Systematics as Cyberscience

Computers, Change, and Continuity in Science

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1 Introducing the Study of a Cyberscience

The connection between new technologies and social change is an issue of contemporary hope and fascination. We look to new technologies to produce desirable change and we fear undesirable effects, finding in computers a particularly potent stimulus for speculation. We watch with awe as changes that were neither anticipated nor desired come to pass, and we puzzle as structures we thought fragile turn out to endure. In this book I continue the exploration of the dynamics of change and continuity in relation to information and communication technologies (ICTs) that I began in a previous work, *Virtual Ethnography* (Hine 2000). In that book I looked at the social dynamics which made use of the Internet meaningful in the specific context of a media event in the late 1990s. I took an ethnographic perspective on change, looking at the ways that people made sense of their Internet activities in terms both of transformation and of reinforcement of the status quo. This time I turn to an area where the hopes and expectations of transformation through ICTs have been particularly intense of late: science. I deploy an ethnographically informed style of inquiry to explore the ways in which use of ICTs makes sense to a particular group of scientists. I range more widely in search of meaning-making practices, exploring multiple dimensions of the scientific discipline that inform the sense which participants make of ICTs. I also spend more time offline than previously, as I explore the ways that the virtual discipline makes sense to its practitioners and find it rooted in diverse facets of the existing structures, practices, and material culture. I find myself in territory where the idea of change is particularly politicized, where reflexivity is a highly developed practice, and where there is heightened consciousness of the importance of heritage.

This book is a sociological account of how one of the oldest branches of science turned itself into one of the newest and became a cyberscience. As the branch of biology concerned with naming organisms and exploring

their relationships, taxonomy, or systematics,[1] has a heritage that reaches back for centuries. Recently it has renewed itself, thanks at least in part to the use of computers. This book explores the emergence of a virtual culture of taxonomy and investigates how that culture is entwined with the past traditions, the material culture, and the institutions and practices of the discipline. My aim was to find out how the relationship between ICTs and this branch of science came about, and to explore the dynamics of change and continuity that this relationship entails. It is no accident that I chose this particular area to focus upon. As well as researching the transition that taxonomy has made through visits to initiatives and projects, through observation of taxonomy online, offline, and in the published literature and through interviews with protagonists, I have also to a large extent lived the transition. It therefore seems appropriate to start this introduction on an autobiographical note. This will then bring me to a more conventional introduction to the focus of the book and the content of the individual chapters.

An Autobiographical Entry into the Field

For a long time I thought I wanted to study plants, and not people. The early 1980s found me, rather dazzled by the grandness of my new surroundings, entering the Botany Department at the University of Oxford as an undergraduate. My memories of the course have become hazy with time, and no doubt the parts that I enjoyed or disliked the most stand out disproportionately through the haze. I recall afternoons immersed in drawing exotic plants from the Botanic Gardens, and perched on a stool at a wooden bench, peering down a microscope at a lacy array of plant cells. I remember field trips around the Oxfordshire countryside, wading through bracken, squelching through bogs, and crawling through carpets of primroses, checking their flower centers for the position of stamens and stigma. Casting meter square quadrats on the ground to survey the flora and puzzling over identification keys to find names for obscure little scraps of moss became familiar activities. Even final exams took place partly in the woods, as we traipsed about surveying and making notes, on our honor not to meet up in the undergrowth and share answers with one another. I remember deep frustration at weeklong practical exercises in genetics, centrifuging, pipetting, and incubating for days, only to find that the vital solution had been thrown out by accident on day two and that for the rest of the week I had been carefully nurturing nothing at all. What I do not remember, from any stage of my short career as botanist, is using a com-

puter. Information technology was certainly around, and I now know there were innovations in computing happening in that very building at around the time that I was there; but they were not a part of my consciousness as a botany student at the time.

Lately I have been back to the same botany department that once trained me, and while the fabric of the building is unchanged, many of the internal fittings have altered. Traditional wooden benches have largely given way to more modern office and laboratory fitments. There are, significantly, computers on many desks. Computing has clearly become integrated into the work of those now in the department, not necessarily as a notable or topical element, but simply as a part of getting the job done. The experience of being a botanist has undoubtedly changed too, although there is no doubt that as well as using computers, botanists also still wade through bracken, or bogs, or wherever their particular plants of interest live. Some things remain recognizable, but botany, or plant science as it is more often lately known, has had changes of substance and of image since I left, and among those changes has been a more intensive use of computers.

As an undergraduate botanist in the early 1980s I managed not to touch a computer for three years. As a sociologist at the beginning of the twenty-first century I cannot imagine working without one. Doing academic research without using a computer is now almost unthinkable, in the same way as it is all but inconceivable that any modern institution could work without information technology. Looking around me I can see my present-day colleagues accepting the computer in their working lives in a whole variety of ways. As a well-equipped sociology department we have routine access to computers on our desks, to word-processing, bibliographic, and statistical software, online databases, electronic journals, and access grid technologies for distributed collaboration. We maintain our Web presence, as a department and individually, as routinely as once we might have produced a printed prospectus or updated a curriculum vitae. Email, even to colleagues in the next office, is a usual part of an increasingly time-stretched and space-shifted academic existence. Whether searching for previously published work, communicating and collaborating with colleagues, recording data, calculating results, or writing an article, most researchers will depend on digital technologies in some form to support a project at all stages. The availability of these technologies opens up new avenues of research and imperceptibly smoothes the work of existing projects.

ICTs seem to have transformed the climate in which research is conducted to such an extent that researching credibly without them has become in a short space of time not simply more difficult, but almost

impossible. Within the span of my career, working practices seem already to have changed dramatically. Some would say that we have only just started to find out what new possibilities are opening up. The applications I have listed tend to mirror existing activities, or are limited to reproducing tasks that are fully recognizable in terms of what went before. But use of ICTs could potentially go much deeper, transforming the nature of scientific work and communication to produce results not so recognizable in terms of former practice. Studying the integration of these technologies with science right now, as this book does, provides the chance to check up on that ongoing process and to consider what is happening at a point when we still have the chance to open the black box (Latour 1987) and unpack the social dynamics within which the structures being set in place make sense. We have an opportunity to work out what assumptions and interests are shaping the developments that are occurring. There is also a possibility to learn from experience, since different scientific disciplines could learn some valuable lessons from one another for their own futures, particularly as they become sites for explicit intervention through initiatives in e-science and cyberinfrastructure.

Much of the ICT in science has been introduced with the hope that it will improve the work that researchers do or make it more efficient. Most projects now come with a pressure for results in the shortest possible time, whether that be due to the constraints of a funding cycle, the race to outperform competing groups, the rival pressures of administrative and teaching tasks (themselves also increasingly computer intensive), or the urgency imposed by a pressing question of, say, environmental conservation or policy recommendation. Whatever the source of time pressure, tools to increase the efficiency of research have an immediate appeal. Along with efficient use of time and resources another factor to encourage use of computers is provided by the importance of accuracy in science. Here computerization holds the promise of automation, of excluding human error and enhancing reliability and reproducibility, and thus fits in well with values that science holds dear. Without ever setting out to make our work more computer intensive, we pick up individual tools that seem appealing and that we see our colleagues using effectively, and thus we find ourselves year-on-year relying on a wider and slightly different raft of technologies to support our work. Change is variable in pace and often incremental. Every department has its leaders who always know the latest tips, and its members who lag behind, needing to be encouraged or bullied to use a tool adopted by everyone else: individual approaches and experiences vary within an overall advancing trend of computer use.

On a policy level, the increase in use of ICTs in science has some obvious attractions. Digital publishing offers the possibility of rejuvenating an increasingly expensive formal scientific communication system, giving more researchers access to more publications, quickly, cheaply, and conveniently. Informal scientific communication, via email, newsgroup, and mailing list, promises to tie researchers into networks and keep them abreast of the latest developments. On a larger scale, databases and networking initiatives offer to make work more efficient and cost-effective by enabling the sharing of results between geographically separated groups of researchers, and reducing the duplication of effort. Unprecedented levels of computing power available to researchers seem to demand matching grand visions from programs of research and analysis previously unimaginable. These grand projects need organizational innovation, large-scale funding, and the political and individual will to imagine them and make them happen. They thrive on persuasive visions of how science ought to be and how new futures can be realized through new technologies.

Amid the pressures for efficiency and accuracy and the impetus to realize grand visions and undertake large scale data-sharing projects, computing therefore appears to have an automatic appeal for promoting change in desirable directions. We know already, however, that this kind of promise is rarely realized. Time and again complex social dynamics defeat brave promises like the paperless office (Sellen and Harper 2002) or predictions that teleworking would put an end to commuting to work (Gillespie and Richardson 2000). The apparently blanket transformative properties of ICTs turn into complex and diverse patterns of take-up and impact which are often counterintuitive (Woolgar 2002b). Efficiency is only one part of a story which will involve competing problem definitions, interests, and identities. In exploring the cumulative transformation of a cultural domain as a complex field of sociotechnical interactions, we need then to focus on the processes that bring transformation about. What are the dynamics of change? What factors influence the course of innovation? Whose voices influence the process, and how are the outcomes assessed? Who has a stake in recognizing change, or in identifying continuity? Excluding technology as a transformative agent in its own right enables one to start looking for other agencies and processes that enable cultures, including science, to change and to be recognized as having changed in conjunction with technologies.

In this book I will be addressing these questions through a focus on the processes by which ICTs have been introduced into one branch of science, systematics. The intention is to consider the social dynamics that surround

the introduction of ICTs as captured in the questions above, and to track the identities, roles, institutions, and responsibilities that emerge as a result. I explore how particular uses of ICTs make sense to those involved, with a specific focus on the processes of imagining that enable participants to think about themselves, the territories they inhabit, the goals they strive for, and the capacities of the technologies they hope to employ. The questions raised by looking at the promises made for computerization in science become ones that deserve answers on a very local scale. In the conclusion I draw some generalizable lessons, for the study of ICTs and for the support of ICTs in science in particular, but these are bracketed by the specific nature of the social dynamics that surround and shape any particular instance we study. The value of a case study is in providing a deeper understanding of process, which in turn provides questions with which to interrogate other settings. The focus of this book is on the potential transformation of one field of science, but the aspiration is to use this approach to question some of the assumptions in current science policy and contribute to the sociology of science more broadly.

In order to map out further the scope and style of this study of transformation in biology, I will continue with the autobiographical story. After graduating as a botanist I found myself without a clear direction. Not knowing what I wanted to do led me, like so many others, to take a postgraduate qualification: the subject that I chose was of all things a course in computing. With a confidence borne of ignorance I enrolled myself in 1986 in a course designed to produce the hybrid computer-literate biologists who were just beginning to be in demand in the discipline. The MSc in Biological Computation at the University of York had been running for several years already, drawing on the expertise of staff from biology and from computer science. We trained in Fortran, Basic, and Pascal, in numerical and statistical methods, in the structuring of databases, and in the interfacing of laboratory instruments with computers. Clearly, then, my experiences as an undergraduate botanist were not mirrored throughout biology. I might have managed not to encounter computing as an undergraduate, but the contents of the biological computation course revealed some well-rehearsed ways in which the connection between biology and computers was being forged. In such courses the foundations of the discipline of bioinformatics, a hybrid of biology and computing, were being solidified. The hunch that computing would be a good career move for a biologist proved to be very well founded for many of my colleagues in the course: I often encounter them in key roles as I explore the contemporary uses of computing in biology.

My own career moves continued to be unplanned and not entirely conventional. After a year spent in a job processing data for species distribution maps, I returned to study for a doctorate, this time looking at the use of databases in biology. The idea was to see whether information systems could give a solution to a problem that was topical at the time among taxonomists, the "nomenclatural instability" caused by classificatory changes affecting the names of organisms. The complex chains of synonyms built up as classifications were revised were thought to be damaging the status of the taxonomy and the reputation of taxonomists. Instability of names was said to interfere with the work of other biologists who depend on classifications for utility and for scientific content. Databases were being proposed as solutions to give a user-friendly interface to complex systems of synonymy. I spent my time as a doctoral student grappling with database design issues, but also interviewing biologists about their use of taxonomy, and becoming immersed in the concerns of a taxonomic community passionate about its work and worried about its sustainability. I increasingly wanted to know what kind of solutions the community would find attractive and sustainable, and how far change might be a feasible proposition. I found myself interested not so much in developing computer systems myself, as in the sociological questions that arose from their deployment. It was thus, thanks to some helpful and open-minded sociologists, that at the beginning of the 1990s I found myself beginning a new career as a sociologist of science and technology.

Since leaving biology my sociological interests have ranged across a variety of areas far removed from taxonomic databases looking at the social processes that confer sense on particular technological solutions. The issue of the role of ICTs in knowledge production remains a live and practical concern for me as a sociologist as much as it is for the biologists I have been studying. In the sociology department, as in the contemporary botany department, computing and computer-mediated communication are used routinely, sometimes the topic of particular initiatives but more often an unremarked part of getting the job done. Our experience of change happens on different levels. Sometimes we consciously set out to do something new; at other times we may be jolted into a consciousness of change by reflection on how different our working style was just a few years ago. I have been conscious in writing this book that compared to the last time I have quite different resources available to me, as I now write accompanied by an always-on Internet connection and have an extensive personal library available to me through my bibliographic software. I wonder how my writing and my connection with my discipline may have changed with

these alterations in my writing practices, and I strive to remember still to go to libraries and seek out the nondigital literature. I find myself keen to change in desirable directions, but suspicious of being changed by default.

The issue of changing science, and the role of ICTs in that process, is therefore something that interests me personally as well as theoretically, and it has become a stimulating place to pursue the interests in the social dynamics of meaning-making around ICTs that have concerned me as a sociologist of science and technology. Sciences and social sciences, like so many areas of contemporary life, seem to have undergone a quiet transformation in working practices, and a variety of initiatives seem to want to change them still further. In the next chapter I explore how in policy circles some aspects of the use of computers in science have become topical as sites for intervention in how science is done, while other kinds of computing work have been overlooked altogether. It is timely to reflect on the assumptions about technology that inform policy directions and routine work, and to think about the dynamics of continuity and change that encounters with new technologies occasion for science. Science and technology studies (STS) provides the tools for the critical perspective both on scientific practice and on the technology that this task requires.

Positioning a Case Study of a Cyberscience

The culture of contemporary science, including its adoption of ICTs, deserves documentation in its own right. There are also, however, more pragmatic rationales for carrying out this study, one of which is to contribute to understanding of ICTs as a site of policy intervention in contemporary science. To information scientists implementing ICT solutions in science, I offer a means to think about the dynamics of the situations in which their work intervenes. The book will, I hope, also be interesting to practitioners of the science that I discuss. I am sure that they will be infuriated by omissions and misunderstandings in my representation, but I hope that they will find their work described with respect and sympathy for their day-to-day experiences of getting their job done. Systematics has a strong tradition of self-examination, and this book, in offering new light on the structures and practices of the discipline, may fuel this tradition. To an audience within STS, I hope to contribute to understanding of the mechanisms by which scientific cultures change and are seen to change, and to demonstrate the interweaving of policy pronouncements and daily experience in the work of a scientific discipline. Finally, for anyone interested in the role of ICTs in contemporary society and concerned with how we can best tease

out and explore the social implications of these technologies, I provide a case study that demonstrates the multidimensional cultural embedding of these technologies within a key area of social life over time. Cyberscience should give Internet research an interesting case study with which to work.

The term cyberscience needs some introduction. By using it I do not intend to indicate that there has necessarily been a radical shift or discontinuity in the ways in which science is practiced and communicated. Rather, the term is used as a qualitative indicator of the increasingly intimate relationship between scientific research and ICTs. As in many spheres of work, the use of these technologies has become inseparable from the doing of the work: the concept of "doing it by hand" has become meaningless. The term cyberscience demarcates this intimate connection as a site for examination. Just as cyberspace is used to mean a form of space realized through ICTs, so cyberscience implies the realization of science through those technologies. This realization of science includes both the representation of knowledge and the practice of research: cyberscience is not just about communicating science, but about ways of doing science as well. Just as cyberspace is turning out not to imply a replacement of real space, so cyberscience is unlikely, I would suggest, to displace or make irrelevant our existing notions of science. As the term cyberspace has been a rallying point to make apparent the reality of the experience of immersion in ICTs, so I would like to use the term cyberscience to mark as notable the extent to which ICTs have come to pervade science. Framing cyberscience in this way aims to topicalize ICTs so as to interrogate their use. This interrogation acts in two directions. In the first place, it questions assumptions that more and better technologies are needed for science. It becomes possible to ask what these technologies are supposed to do, for whom and in what context. Working in the opposite direction, there is purchase in looking for aspects of technology use that are deemed routine or unremarkable, and bringing into the spotlight their role in shaping practices and outcomes.

There is a methodological risk in gathering up all uses of ICTs in science as a single phenomenon as if their unity were a given. This class of technologies is a useful starting point for a study, since in the complex of computer-mediated communication, computation, data processing, and distributed computer networks we find the technologies upon which so many predictions of social transformation have been pinned. It should remain though an open question for ethnographic exploration whether this grouping of technologies has meaning for practitioners in their everyday work, or whether quite different distinctions and categories come to the fore. I do not, therefore, intend to labor the point about cyberscience

too much or to suggest that the term will necessarily cover a unified phenomenon. Although the term cyberscience is useful, first as a handy shorthand for "the intensive use of ICTs within scientific research practices and knowledge representations," and second as a reminder to look both for the notable and the overlooked uses of these technologies in science, I do not intend to let the term get in the way of the analysis.

It may seem odd to base an examination of cyberscience on the discipline of biology. Biology is traditionally seen as the least technologically sophisticated and most craft based of the sciences. For example, Walsh et al. (2000) compared use of email within physics, experimental biology, sociology, and mathematics, and found that the biologists both had least experience using email and sent and received the fewest messages. However, there are some specific reasons why biology, and particularly the field of biology known as systematics or taxonomy, does form an interesting and instructive site to consider what cyberscience might entail. Possibly because of the traditional view of biology as nontechnical, new technologies have often been matters for debate within the field, and thus clear traces remain for a historical sociology of their introduction. Developments have been rapid, as I noted in my autobiographical sketch. Biology has achieved a considerable level of integration of research with information technology in a short space of time. Bioinformatics is now a recognized area, and while most prominent in genomics, this field has also had considerable influence within systematics. The process by which this happened is a fascinating complex of accommodations in research practices, roles, expertise, and technologies.

Within biology, systematics has particular value as a case study. Systematics has undergone long periods as an unfashionable and sometimes derided practice, but has emerged into the spotlight in the last decade with the growing political prominence of biodiversity conservation. As a discipline systematics has thus had to pay serious attention to its image, and use of technology has played a significant part. A wide range of ICTs has been incorporated into practice within systematics. Systematists routinely use email to communicate with one another, and mailing lists provide both for discipline-wide communications and for specialist groups to form within the discipline. Most systematists work in institutions such as natural history museums and botanic gardens, and much of their work revolves around the collections of specimens held in those institutions, which are used to develop ways of classifying and naming groups of organisms. We now have several decades of experience in developing computerized databases of specimen collections, increasingly now containing images as well as information from specimen labels, and publicly available via Web sites. Initiatives range in scale from the working data-

bases of individual specialists to large-scale efforts to link the databases of several institutions. There are also high-profile efforts to develop user-friendly universal portals to distributed databases of biodiversity information, and to make available authoritative databases of all species names.

Systematics has recently been the subject of considerable attention on a global stage, as questions of biodiversity conservation have been debated, most significantly at the Rio Earth Summit in 1992 and in subsequent discussions around the international Convention on Biological Diversity signed at that summit. The particular spatial anomalies of systematics have been a prominent part of discussion. The distribution of specimen collections does not mirror the distribution of the organisms the specimens represent. Instead, major institutions hold concentrations of collections which have their own geography, often mirroring past patterns of colonization. Former colonies therefore find that the resources to understand their biological diversity are often far away in the institutions of their former colonizers. The Convention on Biological Diversity was formulated as a policy instrument to address these inequalities by enforcing the sharing of expertise and access to resources, and ICTs have often been seen as the practical route to achieving these goals. Without wishing to give too much of the story away, we could say that systematics proves to be a site where belief in technology as an agent of change, and as symbolic of a desire to change, has been particularly apparent.

Biology in general, then, is an appropriate site in which to look at the growth and significance of ICTs in scientific practice. Within biology, systematics provides a place to look at computer-mediated communication, at computerized analysis and databases, both as small-scale projects and large initiatives, as part of routine work and as a component of topical public debate. In this regard it is interestingly different from another obvious candidate for a case study, genomics. The Human Genome Project, as a high-profile international initiative, made intensive use of information technologies. Indeed, visions of technological possibility played a strong role in arguments that the initiative should be funded at all. Genome work is highly data intensive: sequencing of DNA produces masses of data, which can be meaningfully handled only by automated analysis, searching, and pattern matching. Procedures for submitting data to public databases are well established and integrated with the journals in the field. If one is looking for a model of cyberscience, then genomics would seem an obvious place to start.

There are reasons, however, why genomics is not the most useful case study for the particular purposes of this book. I wanted to be able to trace the changing expectations of computers over time as a discipline

developed, and to look at the ways in which the technology was implicated in the working practices of the discipline and in the relationships of the discipline with its users. In this respect, a case study as driven by visions of large-scale computing as the Human Genome Project could be counterproductive. All case studies are, of course, unique. That is their strength as well as their weakness. I hoped, however, in the choice of systematics to have a case study that was continuous in some recognizable ways with the experience of other disciplines, as well as being interesting for its distinctiveness. In the conclusion I return to the question of general issues that may be drawn from the case study of systematics, and specifically this question of the comparisons with genome research, which as we see in chapter 3 is a live issue for participants as well as commentators.

Outline of the Book

In the remainder of this introduction I will describe the content of the book chapter by chapter, in order to further map out the approach and give a taste of the kind of insights that it provides for. Chapter 2 examines the technological focus of cyberscience, exploring first what claims are made for ICTs in science, and second what roots these ways of thinking have in our beliefs about these technologies more broadly. It appears that, through notions such as e-science and the collaboratory, high-profile ICTs have attracted policy interests in shaping scientific practice in particular directions. As a policy tool ICTs have an appeal as ways of promoting efficiency, data sharing, collaboration and speed. Viewed from a sociological perspective, however, these claims appear somewhat problematic. Not only may the perceived benefits not be realized, but other unpredictable consequences may transpire.

A critical approach to the expectations that shape policy interest in ICTs for science turns attention onto the processes through which technologies are adopted and interpreted by their users. Sociology of science and technology provides ways of thinking through the social dynamics of these processes of adoption. From studies of technological change in organizations, the concept of "technology in practice" (Orlikowski 2000) offers a route to thinking about the situatedness and specificity of any particular implementation of a technology. From sociology of science, the idea of co-construction provides a way to articulate the intricate relationship between the tools researchers use and the goals they aspire to achieve (Clarke and Fujimura 1992). Taken together, these approaches suggest an exploration of the ways in which scientific disciplines make ICTs their own, and, in the process, articulate new versions of themselves and their aspirations.

Taking the introduction of ICTs as a moment of co-construction provides a powerful rationale for an ethnographically informed investigation, looking for the practices within which particular technological solutions are made to make sense. ICTs are, at least by reputation, thoroughly troubling to spatial organization. It is precisely because they are thought to alter social relations in time and space that we find them so interesting: it therefore seems perverse to tackle understanding them through a spatially focused ethnography that looks at a laboratory (or an equivalent bounded location, such as an herbarium or museum). If we are to retain the possibility of discovering new organizational forms in science, we need to adopt a methodological approach that remains open to finding and exploring such forms. In an area as politically charged and subject to open intervention as ICTs, it also seems important to look deliberately beyond the immediate local environment rather than waiting for the global to emerge in the local in traditional ethnographic style. My case study of ICTs in systematics therefore employed a combination of multi-sited ethnography, historical review, and textual analysis across a series of settings. Building on the virtual ethnographic approach (Hine 2000), which insists that virtual settings are both cultural sites in their own right and cultural artifacts subject to ongoing processes of interpretation, the case study explored online landscapes as they made sense within diverse contextualizing frameworks. The findings of this research are arranged into the four chapters that follow, examining in turn the policy perspective, the material culture, the communication system, and the institutional/spatial form of systematics as they relate to the use of ICTs.

Chapter 3 begins the examination of the case study of systematics by both setting the scene for understanding contemporary systematics and exploring how ICTs are imagined in policy commentaries on the discipline. The data for this chapter are drawn largely from a 2002 policy report, produced by the UK's House of Lords Select Committee on Science and Technology, which reviewed the current state of the discipline and recommended that it should take steps to become a thoroughly Web-based discipline. The chapter examines the reasoning presented in support of this recommendation, and explores the themes that arise in the report and the evidence from stakeholders on which the report is based. Themes of importance include: the relationship between material and virtual specimens, and the audiences for their availability; the complex political geographies of systematics; the balance between automation and expertise; and the role of evocative objects and the branding of initiatives. Historically, these themes can be seen to have varied as the concerns of the discipline and its political context have altered. This chapter begins the work of establishing that ICTs in systematics

are thoroughly shaped by the context of the discipline that employs them, which in turn consists of a highly distinctive culture in terms of its organizational forms, funding structures, working practices, and material culture. The introduction of ICTs into systematics proves to be a site for imagining the present, past, and future of the discipline.

A further perspective on the mutual articulation of ICTs and systematics is provided by looking at the way the discipline works with objects to produce its distinctive ways of exploring the natural world. Chapter 4 focuses on this material culture of systematics and investigates where the developing virtual culture supplements, replaces, and builds on that material culture. It emerges that such virtual culture as has developed is portrayed by systematists as thoroughly entwined with the beliefs and practices that surround their material culture. The discipline is founded on ordered collections of physical specimens as a representation of the diversity of the natural world. ICTs are providing new ways of ordering specimens and making them available to traditional audiences and wider publics. Virtual technologies allow for the material culture through which objects are collected, ordered, and displayed to be experienced in new ways. Processes of co-construction dominate as visions for virtual technologies are articulated and in turn provide new ways of understanding and specifying the qualities of material specimens.

In chapter 3, the role of ICTs in systematics is explored through analysis of public, high-profile commentary. Such talk is, of course, limited in the extent to which it reflects the daily experience of those working in the field. Even those practicing taxonomists who gave the evidence on which the report analyzed in chapter 3 was based were clearly speaking very consciously in a public arena. In chapter 4, communication practices that underpin and interpret the virtualization of taxonomy's material culture are explored in passing. Chapter 5 turns attention directly to communication practices, to ask how these have altered and been respecified in light of new technologies, and with what significance for the practices and outcomes of taxonomy. Having introduced the role of computer-mediated communication in developing understandings of the formal taxonomic communication system, the main focus of chapter 5 is a mailing list: a form of communication that is still public but in a much less formal and politically charged sense than the academic literature or the report that forms the basis for chapter 3.

A mailing list for taxonomists provides material for assessing the role of ICTs in the working practices of the discipline, in two senses. In the first sense, the existence of the list speaks to the use of the technology by members, and the membership of the list provides some indication of the extent

to which this technology has become a routine way for taxonomists to communicate with one another. In a second sense, the content of the messages provides material to consider how much, and in what senses, use of ICTs is topical within the discipline. The list is frequently used as a way of announcing new products, which often take the form of digital technologies. The list attests both to the importance of these technologies and to the emphasis on publicizing one's products in contemporary systematics. The mailing list gives a perspective on taxonomy that contrasts with the wholesale shift toward Web-based science advocated by the Select Committee. It reveals a highly self-conscious and reflexive discipline, which is able to use the list to realize itself as a community, and yet maintains a very individualized set of goals and priorities, revolving around institutional affiliations and taxonomic groups.

The mailing list analyzed in chapter 5 was frequently used to publicize initiatives and products. Chapter 6 shifts focus to examine the institutional locations within which these initiatives arise and to consider how far ICTs are restructuring systematics on this level. It has become routine to use computerized analysis of some kind in classification, and curatorial work also routinely deploys databases. This has so far been achieved without significant change to the experience, location, and institutional organization of work in systematics. Large-scale database initiatives, however, involve more explicit and deliberate social innovation. The work of database construction involves negotiations to draw appropriate boundaries between taxonomy and its publics and to integrate the work of database construction and the production of data into existing working practices. Existing institutions still have a strong role to play in systematics, not least because they house the collections of material specimens on which the discipline is based. Systematics institutions are expected to make their resources accessible, but also have to maintain their distinctive identities and their fundability. ICTs provide ways of managing this tension, along with a reflexive opportunity to reconsider the status and importance of relations with users. The implementation of access initiatives provides a new occasion for thinking through what material specimens are used for and by whom, and for working out the relative status of material and virtual specimens and products. At the same time, individuals within institutions are conscious of career pressures, and initiatives are being carefully designed to give due credit, maintaining the existing emphasis within taxonomy on the reputation of individuals. This chapter demonstrates the complex dynamics between transformation and continuity that prevail on the institutional level.

Chapters 3 through 6 explore the uses of ICTs in systematics from a set of different perspectives: the policy domain, the material culture, the communication system, and the institutionally located set of working practices. Although treated separately, these ways of understanding the discipline are clearly thoroughly interwoven with one another. To have left out any one would be to have omitted a significant part of the environment of contemporary systematics. Including all of these perspectives allows us to see how ICTs are involved in systematics not just as isolated initiatives or as a different way of doing work, but as highly influential sites for imagining what the discipline is across all levels. Chapter 7 pulls together the implications of these observations from a policy perspective and for sociology of science and technology. Contemporary systematics is ICT saturated, but in a way that is so thoroughly shaped by the current concerns of the discipline that it becomes difficult to talk about the effects of ICTs as an agent of change. Instead, ICTs have been a useful resource for systematics to realize itself in the current climate, through the development of very distinctive manifestations of ICTs deemed appropriate to its own concerns. Understandings of ICTs for systematics are thoroughly situated in the detail of the current priorities, political status, and funding climate of the discipline but are also connected with imaginings of the potential of ICTs in other domains. The introduction of ICTs emerges as a therapeutic moment for systematics, involving co-constructions of the past, present, and future of the discipline, while also imagining change for the discipline and the territory within which that change is to occur.

To return to where we started, then, it is clearly problematic to talk about ICTs as ways of making science more efficient. It is true that database projects are providing unprecedented access to taxonomic data. Exciting initiatives are being undertaken by technically savvy and often idealistically motivated individuals to address persistent inequalities in availability of resources for taxonomic work. It is not clear, however, that direct benefits of such access are thoroughly understood, or indeed are always a significant driver behind the projects in the first place. A suitable political and funding climate can provide ample justification for projects to go ahead without any direct evidence as to benefits or any identifiable bodies of active users. Policy interventions which intend to use ICTs as a means to promote change in the science system therefore need to proceed with caution. The upshots may be highly specific to the political status, funding concerns, existing organizations, and working practices of a given discipline. It cannot be guaranteed that efficiency gains, as these are normally understood, will result.

This book is likely to offer the most to people already interested in science, but it also clearly has theoretical and methodological messages for the study of ICTs as cultural artifacts more broadly. The theoretical issues with wider significance than for science studies alone revolve around ICTs as resources for the reflexive reshaping of areas of practice. What people do with ICTs depends on understandings of both their functional qualities and their cultural meanings. What people do with these technologies is thus embedded in their daily understandings of goals and how these are to be achieved. At the same time, our understandings of what is to be done on the everyday level are thoroughly infused with a sense of the environment, both technical and cultural, in which we are working, and our sense of possibilities is shaped by the technologies that are available. An understanding of the development of ICTs in any area of social life can usefully draw on investigation across multiple facets of that area of life, including the details of daily practice and the occasions of public commentary and policy intervention.

My choice of site for the case study in this book was thoroughly shaped by my biography, and I felt it important that this introduction should have a strong biographical feel. It would be disingenuous to have given the impression that I came to systematics as any kind of distanced or impartial observer. From the outset I was not inclined to accept the stereotype of systematics as a dry pursuit, practiced by people cut off from the rest of the world, suffering, as Baroness Walmsley described it, "from an image of anorak-clad scientists poring over disintegrating specimens in dusty archives" (Hansard 2002: col. 921). I cared about the depth of history that systematics carried with it, and loved the fact that this was a branch of science that celebrated its past. At the same time, I knew it was a living discipline, and was convinced how important it would prove in the struggle to preserve biodiversity. I still, though, encountered surprises in the interviews and visits that I undertook for this book. Time and again I was taken aback by the political savvy, deep engagement, technological sophistication, and passionate will to explore new ways of working and to engage with global concerns that I encountered. I have portrayed these people as I found them, and have found my initial sympathies turned into a much increased respect. The mobile and connective approach which I adopted has allowed me to appreciate the complex world in which contemporary systematists work. I hope that they will see this book as complementary to their concerns.