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# Is fossil insect taxonomy compatible with database-based research?

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## Abstract

The lack of veracity in assignments of fossil insects to generic and even higher taxonomic levels has been a well-recognized problem since the late 19th century. This is of course partly a function of the lack of well-preserved morphological detail in fossils, but also to a misplaced sense of the need to assign generic and specific names–that specimens not assigned genus and species names are somehow of less value than those that are. In the present review, the early history of paleoentomological assignments is reviewed, including the origin and use of "Open nomenclature" and other attempts by authors to indicate a degree of inaccuracy in their identifications. Numerous examples are provided, both old and recent, as the problem of incorrect taxonomic assignments persists. Public databases are of increasing importance to the field of paleoentomology, but the numerous inaccuracies in the primary literature have often been transferred directly to the databases. In many cases, original attempts to suggest degrees of inaccuracy are not countenanced. The advent of database-based research is particularly susceptible to the burden of incorrect taxonomic assignments. We suggest changes in the way that databases record indications of uncertainty but recognize that it is not the responsibility of database managers to ascertain these inaccuracies. Every scientist in the field is obligated to correct inaccurate assignments and to assign, where necessary, previously named specimens to *incertae sedis*. We submit that the field must recognize that a specimen identified to, at some level, *incertae sedis*, can be as valuable to science as those that are assigned valid and well supported taxonomic assignments.

**Keywords:** paleoentomology, form taxa, open nomenclature

## Introduction

A recent search of the Paleobiology Database (PBDB, 2024) listed 42,210 specimens of insects that had been identified to the species level and a total of 28,959 unique species names. Although many broadly based studies making use of insect fossils have focused on family-level data (Labandeira & Sepkoski, 1993; Labandeira, 2005), Jablonski & Finarelli (2009) stated "genera are the primary analytical units for a wide range of large-scale paleontological and neontological analyses, across topics such as global diversity dynamics, macroevolutionary trends, paleoecology, systematics, and biogeography". Several studies of fossil metazoan diversity have been published at the genus level (Bambach *et al*., 2004; Bush & Bambach, 2015), and even at the species level (Finkelstein *et al*., 2006; Carrasco *et al*., 2009; Jouault *et al*., 2022), that were based on data downloaded *en masse* from the Paleobiology Database and other such compilations of taxonomic names and associated metadata. A recent PBDB-based "statistical study on taxonomic diversity of insects—at specific, generic and familial levels" during the Permian and Triassic periods, was published by Gui *et al*. (2023).

If current trends are any indication, large-scale database-based genus-level studies of fossil insect diversity and paleoecology will soon begin to appear in the literature. Unfortunately, paleoentomological database-centered research can be easily compromised

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by taxonomic assignments that are inaccurate, wholly or partially, or that, due to poor preservation, should never have been assigned to begin with. While the ramifications of a naturally incomplete fossil record are often acknowledged in paleoecological and paleobiogeographical studies, shortfalls stemming from incomplete or inaccurate assignment of paleofauna often go wholly unchecked. Errors in taxonomic assignments were often accepted as background statistical noise within paleontology as an exclusive field (Raup, 1991). With a steady rise in the use of fossil records that are incorporated into broader integrative methods, such as fossil calibration of phylogenies (Chazot *et al*., 2019), species distribution modeling, and ecological niche modeling (Clapham & Karr, 2012), addressing the schism in data standards between the extant and the extinct is more important than ever.

More than two decades ago, Forey *et al*. (2004) summarized problems related to the naming and classifying of fossils, and discussed the mismatch between paleontological and neontological taxon concepts and the misuse of taxonomical ranks in paleontology. In addition, the issue of the definition of the term 'genus' has been addressed by Dubois (1988) and the concept of genus in paleontology has also been discussed by Kraichak *et al*. (2017 and references therein—but see Lücking, 2019). It is important to note that the 'genus' category is often completely different as defined by database providers (*e.g*., Vandepitte *et al*., 2015). However, a semantic definition of 'genus' is not the issue discussed in the present study. The central question raised in the present study is whether digital databases (*e.g.* the PBDB, EDNA [The Fossil Insect Database], SD [Systema Dipterorum], FDB [Florissant Fossil Beds], and HOL (Hymenoptera On-line]) can record published descriptions and reports of insect fossils in a manner that allows researchers to distinguish between valid data and data that is inaccurate or illegitimate. We attempt to document several ways through which inaccurate and illegitimate data have been and continue to be generated (*e.g*., assignments made in the absence of sufficient data, misuse of open nomenclature and use of form species) and suggest mechanisms that will allow database-based research to eliminate such data.

## Results

*Background: A centuries-old problem*

The late nineteenth and early twentieth centuries experienced the origin and expansion of paleoentomology as a distinct and legitimate science. The accomplishments and progress of modern paleoentomologists was built on the work of exceedingly productive scientists such as Samuel Scudder, Anton Handlirsch, Robin John Tillyard, Andrey Vasilyevich Martynov, Theodore Cockerell, Charles Brues, Axel Melander and others (Grimaldi & Engel, 2005). Unfortunately, this early work left modern paleoentomologists with official descriptions of many species that are, quoting Carpenter (1992), "doubtfully assigned"; such assignments may number in the thousands. In some cases, the descriptions themselves are exceedingly short: Meunier (1907) described 60 new species of Dolichopodidae (Diptera) in less than 3 1/2 pages of text.

Many fossils were simply too poorly preserved to be identified to a genus; many descriptions were based on a single wing. Large numbers of such specimens were often incorrectly assigned to a genus, many of which are extant, and to species. Scudder (1890) described seven genera and 13 new species in the family Miridae (Hemiptera) about which Carvalho (1959) said "Scudder's genera and species are entirely unreliable and cannot be placed in tribes or subfamilies". After examination by specialists in the relevant families, 90% of the fossil Coleoptera of North America described in the early 20th century were determined to have dubious generic assignments (Carpenter, 1992). Often these assignments were qualified with inclusion of a question mark immediately after the generic epithet or some other statement of reservation. The term "smudges" has been applied to a number of such fossils (Yeates, 1994).

Although, at that time, the etymological basis for species names were rarely explained, assignment of specific epithets such as those of *Aulobaris damnata* (Scudder, 1892), *Cardiophorus* (?) *deprivatus* and *Monocrepidus dubiosus* (Wickham, 1916), *Tenthredo misra* and *Scolioneura vexabilis* (Brues, 1908), *Podabrus fragmentatus* (Wickham, 1914), *Stereochorista frustrata* (Tillyard, 1919), *Sphegina obscura* (Hull, 1945), *Haruspex (?) defectus* (Cockerell, 1926), *Camponotus miserabilis* (Förster, 1891) may have been a reflection of the authors' frustrations with the taxonomic placement of poorly preserved specimens. These authors stated, "This is an obscure specimen" (Hull, 1945), or "from the elytron alone it is of course impossible to be sure of the genus" (Cockerell, 1926), or "the beetle is perhaps not a true *Cariophorus*," or "This specimen is not especially well preserved and does not offer any striking characters" Wickham (1916), and "This species might perhaps be excluded from *Scolioneura*" (Brues, 1908).

In some cases, the inaccuracy of some such assignments has been established in subsequent redescriptions and reassignments to entirely different taxa, occasionally at the ordinal level. For example, *Laasbium agassizii* Scudder, 1900 and *Laasbium sectile* Scudder, 1900, both described as staphylinid beetles, were transferred to Dermaptera by Chatzimanolis & Engel (2010). The Florissant Formation

wasp *Oxyserphus defectus*, originally identified as a member of an extant genus *Paramesius* ("undoubtedly is a member of this genus or of a very closely related one") in the family Diapriidae (Diaprioidea), was transferred to a different superfamily, Proctotrupidae (Proctotrupoidea) (Brues, 1910; Kolyada, 2009). The seven Green River rove beetles described by Scudder (1890) are "Almost all . . . taxonomically misplaced and perhaps some do not belong in Staphylinidae" (Chatzimanolis, 2013).

While we agree with Carpenter (1992), and many others that numerous generic assignments of the late 19th and early 20th century were poorly done and dubious, we must not judge the individuals involved in the light of present-day taxonomic entomology. Taxonomists who described fossil insect taxa over 100 years ago exercised their judgement given the state of knowledge that existed at that time and according to prevailing taxonomic standards. Although the International Commission on Zoological Nomenclature (ICZN) was founded in 1895, what we now consider as modern standards of systematic entomology were decades in the future. Carpenter (1992) stated that many fossil beetles with unreliable generic assignments "were . . . placed into existing genera long before the current concepts of those genera were reached".

Importantly, the spurious description and subsequent errata of fossil taxa are not limited to classical paleotaxonomists. Nonspecialist paleotaxonomists continue to have a longstanding tension with neoentomologists who often revise fossil taxa placed within their group of specialization (*e.g*., Jaschhof 2006–but see also Fedotova & Perkovsky, 2007). Very often, these revisions involve reclassification of taxa to a *nomen dubium* or to *incertae sedis*.

While neoentomologists often specialize in a single taxonomic group, paleoentomologists, perhaps of necessity, are often generalists, describing an exceedingly large breadth of taxa–often all Insecta. This absence of taxonomic specialization can lead to misunderstandings of character evolution in a group which is only further magnified by the often poor conditions of the fossils themselves, both amber and compression. The specialization of a neoentomologist is often needed when cryptic or notoriously difficult taxa are studied. Alternatively, many neoentomologists often lack an understanding of taphonomic processes that can lead to misinterpretation of artifacts or the role of fossilization on the structure of characters. Clearly, a collaborative effort of neoentomological specialization and paleontological expertise would provide the most robust understanding of fossil taxa.

*Open nomenclature*

Placement of a question mark, either before or after the generic epithet within parentheses, or not, to denote uncertainty in generic assignments, is a long-established convention. The question mark, along with parentheses marks, and the abbreviations *sp.*, *indet*., *aff.*, and *cf.* are components of an 'Open Nomenclature' that are used to denote uncertainty, or in some interpretations, different degrees of uncertainty (Richter, 1943; Lucas, 1986; Matthews, 1973, Bengston, 1988). Marshall (1874) listed "*Psilodora maculata* -?*Figites syrphi*", "*Allotria defecta* -?*A. xanthocephala*", and "*Campoplex anceps* -?*Campoplex pugillator*", among others, as specimens of the uncertain status in the synonymy of a number of extant species of Hymenoptera. Statz (1938) explained his questionable assignment of fossil Hymenoptera to extant genera by stating "It was possible to consider with certainty a large number of the fossilized insects that are studied in the following pages, as belonging to a recent genus. In the instances where this was not possible, a question mark was added to the genus name." A question mark also has been used with respect to higher taxonomic ranks such as subfamily and family (Viertler *et al*., 2022). Quotation marks have been used for a similar purpose. Statz (1938) rationalized his use of quotation marks as follows: "With other specimens, especially the smallest of them, the ranking was only possible up to group or subfamily. In these cases, I referred to the genus description of older authors, … In order to clarify the meaning of these genus names, I always put them in quotation marks." Such designations of uncertainty have been applied to fossils by both paleoentomologists and neoentomologists (*e.g*., Spasojevic *et al*., 2018, 2022).The use of open nomenclature in databases has been reviewed previously and, in some cases, recommendations made (Sigovini *et al*., 2016; Horton *et al*., 2021). Misunderstandings of database structure and database hierarchy *vs*. taxonomic treatment have also been addressed.

Another common convention that can convey uncertainty is the use of prefixes such as litho-, archeo-, palaeo-, and others to a stem that is the name of an extant genus (*e.g*., *Palaeotorymus*, *Palaeovespa* and *Palaeopsocus*). Cockerell (1921) described *Lithobelyta reducta* (Hymenoptera: Proctotrupoidea) with "resembles *Belyta*, but the stigma and marginal cell are absent"; Antropov *et al*. (2014) placed this species in Chalcidoidea Family indet. Obviously, use of such prefixes, when applied to a genus, subfamily, or family, that can be shown to be related to but definitively distinct from an extant taxon, can be informative and legitimate (Granzow, 2000). When applied to specimens that lack sufficient detail for such a placement and allow differentiation from another taxon, it simply confounds the taxonomy and introduces an element of overprecision. Use of such prefixes can lead to even greater confusion when a taxon is transferred to a new family. The use of *indertiminabilis*

(indet.) is favored for assignment of taxa which are degraded or unidentifiable at a species level, providing a designation for a taxon while reducing the cluttering of lower taxonomic ranks with taxa presenting too little information (Matthews, 1973; Granzow, 2000). *Species inquirenda* is an applicable designation as well, one which is codified for taxa with doubtful placement due to a lack of identifiable information (ICZN 67.2.5). The use of a prefix-based naming convention provides only a superficial solution for denoting uncertainty relative to modern taxa.

*Form taxa*

Perhaps the most pervasive and problematic convention is the parataxon. Originally created to describe fossils of different elements of a plant (*e.g*., detached leaves and flowers) that were thought to comprise a single species (ICBN Article 3), they are also referred to as 'assemblage taxa' and are a very important concept in paleobotany, without which, paleobotany would be hobbled as a discipline (Meyen, 1987; Cleal & Thomas, 2021, and references therein). Unlike insects, plants are often preserved as separate organs, including leaves, pollen organs, ovulate organs, stems, seeds, roots, and pollen or spores. This means that, for fossil plants, the fossil record presents us with a segregated and partial picture of a whole-plant taxon. For example, the marattialean tree fern *Psaronius*, which is host to a wide variety of arthropod herbivory in the Late Pennsylvanian. The trunks are *Psaronius*; rachises are *Stipitopteris*; leaf scars of the rachises on the stem are *Caulopteris*; sporangia are *Scolecopteris*; foliage *Pecopteris*; spores *Convulitispora*—all form taxa.

Similarly, a second and separate paleobotanical practice is the use of plant morphotypes (*vs*. form taxa) which allows paleobotanists to make sense of the Cenozoic and Cretaceous fossil record of angiosperms (Wilf, 2008). This averts the historical problem of naming plant genera and species as soon as they were discovered after look-alike leaves from modern plant species without any regard to potential variation in the present or future of similar plant specimens in other basins.

However, in the field of paleoentomology, parataxa have been widely misunderstood and misused. Unlike a single fossil plant species described from an isolated leaf, an isolated seed and an isolated flower, the assignment of, for example, an isolated wasp leg, an isolated wing and an isolated antenna of different ages and localities, to a single species, is unheard of. In paleoentomology, the concept of parataxa has taken on a completely different meaning.

Rasnitsyn (1986) defined two types of parataxa: 1) The formal or form-taxon that is treated "only in the framework of a special system which is parallel to [an orthotaxon] and completely independent of it" and "are possibly (sometimes even certainly) a synonym of some orthotaxon and yet they should not be synonymized with the latter", and 2) The collective taxon that is "usually of generic rank that can be assigned to a higher taxon but cannot be organized there in a special system". Specimens placed in collective taxa are thought of as being so poorly or incompletely preserved that they cannot be assigned to any orthotaxon other than that higher taxon to which it is referred. For example, the genus *Myrmeciites* was "proposed for all fossil ant species referable to the subfamily *Myrmeciinae*" that cannot be assigned to any tribe or genus of that subfamily due to lack of preserved morphological detail (Archibald *et al*., 2006), resulting in polyphyletic taxa. Although collective taxa cannot be assigned type species (ICZN Article 67.14), Rasnitsyn (1986) argued that collective taxa, like formal taxa, have types. In the former case, it would be the type of the taxon to which the collective taxon is referred.

The distinction between these two kinds of parataxa is made unclear by the designation of, for example, the formal genus *Ponerites* for "Fossil ants preserved not well enough to fit [the] orthotaxa" within Ponerinae (Dlussky & Rasnitsyn, 2002). Many, but not all, generic epithets of collective and form (or formal) parataxa end in the suffix *–ites* (Latin, having the nature of), affixed to a stem that denotes the orthotaxon to which the genus is referred. The net effect is that large numbers of fossil insects that are too poorly or incompletely preserved to identify to a legitimate orthotaxon have been assigned "generic" names that are meaningless at the genus and even higher taxonomic levels. In some cases, the suffix *–ites* was used in the creation of generic epithets, not as parataxa, but simply because of a lack of alternatives. Statz (1938) stated "With other specimens, especially the smallest of them, the ranking was only possible up to group or subfamily. In these cases, I referred to the genus description of older authors, … Where no such genus existed, the name of the genus was given the ending '*-ites*'." It should be noted that the practice of attaching the suffix -ites to existing generic names for fossils in order to distinguish them from extant genera is not allowed and such generic names are unavailable (ICZN Art. 20).

*Modern usage*

In 2014, 552 new species of fossil insects were described (PBDB, 2024). Antropov *et al*. (2014) described 51 new species from the 34 Ma Bembridge Marls of the Bouldnor Formation, on the Isle of Wight, United Kingdom. These specimens serve here as a microcosm of the current status of fossil insect taxonomic convention. Antropov *et al*. (2014) created 13 new, extinct genera. Among these was the morphogenus (form genus) *Taphopone* and the new (morpho)species *T. macroptera*, *T. petrosa*, *T.*

*aberrans* and *T. microptera*. Also created were ten new species names in the morphogenera *Emplastus* ("The morphogenus *Emplastus* may embrace representatives of various dolichoderine genera"), *Paraphaenogaster*, *Solenopsites* ("This morphogenus can include all poorly preserved impressions of small Myrmicinae without propodeal spines or teeth and with a pedunculate petiole, but really belong to many different orthotaxa."), *Leucotaphus* ("Fossil ants not well enough preserved to fit orthotaxa, and with following combination of traits: … Undoubtedly many fossil species described as *Formica* and *Lasius* from poorly preserved impressions deserve transfer into this morphogenus.") and *Ponerites*. All 14 of the species named above are listed in the PBDB, HOL and EDNA, as orthotaxa–regular legitimate genera and species.

A number of new species names in Antropov *et al*. (2014) incorporated open nomenclatural elements of uncertainty such as the question mark and parentheses. They include "*Scambus*" *fossilis* sp. nov. ("it is possible that the real position of the fossil within the subfamily is somewhat different"), "*Hemiteles*" *acourti* comb. nov., "*Hemiteles*" *dirus* sp. nov. and "*Hemiteles*" *protervus* sp. nov. ("note the very preliminary character of the attribution. New species are described as "*Hemiteles*" because this attribution looks likely but cannot be well grounded at present.") as well as *Eubazus* ? *brodiei* sp. nov. ("The absence of forewings is a serious problem for understanding the real taxonomic position of this fossil . . . the new species is included tentatively in the genus *Eubazus*."), *E.*? *grandareola*, *E.*? *hooleyi*, *Hellenius*? *kozlovi* sp. nov., *Dolopsidea*? *intermedia* sp. nov. and *Bracon*? *antefurcalis* ("I tentatively include this new species in the genus *Bracon* until additional information about its morphology is known."). In the cases of *Oxyserphus kozlovi* sp. nov. ("Incomplete preservation of the holotype makes the diagnosis tentative.") and *Chremylus infuscatus* sp. nov. ("The position of this species in *Chremylus* is not certain because of insufficient preservation, but seems acceptable for the present."), punctuation marks such as ? and " " were not used although there was a degree of uncertainty in the generic assignment. Uncertainty in higher taxonomic assignments were also designated by a question mark (*e.g*., "Tribe? Bombini Latreille, 1802"). All 12 of the species named in the two paragraphs above are listed in the PBDB and EDNA, as orthotaxa–legitimate genera and species. Those specimens demarked by the modifier "?" appeared in the PBDB under "identified name" with the modifier, but in the "accepted name", the modifier was absent.

The names of several new genera were formed by use of prefixes such as palaeo-, proto- and oligo-, the latter for Oligocene, and the names of extant genera, such as *Palaeoscolia*, *Protosceliphron*, *Oligobombus*, *Palaeomicrogaster*, *Palaeopolybia* and *Protopolistes* (Antropov *et al*., 2014). In the case of *Oligobombus*, it was stated that the "absence of the most important features of the head, legs and mesosoma prevents identification of its exact tribal position."—note that the genus *Bombus* is the only genus in the tribe Bombini. Higher taxonomic assignments were also designated by use of such a prefix (*e.g*., Tribe Protosceliphrini).

Other specimens were recorded without a specific epithet as simply 'sp.', such as *Mischoserphus* sp. ("Comparison with other congeners is impossible based on the characters available.") or as genus and species indet. within a higher taxon, such as Family indet., Formicidae *incertae sedis*, Megachilinae *incertae sedis*, Pimplinae genus and species indet., and Ichneumonidae indet. In the latter case, individual specimens were differentiated via their museum inventory numbers.

It is apparent that modern taxonomic paleoentomology often uses the same or similar antiquated and uncertain conventions to denote uncertainty regarding the accuracy of generic designations. The usage of open nomenclature is not regulated by the International Code of Zoological Nomenclature and, as indicated in Antropov *et al*. (2014), varies from author to author. Bengston (1988) stated that the use of quotation marks "indicate that the species is thought to belong to a new genus-group related to the named genus but the material available is insufficient for the formal erection of a new genus". Such a message also is indicated by the use of 'aff.' in front of a genus name. Bengston (1988) then recommended that quotation marks be used to indicate that a name is obsolete as was previously suggested by Jeppsson and Merrill (1982). Bengston considered '?' and 'cf.' (Latin, *conferre* meaning to compare) to be synonymous, but Richter (1943), as paraphrased by Bengston, considered the 'cf.' attribution to mean "probable but uncertain" and '?' "improbable but possible". This subtlety is certainly lost on most modern taxonomists. Bengston went on to recommend that 'cf.' in front of a genus name indicate provisional identification and '?' in front of a genus name indicate uncertain identification. However, many assignments are provisional precisely because they are uncertain.

*Database queries*

The disappearance of open nomenclature qualifiers from the literature often takes place as soon as the first subsequent reference to a particular species is published. For example, *Neorhynchocephalus* (?) *melanderi* [Bequaert & Carpenter, 1936] in Melander (1949), and almost invariably in publications of checklists (*e.g*., *Microstylum*? *destructum* [Cockerell, 1909] in Evenhuis, 1994; *Andrena* (?) *clavula* [Cockerell, 1906] in Zeuner & Manning, 1976; *Capsus* (?) *lacus*, *Carmelus* (?) *gravatus* and *Fuscus* (?) *faecatus* [Scudder, 1890] in Carvalho,

1959). These actions are not strictly "Garbage in, garbage out.", they provide the taxonomic assignments with unwarranted validity that is subsequently promulgated in the literature and undermines the intentions of the authors of the original descriptions.

The disappearance of open nomenclature qualifiers and the transformation of parataxa to orthotaxa also takes place during database compilation. There are a number of large public on-line databases that contain data on fossil insects. These include the fossil Insect database EDNA (http://edna.palass-hosting.org/search.php), the Paleobiology Database (PBDB) (https://paleobiodb.org/#/), the locality-specific Florissant Fossil Beds database (FDB) https://flfo-search.colorado.edu, the Hymenoptera-specific Hymenoptera Online (HOL) (http://hol.osu.edu/) and the Diptera-specific Systema Dipterorum (SD) http://www.diptera.org. These and other databases provide ready access to large compilations of data that are essential to the modern field of paleobiology–and which, in the vast majority of cases, are accurate and reliable. It is not the purpose of this communication to review and critique databases. However, a limited number of examples will be used to make the point that database data entry can lead to information loss and the promulgation of invalid taxonomic assignments.

The "Select by Taxonomy" option of the PBDB includes, under "Preservation", an option to utilize filters such as "regular taxa", "form taxa" and "ichnotaxa". Additional available options include the inclusion or exclusion of "specific modifiers". These latter filters include a wide array of open nomenclature such as "aff.", "cf.", "?" and quotation marks. As discussed earlier however, none of the form genera and 14 form species described by Antropov *et al*. (2014), are recorded as such in the PBDB, EDNA or HOL. Records of form taxa do occur—when a search of PBDB for "Insecta" and "Form taxa only" is done; 289 occurrences are returned.

Searches of EDNA and the FDB for the 24 species listed in Meyer (2003) originally described with a question mark (*i.e*., "(?)") revealed that all were recorded only as regular orthotaxa–neither database provides for the identification of either open nomenclature modifiers or parataxa. Systema Dipterorum states that "For names of uncertain placement… A special name consisting of a lead * (asterisk) followed by either F (= family-group) or G (= genus-group) and the name of the taxon in which their placement is certain". In Meyer (2003) only two dipterans are designated with open nomenclature, in this case, a question mark. Both *Microstylum*(?) *destructum* (Asilidae) and *Neorhynchocephalus*(?) *melanderi* (Nemestrinidae) were recorded in Systema Dipterorum as the orthotaxa with the question mark removed. Searches for *FAsilidae and *FNemestrinidae returned a null set and neither term occurred when the two specimens were viewed.

All of the 12 new species created by Antropov *et al*. (2014), that contained either question or quotation marks as modifiers, are listed in the PBDB and EDNA as valid taxa. In the HOL database, species of *Scambus* and *Hemiteles* were not recorded; the remainder were recorded as valid taxa. Also, in Antropov *et al*. (2014), a Table 1 lists five specimens originally described with a question mark immediately after the genus name, that were listed as "not revised". In searches of HOL, *Miota*? *strigata* was listed as the "original name" while the "subsequent name" was listed as valid and without the modifier–Johnson (1992) was cited as the source of the change. However, Johnson (1992) is a catalog. Antropov *et al*. (2014) provided the generic assignment with unwarranted validity with the statement "This genus is distributed worldwide". Both *Zygota*? *filicornis* and *Pteromalis*? *vectensis* were listed as valid and without the question mark; the latter's original name was mistakenly listed without the modifier. *Phanomeris*? *colenutti* was listed without the modifier with a valid recombined name of *Ontsira colenutti* which was described in Antropov *et al*. (2014). *Mesitius*? *rectinervis* was not in the database.

Searches of EDNA and the PBDB document the absence of the original open nomenclature modifiers (question and quotation marks) in 27 specimen names of Hymenoptera established by Statz (1938) and the modifier "sp." in 18 fossil Diapriidae (Hymenoptera) published by Perrichot & Nel (2008) and Lak & Nel (2009). For someone compiling a list of diapriid fossils from online databases, these 18 specimens do not exist. The FDB does record over 400 genera with genus names that start with or end with a quotation mark and several others with genus names that start with, ends with, or contains a question mark, as a result of reference to Carpenter (1992) (H.W. Meyer, pers. comm.).

Five species in three parataxa that contained the suffix *-ites* (*Diapriites*, *Platygasterites* and *Scelionites)* were designated as parataxa by Statz (1938). He stated "I have therefore erected the genus *Diapriites* which is regarded as a collective group for such fossil Diapriinae that are not otherwise accommodated generically in the subfamily and for which their preservation status does not allow the formation of specific genera." EDNA lists all of these species as valid orthotaxa; HOL lists all five as valid names but also references the name changes *Scelionites* to *Scelio* and *Diapriites* to *Diapria* (Johnson, 1992); the PBDB lists all five original designations as valid regular taxa–it does not record the genus names *Scelio* or *Diapria*.

Designations of uncertainty at the generic level also often reflect uncertainty at higher taxonomic ranks; these questionable or inaccurate higher rankings are subsequently recorded in modern databases. For example, Statz (1938), in his descriptions of "*Campoplex*" *parvulus* and

"*Campoplex*" *pumilus*, assigned them to Ichneumonidae: Ophioninae: Campoplegini. HOL places the extant genus *Campoplex* in Campopleginae, Campoplegini having been upgraded to subfamily status. The PBDB cites Genera Ichneumonorum Nearcticae Version: 2014.09.16 (GIN; http://www.amentinst.org/GIN/) as a reference for *Campoplex* belonging to "Campoplegoidae", an invalid name that appears in neither Statz (1938) nor GIN. The PBDB provides this citation so as to place the extant genus *Campoplex* in the subfamily Campopleginae. However, in so doing, the database suggests that the two species of fossil *Campoplex* were determined by GIN to belong to Campopleginae. In actual fact, the two fossil specimens described by Statz are Ichneumonidae *incertae sedis* (D. Wahl, pers. comm.). The projection of generic level uncertainty to high taxonomic ranks, when recorded in databases, undermines the veracity of database-based studies at the subfamily and family levels.

Much, if not all, of this confusion is based directly on attempts to assign specimens that do not have the morphological detail required to accurately assign them to a desired taxonomic rank. The results of this near universal compulsive behavior cast a shadow of unfounded confidence on the entire field of Paleoentomology. Such data must be recorded in our databases as originally published as parataxa or uncertain assignments (as denoted through use of open nomenclature)–and distinguished from valid orthotaxa. It is again emphasized that the databases themselves, and the scientists who create and manage them, are not at fault; they are simply recording, albeit incompletely, what the paleoentomological community is providing in the literature.

*Proposals*

1) We propose the elimination of form taxa, as defined by Rasnitsyn (1986), and currently used in the field of paleoentomology. Similar proposals have been made by others (Lively, 2019). As described above, listings of such specimens, at the genus and species levels, as orthotaxa in databases cripples the accuracy of database-based studies. Specimens currently identified as *Myrmeciites* should be recorded as *Myrmeciinae incertae sedis* and distinguished from similar specimens of the subfamily by use of an appropriate museum-specific collection number. We fail to understand why *Myrmeciites goliath* is, in any way, better than *Myrmeciinae* XYZ 123456. The parataxa described by Antropov *et al*. (2014), *Taphopone*, *Emplastus*, *Paraphaenogaster*, *Solenopsites*, *Leucotaphus* and *Ponerites*, should all be assigned to, and only to, the taxonomic rank to which they can be definitively identified. We do not believe, as posited by Lively (2019) and Rasnitsyn (pers. comm.), that, in the absence of a generic assignment, such specimens will disappear from reviews and databases, despite their potential scientific value. These specimens and their designations, when treated by researchers and databases with the same respect as better-preserved specimens assigned to legitimate genus species, will not simply cease to exist.

The appropriateness, even the validity of open nomenclature within the actual genus and species name can be questioned—Linnaeus did not envision a trinomial. However, the immediate problem is not the validity of open nomenclature or for that matter, its inconsistent use. As Richter (1943) indicated, as paraphrased by Bengston (1988), open nomenclature is potentially useful since "should a specimen be too hastily referred to a known species or genus, taxonomic information may be concealed or distorted. If on the other hand the specimen is left without any attempt at identification, potentially useful information may be left in limbo." The problem, as detailed in the sections above, is the current failure of most modern databases to be unerring in their reporting of original assignments. Unfortunately, mistakes exist and a large portion of them derive from failure to convey unrevised original indications that generic and other taxonomic designations are doubtful, uncertain and suspect. As such, the open nomenclature system is essentially incompatible with current database-based research, unless changes are made and all taxa with any indication of uncertainty can be identified and easily partitioned during database searches. Researchers who simply download existing lists of unfiltered–and in some cases filtered–genera for use in studies of first and last appearances, phylogeny, biogeography, and phylogeny calibration, will generate inaccurate conclusions based on inaccurate data. Bush & Bambach (2015), in a study of the Mesozoic–Cenozoic diversification of marine Metazoa, downloaded a list of genera 837 pages long from the PBDB–a study that could not have been envisioned let alone completed, without the use of a digital database. To QC their data, "Genus names qualified by aff., ex. gr., *sensu lato*, informal or quotation marks were excluded, as were trace fossils, form taxa . . .". If a comparable study of the Insecta were done today, its conclusions would be erroneous and invalid.

2) Modern databases must allow searches that will readily distinguish between invalid (*e.g*., parataxa) and valid assignments. Parataxa, whether formal or collective, are not valid designations (orthotaxa) and must be so designated. *Myrmeciites* (Archibald *et al*., 2006), originally described as identical to Myrmeciinae *incertae sedis*, is not a valid genus; its creation simply reflects the constraints of current nomenclature systems. Note that *Myrmeciites* has subsequently been assigned to Hymenoptera *incertae sedis* (Urbani, 2008). Unfortunately, even if form data are recorded as such in a database, users must be aware of the parataxa *vs.* orthotaxa conundrum. Gui *et al*. (2023), in their study of the evolution of insect diversity in the Permian and Triassic periods, excluded "Indeterminate,

unnamed taxa" from their search of the PBDB but not the 62 form taxa, although the latter were clearly demarked in the database. Ponomarenko (2011), in describing numerous of these specimens, stated "The findings are represented by isolated elytra, the position of which in the natural system is often impossible to establish; they are, therefore, described in a formal system".

3) A complicating factor, and a problem for scientists who opt to be conservative and designate a specimen as, for example, Bombini indet., is the failure of genus-centric databases to record specimens not directly associated with genus or genus species designations, (*e.g.*, taxa followed by *incertae sedis* or indet. or followed by sp.). This failure sentences potentially important specimens to oblivion. Archibald's (Archibald *et al*., 2006) *Myrmeciites (?) goliath* is recorded, incorrectly, in Systema Dipterorum as *Myrmeciites goliath* but his *Myrmeciites incertae sedis* Specimen 2003.2.9 CDM 033 and Specimen SR05-03-01 are absent. We therefore suggest that paleoentomological databases include all published specimens regardless of the taxonomic level to which they are identified. There is no impediment to recording such specimens in searchable databases.

We have documented the inability of the major databases to properly record all taxonomic designations that contain open nomenclature modifiers. We do not wish to suggest exactly how the databases provide these search options, nor do we think that all databases need to provide identical mechanisms for these searches. The ability to search for "name contains?", "name ends with *incertae sedis*", "name ends with sp." and "name starts with" are obvious starting points. Recent efforts to provide a global minimal data standard for taxonomy have been explored in systems such as DarwinCore or more recently GIST (Sandall *et al*., 2023). These data standards are designed around interoperability and interdisciplinarity across fields, something which has been increasingly important in paleotaxonomic data.

Although the programming required to implement these changes would hopefully require relatively minimal effort, most on-line databases are restricted by a lack of long-term reliable funding. The EDNA database exists on exceedingly minimal support. To make matters worse, the identification and documentation of the records to be changed will require an enormous commitment of time and personnel from academic and government institutions. Simple searches for genus names that end with *-ites* would not provide reliable records of all collective parataxa because many orthotaxa also end with this suffix, and each individual original description and all subsequent revisions would have to be accessed and examined.

Efforts to make the suggested changes to our databases cannot be restricted to database compilers and managers. The onus is on the paleoentomological community to make the effort required to reassign the many questionably assigned taxa already in the literature (Spasojevic *et al*., 2022). *Viunculomusca*, a genus created by Townsend (1938) for a single dipteran fossil larva described by Scudder (1890) as "represented only by parts of emptied skins… No specimen sufficiently perfect to show the shape or the length" and by Carpenter (1992) as "Family Uncertain", should be recorded as Diptera: Brachycera *incertae sedis* or equivalent so as to allow database users to determine that the genus *Viunculomusca*, while perhaps of historical value, is of no taxonomic or phylogenetic value beyond the suborder level and eliminate it from their compilations of data. Our descriptions of new specimens should, ideally, always be accompanied by reviews of related fossil specimens and their redescription and reassignment where necessary. Given the large numbers of genera in need of re-examination, a systematic and hopefully collegial effort, implemented over a significant period of time, will be required. Existing examples of such work, out of the many available (for the sake of demonstration, we will here limit ourselves to generic names constructed with a prefix that may have suggested a degree uncertainty in the original description), include corroboration of the validity of the placement of *Proplebeia* within the lineage of *Plebeia* (Camargo *et al*., 2000), establishment of the position of *Eolestes* within Lestoidea (Greenwalt & Bechly, 2014), and reassignment of six species of the extinct genus *Cryptoserphus* to three different extant genera (Kolyada & Mostovski, 2007).

The paleoentomological community can make the database compiler's job easier by ensuring that new descriptions extend only to the lowest ranking taxon for which definitive identification can be made. A fossil specimen should be assigned to an existing genus only if it can be definitively shown to belong to that genus. Similarly, if a specimen cannot be shown to belong or not belong to an existing genus, it should not be summarily assigned to a genus purported to be related to that genus (*e.g.*, via use of a prefix such as Paleo-, Litho-, Archeo-, *etc*., use of open nomenclature or creation of a parataxon). Instead of adding Litho- or Eo- we should, when appropriate, simply concede that we don't know.

If a definitive identification cannot be made, the specimen should enter the literature and databases as *incertae sedis* relative to the lowest taxon for which identification is definitive. Specimens so designated can be of great importance. A recent example is the description of phantom midges from the earliest Miocene of the Foulden Mar in the South Island of New Zealand. Identified only to the family Chaoboridae, they contribute to documentation of the time frame of a Neogene extinction of this group of flies (Baranov *et al*., 2024). Should we then eliminate open nomenclature entirely? The admonitions of Richter (1943) notwithstanding, can the paleoentomological

community, including publishers, editors and reviewers, live with *incertae sedis*?

In conclusion we wish to point out a few aspects of paleoentomological research that may or may not be obvious to those interested in the study. First, we ask "what's an acceptable burden of proof for erecting a new taxon? What is the limit to where something can be named?" This is obviously not easily answered and may, perhaps, rest within the realm of the describer. But it should be noted, that with modern database access, the 'knowability' or 'discoverability' of a fossil taxon, whether it be a family or species, *does not* require the fossil to be assigned to a species, genus, or any other category that cannot be established based on data at hand. A simple museum code, assigned to an appropriate name, will provide the necessary discoverability. Second, for higher-level applications of fossil data, where large-scale phenomena are being considered, such as paleoclimatological studies, or phylogeny calibration applications, often a family-group assignment is all that is needed. Lastly, we would like to address the 'everything is new' or 'mihi itch' phenomena (reviewed by Evenhuis, 2008). Assignments of genus and species names based on the concept that 'everything is new' means missing the clear and obvious presently valid genera, preventing us from unraveling, perhaps, a more accurate age assignment for a genus, or the presence/absence of a distinct biological attribute that is being studied. In closing, we assert that failure to address the issues regarding the accuracy of paleontological record results, ultimately involves losing large amounts of data and knowledge of the natural history and evolution of the planet's insect fauna.

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