ELECTRONIC TAXONOMIC DATABASES FOR *BURSAPHELENCHUS* AND OTHER APHELENCHID NEMATODES

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INTRODUCTION

Nematodes are the most abundant metazoans, comprising more than 80% of all animals alive today. Since 1743, when Needham (Needham, 1743) described the first nematode, approximately 20,000 - 30,000 species have been named, with estimates of species remaining to be described ranging from 100,000 to 1 million (Blaxter, 2004; De Ley, 2000). Unfortunately, the taxonomic community is woefully inadequate for this task. The number of taxonomists currently describing new species of nematodes around the world is less than 100, and significant increases are not expected. If each of these taxonomists were able to describe 10 new species every year, it would take between 100 to 1,000 years to name these yet to be described species.

TYPE SPECIMENS

Original descriptions of nematodes provide the working database that drives nematode taxonomy. Theoretically, the taxonomy of animals is based on type specimens (Ride et al., 1999) that are selected and illustrated in the original description. In order to satisfy the rules for naming species, each is designated by a type; thus, the type becomes the definition of the species. Whenever doubts arise about the identification of a particular population of nematodes, the taxonomist can request to see the type, or at least a paratype, from the museum in which it was deposited by the original author. If the specimen is identical to the type, then it belongs to that species; however, if it is significantly different, then it belongs to another species, perhaps even one that has not been described. Obviously, this assessment is subjective, but all species descriptions can be further scrutinized when a taxonomist critically examines a particular group of species. Although complicated rules govern the change in classification and how specimens are allocated to species, subsequent authors can propose corrections to species descriptions through clarifications, emendments, and by making synonyms.

Unfortunately, type specimens of nematodes are often inadequate resources to satisfy the requirements that they are supposed to fulfill. Many type specimens are suitable at the initial time of designation, but they slowly deteriorate over time until they become nearly useless for their original intent. Because these specimens are so fragile, many museums are reluctant to send them out to taxonomists who make requests to view them. Taxonomists that go through the pains to request and review these type specimens are often frustrated because the specimens may have been poorly preserved and mounted onto glass slides. As a result of these limitations of the types, often the original publication, with its description of the type, remains the sole source that is used to evaluate specimens in order to make an identification, to justify the description of a new species, or to review the status of various taxonomic units.

ORIGINAL DESCRIPTIONS

Original descriptions contain a description of the type that often replaces the use of the real type, except in very unusual circumstances that warrant its request; therefore, published species descriptions are the primary source for classification and identification. Therefore, each taxonomist who intends to describe a new species, or to evaluate a particular taxonomic unit, must begin the arduous task of collecting all of the descriptions or every species within that group. Unfortunately, this task is often difficult and time consuming since many were published in obscure journals that may be difficult to find. Some descriptions may be available as reprints; others must be photocopied from journal collections in the local library, and many may have to be requested from colleagues or other lending libraries. Even for genera with few species, the task of collecting all of the descriptions is difficult and time consuming. Genera containing more than 100 species may require several years to obtain all of the described species.

Unfortunately, original descriptions have been, and continue to be published in a wide variety of journals in numerous countries around the world. As the numbers of species descriptions increase every year, the difficulty of collecting all of the descriptions increases as well. Some are widely available and well known, but others are difficult to obtain and often obscure. Furthermore, many of these journals were published on inexpensive paper that has become brittle, yellowed, and sometimes, even faded. Like the type specimens, the publication is also subject to deterioration. Proper

storage of these materials requires the use of very expensive facilities where humidity, temperature, and exposure to the ultra-violet light can be carefully controlled.

Most descriptions were published in English, but many were published in French, German, Spanish, Portuguese, Chinese, Russian, Japanese, and other less well-known languages. Translation of these descriptions into English is often difficult and costly. Furthermore, few of these translations warrant publication and are, therefore, not available except for the taxonomist who initiated the translation. Theoretically, some species descriptions have been translated many times in the past and are likely to be translated again in the future.

As physical objects, these descriptions can be damaged by the elements, lost or misplaced, require space for their storage, and are not readily shared with others. Each taxonomist has to collect all of these descriptions; therefore these collections are very personal and only known and valued by the original collector. Often they are discarded or forgotten after the collector retires.

ELECTRONIC DATABASES

Fortunately the desktop computer has made it possible to store large amounts of information electronically (Eisenback, 1997). These electronic databases can be archived and stored, duplicated, and shared. If they are made available on the Internet, they can be utilized by anyone who has access to the World Wide Web. Unfortunately, if these works are archived improperly, they can rapidly become inaccessible because of changes in proprietary format.

The solution to making an electronic database that will be long-lived is to choose a format that will last into the future.

MATERIALS AND METHODS

The portable document format (PDF) popularized by Adobe Systems Incorporated has revolutionized paper documents into an electronic format that makes it possible to reliably create, combine, and control documents for easy distribution and data collection. Adobe Acrobat® PDF documents are easily accessible and require minimal storage space. The Adobe Acrobat PDF format is recognized internationally and has standards that insure that documents will remain readily assessable in the

future. This file format has been useful for ten years despite continuous changes in operating systems and hardware platforms.

The most difficult part of making an electronic taxonomic database is the collection of all of the original descriptions. After all of the originals have been gathered, the electronic taxonomic databases are put together by scanning the original publication on a flatbed scanner in black and white mode for text at 300 dpi resolution. Pages containing photographs are scanned in either grayscale or color at 300 dpi. The images of the scans are cleaned and sometimes enhanced with a photo editing software program like Adobe Photoshop® and saved as PDF documents. The individual pages of PDF documents are merged together into one document and the images of text are recognized with the optical character recognition (OCR) software that is included with Adobe Acrobat®. This step is an important part of making the document fully searchable; otherwise, the pages with text are actually just copies of the images of the text that is on the page.

The individual descriptions are named with the genus and species name and put together into one folder with the name of the genus, the taxonomic authority of that genus, and the date of publication. If one publication contains the description of more than one species, then that PDF is copied and given another name until all of the new species in that publication are duplicated. Therefore, one publication with 100 new species will be copied 100 times. Likewise, the name that was used in the original description is the name that is used to place it into the file folder containing the name of the genus. If a species has been transferred to another genus or considered to be a synonym or placed into another taxonomic category, one copy will remain in the folder of the genus as it was originally named, and another copy will be renamed and placed in the folder for the new category. For example, the original description of *Bursaphelenchus cocophilus* can be found in the folder with the species descriptions of *Aphelenchus* as it was originally described (Cobb 1919), *Rhadinaphelenchus*, as it was later renamed (Goodey 1960), and finally *Bursaphelenchus* to which it was transferred (Baujard, 1989).

RESULTS

All of the original descriptions of the pine wood nematodes (*Bursaphelenchus* sp.) have been digitized and made available as an electronic taxonomic database (Vieira et al., 2003). In addition to the species descriptions, the major taxonomic literature on this group was included in the collection of descriptions. In addition to the pine wood nematodes, all of the descriptions of the aphelenchid nematodes are currently scheduled to be digitized. Hopefully, some day in the near future, all of the descriptions of all of the species in the entire phylum of Nematoda will be digitized and available on the Internet.

CONCLUSIONS

Electronic taxonomic databases provide a powerful resource for nematode taxonomists. With these databases the original descriptions of nematode species are beginning to be preserved in a digital format that is searchable, shareable, and storable. As collections of all of the groups become available, the drudgery of collecting and maintaining all of the species descriptions in a particular group will be greatly reduced to the task of adding new species as they are described.

Most taxonomic databases on the Internet are a simple listing of names with perhaps a few of the most important morphological features (Gewin, 2002; Page, 2005; Paterson, 2003). If all of the original descriptions can be collected and digitized, the nematodes will be the first group of organisms to be preserved and placed into a single database. This database will be a tremendous resource that will have a long-lasting and major impact on the taxonomy of the nematodes.

REFERENCES

Baujard, P. 1989. Remarques sur les genres des sous-familles Bursaphelenchidae Paramanov, 1964 et Radinaphelenchinae Pramanov, 1964 (Nematoda: Aphelenchoididae). Revue de Nématologie 12:323-324.

Blaxter, M. L. 2004. The promise of DNA taxonomy. Phil. Transactions Royal Society London B 359:669–679

Cobb, N. A. 1919. A newly discovered nematode *Aphelenchus cocophilus* n. sp. connected with a serious disease of the coconut palm. West Indian Bulletin 17:203-210.

De Ley, P. 2000. Lost in worm space: phylogeny and morphology as road map to nematode diversity. Nematology 2:9-16.

Eisenback, J. D. 1997. Root-knot nematode taxonomic database. CAB International: Wallingford, UK.

Gewin, V. 2002. Taxonomy: All living things, online. Nature 418:362-363.

Goodey, J. B. 1960. The classfication of the Aphelenchoidea Fuch,1937. Nematologica 5:111-126.

Needham, Turbervill. 1743. A Letter from Mr. Turbevil Needham, to the President; Concerning Certain Chalky Tubulous Concretions, Called Malm: With Some Microscopical Observations on the Farina of the Red Lily, and of Worms Discovered in Smutty Corn. *Philosophical Transactions*, Vol. 42:634-641

Page, R. D. M. 2005. A taxonomic search engine: Federating taxonomic databases using web services. BMC Bioinformatics 6:48. (http://www.biomedcentral.com/1471-2103/6/48)

Paterson, D. 2003. Progressing towards a biological names register. Nature 422:661.

Ride, W. D. L. (Chairman), H. G. Cogger, C. Dupuis, O. Kraus, A. Minelli, F. C. Thompson, and P. K. Tubbs. 1999. International Code of Zoological Nomenclature, 4th ed. The International Trust for Zoological Nomenclature: The Natural History Museum, London. (http://www.iczn.org/iczn/index.jsp)

Vieira, P., M. Mota, and J. D. Eisenback. 2003. Pine wood nematode taxonomic database. Mactode Publications: Blacksburg, VA.