THE ROYAL SOCIETY

Published online 18 March 2004

Taxonomy: where are we now?

Taxonomy, a term that we usually restrict to the classification and naming of organisms, began when people first were able to communicate with one another, no less than several tens of thousands of years ago. Before the invention of written language *ca*. 5600 years ago, oral classification systems were used. These share several characteristics, no matter how rich or diverse the biota among which the people who used them lived. In all such taxonomic systems, approximately several hundred kinds of organism were recognized. These names were applied to many more kinds of organism than what we consider scientific names now if the taxa were of little use or interest, fewer if they were of greater use, and there was very little attempt to construct hierarchical classifications. These were unnecessary because the properties of all the kinds of organism named in the language were known to its speakers.

The descriptions of various kinds of organism by the Greeks and the Romans amounted to written accounts of such folk taxonomies, and followed the same principles. No one had any idea of trying to tie together the taxonomies of organisms found in different parts of the world, and such works were therefore neither comprehensive nor encyclopaedic. As the descriptions existed only in manuscripts, they could not be disseminated widely, and in any case would have been of limited value in areas other than those for which they were developed.

With the deployment of movable type in Europe in the middle of the fifteenth century, the stage was set for the first great taxonomic revolution. It was then possible for many scholars to have access to books that at first amounted to the local folk taxonomies recorded in different parts of Europe. The widespread interest in using plants as medicines stimulated efforts to see, for example, the extent to which what Aristotle had described in Greece could be transferred to England, and comparisons began to lead to the formation of larger and more comprehensive books.

By the time of full development of the age of encyclopaedism towards the end of the seventeenth century, scholars had begun to produce works in which all available knowledge would be set forth, and the interest in plants, animals and other organisms blossomed. The development of binomial nomenclature by the Swedish naturalist Carl Linnaeus some 50 years later provided a system of names that was convenient and more durable than polynomials used earlier. Hierarchical categories were superimposed on the developing systems because it was no longer possible for anyone to have as part of their active knowledge the properties of all the organisms being classified. For *ca*. 300 years, then, people have been concerned with the classification of all organisms on Earth, and recording information about them on a wide geographical basis, as exploration gradually delivered biological information about all parts of our planet and institutions were founded to accommodate the specimens and libraries that resulted from these studies.

At present, we feel dissatisfied with the state of taxonomy, lamenting the fact that there are relatively few individuals working in the field and that inadequate numbers of people are being trained, even though the number of scholars exploring various aspects of the diversity of organisms is actually much larger than it has ever been in the past. I would suggest that our unease arises from several sources.

First, we now know that many more kinds of organism exist than we had estimated previously. Over the past 50 years, the number of named species has grown from *ca*. 1.4 to *ca*. 1.6 million, but the estimates of the actual number (eukaryotes only) are from 2 million or fewer to anywhere from 10 million to several tens of millions. Our task is much greater than we thought earlier, particularly because of the fact that no more than 5% of the named organisms are understood in any biological detail.

Second, universities have been largely abandoning the field of taxonomy in favour of new, rapidly expanding biological disciplines. The postulate of a double helical model for DNA and the subsequent revolution that has occurred in all fields of biology has properly excited scientists, students and administrators alike. Consequently, resources have been focused on realizing the unimaginable gains that have been made in the 51 years since 1953, when Francis Crick and James Watson first showed the way to modern biology. If universities do not train the many taxonomists that we need, who will?

Third, the distribution of taxonomists, like the distribution of all kinds of scientists and engineers, is highly skewed geographically. Some 82% of the world's people live in less-developed countries, with *ca*. 15% of the world's resources and perhaps 80% of its biodiversity. Without the implementation of major programmes to help them develop the necessary skills and build strong institutions to deal with the taxonomy of their own organisms, there is probably little hope for a rapid development of broad taxonomic knowledge.

Fourth, we expect much more from organisms now than ever in the past. It has been said that the twenty-first century will be the age of biology, but we can use the properties of organisms to build a sustainable, productive era only if we know what those organisms are and understand them much better than is the case now. Otherwise, we shall be limited to the very few that we know well, and clearly will not be able to do what might be possible with broader knowledge.

Fifth, the expansion of the world's population from 2.5 billion to 6.3 billion since 1950, expectations of increasing

One contribution of 19 to a Theme Issue 'Taxonomy for the twenty-first century'.

affluence and consumption everywhere, and the wide use of inappropriate technologies have led a condition in which we are using the world's resources unsustainably—at a faster rate than they can be renewed—and driving a major proportion of the world's species—perhaps as many as two-thirds—to extinction during the course of the century that we have just entered. Alien invasives, global change and other factors we are just starting to understand can only make the situation worse. This means that we would like to accelerate and make much more efficient the process of taxonomic exploration, discovery and description, and we have not got and are not training the scholars who would be able to make this acceleration possible.

What can we do? The preservation of species depends more than anything else on the attainment of a sustainable world, and will be possible only to a limited scale in an unsustainable one. The accumulation of knowledge about organisms itself will help to some degree to make the world sustainable, but many other factors, including population stability, finding sustainable levels of consumption and the deployment of better technologies, are more important. Those familiar with the world have an obligation to help to inform others about these problems, to contribute to the development of a global society that will work for the benefit of most people, and to use the political process to help attain these goals. We must also work to apply the knowledge about diversity to the development of appropriate conservation schemes, knowing that these can succeed to any extent only in a sustainable world.

In the accumulation of knowledge about organisms and its deployment for many purposes, the efficient use of the products of the information revolution is even more important than the development of movable type 550 years ago. The registration of all properties of organisms in efficiently constructed databases, automated identification, Web pages for different kinds of organism—these and many other techniques are absolutely indispensable and need funding as amply as can be provided. There is simply no other way to achieve the aims of taxonomy broadly, as many of us have been pointing out for decades. Many more efficient ways can and are being developed to deal with the description of organisms. Fully harnessing the power of the Web clearly will and must expedite taxonomic progress in the future, building soundly on the systems of the past but expediting the accumulation and dissemination of information.

I have very limited enthusiasm for the construction of a world catalogue of say, nematodes, and consider that it would be of limited value—because we would know next to nothing about the organisms entered in it. I consider that it does not matter much whether they would be classified by morphology, nucleic acid profiles, cytochrome *c* barcoding or some other method: we still would not have gained much, in my opinion, when the exercise was concluded. Alternatively, I am enormously enthusiastic about sampling the diversity, geographical, ecological and systematic, of nematodes and all other groups, a kind of exercise that has rarely been funded but in my opinion ought to be emphasized. There is really no excuse for perpetuating our level of ignorance about nematodes, fungi or mites and at the same time no hope, in my opinion, of completing world catalogues before many of them disappear. This clearly calls for sampling, but if we do not even understand continental or latitudinal patterns of variation in the diversity of these groups, how can we deal with them appropriately? We do not really even know if there are more species of nematodes or fungi in the tropics than in temperate regions, and are doing very little to try to find out.

For prokaryotes, the situation is much worse, and we really have no basis whatever for calculating world diversity at present, leaving aside questions of what a convenient species definition might be. Those who are attempting to give us some basis for understanding their diversity should be highly encouraged.

Conservation plans, necessarily based on better-known groups of organisms, need full encouragement and development in this age of extinction. Implemented on a landscape or ecosystem basis, and especially if they take into consideration the critically important survival of biodiversity in areas that have already been modified a great deal—Michael Rosenzweig's 'reconciliation ecology'—they will help greatly to conserve as many organisms as possible for future generations.

Finally, nothing will substitute for the activities of the field naturalist. No matter how much we may speak about instant identification through DNA analysis, hand-held keys or other modern approaches, unless there are very many people who can recognize organisms, find them, go into the field and find them again, whether they be in the tropical moist forests of Congo or the chalk grasslands on the South Downs of England, nothing will work. We who have been trained to recognize and deal with organisms in nature can think of many fantastic devices and approaches, but how would they be employed if people could not find and recognize the organisms? In this respect, the All Taxa Biological Inventory being carried out in the Great Smoky Mountains National Park in the USA, involving as it does large numbers of amateur and professional biologists, may afford us the best operational model.

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