

Why Classify?

An Appreciative Look at Biodiversity with Special Reference to Fungi

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I have been asked to address the question "Why Classify?" Fortunately there are excellent reasons why we should — why we must — classify fungi and other living organisms. Yet today we are also faced with almost insuperable difficulties in doing so. I will talk about the reasons, then the obstacles, and finally make a few suggestions as to what we might do about overcoming them.

The Reasons

Reason one: It's fun; to some of us the richness and diversity of life on Earth is absolutely fascinating. Most people are conscious of it only in the vaguest way. Yet to me, and I'm sure to many of you, biodiversity is one of the main things that makes the Earth such an interesting place to live. If you ask people why they travel, some will say, for a change in climate, or a change of scenery, or to experience different cultures. I travel because I want to experience more biodiversity.

A few years ago, I did a lecture tour of China. The central Chinese landscape has little biodiversity. There were crop plants, weeds of cultivation and trees planted for shade, wood or fruit. Not much else. If the people hadn't been so fascinating, I would have found my trip quite boring. In contrast, when I was in Namibia, I found that their new constitution includes the requirement to preserve biodiversity. I hope they have the will to do it.

I am back here in New Zealand, not only to give a couple of talks, but also to revisit the biota, and especially

the fungi, of your country in their almost infinite beauty and diversity. To fly to South Africa or Australia or New Zealand is at one level to go from one part of the English-speaking world to another. I immediately recognise many aspects of the culture as similar to the English one in which I was raised, and the Canadian one in which I now live.

But at a biological level, when I come to the antipodes I am entering a different and exciting world. In September, my wife Laurie and I went to Perth in Western Australia for a mycorrhiza conference. We arrived late at night, unaware in the darkness of what was all around us. In the morning we walked across the road into King's Park, to be instantly surrounded and almost overwhelmed by the profuse spring flowering of the native bush. Almost every flower, bird, and tree was new to us. For me, it was a real rush, an authentic high.

My family also spent part of a sabbatical on the Great Barrier Reef, where we were dazzled by the beauty, the diversity and the interactions of fish, invertebrates, reptiles and birds. According to the terms of reference of my Guggenheim Fellowship, I was officially working on microscopic fungi that live inside coral skeletons. But over a couple of months of regular scuba diving, I also learned to recognise many families, genera and even species of beautiful reef fish because I met them every day. Not least among these were several species of shark — white tips, black tips, sometimes tiger. Most people worry about sharks, and why not? I did too, at first. But I soon found that the species I was meeting weren't the least bit interested in eating me. No, what I really had to watch out for were such inoffensive-looking things as stonefish and cone shells, both of which can be lethal. I had to learn



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how to identify these things as a matter of survival, and for this I relied on classifications erected by other taxonomists.

I could paint parallel pictures of the African biota I have experienced in such places as the Helderberg nature reserve near Somerset West, or the fynbos near Betty's Bay in the Cape, or the superb Etosha Pan game park in Namibia, or Mana Pools on the bank of the Zambesi in Northern Zimbabwe. Southern Africa and Australia each have close to 1,000 species of birds, mostly new to people from the Northern Hemisphere. Southern Africa has 20,000 species of flowering plants. Biodiversity is where these countries are at. Remember that I grew up in Britain, where there are only 2,000 species of flowering plants.

In Africa this diversity extends in a small way to the mammals. Think how boring these wonderful game parks would be if they were inhabited by only one kind of herbivore and one kind of carnivore. Who would go there? The wide spectrum of antelopes in Kruger Park in the Transvaal, at Mkuze and Mfolozi in Natal, and at Etosha Pan in Namibia is exciting and challenging. "What was that?" we would say to each other. "Was it a steenbok or a duiker or a klipspringer?" The average person can't tell these small antelopes apart. Communication of the information you need to do that is the responsibility of taxonomists, and in a minute or two I will examine the way in which they live up to it.

But merely to browse among this biological wealth is ultimately frustrating to many of us. I know very little about the plants of tropical rain-forests, and I am somewhat appalled by my ignorance whenever I enter one of these uniquely rich environments. I know that many people look on plants as nothing more than the green wallpaper of the outdoors, but they really are missing one hell of a lot. I do not like to remain ignorant.

Reason two: We want — we need — to know the names of organisms. Many primitive societies believe that if you know the name of something, you have some power over it. Biologists know that this is true, because once you have the correct Latin binomial, you have the key to its literature. I began my academic career as an ecologist, but I soon found that I couldn't do good ecology unless I knew the identities of the organisms I was working with.

This concept can be applied much more broadly. Every human being is a classifier from birth — the first task for Adam was to name the plants and animals! First you learn to differentiate between your parents and other people, then among relatives, friends and strangers. Later you learn which things are edible, which poisonous. This taxonomic process is essential, because it helps us to make important decisions: whom to trust, what to eat. Even what to buy — how many other disciplines have a section of the newspaper named after them? Classified! So we want more than names, we want information that will enable us to make comparisons and choices.

Reason three: We want to know how organisms we see are related to those we have already encountered. In the game parks of Natal in South Africa, I noticed the considerable similarity between two kinds of antelope, the nyala and the kudu. It seemed to me that they were probably sibling species. But I needed a framework within which to place them. Somebody — a taxonomist — has usually provided such a framework, at least for better-known groups such as mammals, birds, fish and plants. For each group, millions of observations have been organised into a more or less coherent statement — a classification, often in the form of an illustrated handbook.

This classification is a data storage and retrieval system, designed with two purposes in mind:

- To embody comprehensive taxonomic information in a hierarchical, organised form, which represents a hypothesis about the way in which the various organisms are related to one another
- To facilitate identification

Taxonomists are not so foolish as to try to produce these systems all by themselves. They take information from every other discipline. And as their ideas become more refined, they may throw new questions at the biochemists, the physiologists and the molecular biologists. We should not be surprised to find that a great deal of the work done in these other disciplines has direct implications for systematics.

I'd like to point out that two of the aims of taxonomic systems, the representation of relationships, and the *facilitation of identification*, are not always well integrated, especially given the kind of organisation biologists always insist on imposing on the documents they produce. Novices would like to use the system to identify organisms they don't know, and they expect it to be user-friendly. But it usually isn't, because it insists on putting *closely related* forms together, often *at the expense of ease of identification*. Taxonomists, influenced by the overriding central importance of evolutionary theory in biology, insist that the organisation of the document must first and foremost reflect what we know about relatedness, and thus phylogeny. To hell with identification — after all, the specialist who wrote the book knows the group already. I will return to this matter later, because I have a solution for this problem.

To classify well is to understand the organisms being systematised. At the beginning we know little, and many different classifications are possible. We might classify books on the colour of their covers, on their size, on their weight, on the number of pages. These are genuine features, and might be useful to people who make books. But they are not very rich in the kind of information most of us are looking for in a library, and we would obviously choose to classify books by their subjects and their authors.

When we first classify a group of organisms, we often have no idea which characteristics will work best. Different scientists with differing points of view often erect different classifications for the same group. These competing systems are not necessarily evidence of incompetence on anyone's part. Each, as I said earlier, represents a hypothesis. As our knowledge accumulates, the number of possible classifications decreases until eventually we should arrive at a single scheme that reflects everything we have ever learned about the organisms. In the meantime, we can't treat disease of our crops or ourselves properly until we know what kind of organism is causing it. Once we know its place in the taxonomic scheme of things, we can look in a rational way for chemicals that are selectively toxic to that group, or specific parasites to which it is susceptible, or the stage of its life cycle at which it is most vulnerable. Identification must precede action.

All of the reasons I have given so far have a certain compelling logic (or at least, I hope they do), but why do I think taxonomic activity is absolutely essential?

The answer is **reason four: the interconnectedness, the interdependence of life** makes the study of biodiversity so crucial. It's essential to classify, to systematise, whether we like it or not. Everything is hitched to everything else, and if you believe chaos theory, you have to start worrying about every last little change we make in the biosphere, especially if that change is the permanent deletion of a genome, otherwise known as extinction.

We know that our progenitors were the prokaryotes, and that, free-living or symbiotic, they still play vital roles in the biosphere. Bacteriologists must be cheered by the current understanding that multicellular eukaryotes like ourselves are really just mixed colonies of cooperating prokaryotes, though even they might be prepared to admit that the whole was usually rather more than the sum of its parts. Animals cannot exist without plants. But how many are aware that plants would not exist without the intimate collaboration of fungi? Current thinking has the fungi, already established in what passed for soil during the early palaeozoic, establishing essential mutualistic relationships with the earliest land plants. Such links have lasted until the present — over 90% of plants still have mycorrhizal associations.

So we ignore any part of the biological spectrum at our peril. But do we know enough about that spectrum? **Reason five tells us: science has described about 1.5 million species, mostly insects, but we are absolutely sure that millions more have so far eluded us.** Our ignorance is profound, but very uneven. We know almost all the birds and mammals and fish, but only a small fraction of the arthropods and only a few percent of the fungi. Estimates of the number of described fungi range from 70,000 to over 100,000, but our best estimate of the total world mycota is about 1.5 million. Since my lab alone has described about 200 new taxa in the past three years, and I have many more undescribed taxa sitting in my files, I don't find this figure inflated.

When I came to New Zealand on sabbatical some years ago, one of my graduate students and I had just finished the manuscript of what was supposed to be a world monograph on the hyphomycete genus *Chalara* and its allies. And what do you think happened in New Zealand? I found a whole raft of new species of *Chalara*, and it took us another two years before we finally saw the back of that monograph. It is obvious to me that New Zealand has many thousands, or even tens of thousands, of undescribed fungi, and one of your jobs as a scientific community should be to document them. And in order to keep them around long enough to find them, you must save whole ecosystems. And for that to happen, you have to make input to the processes of popular education and politics.

Now I believe that from an ethical point of view all those organisms have as much right to exist as we do. But we all know that biological ethics don't cut much ice with politicians or industrialists, or even small-time entrepreneurs. Ethical arguments probably haven't prevented a single extinction, though emotional arguments have prevented, or at least delayed, quite a few. For example, millions of dollars have been spent on whooping cranes, California condors, pandas and so on, because large numbers of people know about them, and are willing to defend their interests. But plants? Insects? Fungi? Who out there knows, who cares? Who has an emotional investment in them?

In order to defend such anonymous, apparently unglamorous creatures, we must advance **reason six: among those unknown hordes are many potentially valuable species — species that will yield some new metabolite that serves a human purpose.** Remember the unassuming rosy periwinkle, *Catharanthus roseus*, found only in Madagascar, and possibly, like many other species on that island, headed for oblivion, but rescued by the recognition that it produced compounds named vinblastine and vincristine, biologically active substances that have been largely instrumental in reducing the death-rate from leukaemia from 90% to 5%. Or an obscure microscopic fungus called *Tolypocladium inflatum* — it doesn't have a common name — which produces cyclosporine, a selective immunosuppressant that rescued organ transplants from oblivion and made them almost routine. The list is growing, just as global biodiversity is shrinking at the hands of the exploding human population.

And that brings me to **reason seven: it's almost too late to do the job, to describe the full range of biodiversity, because habitat destruction and degradation are rapidly rendering numerous taxa, including many we don't even know about, extinct.** Extinction is difficult to prove, but we are sure it is going on.

To sum up the first part of my discussion, the cataloguing of life is not just a scientific parlour game or a form of stamp-collecting. It discovers important renewable resources. It gives coherence and form to our ideas about the world and ourselves. And it emphasises the

increasingly urgent need to preserve whole ecosystems rather than individual species.

Biologists and pharmacologists are not the only ones interested in the biological spectrum. Geologists use indicator organisms to build hypotheses about ancient climates and catastrophes, all of which are important in interpreting the present and predicting, and even possibly managing, the future. What would happen if a comet struck the Earth? We now know in some detail, because it happened at the end of the Cretaceous, causing extensive extinctions. Now technology can seek a way to foresee and forestall such a catastrophe. And that is ironic in the extreme, because we ourselves are bringing about, through our own efforts, unaided by any celestial body, one of the greatest extinctions in the history of the planet.

We must attempt to complete the catalogue so that we know what is out there. We should not be allowed to destroy ecosystems in ignorance of what is in them. Oh, we may elect to do it anyway, but as a species ourselves, we should be faced fairly and squarely with the inescapable consequences of those actions. And only taxonomists can provide that evidence. Most of the 200 species my laboratory has recently described are from threatened ecosystems in the tropics, and since that is where the pace of destruction is most rapid, that is where we must concentrate our efforts. There are still, of course, thousands of unknown fungi in countries like Canada; we have described a few of them, too. And we continue to find them. But the sheer magnitude of the job overwhelms us.

I'm sure that you, as biologists, are all convinced of the necessity of completing the biological inventory, and of constructing a phylogenetic classification which will help us to recreate the history of life and its major events.

The Obstacles

But, and it's a huge but, there are serious, perhaps insurmountable obstacles in our path. Let me list a few.

Obstacle one: the discipline of taxonomy or biosystematics is out of fashion right now with at least two important segments of the academic community — students and granting agencies. Both seem to want to focus largely if not exclusively on molecular biology. This is unfortunate for students, because: (1) they may never see the sun again and (2) they will be unable to recognise the organisms with whose DNA they are playing.

But I want to point out that even molecular biologists often turn out to be investigating one of two things — either the essential unity of all living organisms or the evolving differences among living organisms — and those are the very things systematists are interested in. If systematics didn't exist, we would have to invent it, to provide the molecular biologists, and everybody else, with a frame of reference.

Obstacle two: there is a huge number of living things for us to cope with. I have heard positively out-

landish estimates for the total number of insect or arthropod species, ranging up to 30 million and more: this, when we have described only about one million. And the total number of species of all forms of life has been estimated at from 5 million to 80 million. No one knows the real number. But I have a better feel for the fungi, where we have described somewhere between 70,000 and 100,000 species. The current estimate of the total number of fungal species likely to be present on Earth, as I mentioned earlier, is about 1.5 million. Do I take that number seriously? Yes, because it was based mainly on the ratio between the number of flowering plants in Britain (about 2,000) and the number of fungi known in Britain (about 12,000). That ratio is about 6:1. If we assume that there are about 250,000 species of flowering plants in the world, then extrapolation of the 6:1 ratio takes us to 1.5 million.

This estimate did not take into account the possibly astronomical number of undescribed members of the *Laboulbeniales*, which grow harmlessly on the exoskeletons of arthropods, that might be found on all those undescribed insects. Essentially, all this means is that we have probably described only 4-6% of the extant fungi, and possibly fewer. How appalling to learn, then, that the proposed biological inventory for the US will apparently ignore the fungi. I can hardly comprehend such blindness and stupidity. But there are other kinds as well.

Obstacle three: human activities are driving many species into extinction. Norman Myers of Oxford suggests that within 50 years, we could lose one-third, possibly one-half or more of existing species. Many scientists think that we stand on the brink of the greatest extinction since the end of the Cretaceous, 65 million years ago, when 50% of species were extinguished. Others liken the carnage to that which happened at the end of the Permian, when an even higher percentage of taxa were extinguished. Rain-forests cover only 7% of the earth's surface, but it is estimated that they contain 50% to 80% of the species diversity of the planet. The tiny country of Panama has as many plant species as the whole of Europe. Rain-forests are one of the most threatened environments in the world; 200,000 square kilometres per year are being destroyed. With them, unknown and undescribed species of plants animals and fungi are undoubtedly being extinguished. The only difficulty is to know how many. One estimate I read recently was that we are losing 1,000 to 10,000 species per year. Another suggested one per hour, and a third, one per day.

To be honest, no one knows what the rate of extinction is. And it is highly unscientific to claim, as many are doing, that we are losing specific numbers of taxa. As I said, this is impossible to prove, and can only cast doubt on anything else we say, no matter how well founded it may be. Nevertheless, I'm sure that we do all have an anguished feeling of certainty that it is happening.

One reason we don't know is that 80% of the world's biodiversity is in countries that are home to only 6% of its scientists. The World Conservation Monitoring Centre in

Britain documents 311 species which have disappeared since 1600. This number includes 117 birds, 54 mammals, 20 reptiles, 24 fish and 96 invertebrates, but no fungi. This list is an interesting historical document, but probably has little relevance to what is actually going on now.

Whatever anyone says about the current rate of extinction is bound to be contentious, since it is much harder to prove than are past extinctions unequivocally documented in the fossil record. I read just a couple of weeks ago about a small butterfly, the Palos Verdes Blue, which was considered to have become extinct in 1983. It has just been seen again by the same scientist who had made what he had thought to be the last sighting, more than a decade earlier. He said (rather unscientifically, I thought, but with understandable emotion) "It was a real resurrection."

And as far as I am concerned, one species lost is one too many. Humans typically make value judgments that have everything to do with human needs and wants, and nothing to do with the almost totally unknown population dynamics of the living world. Some scientists say that we can never describe everything, the subtext being that we shouldn't even make the attempt. I reject that defeatist attitude, and would simply say that we must try to get as far as we can, given our limited resources.

Over the past three years, as I said, my laboratory has described about 200 new taxa of microscopic fungi, mainly from the tropics. This sounds like a lot, and to those of us doing the describing, it represents a major effort. But we have to admit that it is a fleabite, compared with what's out there. I feel sure that in the coming decades, many fungi will become extinct, some, especially microscopic forms, before we even know that they are there. I'll give you one possible candidate for extinction. Some of you may have read about a large polypore, a shelf-or bracket-fungus, called *Oxyporus nobilissimus* which occurs only in old growth forests on the west coast of North America. Until recently it held the record for the world's largest fungal fruiting body, for a specimen weighing in at 136 kilograms. Few collections have been made, and fewer and fewer can be expected to turn up as the last old-growth forests are logged.

Europe is the only place in the world where anyone has any idea about how many macroscopic fungi are present, and how many of those are threatened. In Europe, 2984 species have been included in what are called Red Lists of declining, threatened or extinct taxa. In Holland alone, 200 participants have compiled 300,000 records, drawing upon long-standing foray lists to plot the decline or demise of no fewer than 944 species. Sweden has a Red List of 550 species, and Finland one of 325 species. These lists in most cases concern only macrofungi that have been the object of attention by amateur and professional mycologists over the years. The many thousands of microscopic fungi we also know to exist, but do not have sufficient documentation about, are hardly dealt with at all. Most other parts of the world

simply don't have the kinds of data to permit such retrospective judgement. And in many areas it is obviously too late to obtain such data. We are ignorant, and we are inevitably going to remain ignorant. We are going to lose some of our fungi without even being aware that they have gone.

Will it matter? It depends how important you think *Penicillium notatum* and *Penicillium chrysogenum* are. It depends how important you think *Tolypocladium inflatum* is. Without these microscopic fungi we would not have penicillin and cyclosporin, two of the most important pharmaceuticals of the last 50 years.

A fourth obstacle is the attitude of our society. People care about nasty chemicals in the environment, since those chemicals have a habit of sneaking into the food and into the water supply, and affecting everyone. People also seem to care about such cuddly mammals as the panda. But most people in our Western-style societies are profoundly anti-intellectual, and quite frankly couldn't give a damn about the extinction of organisms they have never even seen. Quite honestly, I think we need a revival of the old polytheistic religions in which every brook and stone had a resident spirit, that had to be respected.

Despite the discoveries of penicillin, cyclosporine, vinblastine and vincristine, despite everything we know, and despite the best arguments that we have been able to muster in the halls of politics and academe, **obstacle five is that the resources of biosystematics are not only inadequate now, but instead of being augmented, are being steadily eroded.** Mycologists and botanists are retiring and, in the case of the National Museum of Canada, have even been fired. They are not being replaced. Is this the beginning of the end for classificatory science?

What Can We Do?

Here beginneth the last chapter in my chronicle. What can we do to change the course of events? If we are taxonomists, apparently not much, since our track record to-date is distinctly uninspiring. Despite what we might call our best efforts, our numbers and our funding are still shrinking every year. Perhaps biologists of other stripes, who are our customers, can do more. I realise that science exists in, and is perhaps itself, a dog-eat-dog world. We compete with each other for jobs and grants. And unless a taxonomist is willing to go molecular, he or she is unlikely either to be hired, or to be particularly successful in the strenuous competition for research money, at least in the world of the nineties.

But surely taxonomists are not the only ones who are frightened by the enormity of what is happening, although I am shocked by the apparent complacency or apathy of many of my biological colleagues. In Canada, some of our best environmentalists are, perhaps surprisingly, geologists. I have a theory about this. I think geologists are rather like field biologists. They often work in remote, relatively unspoiled places. And they get hooked

on such places, as I have been hooked. Or they work in the mining or petroleum sectors, and get to see the direct results of human cupidity in the slag heaps, gravel pits, mine excavations and toxic effluents generated by the extractive industries. Or they are concerned with climate, and the way it may be changing. In any case, there they are, fighting shoulder to shoulder with us.

But we need many more supporters from other disciplines. **The first thing we need is the time and energy of every educated person who has an understanding of the situation.** Every person who worries about what his or her children and grandchildren will inherit. Surely that means everyone in this room today. It means actually getting off our butts and putting some energy into supporting the conservation and documentation of biodiversity.

Secondly, we need to be political, and to get far-sighted people onto grant-selection committees and as government advisers. Each one of us can become an unofficial government adviser, through the power of the mail. I never hesitate to give them my advice, and I understand that politicians regard one letter as evidence that many more people believe the same thing. I recently read that when US politicians learned that 80% of the voters wanted more law enforcement, they quickly found the money to hire 100,000 new police. Now I'm not going to set my sights that high, but even 1,000 or 100 new biosystematic positions would make a real difference to our ability to complete the biological inventory.

Let me share with you the Canadian experience, which as you will see is mixed. Over the past 30 years, I have spent a fair amount of my time doing fungal taxonomy, though my laboratory has also done ecology, development, toxicology, mycorrhizae and aerobiology. I have been able to convince our main Canadian scientific granting agency, the Natural Sciences and Engineering Research Council, to give us \$90,000 a year for the past 10 years, a fair chunk of that money going to support one man, my research associate Dr Nag Raj, who took 17 years to produce one book about coelomycetes (and what a wonderful book it is). Now that's faith, of a kind we don't see too often any more. Which of us could now begin a 17-year project without at least disguising it as something else? So the Canadian system, of which I am very supportive and proud, has paid for long-term taxonomic research — and continues to do so. Even though I am taking early retirement this year, I have just received three-year funding at \$45,000 a year to support more of the same.

And yet the same Federal Government that provides the Natural Sciences and Engineering Research Council with its funding has just seen fit to cancel a trivial million-dollar grant to the Royal Society of Canada. As an active Fellow of that Society I may be slightly biased, but in my opinion the Society, though inappropriately named, is effectively our National Academy, and can call upon tremendous expertise when asked to do a job for the Government. Knowing the kind of support the Royal

Society of London, and the US National Academy of Sciences get, I can only shake my head in disbelief. Is Canada headed for Third World status? Fortunately, such attitudes are not universal. When the Seckenburg Natural History Museum in Frankfurt has to cut back, something strange happens — it is the exhibits, rather than the research, that suffer. It's all in the underlying attitude. Can such intellectually supportive attitudes be fostered in our own countries, our own cultures? Biosystematics needs many more workers if its job is to be done successfully. During the educational process we need to foster the kind of attitudes that will make people want to do that job.

So the third thing we need to do is to educate our public, our fellow scientists and, perhaps most important of all, our students, about the necessity of documenting biodiversity. And we don't have very much time to do it. Because our own species is multiplying in numbers and in demands at an unprecedented rate, over 90 million new people every year. The population of Kitchener-Waterloo, the city where I live, in a day. The population of another New Zealand every two weeks. The population of another Canada every few months. And all these people take room and resources, both of which are inevitably usurped from other species. How much longer can this go on before the world becomes biologically depauperate? Not long. **The fourth thing we must do is: do it now.** And the education we offer must be not merely on the need for preservation of ecosystems, but on such basics as birth control, and on moderation of expectations — ours as well as everyone else's.

I have some sort of understanding that the people in power think of people like me as harmless crazies, and I wonder if we can afford to go on letting them think that until the last natural ecosystem has been destroyed in the name of money, or whether at some point we may have to become radicalised and put our bodies on the line. Better that, perhaps, than to become ecoterrorists. The methods of the IRA are always wrong. But we may yet need to stand out and be counted. I hope some of you would do that too.

Now, on a more intellectual note, what can we do, given our limited resources, to render our taxonomic efforts more efficient, and our data more accessible and usable? Systems of classification, as I said earlier, are almost always theories about the ways in which organisms are related. There is nothing wrong with that. Yet the grand vision of the classifier often gets in the way of the average user. Let me cite the many so-called guides to the birds of this country or that. Even though these works of classification are aimed directly at the layperson, the birds are not arranged in terms of their habitat, their geographic range, their sizes, their colours, or any other accessible kind of system. No, they are arranged in what is believed to be a phylogenetically based system, and the amateur must learn by rote where to look for particular groups of birds. That is how strongly ingrained the phylogenetic approach is in biology. Using the same material, I could design a more practical guide to the birds in a

couple of weeks, but since I'm not an ornithologist, no-one would publish it.

In some books, especially those dealing with plants, the authors often attempt to compensate for the inaccessible nature of the system by providing a dichotomous key. As an undergraduate I had frequent, and often extremely frustrating, recourse to such keys. They were not the answer. From the depths of my ignorance, I had to provide a perfect set of answers to a linear series of questions. If I could not answer any one of that series, I was lost. But now we can finally provide something that really works. I have personally compiled several databases which are at the same time, in their entirety, synoptic keys. My solution is to put all the taxonomic information in a computer, and use a search program that permits random access to the data. This means that when someone wants to identify an organism, they can describe to the computer whatever characters they can find, and are sure of, in whatever order they choose. The computer will then tell them in a second or two just how many taxa possess the chosen characters. Features can be added or deleted until the number of possibilities is reduced to one.

Users of this database never have to worry about being asked questions they can't answer, which of course is the normal experience when one uses a dichotomous key. Naturally it helps to know something about the kind of character that is useful, but with a minimum of instruction, I have found that undergraduates can perform successful identifications. This success is highly reinforcing, and encourages them to keep learning. If biodiversity is less daunting, more accessible and understandable, more people may be persuaded to defend it, and even to study it.

In Africa, after spending quite a lot of time watching antelope and not always knowing what I was looking at, I finished up compiling a simple computer database on the antelopes of southern Africa. It did not overtly address the concept of relationships among the antelopes, though there was obviously an underlying assumption that they were all closely related, and an analysis of the charac-

teristics used in the database could easily produce some kind of estimate of the similarity and possibly even the relationships among the various taxa. But it did enable me to identify antelopes quickly and reliably.

The fifth thing we must do, then, is put all our taxonomic and biodiversity data into computers, and make it as accessible as possible to everyone who needs it. This will immediately make our input of time and energy much more effective than ever before. Computers make it easy to store, disseminate and gain access to vast amounts of taxonomic information. A single compact disc can store 650 megabytes of information, and give access to any piece of it in a few seconds. All we have to do is produce the information (he says, jokingly). A few more rosy periwinkles and *Tolypocladiums* would engender a lot of publicity, followed by political interest, followed by funds. At least we can only hope so.

Perhaps we can take some comfort from the fact that if taxonomists became extinct, someone would have to reinvent them. Humans have always been taxonomists out of necessity. They had to learn to distinguish edible from poisonous plants, innocuous from predatory animals, and human friends from foes. Why classify? Because we must. Classification is a central theme in biology, an attempt to represent the evolutionary history of life. It draws from all the other disciplines, synthesises that information, and issues new challenges to them

My main hope is that the more we know, and the more we can teach others, about the millions of organisms with which we supposedly share this planet, the more we will all respect and nurture them.

I will close by calling on a rather unlikely ally, Albert Einstein, no biologist he, who wrote: "Our task must be to free ourselves...by widening our circle of compassion to embrace all living creatures and the whole of nature and its beauty." I hope you will join me in this task.