Anopheles
(insect: dipteran)

Overview

Arthropods are coelomate metameric invertebrate animals with a chitinous exoskeleton and jointed limbs. They undergo protostomial embryonic development and grow by cuticular moulting (ecdysis). Three main subphyla are recognized: Chelicerata, Crustacea and Hexapoda. Insects are hexapods with three pairs of uniramous legs, three tagmata (head, thorax, abdomen), ectognathous mouthparts with whole-limb mandibles, and one pair of antennae. Diptera (true flies) have two pairs of wings, but the hindwings are reduced to stabilizing halteres. All species are holometabolans and exhibit complete metamorphosis whereby vermiform larval stages undergo pupation and transform into free-flying adults. Several major parasitic groups are recognized: nematocerans (small slender bodies, long filamentous antennae, narrow wings) and brachycerans (larger bodies, short stout antennae, broad wings); the latter being divided into the Tabanomorpha (larval head capsule sclerotized) and the Muscomorpha (larval head not sclerotized, circular-seamed (cyclorrhaphous) pupae). Nematocerans include the culicids (mosquitoes), ceratopogonids (midges); simuliids (black flies) and psychodids (sand flies): only the females are parasitic and have piercing-sucking mouthparts. Culicids have elongated mouthparts adapted for piercing plants and animals. Male mosquitoes feed on plant nectar and juices, whereas females also feed on blood from vertebrate hosts to obtain nutrients for egg production. Eggs are laid in or near water and both the larval and pupal stages are aquatic and mobile. Four genera are of considerable biomedical importance, both culicine (*Culex*, *Aedes*, *Mansonia*) and anopheline (*Anopheles*) mosquitoes being voracious feeders and transmission vectors for other diseases. Adult anopheline mosquitoes have spotted wings, long palps, rest with a raised abdomen, lay single eggs with floats and their larvae lack siphons. Bites by female mosquitoes are responsible for blood loss, annoyance, inflammation and hypersensitivity reactions. There are approximately 495 *Anopheles* spp. worldwide, with up to 100 species implicated in the transmission of malaria, arboviruses, filarial nematodes and canine heartworm.

Classification:

Domain:	Eukaryota (membrane-bound nucleus)
Supergroup:	Amorphea (unikonts with single flagellum, or nonflagellated amoebae)
Kingdom:	Metazoa (multicellular eukaryotes, heterotrophs, notably animals)
Group:	Protostomia (triploblastic, spiral cleavage)
Subgroup:	Ecdysozoa (cuticle moulted = ecdysis)
Phylum:	Arthropoda (chitinous exoskeleton, segmented body, jointed limbs, haemocoel)
Subphylum:	Hexapoda (three tagmata, three pairs uniramous legs, whole-limb mandibles, Malpighian tubules)
Class:	Insecta (ectognathous mouthparts (bases lie outside head capsule), single pair antennae, many with wings)
Superorder:	Holometabola (Endopterygota) (young do not resemble adults, pupae, with internally developing wings)
Order:	Diptera (true flies, single pair of forewings, hindwings modified into halteres, vermiform larvae)
Suborder:	Nematocera (midges/mosquitoes, long filamentous antennae, aquatic larvae/pupae)
Family:	Culicidae (mosquitoes, elongate mouthparts form proboscis, slender wings with scales on veins/margins)
Subfamily:	Anophelinae (scutellum rounded or straight, abdominal sternites lack scales, larva lacks air-tube)
Genus:	*Anopheles* (parasitic on skin of mammals/birds)
Species:	various species annoy vertebrate hosts, cause blood loss and dermal lesions, and transmit other diseases

Parasite biodiversity and host range: Most Metazoa are multicellular triploblastic animals with differentiated tissues, many being bilaterally symmetrical with a body cavity. Most invertebrate animals are protostomes as their embryonic development involves spiral determinate cleavage. Those that moult their external cuticles during their life-cycles (process known as ecdysis) are grouped together in the unique clade Ecdysozoa, including the nematodes (roundworms), onychophorans (velvet worms), tardigrades (water bears) and arthropods (myriapods, chelicerates, crustaceans and hexapods). Arthropods have small segmented bodies encased in chitinous exoskeletons with articulated limbs. Most species are free-living in terrestrial and aquatic habitats, although a small range are ectoparasitic on other animals, some feeding on the blood or skin of vertebrates. Five subphyla are recognized: Chelicerata, Crustacea, Hexapoda, Myriapoda and Trilobita. Insects are hexapods with six legs, three distinct body parts, two antennae and mouthparts with whole-limb mandibles. Insects are the most biodiverse group on the planet, with millions of species described in numerous taxa. Notorious ectoparasitic species belong to four orders in two superorders: the Hemipterodea (Exopterygota) containing the orders Hemiptera (bugs) and Phthiraptera (lice); and the Holometabola (Endopterygota) containing the orders Siphonaptera (fleas) and Diptera ('true' flies). Flies are small winged holometabolans that undergo complete (holometabolous) metamorphosis with vermiform larvae undergoing pupation in silk cocoons. Thousands of dipteran species have been described throughout the world, most being free-living saprophages (detritivores) but some being parasitic either as adults biting and feeding on hosts (often haematophagous) or producing larvae that invade host tissues (condition known as myiasis). Two major suborders are recognized: the Nematocera (with small bodies, long filamentous antennae, narrow wings and aquatic larvae and pupae); and the Brachycera (with large bodies, short stout antennae often with aristae and broad wings).

Major parasitic dipteran families	Biodiversity	Parasitic stages	Status	Pathogenesis*	Disease transmission
Suborder: Nematocera (small midges/mosquitoes, thread-horned with long filamentous segmented antennae (= nemato-cera), aquatic life-cycles (larval/pupal stages associated with water), female adults require blood meal before they can lay eggs) (34 families)					
Culicidae (mosquitoes)	3 subfamilies, 70 genera, 3,500 species	adult ♀	obligate	blood-sucking	viral, protozoal, helminth
Psychodidae (moth flies, sand flies)	5 subfamilies, 150 genera, 3,000 species	adult ♀	obligate	blood-feeding	viral, bacterial, protozoal
Simuliidae (black flies)	3 subfamilies, 30 genera, 2,000 species	adult ♀	obligate	blood-feeding	protozoal, helminth
Ceratopogonidae (biting midges)	4 subfamilies, 110 genera, 6,000 species	adult ♀	obligate	blood-feeding	viral, protozoal, helminth
Suborder: Brachycera (large tabanid/March flies, with stout and fewer antennal segments (= brachy-cera), antennae often with aristae, females with slashing-sponging mouthparts to pierce skin and feed on pool of blood (telmophagy)) (120 families)					
Infraorder: Tabanomorpha (larval head capsule incomplete posteriorly (only anterior parts sclerotized))					
Tabanidae (horse flies, deer flies)	3-5 subfamilies, 133 genera, 4,300 species	adult ♀ [+ larvae]	obligate [accidental]	blood-feeding [GI, UG, TR myiasis]	viral, bacterial, protozoal, helminth
Infraorder: Muscomorpha (Cyclorrhapha) (aristate antennae, setose bodies, cyclorrhaphous pupa)					
Section: Calyptratae (calypters cover halteres)					
Superfamily: Muscoidea (synanthropic flies)					
Muscidae (house flies, stable flies)	9-10 subfamilies, 190 genera, 4,200 species	adult ♀, ♂ [+ larvae]	obligate [accidental]	biting, blood-feeding [CU, GI, TR myiasis]	bacterial, helminth
Superfamily: Oestroidea (cause larval myiases) (6 families)					
Calliphoridae (blow flies)	11 subfamilies, 75 genera, 1,100 species	larvae	facultative, obligate	CU, GI, NP, AU, UG TR, myiasis	-
Sarcophagidae (flesh flies)	3 subfamilies, 108 genera, 2,500 species	larvae	facultative, obligate	TR, GI, CU myiasis	-
Oestridae (bot flies, warble flies)	5 subfamilies, 25 genera, 150 species	larvae	obligate	CU, GI, NP, OC myiasis	-
Superfamily: Hippoboscoidea (pupa-bearers)					
Glossinidae (tsetse flies)	1 genus, 3 species-groups, 25 species	adult ♀, ♂	obligate	blood	protozoal
Hippoboscidae (louse flies, keds)	1-3 subfamilies, 21 genera, 212 species	adult ♀, ♂	obligate	blood	viral, protozoal, helminth

*type of myiasis: AU = auricular; CU = cutaneous; GI = gastro-intestinal; NP = naso-pharyngeal; OC = ocular; TR = traumatic; UG = uro-genital.

The suborder Nematocera comprises small slender flies that are 'thread-horned' i.e. they possess long filamentous antennae composed of many articulating segments (= nemato-cera). Adults have long narrow wings (with many branching veins) and specialized mouthparts (short or long) with a protective sheath (labium and labellae) protecting feeding stylets (labrum, mandibles, maxillae and hypopharynx) and flanked by 4-5 segmented palps (usually pendulous but slender in mosquitoes). Many species have aquatic life-cycles (larval/pupal stages associated with water) and all undergo complete metamorphosis whereby adults eclose from puparia through longitudinal slits (rather than circular caps like Cyclorrapha). The suborder contains 7 infraorders: Axymyiomorpha (larvae in decomposing wood); Bibionomorpha (gnats, lovebugs); Blephariceromorpha (mountain midges); Culicomorpha (mosquitoes, midges, black flies); Psychodomorpha (moth flies); Ptychopteromorpha (primitive crane flies); and Tipulomorpha (crane flies). The infraorder Culicomorpha contains 2 superfamilies: Chironomoidea (biting, non-biting and trickle midges, black flies); and Culicoidea (midges, mosquitoes). The superfamily Culicoidea contains 4 families: Chaoboridae (phantom midges); Corethrellidae (frog-biting midges); Dixidae (meniscus midges); and Culicidae (mosquitoes). The family Culicidae are characterized

by adults with thin elongate bodies with long mouthparts forming a conspicuous forward-projecting proboscis, slender wings with scales covering wing veins and at least 10 veins reaching the wing margins, and long filamentous antennae (males with plumose aristae, females with fewer shorter hairs). Several thousand mosquito species have been described in around 70 genera in 3 subfamilies: Anophelinae with 3 genera (*Anopheles, Bironella, Chagasia*); Toxorhynchitinae with 1 genus (*Toxorhynchites*); and Culicinae with 9 tribes and over 30 genera (including *Aedes, Culex*, *Mansonia*); with another 15 unplaced genera and 5 fossil genera.

Subfamily	Genera*	Preferred hosts	Site	Transmission
Culicinae	*Culex* (*Cx.*)	mammals, birds	skin	free-flying adults seek hosts
	Aedes (*Ae.*)	mammals, birds	skin	free-flying adults seek hosts
	Mansonia (*Ma.*)	mammals, birds	skin	free-flying adults seek hosts
Anophelinae	*Anopheles* (*An.*)	mammals, birds	skin	free-flying adults seek hosts

*Genus name given with internationally-recognized 2-letter abbreviation.

Anopheline mosquitoes are characterized by adults having a rounded or straight scutellum, abdominal sternites lacking scales, and larval stages without air-tubes. Members of the genus *Anopheles* (syn. *Baimaia*) are found near water throughout the world, except Antarctica. They are mainly distributed around equatorial and tropical regions, but can be found in cooler climates. In many areas, they are found in close association with human populations due to activities such as deforestation and irrigation which displace or extend suitable habitats. Female *Anopheles* mosquitoes feed on many mammalian species, including humans, domestic and wild animals. They are not exclusively human (anthropophilic) or animal (zoophilic) and most mosquito species are host preferential rather than host specific. Their biting behaviour may cause considerable annoyance to their hosts, sometimes exacerbated by host inflammation and hypersensitivity. Over 495 *Anopheles* spp. have been described in 8 subgenera, with a growing number of species proving to be highly efficient vectors for the transmission of various blood-borne diseases in animals and humans, particularly those caused by arbo-viruses (= arthropod-borne viruses), haemoprotozoa and filarial nematodes, including encephalitis syndromes, canine heartworm, lymphatic filariasis (leading to elephantiasis) and malaria (in both animals and humans) (summarized below).

***Anopheles* species (regional exemplars)**	**Hosts**	**Vectorial capacity**	**Distribution**
An. atroparvus, claviger, hispaniola, labranchiae, messeae, pattoni, sacharovi, sinensis	humans	haemoprotozoa (malaria)	Europe
An. albimanus, albitarsis, allopha, aquasalis, argyritarsis, aztecus, bellator, braziliensis, cruzii, darlingi, freeborni, pseudopunctipennis, punctimacula, punctipennis, quadrimaculatus, nuneztovari	humans, primates	haemoprotozoa (malaria), filarial nematodes (*Wuchereria*)	Americas
An. arabiensis, bwambae, christyi, funestus, gambiae, hispaniola, melas, merus, moucheti, multicolor, nili, paulini, pharoensis, sergenti	humans	haemoprotozoa (malaria); filarial nematodes (*Wuchereria*)	Africa
An. gambiae, funestus	mammals, humans	togaviruses (O'nyong-nyong)	Africa
An. cinctus, dureni, marchadyi, smithi	rodents	haemoprotozoa (malaria)	Africa, Asia
An. annularis, culicifacies, dirus, fluviatilis, maculatus, minimus, nigerrimus, pulcherrimus, sacharovi, stephensi, superpictus, tesselatus	humans	haemoprotozoa (malaria)	Central Asia
An. aconitus, anthropophagus, balabacensis, campestris, candidiensis, dirus, donaldi, elegans, flavirostris, hackeri, introlatus, kweiyangensis, letifer, leucophryus, ludlowae, maculatus, minimus, nigerrimus, pattoni, philippinensis, sinensis, subpictus, sundiacus, vagus, whartoni	humans, primates	haemoprotozoa (malaria); filarial nematodes (*Wuchereria*)	Asia
An. anthropophagus, barbirostris, campestris, donaldi, kweiyangensis, nigerrimus, sinensis	humans	filarial nematodes (*Brugia*)	Asia
An. annulipes, bancrofti, farauti, karwari, koliensis, punctulatus, subpictus	humans	leporivirus (myxoma); haemoprotozoa (malaria); filarial nematodes (*Wuchereria*)	Australasia
An. crucians, punctipennis	mammals	filarial nematodes (*Dirofilaria*)	cosmopolitan

Full species list (compilation of several on-line databases)

***Anopheles* species**	**Subgenus**
An. aberrans	*Anopheles*
An. acaci	*Anopheles*
An. acanthotorynus	*Stethomyia*
An. aconitus	*Cellia*
An. africanus	Unassigned
An. ahomi	*Anopheles*
An. ainshamsi	*Cellia*
An. aitkenii	Unassigned
An. albertoi	*Nyssorhynchus*
An. albimanus	*Nyssorhynchus*
An. albitarsis	*Nyssorhynchus*
An. albotaeniatus	*Anopheles*
An. algeriensis	*Anopheles*
An. alongensis	*Anopheles*
An. amharicus	*Cellia*
An. amictus	*Cellia*
An. anchietai	*Anopheles*
An. annandalei	*Anopheles*
An. annularis	*Cellia*
An. annulatus	Unassigned
An. annulipalpis	*Anopheles*
An. annulipes	*Cellia*
An. anomalophyllus	*Nyssorhynchus*
An. anthropophagus	Unassigned
An. antunesi	*Nyssorhynchus*
An. apicimacula	*Anopheles*
An. apoci	*Cellia*
An. aquasalis	*Nyssorhynchus*
An. arabiensis	*Cellia*
An. arboricola	*Anopheles*
An. ardensis	*Cellia*
An. argenteolobatus	*Cellia*
An. argyritarsis	*Nyssorhynchus*
An. argyropus	*Anopheles*
An. arnoulti	Unassigned
An. artemievi	*Anopheles*
An. arthuri	*Nyssorhynchus*
An. aruni	*Cellia*
An. asiatica	*Lophomyia*
An. asiaticus	*Anopheles*
An. atacamensis	*Nyssorhynchus*
An. atratipes	*Anopheles*
An. atroparvus	*Anopheles*
An. atropos	*Anopheles*
An. aurirostris	*Cellia*
An. austenii	*Cellia*
An. auyantepuiensis	*Kerteszia*
An. azaniae	*Cellia*
An. azevedoi	*Cellia*
An. aztecus	*Anopheles*
An. baezai	*Anopheles*
An. baileyi	*Anopheles*
An. baimaii	*Cellia*
An. baisasi	*Cellia*
An. balabacensis	*Cellia*
An. balerensis	*Anopheles*
An. bambusicolus	*Kerteszia*
An. bancroftii	Unassigned
An. barberellus	*Cellia*
An. barberi	*Anopheles*
An. barbirostris	*Anopheles*
An. barbumbrosus	*Anopheles*
An. barianensis	*Anopheles*
An. beklemishevi	*Anopheles*
An. belenrae	*Anopheles*
An. bellator	*Kerteszia*
An. benarrochi	*Nyssorhynchus*
An. bengalensis	*Anopheles*
An. berghei	*Cellia*
An. bervoetsi	*Cellia*
An. boliviensis	*Kerteszia*
An. borneensis	*Anopheles*
An. brachypus	Unassigned
An. bradleyi	*Anopheles*
An. braziliensis	*Nyssorhynchus*
An. brevipalpis	*Anopheles*
An. brevirostris	*Anopheles*
An. brohieri	*Cellia*
An. brucei	*Cellia*
An. brumpti	*Cellia*
An. brunnipes	*Cellia*
An. bulkleyi	*Anopheles*
An. bustamentei	*Anopheles*
An. buxtoni	*Cellia*
An. bwambae	*Cellia*
An. calderoni	*Anopheles*
An. caliginosus	*Anopheles*
An. cameroni	*Cellia*
An. campestris	*Anopheles*
An. canorii	*Stethomyia*
An. carnevalei	*Cellia*
An. caroni	*Cellia*
An. carteri	*Cellia*
An. chiriquiensis	*Anopheles*
An. chodukini	*Anopheles*
An. christyi	*Cellia*
An. cinctus	*Cellia*
An. cinereus	Unassigned
An. claviger	*Anopheles*
An. clowi	*Cellia*
An. colledgei	*Anopheles*
An. collessi	*Anopheles*
An. coluzzii	*Cellia*
An. comorensis	*Cellia*
An. concolor	*Anopheles*
An. confusus	*Cellia*
An. corethroides	*Anopheles*
An. costai	*Anopheles*
An. costalis	Unassigned
An. courdurieri	Unassigned
An. coustani	*Anopheles*
An. cracens	*Cellia*
An. crawfordi	*Anopheles*

An. cristatus	*Cellia*
An. cristipalpis	*Cellia*
An. crucians	*Anopheles*
An. cruzii	*Kerteszia*
An. crypticus	*Anopheles*
An. cucphuongensis	*Anopheles*
An. culicifacies	*Cellia*
An. culiciformis	*Anopheles*
An. culifacies	Unassigned
An. cydippis	*Cellia*
An. daciae	*Anopheles*
An. dancalicus	*Cellia*
An. darlingi	*Nyssorhynchus*
An. daudi	*Cellia*
An. deaneorum	*Nyssorhynchus*
An. deemingi	*Cellia*
An. demeilloni	*Cellia*
An. diluvialis	*Anopheles*
An. dirus	*Cellia*
An. dispar	*Cellia*
An. dissidens	*Anopheles*
An. distinctus	*Cellia*
An. domicolus	*Cellia*
An. dominicanus (fossil)	Unassigned
An. donaldi	*Anopheles*
An. dravidicus	*Cellia*
An. dthali	*Cellia*
An. dualaensis	*Cellia*
An. dunhami	*Nyssorhynchus*
An. dureni	*Cellia*
An. earlei	*Anopheles*
An. eiseni	Unassigned
An. ejercitoi	*Anopheles*
An. elegans	*Cellia*
An. engarensis	*Anopheles*
An. eouzani	*Cellia*
An. epiroticus	*Cellia*
An. erepens	*Cellia*
An. erythraeus	*Cellia*
An. ethiopicus	*Cellia*
An. evandroi	*Anopheles*
An. evansae	*Nyssorhynchus*
An. faini	*Cellia*
An. farauti	*Cellia*
An. fausti	*Anopheles*
An. filipinae	*Cellia*
An. flavicosta	*Cellia*
An. flavirostris	*Cellia*
An. fluminensis	*Anopheles*
An. fluviatilis	*Cellia*
An. fontinalis	*Cellia*
An. forattinii	*Anopheles*
An. fragilis	*Anopheles*
An. franciscanus	*Anopheles*
An. franciscoi	*Anopheles*
An. freeborni	*Anopheles*
An. freetownensis	*Cellia*
An. freyi	*Anopheles*
An. funestus	*Cellia*
An. fuscicolor	*Anopheles*
An. fuscivenosus	*Cellia*

An. gabaldoni	*Anopheles*
An. gabonensis	*Cellia*
An. galvaoi	*Nyssorhynchus*
An. gambiae	*Cellia*
An. garnhami	Unassigned
An. georgianus	*Anopheles*
An. gibbinsi	Unassigned
An. gigas	*Anopheles*
An. gilesi	*Lophopodomyia*
An. goeldii	*Nyssorhynchus*
An. gomezdelatorrei	*Lophopodomyia*
An. gonzalezrinconesi	*Kerteszia*
An. grabhamii	*Anopheles*
An. gracilis	Unassigned
An. grassei	*Cellia*
An. greeni	*Cellia*
An. grenieri	*Cellia*
An. griveaudi	*Cellia*
An. guarani	*Nyssorhynchus*
An. guarao	*Anopheles*
An. hackeri	*Cellia*
An. hailarensis	*Anopheles*
An. halophylus	*Nyssorhynchus*
An. hamoni	*Cellia*
An. hancocki	*Cellia*
An. hargreavesi	*Cellia*
An. harperi	*Cellia*
An. harrisoni	*Cellia*
An. hectoris	*Anopheles*
An. heiheensis	*Anopheles*
An. hermsi	*Anopheles*
An. hervyi	*Cellia*
An. hilli	*Cellia*
An. hinesorum	*Cellia*
An. hodgkini	*Anopheles*
An. homunculus	*Kerteszia*
An. hughi	*Cellia*
An. hunteri	*Anopheles*
An. hyrcanus	*Anopheles*
An. implexus	*Christya*
An. incognitus	*Cellia*
An. indefinitus	*Cellia*
An. ininii	*Nyssorhynchus*
An. insulaeflorum	*Anopheles*
An. intermedius	Unassigned
An. interruptus	*Anopheles*
An. introlatus	*Cellia*
An. inundatus	*Anopheles*
An. irenicus	*Cellia*
An. jacobi	Unassigned
An. jamesii	*Cellia*
An. janconnae	*Nyssorhynchus*
An. jebudensis	*Cellia*
An. jeyporiensis	*Cellia*
An. judithae	*Anopheles*
An. karwari	*Cellia*
An. keniensis	*Cellia*
An. kiangsuensis	Unassigned
An. kingi	*Cellia*
An. kleini	*Anopheles*
An. kochi	*Cellia*

An. kokhani	*Cellia*
An. kolambuganensis	*Cellia*
An. koliensis	*Cellia*
An. kompi	*Stethomyia*
An. konderi	*Nyssorhynchus*
An. koreicus	*Anopheles*
An. kosiensis	*Cellia*
An. kweiyangensis	*Anopheles*
An. kyondawensis	*Baimaia*
An. labranchiae	*Anopheles*
An. lacani	*Cellia*
An. laneanus	*Kerteszia*
An. lanei	*Nyssorhynchus*
An. latens	*Cellia*
An. leesoni	*Cellia*
An. lepidotus	*Kerteszia*
An. lesteri	*Anopheles*
An. letabensis	*Cellia*
An. letifer	*Anopheles*
An. leucosphyrus	*Cellia*
An. lewisi	*Anopheles*
An. liangshanensis	*Anopheles*
An. limosus	*Cellia*
An. lindesayi	Unassigned
An. listeri	*Cellia*
An. litoralis	*Cellia*
An. lloreti	*Cellia*
An. longipalpis	*Cellia*
An. longirostris	*Cellia*
An. lounibosi	*Cellia*
An. lovettae	*Cellia*
An. ludlowae	Unassigned
An. lungae	*Cellia*
An. lutzii	*Nyssorhynchus*
An. macarthuri	*Cellia*
An. machardyi	*Cellia*
An. maculatus	*Cellia*
An. maculipalpis	*Cellia*
An. maculipennis	*Anopheles*
An. maculipes	*Anopheles*
An. majidi	*Cellia*
An. malefactor	*Anopheles*
An. maliensis	*Cellia*
An. manalangi	*Anopheles*
An. mangyanus	*Cellia*
An. marajoara	*Nyssorhynchus*
An. marshallii	*Cellia*
An. marteri	*Anopheles*
An. martinius	*Anopheles*
An. mascarensis	*Cellia*
An. mattogrossensis	*Anopheles*
An. maverlius	*Anopheles*
An. medialis	Unassigned
An. mediopunctatus	*Anopheles*
An. melanoon	*Anopheles*
An. melas	*Cellia*
An. menglangensis	*Anopheles*
An. meraukensis	*Cellia*
An. merus	*Cellia*
An. messeae	*Anopheles*
An. millecampsi	*Cellia*

An. milloti	*Cellia*
An. minimus	*Cellia*
An. minor	*Anopheles*
An. minutus	Unassigned
An. mirans	*Cellia*
An. moghulensis	*Cellia*
An. montanus	*Anopheles*
An. mortiauxi	*Cellia*
An. moucheti	Unassigned
An. mousinhoi	*Cellia*
An. multicinctus	*Cellia*
An. multicolor	*Cellia*
An. murphyi	*Cellia*
An. namibiensis	*Anopheles*
An. natalensis	*Cellia*
An. nataliae	*Cellia*
An. neivai	*Kerteszia*
An. nemophilous	*Cellia*
An. neomaculipalpus	*Anopheles*
An. nero	Unassigned
An. nigerrimus	*Anopheles*
An. nigritarsis	*Nyssorhynchus*
An. nilgiricus	*Anopheles*
An. nili	*Cellia*
An. nimbus	*Stethomyia*
An. nimpe	*Anopheles*
An. nitidus	*Anopheles*
An. nivipes	*Cellia*
An. njombiensis	*Cellia*
An. noniae	*Anopheles*
An. notanandai	*Cellia*
An. notleyi	*Cellia*
An. novaguinensis	*Cellia*
An. nuneztovari	*Nyssorhynchus*
An. obscurus	*Anopheles*
An. occidentalis	*Anopheles*
An. oiketorakras	*Lophopodomyia*
An. okuensis	*Christya*
An. omorii	*Anopheles*
An. oreios	*Cellia*
An. oryzalimnetes	*Nyssorhynchus*
An. oswaldoi	*Nyssorhynchus*
An. ovengensis	*Cellia*
An. pallidus	*Cellia*
An. palmatus	*Anopheles*
An. paltrinierii	*Cellia*
An. paludis	*Anopheles*
An. pampanai	*Cellia*
An. papuensis	*Anopheles*
An. parangensis	*Cellia*
An. parapunctipennis	Unassigned
An. parensis	*Cellia*
An. parvus	*Myzorhynchella*
An. pattoni	*Cellia*
An. pauliani	*Cellia*
An. peditaeniatus	*Anopheles*
An. perplexens	*Anopheles*
An. persiensis	*Anopheles*
An. peryassui	*Anopheles*
An. petragnani	*Anopheles*
An. peytoni	*Anopheles*

An. pharoensis	*Cellia*
An. philippinensis	*Cellia*
An. pholidotus	*Kerteszia*
An. pictipennis	*Nyssorhynchus*
An. pilinotum	*Anopheles*
An. pinjaurensis	*Anopheles*
An. plumbeus	*Anopheles*
An. pollicaris	*Anopheles*
An. powderi	*Anopheles*
An. powelli	*Anopheles*
An. prachongae	*Anopheles*
An. pretoriensis	*Cellia*
An. pristinus	Unassigned
An. pseudobarbirostris	*Anopheles*
An. pseudojamesi	*Cellia*
An. pseudomaculipes	*Anopheles*
An. pseudopictus	*Anopheles*
An. pseudopunctipennis	Unassigned
An. pseudosinensis	*Anopheles*
An. pseudostigmaticus	*Anopheles*
An. pseudosundaicus	*Cellia*
An. pseudotibiamaculatus	*Lophopodomyia*
An. pseudowillmori	*Cellia*
An. pujutensis	*Cellia*
An. pulcherrimus	*Cellia*
An. pullus	*Anopheles*
An. punctimacula	*Anopheles*
An. punctipennis	*Anopheles*
An. punctulatus	*Cellia*
An. pursati	*Anopheles*
An. quadriannulatus	*Cellia*
An. quadrimaculatus	*Anopheles*
An. rachoui	*Anopheles*
An. radama	*Cellia*
An. rageaui	*Cellia*
An. rampae	*Cellia*
An. ranci	*Cellia*
An. rangeli	*Nyssorhynchus*
An. recens	*Cellia*
An. reidi	*Anopheles*
An. rennellensis	*Cellia*
An. rhodesiensis	*Cellia*
An. riparis	*Cellia*
An. rivulorum	*Cellia*
An. rodhaini	*Cellia*
An. rollai	*Kerteszia*
An. rondoni	*Nyssorhynchus*
An. roperi	*Anopheles*
An. rottensis (fossil)	Unassigned
An. roubaudi	*Cellia*
An. ruarinus	*Cellia*
An. rufipes	*Cellia*
An. sacharovi	*Anopheles*
An. saeungae	*Anopheles*
An. salbaii	*Cellia*
An. samarensis	*Anopheles*
An. sanctielii	*Nyssorhynchus*
An. saperoi	Unassigned
An. saungi	*Cellia*
An. sawadwongporni	*Cellia*
An. sawyeri	*Nyssorhynchus*

An. scanloni	*Cellia*
An. schueffneri	*Cellia*
An. schwetzi	*Cellia*
An. separatus	*Anopheles*
An. seretsei	*Cellia*
An. sergentii	Unassigned
An. seydeli	*Cellia*
An. shannoni	*Anopheles*
An. similissimus	*Anopheles*
An. sinensis	*Anopheles*
An. sineroides	*Anopheles*
An. sintoni	*Anopheles*
An. sintonoides	*Anopheles*
An. smaragdinus	*Anopheles*
An. smithii	*Cellia*
An. soalalaensis	*Anopheles*
An. solomonis	*Cellia*
An. somalicus	*Cellia*
An. splendidus	*Cellia*
An. squamifemur	*Lophopodomyia*
An. squamosus	*Cellia*
An. stephensi	*Cellia*
An. stigmaticus	*Anopheles*
An. stookesi	*Cellia*
An. striatus	*Nyssorhynchus*
An. stricklandi	*Anopheles*
An. strodei	*Nyssorhynchus*
An. subpictus	*Cellia*
An. sulawesi	*Cellia*
An. sumatranus	*Anopheles*
An. sundaicus	*Cellia*
An. superpictus	*Cellia*
An. swahilicus	*Cellia*
An. symesi	*Anopheles*
An. takasagoensis	*Cellia*
An. tasmaniensis	*Anopheles*
An. tchekedii	*Cellia*
An. tenebrosus	*Anopheles*
An. tessellatus	Unassigned
An. theileri	*Cellia*
An. theobaldi	*Cellia*
An. thomasi	*Stethomyia*
An. tibiamaculatus	*Anopheles*
An. tigertti	*Anopheles*
An. torresiensis	*Cellia*
An. triannulatus	*Nyssorhynchus*
An. trinkae	*Nyssorhynchus*
An. turkhudi	Unassigned
An. umbrosus	*Anopheles*
An. upemba	Unassigned
An. vagus	*Cellia*
An. vanderwulpi	*Anopheles*
An. vaneedeni	*Cellia*
An. vanhoofi	*Cellia*
An. vanus	*Anopheles*
An. vargasi	*Lophopodomyia*
An. varuna	*Cellia*
An. vernus	*Cellia*
An. veruslanei	*Anopheles*
An. vestitipennis	*Anopheles*
An. vietnamensis	*Anopheles*

An. vinckei	*Cellia*
An. vulgaris	Unassigned
An. walkeri	*Anopheles*
An. walravensi	*Cellia*
An. watsonii	*Cellia*
An. wejchoochotei	*Anopheles*
An. wellcomei	Unassigned
An. wellingtonianus	*Anopheles*

An. whartoni	*Anopheles*
An. willmorei	*Cellia*
An. wilsoni	Unassigned
An. xelajuensis	*Anopheles*
An. xui	*Anopheles*
An. yaeyamaensis	Unassigned
An. ziemanni	*Anopheles*

Parasite morphology: Mosquitoes form four developmental stages: eggs, larvae (four instars), pupae and adults (imagos). Eggs appear as brown ellipsoidal bodies 1-4 mm in length with a pair of lateral floats for buoyancy. They occur singly on the water surface and are not collected into flotation rafts like many culicine species. Mosquito larvae (wrigglers or wigglers) have dark tubular bodies with a small rounded head, globular thorax and elongate segmented abdomen. The head has chewing mouthparts with an anterior mouth brush, 2 lateral antennae and 2 eyes comprised of clusters of lateral ocelli. The thorax is often highly setate and the abdomen terminates in a short plate bearing respiratory spiracles (unlike the air tubes (respiratory siphon) of culicine larvae) and a lateral anal segment with long setae in conspicuous brushes. The wrigglers swim to the water surface at frequent intervals to breathe through their posterior spiracles by floating parallel to the water surface (not head-down like culicine larvae). Four larval stages are formed - all being similar in morphology but becoming successively larger (first stage larvae measure up to 1.5 mm in length and fourth stage larvae up to 8-10 mm). Mosquito pupae (tumblers) are comma-shaped when viewed from the side, translucent and about 3.5 mm in length. The head and thorax are merged into a large cephalothorax with the abdomen curving underneath. Pupae breathe through a pair of respiratory trumpets on the cephalothorax. Adult *Anopheles* mosquitoes are small winged insects with slender bodies up to 12 mm long, elongate mouthparts, thin legs and narrow wings. Their bodies are covered with scales, setae and fine hairs which give distinctive marking for each species. Anopheline mosquitoes commonly have brown to grey bodies and often have spotted wings. The body is divided into a small rounded head, a globular thorax, and a long segmented abdomen. When at rest, anopheline mosquitoes hold their abdomen in the air in line with their proboscis, both forming an acute angle to the substrate (whereas culicine mosquitoes rest with their abdomen more or less parallel to the substrate but at an angle to their proboscis). The head has 2 large compound eyes consisting of hundreds of ommatidial lenses wrapped around the front and sides, with long filamentous segmented antennae arising between the eyes (pilose in females and plumose in males). Both male and female anopheline mosquitoes have 2 elongate anterior palps, almost as long as the proboscis (unlike culicine mosquitoes whose females have short palps). The palps in male anophelines are also broadened (clubbed) at their tips (not clubbed in culicines). The long anterior proboscis (often as long as the head and thorax combined) contains complex piercing-sucking mouthparts consisting of a delicate labium (with terminal labella) forming a protective sheath for the other stylet-like mouthparts (fascicle comprising labrum, pair of mandibles, hypopharynx and pair of maxillae). The mandibles (with pointed tips) and maxillae (with serrated tips) are used to puncture skin, and then the labrum (with curled edges) fits together with the mandibles to form a tubular food canal, while the hypopharynx forms a salivary canal. Female mosquitoes use their mouthparts to feed on blood from vertebrate hosts or sugar solutions from plants, whereas males do not feed on blood as their mandibles and maxillae have atrophied and cannot pierce skin. Liquid food is ingested with the aid of muscular cibarial and pharyngeal pumps into the tubular oesophagus. Dilute fluids (plant sugars) are shunted for temporary storage into saccular diverticula (ventral diverticulum often called the crop) whereas nutrient-rich foods (blood) are routed through the proventricular valve to the tubular midgut (for digestion), hindgut (connected to Malpighian excretory tubules), bulbous rectum and terminal anus. The thorax has 2 pairs of respiratory spiracles and is covered by a rigid scutum with a posterior scutellum and conspicuous bristles (setae absent from prespiracular and postspiracular areas). Dorsally, the thorax is the point of attachment for a pair of slender membranous wings with small squamae framed by prominent veins (distinctive pattern of costa (C), subcosta (Sc), radius (R), media (M), cubitus (Cu) and anal (A) primary veins and branches). The wings often appear spotted due to patches of dark and light scales (whereas the wings of culicine mosquitoes usually appear light). The posterior thorax also contains a small pair of club-like halteres (highly reduced hindwings thought to help stabilize flight). Ventrally, the thorax gives rise to 3 pairs of long thin legs, each consisting of 5 segments (coxa, trochanter, femur, tibia and tarsus) with the terminal tarsi carrying 2 claws (pulvilli absent) surrounding a central pad (empodium). The abdomen is clearly segmented and capable of massive expansion (to accommodate large meals and developing eggs) due to membranous areas between each set of tergites and sternites. The posterior abdomen may be pointed or blunt depending on the species and abdominal scales are absent. Typically, 7 pairs of spiracles are found along the edges of the abdomen segments, and paired gonads are located within the posterior abdomen. The terminal abdominal segments are often modified by genital structures (ventral gonopores, female postgenital lobes (cerci), and male terminalia (including claspers)). Mature males have 2 testes with tubular vas deferens leading to a seminal vesicle (with lateral accessory glands) connected to a tubular ejaculatory duct that discharges through a retractable aedeagus (penis). Female mosquitoes have 2 ovaries (with polytrophic ovarioles) whose ducts unite to form a common oviduct connected to the gonopore via a genital chamber associated with spermathecae (for sperm storage) and small accessory glands.

Site of infection: Pre-adult developmental stages of mosquitoes occur in aquatic habitats. Larvae feed on organic material in water by filtering or gathering suspended material, scraping or shredding material from substrates and plants, and some species even prey on small aquatic invertebrates. Pupae are non-feeding aquatic stages which undergo metamorphosis to form winged adults. All adult mosquitoes are free-flying and move about their environments seeking food sources and mates. Both male and female *Anopheles* mosquitoes are able to feed on natural sugars from flowers and rotting fruits. However, females are also haematophagous (blood-

feeding) ectoparasites on vertebrate hosts. Blood provides an iron-rich protein source necessary for the production of eggs. Mosquitoes are attracted to hosts by carbon dioxide plumes and other breath chemicals, body odours and heat. Bite sites are related to convection currents around their hosts: when standing, they will bite around the foot or heel region, but if lying down, they will bite any body part close to the ground, including the torso. Many *Anopheles* spp. bite during the night (nocturnal) when their host sleeps, other species are active at dawn or dusk (crepuscular), and some will enter dwellings to feed (endophagic) and rest (endophilic). They may feed on a wide variety of sympatric vertebrate hosts (mammals, birds and reptiles), although many species have strong preferences for particular host species (especially ungulates, carnivores, rodents and birds). *Anopheles* spp. are distributed throughout the world, being particularly numerous in tropical and subtropical regions but also inhabiting cool temperate zones.

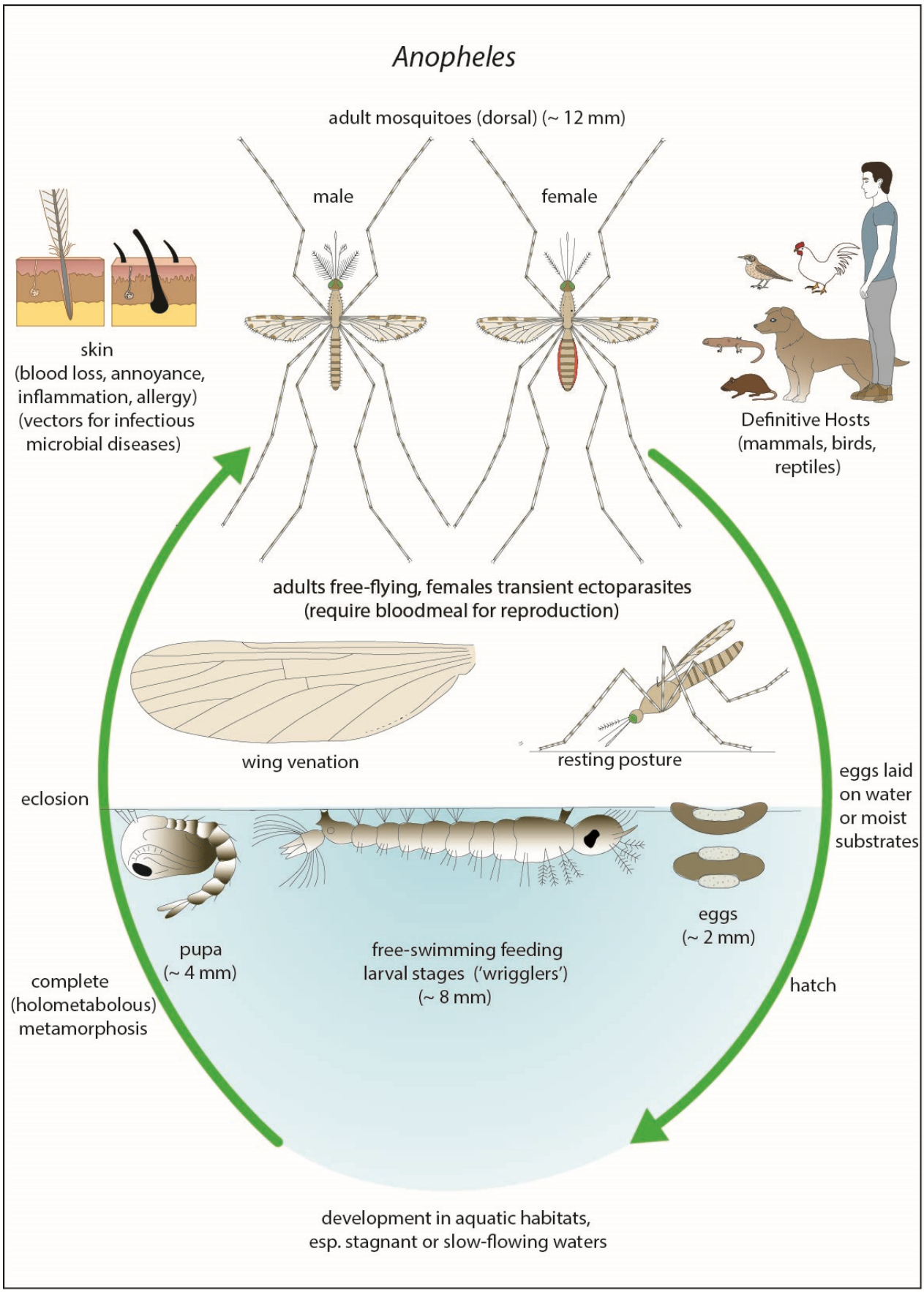
Pathogenesis: Female mosquitoes use their proboscis to pierce the skin of vertebrate hosts, penetrate small blood vessels and inject saliva before and during blood-feeding. Mosquito saliva contains several potent vaso-active chemicals with anti-coagulant, anti-platelet and vasodilatory activities. Initial exposure to mosquitoes often elicits little reaction, but subsequent bites show inflammatory reactions involving reddened (erythematous) papules and wheals around the puncture site. Bites may elicit itching sensation (pruritus) which induce scratching and may lead to secondary infections. Severely affected animals may develop papular dermatitis with cutaneous oedema, epidermal ulceration, crusting, and alopecia. Mosquito swarms can cause significant blood loss (anaemia) as well as considerable irritation and annoyance (biting stress) leading to risky and energetic aversion behaviours. Domestic livestock may be distracted from feeding and exhibit poor growth with lowered weight gains and reduced milk production. Repeated and persistent attack can result in hypersensitivity (immediate type I and/or delayed type IV) and severe allergic reactions (Skeeter syndrome), sometimes with unusual local or systemic effects such as angioedema, urticaria, wheezing, skin rashes and anaphylaxis. *Anopheles* mosquitoes also act as biological vectors for various infectious diseases, particularly viruses (incl. togaviruses, flaviviruses and bunyaviruses, collectively known as “arbo-viruses” (= arthropod-borne viruses)), protozoa (especially haemosporidians causing malaria) and nematodes (filarial worms). Various *Anopheles* spp. have been found to be highly efficient vectors for the transmission of viruses causing infectious equine anaemia, equine encephalitis and rabbit myxomatosis, nematodes causing canine heartworm (*Dirofilaria*) and human lymphatic filariasis (*Wuchereria* and *Brugia* spp.), and haemosporidia causing some mammalian, avian and reptilian malaria (note that anopheline mosquitoes are the sole vectors for the *Plasmodium* spp. causing human malaria]. Curiously, *Anopheles* spp. are not known to act as biological vectors for bacteria, although some species have been shown to be capable of mechanically transferring some bacterial species causing tularaemia and anthrax.

Developmental cycle and mode of transmission: Adult mosquitoes are efficient flyers and they actively seek hosts using chemotactic mechanisms, especially homing in on carbon dioxide plumes from expired breath. They can fly up to a few kilometres in their 2-3 week life-span, though females stay close to water sources to lay eggs. Females may deposit anywhere from 50-200 eggs per oviposition on the water surface, and the eggs have characteristic lateral floats that prevent them from sinking. The eggs hatch in 1-4 days releasing larvae which feed on organic material (detritus and micro-organisms) in stagnant or slow-flowing waters (pools, ponds, puddles, flooded tree-holes and even temporary water-filled containers). Anopheline larvae lie parallel to the water surface and breathe through pair of spiracles at the posterior end of the abdomen (while culicine larvae hang suspended from the water surface and breathe through prominent air tubes). The larvae develop through 4 instars over 3-20 days depending on environmental conditions, particularly water temperature and availability of larval food sources. The final larval instar then forms a non-feeding pupa in which to undergo complete metamorphosis. The pupae remain at the water surface breathing air using prothoracic respiratory siphons, but they can be highly mobile if disturbed. Pupation is completed within 1-7 days when the pupal case splits to release the adult which rests on nearby objects to harden its cuticle and inflate its wings. Adults then fly about their environments feeding on nectar and plant juices. Mating often occurs within 24 hours of emergence, but females are anautogenous and require bloodmeals from vertebrate hosts to complete their gonotrophic cycles and produce eggs. Females can bite multiple times and may take up to 3 bloodmeals before resting for several days prior to laying eggs.

Differential diagnosis: The visual detection of mosquitoes in the process of feeding is often not possible due to their nocturnal and transient feeding habits. Any resultant host reactions to bites are nonspecific and frequently delayed in onset. Capturing mosquitoes (by spraying or trapping) allows for their microscopic examination (using a magnifying lens or microscope) and identification. *Anopheles* species can be distinguished from other mosquito genera by the presence of black and white scales on their wings, the length of their palps being equal to the proboscis, and the elevated angle of their abdomens when resting (rather than being parallel to the resting surface). In some cases, serological tests for host antibodies to *Anopheles*-specific salivary proteins can be used to diagnose previous contact and the state of host immunity, especially in allergic or immunocompromised patients. A range of molecular biological techniques using polymerase chain reaction (PCR) amplification of specific gene sequences have been used on mosquito extracts to identify putative sources of bloodmeals, infer phylogenetic relationships between mosquito taxa, and also detect infectious micro-organisms carried by mosquitoes.

Treatment and control: There are currently no direct treatments for mosquito bites, apart from providing symptomatic relief using corticosteroids, antihistamines and anti-pruritic lotions, especially in allergic patients. Various insecticides have been developed to

kill adult mosquitoes, most containing organophosphates (dioxathion, fenchlorvos), organophosphonates (chlorfenvinphos, trichlorfon), monothiophosphates (coumaphos, diazinon), dithiophosphates (malathion, phosmet), carbamates or pyrethrum and its derivatives (permethrin, cyfluthrin, cypermethrin). Various formulations may be used as aerosol and/or topical sprays, dust-bags or impregnated into eartags which can also be affixed to animal collars and halters. Several traps have been developed to bait and immobilize or electrocute flying insects, and various insect repellents are available as sprays or lotions, notably those containing diethyltoluamide (DEET). Many control programs have been based on the indoor residual spraying of insecticides but their success has been compromised by the emergence of insecticide resistance by mosquito populations. Barriers can be used to separate mosquitoes from their hosts, including installing window screens, screening beds with impregnated nets, and covering exposed skin with clothing. Reducing mosquito larvae populations has proven very successful, mainly by eliminating potential breeding sites (swamps, ditches, puddles, etc) and spraying water sources with chemicals to kill, smother or starve larvae. Some measure of biological control has also been achieved by using natural predators (mosquito fish and dragonflies) to reduce larval populations, using natural pathogens (microsporan parasites and *Wolbachia* bacteria) to reduce mosquito fitness, and releasing sterilized males or transgenically modified mosquitoes. Many countries have adopted multiple methods of mosquito control in public health programs in attempts to curb the transmission of mosquito-borne infectious diseases.


Anopheles
adult mosquitoes (dorsal) (~ 12 mm)
male
female
skin
(blood loss, annoyance, inflammation, allergy)
(vectors for infectious microbial diseases)
Definitive Hosts
(mammals, birds, reptiles)
adults free-flying, females transient ectoparasites
(require bloodmeal for reproduction)
wing venation
resting posture
eclosion
eggs laid on water or moist substrates
pupa
(~ 4 mm)
free-swimming feeding larval stages ('wrigglers')
(~ 8 mm)
eggs
(~ 2 mm)
complete (holometabolous) metamorphosis
hatch
development in aquatic habitats,
esp. stagnant or slow-flowing waters

Anopheles adult

Anopheles egg

Anopheles larva head

Anopheles pupa