Parasite Systematics in the 21st Century: Opportunities and Obstacles

Daniel R. Brooks
University of Toronto, dnlbrooks@gmail.com

Eric P. Hoberg
United States Department of Agriculture, eric.hoberg@ars.usda.gov

Opinion TRENDS in Parasitology Vol.17 No.6 June 2001

Parasite systematics in the 21st century: opportunities and obstacles

Daniel R. Brooks and Eric P. Hoberg

Taxonomic names and phylogenetic hypotheses are indispensable tools for modern biological research, both basic and applied. Like all disciplines, parasitology suffers from the 'taxonomic impediment' – a global shortage of professional taxonomists and systematists. Only a fraction of the species of parasites on this planet have been identified, and the evolutionary relationships of only a minority of those are understood; thus, information on how to manage parasite biodiversity, including known and potential disease agents, is incomplete. A renewal of systematic parasitology has a key role in redefining the relationship between mankind and the organisms whose biology fascinates us so much.

As the 21st century begins, interest in parasites has never been greater. Parasites are becoming recognized as significant players in the evolutionary game and are seen as excellent model systems for general evolutionary studies[1,2]. In addition, parasitic disease of humans, livestock and wild biodiversity represents a major concern for most countries. Whether an acute crisis or a chronic condition is being faced, the biodiversity crisis is on a scale greater than one could have imagined 50 years ago. Increasingly, discussions about managing the biodiversity crisis include parasitism and parasitology.

Valuing systematics

Systematists provide two kinds of information. The first of these is the names and characteristics of all known species. Species are essential elements of biodiversity – genealogical information systems that store and transmit the information leading to the emergence of ecosystems with their complex interactions. Without systematics, biological science could not proceed. All biological research begins with one or more names of species, and it is systematists who make certain that everyone knows what names such as *Plasmodium falciparum* or *Schistosoma mansoni* mean when they are talked about. Second, systematists also provide the framework for comparative studies in basic and applied biology. The predictable parts of biological systems are those elements, both form and function, autecological and synecological, that have persisted through evolutionary time[1,3,4].

The Convention on Biological Diversity (CBD)[5] designated species as the fundamental units of biodiversity, and ecosystems management and sustainable development as containing the organizing principles for managing global biodiversity. Biologists and ecosystems managers alike quickly realized that the current inventory of the world's species was far too limited to implement the CBD mandate properly and that a crucial shortage of trained taxonomists – the so-called 'taxonomic impediment – contributed directly to the problem[6–11]. The Conference of the Parties (COP) to the CBD has endorsed a Global Taxonomy Initiative (GTI) to improve taxonomic knowledge and capacity to further country needs and activities for the conservation, sustainable use and equitable sharing of benefits and knowledge of biodiversity[12]. The initiative has three components, and each one will be discussed in turn.

Systematic inventory

The CBD mandate states that all signatories undertake a national inventory of their biodiversity resources. Such national inventories are biodiversity development and conservation projects, a means for restoring global taxonomic capacity. Regardless of the focus of any inventory, the GTI mandates guidelines for choosing priority taxa for such inventories. Parasites satisfy all those criteria[13–16], as outlined below.

Taxa should be intrinsically important to humans

Parasites are agents of disease in humans, livestock and wildlife and have consequent socio-economic significance. Knowledge about their lifestyle is particularly important when the risk of loss of bio-containment by introduced species is being assessed. Changes in parasite lifestyle as a result of introduced species could be due to a number of factors. For example, parasites of introduced species might move into the agricultural landscape or wildlands and switch to native hosts, or perhaps parasites of native species move out of the agricultural landscape or wildlands and infect the introduced, economically important host species. A less-common factor could involve local people and tourists sharing parasites and parasitic diseases between themselves and between human and non-human hosts. Some parasite species might even provide revenue as model systems for pharmaceutical companies or as biocontrol agents.

Taxa should be intrinsically important to ecosystems that humans want to preserve

Parasites are significant regulators of host populations and are potent agents that maintain the integrity and stability of ecosystems. Complex feedback loops involving parasites, herbivores and habitat structure in ruminant grazing systems further indicate the significance of parasites as determinants of community structure. Parasites can also be important mediators of host behaviour. Introduced parasites can have unpredictable and deleterious impacts on native species of hosts. It is therefore important to be able quickly to distinguish native from introduced parasite species.

Daniel R. Brooks*
Dept of Zoology, University of Toronto, Toronto, ON, Canada M5S 3G5.
*e-mail: dbrooks@zoo.utoronto.ca

Eric P. Hoberg
United States National Parasite Collection, Animal Biosystematics Laboratory, ARS USDA, BARC East 1180, Beltsville, MD 20705, USA.

http://parasites.trends.com 1471-4922/01/$ – see front matter PII: S1471-4922(01)01894-3

Taxa should provide efficient means of learning something of importance

Parasites, especially those that have complex life cycles involving more than one obligate host, are indicators of stable trophic structure in ecosystems. This is because all the biotic components necessary for completion of the life cycle must co-occur regularly in order to maintain any given parasite species. Knowing the complement of parasite species inhabiting any given host thus provides a means of rapid assessment of the breadth and form of trophic interactions of host species. Parasites are key to understanding the context of global change.

Taxa should be geographically widespread

Many parasite taxa are widespread geographically. At the same time, they are highly localized with respect to infecting particular hosts, which themselves can be the focus of particular inventory activities.

Taxa should provide opportunity for international networking

Parasite systematics is in serious trouble worldwide. Laboratories throughout the world have eroded the infrastructure for taxonomy and systematics at a crucial time. New survey opportunities and recognition of the importance of parasites might stimulate international collaboration and recognition of the need for the development or renewal of systematics infrastructure in every country.

Predictive classifications

A crucial element in preserving biodiversity within the context of the CBD is managing information about the 1.7 million species currently known, as well as those yet to be discovered. The framework for such information systems must include the capability of making predictions about the characteristics of species based on what is known about the biology of close relatives. This requires knowledge of phylogenetic relationships; phylogenetic classification systems are the most effective framework for predictive information systems about organisms and their place in the biosphere[6,15,17]. Although systematists have made giant leaps forward in understanding the interrelationships of life, phylogenetic hypotheses are still lacking for many groups. Diversitas, the United Nations Environment Programme (UNEP) in biodiversity, proposes to co-ordinate international research to achieve a phylogenetic framework for all of life resolved to the family level by the year 2010. Parasitology quietly leads the way in this effort. For example, phylogenetic analyses of the parasitic platyhelminths began appearing in 1985 (Refs 18,19), and today the initial skeleton of a phylogenetic tree for all the parasitic platyhelminths to family level is available[1,20,21]. There is still much room for discussion and improvement, but parts of parasitology are more than a decade ahead of the SA2K-I agenda.

The past decade has seen the integration of phylogenetic information in all areas of evolutionary research and in a growing number of areas of applied research, thus providing common ground to serve the professional agendas of evolutionary biologists and ecologists, as well as of biodiversity and conservation managers. Using phylogenetic frameworks to make predictions can cut the time and costs of research and development, or of planning and prioritization[15,22]. Phylogenetic study of parasites can help assess the suitability of proposed biological control agents, recognize introduced species and predict the epidemiology of emergent diseases. Indeed, understanding the evolutionary basis of disease resistance will come from a comparison of closely related host species, one resistant and the other susceptible to a given pathogen, just as understanding the evolutionary basis for causing disease will come from comparing closely related parasites, one pathogenic and the other not.

Managing systematic knowledge bases

Electronic data handling and inter-linked knowledge systems are becoming the principal medium for all activities associated with applying systematic information in biodiversity studies and policies. The Organization for Economic Co-operation and Development (OECD) Megascience Forum declared this crucial need for systematic information a global priority in mid-1998. Parasite systematists could contribute significantly to this area, establishing phylogenetic and species home pages, and on-line identification guides and keys. The phylogenetic home pages could provide inter-linked phylogenetic trees, modified periodically as needed, for all groups of parasites, whereas the species home pages could provide useful information on each species. These sections could include: 'what is it?' (and 'how can it be distinguished from others?'), (2) 'where is it?', and (3) 'what is its natural history?' The on-line identification guides and keys could be designed to aid a large user community.

Seeing and overcoming the taxonomic impediment in parasitology

Comparative studies using phylogenetic information have appeared in virtually every area of biology during the past decade, including applied research in parasitology[23,24]. However, the primary limiting factor in all comparative studies, both basic and applied, is a shortage of robust estimates of phylogeny[25]. This is because enthusiasm for using phylogenetic insights to further research has outrun the availability of professional systematists. What do professional systematists offer non-systematists? They are trained to amass and assess various forms of data, and are thus able to generate combined analyses using information from many different sources[24,26–28]. Systematists can also provide the most robust possible interpretation of phylogenetic results, helping researchers avoid the embarrassment of claiming support for one particular theory when their published data actually support the opposite[29].

The growing number of phylogenetically informed studies in basic and applied parasitology highlights some harsh realities. First, although their number is growing, well supported phylogenies are still rare; second, the groups that have attracted phylogeneticists are rarely the groups that have attracted non-systematists; and third, the number of active systematists decreases yearly. The solution to these problems requires a large amount of support from non-systematists, for example (1) supporting the training and hiring of more systematists, (2) providing more support for museum collections and museum systematists, and (3) becoming better versed about phylogenetic methodology. Surely it is more time- and cost-effective for modern molecular laboratories in tropical medicine and public health to hire professional systematists than to produce poor phylogenetic trees that will need to be re-done to achieve stable results? Systematists, for their part, must provide more and larger databases, integrating all available molecular and morphological data; encourage students to work on groups that are important to non-systematists; and develop better ways to explain their ideas to a naive, but enthusiastic, audience.

In an effort to focus attention on the value of the taxasphere and promote the GTI, DIVERSITAS has designated 2001–2002 as the International Biodiversity Observation Year (IBOY). One of the projects sanctioned by the IBOY steering committee is an inventory of the parasites of stickleback fishes worldwide, and is led by David Marcogliese, the 2001 winner of the Henry Baldwin Ward Medal of the American Society of Parasitologists. The IBOY is an excellent opportunity for coalitions of international, national and local political, social development and environmental agencies to provide a fuller inventory and better knowledge of the parasites on this planet. Perhaps the World Federation of Parasitologists and its subsidiary societies could endorse ongoing parasite inventory projects throughout the world during 2001–2002 as a sign of their commitment to systematic parasitology.

Concluding remarks

Saving biodiversity and promoting human socio-economic development is a complex issue that requires networks of both people and research programs. Networks require a common language and discourse, as well as collaborative development of theory and research programs. Modern systematists are the masters of a language powerful enough to facilitate such necessary discourse.

Acknowledgements
D.R.B. acknowledges long-term support from the Natural Sciences and Engineering Research Council (NSERC) of Canada.

References

1 Brooks, D.R. and McLennan, D.A. (1993) *Parascript: Parasites and the Language of Evolution*, Smithsonian Institution Press
2 Poulin, R. (1997) *Evolutionary Ecology of Parasites*, Chapman & Hall
3 Brooks, D.R. and McLennan, D.A. (1991) *Phylogeny, Ecology and Behavior: A Research Program in Comparative Biology*, University of Chicago Press
4 Brooks, D.R. and McLennan, D.A. *The Nature of Diversity: A Voyage of Discovery through Space and Time*, University of Chicago Press (in press)
5 Glowka, L. *et al.* (1994) *A Guide to the Convention on Biological Diversity*, International Union CN
6 SA2000 (Systematics Agenda 2000) (1994) *Systematics Agenda 2000: Charting the Biosphere*. Technical Report, American Museum of Natural History
7 Jones, T. (1995) Down in the woods they have no names – BioNET-INTERNATIONAL. Strengthening systematics in developing countries, *Biodiv. Conserv.* 4, 501–509
8 Hoagland, K.E. (1996) The taxonomic impediment and the Convention on Biodiversity. *Assoc. Syst. Coll. Newsletter* 24, 62
9 Hoagland, K.E. (1996) The taxonomic impediment and the Convention on Biodiversity. *Assoc. Syst. Coll. Newsletter* 24, 66–67
10 Blackmore, S. (1996) Knowing the earth's biodiversity: challenges for the infrastructure of systematic biology. *Science* 274, 63–64
11 PCAST (President's Committee of Advisors on Science and Technology) (1998) PCAST Panel on Biodiversity and Ecosystems. Washington DC US Govt Printing Office, Washington DC
12 Cresswell, I.D. (2000) The Global Taxonomy Initiative – *Quo vadis*? *Biol. Int.* 38, 12–16
13 Hoberg, E.P. (1997a) Phylogeny and historical reconstruction: host–parasite systems as keystones in biogeography and ecology. In *Biodiversity II: Understanding and Protecting Our Biological Resources* (Reaka-Kudla, M.L. *et al.*, eds), pp. 243–261, Joseph Henry Press
14 Hoberg, E.P. (1997b) Parasite biodiversity and emerging pathogens: a role for systematics in limiting impacts on genetic resources. In *Global Genetic Resources: Access, Ownership and Intellectual Property Rights* (Hoagland, K.E. and A.Y. Rossman, eds), pp. 71–83, Association of Systematics Collections, Washington, DC
15 Brooks, D.R. and E.P Hoberg (2000) Triage for the biosphere: The need and rationale for taxonomic inventories and phylogenetic studies of parasites. *Comp. Parasitol.* 68, 1–25
16 Brooks, D.R. *et al.* Parasitos y la biodiversidad. In *Enfoques Contemporaneos para el estudio de la Biodiversidad* (Hernandez, M.H. *et al.*, eds), Universidad Nacional Autónoma de Mexico (in press)
17 Simpson, B.B. and Cracraft, J. (1995) The science of biodiversity. *BioScience* 45, 670–672
18 Brooks, D.R. *et al.* (1985) The phylogeny of the Cercomeria Brooks, 1982 (Platyhelminthes). *Proc. Helminthol. Soc. Wash.* 52, 1–20
19 Brooks, D.R. *et al.* (1985) Phylogenetic analysis of the Digenea (Platyhelminthes: Cercomeria) with comments on their adaptive radiation. *Can. J. Zool.* 63, 411–443
20 Littlewood, D.T.J. *et al.* (1999) The interrelationships of all major groups of platyhelminthes: phylogenetic evidence from morphology and molecules. *Biol. J. Linn. Soc.* 66, 75–114
21 Littlewood, D.T.J. and Bray, R.A., eds *The Platyhelminthes – Phylogenetic Perspectives*, Taylor & Francis (in press)
22 Brooks, D.R. (1998) Triage for the Biosphere. In *The Brundtland Commission's Report – 10 Years* (Softing, G.B. *et al.*, eds), pp. 71–80, Scandinavian University Press
23 Hoberg, E.P. and Lichtenfels, J.R. (1994) Phylogenetic systematic analysis of the Trichostrongylidae (Nematoda) with an initial assessment of coevolution and biogeography. *J. Parasitol.* 80, 976–996
24 Nadler, S.A. and Hudspeth, D.S.S. (2000) Phylogeny of the Ascaridoidea (Nematoda: Ascaridida) based on three genes and morphology: hypotheses of structural and sequence evolution. *J. Parasitol.* 86, 380–394
25 Brooks, D.R. and D.A. McLennan, (1994) Historical ecology as a research programme: scope, limitations and future. In *Phylogenetic Approaches to Ecology* (Eggleton, P. and Vane-Wright, R., eds), pp. 1–27, Academic Press
26 León-Règagnon, V. *et al.* (1999) Differentiation of Mexican species of *Haematoloechus* Looss, 1899 (Digenea: Plagiorchiformes): combining molecular and morphological evidence. *J. Parasitol.* 85, 935–946
27 Hoberg, E.P. *et al.* Phylogeny among orders of the Eucestoda (Cercomeromorphae): integrating morphology, molecules and total evidence. In *The Platyhelminthes – Phylogenetic Perspectives* (Littlewood, D.T.J. and Bray, R.A., eds), Taylor & Francis (in press)
28 Zamparo, D. *et al.* Phylogenetic analysis of the Rhabdocoela (Platyhelminthes) with emphasis on the Neodermata and relatives. *Zool. Scripta* (in press)
29 Brooks, D.R. and McLennan, D.A. (1992) The evolutionary origin of *Plasmodium falciparum*. *J. Parasitol.* 78, 564–566