Maarten J.J.E. Loonen

Linnaeus as Biologist. The Importance and Limitations of Linnaean Systematics in Biology

Linnaeus is the founding father of a unifying international nomenclature which is still used in biology today. Three hundred years ago, Linnaeus was born in Sweden, into an age of exploration, a time when an increasing number of new species was discovered and brought to attention. Linnaeus proposed a framework for organizing this biodiversity. Simple morphological traits became the key to classification and part of the classification was incorporated in the name of a species. By doing so, he initiated the solution for the first bioinformatics crisis. In the course of three centuries, naming became complex again because of our increasing knowledge of classification. The first step to complexity came with Darwin, who developed his theory of evolution. This became the new basis of classification. Secondly, molecular techniques gave a measure of relatedness far beyond the accuracy of morphological traits. In an effort to incorporate these developments into Linnaean systematics, a new crisis in bioinformatics emerges. It is time to re-use the wisdom of Linnaeus and opt for a simple solution.

Linnaeus combined nomenclature and taxonomy and developed a simple system for both. Nomenclature stands for "regulations for

© *TijdSchrift voor Skandinavistiek* vol. 29 (2008), nr. 1 & 2 [ISSN: 0168-2148]

naming in science and the whole set of names as a system". Linnaeus based his system of naming on two Latin names, where the first one was the category [the *genus*] and the second one was the specific object [the *species*]. Taxonomy is the "study of classification and systematics". Linnaeus based his classification on simple morphological features. For birds he used the shape of the bill. For plants he used details of the stamens and pistels within the flower.

The sexual organs within flowers can be divided into male and female parts. The male part is a *stamen*, usually an anther containing the pollen on top of a filament. The female part is a *pistil*, with a stigma where the pollen is caught and a style through which the pollen grows into the ovary to fertilize the plant. The choice for the sexual organs of the flower as a key to classification led to some controversy but probably also contributed to the success of the system.[1] Linnaeus deliberately used sexual terms as "marriage" and "bed-sharing" as a description for his classification.

In 1735, Linnaeus published his *Systema naturae* in The Netherlands. In this book he introduced his system. In 1753 this was followed by *Species plantarum* in which he named and described over 8000 plant species. In 1758, in the tenth edition of *Systema naturae* he also introduced a system for zoological names. The latter two books are seen as the beginning of the official naming of species and contain the oldest scientific name to which can be referred.[2]

Linnaeus became very popular.[3] He spent a lot of time educating people. His method was easy to understand and fun to use. I still remember my own experience with taxonomy. We had to identify plants by using a key with simple questions on morphological traits. After reaching a Latin name and species description, there

1 Fara 2003.

2 Duris 2007.

3 Blunt 2001.

was a feeling of enlightenment. Biodiversity was no longer leading to an incomprehensible mass of shapes, colours and beauty. Variation was structured and linked to knowledge. Followers of Linnaeus travelled the world and were called "apostles". Linnaean Societies started in Paris (1787), London (1788), Philadelphia (1806) and Bordeaux (1818). Even 300 years after his birth, many activities worldwide focussed on his work. In Groningen there was an exhibition[4] and a symposium organised in 2007.

Linnaeus developed a hierarchical system of ranks or *taxa* from species via genus, order, class to kingdom. Later some taxa were added and the standard list of ranks is now: species, genus, family, order, class, phylum, kingdom and domain. As knowledge increased, even more hierarchical levels were included: subfamily, suborder, subclass, subphylum, superclas, superorder, infraorder, superfamily and tribe. Below the species level in zoology the terms subspecies and morph are used. In botany the terms variety and form are the lower levels.

In my professional life as a biologist, I encountered several situations in which nomenclature proved complex. Going abroad, common names are insufficient. The robin in Europe [*Erithacus rubecula*] is a different bird from the robin in America [*Turdus migratorius*]. Working with the barnacle goose [*Branta leucopsis*], I discovered that the Dutch vernacular name, "brandgans", is used in German for the shellduck [*Tadorna tadorna*]. Even within one language there might be several names used. In Britain, the Arctic bird named *Stercorarius parasiticus* by Linnaeus in 1758 is called "arctic skua", while in the New World the same species is called "parasitic jaeger". A similar example is *Phalaropus fulicaria*. It is a small wader which was named after the colour of its breeding plumage in the New World as "red phalarope". In Britain it was only seen in win-

4 Universiteitsmuseum Groningen, 22-09-2007 – 27-01-2008.

ter plumage with greyish feathers and named "grey phalarope". Latin names according to the Linnaean system of nomenclature do vary too. Depending on new insights in evolutionary relations between species, the lesser snow goose has been changing from *Chen caerulescens* to *Anser caerulescens*. But at this moment both the American Ornithologist's Union and Birdlife International have decided to use the original name again and have assigned this species again from *Anser*, the grey geese, to the genus *Chen*, the white geese. A similar change happened with the polar bear (*Ursus maritimus*, Phipps 1774). The first description of the polar bear was made by Constatine Phipps. But in this first description the animal was called *Thalarctos maritimus* which was later changed into *Ursus maritimus* based on new insights in classification.

By using the number of hits in an internet search with Google, I have tested the occurrence of variations of the name. Polar bear gave 1,870,000 hits. Ice bear, a wrong translation of the name to English gave 163,000 hits. For the Latin name, I found four versions: *Ursus maritimus* (260,000 hits), *Ursus arcticus* (47 hits), *Thalarctos maritimus* (24,300 hits) and *Thalarctus maritimus* (37 hits). Two of these names are clearly mistakes.

The species concept is another problem in nomenclature[5] with the polar bear as an example. Genetic studies have shown that some brown bears (*Ursus arctos*) are more closely related to polar bears than they are to some other brown bears.[6]

In Canada geese, twelve different varieties were named. These varieties were later grouped into three subspecies. Since 1998, Canada geese are split into two new species: "Canada goose" (*Branta canadensis*) and "cackling goose" (*Branta hutchinsii*) based on a comparison of mitochondrial DNA. The two varieties which formerly

5 Marris 2007.

6 Barnes et al. 2002.

formed one subspecies have each ended up in a different new species. The species concept plays not only a role in taxonomy, but has major consequences for monitoring and conservation. Observers maintain species lists and tend to spend much more effort in finding a new species than finding a new variety of species. In conservation a species is usually the focus of protection and the disappearance of a species has a higher priority than the disappearance of a variety.

While the naming of well-known birds is relatively stable, the naming of small creatures like planktonic algae has proved highly dynamic. I worked for five years at an ecological consultancy where each month several water samples from the North Sea were analyzed for algal species composition. Within an average sample, a trained analyst behind a microscope recognized 90 to 120 species and gave all these species an estimated density within two hours. At the start of this project in 1990, they were unsure which species could be quantified and focused only on species larger than 0.2 micron. Over the years, some of the smaller species became important because they caused toxic algae blooms, and more and more species were identified as our experience grew. In 2005, we tried to analyze the data set for trends in time and found that we had to reconstruct the knowledge of the species on an annual basis to make a comparison of biodiversity over the years possible. Small species occurring in large quantities were not new in the samples but were new in our detection method.

The coding of individual species with only a Latin name also proved insufficient. As Latin names changed with the development of taxonomy, and several species were renamed, split or lumped, it was important to code the species in the database not only with a Latin name. Officially each Latin name needs to hold also a reference to the original taxonomical description (author and year of publication). But details on the taxonomic key used to identify the species are also essential to fully document the observed species.

The basis for the observed problems relate to changes in Linnaean systematics after Linnaeus died.[7] In 1859, Charles Darwin published his book *On the origin of species by means of natural selection*. His theory of evolution was also based on morphological traits and introduced the principle of "common descent" into the problem of classification. It was generally accepted that classification should reflect relatedness and part of the nomenclature was re-shuffled to represent new knowledge.

In 1953, based on X-ray diffraction images taken by Rosalind Franklin and the information that the bases were paired, James D. Watson and Francis Crick suggested what is now accepted as the first accurate model of DNA structure.[8] The molecular basis for relatedness became understood and measurable with new molecular techniques. The basis for biological classification moved from morphological traits towards biochemical (enzyme electrophoresis) and molecular (DNA-sequence) traits.

A new philosophy of classification was suggested, called cladistics.[9] Cladistics arranges organisms only by their order of branching in an evolutionary tree and not by their morphological similarity. There are no taxa such as species-genus-order-class-kingdom, and relatedness is calculated as a single value. With the development of molecular techniques as measures for relatedness, names which incorporated relatedness became more dynamic. The main branches of the "tree of life" had their own institutions and rules for naming. For plants this was the International Code of Botanical Nomenclature,[10] for animals this was the International Commission on Zoo-

---

7 Godfray 2007.

8 Watson & Crick, 1953.

9 Ereshefsky 2001.

10 http://ibot.sav.sk/icbn/main.htm

logical Nomenclature[11] and for bacteria this was the International Committee on Systematics of Prokaryotes.[12] Linnaean systematics was no option for virus classification.[13] Viruses are organized in seven groups based on DNA or RNA viruses, single stranded or double stranded molecules and the mode of replication.

As an ornithologist, I had to learn about avian influenza virus, which is classified by subtype on the basis of the two main surface glycoproteins hemagglutinin (HA) and neuroaminidase (NA). HA has 16 varieties and NA 9, resulting in 144 potential combinations, of which most are found.[14] The subtypes are further divided into strains, which differ in species selectivity and pathogenesis. New strains develop constantly through mutation and old strains often go extinct. New systems for naming have been proposed and would mean the end of Linnaean systematics.[15] BIOCODE was drafted in 1997 as a synthesis of existing codes but passed the implementation date of 1 January 2000 without general acceptance. PHYLOCODE.[16]started in 2000 and is a phylogenetic nomenclature. It requires phylogenetic definitions for every name and does not contain mandatory ranks. The oldest species name should be preserved and unique names should be given. Implementation is tentatively scheduled for 2010, though general acceptance is still lacking.

In my opinion, a modern system of classification like the PHYLOCODE is the only proper way to proceed for a classification based on relatedness. However, this type of classification has never

---

11 http://www.iczn.org/

12 http://www.the-icsp.org/

13 http://www.virustaxonomyonline.com

14 Munster 2006.

15 Ereshefsky 2001.

16 http://www.phylocode.org

been part of the classification system of Linnaeus. He used morphological traits to hierarchically classify species, which also provided a key towards finding the species name. We can do this again and stick to a name once it is officially linked with a species description even when classification changes.

A full species reference without ambiguity should then contain not only the Latin name, but also a reference to the phylocode and a reference to the classification key according to which the species name was found. The phylocode should link to the original description and to modern classification.

Reference list

Barnes,P., Matheus, P., Shapiro, B., Jensen, D. & Cooper A. 'Dynamics of Pleistocene population extinctions in Beringian brown bears'. *Science*, vol. 295, 2002, pp. 2267-2270.

Blunt W. *Linnaeus: the complete naturalist*. Princeton NJ 2001.

Duris, P. *Linnaeus – de ordening van plant en dier. Natuur wetenschap en techniek*, Amsterdam 2007.

Ereshefsky, M. *The poverty of the Linnaean hierarchy: a philosophical study of biological taxonomy*. Cambridge 2001.

Fara, P. *Sex, botany & empire: the story of Carl Linnaeus and Joseph Banks*. Cambridge 2003.

Godfray, H.C.J. 'Linnaeus in the information age'. *Nature* vol. 446, pp. 259-260.

Marris, E. 'The species and the specious'. *Nature* vol. 446, 2007, pp. 250-253

Munster V.J. *Ecology, evolution and pathogenesis of avian influenza viruses*. [Ph. D. thesis] Rotterdam: Erasmus MC 2006.

Watson J.D. & Crick F.H.C. 'A Structure for Deoxyribose Nucleic Acid'. In: *Nature* vol. 171, 1953, pp. 737–738.