

# Representations of Information Technology in Disciplinary Development: Disappearing Plants and Invisible Networks

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*This article describes developments in the use of information technology (IT) in the biological discipline of taxonomy, using both a historical overview and a detailed case study of a particular information systems project. Taxonomy has experienced problems with both its scientific legitimacy and its utility to other biologists. IT has been introduced into the discipline in response to these perceived problems. The information systems project described here served as a means of managing the tensions between scientific legitimacy and utility. It is argued that this project represents an example of the use of a technological development in an attempt to re-engineer a discipline. The development of the information system is analyzed as an attempt to develop a scientific instrument that will embody a particular model of the discipline. The concerns of taxonomy with status and legitimacy make it appropriate that this new technology should be introduced at the interface between the discipline and the rest of biology as a means of disseminating results, and thus come to represent the discipline and the plants described to outsiders, just as the system represents outsiders to taxonomists.*

## Introduction

The incorporation of information technology (IT) into the research practices of biological taxonomy or systematics brought about a complex set of adjustments and accommodations involving both the technology and the discipline itself. The new technology embodied a particular model of the discipline, and the representations of the technology and its capabilities were crucial in implementing changes in the discipline and persuading interested

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parties to accept the new model. It appears that organizing changes around a technological development is a particularly powerful means of bringing about change.

Recent studies in the sociology of technology have questioned the idea that technologies have effects and argue that the character and the capabilities of a technology are open to a process of social construction. The effects of the technology are then also a matter for negotiation (Mackenzie and Wajcman 1985; Bijker, Hughes, and Pinch 1987). Similarly, works in the sociology of scientific knowledge have brought out the process of social construction and negotiation involved in the "discovery" of a scientific fact (for example, Knorr-Cetina and Mulkay 1983; Lynch 1985; Latour and Woolgar 1986). These two lines of thought form the basis for the analysis of the role played by IT in taxonomy.

The instruments used in scientific research can be seen as embodying prior social selections and scientific theories (Latour and Woolgar 1986; Knorr-Cetina 1981; Schaffer 1989). Traweek (1988) suggests that the detectors used by high-energy physicists embody their models of the means to achieve good physics. IT can also be seen as a scientific instrument—one used specifically for the dissemination of scientific results—and I will argue here that the attempts to have IT accepted as an unproblematical reflection of taxonomic facts also involve attempts to promote a particular model of the discipline.

The first part of this article discusses some recent debates in taxonomy and the role of IT in these debates. Taxonomy is an old and established discipline, but recently it has been beset by controversies over its legitimacy in terms of both scientific credibility (Vernon 1993) and utility to the rest of biology. In each case of controversy, IT was enlisted in support of the particular cause of the moment, and in each instance the technology and the discipline itself took on a new character. The tensions between utility and science in taxonomy will be examined here in order to provide a framework for an analysis of IT as a technology that shapes the discipline rather than acting as its neutral servant.

The second part of the article contains a more detailed study of the International Legume Database and Information System (ILDIS), which was designed to solve some of the perceived problems of taxonomy. The aim of the project was to produce an information system that would allow taxonomists to continue to work in the traditional way, while also enhancing the utility of the products of taxonomy to its users. As a result of the social, political, organizational, and more traditionally scientific work that went into this project, the information system came to represent both the plants being described and the taxonomists doing the work—the disappearing plants and the invisible network. The ILDIS system became not only nature's spokes-

man (Stemerding 1993), but also the taxonomists' spokesman. In the process of development, the information system, rather than other biologists, comes to stand as the user of taxonomic information for the taxonomists concerned. As an example of a technology that taxonomists used to resolve the tensions in their discipline, ILDIS demonstrates that the incorporation of a new technology into a scientific discipline may involve changes both in the discipline and in the technology.

### IT in Taxonomy

As the part of biology concerned with the classification of living organisms, formal biological taxonomy (or more precisely, the nomenclatural part of it) dates back to the eighteenth century, when Linnaeus published the first comprehensive taxonomic systems for plants and animals using binomial nomenclature. However, here we are concerned with a much more recent period.

In 1940, a number of leading taxonomists announced a new dawn in taxonomy in a symposium volume entitled *The New Systematics* (Huxley 1940).<sup>1</sup> The articles in the volume claimed to complete the integration of taxonomic practices with evolutionary thinking and advocated the use of new characteristics for the discrimination of species: taxonomy was to be made experimental and scientific.

Despite the optimism expressed in 1940, the scientific status of taxonomy was by no means established, and a new debate about proper methods for grouping living organisms took place in the 1960s and 1970s. Two theoretical positions were propounded: one grouping organisms on certain mathematically calculated criteria of similarity (phenetics), and the other basing its classifications on the elucidation of evolutionary pathways by a method named cladistics. The proponents of each of these methods claimed objectivity for their own approach and were united only in attacking the "craft" practices of traditional taxonomy.

The proponents of phenetics claimed that it was based on a number of principles, one of which was: "Taxonomy is viewed and practised as an empirical science" (Sneath and Sokal 1973, 5). Pheneticists attempted to define algorithms for producing classifications based on the characters of relevant organisms, which were grouped on the basis of overall similarity. The use of computerized methods of analysis was said to be indispensable for the complicated and unwieldy calculations involved in the use of these algorithms. The phenetic method was claimed to be rational and objective because of its reliance on computerized methods and because taxonomic

decisions could finally be made explicit rather than relying on the previous inexplicable and subjective decisions of the individual taxonomist<sup>2</sup>

The proponents of cladistics also claimed to provide objective means both for producing classifications and for their subsequent testing against evolutionary theories, thus achieving the double feat of an objective taxonomy and a potential falsifier for evolutionary theory. The method also revolved around the characters of organisms, but it defined groups on the basis of recency of common ancestry. IT was not involved when the theory was originally formulated,<sup>3</sup> but it was incorporated to such an extent that "doing cladistics" today appears almost synonymous with choosing a program to do cladistics, and a conference on evolutionary biology includes as a matter of course a session in which scientists demonstrate and attempt to sell their computer packages (Benton 1990).

Much of the phenetics/cladistics debate was conducted in the pages of *Nature*. The mood of these exchanges can be summarized here by a few examples. A book on numerical taxonomy, written by two of the proponents of phenetics, was reviewed by another pheneticist, Sokal (1972), under the title, "Taxonomy Rationalized." On the opposing side, in the course of particularly fervent public argument, the cladists Fink and Wiley (1979) refer to their results as "hypotheses about relative recency of common ancestry among the taxa concerned" and make the statement that "It is not the cladist who 'makes' a lungfish more closely related to a cow than to a salmon. . . . Evolutionary history as exemplified by a genealogical descent with modification (a Darwinian concept) 'makes' it so."<sup>4</sup> An earlier letter in *Nature* (Panchen, 1979) accuses cladists of paying "lip service to the hypothetico-deductive method" and appeals to traditional scientific methodology as an arbiter. In both cases, the claim is that taxonomy does not constitute the phenomenon but discovers and displays an underlying objective reality: a reality not available to the proponents of the opposing method.

The course of the cladistics versus phenetics controversy has been documented by Hull (1988), who applies an evolutionary model to the development of taxonomy. At present, it appears that the cladists have won, at least in terms of the numbers of taxonomists adopting and using their methods. Although taxonomists concede that numerical methods may be a useful tool in some cases, they acknowledge the primacy of evolutionary descent as a basis for taxonomy. For the purposes of this article, the debate's interest lies in its emphasis on a rhetoric of scientific legitimacy and on the invocation of IT as raising taxonomy from the status of a craft to that of a science.

The emphasis on the scientific status of taxonomy was also apparent in initiatives that aimed to reduce the routine drudgery of identification and

cataloguing and to free taxonomists for the more serious work of their science. Speaking of the museum staff who make up the majority of the country's taxonomists, Graham complained that: "[S]taff . . . are so occupied with the demands of a world collection and routine identification, that little time remains for research on the fundamental British and other European material. . . . Taxonomy has too long been the Cinderella of the sciences. We owe a duty to our illustrious pioneers to see that this does not continue" (1972, 475)

Whole symposia, such as the Systematics Association symposium in 1973, have been devoted to discussions of how the automation of routine tasks could be achieved (Pankhurst 1975). Papers here described algorithms for identifying specimens and the production of generalized databanks that, with the help of a suite of programs, could carry out all the tasks of writing a Flora: preparing the keys and then identifying specimens so that the taxonomist would be involved in the production of the data but not necessarily in its dissemination. These proposals were contrasted with the use of computers in phenetics: "The criticisms of the early computer-derived classifications may have been justified and even if some scepticism still occurs in phenetics the advantages of automatic identification, key construction, and mapping cannot be denied" (Wilkinson 1975, 295). The same author also attempts to answer the question of why taxonomists need computers at all:

Firstly, many taxonomists are primarily interested in the fundamental research of their groups and therefore too much routine identification becomes a burden. . . . If accurate computerised keys and identification programs can be produced, computer operators with some knowledge of the biology and nomenclature of the group can be trained to carry out this work, so leaving the expert to his research. (p. 295)

Computer identification systems are also said to limit the amount of time necessary for identifying specimens, and to have a training function.

Underlying these comments is an assumption that taxonomy is difficult, that it is only for experts, and that these experts must be relieved of the onerous task of serving the public and other biologists. A similar line of thought was pursued at the 1984 Systematics Association symposium entitled "Databases in Systematics" (Allkin and Bisby, 1984). A number of contributors to this symposium advocated the use of databases for cataloguing and curating botanic gardens and herbaria. In the concluding article, Lucas referred to three major advances in taxonomy since the Systematics Association symposium in 1973 (Pankhurst, 1975). These were the coming of a new pragmatism in the discipline, the availability of computers for all, and user friendliness, which makes taxonomy available to a wider range of biologists.

Availability is important, because "What is the point of carrying out research if it cannot be made available quickly and cheaply" (Lucas 1984, 323).

In the late 1980s and early 1990s the debate shifted from objectivity and automation to utility. Instead of enhancing the scientific status of taxonomy, the methodological debates of the previous years were now said to have damaged taxonomy in the eyes of other biologists: in an article entitled "Taxonomy blooded by cladistics wars," Gee asserts

The emergence in the 1980s of cladistics, in principle an objective method of building phylogenies from structural similarity between forms, provoked arguments between the newcomers and the traditionalists unusual for their savagery. The result was to corrode the climate in a small community of researchers and to invite outsiders to regard these unseemly wrangles as signs of a subject in terminal crisis. (1988, 585)

However, Gee goes on to promote the success of cladistics: "serious taxonomy based on the old subjective ways is now almost unthinkable" (p. 585).

Although the heat of the cladistics versus phenetics versus traditionalists debate has apparently died down, at least as far as the interest of the popular biological press is concerned, and the use of cladistic methods is now widespread, a tacit redefinition has taken place. The taxonomic activities that can be automated, operationalized, and rationalized are no longer important: despite the widespread use of computer programs for cladistic analysis in taxonomy, classification remains a task for experts. In the aftermath of the phenetics/cladistics debate the emphasis on objectivity has also died down. Many taxonomists accept that whatever method is used for forming groups, the rank of those groups cannot be determined objectively, and that although the species has a special status as a "real" grouping with some biological meaning, the same cannot be said of the higher groupings such as genus and family.

The issue of responsibility for actions has gained new prominence in taxonomic discourse. Rather than focusing on how to be more scientific, the debate has moved to whether compromise is necessary in order to provide a better service. A whole new category of people has been created: the users. There is no consensus on who these users are, where they can be found, and what their needs are, but the need to consider these questions is generally acknowledged.

A number of letters to *Nature* in the late 1980s and early 1990s complained about the difficulties experienced in keeping track of the name changes of organisms. One exchange was triggered by a letter from Crisp and Fogg (1988), attacking the inconvenience to "ordinary biologists" of having to keep track of classificatory name changes caused by "mere changes of

opinion." In the replies, it appears that "science" has become an excuse for practical difficulties rather than an ideal to be attained. At about the same time as these letters, came a flurry of complaints from taxonomists that their grant proposals were no longer being funded (the research councils were said no longer to consider taxonomy scientific).

Suggested "fixes" to ensure the survival of taxonomy and a new respect for its practices focused in the first instance on tinkering with the nomenclatural codes. These codes lay out the principles of naming organisms and provide rules for determining the valid name by which a given grouping should be known within a given classificatory system. It was suggested that the classificatory information should somehow be decoupled from nomenclature, so that taxonomists could continue working as they had been without upsetting "ordinary biologists."

It appeared later that merely altering the nomenclatural codes was not enough. Models of the way in which taxonomic information was disseminated—as a "shop-counter" and as "diffusion"—were used as the rationale for a whole new class of user-oriented taxonomic information systems (Bisby 1984). Early in 1991 a symposium was held to address the problem of instability of names (Hawksworth 1991). The views of the proponents of change were hotly disputed by those who clung to their scientific autonomy. Titles of their contributions are telling: "Responsibility and Irresponsibility in Times of Nomenclatural Change" and "What Must Be Done to Save Systematics." An entire session was devoted to "User Needs for Stability in Names." Bisby and Hawksworth's closing paper contained the following statement:

We believe systematics can be saved from its present crisis by the development of user-oriented information products. The modern world values information services highly and is willing to pay for them. Taxonomy is a biological information system from which valuable products and services could be produced to meet the demands from the much expanded interest in all aspects of species diversity. (1991, 332)

The authors implied that by charging for their services taxonomists might achieve recognition for their work.

The arguments about user needs focused on how these needs should be met and not on whether they should be met, just as in the cladistics/phenetics debate the emphasis was on how taxonomy should be made scientific, not on whether it should be made scientific. Again, the rhetoric of meeting and continuing to meet external needs is prominent.

The representations of both taxonomy as a discipline and of the IT used in that discipline may be seen to be flexible and interrelated. Changes to the

"moral order of representation" (Woolgar 1991, 65)—the interpretations of what constitutes adequate taxonomy—are mediated through these debates and through the introduction of IT into the field as "the sense of context and machine mutually elaborate each other" (Woolgar 1991, 68). The legitimacy of taxonomy as a field of inquiry is promoted both by claims to scientific status and by emphasis on service. In the debates conducted in public arenas, the representations of IT and of the discipline varied in tandem.

### **The ILDIS Projects**

The discussion of debates in taxonomy demonstrates the inter-constitutive nature of the discipline and the technology that it employs. It also provides the background for a detailed case study of the development of an information system whose creators emphasized the efficient dissemination of taxonomic information to users.

The development of the information system described here was the initiative of a group of scientists concerned with the study of the Leguminosae: a family of plants of great economic importance containing many crop plants and encompassing almost one-twelfth of the world's flora. The scientists involved have included representatives of the major international botanical institutions, universities, and research groups prominent in the study of various aspects and sub-groupings of the plants covered by the project. The plan has been to produce an information system that will record information about these plants and allow its dissemination to a wider audience of applied biologists. At present most of the biologists involved in creating the system are taxonomists: the information system is visualized as a taxonomic "backbone" containing a consensus classification to which other types of information may be attached and cross-indexed. Much of the work of the project to date has concerned the construction of the taxonomic core, although work has also progressed on at least two of the "modules" of other information to be supplied by non-taxonomists.

The progress of the project has involved many reconceptualizations and retellings of its purpose and origins, and it is not my intention either to present an "authoritative" account, or to gloss over the inconsistencies and variations in the accounts available. However, these variations are not the subject of this particular study, as they were for Woolgar (1976) and Gilbert and Mulkey (1984), who have highlighted the analytic importance of conflicting accounts by scientists of their activities. The accounts are particularly likely to vary in this case because the participants have been involved in explicitly "selling"

their project to funding agencies, to potential participants and customers, and to the public at large. In addition, the idea of the project has changed, together with changing circumstances and the availability of participants and funding. The account rendered here is therefore merely a distillation of some aspects of the project from a limited perspective. This account is based on documents relating to the project, both published articles and internal correspondence and literature, discussions with participants, and attendance at one of the international workshops for participants, held at the Coordinating Centre.

ILDIS is frequently portrayed as an outgrowth of an earlier project that covered only a sub-section of the plants included in the main system. This pilot project was an experimental exercise intended to display the possibilities of storing and retrieving botanical information in electronic format. The publicity literature for the current system places it within the "meeting user needs" paradigm of taxonomic debate:

The long term aims of the ILDIS project are to provide:

1. a source of information for the development of all useful legume crops and legume products, especially in the arid zones and humid tropics;
2. a focus for the study and conservation of legumes. (ILDIS Publicity leaflet 1992)<sup>6</sup>

However, accounts of the Inaugural Workshop for the ILDIS project suggest that taxonomists greeted such user orientation with a degree of skepticism:

Most of the questions revolved around the fundamental decision in 3 (information service v. taxonomic/nomenclatural database), and this was continued into the discussions of the Data Content Group on the next morning. The recommendation 8d in the minutes of that meeting, which allowed for a parallel nomenclatural/taxonomic datafile, assuaged some anxiety about the loss of taxonomic information and critical procedures. (ILDIS Report on the Inaugural Workshop held at the Coordinating Centre, 23-25 September 1985)

How then was the consensus about the system to be achieved? It is impossible to attribute success or failure to the participants: only time will tell whether the claims made for the project will be accepted. At the time of writing, the project has been running for approximately seven years. It has attracted a wide range of participants from many countries, and an infrastructure has been established. Yet, the information system is still under development, and the hopes for a wide range of users have not yet been fulfilled. Because we are interested in an information system "in the making," it is fitting that no neat end to the story is available. It remains to be seen whether success or failure will eventually be attributed to the efforts of this group of biologists.

*Centralization and Control*

The ILDIS project is an international, collaborative organization. The project differs in a number of respects from the usual manner of organizing scientific research. The participants involved in the ILDIS project have formed an Executive, a Board of Trustees that is the official owner of the database, and a variety of committees for particular purposes. They registered the project as a charity in the United Kingdom to provide it with a legal status. They have made formal agreements with a number of universities and institutions on the form of their collaboration and the ownership of any data involved. A joint publishing agreement has been entered into with commercial publishers. The project has been funded through subsidies from the institutions concerned, by grants from research councils and charitable institutions, and by the collaborative publishing arrangement. It is hoped that in the future the project will be funded at least in part by royalties from two major publications and from the provision of electronic data sets. The product is conceived not as a database but as a classificatory system. The production of a consensus on a worldwide classification system for the relevant group of plants is portrayed as the main feature of the project, and the provision of this data in electronic format is presented as an added bonus. The ambition to develop a consensus on a classification of this scale is unprecedented. The available classifications for any group of organisms generally cover only part of the world or a small group of organisms, and conflicts between the available systems of nomenclature are usually difficult to resolve. Taxonomy, just as any other science, has no specific rules for arriving at a consensus. The project is therefore innovative in organization and in intent. Only with the adoption of IT has this impetus to form a consensus classification been realized.

The legitimacy of the ILDIS project to speak for specialists in this family of plants to the world depended on persuading the participants, recognized experts, to lend their names and affiliations to ILDIS. Similarly, the user organizations, publishers, and scientific institutions were persuaded to lend their credentials to the project. The user organizations are particularly important because they give credibility to the claim that user needs have really been considered. Yet, the needs of ILDIS in this respect must coincide with the needs of their participants and collaborators, who must be persuaded that it is vital to be involved in such an innovative project. Specialists who ignore the project would risk being omitted from a consensus, a potentially disastrous isolating experience for a scientist. Such concerns may offset the reluctance of taxonomists to participate in a project designed specifically to benefit non-taxonomists. The argument that taxonomists must participate in

such projects to improve the image of their profession and to secure future funding is invoked here, just as it was in the wider debates on the survival of the discipline. For botanists in far-flung reaches of the world, the project may provide an opportunity to travel and exchange ideas. The report of the Inaugural Workshop also reiterates the belief that IT in taxonomy will relieve the drudgery and liberate scientists, listing this as another reason for participation:

Like many contributors his interest came more as that of a life-long legume-addict than directly because of interest or specialisation in electronic data-processing. As legume experts, routine factual enquiries on the taxonomy and biology of legumes land on our desks every day. But to answer them requires laborious skill and library work, often using monographs that are cumbersome to use and difficult to obtain. To apply information technology here is a must. (ILDIS Report on the Inaugural Workshop Held at the Coordinating Centre, 23-25 September 1985)

Another contributor cites the persuasiveness and personal enthusiasm of the main organizer of the project as the reason for his participation. This main organizer has been a prominent figure in the recent disciplinary debates about the need to develop information services in taxonomy.

The question of credit for contributors is frequently and explicitly discussed in the ILDIS documentation. The booklet containing a detailed description of the basic data fields, for example, states

Geographical checklist compilers and ILDIS taxonomic coordinators will be credited for their work on producing the database within the database itself. Anyone using the database will see who has been involved in the collation of the Type One information. Credits to both the geographical checklist compilers and the taxonomic coordinators will appear on the screen before access to the database is allowed every time the database is started using the ALICE software. (ILDIS booklet, *Type One Data Fields: Detailed Specification* [Version 10, June 1990])

It is, however, possible to ignore these credits in certain circumstances. During a demonstration of the latest version of the software given to participants at the Third Workshop, a member of the Executive said, on entering the software for the second time, "Skip the credits." It appears that the credits are largely intended for the external community of users.

The participants need not be actually present at all. Once they have contributed their data, and their credentials have been added to the list, the taxonomists are free to continue their research in the knowledge that their results are being disseminated by ILDIS. The appearance of participation is maintained by the impressive lists of institutions and scientists in the publicity material, each pledging credentials in support of the project. The impression

is strengthened at the Coordinating Centre, its filing cabinets bulging with letters and faxes. A visitor to the center is confronted by three rooms, a staff of four, and an invisible network. This situation changes during ILDIS Workshops, three of which have been held during the seven-year life span of the project. On these occasions, participants who could obtain the funding and had the time to come to the Coordinating Centre to discuss progress and make plans for the future. The effect on the Coordinating Centre was like the sudden flowering of the desert after rain. Quiet routine and a small core of dedicated personnel gave way to throngs of people discussing and debating the project. Yet, in formal sessions on the first day of the Third Workshop, the visitors hardly spoke. The Executive reported, asked for comments, indeed exhorted opinion, yet little response was forthcoming. Only as the workshop progressed to its third and final day did the guests begin to express their opinions. Even when the Coordinating Centre encourages debate, its authority is hard to resist. This small core of personnel seems to own the project, although formally it is owned by its Board of Trustees. The trustees remain largely silent in comparison with the Executive, and particularly the main organizer.

The data contributed by the participants are, of course, vital for the project; however, these contributions are prepared over long periods of time in relative isolation from the Centre. Contributors communicate frequently with the Centre only when they are using the software provided for data entry. This communication consists largely of requests for guidance on use of the software. By contrast, the three members of the Executive consult frequently on matters of policy and practice. The Board of Trustees meets less frequently, providing overall guidance and passing resolutions on the future shape of the project. The continued support of the data contributors is vital, and their views must thus be taken into account in the strategies adopted by the project, but the policy of central control—on a day-to-day basis by the Executive and on longer-term matters by the Board of Trustees—is enshrined in the constitution of the project as laid out in its Trust Deed. Data contributors stand for election as trustees and vote in an institutional capacity on the composition of the board. Contributors may also participate in committees formed to consider particular aspects of policy; these include a Data Content Committee, a Software and Computing Advisory body, and a User Services group.

The choice of scientists approached as taxonomic coordinators was explained in a grant proposal: "Where several experts are known, care has been taken either to contact one of known moderation of views, or, where several experts have regional knowledge of widespread taxa, the experts are being asked to collaborate" (ILDIS grant proposal case for support, G.C., S.Q., and K.A., 14 September 1990).

In addition to having control over the selection of coordinators, the Coordinating Centre also exercises direct control over the data content. The role of the Coordinating Centre in controlling and vetting inputs to the information system is made evident in a booklet explaining the geographical system for contributors of data: "The main table to consult when entering geographical information to an ILDIS database is Table One. It lists all the units at the country level which are used in the database (please do not add any new countries)" (ILDIS booklet, *Type One data: Geography* [Version 4, August 1990]).

Controlling the interpretations of taxonomic coordinators does present some problems:

I've put back Malawi, N. Yemen and Oman, which [K] deleted. In the last two cases there are specimens in the Kew herbarium—[K] should never have removed these records. Does indicate we shall need to run datasets against each other to see what the coordinators have been up to and it will take a lot of effort and skill to stop this son of thing. (ILDIS fax from S.Q. to G.C., 10 October 1991)

Through control of this kind, the computer is made to speak in a coherent way of the distribution of plants. Similar kinds of control over other aspects of the system provide a new language for characterizing plants. An intelligible dialogue with the computer is only possible when this language is understood.

Because opinions and resources are channeled through a coordinating center, ILDIS allows taxonomists, some of whom may feel their differences to be irreconcilable, to speak with a united voice to the outside world. In portrayals of the project such as grant proposals, centralization is emphasized as a strength of the project. However at the Third Workshop, G.C., the main organizer, praised the efforts of single motivated individuals in mobilizing resources and held them largely responsible for the success of the project. The centralization of ILDIS presents a great contrast to traditional taxonomic research, in which classifications are often published by individuals and biologists requiring a set of names for organisms are left to decide which of the competing classifications to use. The invisible network of participants, advisers, and institutional alliances lends weight to the claims to authority of the ILDIS project.

The plants are involved in the project only as objects of representations to which they are subjected, only insofar as they conform to the characteristics attributed to them. They remain mute and unprotesting. What, after all, is nature: green, leafy, spiky, nitrogen fixing—or composed of bits and bytes, variations in voltage? The tyranny of the genus, the species, the all-too-neat pigeonhole has reigned over these plants for more than two centuries. Now

they are subjected to a new discipline imposed in the name of the relational database, the record, and the alphanumeric field. The plants have even disappeared from the logo in recent months, with the adoption of a donated abstract design. However, it seems that in the correspondence surrounding the decision to adopt this design, many were strongly in favor of retaining the old logo depicting the plants, emphasizing the role of the system in "standing for" plants.

As a researcher seated in the offices of the Coordinating Centre, leafing through the files of correspondence relating to the choice of logo, it suddenly occurred to me to look for plants. There are none. No decorative house plants on windowsills. No research material. Not even a poster. The furniture of the project consists of desks full of papers, filing cabinets, shelves of files and manuals; the hum-whir of the computing equipment is constant. I moved to the other office. Here, I found one solitary poster for a long past Botanical Congress, bearing the stylized image of a plant. It seemed dog-eared in contrast to the sharp new computers and office furniture. Somewhere, next door possibly, I gathered there is a "laboratory," peopled by "taxonomists." Possibly these were the people who moved through the office occasionally, to whom I was never introduced (after all, I was here to study the effects of IT). Possibly these people are the custodians of the plants. Certainly, the presence of the plant itself is not necessary for the functioning of the ILDIS project: the plant has been disenfranchised, and the project speaks for it.

### *Managing the Science/Utility Tension*

One aim of the ILDIS project was to provide a means of resolving tensions between scientific rigor and utility within taxonomy. This was to be achieved by constructing the information system as provider (to users) and user (to taxonomists) of taxonomic information. By cooperating in the construction of the system, taxonomists were to be induced to arrive at a consensus classification, which would then be available to those biologists who required a stable "best guess" as to the state of the natural world. The previous section discussed how the system came to stand for both plants and taxonomists. However, the development of the system required funding, and here it appeared that managing the tensions in taxonomy also extended to funding bodies and that it was difficult to convince research councils that the project was sufficiently scientific to receive funding.

A number of applications have been made to funding agencies, such as national research councils and the EC, and to charities with either general or specifically botanical remits. Rip (1986) demonstrated how much work scientists have to invest in creating obligatory passage points between the

aims of a funding agency and their own research plans. The funding applications submitted by the ILDIS project are no exception. Where the proposal concerned a charity with general rather than botanical aims, the goals of ILDIS were presented in a global economic setting:

This is one of the most important groups of plants for man and the environment. For example, dry pulses are traded at  $2 \times 10^9$  US\$ p.a. Legumes provide a range of food, fodder and drugs of particular significance in some of the poorest communities and they generate most of the world's biologically fixed nitrogen (about  $1.75 \times 10^8$  tons p.a.) as members of both temperate and tropical ecosystems. (ILDIS Grant Proposal Project Summary, February 1992)

In this application for funding the central coordination of the project, the qualities of the plants themselves were enlisted in the support of the project: if the plants with which ILDIS is concerned are of such vital importance, then surely ILDIS must be also. An unsuccessful application for a similar purpose was submitted to a scientific research council and led to a series of exchanges about the scientific status of the proposed work. The original proposal, 'Experiments with Coordination and Consensus-Seeking in the Taxonomy of the Leguminosae,' was rejected on the following grounds:

The opinion of the Subcommittee is that the application proposed an exercise in information collation and did not contain the essential elements of scientific research required by the Subcommittee. The proposal did not involve any new experimentation or observations, but rather its approach was clerical, encouraging consensus decisions by increasing taxonomists' awareness of already available information. The Subcommittee is willing to support taxonomic research programmes but this application was considered to have the wrong approach. Further applications would be welcome if the aims are to break new ground in numerical approaches to taxonomy. Although inappropriate to [the Subcommittee], the value of the proposed work was recognised. (ILDIS letter to G.C., 9 January 1991)

The main organizer protested that the rejection of the proposal was due to an incomplete understanding of the issues: "My advisors have noted that the membership of the subcommittee may have an undue molecular bias making it possible that the issues were not fully appreciated" (ILDIS, letter from G.C. to head of funding agency, 9 September 1991). This protest resulted in permission to resubmit the proposal with additional supporting information. The extra information which was submitted argued explicitly for the scientific status of the proposed project:

It should be stressed that the "consensus" referred to is not a social event achieved say by voting, but a scientific event achieved by meticulous analysis of comparative data ensuring that all of the data available to each of them is incorporated in the synthesis. It is at this point that experts who have previously

disagreed see that some of the distinctions which they had previously sustained may no longer be valid against the background of the larger dataset. (ILDIS, letter from G.C. to funding agency, 15 November 1991)

The struggles for scientific legitimacy at the disciplinary level are re-enacted here in the specific context of the grant proposal.

The representations of the project vary widely, and in some ways systematically, because the organizers are involved in selling their project to potential users, to participants, and to funding agencies. The system is represented simultaneously as an essential survival mechanism for taxonomy, as a selfless act in the provision of useful information to other biologists, and as a scientific process. The role of the system in allowing taxonomists to serve their public and to maintain their traditional research activities is stressed in a grant proposal:

This coordination and consensus-seeking will in no way seek to suppress the regular work of taxonomists in proposing new classifications and updating treatments to take account of new discoveries. We are simply trying to decouple the necessary flux and debate that goes on amongst taxonomists from the single consensus system that might responsibly be made available to the rest of biology as a stable reference system. (ILDIS, Grant Proposal Case for Support, G.C., S.Q., and K.A., 14 September 1990)

This Janus-faced (Latour 1987) representation offers a key to understanding the role of the ILDIS system in redefining taxonomic knowledge, with its emphasis on retaining taxonomic practices intact while radically transforming the discipline in the eyes of other biologists.

### *Information System as User*

Enlisting the support of users is vital for the success and "black-boxing" of the database. ILDIS would then become a standardized package (Fujimura, 1992), combining into a robust system the hardware and software of the system, the contributors and users of information, the planners and the key punchers, and the information itself. The information system embodies the processes of discussion, negotiation, and compilation that have gone into its creation. The role of the organization is to maintain control over the sanctioned interpretation of this system, promoting it by seeking to enlist "the user" as part of the system. Having created their package, the taxonomists must then seek to control its use and to direct the reaction to its contents. Success may depend on the users' acceptance of the representation thrust upon them, and on their agreement to conform to the "conceptions of

audience" that the information system embodies (Cooper and Woolgar 1993). Representing taxonomists and plants to users, the system also represents these users to the taxonomists. In their discussions, the participants in the ILDIS project construct their users. If the ILDIS system is to serve its purpose, it must become the true user of taxonomic information as far as the taxonomists are concerned.

A publicity leaflet specifies a conception of the user constituency: "ILDIS is committed to providing flexible, easy to use information services on Legumes to a wide range of environmental, botanical, pharmaceutical, agricultural and regulatory disciplines including plant exploitation, biotechnology, biodiversity and conservation" (ILDIS publicity leaflet 1992).

Discussions at workshops and in the newsletter made it apparent that the exact nature of "user needs" and the means by which these could best be met were subject to debate. Representatives of user agencies and of scientific communication organizations claimed to possess a superior knowledge of these factors. However, there was agreement that user needs were unquestionably distinct from the specialist information requirements of the taxonomist:

The ultimate aim is a sensible list of names likely to be encountered in literature still used for plant identification. Concurrently it may be useful to record all synonyms in [another database] for the benefit of future taxonomic work, rather than the general users of the ILDIS database. (ILDIS *Newsletter*, No. 4, July 1990)

Taxonomists repeatedly made the distinction between the working hypothesis of the taxonomist and the relatively certain, stable information which could be passed on to users. The information system thus becomes an explicit mechanism for controlling the dissemination of results.

Potential user agencies, producers of their own biological databases who might subscribe to electronic checklists of plant names, were wooed by the organizers of ILDIS. They were important, both as major users who lent credibility to the claims of the project and as sources of funding from royalties. Sometimes it seemed that users might not themselves realize what they need, as a comment made by an adviser at the Inaugural Workshop shows: "but with a completely new facility one has to educate users before it can be properly evaluated" (ILDIS Report on the Inaugural Workshop, 23-25 September 1985). Thus the ILDIS project moved beyond the confines of taxonomy to construct not only plants and the taxonomic discipline, but also its own user community.

## Conclusion

Above, I described how taxonomists attempted to re-engineer their discipline and ameliorate the tensions inherent in it through the medium of a new technological development. If IT was to be successful in disseminating the results of taxonomic work, the information system must be viewed as an unproblematic representation of these results. Thus, the disappearing plants and the invisible network are replaced by the information system, and the biologists who are to be the users are from the perspective of the participants also replaced by the information system. The development of the ILDIS system appears to follow the pattern suggested by Schaffer (1989). The "transparency" of a scientific instrument is an achievement rather than a given. The black-boxing of the instrument so that users treat it as providing an unproblematic representation of reality requires that the instrument itself disappears (Gooding, Pinch, and Schaffer 1989,5). The work of the developers of the ILDIS system may be seen as evidence of the tension between the need to gain credit and recognition for their efforts and the need to hide the active construction work in order for the system to function as a transparent scientific instrument. The ILDIS system gives users access to the taxonomy of the Leguminosae, while allowing taxonomists to continue with their studies of plants undisturbed. As an instrument for the dissemination of scientific facts, the ILDIS system is not just a reified theorem about taxonomic facts but also a model of the taxonomic discipline itself. Black-boxing the system as a window on taxonomic facts also achieves the feat of re-engineering the discipline. The question of whether the ILDIS view of taxonomy will be accepted depends on how successful its developers are in promoting their system as a transparent instrument for viewing taxonomic realities. This, in turn, depends on the enlistment of an appropriate user community or on the biologists' acceptance of the conceptions of audience embodied by the system (Cooper and Woolgar 1993).

## Notes

1. "Taxonomy" and "systematics" are both widely used to cover the broad area of the practice of classifying living organisms, and many authors appear to use them interchangeably. However, those who do make distinctions generally follow Simpson (1961) in adopting a hierarchical structure of definitions, in which taxonomy is part of systematics, and classifying and naming groups are a part of taxonomy. Systematics is reserved as a general term to include the study of evolutionary history and biogeography. The use of the term *systematics* is,

it appears, an attempt to enhance the status of the activity described from mere cataloguing to that of a science. In the United States, it appears that the term "taxonomy" is all but obsolete.

2. Such a discursive move lends support to suggestions that acceptance of a new form of representation may devalue older forms and may alter what counts as knowledge, just as Ong (1982) and Goody (1977) suggested that the transition from orality to literacy affected knowledge.

3. The cladistic or phylogenetic methodology was first proposed by Hennig (1950), but it did not become widely known until English translations of his work became available in the mid-1960s (Mayr 1982).

4. The reference to "Darwinian," in which this adjective seems to confer immediate respectability to a concept, is a common theme in such publications.

5. The name of the project was altered in an earlier version of this paper, as agreed with the organizers of the project when this research began. However, the actual name of the project has been used here, in response to a request from the organizer of the project on reading the earlier version: "Given that we are openly trying to promote ILDIS as a prototype in international/scientific organizations, I think ILDIS would be proud to get credit for what you describe!"

6. Documents referenced in this section were obtained from ILDIS archives.

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