Chapter 1

The Phylogeny and Classification of *Anopheles*

Ralph E. Harbach

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/54695

1. Introduction

Anopheles was introduced as a genus of mosquitoes in 1818 by Johann Wilhelm Meigen [1], a German entomologist famous for his revolutionary studies of Diptera. Little was done on the taxonomy of *Anopheles* until the discovery during the last two decades of the 19th century that mosquitoes transmit microfilariae and malarial protozoa, which initiated a drive to collect, name and classify these insects. In 1898, the Royal Society and the Rt. Hon. Joseph Chamberlain, Secretary of State for the Colonies of Britain, appointed a Committee to supervise the investigation of malaria. On 6 December 1898, Mr. Chamberlain directed the Colonies to collect and send mosquitoes to the British Museum (Natural History) (Figure 1), and in 1899 the Committee appointed Frederick V. Theobald to prepare a monograph on the mosquitoes of the world, which was published in five volumes between 1901 and 1910 [2–6]. As a consequence, many new generic names were introduced in an effort to classify numerous new mosquito species into seemingly natural groups. Theobald proposed 18 genera for species of *Anopheles* based on the distribution and shape of scales on the thorax and abdomen. Four of these proposed genera, *Cellia*, *Kerteszia*, *Nyssorhynchus* and *Stethomyia*, are currently recognized as subgenera of *Anopheles* and the other 14 are regarded as synonyms of one or other of subgenera *Anopheles*, *Cellia* or *Nyssorhynchus*. Theobald, however, was not the only person to propose generic names for species of *Anopheles*. During the first three decades of the 20th century, 37 genera (including the 18 recognized by Theobald) were established for species of *Anopheles* [7].

As additional new species were discovered, it became increasingly apparent that Theobald's system of classification was neither practical nor natural. Frederick Knab in North America, one of the early critics of Theobald's classification, stated that "the subject was made needlessly difficult by hasty work and by the sub-division of the old genus *Anopheles* into numerous ill-defined and fancifully differentiated genera. The intricacies of this 'system,' unwarranted from both a scientific and practical standpoint, even the trained entomologist could not tread with safety, and to others it could be no less than hopeless or disastrous" [8]. Consequently, during the two decades following the completion of Theobald's monograph in 1910, significant changes were made toward a much more conservative system of classification, culminating in the reduction of 38 genus-group names (including *Anopheles*) to the recognition of the single genus *Anopheles*.

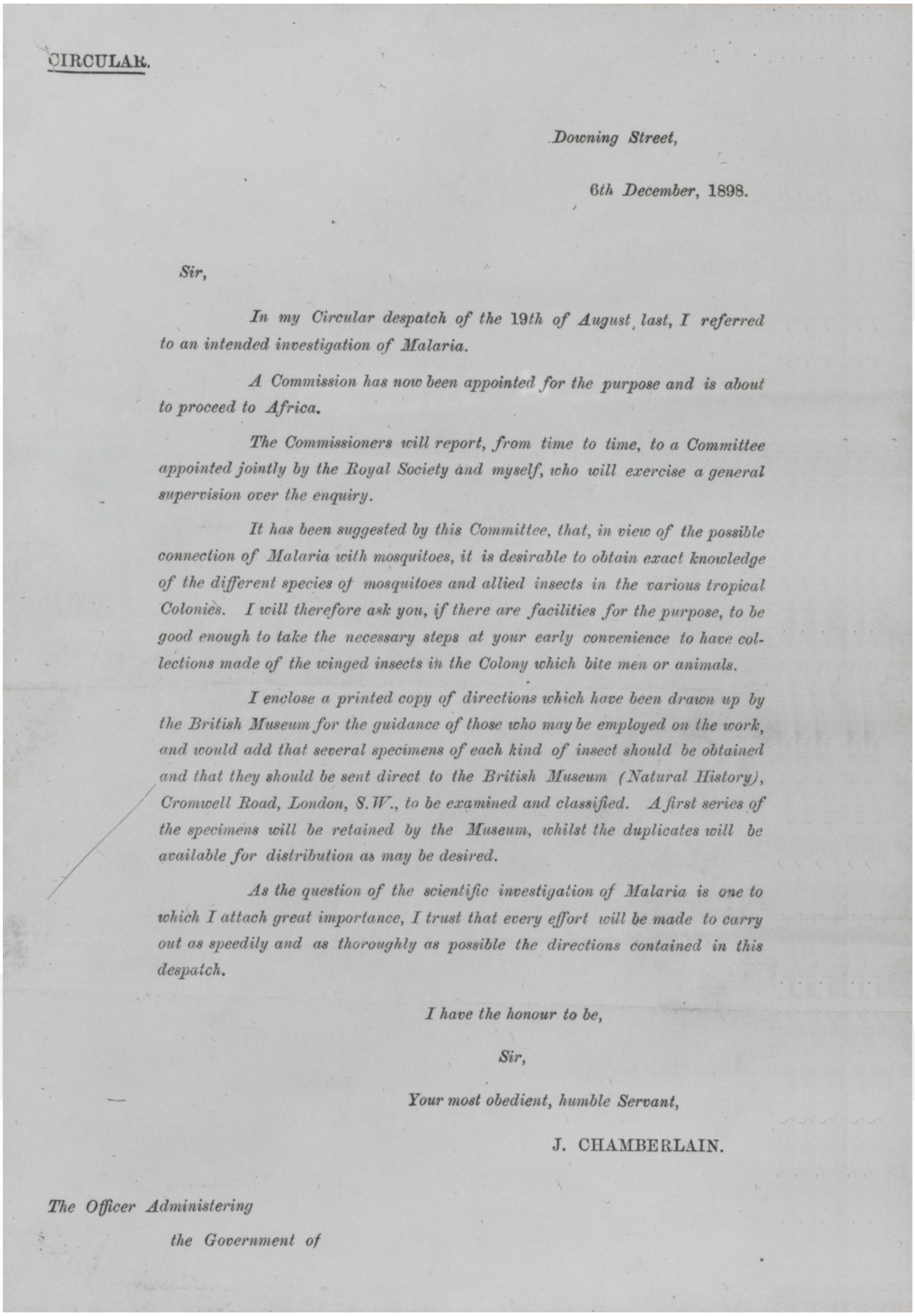
The current subgeneric classification of *Anopheles* is based primarily on the number and positions of specialized setae on the gonocoxites of the male genitalia (Figure 2), and this basis of classification has been accepted since it was introduced by Sir (Samuel) Rickard Christophers in 1915 [9]. Christophers proposed three generic subdivisions, which F.M. Edwards [10] and Francis Metcalf Root [11] formally recognized as subgenera *Anopheles*, *Myzomyia* (=*Cellia*) and *Nyssorhynchus*. Edwards adopted this system and added subgenus *Stethomyia* in his classical treatise on family Culicidae published in 1932 [12]. This system recognized *Kerteszia* as an informal group within subgenus *Nyssorhynchus*. *Kerteszia* was elevated to subgeneric status by W.H.W. Komp [13]. Subgenus *Lophopodomyia* was proposed by P.C.A. Antunes in 1937 [14] and subgenus *Baimaia* was introduced by Ralph E. Harbach and his colleagues in 2005 [15].

Genus *Anopheles* currently includes 465 formally named species that are disproportionately divided between seven subgenera: *Anopheles* (cosmopolitan, 182 species), *Baimaia* (Oriental, one species), *Cellia* (Old World, 220 species), *Kerteszia* (Neotropical, 12 species), *Lophopodomyia* (Neotropical, six species), *Nyssorhynchus* (Neotropical, 39 species) and *Stethomyia* (Neotropical, five species) [16]. Four of the subgenera, *Anopheles*, *Cellia*, *Kerteszia* and *Nyssorhynchus*, include the species that transmit human malarial parasites. Most vector species of *Anopheles* have been found to comprise complexes of sibling species.

2. Classification of genus *Anopheles*

The aim of classification is to group and categorize biological entities that share some unifying characteristics. Classification has been defined by Ernst Mayr & W.J. Bock [17] as "The arrangement of similar entities (objects) in a hierarchical series of nested classes, in which each more inclusive higher-level class is subdivided comprehensively into less inclusive classes at the next lower level." These classes (groups) are known as **taxa** (singular: **taxon**). The level of a taxon in a hierarchical classification is referred to as a **taxonomic rank** or **category**. Ideally, taxonomic categories should denote equivalent phylogenetic rank; however, in practice they are basically subjective groupings of subordinate taxa that are presumed to represent monophyletic groups of species that are assigned to taxonomic ranks based on shared morphological and biological characteristics that are not a measure of phylogenetic equivalence. For this reason, the taxonomic categories of genus *Anopheles*, including the formal rank of subgenus, should not be considered to represent equivalent phylogenetic ranks.

http://dx.doi.org/10.5772/54695



CIRCULAR.

Downing Street,

6th December, 1898.

Sir,

In my Circular despatch of the 19*th of August last, I referred to an intended investigation of Malaria.*

A Commission has now been appointed for the purpose and is about to proceed to Africa.

The Commissioners will report, from time to time, to a Committee appointed jointly by the Royal Society and myself, who will exercise a general supervision over the enquiry.

It has been suggested by this Committee, that, in view of the possible connection of Malaria with mosquitoes, it is desirable to obtain exact knowledge of the different species of mosquitoes and allied insects in the various tropical Colonies. I will therefore ask you, if there are facilities for the purpose, to be good enough to take the necessary steps at your early convenience to have collections made of the winged insects in the Colony which bite men or animals.

I enclose a printed copy of directions which have been drawn up by the British Museum for the guidance of those who may be employed on the work, and would add that several specimens of each kind of insect should be obtained and that they should be sent direct to the British Museum (Natural History), Cromwell Road, London, S.W., to be examined and classified. A first series of the specimens will be retained by the Museum, whilst the duplicates will be available for distribution as may be desired.

As the question of the scientific investigation of Malaria is one to which I attach great importance, I trust that every effort will be made to carry out as speedily and as thoroughly as possible the directions contained in this despatch.

I have the honour to be,

Sir,

Your most obedient, humble Servant,

J. CHAMBERLAIN.

The Officer Administering

the Government of

Figure 1. Letter issued from Downing Street on 6 December 1898 directing the British Colonies to collect and send mosquitoes to the British Museum (Natural History).

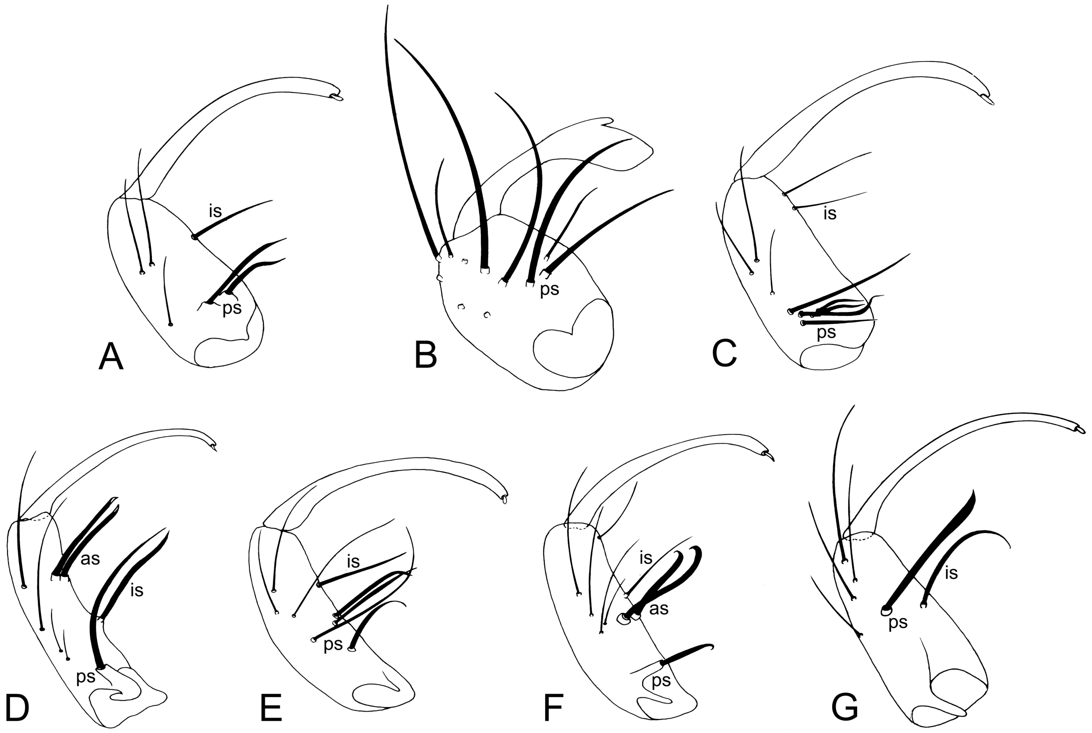


Figure 2. Subgenera of *Anopheles* – specialized setae on the gonocoxites of the male genitalia (after Harbach & Kitching [18]): A, *Anopheles*; B. *Baimaia*; C, *Cellia*; D, *Kerteszia*; E, *Lophopodomyia*; F, *Nyssorhynchus*; G, *Stethomyia*. as, accessory setae; is, inner seta; ps, parabasal seta(e).

Infrasubgeneric categories (taxonomic ranks below subgenus) have no formal status under the *International Code of Zoological Nomenclature* [19]. They are convenience categories only, often based on superficial similarities that may not indicate natural relationships. The informal categories used in the classification of *Anopheles* include Sections, Series, Groups, Subgroups and Complexes (see Appendix 1).

Unlike formal taxonomic categories, which precede the name of the taxonomic unit, for instance family Culicidae, genus *Anopheles* and species *gambiae*, the names of informal taxonomic categories follow the name of the taxonomic unit, for example the Pyretophorus Series, Hyrcanus Group or Gambiae Complex, which are written in Roman (i.e. non-italic) script with the first letter capitalized. It should be stressed that both formal and informal taxonomic entities are conceptual constructs invented by taxonomists for the purpose of creating some order in the diversity of species. For example, the species *gambiae* and the Hyrcanus Group, which are human-conceived taxonomic concepts, cannot be observed as entities or visualized under a microscope.

The internal classification of genus *Anopheles* (between genus and species levels) is based primarily on the schemes proposed by Edwards [12], John A. Reid & Kenneth L. Knight [20], Alexis Grjebine [21], M.T. Gillies & Botha de Meillon [22], Reid [23], Michael E. Faran [24] and Kenneth J. Linthicum [25]. These schemes were reviewed, amalgamated and updated in 1994 [26] and updated again in 2004 and 2012 [27,16 respectively]. The three largest subgenera, i.e. *Anopheles*, *Cellia* and *Nyssorhynchus*, are divided into hierarchical systems of informal taxonomic categories (Appendix 1; examples shown in Figure 3). Subgenus *Anopheles* is divided into two Sections based on the shape of the pupal trumpet. The Laticorn Section was created for species with a wide funnel-shaped trumpet having the longest axis transverse to the stem, and the Angusticorn Section for species with a semi-tubular trumpet having the longest axis vertical more or less in line with the stem [20]. Subgenus *Nyssorhynchus* is divided into three Sections based on unique combinations of larval, pupal and adult characters [28]. Subgenus *Cellia* and the Sections of subgenera *Anopheles* and *Nyssorhynchus* are divided into Series, the larger Series are divided into species Groups, and some Groups are further divided into Subgroups and species Complexes. Most of the groupings at each level of classification are presumed to represent natural groups of species, thus implying phylogenetic relationships, but much additional basic taxonomic research is needed before the formal and informal taxa can be firmly established as monophyletic entities. The internal classification of the genus (subgenera and infrasubgeneric groups) is detailed in Appendix 1. An alphabetical list of all formally named, currently recognized species and their position in the classification is provided in Appendix 2. Similarly, all currently known sibling species complexes are listed in Appendix 3, and the unnamed and provisionally designated species of the complexes and their position in the classification are listed in Appendix 4.

3. Phylogeny of *Anopheles*

Anopheles is undoubtedly the most studied and best known genus of mosquitoes, largely because of their great impact on human health. As vectors of causative agents of malaria and filariasis, *Anopheles* mosquitoes have affected the lives of more humans than any other insects. As a matter of fact, *Anopheles* is one of few groups of eukaryote organisms that have had an impact on human evolution – the emergence of sickle cell anemia as a mode of resistance to malarial protozoa. As a result of more than a century of studies by medical entomologists, taxonomists and geneticists, 537 species of *Anopheles* are currently known and most have been formally named (87%) (Appendix 2), but until recently little work has been done to understand the evolution and phylogenetic relationships of these mosquitoes.

Figure 3. Hierarchical classification (from specific to general) of A. *Anopheles freeborni*, Freeborni Subgroup, Maculipennis Group, Anopheles Series, Angusticorn Section, Subgenus *Anopheles*; B. *Anopheles minimus*, Minimus Complex, Minimus Subgroup, Funestus Group, Myzomyia Series, Subgenus *Cellia*; C. *Anopheles albimanus*, Albimanus Series, Albimanus Section, Subgenus *Nyssorhynchus*.

The phylogenetic studies of anopheline mosquitoes conducted to date are summarized in Appendix 5. In view of the impact of malaria on human health, it is not surprising that most of these studies have dealt with species Groups, Subgroups and Complexes that include vectors of human malarial protozoa. It is obvious that the evolutionary relationships of malaria vectors and their closest allies have received more attention than other groups. However, none of these studies can be regarded as complete in terms of taxonomic coverage of any group, and the field of disease vector systematics presents many opportunities for further research. Phylogenetic patterns are used to interpret bionomic features such as differences in the nature of blood-feeding by adult females, feeding behavior and the occurrence of immature stages in aquatic habitats.

Mosquitoes probably evolved in the Jurassic [12,29,30] (146–200 Mya)[1], along with the early mammals, first birds and first flowering plants. Unfortunately, due to the paucity of mosquito fossils, there is no direct indication of the evolutionary history of anopheline mosquitoes. The second oldest fossil mosquito, *Paleoculicis minutus* [31] from the Late Cretaceous (66.0–100.5 Mya), has morphological features that indicate a closer affinity with culicine than anopheline mosquitoes, which suggests that this ancestral lineage is younger than the lineage that gave rise to subfamily Anophelinae. *Anopheles* (*Nyssorhynchus*?) *dominicanus* [32] and *An*. (?) *rottensis* [33] are the only fossil anopheline mosquitoes. The former is from the mid-Tertiary (about 15–45 Mya) and the latter is from the Late Oligocene of Germany (approximately 25 Mya). If the anopheline mosquitoes are indeed ancestral to all other Culicidae [18,34], it would appear from available fossil evidence that extant groups may have evolved in the Cenozoic Era (<66.0 Mya). From divergence times based on sequence data for nuclear protein-coding genes and fossil calibration points, it appears that major mosquito lineages date to the Early Cretaceous (100.5–145.0 Mya), and the ancestral lineage of anophelines may have appeared as early as the Jurassic (~145 Mya) [34].

Anopheles is the nominotypical genus of subfamily Anophelinae. In addition to *Anopheles* (cosmopolitan), the subfamily includes two other genera: *Bironella* (Australasian) and *Chagasia* (Neotropical). Cladistic analyses of morphological data and DNA sequences of various ribosomal, mitochondrial and nuclear genes strongly support the placement of *Chagasia* in an ancestral relationship to all other anophelines [18,34–41].

In 2000, Sallum et al. [40] performed the first phylogenetic analysis of subfamily Anophelinae, based on morphological characters. The results indicated that genus *Anopheles* is paraphyletic because it included genus *Bironella*. Subgenera *Kerteszia*, *Nyssorhynchus*, *Cellia*, *Lophopodomyia* and *Stethomyia*, along with genus *Bironella*, were found to be monophyletic taxa dispersed among various Series and species Groups of subgenus *Anopheles*. The Christya Series of subgenus *Anopheles* was placed with *Kerteszia* + *Nyssorhynchus* and this clade was sister to *Cellia* + all other anophelines except *Chagasia*.

Two years later, Sallum et al. [41] conducted a molecular analysis of anopheline relationships based on ribosomal (18S, 28S) and mitochondrial (COI, COII) DNA sequences. The results of

1 Geological ages of eras and periods follow the geological timescale determined by the International Commission on Stratigraphy (http://www.stratigraphy.org).

that study cannot be compared directly with the results of their earlier study [40] because significantly fewer taxa were included in the analyses. Nevertheless, the molecular data corroborated the paraphyly of genus *Anopheles* relative to *Bironella* and the sister-group relationship of *Kerteszia* and *Nyssorhynchus*, and supported the monophyly of the other subgenera and genus *Bironella*, which was reconstructed as the sister to *Lophopodomyia* rather than *Stethomyia*.

In 2005, Harbach & Kitching [36] revised and expanded the phylogenetic analysis of Sallum et al. [40], with special consideration of the specialized setae of the male gonocoxites (Figure 2) that diagnose the subgenera. Parsimony analysis of the data set under implied weighting supported the monophyly of subgenera *Cellia*, *Kerteszia* and *Nyssorhynchus*, and the sister relationship of *Kerteszia* + *Nyssorhynchus*. Subgenus *Anopheles* was recovered as a polyphyletic lineage basal to a monophyletic clade consisting of *Kerteszia* + *Nyssorhynchus* and *Cellia* in a sister-group relationship. *Bironella*, *Lophopodomyia* and *Stethomyia* were firmly nested within subgenus *Anopheles*, which would be paraphyletic even if these taxa were subsumed within it. Subgenus *Baimaia*, represented by *An. kyondawensis*, was supported as the sister of *Bironella* + all other *Anopheles*. *Bironella* and *Stethomyia*, contrary to the earlier study of Sallum et al. [40], were also supported as monophyletic clades separate from subgenus *Anopheles*. The preferred cladogram of Harbach & Kitching (Figures 4 and 5) is taken here to represent the best available estimate of anopheline phylogeny and evolutionary relationships because it is based on a greater number of taxonomic groups and homologous characters than all other hypotheses published to date.

A later analysis of subgenus *Anopheles* by Collucci & Sallum [42] included 38 species representing the same Series (6) and species Groups (15) of the subgenus that were included in the study of Sallum et al. [40]. The data were analyzed using successive approximations character weighting (SACW) and implied weighting (IW). Most of the relationships between members of the subgenus were either moderately or poorly supported. The Laticorn Section was recovered as a monophyletic clade in the IW analysis, suggesting that the laticorn development of the pupal trumpet is a derived condition for subgenus *Anopheles*. In the SACW analyses, members of the group comprised a paraphyletic lineage relative to the Cycloleppteron Series. The Angusticorn Section was recovered as a polyphyletic assemblage in both analyses. These results are contradicted by those of Sallum et al. [40] and Harbach & Kitching [36] who found that neither section is monophyletic. Below the section level of classification, only the Lophoscelomyia and Arribalzagia Series were recovered as monophyletic assemblages. The Myzorhynchus Series was paraphyletic relative to the Cycloleppteron, Christya and Arribalzagia Series, and the Anopheles Series was polyphyletic. Surprisingly, the two species of the Cycloleppteron Series included in the analyses were not grouped together, suggesting that the series is not monophyletic. In contrast, the Arribalzagia, Christya, Cycloleppteron, Lophoscelomyia and Myzorhynchus Series were recovered as monophyletic assemblages in the IW analysis of Harbach & Kitching (Figure 4). Furthermore, with the removal of subgenus *Baimaia*, the remaining species of the Anopheles Series included in their analysis also formed a monophyletic group. With the exception of the Pseudopunctipennis Group, all the species groups represented in the analysis of Collucci & Sallum (Aitkenii, Albotaeniatus, Culiciformis, Hyrcanus, Plumbeus, Umbrosus Groups) were recovered as monophyletic assemblages with moderate to strong support [the Pseudopunctipennis Group was also found to be polyphyletic in the study of Harbach & Kitching (Figure 4)]. The Hyrcanus Group was paired with *An. coustani*, which corroborates previous hypotheses of a close relationship between the Hyrcanus and Coustani Groups [20,36,40,43]. Unfortunately, the analyses of Collucci & Sallum are biased by the selection of outgroup taxa whose interrelationships with the ingroup taxa were unresolved in previous studies. Thus, the results of their study cast doubt on their assertion that subgenus *Anopheles* is monophyletic. Based on the relationships recovered by Harbach & Kitching, subgenus *Anopheles* would be monophyletic if subgenus *Lophopodomyia* were to be reduced to the status of a species Group of the Anopheles Series (Figure 4). The Anopheles Series is a morphologically diverse assemblage of species and informal taxonomic groups, a number of which at one time or another were deemed to merit recognition as subgenera [20]. Sallum et al. [40] also found the Anopheles Series to be polyphyletic, but with its members interspersed in a complexity of inter-group relationships rather than arrayed in a pectinate sequence (Figure 4).

All phylogenetic studies conducted to date have demonstrated the monophyly of subgenera *Cellia* [36,38–41], *Kerteszia* [36,38–41,44] and *Nyssorhynchus* [36,38–41], and the sister pairing of *Kerteszia* and *Nyssorhynchus* [36,40,41]. The sister relationship of *Cellia* and the two New World subgenera is not inconsistent with the molecular analyses of Sallum et al. [41] if *Lophopodomyia* + *Bironella* is excluded from the clade that contains *Kerteszia* + *Nyssorhynchus*, but it differs markedly from the results of their earlier study based on morphology and a larger number of taxa [40], which placed *Kerteszia* + *Nyssorhynchus*, along with *An. implexus* (Christya Series), in a sister-group relationship with *Cellia* + a clade comprised of *Bironella*, *Lophopodomyia*, *Kerteszia* and *Nyssorhynchus*. *Anopheles implexus* (Christya Series) is sister to the terminal clade formed by *Kerteszia*, *Nyssorhynchus* and *Cellia* in Figure 4.

4. Distribution and phylogeography of *Anopheles*

Interpreting the current distributions of anophelines in an evolutionary context is problematic. The supercontinent of Pangaea existed in the Late Paleozoic and Early Mesozoic Eras from about 300–200 Mya and gradually separated 200–145 Mya into the two supercontinents of Laurasia and Gondwana [45]. As noted above, evidence from DNA sequence data and fossil calibration points [34] indicates that ancestral anophelines diverged from ancestral culicines about 217 Mya (230–192 Mya), before the complete splitting of Pangaea. If this was the case, then the separation of *Anopheles* and *Bironella* about 54 Mya (75.8–37.1 Mya, end of the Cretaceous to near the end of the Eocene Epoch of the Cenozoic) [34] must have occurred after the separation of Gondwana into multiple continents, i.e. Africa, South America, India, Antarctica and Australia, in the Cretaceous. Atlantica (the land mass that comprised present-day South America and Africa) separated from eastern Gondwana (the land mass that comprised Antarctica, India and Australia) 150–140 Mya. South America started to separate from Africa in a south-to-north direction during the Middle Cretaceous (about 125–115 Mya) [46]. At the same time, Madagascar and India began to separate from Antarctica, and separated from each other 100–90 Mya during the Cenomanian and Turonian Stages of the Late Cretaceous. India continued to move northward and collided with Eurasia about 35 Mya. Laurasia split to give rise to North America/Greenland and Eurasia about 60–55 Mya. Africa began to move northeastward toward Europe and South America moved northward to separate from Antarctica. North and South America were joined by the Isthmus of Panama during the Pliocene, approximately 3.7–3.0 Mya.

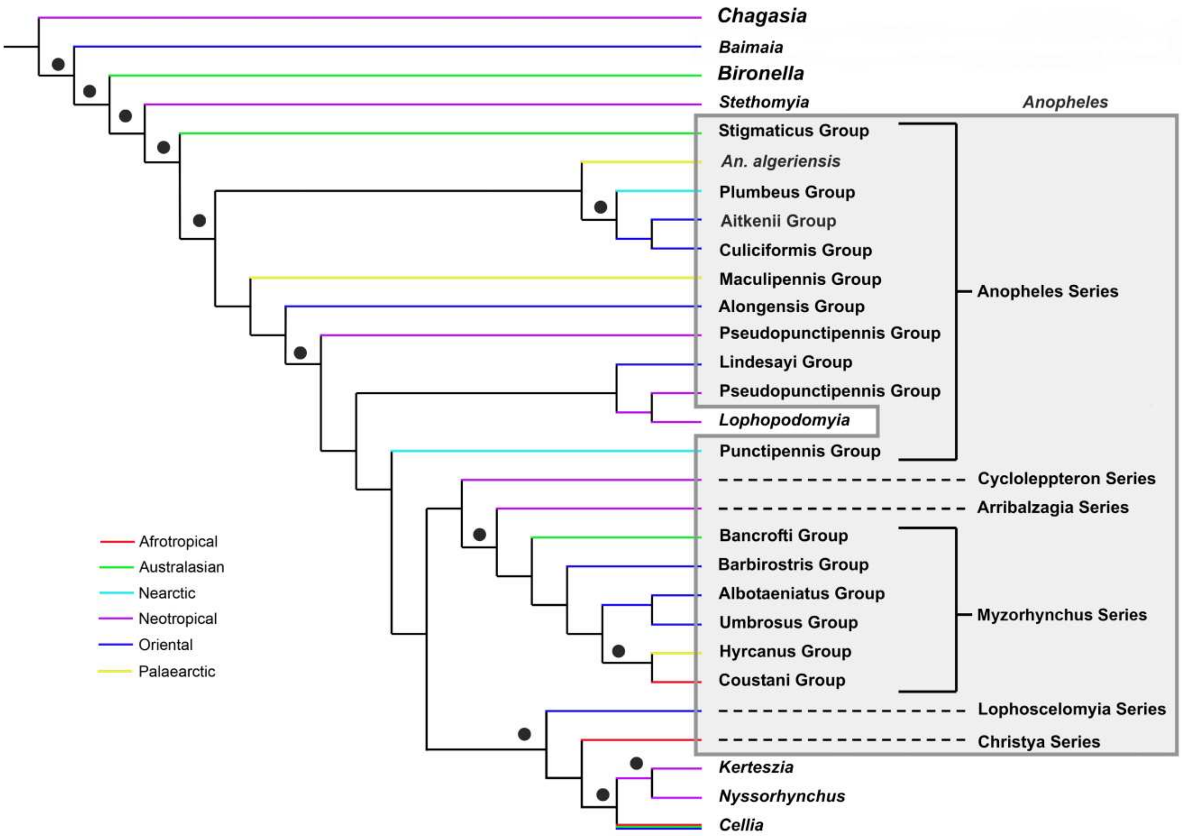


Figure 4. Phylogeny of subfamily Anophelinae, modified from Harbach & Kitching [36], indicating relationships within subgenus *Anopheles*. Filled circles indicate Bremer support values greater than 0.8.

Belkin [47] hypothesized that anophelines initially differentiated in the American Mediterranean Region. In concert with this postulate, Harbach & Kitching [36] suggested a possible New World origin of subfamily Anophelinae based on the basal placement of *Chagasia* relative to *Anopheles* + *Bironella* in their phylogeny of mosquito genera. Based on a phylogeny of 16 anopheline species inferred from sequences of two protein-coding nuclear genes and the Neotropical distribution of *Chagasia* and four of the seven subgenera of *Anopheles*, Krzywinski et al. [39] agreed with the hypothesis that South America was the center of origin of Anophelinae. However, as will be seen below, more recent studies suggest a different scenario for the evolution of the extant groups of the subfamily. This scenario closely reflects Christophers [48] insightful observations:

Subgenus *Anopheles* appears to be the oldest of the predominant subgenera, not only on [morphological grounds], but by reason of its worldwide distribution and the greater diversity and distinctness of its forms; almost every species of the subgenus appears to be as distinctive as are the species groups of subgenus *Myzomyia* [=*Cellia*], if not more so.

Nyssorhynchus appears to be a Neotropical development from some pre-*Anopheles* form, whilst the group *Arribalzagia* appears to be a highly specialized development of subgenus *Anopheles*.

Myzomyia shows every evidence of being a new and actively disseminating branch, as is suggested by its complete absence from the New World. Had it been once disseminated throughout North America it is unlikely that it would have been eliminated from the whole continent so completely as to leave not a single species in this area, though there is no actual proof that this did not occur. The apparent affinity between the group *Neomyzomyia* and subgenus *Nyssorhynchus* suggests an intermediate ancestor, though not necessarily one in the south, *i. e.*, such affinity does not prove or suggest a land-connection between Australia and South America, as the common ancestor may have been derived from the north and later eliminated. [next paragraph omitted]

The date of isolation of South America, judging by the history of mammals, would be from the middle of the Eocene, when connections between North and South America were severed, until the end of the Pliocene (*Zittel*). The anopheline fauna, therefore, arose from elements which pre-dated this period, and there were already subgenus *Anopheles*-like forms, as well as some earlier type from which *Nyssorhynchus* arose.

At some unknown period a similar special development took place, resulting in an early form (*Neomyzomyia*) of subgenus *Myzomyia*. This form appears to have once been distributed throughout the Oriental, Ethiopian [i.e. Afrotropical], and Australian Regions, and to have later undergone some regression, eventually remaining in greatest strength in the Australian Region.

Edwards, in reviewing the fossil remains of mosquitoes, notes that probably all the main divisions of the family [Culicidae] existed in Mid-Tertiary much as they do today, and with almost identical characters, and considers that, though no fossil *Anopheles* have been found, there can be no doubt from its morphology that this is also an old genus, probably older than any culicine form.

Based on the relationships shown in Figure 4, distributions of the principal group taxa (Appendix 6) and the geological dates listed above, it would appear that the ancestral lineage of *Anopheles* existed before the breakup of Pangaea and subsequently diversified into the modern subgenera and species after the separation of the continents. This would explain the cosmopolitan distribution and greater diversity of subgenus *Anopheles*, but not the earlier divergence of genus *Chagasia* and subgenus *Stethomyia*, which are confined to the Neotropical Region, the Oriental subgenus *Baimaia* and the Australasian genus *Bironella* (Figure 4). *Chagasia* possess several features that characterize species of subfamily Culicinae, including the strongly arched mesonotum, trilobed scutellum (Figure 6) and setae on the postpronotum. Based on these shared features, *Chagasia* has been considered an ancient group showing affinities with non-anophelines and phylogenetic analyses of morphological data and DNA sequences of various ribosomal, mitochondrial and nuclear genes strongly support its placement in an ancestral relationship to all other anophelines [33,35–41]. From the foregoing, however, it is inferred here that *Chagasia*, with only seven species, is a relic of a once more widely distributed taxon that is now confined to residual areas of South and Central America. It is also possible, although less likely, that *Chagasia*, as suggested by the late John N. Belkin for other mosquitoes [47], may have originated through hybridization between early anopheline and culicine forms.

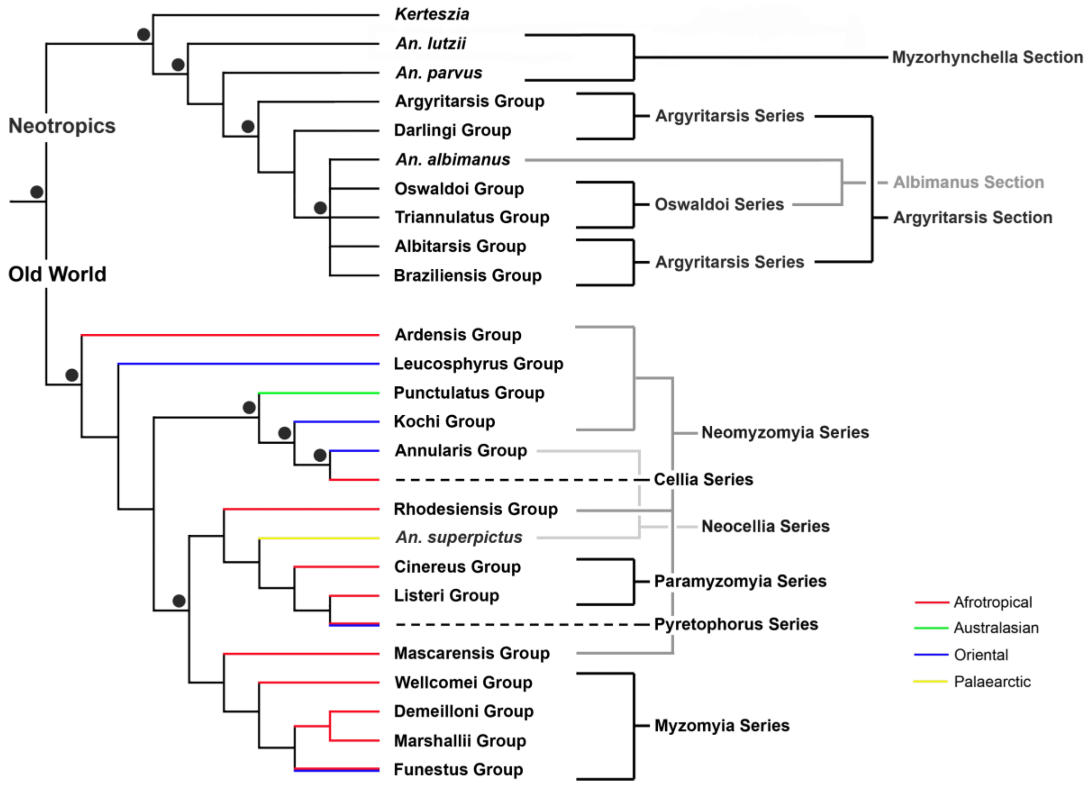


Figure 5. Phylogeny of subgenera *Cellia*, *Kerteszia* and *Nyssorhynchus*, modified from Harbach & Kitching [36], indicating relationships within subgenera *Cellia* and *Nyssorhynchus*. Filled circles indicate Bremer support values greater than 0.8.

Similarly, *Bironella* (as suggested by Christophers [48]), *Baimaia* and *Stethomyia*, with few species and restricted distributions, are also the remnants of once much more widely distributed forms. The isolation of ancestral members of subgenus *Anopheles* in South America also explains the uniqueness of the extant Neotropical fauna of the subgenus, especially the well-differentiated Arribalzagia Series. In accordance with this hypothesis, the following groups are also probably residual elements of once more widely distributed ancestral forms of subgenus *Anopheles*: the Afrotropical Christya Series (two species), the Australasian Atratipes (two species) and Stigmaticus (six species) Groups, the Oriental Alongensis (two species) and Culiciformis (three species) Groups, the Oriental Lophoscelomyia Series (five species) and the Neotropical Cycloleppteron Series (two species). It is noteworthy that the extant members of the relict groups are not vectors of human malarial parasites.

As noted previously, subgenus *Anopheles* has an almost world-wide distribution. Species are found at elevations from coastal areas to mountainous terrain in temperate, subtropical and tropical areas, but are absent from the majority of the Pacific Islands, including the large ones of New Zealand, Fiji and New Caledonia. The sole species of subgenus *Baimaia* has been found only in forested hilly and mountainous areas between 14° and 17° north on either side of the

Thai-Myanmar border and at a location near the Thai-Laos border in Thailand, and is probably also a relict taxon that has retained generalized ancestral features of the male genitalia [36]. Most species of subgenus *Cellia* have distributions in the Afrotropical, Australasian and Oriental Regions, but some species occur in southern areas of the Palaearctic. Species of *Cellia* are conspicuously absent from the majority of the islands of the Pacific, including New Zealand, Fiji and New Caledonia. Species of subgenus *Kerteszia* are found in the Neotropical Region, from Veracruz State in Mexico through Central America and Atlantic South America, along the Andes and along the coast, to the States of Misiones in Argentina and Rio Grande do Sul in Brazil, and also occur south along the Pacific Coast of South America to the State of El Oro, Ecuador. The subgenus is absent from all islands of the West Indies except Trinidad, and from most of the vast expanse of the Amazon basin in South America [49]. Species of subgenus *Lophopodomyia* are known to occur in areas of Panama and northern South America (Brazil, Colombia, Ecuador, French Guiana and Venezuela). Species of subgenus *Nyssorhynchus* are restricted to the Neotropical Region, except for *An. albimanus*, which extends into the Nearctic Region (northern Mexico and along the Rio Grande River in Texas). Finally, species of subgenus *Stethomyia* principally occur in southern Central America (Costa Rica and Panama) and northern South America (Brazil, Colombia, French Guiana, Guyana, Suriname and Venezuela), but one or two species are known to occur on the islands of Trinidad and Tobago and as far south as Peru and Bolivia.

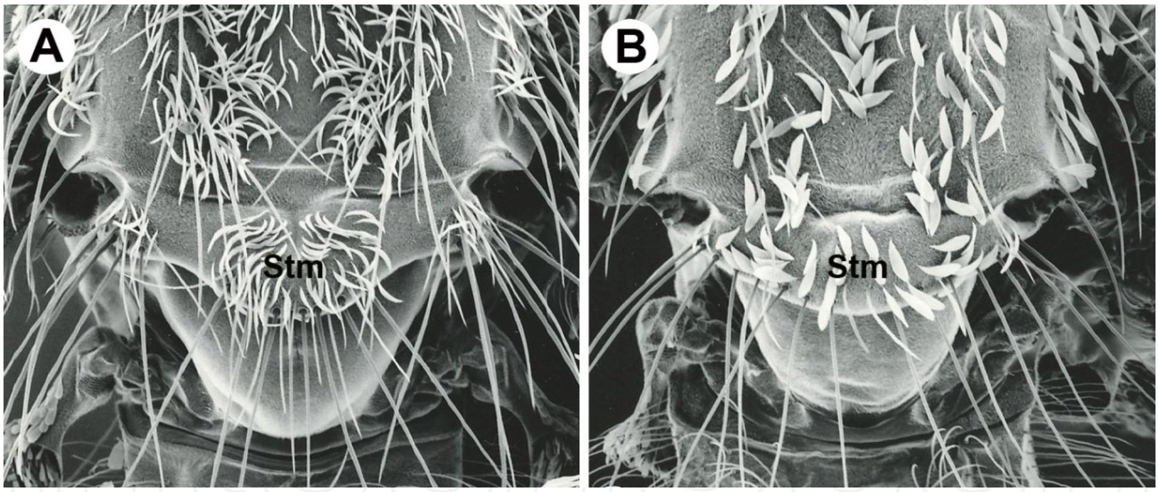


Figure 6. Two forms of the mosquito scutellum (Stm): A, trilobed scutellum of *Chagasia* and species of subfamily Culicinae; B, evenly rounded scutellum of *Anopheles*, with few exceptions. Original images from Harbach & Kitching [18].

Subgenera *Kerteszia*, *Lophopodomyia*, *Nyssorhynchus* and *Stethomyia*, and the Arribalzagia and Cycloleppteron Series of subgenus *Anopheles* are special to the Neotropical Region, where they probably originated following the separation of South America and Africa. The derived position of subgenera *Cellia* and *Kerteszia* + *Nyssorhynchus* relative to subgenus *Anopheles* (Figure 4) supports the hypothesis that the stem lineage of these subgenera originated in Gondwana and diverged following the separation of Atlantica to give rise to *Cellia* in Africa and *Kerteszia* and *Nyssorhynchus* in South America. It is interesting to note that *Lophopodo-*

myia and the Pseudopunctipennis Group are sister taxa in Figure 4, which is plausible in view of the hypothesized evolution of these groups from Neotropical ancestors. The Pseudopunctipennis Group is nearly restricted to the Neotropics, except for *An. franciscanus* and a minor extension of *An. pseudopunctipennis* into the Nearctic Region, which undoubtedly occurred relatively recently, after the land bridge formed to connect North and South America 3.7–3.0 Mya. Except for these two species, all *Anopheles* species in the Nearctic Region are members of the Anopheles Series of subgenus *Anopheles*. Half of the species of the Holarctic Maculipennis Group (24 species) occur in the Nearctic Region and the other half occur in the Palaearctic. This indicates that the Maculipennis Group must have evolved in the Northern Hemisphere prior to the separation of North America and Eurasia during the Paleocene and Eocene Epochs (60–55 Mya). The Plumbeus Group includes species in the Nearctic (2), Neotropical (4) and Palaearctic (3) Regions. Its position in the cladogram shown in Figure 4 is based on *An. judithae*, a Nearctic species. This group may be what paleontologists call a "stem group" [50], a paraphyletic or polyphyletic assemblage of species that share features of extinct taxa. The spotted distribution of these "living fossil" species suggests that their extinct relatives, ancestral forms of the Anopheles Series, existed before the separation of Pangaea. This bodes well with Christophers & Barraud's 1931 hypothesis [51] that the eggs of species of the Plumbeus Group are primitive compared to other species of subgenus *Anopheles*.

Species in subgenus *Cellia* are confined to the Eastern Hemisphere, with members in the Afrotropical, Australasian, Oriental and Palaearctic regions (Figure 5, Appendix 6). The Afrotropical Region is characterized by a large number of species of subgenus *Cellia* and relatively few species of subgenus *Anopheles*. The Myzomyia Series is especially dominant, but species of the Neocellia, Neomyzomyia and Pyretophorus Series also occur in the region. The Myzomyia, Neocellia and Pyretophorus Series are represented in the Afrotropical and Oriental Regions, but no species, species groups or subgroups of these series (with the exception of the Minimus Subgroup) are common to both regions (see Appendix 6). The Myzomyia Series is a dominant group in Africa, where *An. funestus* is a principal malaria vector [52,53]. Related species of the Funestus Group, including *An. minimus* and other members of the Minimus Subgroup, are major vectors of malarial parasites in southern Asia [52,54]. Evidence from phylogenetic analyses of mitochondrial DNA (ITS2 and D3 sequences) indicates that the Funestus Group originated in the Afrotropical Region [55]. The Neocellia Series also includes several important malaria vectors in southern Asia, notably *An. stephensi* and members of the Maculatus Group [52,54]. The Pyretophorus Series includes the formidable malaria vectors of the Gambiae Complex in Africa and important vectors of the Sundaicus and Subpictus Complexes in Southeast Asia [53,54]. The morphology-based phylogeny of Anthony et al. [56] indicates that the Pyretophorus Series originated in Africa and suggests that the capacity to vector malarial parasites is an ancestral condition subsequently lost independently in several lineages.

The anopheline fauna of the Australasian Region also shows evidence of isolation, but not to the degree indicated by the Neotropical fauna. The isolation appears to be more recent, corresponding to the separation of Australia from Antarctica between 37.0–33.5 Mya. The region includes a preponderance of species of the Neomyzomyia Series of subgenus *Cellia*, which may signal a relatively recent arrival from the Oriental Region, with some diversification. Members of the Neomyzomyia Series are the only *Anopheles* in the South Pacific [47]. Species groups of the series are confined to the Afrotropical (Ardensis, Mascarensis, Pauliani, Ranci, Rhodesiensis and Smithii Groups), Australasian (Punctulatus Group, Lungae Complex and unassigned species) or Oriental Region (Kochi, Leucosphyrus and Tessellatus Groups) (Appendix 6). The Neomyzomyia Series has been regarded as the most primitive series of subgenus *Cellia* based on egg morphology and the reduced or non-existent cibarial armature of females [57–59], and is thought to have originated in Africa and subsequently disperse eastward to the Oriental and Australasian Regions [52,59]. None of the African species of the Neomyzomyia Series, except for *An. nili*, are major vectors of malaria. In comparison, most species of the Oriental Leucosphyrus and Australasian Punctulatus Groups of the Neomyzomyia Series are important vectors of both primate and human malarial parasites. The Cellia and Paramyzomyia Series of subgenus *Cellia* are restricted to the Afrotropical Region, except for *An. pharoensis* (Cellia Series) and *An. multicolor* (Paramyzomyia Series) which occur in adjacent arid areas of the Palaearctic (Sahara and Middle East). It seems reasonable to hypothesize that those series that are presently represented by groups in the Afrotropical, Australasian and Oriental Regions arose before eastern Gondwana (Antarctica, India and Australia) fragmented. The Mascarensis, Pauliani and Ranci Groups are confined to Madagascar, which supports the hypothesis that the ancestral forms of at least these groups of the Neomyzomyia Series existed before Madagascar separated from India 100–90 Mya.

Human malaria probably evolved in Africa along with its mosquito hosts and other primates. Modern humans arose in Africa about 200,000 years ago and dispersed into Eurasia [60], reaching Australia about 40,000 years ago. Migration into the New World occurred about 15–20 millennia ago, and most of the Pacific Islands were colonized by four thousand years ago. The point here is that the rise and dispersal of modern humans occurred long after the formation of the continents and the evolution of the major groups of *Anopheles*. Consequently, it seems reasonable to assume that human malarial parasites accompanied humans during their migration out of Africa and were passed on to species of *Anopheles* in other regions that had the ecological, physiological and behavioural attributes required to propagate infections and maintain transmission. These taxa were surely already adapted to feeding on primates, including the ancestors of *Homo sapiens*, and were capable of developing and transmitting the *Plasmodium* species specific to those hosts.

Comprehensive information on the dominant malaria vectors of the world, most of which are presumably recently evolved members of sibling species complexes (Appendix 3), is summarized in a series of publications (and a chapter of this book) by M. Sinka and a team of regional experts and technical advisors – the Americas [61], Africa, Europe and the Middle East [53], the Asia-Pacific Region [54] – that culminated in a thorough review of the principal malaria vector taxa of the world [62]. At present, 96 formally named species of *Anopheles* are members of 26 sibling species complexes (Appendix 4). Twenty of these nominal species actually consist of more than one species, which all together comprise a total of 67 species. Excluding the name-bearing type species, the 58 species, plus five other unnamed species that are not members of species complexes, a total of 72 species, have yet to be given formal Latin names (Appendix 4).

5. Conclusion

A more robust phylogeny of *Anopheles* mosquitoes than is currently available may be of use in the fight against malaria. Foley et al. [37] suggested that it may help "by elucidating descent relationships of genes for refractoriness, insecticide resistance, and genetically determined ecological and behavioral traits important to malaria transmission." Interrupting the life cycle of malarial parasites by genetically manipulating vector receptiveness to infection is a potential approach to malaria control. A natural classification of *Anopheles* predictive of biological and ecological traits could facilitate the manipulation of vector genomes by informing the dynamics of introduced genes. Obviously, co-evolutionary studies of parasites and vectors require phylogenies for the mosquitoes. This must far exceed the taxon-limited (exemplar-based) studies conducted to date as they do not provide a basis for gaining insights into interspecific and co-evolutionary relationships of vectors and parasites.

It seems fitting to end here with a comment concerning interspecific hybridization, which was mentioned above in relation to genus *Chagasia* in the Neotropical Region. Although anopheline species occur in sympatry in most ecosystems, hybridization has only been detected at very low levels between certain members of species complexes in subgenus *Cellia*, e.g. *An. gambiae* with both *An. arabiensis* and *An. bwambae* in Africa [63,64], *An. dirus* and *An. baimaii* in Thailand [65] and *An. minimus* and *An. harrisoni* in Vietnam [66]. However, as advocated by Belkin [47], hybridization could provide sufficient genetic variation to permit adaptation to new habitats. Hybridization may occur regularly between some species, particularly widely distributed species that are morphologically similar. It could have played a role in the speciation and evolution of *Anopheles* mosquitoes and the pathogens they transmit.

Appendix 1 — The internal classification of genus *Anopheles*

Subgenus	Section	Series	Group	Subgroup	Complex	Author
Anopheles						[1]
	Angusticorn					[20]
		Anopheles				[12]
					Claviger	[67]
			Alongensis			[68]
			Aitkenii			[10]
			Atratipes			[69]

Subgenus	Section	Series	Group	Subgroup	Complex	Author
			Culiciformis			[20]
			Lindesayi			[20]
					Gigas	[70]
					Lindesayi	[70]
			Maculipennis			[20]
				Maculipennis		[71]
				Quadrimaculatus		[71]
				Freeborni		[71]
			Plumbeus			[20]
			Pseudopunctipen-nis			[20]
			Punctipennis			[20]
					Crucians	[72]
			Stigmaticus			[20]
		Cycloleppteron				[12]
		Lophoscelomyia				[12]
			Asiaticus			[23]
				Asiaticus		[73]
				Interruptus		[73]
	Laticorn					[20]
		Arribalzagia				[74]
		Christya				[75]
		Myzorhynchus				[12]
			Albotaeniatus			[20]
			Bancroftii			[20]
			Barbirostris			[20]
				Barbirostris		[23]
					Barbirostris	[76]
				Vanus		[23]
			Coustani			[20]
			Hyrcanus			[77]
				Lesteri		[78]
				Nigerrimus		[78]

Subgenus	Section	Series	Group	Subgroup	Complex	Author
			Umbrosus			[79]
				Baezai		[73]
				Letifer		[23]
				Separatus		[73]
				Umbrosus		[73]
Baimaia						[15]
Cellia						[80]
		Cellia				[75]
			Squamosus			[21]
		Myzomyia				[75]
			Demeilloni			[22]
			Funestus			[81]
				Aconitus		[82]
				Culicifacies		[81]
				Funestus		[81]
				Minimus		[82]
					Fluviatilis	[83]
					Minimus	[84]
				Rivulorum		[81]
			Marshallii			[22]
					Marshallii	[85]
			Wellcomei			[22]
		Neocellia				[75]
			Annularis			[23]
					Annularis	[86]
					Nivipes	[87]
			Jamesii			[73]
			Maculatus			[88]
				Maculatus		[73]
				Sawadwongporni		[73]
		Neomyzomyia				[75]
					Annulipes	[89]

Subgenus	Section	Series	Group	Subgroup	Complex	Author
					Longirostris	[90]
					Lungae	[47]
			Ardensis			[22]
					Nili	[22]
			Kochi			[73]
			Leucosphyrus			[91]
				Hackeri		[92]
				Leucosphyrus		[93]
					Dirus	[94]
					Leucosphyrus	[92]
				Riparis		[93]
			Mascarensis			[26]
			Pauliani			[21]
			Punctulatus			[95]
					Farauti	[96]
			Ranci			[21]
				Ranci		[21]
				Roubaudi		[21]
			Rhodesiensis			[22]
			Smithii			[22]
			Tessellatus			[73]
		Paramyzomyia				[51]
			Cinereus			[22]
			Listeri			[22]
		Pyretophorus				[12]
					Gambiae	[97]
			Ludlowae			[73]
					Sundaicus	[98]
			Subpictus			[73]
					Subpictus	[99]
Kerteszia						[100]
					Cruzii	[101]

http://dx.doi.org/10.5772/54695

Subgenus	Section	Series	Group	Subgroup	Complex	Author
Lophopodomyia						[14]
Nyssorhynchus						[102]
	Albimanus					[103]
		Albimanus				[24]
		Oswaldoi				[24]
			Oswaldoi			[24]
				Oswaldoi		[24]
					Nuneztovari	[104]
				Strodei		[24]
					Benarrochi	[105]
			Triannulatus		Triannulatus	[24]
	Argyritarsis					[103]
		Albitarsis				[25]
			Albitarsis			[25]
					Albitarsis	[106]
			Braziliensis			[25]
		Argyritarsis				[25]
			Argyritarsis			[25]
			Darlingi			[25]
			Lanei			[25]
			Pictipennis			[25]
	Myzorhynchella					[107]
Stethomyia						[80]

Appendix 2

Alphabetical list of formally named species of *Anopheles* and their position in the classification of the genus. For species Complexes, see Appendices 3 and 4; for authorship of species, visit http://mosquito-taxonomic-inventory.info/valid-species-list.

Species	Subgenus	Section	Series	Group	Subgroup
aberrans	*Anopheles*	Angusticorn	Anopheles	Aitkenii	

Species	Subgenus	Section	Series	Group	Subgroup
acaci	*Anopheles*	Angusticorn	Anopheles	Aitkenii	
acanthotorynus	*Stethomyia*				
aconitus	*Cellia*		Myzomyia	Funestus	Aconitus
ahomi	*Anopheles*	Laticorn	Myzorhynchus	Barbirostris	Vanus
ainshamsi	*Cellia*		Neocellia		
aitkenii	*Anopheles*	Angusticorn	Anopheles	Aitkenii	
albertoi	*Nyssorhynchus*	Albimanus	Oswaldoi	Oswaldoi	Strodei
albimanus	*Nyssorhynchus*	Albimanus	Albimanus		
albitarsis	*Nyssorhynchus*	Argyritarsis	Albitarsis	Albitarsis	
albotaeniatus	*Anopheles*	Laticorn	Myzorhynchus	Albotaeniatus	
algeriensis	*Anopheles*	Angusticorn	Anopheles		
alongensis	*Anopheles*	Angusticorn	Anopheles	Alongensis	
amictus	*Cellia*		Neomyzomyia		
anchietai	*Anopheles*	Laticorn	Arribalzagia		
annandalei	*Anopheles*	Angusticorn	Lophoscelomyia	Asiaticus	
annularis	*Cellia*		Neocellia	Annularis	
annulatus	*Cellia*		Neomyzomyia		
annulipalpis	*Anopheles*	Angusticorn	Cycloleppteron		
annulipes	*Cellia*		Neomyzomyia		
anomalophyllus	*Nyssorhynchus*	Albimanus	Oswaldoi	Oswaldoi	Oswaldoi
antunesi	*Nyssorhynchus*	Myzorhynchella			
apicimacula	*Anopheles*	Laticorn	Arribalzagia		
apoci	*Cellia*		Myzomyia		
aquasalis	*Nyssorhynchus*	Albimanus	Oswaldoi	Oswaldoi	Oswaldoi
arabiensis	*Cellia*		Pyretophorus		
arboricola	*Anopheles*	Angusticorn	Anopheles	Plumbeus	
ardensis	*Cellia*		Neomyzomyia	Ardensis	
argenteolobatus	*Cellia*		Cellia		
argyritarsis	*Nyssorhynchus*	Argyritarsis	Argyritarsis	Argyritarsis	
argyropus	*Anopheles*	Laticorn	Myzorhynchus	Hyrcanus	
artemievi	*Anopheles*	Angusticorn	Anopheles	Maculipennis	Maculipennis

http://dx.doi.org/10.5772/54695

Species	Subgenus	Section	Series	Group	Subgroup
arthuri	*Nyssorhynchus*	Albimanus	Oswaldoi	Oswaldoi	Strodei
aruni	*Cellia*		Myzomyia	Funestus	Funestus
asiaticus	*Anopheles*	Angusticorn	Lophoscelomyia	Asiaticus	Asiaticus
atacamensis	*Nyssorhynchus*	Argyritarsis	Argyritarsis	Pictipennis	
atratipes	*Anopheles*	Angusticorn	Anopheles	Atratipes	
atroparvus	*Anopheles*	Angusticorn	Anopheles	Maculipennis	Maculipennis
atropos	*Anopheles*	Angusticorn	Anopheles	Maculipennis	
aurirostris	*Cellia*		Neomyzomyia		
austenii	*Cellia*		Myzomyia	Marshallii	
auyantepuiensis	*Kerteszia*				
azaniae	*Cellia*		Myzomyia		
azevedoi	*Cellia*		Paramyzomyia	Cinereus	
aztecus	*Anopheles*	Angusticorn	Anopheles	Maculipennis	
baezai	*Anopheles*	Laticorn	Myzorhynchus	Umbrosus	Baezai
baileyi	*Anopheles*	Angusticorn	Anopheles	Lindesayi	
baimaii	*Cellia*		Neomyzomyia	Leucosphyrus	Leucosphyrus
baisasi	*Cellia*		Neomyzomyia	Leucosphyrus	Leucosphyrus
balabacensis	*Cellia*		Neomyzomyia	Leucosphyrus	Leucosphyrus
balerensis	*Anopheles*	Laticorn	Myzorhynchus	Albotaeniatus	
bambusicolus	*Kerteszia*				
bancroftii	*Anopheles*	Laticorn	Myzorhynchus	Bancroftii	
barberellus	*Cellia*		Myzomyia		
barberi	*Anopheles*	Angusticorn	Anopheles	Plumbeus	
barbirostris	*Anopheles*	Laticorn	Myzorhynchus	Barbirostris	Barbirostris
barbumbrosus	*Anopheles*	Laticorn	Myzorhynchus	Barbirostris	Vanus
barianensis	*Anopheles*	Angusticorn	Anopheles	Plumbeus	
beklemishevi	*Anopheles*	Angusticorn	Anopheles	Maculipennis	Quadrimaculatus
belenrae	*Anopheles*	Laticorn	Myzorhynchus	Hyrcanus	
bellator	*Kerteszia*				
benarrochi	*Nyssorhynchus*	Albimanus	Oswaldoi	Oswaldoi	Strodei
bengalensis	*Anopheles*	Angusticorn	Anopheles	Aitkenii	

Species	Subgenus	Section	Series	Group	Subgroup
berghei	*Cellia*		Myzomyia	Marshallii	
bervoetsi	*Cellia*		Myzomyia		
boliviensis	*Kerteszia*				
borneensis	*Anopheles*	Angusticorn	Anopheles	Aitkenii	
bradleyi	*Anopheles*	Angusticorn	Anopheles	Punctipennis	
braziliensis	*Nyssorhynchus*	Argyritarsis	Albitarsis	Braziliensis	
brevipalpis	*Anopheles*	Laticorn	Myzorhynchus	Umbrosus	
brevirostris	*Anopheles*	Laticorn	Myzorhynchus	Umbrosus	
brohieri	*Cellia*		Myzomyia	Marshallii	
brucei	*Cellia*		Myzomyia	Funestus	Rivulorum
brumpti	*Cellia*		Cellia		
brunnipes	*Cellia*		Myzomyia		
bulkleyi	*Anopheles*	Angusticorn	Lophoscelomyia		
bustamentei	*Anopheles*	Laticorn	Arribalzagia		
buxtoni	*Cellia*		Neomyzomyia	Ardensis	
bwambae	*Cellia*		Pyretophorus		
calderoni	*Anopheles*	Laticorn	Arribalzagia		
caliginosus	*Anopheles*	Laticorn	Myzorhynchus	Coustani	
cameroni	*Cellia*		Neomyzomyia	Rhodesiensis	
campestris	*Anopheles*	Laticorn	Myzorhynchus	Barbirostris	Barbirostris
canorii	*Stethomyia*		Neomyzomyia	Smithii	
carnevalei	*Cellia*		Neomyzomyia	Ardensis	
caroni	*Cellia*				
carteri	*Cellia*		Myzomyia	Demeilloni	
chiriquiensis	*Anopheles*	Angusticorn	Anopheles	Pseudopunctipennis	
chodukini	*Anopheles*	Laticorn	Myzorhynchus	Hyrcanus	
christyi	*Cellia*		Pyretophorus		
cinctus	*Cellia*		Neomyzomyia	Ardensis	
cinereus	*Cellia*		Paramyzomyia	Cinereus	
claviger	*Anopheles*	Angusticorn	Anopheles		
clowi	*Cellia*		Neomyzomyia	Punctulatus	

Species	Subgenus	Section	Series	Group	Subgroup
colledgei	*Anopheles*	Angusticorn	Anopheles	Stigmaticus	
collessi	*Anopheles*	Laticorn	Myzorhynchus	Umbrosus	Letifer
comorensis	*Cellia*		Pyretophorus		
concolor	*Anopheles*	Angusticorn	Anopheles		
confusus	*Cellia*		Myzomyia	Funestus	Funestus
corethroides	*Anopheles*	Angusticorn	Anopheles	Stigmaticus	
costai	*Anopheles*	Laticorn	Arribalzagia		
coustani	*Anopheles*	Laticorn	Myzorhynchus	Coustani	
cracens	*Cellia*		Neomyzomyia	Leucosphyrus	Leucosphyrus
crawfordi	*Anopheles*	Laticorn	Myzorhynchus	Hyrcanus	Lesteri
cristatus	*Cellia*		Neomyzomyia	Leucosphyrus	Riparis
cristipalpis	*Cellia*		Cellia		
crucians	*Anopheles*	Angusticorn	Anopheles	Punctipennis	
cruzii	*Kerteszia*				
crypticus	*Anopheles*	Laticorn	Myzorhynchus	Coustani	
cucphuongensis	*Anopheles*	Angusticorn	Anopheles	Alongensis	
culicifacies	*Cellia*		Myzomyia	Funestus	Culicifacies
culiciformis	*Anopheles*	Angusticorn	Anopheles	Culiciformis	
cydippis	*Cellia*		Cellia	Squamosus	
daciae	*Anopheles*	Angusticorn	Anopheles	Maculipennis	Maculipennis
dancalicus	*Cellia*		Neocellia		
darlingi	*Nyssorhynchus*	Argyritarsis	Argyritarsis	Darlingi	
daudi	*Cellia*		Pyretophorus		
deaneorum	*Nyssorhynchus*	Argyritarsis	Albitarsis	Albitarsis	
deemingi	*Cellia*		Neomyzomyia	Ardensis	
demeilloni	*Cellia*		Myzomyia	Demeilloni	
diluvialis	*Anopheles*	Angusticorn	Anopheles	Maculipennis	Quadrimaculatus
dirus	*Cellia*		Neomyzomyia	Leucosphyrus	Leucosphyrus
dispar	*Cellia*		Neocellia	Maculatus	
distinctus	*Cellia*		Myzomyia	Wellcomei	
domicola	*Cellia*		Myzomyia		

Species	Subgenus	Section	Series	Group	Subgroup
donaldi	*Anopheles*	Laticorn	Myzorhynchus	Barbirostris	Barbirostris
dravidicus	*Cellia*		Neocellia	Maculatus	Maculatus
dthali	*Cellia*		Myzomyia		
dualaensis	*Cellia*		Neomyzomyia		
dunhami	*Nyssorhynchus*	Albimanus	Oswaldoi	Oswaldoi	Oswaldoi
dureni	*Cellia*		Neomyzomyia	Ardensis	
earlei	*Anopheles*	Angusticorn	Anopheles	Maculipennis	Freeborni
eiseni	*Anopheles*	Angusticorn	Anopheles	Pseudopunctipennis	
ejercitoi	*Anopheles*	Laticorn	Myzorhynchus	Albotaeniatus	
elegans	*Cellia*		Neomyzomyia	Leucosphyrus	Leucosphyrus
engarensis	*Anopheles*	Laticorn	Myzorhynchus	Hyrcanus	
eouzani	*Cellia*		Neomyzomyia	Ardensis	
epiroticus	*Cellia*		Pyretophorus		
erepens	*Cellia*		Myzomyia	Wellcomei	
erythraeus	*Cellia*		Myzomyia		
ethiopicus	*Cellia*		Myzomyia		
evandroi	*Anopheles*	Laticorn	Arribalzagia		
evansae	*Nyssorhynchus*	Albimanus	Oswaldoi	Oswaldoi	Oswaldoi
faini	*Cellia*		Neomyzomyia	Smithii	
farauti	*Cellia*		Neomyzomyia	Punctulatus	
fausti	*Anopheles*	Angusticorn	Anopheles	Plumbeus	
filipinae	*Cellia*		Myzomyia	Funestus	Aconitus
flavicosta	*Cellia*		Myzomyia		
flavirostris	*Cellia*		Myzomyia	Funestus	Minimus
fluminensis	*Anopheles*	Laticorn	Arribalzagia		
fluviatilis	*Cellia*		Myzomyia	Funestus	Minimus
fontinalis	*Cellia*		Myzomyia		
forattinii	*Anopheles*	Laticorn	Arribalzagia		
fragilis	*Anopheles*	Angusticorn	Anopheles	Aitkenii	
franciscanus	*Anopheles*	Angusticorn	Anopheles	Pseudopunctipennis	
franciscoi	*Anopheles*	Laticorn	Myzorhynchus	Barbirostris	Barbirostris

http://dx.doi.org/10.5772/54695

Species	Subgenus	Section	Series	Group	Subgroup
freeborni	*Anopheles*	Angusticorn	Anopheles	Maculipennis	Freeborni
freetownensis	*Cellia*		Myzomyia	Demeilloni	
freyi	*Anopheles*	Laticorn	Myzorhynchus	Barbirostris	
funestus	*Cellia*		Myzomyia	Funestus	Funestus
fuscicolor	*Anopheles*	Laticorn	Myzorhynchus	Coustani	
fuscivenosus	*Cellia*		Myzomyia	Funestus	Rivulorum
gabaldoni	*Anopheles*	Laticorn	Arribalzagia		
galvaoi	*Nyssorhynchus*	Albimanus	Oswaldoi	Oswaldoi	Oswaldoi
gambiae	*Cellia*		Pyretophorus		
garnhami	*Cellia*		Myzomyia	Demeilloni	
georgianus	*Anopheles*	Angusticorn	Anopheles	Punctipennis	
gibbinsi	*Cellia*		Myzomyia	Marshallii	
gigas	*Anopheles*	Angusticorn	Anopheles	Lindesayi	
gilesi	*Lophopodomyia*				
goeldii	*Nyssorhynchus*	Albimanus	Oswaldoi	Oswaldoi	Oswaldoi
gomezdelatorrei	*Lophopodomyia*				
gonzalezrinconesi	*Kerteszia*				
grabhamii	*Anopheles*	Angusticorn	Cycloleppteron		
grassei	*Cellia*		Neomyzomyia	Pauliani	
greeni	*Cellia*		Neocellia	Maculatus	
grenieri	*Cellia*		Neomyzomyia	Pauliani	
griveaudi	*Cellia*		Neomyzomyia	Ranci	
guarani	*Nyssorhynchus*	Myzorhynchella			
guarao	*Anopheles*	Laticorn	Arribalzagia		
hackeri	*Cellia*		Neomyzomyia	Leucosphyrus	Hackeri
hailarensis	*Anopheles*	Laticorn	Myzorhynchus	Hyrcanus	
halophylus	*Nyssorhynchus*	Albimanus	Oswaldoi	Triannulatus	
hamoni	*Cellia*		Neomyzomyia	Smithii	
hancocki	*Cellia*		Myzomyia	Marshallii	
hargreavesi	*Cellia*		Myzomyia	Marshallii	
harperi	*Cellia*		Myzomyia	Marshallii	

Species	Subgenus	Section	Series	Group	Subgroup
harrisoni	*Cellia*		Myzomyia	Funestus	Minimus
hectoris	*Anopheles*	Angusticorn	Anopheles	Pseudopunctipennis	
heiheensis	*Anopheles*	Laticorn	Myzorhynchus	Hyrcanus	
hermsi	*Anopheles*	Angusticorn	Anopheles	Maculipennis	Freeborni
hervyi	*Cellia*		Neocellia		
hilli	*Cellia*		Neomyzomyia		
hinesorum	*Cellia*		Neomyzomyia	Punctulatus	
hodgkini	*Anopheles*	Laticorn	Myzorhynchus	Barbirostris	Barbirostris
homunculus	*Kerteszia*				
hughi	*Cellia*		Myzomyia	Marshallii	
hunteri	*Anopheles*	Laticorn	Myzorhynchus	Umbrosus	
hyrcanus	*Anopheles*	Laticorn	Myzorhynchus	Hyrcanus	
implexus	*Anopheles*	Laticorn	Christya		
incognitus	*Cellia*		Neomyzomyia		
indefinitus	*Cellia*		Pyretophorus	Subpictus	
ininii	*Nyssorhynchus*	Albimanus	Oswaldoi	Oswaldoi	Oswaldoi
insulaeflorum	*Anopheles*	Angusticorn	Anopheles	Aitkenii	
intermedius	*Anopheles*	Laticorn	Arribalzagia		
interruptus	*Anopheles*	Angusticorn	Lophoscelomyia	Asiaticus	Interruptus
introlatus	*Cellia*		Neomyzomyia	Leucosphyrus	Leucosphyrus
inundatus	*Anopheles*	Angusticorn	Anopheles	Maculipennis	Quadrimaculatus
irenicus	*Cellia*		Neomyzomyia	Punctulatus	
jamesii	*Cellia*		Neocellia	Jamesii	
janconnae	*Nyssorhynchus*	Argyritarsis	Albitarsis	Albitarsis	
jebudensis	*Cellia*		Neomyzomyia	Smithii	
jeyporiensis	*Cellia*		Myzomyia	Funestus	
judithae	*Anopheles*	Angusticorn	Anopheles	Plumbeus	
karwari	*Cellia*		Neocellia		
keniensis	*Cellia*		Myzomyia	Demeilloni	
kingi	*Cellia*		Neomyzomyia	Ardensis	
kleini	*Anopheles*	Laticorn	Myzorhynchus	Hyrcanus	

http://dx.doi.org/10.5772/54695

Species	Subgenus	Section	Series	Group	Subgroup
kochi	*Cellia*		Neomyzomyia	Kochi	
kokhani	*Cellia*		Neomyzomyia		
kolambuganensis	*Cellia*		Neomyzomyia		
koliensis	*Cellia*		Neomyzomyia	Punctulatus	
kompi	*Stethomyia*				
konderi	*Nyssorhynchus*	Albimanus	Oswaldoi	Oswaldoi	Oswaldoi
koreicus	*Anopheles*	Laticorn	Myzorhynchus	Barbirostris	
kosiensis	*Cellia*		Myzomyia	Marshallii	
kweiyangensis	*Anopheles*	Laticorn	Myzorhynchus	Hyrcanus	
kyondawensis	*Baimaia*				
labranchiae	*Anopheles*	Angusticorn	Anopheles	Maculipennis	Maculipennis
lacani	*Cellia*		Neomyzomyia	Ranci	Roubaudi
laneanus	*Kerteszia*				
lanei	*Nyssorhynchus*	Argyritarsis	Argyritarsis	Lanei	
latens	*Cellia*		Neomyzomyia	Leucosphyrus	Leucosphyrus
leesoni	*Cellia*		Myzomyia	Funestus	Minimus
lepidotus	*Kerteszia*				
lesteri	*Anopheles*	Laticorn	Myzorhynchus	Hyrcanus	Lesteri
letabensis	*Cellia*		Myzomyia	Marshallii	
letifer	*Anopheles*	Laticorn	Myzorhynchus	Umbrosus	Letifer
leucosphyrus	*Cellia*		Neomyzomyia	Leucosphyrus	Leucosphyrus
lewisi	*Anopheles*	Angusticorn	Anopheles	Maculipennis	
liangshanensis	*Anopheles*	Laticorn	Myzorhynchus	Hyrcanus	
limosus	*Cellia*		Pyretophorus		
lindesayi	*Anopheles*	Angusticorn	Anopheles	Lindesayi	
listeri	*Cellia*		Paramyzomyia	Listeri	
litoralis	*Cellia*		Pyretophorus		
lloreti	*Cellia*		Myzomyia	Demeilloni	
longipalpis	*Cellia*		Myzomyia	Funestus	Funestus
longirostris	*Cellia*		Neomyzomyia		
lounibosi	*Cellia*		Neomyzomyia	Rhodesiensis	

Species	Subgenus	Section	Series	Group	Subgroup
lovettae	*Cellia*		Neomyzomyia	Smithii	
ludlowae	*Cellia*		Pyretophorus	Ludlowae	
lungae	*Cellia*		Neomyzomyia		
lutzii	*Nyssorhynchus*	Myzorhynchella			
macarthuri	*Cellia*		Neomyzomyia	Leucosphyrus	Riparis
machardyi	*Cellia*		Neomyzomyia	Ardensis	
maculatus	*Cellia*		Neocellia	Maculatus	Maculatus
maculipalpis	*Cellia*		Neocellia		
maculipennis	*Anopheles*	Angusticorn	Anopheles	Maculipennis	Maculipennis
maculipes	*Anopheles*	Laticorn	Arribalzagia		
majidi	*Cellia*		Myzomyia		
malefactor	*Anopheles*	Laticorn	Arribalzagia		
maliensis	*Cellia*		Neomyzomyia	Ardensis	
manalangi	*Anopheles*	Laticorn	Myzorhynchus	Barbirostris	Vanus
mangyanus	*Cellia*		Myzomyia	Funestus	Aconitus
marajoara	*Nyssorhynchus*	Argyritarsis	Albitarsis	Albitarsis	
marshallii	*Cellia*		Myzomyia	Marshallii	
marteri	*Anopheles*	Angusticorn	Anopheles		
martinius	*Anopheles*	Angusticorn	Anopheles	Maculipennis	Maculipennis
mascarensis	*Cellia*		Neomyzomyia	Mascarensis	
mattogrossensis	*Anopheles*	Laticorn	Arribalzagia		
maverlius	*Anopheles*	Angusticorn	Anopheles	Maculipennis	Quadrimaculatus
mediopunctatus	*Anopheles*	Laticorn	Arribalzagia		
melanoon	*Anopheles*	Angusticorn	Anopheles	Maculipennis	Maculipennis
melas	*Cellia*		Pyretophorus		
mengalangensis	*Anopheles*	Angusticorn	Anopheles	Lindesayi	
meraukensis	*Cellia*		Neomyzomyia		
merus	*Cellia*		Pyretophorus		
messeae	*Anopheles*	Angusticorn	Anopheles	Maculipennis	Maculipennis
millecampsi	*Cellia*		Neomyzomyia	Ardensis	
milloti	*Cellia*		Neomyzomyia	Pauliani	

http://dx.doi.org/10.5772/54695

Species	Subgenus	Section	Series	Group	Subgroup
minimus	*Cellia*		Myzomyia	Funestus	Minimus
minor	*Anopheles*	Laticorn	Arribalzagia		
mirans	*Cellia*		Neomyzomyia	Leucosphyrus	Hackeri
moghulensis	*Cellia*		Neocellia		
montanus	*Anopheles*	Laticorn	Myzorhynchus	Albotaeniatus	
mortiauxi	*Cellia*		Myzomyia	Marshallii	
moucheti	*Cellia*		Myzomyia		
mousinhoi	*Cellia*		Myzomyia	Marshallii	
multicinctus	*Cellia*		Neomyzomyia	Ardensis	
multicolor	*Cellia*		Paramyzomyia	Listeri	
murphyi	*Cellia*		Cellia		
namibiensis	*Anopheles*	Laticorn	Myzorhynchus	Coustani	
natalensis	*Cellia*		Neomyzomyia	Ardensis	
nataliae	*Cellia*		Neomyzomyia		
neivai	*Kerteszia*				
nemophilous	*Cellia*		Neomyzomyia	Leucosphyrus	Leucosphyrus
neomaculipalpus	*Anopheles*	Laticorn	Arribalzagia		
nigerrimus	*Anopheles*	Laticorn	Myzorhynchus	Hyrcanus	Nigerrimus
nigritarsis	*Nyssorhynchus*	Myzorhynchella			
nilgiricus	*Anopheles*	Angusticorn	Anopheles	Lindesayi	
nili	*Cellia*		Neomyzomyia	Ardensis	
nimbus	*Stethomyia*				
nimpe	*Anopheles*	Laticorn	Myzorhynchus	Hyrcanus	
nitidus	*Anopheles*	Laticorn	Myzorhynchus	Hyrcanus	Nigerrimus
nivipes	*Cellia*		Neocellia	Annularis	
njombiensis	*Cellia*		Myzomyia	Marshallii	
noniae	*Anopheles*	Angusticorn	Lophoscelomyia	Asiaticus	
notanandai	*Cellia*		Neocellia	Maculatus	Sawadwongporni
notleyi	*Cellia*		Neomyzomyia	Ranci	Roubaudi
novaguinensis	*Cellia*		Neomyzomyia		
nuneztovari	*Nyssorhynchus*	Albimanus	Oswaldoi	Oswaldoi	Oswaldoi

Species	Subgenus	Section	Series	Group	Subgroup
obscurus	*Anopheles*	Laticorn	Myzorhynchus		
occidentalis	*Anopheles*	Angusticorn	Anopheles	Maculipennis	Freeborni
oiketorakras	*Lophopodomyia*				
okuensis	*Anopheles*	Laticorn	Christya		
omorii	*Anopheles*	Angusticorn	Anopheles	Plumbeus	
oryzalimnetes	*Nyssorhynchus*	Argyritarsis	Albitarsis	Albitarsis	
oswaldoi	*Nyssorhynchus*	Albimanus	Oswaldoi	Oswaldoi	Oswaldoi
ovengensis	*Cellia*		Neomyzomyia	Ardensis	
pallidus	*Cellia*		Neocellia	Annularis	
palmatus	*Anopheles*	Angusticorn	Anopheles	Aitkenii	
paltrinierii	*Cellia*		Neocellia		
paludis	*Anopheles*	Laticorn	Myzorhynchus	Coustani	
pampanai	*Cellia*		Myzomyia	Funestus	Aconitus
papuensis	*Anopheles*	Angusticorn	Anopheles	Stigmaticus	
paraliae	*Anopheles*	Laticorn	Myzorhynchus	Hyrcanus	Lesteri
parangensis	*Cellia*		Pyretophorus		
parapunctipennis	*Anopheles*	Angusticorn	Anopheles	Pseudopunctipennis	
parensis	*Cellia*		Myzomyia	Funestus	Funestus
parvus	*Nyssorhynchus*	Myzorhynchella			
pattoni	*Cellia*		Neocellia		
pauliani	*Cellia*		Neomyzomyia	Pauliani	
peditaeniatus	*Anopheles*	Laticorn	Myzorhynchus	Hyrcanus	Lesteri
perplexens	*Anopheles*	Angusticorn	Anopheles	Punctipennis	
persiensis	*Anopheles*	Angusticorn	Anopheles	Maculipennis	Maculipennis
peryassui	*Anopheles*	Laticorn	Arribalzagia		
petragnani	*Anopheles*	Angusticorn	Anopheles		
peytoni	*Anopheles*	Angusticorn	Anopheles	Aitkenii	
pharoensis	*Cellia*		Cellia		
philippinensis	*Cellia*		Neocellia	Annularis	
pholidotus	*Kerteszia*				
pictipennis	*Nyssorhynchus*	Argyritarsis	Argyritarsis	Pictipennis	

http://dx.doi.org/10.5772/54695

Species	Subgenus	Section	Series	Group	Subgroup
pilinotum	*Anopheles*	Angusticorn	Anopheles	Aitkenii	
pinjaurensis	*Anopheles*	Angusticorn	Anopheles	Aitkenii	
plumbeus	*Anopheles*	Angusticorn	Anopheles	Plumbeus	
pollicaris	*Anopheles*	Laticorn	Myzorhynchus	Barbirostris	Barbirostris
powderi	*Anopheles*	Angusticorn	Anopheles	Plumbeus	
powelli	*Anopheles*	Angusticorn	Anopheles	Stigmaticus	
pretoriensis	*Cellia*		Neocellia		
pristinus	*Nyssorhynchus*	Myzorhynchella			
pseudobarbirostris	*Anopheles*	Laticorn	Myzorhynchus	Bancroftii	
pseudojamesi	*Cellia*		Neocellia	Jamesii	
pseudomaculipes	*Anopheles*	Laticorn	Arribalzagia		
pseudopictus	*Anopheles*	Laticorn	Myzorhynchus	Hyrcanus	
pseudopunctipennis	*Anopheles*	Angusticorn	Anopheles	Pseudopunctipennis	
pseudosinensis	*Anopheles*	Laticorn	Myzorhynchus	Hyrcanus	Nigerrimus
pseudostigmaticus	*Anopheles*	Angusticorn	Anopheles	Stigmaticus	
pseudosundaicus	*Cellia*		Pyretophorus		
pseudotibiamaculatus	*Lophopodomyia*				
pseudowillmori	*Cellia*		Neocellia	Maculatus	
pujutensis	*Cellia*		Neomyzomyia	Leucosphyrus	Hackeri
pulcherrimus	*Cellia*		Neocellia		
pullus	*Anopheles*	Laticorn	Myzorhynchus	Hyrcanus	
punctimacula	*Anopheles*	Laticorn	Arribalzagia		
punctipennis	*Anopheles*	Angusticorn	Anopheles	Punctipennis	
punctulatus	*Cellia*		Neomyzomyia	Punctulatus	
pursati	*Anopheles*	Laticorn	Myzorhynchus	Hyrcanus	Nigerrimus
quadriannulatus	*Cellia*		Pyretophorus		
quadrimaculatus	*Anopheles*	Angusticorn	Anopheles	Maculipennis	Quadrimaculatus
rachoui	*Anopheles*	Laticorn	Arribalzagia		
radama	*Cellia*		Neomyzomyia	Pauliani	
rageaui	*Cellia*		Neomyzomyia	Smithii	
rampae	*Cellia*		Neocellia	Maculatus	Sawadwongporni

Species	Subgenus	Section	Series	Group	Subgroup
ranci	*Cellia*		Neomyzomyia	Ranci	Ranci
rangeli	*Nyssorhynchus*	Albimanus	Oswaldoi	Oswaldoi	Oswaldoi
recens	*Cellia*		Neomyzomyia	Leucosphyrus	Hackeri
reidi	*Anopheles*	Laticorn	Myzorhynchus	Barbirostris	Vanus
rennellensis	*Cellia*		Neomyzomyia	Punctulatus	
rhodesiensis	*Cellia*		Neomyzomyia	Rhodesiensis	
riparis	*Cellia*		Neomyzomyia	Leucosphyrus	Riparis
rivulorum	*Cellia*		Myzomyia	Funestus	Rivulorum
rodhaini	*Cellia*				
rollai	*Kerteszia*				
rondoni	*Nyssorhynchus*	Albimanus	Oswaldoi	Oswaldoi	Strodei
roperi	*Anopheles*	Laticorn	Myzorhynchus	Umbrosus	Letifer
roubaudi	*Cellia*		Neomyzomyia	Ranci	Roubaudi
ruarinus	*Cellia*		Neomyzomyia	Rhodesiensis	
rufipes	*Cellia*		Neocellia		
sacharovi	*Anopheles*	Angusticorn	Anopheles	Maculipennis	Maculipennis
salbaii	*Cellia*		Neocellia		
samarensis	*Anopheles*	Laticorn	Myzorhynchus	Umbrosus	
sanctielii	*Nyssorhynchus*	Albimanus	Oswaldoi	Oswaldoi	Oswaldoi
saperoi	*Anopheles*	Laticorn	Myzorhynchus	Albotaeniatus	
saungi	*Cellia*		Neomyzomyia		
sawadwongporni	*Cellia*		Neocellia	Maculatus	Sawadwongporni
sawyeri	*Nyssorhynchus*	Argyritarsis	Argyritarsis	Argyritarsis	
scanloni	*Cellia*		Neomyzomyia	Leucosphyrus	Leucosphyrus
schueffneri	*Cellia*		Neocellia	Annularis	
schwetzi	*Cellia*		Myzomyia		
separatus	*Anopheles*	Laticorn	Myzorhynchus	Umbrosus	Separatus
seretsei	*Cellia*		Paramyzomyia	Listeri	
sergentii	*Cellia*		Myzomyia	Demeilloni	
seydeli	*Cellia*		Myzomyia	Marshallii	
shannoni	*Anopheles*	Laticorn	Arribalzagia		

http://dx.doi.org/10.5772/54695

Species	Subgenus	Section	Series	Group	Subgroup
similissimus	*Anopheles*	Laticorn	Myzorhynchus	Umbrosus	
sinensis	*Anopheles*	Laticorn	Myzorhynchus	Hyrcanus	
sineroides	*Anopheles*	Laticorn	Myzorhynchus	Hyrcanus	
sintoni	*Anopheles*	Angusticorn	Anopheles	Culiciformis	
sintonoides	*Anopheles*	Angusticorn	Anopheles	Culiciformis	
smaragdinus	*Anopheles*	Angusticorn	Anopheles	Maculipennis	Quadrimaculatus
smithii	*Cellia*		Neomyzomyia	Smithii	
solomonis	*Cellia*		Neomyzomyia		
somalicus	*Cellia*		Neomyzomyia	Ardensis	
splendidus	*Cellia*		Neocellia	Jamesii	
squamifemur	*Lophopodomyia*				
squamosus	*Cellia*		Cellia	Squamosus	
stephensi	*Cellia*		Neocellia		
stigmaticus	*Anopheles*	Angusticorn	Anopheles	Stigmaticus	
stookesi	*Cellia*		Neomyzomyia		
stricklandi	*Anopheles*	Angusticorn	Anopheles	Aitkenii	
strodei	*Nyssorhynchus*	Albimanus	Oswaldoi	Oswaldoi	Strodei
subpictus	*Cellia*		Pyretophorus	Subpictus	
sulawesi	*Cellia*		Neomyzomyia	Leucosphyrus	Hackeri
sundaicus	*Cellia*		Pyretophorus	Ludlowae	
superpictus	*Cellia*		Neocellia		
swahilicus	*Cellia*		Cellia		
symesi	*Anopheles*	Laticorn	Myzorhynchus	Coustani	
takasagoensis	*Cellia*		Neomyzomyia	Leucosphyrus	Leucosphyrus
tasmaniensis	*Anopheles*	Angusticorn	Anopheles	Atratipes	
tchekedii	*Cellia*		Myzomyia		
tenebrosus	*Anopheles*	Laticorn	Myzorhynchus	Coustani	
tessellatus	*Cellia*		Neomyzomyia	Tessellatus	
theileri	*Cellia*		Myzomyia	Wellcomei	
theobaldi	*Cellia*		Neocellia		
thomasi	*Stethomyia*				

Species	Subgenus	Section	Series	Group	Subgroup
tibiamaculatus	*Anopheles*	Angusticorn	Anopheles	Pseudopunctipennis	
tigertti	*Anopheles*	Angusticorn	Anopheles	Aitkenii	
torresiensis	*Cellia*		Neomyzomyia	Punctulatus	
triannulatus	*Nyssorhynchus*	Albimanus	Oswaldoi	Triannulatus	
trinkae	*Nyssorhynchus*	Albimanus	Oswaldoi	Oswaldoi	Oswaldoi
turkhudi	*Cellia*		Paramyzomyia	Cinereus	
umbrosus	*Anopheles*	Laticorn	Myzorhynchus	Umbrosus	Umbrosus
vagus	*Cellia*		Pyretophorus	Subpictus	
vaneedeni	*Cellia*		Myzomyia	Funestus	Funestus
vanhoofi	*Cellia*		Neomyzomyia	Smithii	
vanus	*Anopheles*	Laticorn	Myzorhynchus	Barbirostris	Vanus
vargasi	*Lophopodomyia*				
varuna	*Cellia*		Myzomyia	Funestus	Aconitus
vernus	*Cellia*		Neomyzomyia	Ardensis	
veruslanei	*Anopheles*	Laticorn	Arribalzagia		
vestitipennis	*Anopheles*	Laticorn	Arribalzagia		
vietnamensis	*Anopheles*	Laticorn	Myzorhynchus	Hyrcanus	Lesteri
vinckei	*Cellia*		Neomyzomyia	Ardensis	
walkeri	*Anopheles*	Angusticorn	Anopheles	Maculipennis	
walravensi	*Cellia*		Myzomyia		
watsonii	*Cellia*		Neomyzomyia		
wellcomei	*Cellia*		Myzomyia	Wellcomei	
wellingtonianus	*Anopheles*	Angusticorn	Anopheles	Lindesayi	
whartoni	*Anopheles*	Laticorn	Myzorhynchus	Umbrosus	Letifer
willmori	*Cellia*		Neocellia	Maculatus	
wilsoni	*Cellia*		Neomyzomyia	Smithii	
xelajuensis	*Anopheles*	Angusticorn	Anopheles	Plumbeus	
xui	*Anopheles*	Laticorn	Myzorhynchus	Hyrcanus	
yaeyamaensis	*Cellia*		Myzomyia	Funestus	Minimus
ziemanni	*Anopheles*	Laticorn	Myzorhynchus	Coustani	

http://dx.doi.org/10.5772/54695

Appendix 3

Sibling species complexes of *Anopheles* – formally named and unnamed species. The Maculatus, Maculipennis and Punctulatus Complexes are now considered to be super-complexes referred to as "Groups" with subordinate complexes. Likewise, the Culicifacies Complex is considered to be a Subgroup.

Subgenus *Anopheles*

Barbirostris Complex [76]
- *barbirostris*

Claviger Complex [67]
- *claviger*
- *petragnani*

Crucians Complex [72]
- *bradleyi*
- *crucians* A
- *crucians* B
- *crucians* C
- *crucians* D
- *crucians* E
- *georgianus*

Gigas Complex [70]
- *baileyi*
- *gigas*
- *gigas s.l.*

Lindesayi Complex [70]
- *lindesayi*
- *mengalangensis*
- *nilgiricus*
- *wellingtonianus*

Maculipennis Group [20]
- *atropos*
- *aztecus*
- *lewisi*
- *walkeri*

Maculipennis Subgroup [71]
- *artemievi*
- *atroparvus*
- *daciae*
- *labranchiae*
- *maculipennis*
- *martinius*
- *melanoon*
- *messeae*
- *persiensis*
- *sacharovi*

Quadrimaculatus Subgroup [21]
- *beklemishevi*
- *diluvialis*
- *inundatus*
- *maverlius*
- *quadrimaculatus*
- *smaragdinus*

Freeborni Subgroup [71]
- *earlei*
- *freeborni*
- *hermsi*
- *occidentalis*

Subgenus *Cellia*

Annularis Complex [86]
- *annularis* A
- *annularis* B
- *pallidus*
- *philippinensis*
- *schueffneri*

Annulipes Complex [89]
- *annulipes* A
- *annulipes* B
- *annulipes* C
- *annulipes* D
- *annulipes* F
- *annulipes* G
- *annulipes* H
- *annulipes* I
- *annulipes* J
- *annulipes* K
- *annulipes* L
- *annulipes* M
- *annulipes* N
- *annulipes* O
- *annulipes* P
- *annulipes* Q

Culicifacies Subgroup [108]
- *culicifacies* A
- *culicifacies* B
- *culicifacies* C
- *culicifacies* D
- *culicifacies* E

Dirus Complex [93]
- aff. *takasagoensis*
- *baimaii*
- *cracens*
- *dirus*
- *elegans*
- *nemophilous*
- *scanloni*
- *takasagoensis*

Fluviatilis Complex [83]
- *fluviatilis* S
- *fluviatilis* T
- *fluviatilis* U

Gambiae Complex [96]
- *arabiensis*
- *bwambae*
- *comorensis*
- *gambiae*
- *melas*
- *merus*
- *quadriannulatus*
- *quadriannulatus* B

Leucosphyrus Complex [91]
- *baisasi*
- *balabacensis*
- *introlatus*
- *latens*
- *leucosphyrus*

Longirostris Complex [90]
- Genotype A
- Genotype B
- Genotype C1
- Genotype C2
- Genotype D
- Genotype E
- Genotype F
- Genotype G
- Genotype H

Lungae Complex [47]
- *lungae*
- *nataliae*
- *solomonis*

Maculatus Group [88]
- *dispar*
- *greeni*
- *pseudowillmori*
- *willmori*

Maculatus Subgroup [73]
- *dravidicus*
- *maculatus*

Sawadwongporni Subgroup [73]
- *notanandai*
- *rampae*
- sawadwongporni

Marshallii Complex [85]
- *hughi*
- *kosiensis*
- *letabensis*
- *marshallii*

Minimus Complex [84]
- *harrisoni*
- *minimus*
- *yaeyamaensis*

Nivipes Complex [70,87]
- *nivipes* cytotype 1
- *nivipes* cytotype 2

Nili Complex [22]
- *carnevalei*
- *nili*
- *ovengensis*
- *somalicus*

Punctulatus Group [94]
- *clowi*
- *koliensis*
- *punctulatus*
- *rennellensis*
- sp. nr *punctulatus*

Farauti Complex [94,109]
- *farauti*
- *farauti* 4
- *farauti* 5
- *farauti* 6
- *farauti* 8
- *hinesorum*
- *irenicus*
- *torresiensis*

Subpictus Complex [95]
- *subpictus* A
- *subpictus* B
- *subpictus* C
- *subpictus* D

Sundaicus Complex [97]
- *epiroticus*
- *sundaicus*
- *sundaicus* B
- *sundaicus* C
- *sundaicus* D
- *sundaicus* E

Superpictus Complex [110]
- *superpictus* A
- *superpictus* B

Subgenus *Kerteszia*

Cruzii Complex [101]
- *cruzii* A
- *cruzii* B
- *cruzii* C

Subgenus *Nyssorhynchus*

Albitarsis Complex [106]
- *albitarsis*
- *albitarsis* F
- *albitarsis* G
- *albitarsis* H
- *albitarsis* I
- *deaneorum*
- *janconnae*
- lineage nr *janconnae*
- *marajoara*
- *oryzalimnetes*

Benarrochi Complex [105]
- *benarrochi*
- *benarrochi* B

Nuneztovari Complex [104,111]
- *goeldii*
- *nuneztovari* B/C
- *nuneztovari* A

Triannulatus Complex [112,113]
- *halophylus*
- *triannulatus*
- *triannulatus* C

Appendix 4

Unnamed and provisionally designated members of species complexes and their position in the classification of genus *Anopheles* (Sections of subgenera *Anopheles* and *Nyssorhynchus* are omitted). Excluding nominotypical members, the list includes 72 species that require formal Latin names.

Species	Authors	Subgenus	Series	Group	Subgroup	Complex
albitarsis sp. F,G,H,I	[114,115]	*Nyssorhynchus*	Albitarsis	Albitarsis		Albitarsis
annularis sp. A,B	[86]	*Cellia*	Neocellia	Annularis		Annularis
annulipes sp. A–Q	[89]	*Cellia*	Neomyzomyia			Annulipes
Anopheles CP Form	[116]	*Nyssorhynchus*	Oswaldoi	Oswaldoi	Strodei	
barbirostris clades I–IV	[117]	*Anopheles*	Barbirostris	Barbirostris	Barbirostris	Barbirostris
benarrochi sp. B	[105]	*Nyssorhynchus*	Oswaldoi	Oswaldoi	Strodei	Benarrochi
crucians sp. A–E	[72]	*Anopheles*	Anopheles	Punctipennis		Crucians
cruzii sp. A,B,C	[118]	*Kerteszia*				
culicifacies sp. A–E	[108]	*Cellia*	Myzomyia	Funestus	Culicifacies	Culicifacies
farauti sp. 4,5,6	[109,119]	*Cellia*	Neomyzomyia	Punctulatus		Farauti
fluviatilis sp. S,T,U	[83]	*Cellia*	Myzomyia	Funestus	Minimus	Fluviatilis
funestus-like sp.	[120]	*Cellia*	Myzomyia	Funestus	Funestus	
gigas s.l. (Thailand)	[70]	*Anopheles*	Anopheles	Lindesayi		Gigas
hyrcanus sp_{IR}	[121]	*Anopheles*		Hyrcanus		
janconnae, lineage nr	[122]	*Nyssorhynchus*	Albitarsis	Albitarsis		Albitarsis
longipalpis Type A	[123]	*Cellia*	Myzomyia	Funestus	Minimus	
longipalpis Type C	[123]	*Cellia*	Myzomyia	Funestus	Funestus	
longirostris Genotypes A,B,C1,C2,D,E,F,G,H	[90]	Cellia	Neomyzomyia			Longirostris
marajoara lineages 1,2	[124]	*Nyssorhynchus*	Albitarsis	Albitarsis		Albitarsis
nivipes (2 cytotypes)	[87]	*Cellia*	Neocellia	Annularis		Nivipes
nuneztovari sp. A	[125]	*Nyssorhynchus*	Oswaldoi	Oswaldoi	Oswaldoi	Nuneztovari
nuneztovari B/C	[104]	*Nyssorhynchus*	Oswaldoi	Oswaldoi	Oswaldoi	Nuneztovari
punctulatus, sp. nr	[126]	*Cellia*	Neomyzomyia	Punctulatus		

Species	Authors	Subgenus	Series	Group	Subgroup	Complex
quadriannulatus sp. B	[127]	*Cellia*	Pyretophorus			Gambiae
subpictus sp. A–D	[99]	*Cellia*	Pyretophorus	Subpictus		Subpictus
sundaicus sp. B–E	[98,128]	*Cellia*	Pyretophorus	Ludlowae		Sundaicus
superpictus sp. A,B	[110,129]	*Cellia*	Neocellia			Superpictus
takasagoensis, aff.	[130]	*Cellia*	Neomyzomyia	Leucosphyrus	Leucosphyrus	Dirus
triannulatus sp. C	[113]	*Nyssorhynchus*	Oswaldoi	Triannulatus		Triannulatus

Appendix 5

Phylogenetic studies of *Anopheles* mosquitoes. Groups included in the table are those recognized herein. None of the studies included all taxa that comprise the group investigated, but those marked with an asterisk (*) included the majority of species. Nucleotide sequences include *COI*, *COII*, *cyt b*, *ND4*, *ND5* and *ND6* from mitochondrial DNA (mtDNA); *D2*, *D3*, *18S*, *ITS1* and *ITS2* from ribosomal DNA (rDNA); *EF-1α*, G_6pd and *white* from nuclear DNA.

Group	Data set	Authors
Genus *Anopheles*	Morphology	[40]
		[36]
	cyt b, *ND5*, *D2*	[38]
	ND5, *D2*, G_6pd, *white*	[39]
	COI, *COII*, *D2*	[41]
	18S	[131]
Subgenus *Anopheles*	Morphology	[42]
	COII	[37]
Anopheles Series		
Maculipennis Group	Chromosomes	[132]
	ITS2	[71]* [133,134]
Maculipennis Subgroup	*ITS2*	[135]
Freeborni and Quadrimaculatus Subgroups	*D2*	[136]
Myzorhynchus Series	*ITS2*, *COI*, *COII*	[137,139]
Barbirostris Complex	*ITS2*, *COI*	[117]
Hyrcanus Grou	*ITS2*	[139,140] [141]*

Group	Data set	Authors
	ITS2, *COI*	[142]
Subgenus *Cellia*	Chromosomes	[143,144]
	COII	[37]
Myzomyia Series	Chromosomes	[143,144]
	COII, *D3*	[82]
Funestus Group	*ITS2, COII, D3*	[55]*
	COII, D3	[81]*
Minimus Subgroup	*COII*, *D3*	[145]
Minimus Complex	*D3, ITS2*	[146]*
Neocellia Series	Chromosomes	[87]
Annularis Group	*ITS2*, *COII*, *D3*, *ND5*	[147]
	D3, ITS2	[148]
Maculatus Group	*ITS2*, *COII*, *D3*	[149–151]
Neomyzomyia Series	*ITS2*, *COI*, *COII*, *EF-1α*	[89]
Annulipes Complex	*COI, ND6*	[152]
Leucosphyrus Group		
Punctulatus Group	*ITS2*	[153]
	18S	[154]
Farauti Complex	*ITS1*	[109]
Pyretophorus Series	Morphology	[56]*
	Chromosomes	[144]
	COII	[37]
Gambiae Complex	Chromosomes	[155]
	rDNA, mtDNA	[156]
Sundaicus Complex	mtDNA	[157]
	ITS2, *D2*, *COI*, *ND4*	[158]
	white	[114]
	cyt b, ITS2, COI	[128]
Subgenus *Kerteszia*	Morphology	[44]
Subgenus *Nyssorhynchus*	*ITS2*	[159]
Albimanus Section	Morphology	[24]
Argyritarsis Section	Morphology	[25]
Myzorhynchella Section	*ITS2*, *COI*, *white*	[160]

http://dx.doi.org/10.5772/54695

Appendix 6

Summary of the formal and informal group taxa (species complexes omitted) of genus *Anopheles*. The zoogeographic distribution and the number of formally named and informally designated species (in parentheses) are given for each taxon. Minor extensions of one or more species of a group into an adjacent zoogeographic region are disregarded. C = cosmopolitan; NW = New World; OW = Old World; Af = Afrotropical; Au = Australasian; Ne = Nearctic; Nt = Neotropical; Or = Oriental; Pa = Palaearctic.

Subgenus *Anopheles*– C (191)
Angusticorn Section – OW, NW (95)
Anopheles Series – OW and NW (88)
Alongensis Group – Or (2)
Aitkenii Group – Or (13)
Atratipes Group – Au (2)
Culiciformis Group – Or (3)
Lindesayi Group – Or (7)
Maculipennis Group – Ne, Pa (20)
Maculipennis Subgroup – Pa (10)
Quadrimaculatus Subgroup – Ne (5), Pa (1)
Freeborni Subgroup – Ne (4)
Plumbeus Group – Ne (2), Nt (4), Pac (3)
Pseudopunctipennis Group – Ne (7)
Punctipennis Group – Ne (9)
Stigmaticus Group – Au (6)
Cycloleppteron Series – Ne (2)
Lophoscelomyia Series – Or (4)
Unassigned – (1)
Asiaticus Group – (4)
Unassigned – (2)
Asiaticus Subgroup – (1)
Interruptus Subgroup – (1)
Laticorn Section – Af, Au, Nt, Or, Pa (96)
Arribalzagia Series – Ne (24)
Christya Series – Af (2)
Myzorhynchus Series – Af, Au, Or, Pa (70)
Albotaeniatus Group – Or (4), Pa (1)
Bancroftii Group – Au/Or (2)
Barbirostris Group – Or (16)
Unassigned – (2)
Barbirostris Subgroup – (9)
Vanus Subgroup – (5)
Coustani Group – Af (9)
Hyrcanus Group – Pa (26)
Unassigned – (17)
Lesteri Subgroup – (5)
Nigerrimus Subgroup – (4)
Umbrosus Group – Or (12)
Unassigned – (5)
Baezai Subgroup – (1)
Letifer Subgroup – (4)
Separatus Subgroup – (1)
Umbrosus Subgroup – (1)

Subgenus *Baimaia*– Or (1)

Subgenus *Cellia*– OW (233)
Cellia Series – Af (8)
Unassigned – (6)
Squamosus Group – (2)
Myzomyia Series – Af, Or (71)
Unassigned – Af (16)
Demeilloni Group – Af (7)
Funestus Group – Af, Or (29)
Unassigned – (1)
Aconitus Subgroup – Or (5)
Culicifacies Subgroup – Or (5)
Funestus Subgroup – Af (7)
Minimus Subgroup – Af (1), Or (6)
Rivulorum Subgroup – Af (4)
Marshallii Group – Af (15)
Wellcomei Group – Af (4)
Neocellia Series – Af, Or, Pal (24)
Unassigned – Af, Or, Pa (14)
Annularis Group – Or (7)
Jamesii Group – Or (3)
Maculatus Group – Or (9)
Unassigned – (4)
Maculatus Subgroup – (2)
Sawadwongporni Subgroup – (3)
Neomyzomyia Series – Af, Au, Or (121)
Unassigned – Af, Au, Or (42)
Ardensis Group – Af (18)
Kochi Group – Or (1)
Leucosphyrus Group – O (21)
Hackeri Subgroup – (5)
Leucosphyrus Subgroup – (13)
Riparis Subgroup – (3)
Mascarensis Group – Af (1)
Pauliani Group – Af (5)
Punctulatus Group – Au (13)
Ranci Group – Af (5)
Unassigned – (1)
Ranci Subgroup – (1)
Roubaudi Subgroup – (3)
Rhodesiensis Group – Af (5)
Smithii Group – Af (9)
Tessellatus Group – Or (1)
Paramyzomyia Series – Af, Pa (6)
Cinereus Group – Af (2), Pa (1)
Listeri Group – Af (2), Pa (1
Pyretophorus Series – Af (10), Or (12)

Subgenus *Kerteszia*– Nt (14)

Subgenus *Lophopodomyia*– Nt (6)

Subgenus *Nyssorhynchus*– Nt (38)
Albimanus Section – (24)
Albimanus Series – (1)
Oswaldoi Series – (23)
Oswaldoi Group – (21)
Oswaldoi Subgroup – (14)
Strodei Subgroup – (7)
Triannulatus Group – (3)
Argyritarsis Section – (14)
Albitarsis Series – (8)
Albitarsis Group – (7)
Braziliensis Group – (1)
Argyritarsis Series – (6)
Argyritarsis Group – (2)
Darlingi Group – (1)
Lanei Group – (1)
Pictipennis Group – (2)
Myzorhynchella Section – (6)

Subgenus *Stethomyia*– Ne (5)

Author details

Ralph E. Harbach*

Address all correspondence to: r.harbach@nhm.ac.uk

Department of Life Sciences, Natural History Museum, London, UK

Three new species of *Anopheles* were formally described and named while the book was in press: *An*. (*Anopheles*) *vanderwulpi* (= *An. barbirostris* clade II) [161]; *An*. (*Cellia*) *amharicus* (= *An. quadriannulatus* sp. B) and *An*. (*Cellia*) *coluzzii* (= molecular M form of *An. gambiae*) [162]. *Anopheles* (*Anopheles*) *kunmingensis* (Laticorn Section, Myzorhynchus Series, Hyrcanus Group) was inadvertently omitted from Appendix 2 during preparation of the chapter. Thus, the genus now includes 469 formally named species and 70 species that require formal Latin names.

References

[1] Meigen JW. Systematische Beschreibung der bekannten europäischen zweiflügeligen Insekten. Volume 1. Aachen; 1818.

[2] Theobald FV. A Monograph of the Culicidae or Mosquitoes. Volume 1. London: British Museum (Natural History); 1901.

[3] Theobald FV. A Monograph of the Culicidae or Mosquitoes. Volume 2. London: British Museum (Natural History); 1901.

[4] Theobald FV. A Monograph of the Culicidae or Mosquitoes. Volume 3. London: British Museum (Natural History); 1903.

[5] Theobald FV. A Monograph of the Culicidae or Mosquitoes. Volume 4. London: British Museum (Natural History); 1907.

[6] Theobald FV. A Monograph of the Culicidae or Mosquitoes. Volume 5. London: British Museum (Natural History); 1910.

[7] Knight KL, Stone A. A catalog of the mosquitoes of the world (Diptera: Culicidae). Second edition. Thomas Say Foundation 1977;6 1–611.

[8] Knab F. The species *of Anopheles* that transmit human malaria. American Journal of Tropical Diseases and Preventive Medicine 1913;1 33–43.

[9] Christophers SR. The male genitalia of *Anopheles*. Indian Journal of Medical Research 1915;3 371–394.

[10] Edwards FW. A revision of the mosquitos [*sic*] of the Palaearctic Region. Bulletin of Entomological Research 1921;12 263–351.

[11] Root FM. The male genitalia of some American *Anopheles* mosquitoes. American Journal of Hygiene 1923;31 264–279.

[12] Edwards FW. Genera Insectortum. Diptera, Fam. Culicidae. Fascicle 194. Bruxelles: Desmet-Verteneuil; 1932.

[13] Komp WHW. The species of the subgenus *Kerteszia* of *Anopheles* (Diptera, Culicidae). Annals of the Entomological Society of America 1937;30 492–529.

[14] Antunes PCA. A new *Anopheles* and a new *Goeldia* from Colombia (Dipt. Culic.). Bulletin of Entomological Research 1937;28 69–73.

[15] Harbach RE, Rattanarithikul R, Harrison BA. *Baimaia*, a new subgenus for *Anopheles kyondawensis* Abraham, a unique crabhole-breeding anopheline in southeastern Asia. Proceedings of the Entomological Society of Washington 2005;107 750–761.

[16] Harbach RE. Mosquito Taxonomic Inventory. http://mosquito-taxonomic-inventory.info/ (accessed on 1 April 2013).

[17] Mayr E, Bock WJ. Classifications and other ordering systems. Journal of Zoological Systematics and Evolutionary Research 2002;40 169–194.

[18] Harbach RE, Kitching IJ. Phylogeny and classification of the Culicidae (Diptera). Systematic Entomology 1998;23 327–370.

[19] International Commission on Zoological Nomenclature. International Code of Zoological Nomenclature. Fourth Edition. London: International Trust for Zoological Nomenclature; 1999.

[20] Reid JA, Knight KL. Classification within the subgenus *Anopheles* (Diptera, Culicidae). Annals of Tropical Medicine and Parasitology 1961;55 474–488.

[21] Grjebine A. Faune de Madagascar. XXII. Insecies Diptéres Culicidae Anophelinae. Paris: Centre National de la Recherche Scientifique, Office de la Recherche Scientifique et Technique Outre-Mer; 1966.

[22] Gillies MT, de Meillon B. The Anophelinae of Africa South of the Sahara (Ethiopian Zoogeographical Region). Publications of the South African Institute for Medical Research 1968;54 1–343.

[23] Reid JA. Anopheline mosquitoes of Malaya and Borneo. Studies from the Institute for Medical Research Malaya 1968;31 1–520.

[24] Faran ME. Mosquito studies (Diptera, Culicidae) XXXIV. A revision of the Albimanus Section of the subgenus *Nyssorhynchus* of *Anopheles*. Contributions of the American Entomological Institute 1980;15(7) 1–215.

[25] Linthicum KJ. A revision of the Argyritarsis Section of the subgenus *Nyssorhynchus* of *Anopheles* (Diptera: Culicidae). Mosquito Systematics 1988;20 98–271.

[26] Harbach RE. Review of the internal classification of the genus *Anopheles* (Diptera: Culicidae): the foundation for comparative systematics and phylogenetic research. Bulletin of Entomological Research 1994;84 331–342.

[27] Harbach RE. The classification of genus *Anopheles* (Diptera: Culicidae): a working hypothesis of phylogenetic relationships. Bulletin of Entomological Research 2004;94 537–553.

[28] Peyton EL, Wilkerson RC, Harbach RE. Comparative analysis of the subgenera *Kerteszia* and *Nyssorhynchus* of *Anopheles* (Diptera: Culicidae). Mosquito Systematics 1992;24 51–69.

[29] Borkent A, Grimaldi DA. The earliest fossil mosquito (Diptera: Culicidae), in mid-Cretaceous amber. Annals of the Entomological Society of America 2004;97 882–888.

[30] Bertone MA, Courtney GW, Wiegmann BM. Phylogenetics and temporal diversification of the earliest true flies (Insecta: Diptera) based on multiple nuclear genes. Systematic Entomology 2008;33 668–687.

[31] Poinar Jr JO, Zavortink TJ, Pike T, Johnston PA. *Paleoculicis minutus* (Diptera: Culicidae) n. gen., n. sp., from Cretaceous Canadian amber, with a summary of described fossil mosquitoes. Acta Geologica Hispanica 2000;35 119–128.

[32] Zavortink TJ, Poinar Jr GO. *Anopheles* (*Nyssorhynchus*) *dominicanus* sp. n. (Diptera: Culicidae) from Dominican amber. Annals of the Entomological Society of America 2000;93 1230–1235.

[33] Statz G. Neue Dipteren (Nematocera) aus dem Oberoligocän von Rott. II. Teil. V. Familie Culicidae (Stechmücken). Palaeontographica 1944;95(A) 108–120, 6 pls.

[34] Reidenbach KR, Cook S, Bertone MA, Harbach RE, Wiegmann BM, Besansky NJ. Phylogenetic analysis and temporal diversification of mosquitoes (Diptera: Culicidae) based on nuclear genes and morphology. BMC Evolutionary Biology 2009;9 298.

[35] Besansky NJ, Fahey GT. Utility of the *white* gene in estimating phylogenetic relationships among mosquitoes (Diptera: Culicidae). Molecular Biology and Evolution 1997;14 442–454.

[36] Harbach RE, Kitching IJ. Reconsideration of anopheline phylogeny (Diptera: Culicidae: Anophelinae) based on morphological data. Systematics and Biodiversity 2005;3 345–374.

[37] Foley DH, Bryan JH, Yeates D, Saul A. Evolution and systematics of *Anopheles*: insights from a molecular phylogeny of Australasian mosquitoes. Molecular Phylogenetics and Evolution 1998;9 262–275.

[38] Krzywinski J, Wilkerson RC, Besansky N. Evolution of mitochondrial and ribosomal gene sequences in Anophelinae (Diptera: Culicidae): implications for phylogeny reconstruction. Molecular Phylogenetics and Evolution 2001;18 479–487.

[39] Krzywinski J, Wilkerson RC, Besansky N. Toward understanding Anophelinae (Diptera, Culicidae) phylogeny: insights from nuclear single copy genes and the weight of evidence. Systematic Biology 2001;50 540–556.

[40] Sallum MAM, Schultz TR, Wilkerson RC. Phylogeny of Anophelinae (Diptera Culicidae) based on morphological characters. Annals of the Entomological Society of America 2000;93 745–775.

[41] Sallum MAM, Schultz TR, Foster PG, Aronstein K, Wirtz RA, Wilkerson RC. Phylogeny of Anophelinae (Diptera: Culicidae) based on nuclear ribosomal and mitochondrial DNA sequences. Systematic Entomology 2002;27 361–382.

[42] Collucci E, Sallum MAM. Cladistic analysis of the subgenus *Anopheles* (*Anopheles*) Meigen (Diptera: Culicidae) based on morphological characters. Memórias do Instituto Oswaldo Cruz 2007;102 277–291.

[43] Harrison BA, Scanlon JE. Medical entomology studies – II. The subgenus *Anopheles* in Thailand (Diptera: Culicidae). Contributions of the American Entomological Institute 1975;12(1) iv + 1–307.

[44] Collucci E, Sallum MAM. Phylogenetic analysis of the subgenus *Kerteszia* of *Anopheles* (Diptera: Culicidae: Anophelinae) based on morphological characters. Insect Systematics and Evolution 2003;34 361–372.

[45] Merali Z, Skinner BJ. Visualizing Earth Science. John Wiley: Hoboken, New Jersey; 2009.

[46] Valencio D, Vilas JF. Age of the separation of South America and Africa. Nature 1969;223 1353–1354.

[47] Belkin JN. The Mosquitoes of the South Pacific *(Diptera, Culicidae)* [*sic*]. Volumes I and II. Berkeley & Los Angeles: University of California Press; 1962.

[48] Christophers SR. The fauna of British India, Including Ceylon and Burma. Diptera. Vol. IV. Family Culicidae. Tribe Anophelini. London, Taylor and Francis; 1933.

[49] Zavortink TJ. Mosquito studies (Diptera, Culicidae) XXIX. A review of the subgenus *Kerteszia* of *Anopheles*. Contributions of the American Entomological Institute 1973;9(3) 1–54.

[50] Smith AB. Systematics and the Fossil Record: Documenting Evolutionary Patterns. Oxford: Blackwell Scientific Publications; 1994.

[51] Christophers SR, Barraud PJ. The eggs of Indian *Anopheles* with descriptions of the hitherto undescribed eggs of a number of species. Records of the Malaria Survey of India 1931;2 161–192.

[52] Mattingly PF. The Biology of Mosquito-Borne Disease. The Science of Biology Series 1. London: George Allen & Unwin Ltd; 1969.

[53] Sinka ME, Bangs MJ, Manguin S, Coetzee M, Mbogo CM, Hemingway J, Patil AP, Temperley WH, Gething PW, Kabaria CW, Okara RM, Van Boeckel T, Godfray HCJ, Harbach RE, Hay SI. The dominant *Anopheles* vectors of human malaria in Africa, Europe and the Middle East: occurrence data, distribution maps and bionomic précis. Parasites & Vectors 2010;3 117.

[54] Sinka ME, Bangs MJ, Manguin S, Chareonviriyaphap T, Patil AP, Temperley WH, Gething PW, Elyazar IRF, Kabaria CW, Harbach RE, Hay SI. The dominant *Anopheles* vectors of human malaria in the Asia-Pacific region: occurrence data, distribution maps and bionomic précis. Parasites & Vectors 2011;4 89.

[55] Garros C, Harbach RE, Manguin S. Systematics and biogeographical implications of the phylogenetic relationships between members of the Funestus and Minimus Groups of *Anopheles* (Diptera: Culicidae). Journal of Medical Entomology 2005;42 7–18.

[56] Anthony TG, Harbach RE, Kitching IJ. Phylogeny of the Pyretophorus Series of *Anopheles* subgenus *Cellia* (Diptera: Culicidae). Systematic Entomology 1999;24 193–205.

[57] Evans AM. Mosquitoes of the Ethiopian Region. II.–Anophelini adults and early stages. London: British Museum (Natural History); 1938.

[58] Gillies MT. Notes on the eggs of some East African *Anopheles.* Annals of Tropical Medicine and Parasitology 1955;49 158–160.

[59] Mattingly PF. Mosquito eggs III. Mosquito Systematics Newsletter 1969;1 41–50.

[60] Stringer C. The Origin of our Species. London: Penguin Books Ltd; 2011.

[61] Sinka ME, Rubio-Palis Y, Manguin S, Patil AP, Temperley WH, Gething PW, Van Boeckel T, Kabaria CW, Harbach R.E, Hay SI. The dominant *Anopheles* vectors of human malaria in the Americas: occurrence data, distribution maps and bionomic précis. Parasites & Vectors 2010;3 72.

[62] Sinka ME, Bangs MJ, Manguin S, Rubio-Palis Y, Chareonviriyaphap T, Coetzee M, Mbogo CM, Hemingway J, Patilm AP, Temperley WH, Gething PW, Kabaria CW, Okara RM, Burkot TR, Harbach RE, Hay SI. A global map of dominant malaria vectors. Parasites & Vectors 2012;5 69.

[63] Besansky NJ, Lehmann T, Fahey GT, Fontenille D, Braack LEO, Hawley WA, Collins FH. Patterns of mitochondrial variation within and between African malaria vectors, *Anopheles gambiae* and *An. arabiensis*, suggest extensive gene flow. Genetics 1997;147 1817–1828.

[64] Thelwell NJ, Huisman RA, Harbach RE, Butlin RK. Evidence for mitochondrial introgression between *Anopheles bwambae* and *Anopheles gambiae*. Insect Molecular Biology 2000;9 203–210.

[65] Walton C, Handley JM, Collins FH, Baimai V, Harbach RE, Deesin V, Butlin RK. Genetic population structure and introgression in *Anopheles dirus* mosquitoes in Southeast Asia. Molecular Ecology 2001;10 569–580.

[66] Van Bortel W, Trung HD, Manh ND, Roelants P, Verlé P, Coosemans M. Identification of two species within the *Anopheles minimus* complex in northern Vietnam and their behavioural divergences. Tropical Medicine and International Health 1999;4 257–265.

[67] Coluzzi M, Sacca G, Feliciangeli D. Il complesso *A. claviger* nella sottoregione mediterranea. Cahiers ORSTROM, série Entomologie médicale et Parasitologie 1965; 97–102.

[68] Vu TP, Nguyen DM,Tran DH, Nguyen NV. *Anopheles* (*Anopheles*) *cucphuongensis*: a new species from Vietnam (Diptera: Culicidae). *Mosquito Systematics* 1990;22 145–148.

[69] Lee DJ, Hicks MM, Griffiths M, Debenham ML, Bryan JH, Russell RC, Geary M, Marks EN. The Culicidae of the Australasian Region. Volume 5. Nomenclature, synonymy, literature, distribution, biology and relation to disease. Genus *Anopheles*. Subgenera *Anopheles*, *Cellia*. Monograph Series, Entomology Monograph No. 2. Canberra: Australian Government Publishing Service; 1987.

[70] Harrison BA, Rattanarithikul R, Peyton EL, Mongkolpanya K. Taxonomic changes, revised occurrence records and notes on the Culicidae of Thailand and neighboring countries. Mosquito Systematics 1991;22 196–227.

[71] Linton Y. Systematics of the Holarctic *maculipennis* complex. Systematics Symposium: 70th Annual Meeting of the American Mosquito Control Association, February 22–26, 2004, Savannah, Georgia.

[72] Wilkerson RC, Reinert JF, Li C. Ribosomal DNA ITS2 sequences differentiate six species in the *Anopheles crucians* complex (Diptera: Culicidae). Journal of Medical Entomology 2004;41 392–401.

[73] Rattanarithikul R, Harrison BA, Harbach RE, Panthusiri P, Coleman RE. Illustrated Keys to the mosquitoes of Thailand. IV. *Anopheles.* Southeast Asian Journal of Tropical Medicine and Public Health 2006;37(suppl. 2) 1–128.

[74] Root FM. The classification of American *Anopheles* mosquitoes. American Journal of Hygiene 1922;2 321–322.

[75] Christophers SR. Provisional list and reference catalogue of the Anophelini. Indian Medical Research Memoirs 1924;3 1–105.

[76] Satoto TBT. Cryptic species within *Anopheles barbirostris* van der Wulp, 1884, inferred from nuclear and mitochondrial gene sequence variation. PhD Thesis. University of Liverpool; 2001.

[77] Reid JA. The *Anopheles hyrcanus* group in south–east Asia (Diptera: Culicidae). Bulletin of Entomological Research 1953;44 5–76.

[78] Harrison BA. A new interpretation of affinities within the *Anopheles hyrcanus* complex of Southeast Asia. Mosquito Systematics 1972;4 73–83.

[79] Reid JA. The *Anopheles umbrosus* group (Diptera: Culicidae). Part 1: systematics, with descriptions of two new species. Transactions of the Royal Entomological Society of London 1950;101 281–318.

[80] Theobald FV. The classification of the Anophelina. Journal of Tropical Medicine 1902;5 181–183.

[81] Garros C, Harbach RE, Manguin S. Morphological assessment and molecular phylogenetics of the Funestus and Minimus Groups of *Anopheles* (*Cellia*). Journal of Medical Entomology 2005;42 522–536.

[82] Chen B, Butlin RK, Harbach RE. Molecular phylogenetics of the Oriental members of the Myzomyia Series of *Anopheles* subgenus *Cellia* (Diptera: Culicidae) inferred from nuclear and mitochondrial DNA sequences. Systematic Entomology 2003;28 57–69.

[83] Sarala KS, Nutan N, Vasantha K, Dua VK, Malhotra MS, Yadav RS, Sharma VP. Cytogenetic evidence for three sibling species in *Anopheles fluviatilis* (Diptera: Culicidae). Annals of the Entomological Society of America 1994;87 116–121.

[84] Green CA, Gass RF, Munstermann LE, Baimai V. Population-genetic evidence for two species in *Anopheles minimus* in Thailand. Medical and Veterinary Entomology 1990;4 25–34.

[85] Gillies MT, Coetzee M. A supplement to the Anophelinae of Africa south of the Sahara (Afrotropical Region). Publications of the South African Institute for Medical Research 1987;55 1–143.

[86] Atrie B, Subbarao SK, Pillai MKK, Rao SRV, Sharma VP. Population cytogenetic evidence for sibling species in *Anopheles annularis* (Diptera: Culicidae). Annals of the Entomological Society of America 1999;92 243–249.

[87] Green CA, Harrison BA, Klein TA, Baimai V. Cladistic analysis of polytene chromosome rearrangements in anopheline mosquitoes, subgenus *Cellia*, series *Neocellia*. Canadian Journal of Genetics and Cytology 1985;27 123–133.

[88] Rattanarithikul R, Green CA. Formal recognition of the species of the *Anopheles maculatus* group (Diptera: Culicidae) occurring in Thailand, including the descriptions of two new species and a preliminary key to females. Mosquito Systematics 1987;18 246–278.

[89] Foley DH, Wilkerson RC, Cooper RD, Volovsek ME, Bryan JH. A molecular phylogeny of *Anopheles annulipes* (Diptera: Culicidae) sensu lato: The most species-rich anopheline complex. Molecular Phylogenetics and Evolution 2007;43 283–297.

[90] Alquezaar DE, Hemmerter S, Cooper RD, Beebe NW. Incomplete concerted evolution and reproductive isolation at the rDNA locus uncovers nine cryptic species within *Anopheles longirostris* from Papua New Guinea. BMC Evolutionary Biology 2010;10 392.

[91] Reid JA. A preliminary account of the forms of *Anopheles leucosphyrus* Dönitz (Diptera: Culicidae). Proceedings of the Royal Entomological Society of London Series B Taxonomy 1949;18 42–53.

[92] Sallum MAM, Peyton EL, Wilkerson RC. Six new species of the *Anopheles leucosphyrus* group, reinterpretation of *An. elegans* and vector implications. Medical and Veterinary Entomology 2005;19 158–199.

[93] Peyton EL. A new classification for the Leucosphyrus Group of *Anopheles* (*Cellia*). Mosquito Systematics 1990;21 197–205.

[94] Sallum MAM, Peyton EL, Harrison BA, Wilkerson RC. Revision of the Leucosphyrus group of *Anopheles* (*Cellia*) (Diptera, Culicidae). Revista Brasileira de Entomologia 2005;49(Supl. 1) 1–152.

[95] Schmidt ER, Foley DH, Hartel GF, Williams GM, Bryan JH. Descriptions of the *Anopheles* (*Cellia*) *farauti* complex of sibling species (Diptera: Culicidae) in Australia. Bulletin of Entomological Research 2001;91 389–410.

[96] Schmidt ER, Foley DH, Bugoro H, Bryan JH. A morphological study of the *Anopheles punctulatus* group (Diptera: Culicidae) in the Solomon Islands, with a description of *Anopheles* (*Cellia*) *irenicus* Schmidt, sp.n. Bulletin of Entomological Research 2003;93 515–526.

[97] White GB. *Anopheles bwambae* sp.n., a malaria vector in the Semliki Valley, Uganda, and its relationships with other sibling species of the *An. gambiae* complex (Diptera: Culicidae). Systematic Entomology 1985;10 501–522.

[98] Sukowati S, Baimai V, Harun S, Dasuki Y, Andris H, Efriwati M. Isozyme evidence for three sibling species in the *Anopheles sundaicus* complex from Indonesia. Medical and Veterinary Entomology 1999;13 408–414.

[99] Suguna SG, Rathinam KG, Rajavel AR, Dhanda V. Morphological and chromosomal descriptions of new species in the *Anopheles subpictus* complex. Medical and Veterinary Entomology 1994;9 88–94.

[100] Theobald FV. A catalogue of the Culicidae in the Hungarian National Museum, with descriptions of new genera and species. Annales Musei Nationalis Hungarici 1905;3 61–119, figures legends + 4 pls.

[101] Ramirez CC, Dessen EM. Chromosomal evidence for sibling species of the malaria vector *Anopheles cruzii*. Genome 2000;43 143–151.

[102] Blanchard R. Nouvelle note sur les moustiques. Comptes Rendus Hebdomadaires des Séances et Mémoires de la Société de Biologie 1902;54 793–795.

[103] Levi Castillo R. Atlas de los Anofelinos Sudamericanos. Quayaquil, Ecuador: Sociedad Filantrópica de Guayas; 1949.

[104] Sierra DM, Velez ID, Linton Y-M. Malaria vector *Anopheles* (*Nyssorhynchus*) *nuneztovari* comprises one genetic species in Colombia based on homogeneity of nuclear ITS2 rDNA. Journal of Medical Entomology 2004;41 302–307.

[105] Ruiz F, Quiñones ML, Erazo HF, Calle DA, Alzate JF, Linton Y-M. Molecular differentiation of *Anopheles* (*Nyssorhynchus*) *benarrochi* and *An.* (*N.*) *oswaldoi* from Southern Colombia. Memorias do Instituto Oswaldo Cruz 2005;100 155–160.

[106] Wilkerson RC, Parsons TJ, Klein TA, Gaffigan TV, Bergo E, Consolim J. Diagnosis by random amplified polymorphic DNA polymerase chain reaction for four cryptic species related to *Anopheles* (*Nyssorhynchus*) *albitarsis* (Diptera: Culicidae) from Paraguay, Argentina, and Brazil. Journal of Medical Entomology 1995;32 697–704.

[107] Peyton EL, Wilkerson RC, Harbach RE. Comparative analysis of the subgenera *Kerteszia* and *Nyssorhynchus* of *Anopheles* (Diptera: Culicidae). Mosquito Systematics 1992;24 51–69.

[108] Kar I, Subbarao SK, Eapen A, Ravendaran J, Satyanarayana TS, Raghavendra K, Nanda N, Sharma VP. Evidence for a new malaria vector species, species E, within the *Anopheles culicifacies* complex (Diptera: Culicidae). Journal of Medical Entomology 1999;36 595–600.

[109] Bower JE, Dowton M, Cooper RD, Beebe NW. Intraspecific concerted evolution of the rDNA ITS1 in *Anopheles farauti* sensu stricto (Diptera: Culicidae) reveals recent patterns of population structure. Journal of Molecular Evolution 2008;67 397–411.

[110] Oshaghi MA, Yaghobi-Ershadi MR, Shemshad Kh, Pedram M, Amani H. The *Anopheles superpictus* complex: introduction of a new malaria vector complex in Iran. Bulletin de la Société de Pathologie exotique 2008;101 429–434.

[111] Conn J, Puertas YR, Seawright JA. A new cytotype *of Anopheles nuneztovari* from western Venezuela and Colombia. Journal of the American Mosquito Control Association 1993;9 294–301.

[112] Rosa-Freitas MG, Lourenço-de-Oliveira R, de Carvalho-Pinto CJ, Flores-Mendoza F, Silva-do-Nascimento TF. Anopheline species complexes in Brazil. Current knowledge of those related to malaria transmission. Memorias do Instituto Oswaldo Cruz 1998;93 651–655.

[113] Silva-do-Nascimento TR, Lourenço-de-Oliveira R. Diverse population dynamics of three *Anopheles* species belonging to the Triannulatus Complex (Diptera: Culicidae). Memorias do Instituto Oswaldo Cruz 2007;102 975–982.

[114] Brochero HHL, Li C, Wilkerson RC. A newly recognized species in the *Anopheles* (*Nyssorhynchus*) *albitarsis* complex (Diptera: Culicidae) from Puerto Carreño, Colombia. American Journal of Tropical Medicine and Hygiene 2007;76 1113–1117.

[115] Ruiz-Lopez F, Wilkerson RC, Conn JE, McKeon SN, Levin DM, Quiñones ML, Póvoa MM, Linton Y-M. DNA barcoding reveals both known and novel taxa in the Albitarsis Group (*Anopheles*: *Nyssorhynchus*) of Neotropical malaria vectors. Parasites & Vectors 2012;5 44.

[116] Sallum MAM, Foster PG, dos Santos CLS, Flores DC, Motoki MT, Bergo ES. Resurrection of two species from synonymy of *Anopheles* (*Nyssorhynchus*) *strodei* Root, and characterization of a distinct morphological form from the Strodei Complex (Diptera: Culicidae). Journal of Medical Entomology 2010;47 504–526.

[117] Paredes-Esquivel C, Donnelly MJ, Harbach RE, Townson H. A molecular phylogeny of mosquitoes in the *Anopheles barbirostris* subgroup reveals cryptic species: implications for identification of disease vectors. Molecular Phylogenetics and Evolution 2009;50 141–151.

[118] Ramirez CC, Dessen EM. Chromosome differentiated populations of *Anopheles cruzii*: evidence for a third sibling species. Genetica 2000;108 73–80.

[119] Foley DH, Paru R, Dagoro H, Bryan JH. Allozyme analysis reveals six species within the *Anopheles punctulatus* complex of mosquitoes in Papua New Guinea. Medical and Veterinary Entomology 1993;7 37–48.

[120] Spillings BL, Brooke BD, Koekemoer LL, Chiphwanya J, Coetzee M, Hunt RH. A new species concealed by *Anopheles funestus* Giles, a major malaria vector in Africa. American Journal of Tropical Medicine and Hygiene 2009;81 510–515.

[121] Djadid ND, Jazayeri H, Gholizadeh S, Pashaeirad S, Zakeri S. First record of a new member of *Anopheles* Hyrcanus Group from Iran: molecular identification, diagnosis, phylogeny, status of kdr resistance and *Plasmodium* infection. Journal of Medical Entomology 2009;46 1084–1093.

[122] Gutiérrez LA, Orrego LM, Gómez GF, López A, Luckhart S, Conn JE, Correa MM. A new mtDNA COI gene lineage closely related to *Anopheles janconnae* of the Albitarsis complex in the Caribbean region of Colombia. Memorias do Instituto Oswaldo Cruz 2010;105 1019–1025.

[123] Koekemoer LL, Misiani EA, Hunt RH, Kent RJ, Norris DE, Coetzee M. Cryptic species within *Anopheles longipalpis* from southern Africa and phylogenetic comparison with members of the *An. funestus* group. Bulletin of Entomological Research 2009;99 41–49.

[124] McKeon SN, Lehr MA, Wilkerson RC, Ruiz JF, Sallum MA, Povoa MM., Conn JE, Lima JBP. Lineage divergence detected in the malaria vector *Anopheles marajoara* (Diptera: Culicidae) in Amazonian Brazil. Malaria Journal 2010;9 271.

[125] Conn J. A genetic study of the malaria vector *Anopheles nuneztovari* from western Venezuela. Journal of the American Mosquito Control Association 1990;6 400–405.

[126] Foley DH, Cooper RD, Bryan JH. A new species within the *Anopheles punctulatus* complex in Western Province, Papua New Guinea. Journal of the American Mosquito Control Association 1995;11 122–127.

[127] Hunt RH, Coetzee M, Fettene M. The *Anopheles gambiae* complex: a new species from Ethiopia. Transactions of the Royal Society of Tropical Medicine and Hygiene 1998;92 231–235.

[128] Dusfour I, Michaux JR, Harbach RE, Manguin S. Speciation and phylogeography of the Southeast Asian *Anopheles sundaicus* complex. Infection, Genetics and Evolution 2007;7 484–493.

[129] Oshaghi MA, Shemshad Kh, Yaghobi-Ershadi MR, Pedram M, Vatandoost H, Abaie MR, Akbarzadeh K, Mohtarami F. Genetic structure of the malaria vector *Anopheles superpictus* in Iran using mitochondrial cytochrome oxidase (COI and COII) and morphologic markers: A new species complex? Acta Tropica 2007;101 241–248.

[130] Takano KT, Nguyen NTH, Nguyen BTH, Sunahara T, Yasunami, M, Nguyen MD, Takagi M. Partial mitochondrial DNA sequences suggest the existence of a cryptic species within the Leucosphyrus group [*sic*] of the genus *Anopheles* (Diptera: Culicidae), forest malaria vectors, in northern Vietnam. Parasites & Vectors 2010;3 41.

[131] Bargues MD, Latorre JM, Morchon R, Simon F, Escosa R, Aranda C, Sainz S, Fuentes MV, Mas-Coma S. rDNA sequences of *Anopheles* species from the Iberian Peninsula and an evaluation of the 18S rRNA gene as phylogenetic marker in Anophelinae. Journal of Medical Entomology 2006;43 508–517.

[132] White GB. Systematic reappraisal of the *Anopheles maculipennis* complex. Mosquito Systematics 1978;10 13–44.

[133] Gordeev M, Goriacheva I, Shaikevitch E, Ejov M. Variability of the second internal transcribed spacer of the ribosomal DNA among five Palaearctic species of anopheline mosquitoes. European Mosquito Bulletin 2004;17 14–19.

[134] Djadid ND, Gholizadeh S, Tafsiri E, Romi R, Gordeev M, Zakeri S. Molecular identification of Palearctic [*sic*] members of *Anopheles maculipennis* in northern Iran. Malaria Journal 2007;6-6 (10 pp.).

[135] Marinucci M, Romi R, Mancini M, Di Luca M, Severini C. Phylogenetic relationships of seven palearctic [*sic*] members of the *maculipennis* complex inferred from ITS2 sequence analysis. Insect Molecular Biology 1999;8 469480.

[136] Porter CH, Collins FH. Phylogeny of Nearctic members of the *Anopheles maculipennis* species group derived from the D2 variable region of 28S ribosomal RNA. Molecular Phylogenetics and Evolution 1996;6 178–188.

[137] Saeung A, Otsuka Y, Baimai V, Somboon P, Pitasawat B, Tuetan B, Junkum A, Takaoka H, Choochote W. Cytogenetic and molecular evidence for two species in the *Anopheles barbirostris* complex (Diptera: Culicidae) in Thailand. Parasitology Research 2007;101 1337–1344.

[138] Saeung A, Baimai V, Otsuka Y, Rattanarithikul R, Somboon P, Junkum A, Tuetun B, Takaoka H, Choochote W. Molecular and cytogenetic evidence of three sibling species of the *Anopheles barbirostris* form A (Diptera: Culicidae) in Thailand. Parasitology Research 2008;102 499–507.

[139] Ma Y-J, Qu F-Y. *Anopheles hyrcanus* complex from China: sequence differences of ribosomal DNA second internal transcribed spacer and phylogenetic analyses. Entomological Knowledge 2002;39 209–214 (in Chinese).

[140] Ma Y, Xu J. The Hyrcanus Group of *Anopheles* (*Anopheles*) in China (Diptera: Culicidae): species discrimination and phylogenetic relationships inferred by ribosomal DNA internal transcribed spacer 2 sequences. Journal of Medical Entomology 2005;42 610–619.

[141] Hwang UW. Revisited ITS2 phylogeny of *Anopheles* (*Anopheles*) Hyrcanus [*sic*] group mosquitoes: reexamination of unidentified and misidentified ITS2 sequences. *Parasitology Research*, 2007;101 885–894.

[142] Paredes-Esquivel C, Harbach RE, Townson H. Molecular taxonomy of members of the *Anopheles hyrcanus* group from Thailand and Indonesia. Medical and Veterinary Entomology 2011;25 348–352.

[143] Green CA. Cladistic analysis of mosquito chromosome data (*Anopheles* (*Cellia*) Myzomyia). Journal of Heredity 1982;73 2–11.

[144] Pape T. Cladistic analyses of mosquito chromosome data in *Anopheles* subgenus *Cellia* (Diptera: Culicidae). Mosquito Systematics 1992;24 1–11.

[145] Sharpe RG, Harbach RE, Butlin RK. Molecular variation and phylogeny of the Minimus Group of *Anopheles* subgenus *Cellia* (Diptera: Culicidae). Systematic Entomology 2000;25 265–272.

[146] Sawabe K, Takagi M, Tsuda Y, Tuno N. Molecular variation and phylogeny of the *Anopheles minimus* complex (Diptera: Culicidae) inhabiting Southeast Asian countries, based on ribosomal DNA internal transcribed spaces, ITS1 and 2, and the 28S D3 sequences. Southeast Asian Journal of Tropical Medicine and Public Health 2003;34 771–780.

[147] Morgan K, O'Loughlin M, Mun-Yik F, Linton Y-M, Somboon P, Min S, Htun PT, Nambanya S, Weerasinghe I, Sochantha T, Prakash A, Walton C. Molecular phyloge-

netics and biogeography of the Neocellia Series of *Anopheles* mosquitoes in the Oriental Region. Molecular Phylogenetics and Evolution 2009;52 588–601.

[148] Alam MT, Das MK, Dev V, Ansari MA, Sharma YD. PCR-RFLP method for the identification of four members of the *Anopheles annularis* group of mosquitoes (Diptera: Culicidae). Transactions of the Royal Society of Tropical Medicine and Hygiene 2007;101 239–244.

[149] Ma Y, Qu F, Dong X, Zhou H. Molecular identification of *Anopheles maculatus* complex from China. Chinese Journal of Parasitology and Parasitic Diseases 2002;20 321–324 (in Chinese).

[150] Ma Y, Shizhu L, Jiannong X. Molecular identification and phylogeny of the Maculatus Group of *Anopheles* mosquitoes (Diptera: Culicidae) based on nuclear and mitochondrial DNA sequences. Acta Tropica 2006;99 272–280.

[151] Walton C, Somboon P, Harbach RE, Zhang S, Weerasinghe I, O'Loughlin SM, Phompida S, Sochantha T, Tun-Lin W, Chen B, Butlin RK. Molecular identification of mosquito species in the *Anopheles annularis* group in southern Asia. Medical and Veterinary Entomology 2007;21 30–35.

[152] Sallum MAM, Foster PG, Li C, Sithiprasasna R, Wilkerson RC. Phylogeny of the Leucosphyrus Group of *Anopheles* (*Cellia*) Diptera: Culicidae) based on mitochondrial gene sequences. Annals of the Entomological Society of America 2007;100 27–35.

[153] Beebe NW, Ellis JT, Cooper RD, Saul A. DNA sequence analysis of the ribosomal DNA ITS2 region for the *Anopheles punctulatus* group of mosquitoes. Insect Molecular Biology 1999;8 381–390.

[154] Beebe NW, Cooper RE. Distribution and evolution of the *Anopheles punctulatus* group (Diptera: Culicidae) in Australia and Papua New Guinea. International Journal of Parasitology 2002;32 563–574.

[155] Coluzzi M, Sabatini A, Petrarca V, Di Deco MA. Chromosomal differentiation and adaptation to human environments in the *Anopheles gambiae* complex. Transactions of the Royal Society of Tropical Medicine and Hygiene 1979;73 483–497.

[156] Besansky NJ, Powell JR, Caccone A, Hamm DM, Scott JA, Collins FH. Molecular phylogeny of the *Anopheles gambiae* complex suggests genetic introgression between principal malaria vectors. Proceedings of the National Academy of Science, USA 1994;91 6885–6888.

[157] Caccone A, Garcia BA, Powell JR. Evolution of the mitochondrial DNA control region in the *Anopheles gambiae* complex. Insect Molecular Biology 1996;6 51–59.

[158] Wilkerson RC, Foster PG, Li C, Sallum MAM. Molecular phylogeny of Neotropical *Anopheles* (*Nyssorhynchus*) *albitarsis* species complex (Diptera: Culicidae). Annals of the Entomological Society of America 2005;98 918–925.

[159] Marrelli MT, Floeter-Winter LM, Malafronte RS, Tadei WP, Lourenço-de-Oliveira R, Flores-Mendoza C, Marinotti O. Amazonian malaria vector anopheline relationships interpreted from ITS2 rDNA sequences. Medical and Veterinary Entomology 2005;19 208–218.

[160] Bourke BP, Nagaki SS, Bergo ES, da Cruz Cardoso J, Sallum MAM. Molecular phylogeny of the Myzorhynchella Section of *Anopheles* (*Nyssorhynchus*) (Diptera: Culicidae): genetic support for recently described and resurrected species. Memórias do Instituto Oswaldo Cruz 2011;106 705–715.

[161] Townson H, Dyer N, McAlister E, Satoto TBT, Boewono DT, Bangs MJ & Harbach RE Systematics of *Anopheles barbirostris* van der Wulp and a sibling species of the Barbirostris Complex (Diptera: Culicidae) in eastern Java, Indonesia. Systematic Entomology 2013;38: 180–191.

[162] Coetzee M, Hunt RH, Wilkerson R, della Torre A, Coulibaly MB & Besansky NJ *Anopheles coluzzii* and *Anopheles amharicus*, new members of the *Anopheles gambiae* complex. Zootaxa 2013;3619: 246–274.