DOCUMENT RESUME

ED 482 110 IR 058 798

AUTHOR	Hawkey, Roy
TITLE	Systematically Speaking: How Do Natural History Museum Web Sites Represent Science?
PUB DATE	2002-04-00
NOTE	16p.; In: Museums and the Web 2002: Selected Papers from an International Conference (6th, Boston, MA, April 17-20, 2002); see IR 058 778. Some figures contain very small type.
AVAILABLE FROM	For full text: http://www.archimuse.com/mw2002/papers/hawkey/hawkey.html/.
PUB TYPE	Reports - Research (143) -- Speeches/Meeting Papers (150)
EDRS PRICE	EDRS Price MF01/PC01 Plus Postage.
DESCRIPTORS	*Classification; Epistemology; *Museums; *Sciences; *Scientific Methodology; *Web Sites; *World Wide Web
IDENTIFIERS	Natural History; Systematicity; Virtual Museums; *Web Site Design

ABSTRACT

This paper explores the representation of taxonomy, systematics and other aspects of science on selected natural history museum Web sites, using two different but related approaches. One uses a series of categories relating to the nature of science (derived from an evaluation of exhibitions) and applies these to each Web site. In essence, this approach seeks to identify and, where possible, quantify evidence of representation of science as a human endeavor, scientists at work, the status of scientific ideas, doubt and debate, and opportunities for visitors to formulate their own opinions. The second approach concentrates on science processes and practices, the methodology and operation of science, including selection of research programs, collection and analysis of data, evaluation of evidence and its interpretation, development of models, hypotheses and theories, and publication, debate, and peer review. The paper shows that some natural history museum Web sites are now beginning to share their passion for science, especially less fashionable areas, such as systematics, and that such developments coincide with changes in views about the public understanding of science and about the roles of museums. (Contains 38 references.) (Author/MES)

PAPERS
Museums and the Web 2002

Systematically Speaking: How Do Natural History Museum Web Sites Represent Science?

Roy Hawkey, The Natural History Museum, London, UK

Abstract

The first natural history museum Web sites offered little more than visitor information. Then they began to include more of the nature and scope of both collections and exhibitions. Now, they incorporate sophisticated graphic design and feature active involvement by the virtual visitor, but they can also bring the museums' scientific research work to a larger and more diverse audience. Far from being principally for children, and full of dinosaurs and dioramas, major natural history museums are characterized by a high degree of fundamental scientific research.

In the Eighteenth Century, museums were central to the active creation of scientific knowledge, but we now tend to associate science exclusively with laboratories. The popular image of science - test-tube and Bunsen burner - is, for several important aspects of science, inappropriate. One such area is systematics - discovering, describing, naming, classifying organisms and identifying their evolutionary relationships - a major concern of most natural history museums. Yet few Web sites explain its significance, or even make it explicit. This paper explores the representation of taxonomy, systematics and other aspects of science on selected natural history museum Web sites, using two different but related approaches.

One uses a series of categories relating to the nature of science (derived from an evaluation of exhibitions) and applies these to each website. In essence, this approach seeks to identify and, where possible, quantify evidence of representation of:

1. Science as a human endeavour - science as a social and cultural activity, a human enterprise; 2. Scientists at work - showing what scientists actually do in the process of research; 3. The status of scientific ideas - scientific ideas as theories or models, rather than as incontrovertible fact or the revelation of truth; 4. Doubt and debate - introducing scope for further questioning and reinterpretation of evidence.; 5. Opportunities for visitors to formulate their own opinions - reflecting the social construction of science. 1

The second concentrates on science processes and practices, the methodology and operation of science:

1. Selection of research programmes - realization that science is neither certain nor neutral means that justification for research is increasingly evident, often expressed as 'biodiversity' or as benefits to humanity; 2. Collection and analysis of data - traditional and/or contemporary methods, field and laboratory techniques; 3. Evaluation of evidence and its interpretation a perception of science as unanswered questions rather than unquestioned answers; 4. Development of models, hypotheses and theories - presenting the dynamism and fluidity of science as well as an authoritative view of current understanding; 5. Publication, debate and peer review -

A&MI

Archives & Museum Informatics
2008 Murray Ave.
Suite D
Pittsburgh, PA
15217 USA
info@archimuse.com
www.archimuse.com

Search A&MI

Join our Mailing List.
Privacy.

argument and discussion as key elements of the scientific process

The paper shows that some natural history museum Web sites are now beginning to share their passion for science, especially less fashionable areas such as systematics, and that such developments coincide with changes in views about the public understanding of science and about the roles of museums.

Keywords: science; science museums; perception of science; philosophy of web sites; natural history museums; epistemology

Introduction

When it comes to attitudes to science, there is, it appears, no such person as the 'average man or woman'. A recent study concluded from extensive sampling that, in the UK, there are indeed six types, from the informed enthusiast to the 'not for me' (Wellcome Trust / OST, 2000). Yet, regardless of interest in, aptitude for or knowledge of science, many museum visitors perceive science as a series of facts and laws discovered in laboratories (no doubt by men in white coats) and expressed in difficult technical terminology. They are likely, too, to expect museums to be full of dusty objects supported by the antediluvian opinions of expert curators expressed in obscure language (Hawkey, 2001a).

Yet, in the Eighteenth Century, museums were central to the active creation of scientific knowledge. At that time museums were centres both for generating scientific understanding through research and for promulgating that understanding, through science education. Resources fundamental to both areas of activity could be drawn from their collections. Ensuing developments, however, resulted in education becoming the province of schools, while science became confined principally to laboratories. Here, experimentation could take place under controlled conditions, with the consequence that museums came to be regarded merely as places for the storage of existing – and potentially ancient – knowledge (Arnold, 1996).

So, what are natural history museums for? Somewhere to take the children on a wet afternoon? For them to marvel at the dinosaurs? Notions such as these, together with numerous other associated assumptions, are prevalent among the general public, visitors and non-visitors alike. What misconceptions! For, more than any other type of contemporary museum, it is the natural history museums that have maintained the museums' research role. Indeed, unlike most other museums – including, ironically, museums of the physical sciences and of technology – natural history museums are characterized by a high degree of fundamental scientific research. This research activity is reflected in statements, both intentional and incidental, of the aims of natural history museums relating to using collections to make fundamental scientific discoveries about the natural world. For example, The Natural History Museum (UK) has a mission 'to maintain and develop its collections and use them to promote the discovery, understanding, responsible use and enjoyment of the natural world' (NHM, 1996).

Museums per se have such a long-established tradition – the British Museum will shortly celebrate its 250th anniversary – that it is easy to over-estimate the age of museum Web sites. Most date from the mid-1990s; many are more recent; all are continuously and rapidly evolving. The early content of natural history museum Web sites did include something of the nature and scope of both collections and exhibitions, but much was essentially visitor information – about opening times, entrance fees and bus routes. There have subsequently, of course, been vast improvements in graphic design and in enhanced functionality, the latter increasingly featuring active involvement by the virtual visitor. Latterly, other developments of great significance have begun to showcase the museums' scientific research work, conveying fundamental ideas about the life and earth sciences to a much larger and more diverse audience.

A previous paper (Hawkey, 2001b) explored natural history museum Web sites from the perspective of a science teacher, using an embryonic evaluation strategy that, not surprisingly, put great emphasis on educational issues. The present study attempts to develop further such approaches to the analysis and philosophy and practice of Web sites. To some extent it is forced to rely upon an 'expert' understanding of natural history museums and issues in science communication, especially in relation to identifying concepts and strategies that are merely implicit. It may at least provide a foundation for the development of a more sophisticated methodology.

This paper explores the representation of science on selected natural history museum Web sites. What kind of science is evident? How is it presented (in terms of epistemology rather than aesthetics)? What insights are provided into the underlying philosophy and rationale? Are there indications of the processes of investigation and enquiry or of the interpretation of evidence? What view of scientific knowledge is presented? And, in particular, what efforts are made to explain the contemporary relevance of the science of systematics?

Making Science Explicit

What, then, do natural history museum Web sites state explicitly about their science? Table 1 shows a number of useful and informative excerpts from several Web sites, in North America, Europe and Australasia. Many of these give great insight into research practice and, occasionally, philosophy. However, the ease with which such material can be located varies considerably, from those where a clear link to 'Science' or 'Research' is evident on the home page to those who provide little more than annotated lists of departmental organization. This tendency for museums to present themselves as inherently divisional or departmental, often with no more general explanations or evocations, was a greater limiting factor in the choice of museums included in this study than was, for example, language.

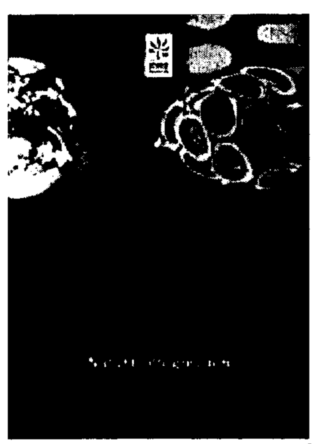

Figure 1: Natural progression

Museum	Science
American Museum of Natural History	For 125 years advanced scientific research has formed the core of the Museum. Scientists at the Museum conduct innovative research programs both in the field and within the walls of the Museum's laboratories and collections areas. (www.amnh.org)
Australian Museum	The Australian Museum undertakes an active and innovative program of research into Australia's environments and indigenous cultures. Biodiversity, geodiversity and the origins and sustainability of Australia's environments and cultures are the key focus of this research. Other work in phylogenetics concerns development and application of phylogenetic methods, philosophy of science, and editorial work for Systematic Biology. (Australian Museum, 2002)
Brussels NHM (Belgium)	.. application of techniques of molecular biochemistry in the fields of systematics, phylogenesis and population genetics. (www.naturalsciences.be)
California Academy of Sciences (USA)	The California Academy of Sciences actively pursues original scientific research and is committed to fostering a spirit of scientific discovery and stewardship of the natural world. Systematic biology, the focus of the Academy's research, is becoming increasingly important as the understanding of the value of biodiversity grows. (www.calacademy.org)
Zoological Museum, Copenhagen (Denmark)	The central research areas are zoological systematics and zoogeography, including... identification, description and naming of species, interpretation of relationships (phylogeny), as well as historical and geographical aspects of evolution and biodiversity. (www.zmu.dk)
National Museum of Natural History (Smithsonian, USA)	NMNH's scientists are... filled with questions and are committed to finding the answers, have enduring curiosity, seeking and finding the puzzle pieces to significant questions about the natural world and about vital topics such as global warming, the loss of biodiversity, and invasive plant and insect species Research provides knowledge as the essential building blocks for integrative, overarching scientific interpretation. It leads to an understanding of processes that shape the natural world. The answers for today's questions come from crossing traditional academic boundaries and integrating multiple perspectives. (MNH, 2000)
The Natural History Museum (UK)	The Natural History Museum is an international leader in the scientific study of the natural world. Science is fundamental to the Museum's role [and] describes the present diversity of nature, promotes understanding of the critical importance of its past, and develops knowledge that supports anticipation and management of the impact of human activity on the environment. (www.nhm.ac.uk)
Naturalis (Netherlands)	Naturalis' collections are a source of knowledge of the characteristics and the development of the earth and life. The collections fulfill the function of natural history archive and serve as reference and basis material for research. (Naturalis, 2001a)
Royal Ontario Museum (Canada)	The ROM will be a world leader in communicating its research and collections to increase understanding of the interdependent domains of cultural and natural diversity, their relationships, significance, preservation and conservation. (www.rom.on.ca)
San Diego NHM (USA)	The extensive scientific collections,... contain materials that support the research of many scientific disciplines, including those working to define and preserve biodiversity and monitor global change. (www.sdnhm.org)
Senckenberg (Frankfurt, Germany)	[holds] large collections as "documents of a nature archive". They are the fundamental basis for research activities around the world in biodiversity, in exploring the biosphere, in the evolution of life and our own origin. (www.senckenberg.de)
Swedish Museum of Natural History	Basic biological research at the Swedish Museum of Natural History concentrates on the origins of animals and plants, their systematics, and their distribution in time and space. (www.nrm.se)

Table 1: Explicit statements of science research policy and practice

A good example is provided by The Natural History Museum, where departmental designations – Botany, Entomology, Library & Information, Mineralogy, Palaeontology and Zoology – have been augmented, if not superseded, by multi-disciplinary research themes. These are presented in *Natural Progression* (NHM, 2001a), the Museum's strategy for science, which is readily available on-line as a downloadable .pdf file: figure 1.

Key elements of scientific enquiry, both process and content, are clearly discernible among the theme descriptors – as illustrated in figure 2 – and are summarized in Table 2). At the next (ie deeper) level, individual projects are highlighted in accessible language (Table 3), but with more sophisticated information and links to further work.

Research themes	Key aspects of science	
	Process	content
Biomedical Sciences	Record / explain	distribution / diversity / ecology / taxonomy
Collections Management	Knowledge	
Earth Materials, History and Processes	Investigations / properties / relationships	origins / history
Ecological Patterns and Processes	Investigate / patterns	conservation / distribution
Environmental Quality	Impact assessment	aquatic & terrestrial pollution
Fauna and Flora	Description / keys / naming	diversity
Systematics and Evolution	Investigate / patterns	biodiversity / evolution / systematics

Table 2: Scientific research at The Natural History Museum (UK)

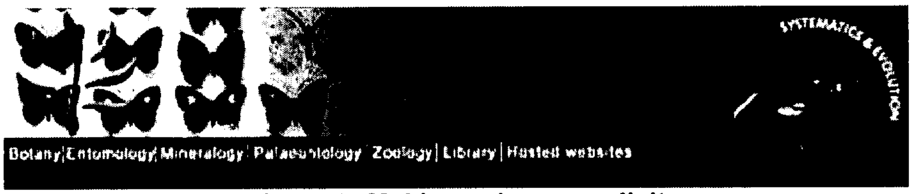

Figure 2: Making science explicit

Evolution : The Systematics and Evolution Theme	**Origin and early evolution of tetrapods (animals with four legs).** http://www.nhm.ac.uk/science/intro/palaeo/project5/index.html
The aim of the Systematics and Evolution Theme is to discover and investigate the broad patterns of biodiversity and evolution, as a foundation for comparative biology and its uses. Scientists use both traditional and modern techniques, the latter frequently derived from molecular biology, to investigate the systematics and evolution of key groups ranging from microbes to fish.	About 380 million years ago, during the Devonian period, a group of fishes evolved limbs and began to leave the water. This move was a tremendous success; all back-boned land animals, or ' tetrapods', (amphibians, reptiles, birds, and mammals, including humans) that have ever lived can ultimately trace their ancestry to these fishes.

Table 3: Example of a research theme and programme

Science in the Balance

Recent developments in thinking about scientific literacy or the public understanding of science have also given increasing emphasis to the processes and practices of science (House of Lords, 2000). This remains a necessary and critical shift in emphasis, despite the fact that many formal science curricula, such as that in the UK (QCA, 1999), have begun include among their requirements some study of the nature, methodology and operation of science, in addition to an understanding of its knowledge base.

All of these issues are, to a greater or lesser extent, contained within the research programs of natural history museums. Potentially, at least, they are accessible through the material made available on-line. There are a variety of ways in which issues in this domain can be expressed and annotated. Table 4 shows how King's (1996) categories compare with those used by Hawkey (2001b), and indicates the synthesis that will be used in what follows in this paper.

Science communication categories (King, 1996)	Science process categories (Hawkey, 2001b)	Natural history museum Web site analysis
• science as a human endeavour	• influences on / mechanisms for selection of research programmes	• Science as a human activity
• scientists at work	• the collection and analysis of data	• Science as enquiry
• doubt and debate	• the evaluation of evidence and its interpretation	• Science as debate
• the status of scientific ideas	• the development of models, hypotheses and theories	• Science as model making
• opportunities for visitors	• publication, debate and peer review	• Science and society

Table 4: Alternative ways of thinking about nature of science issues

Science as a Human Activity

How was the universe created? Are birds and dinosaurs related? What makes us human? What are the consequences of human activity on the plants and animals living in our own back yards? These and other deep questions about the natural world are what motivate our scientists each waking hour. (MNH, 2000)

The human dimension of science is critical in a number of ways, relating not only to who scientists are and what they do but also to which questions society requires them to answer. Presenting science as a social and cultural activity, as a human enterprise, may facilitate enhanced access and help to question the oft-supposed neutrality of science. That science is a human activity (rather than merely pre-determined or abstract) can be reflected to some extent by repetition of 'the museum's scientists', but is best demonstrated by individualized and personalized narratives. Some Web sites, especially those of the larger US natural history museums, include scientists' names, photographs, case studies and even live links to the field. For example, Chicago's Field Museum site has on-line exhibits on 'Women in Science' and on 'Adventures in the Field'.

Members of the general public have, in recent years increasingly come to question earlier notions that science is inherently beneficial and worthy of support. A heightened realization that science is neither certain nor neutral – especially in its selection of topics for research – has been a significant factor in this. Rationale for research is therefore expected to be explicit, even in apparently non-controversial areas, and natural history museum Web sites are beginning to go some way towards providing this.

The most likely to be explicitly expressed, and certainly the most frequently highlighted, is 'biodiversity'. Although a term little understood by non-specialists and absent from many school science curricula – the National Curriculum in England & Wales (QCA, 1999) has recently introduced 'sustainable development', but 'biodiversity' per se is absent - biodiversity is a theme that looms large in the realm of natural history museum Web sites. Natural history museums display a range of examples of biodiversity resources on their Web sites, with explanations that range from the elegiac to the utilitarian, from the moralistic to the homo-centric. Examples are included in table 5.

Other than biodiversity, the most common rationale given for natural history museum research is the benefits that it can offer to humanity: predicting volcanic eruptions and earthquakes, increasing food supplies, locating oil and gas reserves, maintaining and conserving natural resources. Occasionally, reference is made to economic or commercial considerations – and even, rarely, to sources of funding – but often the goal is expressed simply as that of 'better understanding'.

Australian Museum	Special emphasis has been given to the best-possible use of Museum collections in regional planning, and to the links of biodiversity assessment to sustainability and economics.
California Academy of Sciences (USA)	Petroleum geologists use collections to ascertain the identity of fossils with oil deposits; the U.S. Customs Office looks to botany collections for help in identifying imported plants; and farmers and gardeners query Academy researchers about plant pests and their biological control.
Naturalis Netherlands	About 15 years ago, more than 400 species of cichlids, a family of tropical fish, lived in Lake Victoria. Since the introduction of the Nile perch, for the benefit of the fishing industry, numerous species have disappeared forever. A unique species-rich ecosystem has become unbalanced... researchers from Naturalis accurately record how the situation has developed. (Naturalis, 2001b)
Swedish Museum of Natural History	Research on the occurrence of environmental toxins in nature and their effects on animal life is also conducted at the Museum. This is devoted to determining the geographical dispersion of toxins, as well as changes in concentrations and quantities over time.
Te Papa (New Zealand)	The key project is a major Foundation for Research Science and Technology grant-funded project to survey, describe and classify the fish fauna of the New Zealand Exclusive Economic Zone (the fourth largest in the world) and to better understand its origins and relationships. This research is discovering a new species every two to three weeks. (www.tepapa.govt.nz)

Table 5: Examples of rationales for research

In ways very different from that of fictionalized drama, Web sites can also redress the stereotypical notion and show 'that science is not a list of intimidating abstractions in a textbook; it is the imaginative product of personalities who rarely conform to the stereotype of an egghead with a white coat' (Farmelo, 1992).

Science as Enquiry

The vast majority of natural history museum Web sites include considerable reference to the research activity of their scientists. This may be implicit – implied by terms such as discover, describe, identify, experiment, analyse – or, more rarely, explicit. They inform visitors that scientists collect specimens from all over the world (and beyond, in the case of meteorites,!) and study them using a plethora of techniques. Central to this scientific process is the collection of data and its subsequent analysis, and almost every site includes reference – whether in outline or in detail – to more traditional and/or contemporary methods. Table 6 indicates a range of these, divided into predominantly field and laboratory techniques, drawn from a variety of sites.

Some sites try to give visitors an insight in the enquiry process by involving in what is essentially a role-play activity. One such is QUEST (NHM, 1998). Here, would-be researchers are presented with a series of unidentified objects and a set of virtual tools with which they can magnify the object and look at it from different angles, find out fundamental features, such as mass, size and texture, and gather more sophisticated data including age and an image (if any) under uv light. They then make their own on-line record, with any other observations they may wish (Hawkey, 1998, 1999).

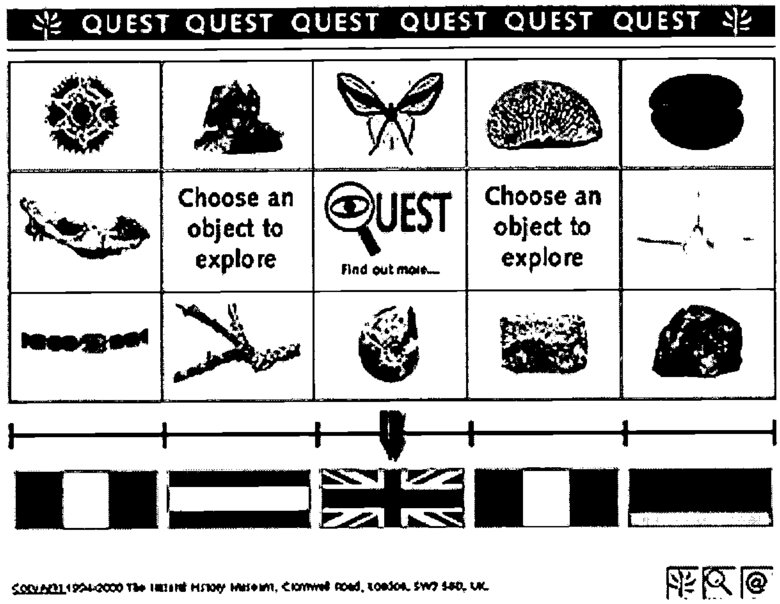

Fig. 3: QUEST's opening screen

	Laboratory	Field
Traditional	• Describe & name • Documentation • Experimental growing • Microscopic analysis	• chemical indicators • collection • ecological techniques • field observation • field research
Contemporary	• age determination by isotope analysis • computer analysis • molecular biology (DNA analysis) • 3d X-ray • mass spectrometry • high resolution transmission /scanning electron microscopy	• fossils to locate oil/gas • satellite telemetry

Table 6: Methods of data collection and analysis

There are even examples that encourage active participation in the collection, identification and mapping of organisms such as woodllice (Hawkey, 2002a): figure 4.

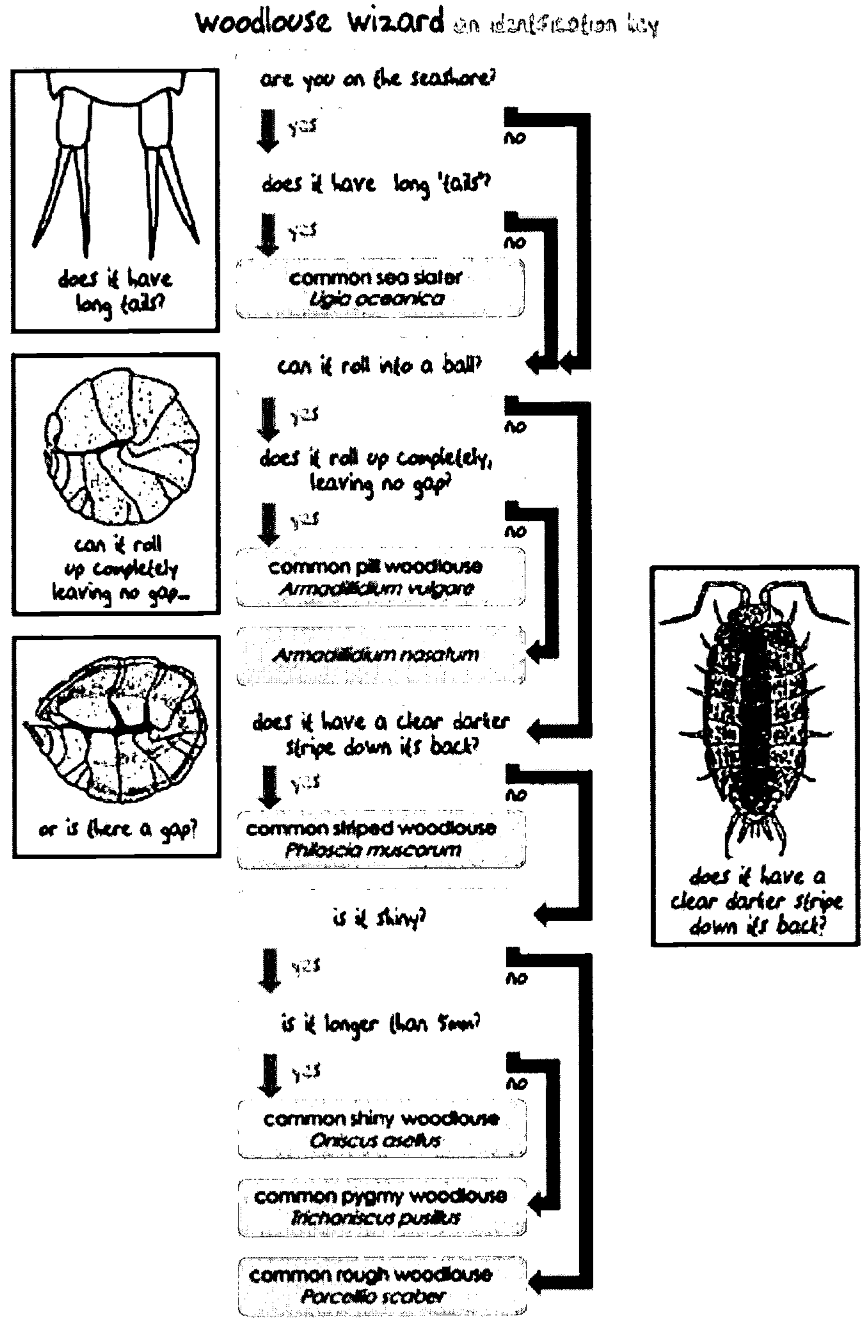

Fig. 4: An Encouragement to go 'Walking with Woodlice'

Science as Debate

Is science presented as unquestioned answers to unanswered questions (AAAS, 1993)? Do natural history museum Web sites expect their virtual visitors simply to collect knowledge or are they encouraged to engage in dialogue leading to understanding? To use a sporting analogy, does the site provide a season ticket or facilitate a free transfer (Hawkey, 2002b)?

Developing visitors' understanding, however simply, of the kinds of questions that scientists ask about evidence – and the ways in which they interpret it – should be a key aim of science communication. However, despite some clear statements of policy, the links between data collection and accepted scientific 'knowledge' are often tenuous. Presenting scientific ideas as the best model so far developed introduces scope for further questioning and reinterpretation of evidence. Although many sites explore the scientific research process, there is little evidence of the dynamic interplay between conflicting or competing ideas. Natural history museums as a sector have yet to acquire the confidence to expose the less committed visitor to the issues. The days when barely tolerated, ignorant visitors were expected to be grateful for whatever expert knowledge a curator was prepared to share are, somewhat paradoxically, still with us, at least on some sites. The more committed can, however, find excellent resources, often in the form of on-line essays. With its explicit emphasis on the acquisition of evidence and its subsequent, controversial interpretation, what could be more enthralling than 'Martian Meteorites, and the search for life on Mars' (Grady, 1999)?

There are other examples worthy of mention here. The AMNH Web site (www.amnh.org) includes many narratives about expeditions, but how telling is the admission that those to central Asia in the 1920s, which became crucial to the understanding of dinosaurs (Novacek, 1996), were actually intended to seek out the origins of humans? The new natural history museum of the Netherlands (Naturalis, 2001c) includes interesting material, too, that reflects upon the need to re-visit specimens collected 150 years ago, as species are not those attributed at the time. Owen's original description of *Iguanadon*'s thumb spike as a horn is well known, as is the discovery that *Oviraptor*'s name was inappropriately accusatory (NHM, 1997) – but at least the Web sites are not sufficiently arrogant to suggest that misinterpretation was a feature only of the naïve scientists of the past!

Science as Model Making

Clarifying the status of scientific ideas as theories or models – rather than as incontrovertible fact or the revelation of truth – can lead to a different view of scientific understanding. However, as Durant (1992) has observed of science museums in general, much of the material that is easily accessible on natural history museum Web sites (ie relatively few clicks from the home page) rather gives the impression that science is 'the sure and solid mastery of nature'. It is not that there are no reflective and discursive approaches, but that they tend to be rather deeper in the site.

Despite some attempts to indicate 'how we know' or 'what we do not yet understand', the majority of natural history museum Web sites do present science as a fixed body of knowledge. This is, in essence, little different from the perspective of their Nineteenth cCntury counterparts – the transmission of the curators' expert knowledge to an ignorant public. The challenge for museums is to present the dynamism and fluidity of science as well as an authoritative view of current understanding (Hawkey, 2001a). For those prepared to delve deeply, there are alternative insights. In many ways parallel to the discussion of life on Mars – and even more difficult to find – is Stringer's (1999) essay, entitled 'Were the Neanderthals Our Ancestors?' Although also concerned with evidence, this provides lively access to the nature and status of scientific ideas.

Other insights that could, given an appropriate treatment, really raise visitors' awareness of the changing status of scientific thinking are to be found on a number of sites – but often buried without further interpretation in the 'science for scientists' pages. For example, the Copenhagen Zoological Museum (2001) reports its Biosystematics Centre as having discovered and described two new animal phyla, re-evaluated hypotheses about gradients of species richness and produced a phylogenetic analysis of a new mammal species. All new ideas, overturning the old order.

Science and Society

Non-scientists – and, especially, the media – frequently express surprise when scientists disagree. And yet, whether or not one takes a Kuhnian view of paradigm shifts, argument, discussion and debate are essential components of the scientific process. Given the inherently interactive nature of the Web as a medium of communication, it is perhaps surprising that there are few examples of facilitating dialogue on museum Web sites, and certainly very few that empower visitors to formulate and contribute their own opinions. However, this is an increasing practice in the science centre sector – although not necessarily on their Web sites – and this may be expected eventually to have an impact.

There are rare examples of Web resources that allow visitors to share findings and ideas. One such is *QUEST*, significant among whose features is an on-line notebook. This provides access to this aspect of science – discussion and debate – that is all too often absent from conventional science resources, and certainly is rarely included as a significant component of formal education (Hawkey, 2000). Certainly, if the museums of the 21st Century are to be places for exploration and learning through discovery where – rather than provide all the answers – exhibits should be interactive and stimulate the visitor to ask questions (Abungu, 1999), then how much more should this be true of museum Web sites.

Systematically Speaking: The Science of Systematics

Science has a limited number of classical and iconic representations, paramount among which are the Bunsen burner and the test-tube, while people's awareness of science is often limited to the kind of practical, experimental work undertaken in laboratories. Although many apparently traditional laboratories may indeed be found in natural history museums, undertaking work of this type (especially in microbiology and in earth sciences), there are many other important aspects of science for which such a popular caricature is quite inappropriate. Principal among these is systematics, a major concern – indeed, the *raison d'être* – of most natural history museums: "In the progress of naming organisms and studying their relationships, systematists collect many specimens. Therefore, natural history museum collections as we know them came into being along with the science of systematics." (California Academy of Sciences, 2000).Fig. 5: An invitation to the Pritzker laboratory

An excellent example of a contemporary natural history museum laboratory is provided by the Pritzker laboratory at Chicago's Field Museum, a 'core facility dedicated to genetic analysis and preservation of the world's biodiversity' (Field Museum, 2000a). The Field Museum's Pritzker Laboratory is a non-departmental multi-user core facility dedicated to genetic analysis and preservation of the world's biodiversity. It is shared by Field Museum curators, staff members and associated outside collaborators who constitute together one of the most diverse groups of evolutionary biologists and systematists in the world. The lab provides researchers with state-of-the-art equipment in molecular biology, enabling them to pursue the study of genetic diversity throughout the tree of life and at all taxonomic levels, from relationships among populations to classes and phyla of organisms.

Systematics is the science involved in the discovery, description, naming and classification of living and fossil organisms and the elucidation of their evolutionary relationships. It therefore encompasses taxonomy, the naming and classification of fossil and living species, although the two terms are often used as if they were synonyms (UK Systematics Forum, 1998). Although it constitutes a fundamental area of study in all natural history museum research, relatively few Web sites make it explicit – and even fewer explain systematics in detail or underline its significance. Those that do, however, give valuable insights into the nature of the scientific study of the natural world. As has been mentioned earlier, The Natural History Museum's Web site identifies 'systematics and evolution' as one of its key research themes.

Taxonomy	Systematics
Taxonomy is the process of: scientific description and naming of living and fossil organisms; placing them within a system of classification; and developing systems for identification. Taxonomy provides a coherent and universal system of names and is an essential foundation in any study of the natural world, particularly in the study of biological diversity and ecology.	Systematics is a broader area of scientific study. For the Museum, systematics covers the naming and investigation of the characteristics and relationships of both minerals and organisms. Systematics includes the taxonomic study of living and fossil organisms, but goes further, investigating evolution, genetics and the development of species. Systematics therefore depends both on the study of museum collections and on the investigation of variation within and between populations of organisms in the field.

Table 7: Definitions of taxonomy and systematics (UK Systematics Forum, 1998)

A further component of Chicago's Field Museum of Natural History – 'Partnerships for Enhancing Expertise in Taxonomy' – features not only the nature and value of the scientific work, but also the impending shortage of suitably skilled scientists (Field Museum, 2000b):

> The accelerating loss of biological diversity in the world, through habitat destruction, pollution, and ecosystem fragmentation, has been accompanied by a loss of taxonomic experts who are trained to discover, identify, describe, and classify the world's organismal diversity. Retirement of taxonomic specialists, shifts in academic recruitment and staffing, and reductions in graduate training have conjoined to impede biodiversity research and conservation, particularly on large but poorly known groups such as bacteria, fungi, protists, and numerous marine and terrestrial invertebrates. Vast numbers of species in understudied "invisible" groups constitute critical elements of food chains and ecosystems, both aquatic and terrestrial, but the high proportion of unrecognized species in these groups limits research and progress in many areas of biology and conservation.

This impending difficulty was also highlighted by an earlier UK parliamentary study (House of Lords, 1992) that bemoaned the absence of systematics from formal education courses. Recent discussions (QCA, 2002) have indicated that this omission is being addressed, although it will be several years before any changes can take effect.

Summary

Despite a number of exceptions such as those exemplified in this paper, the majority of natural history museum Web sites have yet to realize the opportunity to bring their approaches to science and science communication into the modern age. All too often science is presented only as 'revealed truth' and communication as a one-directional transmission. The potential of the Internet for museums to truly share their passion for science, especially the less fashionable areas such as systematics, is clear. That such an opportunity coincides with changes in views about the public understanding of science and about the role of museums (both already evident) makes it an opportunity not be missed. Natural history museum Web sites already provide an extensive resource, but many have some way to go before they are likely to go beyond informing the previously informed or enthusing the already enthusiastic. Most of all, they need to put less emphasis on their own internal organization and rather more on exploring the fundamental principles of science.

References

Abungu, G. (1999). Message from the Director-General. Nairobi: National Museums of Kenya, http://www.museums.or.ke/dg.html, visited 13 February 2002.

American Association for the Advancement of Science (1993). *Benchmarks for Scientific Literacy*, New York: Oxford University Press.

AMNH (American Museum of Natural History (2000). http://www.amnh.org/science, visited 13 February 2002.

Australian Museum (2002). www.amonline.net.au/research/index.cfm Updated January 2002, visited 13 February 2002.

Arnold, K. (1996). Presenting Science as Product or Process: Museums and the Making of Science. In Pearce, S. (Ed.), *Exploring Science in Museums*. London: Athlone Press, 57-78.

California Academy of Sciences (2000). Systematics - The Science & the Collections, http://www.calacademy.org/research/systematics.html Updated January 2002, visited 13 February 2002.

Copenhagen Zoological Museum (2001). Copenhagen Biosystematics Centre. http://www.zmuc.dk/commonweb/cobice.htm visited 13 February 2002.

Durant, J. (1992). Introduction. In Durant, J. (Ed.), *Museums and the public understanding of science*. London: Science Museum

Farmelo, G. (1992). Drama on the galleries. In Durant, J. (Ed.), *Museums and the public understanding of science*. London: Science Museum

Field Museum (2000a). Pritzker laboratory for Molecular Systematics and Evolution, http://www.fieldmuseum.org/research_collections/pritzker_lab/pritzker/index.html Updated December 2001, visited 13 February 2002.

Field Museum (2000b). Partnerships for Enhancing Expertise in Taxonomy, http://www.fieldmuseum.org/research_collections/zoology/zoo_sites/peet Updated 2000, visited 13 February 2002.

Grady, M. (1999). Martian Meteorites, and the search for life on Mars, http://www.nhm.ac.uk/mineralogy/grady/mars.htm, visited 13 February 2002.

Hawkey, R. (1998). Exploring and investigating on the Internet: virtually as good as the real thing? *Journal of Education in Museums*, 19, 16-19.

Hawkey, R. (1999). Learning from objects on-line: virtue and reality. *British Journal of Educational Technology*, 30 (1), 73-77.

Hawkey, R. (2000). Real Education from Virtual Objects: Active Learning in Science On-line. In Robson, R. (Ed.), *Proceedings of M/SET 2000, International Conference on Mathematics/Science Education & Technology*, Charlotte, VA: Association for the Advancement of Computing in Education, 202-206.

Hawkey, R. (2001a). Innovation, inspiration, interpretation: museums, science and learning. *Ways of Knowing Journal*, 1(1), 23-31.

Hawkey, R. (2001b). Science in nature and the nature of science: natural history museums on-line, *Electronic Journal of Science Education* [on-line], http://unr.edu/homepage/crowther/ejse/ejsev5n4.html, visited 13 February 2002.

Hawkey, R. (2002a). Walking with woodlice: biodiversity on-line and in the field. In Andersen, J. & Watson, D. (Eds.), *World Conference on Computers in Education VII: Networking the Learner*. Boston, MA: Kluwer Academic Publishers (in press)

Hawkey, R. (2002b). The lifelong learning game: season ticket or free transfer? *Computers and Education*, 38 (1/3), 5-20 (in press).

House of Lords (1992). *Systematic Biology Research* (First Report of the Select Committee on Science and Technology). London: HMSO

House of Lords (2000). *Science and Society* (Third Report of the Select Committee on Science and Technology). London: The Stationery Office

King, H. (1996). *The nature of science*, unpublished MSc dissertation. London: Imperial College

MNH (National Museum of Natural History) (2000). http://www.mnh.si.edu/re/index_vision.html Updated 2000, visited 13 February 2002.

Naturalis (2001a). Collections. http://www.naturalis.nl/english/collectie.html, visited 13 February 2002.

Naturalis (2001b). Eco-evolutionary biodiversity evaluation. http://www.naturalis.nl/english/biodivers.html, visited 13 February 2002.

Naturalis (2001c). Collection research. http://www.naturalis.nl/english/documentatie.html, visited 13 February 2002.

NHM (The Natural History Museum) (1996) Museum mission statement. http://www.nhm.ac.uk/info/index , visited 13 February 2002.

NHM (1997). *Dinosaurs of the Gobi desert*. http://www.nhm.ac.uk/museum/tempexhib/gobi/gobi2.html, visited 13 February 2002.

NHM (1998). *QUEST*. http://www.nhm.ac.uk/education/quest2/english/index.html , visited 13 February 2002.

NHM (2000). Science research themes, http://www.nhm.ac.uk/science/themes , visited 13 February 2002.

NHM (2001a). *Natural Progression*, London: The Natural History Museum.

NHM (2001b) Walking with woodlice. http://www.nhm.ac.uk/woodlice Updated November 2001, visited 13 February 2002.

Novacek, M. (1996). *Dinosaurs of the flaming cliffs*. New York: Anchor Books.

QCA (Qualifications and Curriculum Authority) (1999). T*he National Curriculum*. London: HMSO

QCA (2002). Personal communication.

Stringer, C. (1999). Were the Neanderthals Our Ancestors? http://www.nhm.ac.uk/palaeontology/v&a/cbs/ancestors.html, visited 13 February 2002.

UK Systematics Forum (1998). *The web of life: a strategy for systematic biology in the United Kingdom*. London: UK Systematics Forum.

Wellcome Trust / Office of Science & Technology (2000). *Science and the Public: A Review of Science Communication and Public Attitudes to Science in Britain*. London: Wellcome Trust / Department of Trade & Industry.