arthropods - Arthropoda](http://www.insectlifeforms.com/Phylums488/JOINTED_LEGGED_ANIMALS_ARTHROPODA_6050_488.aspx) Insect Life Forms

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