

***Development of a National Systematics Infrastructure:
A Virtual Instrument for the 21st Century***

**Report to the
U. S. National Science Foundation
Biodiversity Surveys and Inventories Program**

From the Participants
in the
NSF Workshop

at
The New York Botanical Garden
Bronx, New York

December 11 – 13, 2003

REPORT WRITERS

Jan Wassmer Stevenson and Dennis Wm. Stevenson

WORKSHOP CONVENERS

Dennis Wm. Stevenson and Darrel Frost

WORKSHOP STEERING COMMITTEE

Daphne Fautin, James Hanken, Lynn Kimsey, Robert E. Magill, and Scott Miller

Supported by NSF Proposal 0352943, *Development of a National Systematics Infrastructure:
A Virtual Instrument for the 21st Century.*

Preface

This report will address the development of a systematics infrastructure for the United States, as conceived by members of the systematics community convened in New York City, in December 2003.

Our conceived cyberinfrastructure for systematics does not yet have a name. More than one of us has proposed LINNE, after Carl Linnaeus (later Carl von Linné) who lived in the Age of Enlightenment, when the conceptual roots of our modern Information Age were first laid down.¹ Linné was, of course, the “great biological encyclopaedist”² who envisioned — and then developed — a standardized, scientific system of nomenclature and classification for animals, and plants, and all other living organisms then known to man.³

Those of us convened here hope that, before many more years have elapsed, a systematics infrastructure for all the nation, organized across geography and resources within the nation, can be a source of pride to the nation, with a chosen name of appropriate national character.

But we begin here with a working name of “LINNE,” in tribute to our common father. His life’s work laid the groundwork for all of modern systematics⁴ — and for all that we are beginning to do here, today.

Semantics

Several terms and concepts important for the development of a national systematics infrastructure should be explained for all readers, here at the outset. These terms and concepts will be encountered throughout this Report.

1. Cyberinfrastructure

“The term *infrastructure* has been used since the 1920s to refer collectively to the roads, power grids, telephone systems, bridges, rail lines, and similar public works that are required for an industrial economy to function. Although good infrastructure is often taken for granted and noticed only when it stops functioning, **it is among the most complex and expensive thing[s] that society creates.** (emphasis supplied). The newer term *cyberinfrastructure* refers to infrastructure based upon distributed computer, information and communication technology. If *infrastructure* is required for an industrial economy, then we could say that *cyberinfrastructure* is required for a *knowledge economy*.”⁵

Cyberinfrastructure makes possible the federation of distributed facilities and equipment and instrumentation — and thus enables new science and new *knowledge environments* for science (emphasis supplied). Federation is already happening across the various scientific research communities, with some federation occurring at the grass-roots level, and some through community-wide initiatives with major funding.⁶

Cyberinfrastructure-enabled environments have been given several generic names. Among these are *knowledge environment*, *collaboratory*, *co-laboratory*, *grid-community*, *grid-network*, *data-grid*, *virtual science community*, *e-science community*, and *virtual observatory*.⁷ The different names appear to be useful for describing different emphases, aspects, or applications of the newly-enabled environments. Indeed, several of the generic names appear in this report.

2. Federation

Federation, as a political concept, usually refers to “a middle way forward to co-operation and consensus between territorial interests.”⁸ Though federations (organizations of territorial interests) attempt to avoid both extreme overcentralization and extreme decentralization, a federation has, by definition, some measure of central governance.⁹ Because federation is going on in scientific communities at the grass-roots level, it would appear to have practical advantages for the development of cyberinfrastructures, and cyberinfrastructure-enabled knowledge environments, that are mission-oriented or science-driven.¹⁰

3. Grand Challenge

Long-term science, engineering, and societal advances whose realizations require innovative breakthroughs in information technology research and development, but which will help address our country’s priorities, have been termed multi-decade “Grand Challenges” for the United States. Sixteen national Grand Challenges have recently been identified by the Interagency Working Group appointed to consider these issues by the President’s Office of Science and Technology Policy. One of these is the

development of **knowledge environments for science** and engineering (emphasis supplied).¹¹ As noted above, the building of infrastructure — and that includes the new cyberinfrastructure — is one of the most costly and complex things that society can do. It has, however, now been recognized as a priority for science in the United States.¹²

4. Systematics

A plain meaning of “systematics,” such that would be understandable to the widest possible audience, is: *The field of biology that deals with the diversity of life and uses data to assess taxonomic relationships, especially within an evolutionary framework.*¹³ In this report, systematics is considered in the broadest sense, as it applies to all organisms, across all of the five kingdoms of living organisms: Monera; Protista; Animalia; Fungi; and Plantae.¹⁴ It also includes extinct organisms. It also includes those “intracellular ‘parasites’ that are progressively less alive in terms of being metabolically active,”¹⁵ that is, Viruses, Viroids, and Prions.

5. Virtual Community

People form communities in cyberspace (virtual communities). They do so when they engage in discussion, debate, and collective action — online — while remaining physically within and amidst their private realms.¹⁶ For an individual, the larger virtual community can support and enhance activities of his place-based community. The virtual community can also allow an individual to act, on an ongoing basis, in a larger arena than might otherwise be easy or possible.¹⁷ A common language within a particular context provides the means to move in a virtual community. Shared interests provide the motivation.¹⁸

Would it be possible for a virtual community to coalesce around LINNE?

Linné has left us with a shared language in binomial nomenclature. Those others who came after him and built upon his work have given us a context and framework within which to place our language and our evidence.¹⁹ Systematics is certainly a shared interest. Development of a national systematics infrastructure could be another.

Contents

Preface	page 2
Semantics	page 3
EXECUTIVE SUMMARY	page 6
 DEVELOPMENT OF A NATIONAL SYSTEMATICS INFRASTRUCTURE (LINNE):	
1. Introduction to This Report	page 7
2. LINNE’s Intellectual Justification	page 7
3. LINNE’s Project Definition – Focus and Organizing Principles	page 9
A. Central Focus and Scientific Questions	page 9
<i>Organizing Principle 1</i>	page 10
<i>Organizing Principle 2</i>	page 11
B. Scientific Answers	page 12
<i>Organizing Principle 3</i>	page 12
<i>Organizing Principle 4</i>	page 12
C. Learning System.....	page 13
<i>Organizing Principle 5</i>	page 13
4. LINNE’s Project Definition – Proposed Workshops for Futher Definition	page 14
<i>Enabling New Science With LINNE</i>	page 14
<i>Establishing LINNE’s Virtual Community</i>	page 15
<i>LINNE As A Network Of Place-Based Systematics Nodes</i>	page 17
<i>LINNE As Semantic Web</i>	page 19
<i>LINNE As Composite Picture And Understanding Of The Diversity of Life</i>	page 20
<i>LINNE As National Observatory Focused On The Earth’s Membrane Of Organisms</i>	page 22
<i>LINNE As A Virtual AND Place-Based Learning System</i>	page 23
<i>Let No Lesson Remain Unknown: LINNE As A Source Of Information For Policy- And Decision-Makers</i>	page 24
5. LINNE’s Connection to NSF Strategic Plan, Goals, and Priorities	page 26
6. Evidence of LINNE’s Broad-based Community Support	page 31
7. LINNE’s Proposed Partnerships	page 32
8. Conclusions and a Consideration of Tradition	page 33
<i>Honoring America’s Heritage With LINNE</i>	page 35
 Participants	page 36
Observers	page 39
Acknowledgments.....	page 40
Endnotes	page 41

EXECUTIVE SUMMARY

The US National Virtual Observatory (NVO) now observes the sky and its stars and planets and other rare objects. The nation's Space Physics & Aeronomy Research Collaboratory (SPARC) now observes the Earth's atmosphere. **LINNE will observe** that thin membrane of organisms wrapped around Earth that is the sheer totality of life — and the future of life. As a new, cyberinfrastructure-enabled knowledge environment for the science of systematics in the United States, **LINNE will ask** this pressing Scientific Question: What are the Earth's living and extinct organisms, where do they occur, what are their taxonomic relationships, and what are their evolutionary frameworks?

To answer this Scientific Question, and to observe the Earth's totality of organisms, the United States' systematics community has envisioned these **core components** for LINNE:

- A network of place-based systematics nodes, including the nation's natural history collections, experimental systematics facilities, and systematics data archives
- A new, virtual community of the nation's geographically distributed systematic researchers, and curators, and technical staff
- A semantic web to federate, fuse, explore, and mine the nation's systematics data
- A new education and outreach system that will enable all of LINNE's information and knowledge about organisms to be available to:
 - students, educators, and the general public and
 - policy- and decision makers concerned with the impact of organisms on homeland and national security, public health, a healthy environment, economic prosperity, and a vibrant civil society.

To organize and integrate these components into a new, national systematics infrastructure, five intelligible, interdependent, and mutually-reinforcing **Organizing Principles** have been proposed for LINNE. Among other things, these Organizing Principles will work to integrate and interconnect systematists and nodes that will enable new discoveries in, about, and across: (a) all the Kingdoms of life; (b) all the Domains of life; (c) those intracellular 'parasites' that are progressively less alive in terms of being metabolically active; (d) extinct organisms; and (e) any organisms as yet undiscovered or undescribed.

The systematics community has here outlined a comprehensive series of further workshops to **begin development** of all aspects of LINNE. The workshops to develop LINNE flow directly from LINNE's Organizing Principles. The Organizing Principles, in turn, flow directly from LINNE's Scientific Question. The systematics community has, therefore, conceived an effective way to proceed *from* LINNE's Scientific Question *to* development of a national systematics infrastructure, focused on that question.

For this reason, and for all of the above, we, the systematics community convened here, **request that LINNE be considered** as a priority for National Science Foundation attention.

Development of a National Systematics Infrastructure: Introduction To This Report

This Report proceeds under an assumption that a national systematics infrastructure can be built.²⁰ This assumption has provided a path to guide: (a) the conceptual thinking about the ideas from this Workshop; (b) a real conception for an entity/organization/establishment (i.e., LINNE) that could be a national systematics infrastructure; and (c) practically speaking, the structure of this Report.

This first conception for LINNE, then, is presented against the framework of topics assessed by the National Science Foundation before funding a major, networked science infrastructure.²¹ Those assessed topics would include LINNE's: (a) intellectual justification; (b) project definition; (c) connection to NSF's Strategic Plan, Goals, and Priorities, (d) evidence of broad-based community support, and (e) partnership.²² Each of the following sections of this Report will consider the conception for LINNE from one of these vantage points. The first two sections — LINNE's intellectual justification and project definition — contain the ideas put forth by the participants in this Workshop. The remaining three sections (c, d, and e above) discuss LINNE's consistency with NSF's framework and guidelines.

The reader will notice that this Report references an intimidating number of endnotes. It is perfectly possible to read this Report through and understand the conception for LINNE without turning to any of the notes at all. Should the reader be interested, however, the endnotes provide source information and additional comments on the conception for LINNE as a systematics infrastructure for the nation.

2. Development of a National Systematics Infrastructure: LINNE's Intellectual Justification

"The totality of life, known as the biosphere to scientists and creation to theologians, is a membrane of organisms wrapped around Earth so thin it cannot be seen edgewise from a space shuttle, yet so internally complex that most species composing it remain undiscovered. The membrane is seamless. From Everest's peak to the floor of the Mariana Trench, creatures of one kind or another inhabit virtually every square inch of the planetary surface."

---Edward O. Wilson, *The Future of Life* (2002)²³ (emphasis supplied)

The US National Virtual Observatory (NVO) now observes the sky and its stars and planets and other rare objects.²⁴ The nation's Space Physics & Aeronomy Research Collaboratory (SPARC) now observes the Earth's atmosphere.²⁵ LINNE will observe that thin membrane of organisms wrapped around Earth that is the sheer totality of life — and the future of life.²⁶ Out of many intellectual justifications for LINNE, the President's own office of Science and Technology Policy, has said it best: "[Grand Challenges are] characteristic of humanity's resolve to find solutions . . . that go far beyond mere intellectual curiosity. It is embedded in humanity's very nature to conquer new frontiers for social, economic, and political advancement."²⁷ To that we would only add that it is also embedded in humanity's very nature to conquer new frontiers for science.

Yet LINNE will be both an observatory trained on the Earth's membrane of life, and a new knowledge environment for understanding the totality of organisms which inhabit

it.²⁸ As a new, cyberinfrastructure-enabled knowledge environment for the science of systematics, LINNE will be poised to address several of the nation's priorities, for several decades to come. We recognize at least these connections between LINNE and our nation's priorities, and, thus, these additional, intellectual justifications for LINNE:²⁹

LINNE will:

- Help to maintain U.S. leadership in the science of systematics
- Help to maintain U.S. leadership in the development of cyberinfrastructures for science
- Help to maintain U.S. leadership in the development of knowledge environments for science
- Help to maintain U.S. homeland and national security through
 - greater knowledge about organisms which impact, or could impact, homeland or national security
- Help to promote public health and a healthy environment through
 - greater knowledge about organisms which impact, or could impact, health and
 - greater knowledge about organisms which impact, or could impact, the environment
- Help to promote a well-educated populace through disseminating greater knowledge about
 - living and extinct organisms
 - their occurrences
 - their taxonomic relationships
 - their evolutionary frameworks
- Help to promote economic prosperity through
 - greater knowledge about
 - living and extinct organisms
 - their occurrences
 - their taxonomic relationships
 - their evolutionary frameworks
- Help to promote a vibrant civil society, through social networks resulting from knowledge about and interest in:
 - living and extinct organisms
 - their occurrences
 - their taxonomic relationships
 - their evolutionary frameworks

In any, and all, of these ways, LINNE will help to meet our nation's priorities, and will yield significant advances of practical importance, for many decades to come.³⁰

As presented here, LINNE builds on the systematic community's *decadal vision* for taxonomy and natural history collections that was enunciated in the NSF Workshop in Gainesville, Florida in November 2003. There, the community called for natural history collections in the United States to be managed as one vast network of information and resources about organisms, with nodes in every state. The community's view was that only in this way could the nation's taxonomists and natural history collections realize their full potential, and only in this way could the nation's taxonomists and natural history collections

take on the challenges that they are being asked — and will be asked — to face. Not the least among the challenges the community recognized in Gainesville were the production of a predictable classification of life on earth and the development of strategies for countering the loss of biodiversity almost everywhere.³¹ LINNE, as *a vast network of information and resources about organisms, with nodes in every state*, remains an underlying conception in this Report on developing a national systematics infrastructure. And the challenges recognized in Gainesville remain central to the Grand Challenges recognized in this Report.

Finally, LINNE, as presented in this Report, specifically addresses the purposes and goals of this NSF Workshop “to convene representatives of the systematic biology community in a workshop to envision and plan a national systematics infrastructure to support rapid advancements in taxonomic research for the 21st century.” In funding and participating in this Workshop, the systematics community and NSF recognized that “Recent advances in digital technologies make possible an integrated nationwide virtual platform that can transform how fundamental taxonomic work is done and how taxonomic information and knowledge are made accessible to biologists and society.”³² This Report envisions and begins defining that national systematics infrastructure for the 21st century. It also recognizes that the recent advances in technology make the time to act, now.

3. Development of a National Systematics Infrastructure: LINNE’s Project Definition – Central Questions and Organizing Principles

Yet LINNE could fail.³³ Grand Challenges are, by their very nature, “destination[s] that [lie] far beyond current human understanding and capability”³⁴ We have kept these perils and challenges in mind. Nevertheless, we begin.³⁵

A. Central Focus and Scientific Questions

We begin LINNE and LINNE’s proposed project definition with a set of specific questions. These are the fundamental, scientific questions that systematists know to ask today.³⁶ We believe that these fundamental, scientific, and systematic questions should be the foundation with which to begin LINNE:

“What are the Earth’s living and extinct organisms, where do they occur, what are their taxonomic relationships, and what are their evolutionary frameworks?”

Because LINNE will be a *national* systematics infrastructure, we believe that LINNE should give priority to this subset of questions:

“What are the living and extinct organisms found within the United States, where do they occur, what are their taxonomic relationships, and what are their evolutionary frameworks?”

We propose these two sets of scientific questions as the central focus of LINNE.

But how to proceed, *with best effect*, from a set of identified, fundamental, scientific, and systematic questions for LINNE to: (a) federation of distributed systematics facilities

and equipment and instrumentation; (b) a cyberinfrastructure-enabled knowledge environment for systematics; and (c) a virtual systematics community coalesced around LINNE? Put another way, how to proceed from LINNE's central questions to development of a national systematics infrastructure???

We propose that LINNE's federation, cyberinfrastructure, and virtual community should develop — from the outset — according to a definite set of organizing principles that the systematics community can all agree upon. Organizing principles would direct and authorize the development of a systematics infrastructure for the nation that would be in conformity with principles agreed to by the systematics community. Organizing principles would also confine any development of a national systematics infrastructure that would not be in conformity with those principles. We have, therefore, proposed five intelligible, ³⁸ interdependent, and mutually-reinforcing organizing principles. ³⁹ Together, these organizing principles constitute a framework and direction for beginning LINNE. These five Organizing Principles for a national systematics infrastructure are presented below.

Organizing Principles for Defining and Beginning LINNE

The first two organizing principles relate to LINNE as primarily a *science-driven*, national systematics infrastructure:

- Principle 1. LINNE shall be a new infrastructure, within the United States, of geographically distributed systematics nodes. These nodes shall include:
- (i) systematics institutions; (ii) experimental systematics facilities;
 - (iii) systematics collections and other storage facilities; (iv) systematics data archives; and (v) systematics computing powers. ⁴⁰
- (a) LINNE's nodes shall be developed, organized, linked, and/or federated in such a way as to enable new discoveries about the Earth's living and extinct organisms, their occurrences, their taxonomic relationships, and their evolutionary frameworks.
 - (b) LINNE shall give priority to developing, organizing, linking, and/or federating systematics nodes so as to enable new discoveries about living or extinct organisms occurring within the United States, their occurrences, their taxonomic relationships, and their evolutionary frameworks.
 - (c) LINNE shall seek to include systematics nodes that will enable new discoveries about:
 - i. organisms within the 5 Kingdoms of Monera, Protista, Animalia, Fungi, and Plantae, and any additional kingdoms that may be discovered or described in the future, and
 - ii. organisms within the 3 Domains of Archaea, Bacteria, and Eubacteria, and any additional domains that may be discovered or described in the future, and
 - iii. those intracellular 'parasites' that are progressively less alive in terms of being metabolically active, that is, Viruses, Viroids,

- and Prions, and any additional such organisms that may be discovered or described in the future, and
- iv. extinct organisms, and
- v. any other type or class of organism, as yet undiscovered or undescribed, which does not fit into any of the categories i-iv listed above.

(d) Development, organization, linking, and federation of systematics nodes under LINNE shall be voluntary and not mandatory.

Principle 2. LINNE shall be a new virtual establishment (a virtual community) of the nation's geographically distributed systematists.

- (a) LINNE's virtual community shall be established in such a way as to enable new discoveries about the Earth's living and extinct organisms, their occurrences, their taxonomic relationships, and their evolutionary frameworks.
- (b) LINNE shall give priority to establishing a virtual community so as to enable new discoveries about living and extinct organisms occurring within the United States, their occurrences, their taxonomic relationships, and their evolutionary frameworks.
- (c) LINNE shall seek to include in its virtual community, systematists, having as their area of expertise or study:
 - i. organisms within the 5 Kingdoms of Monera, Protista, Animalia, Fungi, and Plantae, and any additional kingdoms that may be discovered or described in the future, and
 - ii. organisms within the 3 Domains of Archaea, Bacteria, and Eubacteria, and any additional domains that may be discovered or described in the future, and
 - iii. those intracellular 'parasites' that are progressively less alive in terms of being metabolically active, that is, Viruses, Viroids, and Prions, and any additional such organisms that may be discovered or described in the future, and
 - iv. extinct organisms, and
 - v. any other type or class of organism, as yet undiscovered or undescribed, which does not fit into any of the categories i-iv listed above.
- (d) LINNE shall seek to include in its virtual community those scientists who, while not identifying themselves primarily as systematists, nevertheless having as areas of expertise or study, living or extinct organisms, their occurrences, their taxonomic relationships, and their evolutionary frameworks.

- (e) LINNE's virtual community shall seek to include systematists or other scientists, residing outside the nation, who have, as their areas of expertise or study, living or extinct organisms occurring within the nation, their occurrences, their taxonomic relationships, and their evolutionary frameworks.
- (f) LINNE's virtual community shall include those others, such as technicians, engineers, programmers, and support staff, who are working to build LINNE, and/or helping to enable LINNE's new discoveries about the Earth's living and extinct organisms, their occurrences, their taxonomic relationships, and their evolutionary frameworks.⁴¹
- (g) Membership in LINNE's virtual community shall be voluntary and not mandatory.

B. Scientific Answers

LINNE's scientific questions will, of course, yield answers to systematic questions. These current systematic answers and data will, in turn, lead us onward toward our Grand Challenge destination of discovering and describing the totality of organisms that compose the Earth's membrane of organisms.

Organizing Principles for Defining and Beginning LINNE

This second set of organizing principles, then, relates to LINNE as both (a) a *mission-oriented*, national systematics infrastructure, and (b) a national *observatory* focused on the Earth's membrane of organisms.

Principle 3. LINNE shall include mechanisms and procedures, to link systematics answers and systematics data, in such a way as to build a composite picture and understanding of the Earth's living and extinct organisms, their occurrences, their taxonomic relationships, and their evolutionary frameworks.

- (a) LINNE's mechanisms and procedures, to link systematics answers and systematics data, shall prioritize building a composite picture and understanding of living and extinct organisms occurring within the United States, their occurrences, their taxonomic relationships, and their evolutionary frameworks.

Principle 4. LINNE shall further develop mechanisms and procedures, to link systematics answers and systematics data, in such a way as to build a dynamic, composite picture and understanding (that is, an observatory) of the totality of organisms, that make up the Earth's membrane of organisms.

- (a) LINNE shall prioritize developing mechanisms and procedures, to link systematics answers and systematics data, in such a way as to build a dynamic, composite picture and understanding (that is, an observatory) of

the totality of organisms, that make up that portion of the Earth's membrane of organisms, that is wrapped around the United States.

C. Learning System

The fifth organizing principle will not support and enable LINNE's central, inward, scientific focus. Nor will it support the building up of composite pictures of taxonomic relationships, or of evolutionary frameworks, or of the Earth's totality of organisms, or of the Earth's membrane of organisms. Rather, it will turn outward and support and enable the transfer of systematics knowledge outside of the systematics community, and outside of the systematics nodes.

Organizing Principles for Defining and Beginning LINNE

This final organizing principle, then, relates to LINNE as primarily an *education- and outreach-oriented*, national systematics infrastructure.

Principle 5. LINNE's knowledge environment, enabled by Organizing Principles 1, 2, 3, and 4 above, shall be made available as a learning system for use by the general public.⁴²

- (a) LINNE's learning system for use by the general public shall enable the public to learn about the Earth's living and extinct organisms, their occurrences, their taxonomic relationships, and their evolutionary frameworks.
- (b) LINNE's learning system for use by the general public shall prioritize enabling the public to learn about living and extinct organisms found within the United States, their occurrences, their taxonomic relationships, and their evolutionary frameworks.
- (c) LINNE's learning system for use by the general public shall be further developed to enable the public to learn about the totality of organisms that compose the Earth's membrane of organisms.
- (d) LINNE's learning system for use by the general public shall be developed to prioritize enabling the public to learn about the totality of organisms, that compose that portion of the Earth's membrane of organisms, that is wrapped around the United States.

In summary, this Report defines LINNE with two central, Scientific Questions and a set of five, intelligible, interdependent, and mutually reinforcing Organizing Principles. Together, the five Organizing Principles constitute a framework and direction for beginning LINNE. Because the Organizing Principles would authorize actions in conformity with them, they represent an effective way to proceed *from* LINNE's identified Scientific Questions *to* development of a national systematics infrastructure focused on those questions.

4. Development of a National Systematics Infrastructure: LINNE's Project Definition – Proposed Workshops for Further Definition

We believe that it is now time to engage the larger systematics community in focused discussions on development of a national systematics infrastructure. This Report proposes eight further workshops or series of workshops for discussions on defining and beginning LINNE. Each workshop or workshop series would focus on a different but fundamental aspect of development. Suggestions for these further workshops came from our Workshop working group discussions, and from a comparison of our Workshop discussions with documentation on building various other cyberinfrastructure-enabled knowledge environments. They also flow directly from the intelligible Organizing Principles set out for LINNE in the previous section. Finally, the ideas for these Workshops received major inspiration from the presentations by Workshop participants, and from the participants' excitement at the new tools and opportunities emerging for systematics .

The discussion of proposed workshops below will include: (a) the purpose of the proposed workshop (b) the aspect of LINNE to be discussed and the Organizing Principles involved in the proposed workshop; (c) this Report's recommendations for the proposed workshop that would be in conformity with the Organizing Principles involved; (d) this Report's recommendations for the proposed workshop that would promote integration with other aspects of LINNE; and (e) additional recommendations, justifications, and comments.

A. Eight Proposed Workshops for Further Definition of LINNE

Proposed Workshop Series 1. Enabling New Science With LINNE⁴³

A. Purpose:

Workshop/s to identify a few specific, initial, cutting edge systematics research projects, enabled by LINNE, that would lead to new discoveries about living and extinct organisms occurring within the United States, their occurrences, their taxonomic relationships, and their evolutionary frameworks.

B. Aspect of LINNE and Organizing Principles Involved:

Aspect: LINNE as a *science-driven*, national systematics infrastructure.

Organizing Principles: 1 and 2.

C. Conformity with Organizing Principles:

Initial projects discussed at these workshops, and selected for LINNE, should be chosen to span research within the five Kingdoms of Monera, Protista, Animalia, Fungi, and Plantae, or the three Domains of Archaea, Bacteria, and Eukaryota; and extinct organisms; and those 'intracellular parasites' that are progressively less alive in terms of being metabolically active, that is, Viruses, Viroids, and Prions.

D. Additional Recommendations and Justifications:

These workshops and these initial projects would effectuate:

- Making real for all of the nation's systematists, the community-wide consensus and effort that we have reached, in principle, in this Workshop
- Jumpstarting LINNE as a systematics infrastructure for the nation

- Identifying and guiding first appropriate development, organization, linking, and/or federation of systematics nodes under LINNE
- Quickly identifying those most striking commonalities and differences that will be encountered, when uniting systematics answers, or specific questions, or data, from various systematics subdisciplines, under a national systematics infrastructure (LINNE)
- Providing a strong force for the first coalescing of a broad, virtual community around LINNE

E. Additional Comments:

There are many new and exciting tools emerging for systematics that can and will be used to remove the taxonomic impediment. Among them, but not limited to, are:

- DNA Bar Coding
- Remote Robotics for specimen examination
- CatScans for examination of internal structure of both extant plants and animals and fossils
- Digitization of specimens, protologues, label information, field notes and images, etc.
- GPS and GIS interfaces
- Genomic and proteomic tools for phylogenetic assessments and genetic diversity

Proposed Workshop Series 2. Establishing LINNE's Virtual Community

A. Purpose:

Workshop/s to determine first and best practices, procedures, and methods for establishing LINNE's virtual community in the nation, so as to enable new discoveries about living and extinct organisms occurring within the United States, their occurrences, their taxonomic relationships, and their evolutionary frameworks.

B. Aspect of LINNE and Organizing Principles Involved:

Aspect: LINNE as a *science-driven*, national systematics infrastructure.

Organizing Principle: 2.

C. Conformity with Organizing Principles:

Discussions of first and best practices, procedures, and methods for establishing LINNE's virtual community within the nation should include:

- Discussion of an appropriate governance model for LINNE.⁴⁴
- Representation at the Workshops — and in the governance system adopted for LINNE — by systematists, spanning research within the five Kingdoms of Monera, Protista, Animalia, Fungi, and Plantae, or the three Domains of Archaea, Bacteria, and Eukaryota; and extinct organisms; and those 'intracellular parasites' that are progressively less alive in terms of being metabolically active, that is, Viruses, Viroids, and Prions.
- Representation at the Workshops by appropriate members of the scientific community, who, while not identifying themselves primarily as systematists,

nevertheless having as areas of expertise or study, living or extinct organisms, their occurrences, their taxonomic relationships, and their evolutionary frameworks.

- Representation at the Workshops by appropriate others, such as technicians, engineers, programmers, and support staff, who will be working to build LINNE and/or helping to enable LINNE's new discoveries about the Earth's living and extinct organisms, their occurrences, their taxonomic relationships, and their evolutionary frameworks.

D. Recommendations for Promoting Integration with Other Aspects of LINNE:

Discussions of first and best practices, procedures, and methods for establishing LINNE's virtual community within the nation should include:

- Discussion of appropriate virtual community support for the initial systematics research projects enabled by LINNE, that will also begin to publicize LINNE (see recommended workshops *Enabling New Science With LINNE* above).

E. Additional Recommendations, Justifications, and Comments:

Discussions of first and best practices, procedures, and methods for establishing LINNE's virtual community within the nation should include:

- Discussion of appropriate technical practices such as (a) newsgroups; (b) mailing lists; (c) internet relay chat (IRC); (d) MUDs/MOOs; (e) bulletin boards; and (f) computer conferencing to:
 - create and maintain personal relationships in cyberspace.
 - create and maintain small communities in cyberspace.
 - create and maintain public squares in cyberspace.
 - create and maintain small and large arenas in cyberspace.⁴⁵

Additionally, this Report strongly recommends that workshops addressing the establishment of LINNE's virtual community, also address the membership in LINNE of existing systematics associations, organizations, and societies. To this end, we recommend that representatives of existing systematics associations, organizations, and societies, acting in their official capacities, be involved in this series of workshops.

This Report recognizes the vital importance of existing systematics bodies for the support and success of LINNE. It was, indeed, "on the tip of our tongue" to set out an additional, intelligible organizing principle indicating that LINNE would add a national web without competing with the work that member systematics associations, organizations, and societies do best on their own. Perhaps, however, it is unconscionable to make such a broadcast, about membership in LINNE and relationship to LINNE, without hearing the measured voices of the systematics associations, organizations, and societies, themselves.

Finally, sister research communities who are further along in the development of their cyberinfrastructure-enabled knowledge environments repeatedly emphasize, in their development literature and presentations, that these new knowledge environments can hang — or fall — on the social systems that are part of their total systems.⁴⁶ Therefore, this Report recommends that

this series of workshops on establishing LINNE’s virtual community, also include discussions on building LINNE as a successful social organization. A wealth of literature exists on building successful initiatives, collaborations, and organizations from a social standpoint. As an example, we present here recommendations modeled after just one such source explored. This example and recommendation would also be in conformity with LINNE’s Organizing Principles:⁴⁷

1. Recruit into LINNE the *exceptional scholars* who work throughout the 5 Kingdoms of Monera, Protista, Animalia, Fungi, and Plantae, or the 3 Domains of Archaea, Bacteria, and Eukaryota; and extinct organisms; and those ‘intracellular parasites’ that are progressively less alive in terms of being metabolically active, that is, Viruses, Viroids, and Prions. *Exceptional scholars* are those who combine a *vision* of systematics, *expertise* in systematics, a *passion* for systematics, and a *daily commitment* to systematics.
2. Have these well-known *exceptional scholars* voice their commitments to the new (and perhaps unorthodox) idea of LINNE, in union with those younger people trying to establish LINNE. This will help to energize LINNE’s base of support.
3. Have these well-known *exceptional scholars* express and demonstrate their shared inspiration and commitment to bridging systematics subdisciplines and systematics schools of thought when necessary to answer important systematics questions. These are the types of questions too big to be faced by any single subdiscipline in systematics, but also those that are likely to “strike at the heart of change,” both in American culture⁴⁸ and in the culture of the science of systematics. On a practical note, this type of problem solving should open up new and diverse sources of funding, in itself a driver for collaborative work bridging systematics subdisciplines.

Proposed Workshop Series 3. LINNE As A Network of Place-Based Systematics Nodes

A. Purpose:

Workshop/s to explore avenues for developing, organizing, linking, and/or federating place-based systematics nodes under LINNE. LINNE’s nodes, as indicated above, are to include: (a) systematics institutions; (b) experimental systematics facilities; (c) systematics collections and other storage facilities; (d) systematics data archives; and (e) systematics computing powers.⁴⁹

B. Aspect of LINNE and Organizing Principles Involved:

Aspect: LINNE as a *science-driven*, national systematics infrastructure.

Organizing Principle: 1.

C. Comments and Justifications:

This Report recognizes the essential fact that many — if not most — of the systematics nodes required for initiating a new, national systematics infrastructure, already exist in nascent form. These nascent, systematics nodes for LINNE are the same repositories, located throughout the nation, that the community of systematists has been adding to since at least the time of Linné more than 250 years ago.⁵⁰ Distributed throughout the States, these systematics repositories contain the nation’s heritage biological collections.⁵¹

They also contain all of the known *information* about those heritage collections, plus substantially all of the known information *about the living and extinct organisms* of which those collections are analogs. The heritage collections, and their accompanying information, and the repositories in which they reside, make LINNE possible. Federated, they will, we believe, be the actual heart and core of LINNE.

This Report recognizes that the nation's vast and distributed storehouse of heritage biological collections, will be LINNE's vast, *new data* mine. The value of *past* scientific collections for *ongoing* scientific discovery is often poorly understood. In fact, with each new technological advance in systematics research, heritage biological collections are mined for new scientific data.⁵² This Report, therefore, recognizes that the nation's heritage biological collections will be essential, over the next decades, for helping taxonomists and systematists to understand that portion of the Earth's membrane of organisms, that is wrapped around the United States.⁵³

This Report also recognizes that existing, experimental systematics facilities represent nascent systematics nodes for LINNE. We, believe, however, that the experimental systematics facilities currently in existence throughout the nation are inadequate to support the whole systematics community and, going forward, to support LINNE. This Report, therefore, proposes a new, National Systematics Laboratory that could also be a central, systematics node for LINNE. We envision a National Systematics Laboratory as serving the entire systematics community (all taxa and all organisms), and as providing specialized services and instrumentation (e.g., Cat scans), and providing specialized analyses (e.g. genome analyses). These services, instrumentations, and analyses are currently not available to many systematics researchers, or are prohibitively expensive for some individual projects.

In summary, then, this Report recognizes that many — if not most — of LINNE's initial, systematics nodes already exist throughout the nation in nascent form, but that there is an additional need for a new National Systematics Laboratory that could be a central node for LINNE.

D. Conformity with Organizing Principles:

Planning for LINNE's place-based systematics nodes will, no doubt, go forward on a State or regional basis, in addition to a national one. Based on Organizing Principle 1 and our comments above, this Report recommends that the following planning measures be considered in the series of workshops, *LINNE As A Network of Place-Based Systematics Nodes* :

- The initial selection, and the comprehensive selection, of LINNE's place-based systematics nodes, should enable new discoveries about the Earth's living and extinct organisms, their occurrences, their taxonomic relationships, and their evolutionary frameworks.
- The initial selection, and the comprehensive selection, of LINNE's place-based systematics nodes, should give priority to enabling new discoveries about living or extinct organisms occurring within the United States, their occurrences, their taxonomic relationships, and their evolutionary frameworks.

- The initial selection, and the comprehensive selection, of LINNE’s place-based systematics nodes should enable new discoveries about organisms within the 5 Kingdoms of Monera, Protista, Animalia, Fungi, and Plantae, or the 3 Domains of Archaea, Bacteria, and Eubacteria, and extinct organisms, and those intracellular ‘parasites’ that are progressively less alive in terms of being metabolically active, that is, Viruses, Viroids, and Prions.
- D. Recommendations for Promoting Integration with Other Aspects of LINNE:
- The initial selection of LINNE’s place-based systematics nodes should support the specific, initial, cutting edge systematics research projects identified to jumpstart LINNE and to publicize LINNE (*see* Workshop Series 1, *Enabling New Science With LINNE*)
- E. Additional Recommendations for this Workshop:
- The initial selection, and the comprehensive selection, of LINNE’s place-based systematics nodes should include consideration of the proposed National Systematics Laboratory as a new, central node for LINNE.
 - The initial selection, and the comprehensive selection, of LINNE’s place-based systematics nodes should consider as primary candidates, the currently existing repositories of the nation’s biological heritage collections.

Proposed Workshop Series 4. *LINNE As Semantic Web* ⁵⁴

A. Purpose:

Workshop/s to identify best methods, practices, and procedures for federating, fusing, exploring, and mining the nation’s systematics data on living and extinct organisms, their occurrences, their taxonomic relationships, and their evolutionary frameworks.

B. Aspect of LINNE and Organizing Principles Involved:

Aspect: LINNE as a *science-driven*, national systematics infrastructure.

Organizing Principles: 1 and 2.

C. Comments and Justifications:

This Report recognizes the essential fact that the many, heterogenous, systematics data sets throughout the nation, nevertheless contain a homogenous core. This homogenous core in the nation’s distributed, systematics data sets results directly from the standardized use, for more than 250 years, of binomial nomenclature for identifying, naming, and discussing organisms. ⁵⁵ This is, at once, the great contribution of Linné, the shared language of the various systematics subdisciplines, and the shared language of LINNE. Nevertheless, substantial challenges remain to federate, fuse, explore, and mine the data and information from the entire discipline of systematics in this nation. Among the challenges will be to develop new and appropriate (a) standards, (b) production software, (c) programming tools, and (d) data access and analysis.

D. Conformity with Organizing Principles:

LINNE’s federation, fusing, exploration, and mining of data were not major or explicit focuses of this Workshop. This Report, however, recognizes some initial recommendations for the workshop series, *LINNE As Semantic*

Web:

- The initial plans for federating, fusing, exploring, and mining the nation's systematics data — and the comprehensive plans for federating, fusing, exploring, and mining the nation's systematics data — should have as their primary goal to enable new discoveries about the Earth's living and extinct organisms, their occurrences, their taxonomic relationships, and their evolutionary frameworks.
- The the initial plans for federating, fusing, exploring, and mining the nation's systematics data — and the comprehensive plans for federating, fusing, exploring, and mining the nation's systematics data — should prioritize, within their primary goal, the enabling of new discoveries about living and extinct organisms occurring within the United States, their occurrences, their taxonomic relationships, and their evolutionary frameworks.
- The initial plans for federating, fusing, exploring, and mining the nation's systematics data — and the comprehensive plans for federating, fusing, exploring, and mining the nation's systematics data — should have, as an additional goal, the enabling of new discoveries about organisms within the 5 Kingdoms of Monera, Protista, Animalia, Fungi, and Plantae, or the 3 Domains of Archaea, Bacteria, and Eubacteria, and extinct organisms, and those intracellular 'parasites' that are progressively less alive in terms of being metabolically active, that is, Viruses, Viroids, and Prions.

D. Recommendations for Promoting Integration with Other Aspects of LINNE:

- The initial plans for federating, fusing, exploring, and mining the nation's systematics data should support the specific, initial, cutting edge systematics research projects identified to jumpstart LINNE and to publicize LINNE. (*see* Workshop Series 1, *Enabling New Science With LINNE*).
- The initial plans for federating, fusing, exploring, and mining the nation's systematics data — and the comprehensive plans for federating, fusing, exploring, and mining the nation's systematics data — should consider the proposed, new, National Systematics Laboratory as a central node for LINNE.
- The initial plans for federating, fusing, exploring, and mining the nation's systematics data — and the comprehensive plans for federating, fusing, exploring, and mining the nation's systematics data — should specifically support and enable the initial selection, and the comprehensive selection, of LINNE's place-based systematics nodes (*see* Workshop Series 3, *LINNE As A Network of Place-Based Systematics Nodes*).

Proposed Workshop Series 5. *LINNE As Composite Picture And Understanding Of The Diversity Of Life*⁵⁶

A. Purpose:

Workshop/s to consider initial and best mechanisms and procedures, to link LINNE's systematics answers and systematics data, so as to build a *composite picture and understanding* of the Earth's living and extinct organisms, their

occurrences, their taxonomic relationships, and their evolutionary frameworks.⁵⁷

B. Aspect of LINNE and Organizing Principles Involved:

Aspect: LINNE as *tree-of-life* and other *composite pictures* — both science-driven and mission-oriented.

Organizing Principle: 3.

C. Conformity with Organizing Principles:

The purpose of this proposed workshop is coequal with Organizing Principle 3.

D. Recommendations for Promoting Integration with Other Aspects of LINNE:

The initial plans for federating, fusing, exploring, and mining the nations' systematics data should also support the development of LINNE in its aspect as composite picture and understanding of the diversity of life (*see* Workshop Series 4, *LINNE As Semantic Web*.)

D. Comments and Justifications:

In the past few years, the systematics community has engaged in debate on the challenges to be faced in assembling a tree of life — and the perceived benefits to be had in doing so.⁵⁸ The tree of life on Earth is, of course, a most important picture and understanding of the diversity of life. The community's debate on assembling the tree of life can now proceed anew — with LINNE making possible this framework for a modern understanding of biology.

E. Additional Recommendations:

As the community has already recognized, efforts such as assembling the tree of life will require unprecedented coordination and collaboration.⁵⁹ So, too, with developing this overall aspect of LINNE. This Report notes just three of many aspects of coordination and collaboration to be considered by the community in the proposed series of workshops, *LINNE As Composite Picture and Understanding Of The Diversity Of Life*.

- Linking systematics data and the results of systematics research into composite pictures implies that data and research results will largely be available, accessible, affordable, and without restrictions on their use. Yet formal intellectual property rights and traditions of informal data exchange among systematics researchers affect availability, accessibility, affordability, and restrictions on the use of scientific information. How will traditions of data exchange among researchers and formal property rights in scientific information affect this aspect of LINNE — and can the community do anything about it?⁶⁰
- Solitary scholarship in taxonomy and systematics — driven by individual choice, in a manner dictated by individual curiosity, and resulting in individual ends — will continue to be a traditional part of the community's way of work. But LINNE, just as other cyberinfrastructure-enabled knowledge environments have done, will catalyze a new paradigm for work in taxonomy and systematics. That paradigm will involve teams of scholars, often working together over geographic distances, and even over systematics subdisciplines, to answer complex systematics questions.⁶¹ What mechanisms and procedures does the community need to successfully link data and research results

from both work paradigms under LINNE? Should incentives be put into place to induce solitary researchers, or teams of researchers, to understand and assemble *particular missing parts* of Earth's tree of life, contained in LINNE?

- LINNE will not just receive data, but will, itself, be a facility for data publication. What will the community consider and accept as *publication*, and what will be the proper attribution, for example, when: (a) data contained in LINNE is used to complete a piece of research; (b) the research results are quickly published — perhaps just within LINNE, itself; and then (c) the derived data and research results are themselves incorporated into LINNE? ⁶²

Workshop Series 6. LINNE As National Observatory Focused On The Earth's Membrane Of Organisms ⁶³

A. Purpose:

Workshop/s to consider first and best mechanisms and procedures, to federate and fuse the nation's systematics data, and to construct LINNE's semantic web, so as to build LINNE as a national systematics observatory.

B. Aspect of LINNE and Organizing Principles Involved:

Aspect: LINNE as *national observatory* — both science-driven and mission-oriented.

Organizing Principle: 4.

C. Conformity with Organizing Principles:

The purpose of this proposed workshop is coequal with Organizing Principle 4.

D. Recommendations for Promoting Integration with Other Aspects of LINNE:

The initial plans for federating, fusing, exploring, and mining the nation's systematics data should also support the development of LINNE as a national observatory focused on the Earth's membrane of organisms (*see* Workshop Series 4, *LINNE As Semantic Web*).

E. Comments and Justifications:

We recognize the essential fact that the nation lacks a fundamental and full accounting of its organisms, as those organisms occur within its borders. ⁶⁴ We also recognize that, without this fundamental and full accounting, the nation cannot make best, informed decisions about many issues in which organisms are a factor. ⁶⁵

We have agreed that the federating and fusing of the nation's systematics data under LINNE, and the ability of LINNE's semantic web to further organize that information, can make possible, in these next decades, this needed, fundamental, and full accounting of the nation's organisms. ⁶⁶

In addition, we have agreed that the federating and fusing of the nation's systematics data under LINNE, and the ability of LINNE's semantic web to further organize that information, can make possible, in these next decades, a composite picture and understanding of the physical *occurrences* of the nation's organisms, within the nation's borders. ⁶⁷

Finally, we have agreed that the federating and fusing of the nation's

systematics data under LINNE, and the ability of LINNE's semantic web to further organize that information, can make possible, in these next decades, a *dynamic* accounting and composite picture of the nation's organisms — that is, an observatory, in the true sense of the word.⁶⁸

We recognize that these are issues of the greatest possible consequence. We also recognize that the community's decisions, on these aspects of LINNE's development, will have major impacts for both science and society.

F. Conformity with Organizing Principles:

This Report advances only one fundamental recommendation for the Workshop Series, LINNE *As National Observatory Focused On The Earth's Membrane of Organisms*:

- The first and best mechanisms and procedures, to federate and fuse the nation's systematics data, and to construct LINNE's semantic web, should prioritize building a dynamic, composite picture and understanding (that is, an observatory) of the totality of organisms, that make up that portion of the Earth's membrane of organisms, that is wrapped around the United States.

Proposed Workshop Series 7. LINNE As A Virtual AND Place-Based Learning System

A. Purpose:

Workshop/s to consider first and best mechanisms and procedures for making LINNE's knowledge environment available as a learning system for use by the general public.⁶⁹

B. Aspect of LINNE and Organizing Principles Involved:

Aspect: LINNE as *learning system*.

Organizing Principle: 5.

C. Conformity with Organizing Principles:

This Report has set out intelligible Organizing Principles for LINNE that include broad outlines for LINNE's learning system for the general public. According to Organizing Principle 5, this proposed workshop should consider LINNE as:

- ENABLING THE PUBLIC to learn about the Earth's living and extinct organisms, their occurrences, their taxonomic relationships, and their evolutionary frameworks.
- PRIORITIZING ENABLING THE PUBLIC to learn about living and extinct organisms occurring within the United States, their occurrences, their taxonomic relationships, and their evolutionary frameworks
- ENABLING THE PUBLIC to learn about the totality of organisms that compose the Earth's membrane of organisms
- PRIORITIZING ENABLING THE PUBLIC to learn about the totality of organisms, that compose that portion of the Earth's membrane of organisms, that is wrapped around the United States.

D. Additional Recommendations:

This Report also makes the following, initial recommendations for LINNE's education and outreach, and for discussion at this series of workshops. These recommendations follow from our Workshop working

group discussions and from a comparison of our discussions with other knowledge environment learning systems:⁷⁰

- *For Formal Education Through College Level:* LINNE's data — and appropriate of its heritage biological collections — should be used as a basis for creating educational resources that are directly relevant to curricula. These education resources are envisioned as being inquiry-based, and also online, hands-on, and hard-copy.
- *For Informal Education:* LINNE should be integrated with its place-based, systematic nodes, such as natural history museums, *and* with other, appropriate place-based institutions that may not be nodes, such as science centers. Integration should include making LINNE's data — and appropriate of its heritage biological collections — readily usable by informal science educators, exhibit designers, and program developers.
- *For Online Outreach:* LINNE should have as its goal to become the nation's major portal for public and education community access to information about organisms. Access should include user-friendly interfaces for both novice and advanced users. Products should include such things as lesson plans, curriculum products, multi-media products, and educational games.

Proposed Workshop Series 8. *Let No Lesson Remain Unknown – LINNE As A Source of Information For Policy- and Decision-makers.*⁷¹

A. Purpose:

Workshop/s to consider first and best mechanisms and procedures for building LINNE as a source of information for policy- and decision-makers.

B. Aspect of LINNE and Organizing Principles Involved:

Aspect: LINNE as *learning system*.

Organizing Principle: 5.

C. Conformity with Organizing Principles:

This Report has set out intelligible Organizing Principles for LINNE that include broad outlines for LINNE's learning system for the general public. According to Organizing Principle 5, this proposed workshop should consider LINNE as:

- ENABLING THE PUBLIC to learn about the Earth's living and extinct organisms, their occurrences, their taxonomic relationships, and their evolutionary frameworks.
- PRIORITIZING ENABLING THE PUBLIC to learn about living and extinct organisms occurring within the United States, their occurrences, their taxonomic relationships, and their evolutionary frameworks
- ENABLING THE PUBLIC to learn about the totality of organisms that compose the Earth's membrane of organisms
- PRIORITIZING ENABLING THE PUBLIC to learn about the totality of organisms, that compose that portion of the Earth's membrane of organisms, that is wrapped around the United States.

D. Additional Recommendations and Justifications:

This Report has recognized the essential fact that LINNE **relates directly to**

several, identified, national priorities.⁷² Among these are (a) Homeland and National Security, (b) public health, (c) a healthy environment, and (d) economic prosperity. This Report, therefore, recommends that this series of workshops consider appropriate mechanisms and procedures to timely *notify* appropriate policy- and decision-makers, about knowledge that LINNE acquires, that may impact one of these national priorities.

Based on a comparison of this aspect of LINNE with other cyberinfrastructure-enabled knowledge environments, this Report also recommends that LINNE's portal provide a user-friendly interface, specifically geared to policy- and decision-makers. This interface for policy- and decision-makers at LINNE's portal should allow policy- and decision-makers full and timely access to LINNE's data, when they need or desire to access it.

Finally, and also based on a comparison of LINNE with other cyberinfrastructure-enabled knowledge environments, this Report recommends that LINNE include an online product, such as press releases, that would provide new and ongoing information to the public. Press releases would be another mechanism for bringing LINNE's learning system to the general public and should, therefore:

- ENABLE THE PUBLIC to learn about the Earth's living and extinct organisms, their occurrences, their taxonomic relationships, and their evolutionary frameworks.
- PRIORITIZE ENABLING THE PUBLIC to learn about living and extinct organisms occurring within the United States, their occurrences, their taxonomic relationships, and their evolutionary frameworks
- ENABLE THE PUBLIC to learn about the totality of organisms that compose the Earth's membrane of organisms
- PRIORITIZE ENABLING THE PUBLIC to learn about the totality of organisms, that compose that portion of the Earth's membrane of organisms, that is wrapped around the United States.

Press releases should also inform the public about LINNE's ongoing connection to identified national priorities. They should, therefore, address:

- LINNE as helping to maintain U.S. leadership in the science of systematics
- LINNE as helping to maintain U.S. leadership in the development of cyberinfrastructures for science
- LINNE as helping to maintain U.S. leadership in the development of knowledge environments for science
- LINNE as it impacts national priorities, including:
 - Homeland and National Security
 - Health and Environment
 - Economic Prosperity
 - A Well-Educated Populace and
 - A Vibrant Civil Society

B. Summary of Proposed Workshops

In summary then, this Report proposes eight further workshops or series of workshops for further defining and planning LINNE. This set of eight proposed workshops/series of workshops would cover all identified aspects of LINNE. As a set, therefore, these proposed workshops represent a *comprehensive* further planning for LINNE.

Four proposed workshops/series of workshops would be devoted to Organizing Principles 1 and 2 — LINNE as a *science-driven*, national systematics infrastructure. These four workshops/series of workshops are: (1) *Enabling New Science With LINNE*; (2) *Establishing LINNE's Virtual Community*; (3) *LINNE As A Network OF Place-Based Systematics Nodes*; and (4) *LINNE As Semantic Web*. This is the core aspect of LINNE.

One proposed workshop/series of workshops would be devoted to Organizing Principle 3, and the purpose of this proposed workshop would be coequal with that Principle. This proposed workshop/series of workshops is *LINNE As Composite Picture And Understanding Of The Diversity Of Life*. Here, a Tree of Life is identified as one type of “composite picture and understanding of the diversity of life.” And this aspect of LINNE is recognized as being both *science-driven* and *mission-oriented*.

Another proposed workshop/series of workshops would be devoted to Organizing Principle 4, and the purpose of the proposed workshop would be coequal with Principle 4. This proposed workshop/series of workshops is *LINNE As National Observatory Focused On The Earth's Membrane Of Organisms*. Here, the focus would be on: (a) a fundamental and full *accounting* of the Earth's and the nation's organisms, and (b) a composite picture and understanding of the *occurrences* of the Earth's and the nation's organisms. This aspect of LINNE is recognized as being both *science-driven* and *mission-oriented*. It is also recognized in its aspect as a dynamic, national *observatory*, in the true sense of the word.

The final, two proposed workshops/series of workshops would be devoted to Organizing Principle 5. These two workshops/series of workshops are: (1) *LINNE As A Virtual AND Place-Based Learning System*, and (2) *Let No Lesson Remain Unknown — LINNE As A Source Of Information For Policy- And Decision-Makers*. This is LINNE in its aspect as a *learning system* that enables the transfer of systematics knowledge outside of the systematics community and outside of the systematics nodes.

The suggestions for these further workshops came from our Workshop working group discussions, and from a comparison of our Workshop discussions with documentation on building various other cyberinfrastructure-enabled knowledge environments. They also received major inspiration from the presentations by Workshop participants.

Finally, because the set of workshops proposed here flow directly from the Organizing Principles set out for LINNE, they represent an effective way to proceed *from* LINNE's identified Scientific Questions *to* development of a national systematics infrastructure focused on those questions.

5. Development of a National Systematics Infrastructure: LINNE's Connection to NSF Strategic Plan, Goals, and Priorities

A. NSF Strategic Plan

LINNE, as conceived here, directly relates to — and reaches — the National Science Foundation’s specific and foundational objectives, and strategic plan, for ensuring excellence in the nation’s future science.⁷³ LINNE will:

- *Increase the number of scientists actively working with the nation’s organisms*, as LINNE builds up, and out, in order to:
 - enable new science
 - establish its virtual community
 - federate its place-based systematics nodes
 - construct its semantic web
 - build its composite picture and understanding of the diversity of life
 - establish its observatory focused on the Earth’s membrane of organisms
- *Strengthen the systematics subdisciplines*⁷⁴ in the United States through LINNE’s daily
 - access to ideas, and exchange of ideas
 - access to information, and exchange of information
 - access to knowledge, and exchange of knowledge
 - collaborative work
 - competitive work
 - personal relationships in cyberspace
 - small communities in cyberspace
 - public squares in cyberspace
 - small and large arenas in cyberspace
 - new funding opportunities⁷⁵
- *Strengthen research that crosses systematics subdisciplines*, specifically through:
 - LINNE’s initial workshops (*Enabling New Science With LINNE*) to identify first projects spanning research within the 5 Kingdoms of Monera, Protista, Animalia, Fungi, and Plantae, or the 3 Domains of Archaea, Bacteria, and Eukaryota; and extinct organisms; and those ‘intracellular parasites’ that are progressively less alive in terms of being metabolically active, that is, Viruses, Viroids, and Prions.
 and then daily through subsequent
 - cross-subdisciplinary access to ideas, and exchange of ideas
 - cross-subdisciplinary access to information, and exchange of information
 - cross-subdisciplinary access to knowledge, and exchange of knowledge
 - cross-subdisciplinary collaborative work
 - cross-subdisciplinary competitive work
 - cross-subdisciplinary personal relationships in cyberspace
 - cross-subdisciplinary small communities in cyberspace
 - cross-subdisciplinary public squares in cyberspace
 - cross-subdisciplinary small and large arenas in cyberspace
 - cross-disciplinary new funding opportunities⁷⁶
- *Modernize the nation’s systematics research infrastructure* by creating, establishing, and federating a new cyberinfrastructure-enabled-knowledge environment for systematics in these next decades (that is, LINNE, itself).

- *Strengthen work skills of the nation’s systematists* by making all of LINNE’s new capabilities open to all of LINNE’s new community.
- *Support and strengthen local, regional, and national innovation in systematics* through democratizing systematics research and education: LINNE’s data and knowledge, and the means to access that data and knowledge, will be available to students and researchers wherever they are in the United States.

B. NSF Goals

LINNE, as conceived here, also directly relates to — and rises to — the National Science Foundation’s long-term strategic goals as expressed in its *People, Ideas, and Tools* (PIT) framework.⁷⁷

1. *NSF’s People Goal: A diverse, competitive, and globally-engaged U.S. workforce of scientists, engineers, technologists, and well-prepared citizens.*

A Diverse Workforce of Scientists, Engineers, and Technologists

This Report has placed a premium on ensuring that LINNE’s virtual community will include all of the diverse subdisciplines of systematics that have been segmented from each other, in varying degrees, over the last 250 years.⁷⁸ This is, indeed, the direct objective of LINNE’s intelligible Organizing Principle 2. That Principle also sets out that LINNE’s workforce (its virtual community) shall seek to include appropriate scientists from outside of the systematics community and from outside the nation. It also specifically sets out that “LINNE’s virtual community shall include those others, such as technicians, engineers, programmers, and support staff, who are working to build LINNE, and/or helping to enable LINNE’s new discoveries about the Earth’s living and extinct organisms, their occurrences, their taxonomic relationships, and their evolutionary frameworks.”

A Competitive Workforce

As indicated above, LINNE will be poised to address several of the nation’s priorities.⁷⁹ Among these are: (a) maintaining U.S. leadership in the science of systematics; (b) maintaining U.S. leadership in the development of cyberinfrastructures for science; and (c) maintaining U.S. leadership in the development of knowledge environments for science. It will be LINNE’s technological advances that make this leadership possible — in combination with LINNE’s competitive and collaborative workforce.

LINNE, as a new knowledge environment for the whole community of systematics, will strive for the right community balance of:

- competitive spirit that will preserve researcher autonomy
- competitive spirit that will preserve the ability of systematics research to renew itself
- collaborative spirit that will foster research across subdisciplines to answer important systematics questions
- collaborative spirit that will foster the building of:
 - LINNE’s composite picture and understanding of living and extinct

organisms occurring within the United States, their occurrences, their taxonomic relationships, and their evolutionary frameworks. —LINNE’s composite picture and understanding of the totality of organisms, that make up that portion of the Earth’s membrane of organisms, that is wrapped around the United States.

A Globally-engaged Workforce

LINNE, as a *national* systematics infrastructure, does put first priority on: (a) building a composite picture and understanding of organisms occurring within the United States, and (b) building a systematics observatory focused on that portion of the Earth’s membrane of organisms that is wrapped around the United States. But, as systematists are well aware, nature does not know political boundaries. So, in fact, to build this national picture and national observatory, the nation’s systematists will necessarily be engaged with systematists from the global systematics community for discussion, comparison, exchange of ideas, and exchange of data about our nation’s organisms.

In addition, Organizing Principle 2 specifically sets out that LINNE’s virtual community shall seek to include systematists or other scientists, residing outside the nation, who have, as their areas of expertise or study, living or extinct organisms occurring within the nation.

A Workforce of Well-Prepared Citizens

Among the nation’s priorities that LINNE is so well poised to address, are: (a) promoting a well-educated populace; and (b) promoting a vibrant civil society through social networks that resulting from knowledge about, and interest in, living and extinct organisms.⁸⁰ Intelligible Organizing Principle 5 specifically addresses these national priorities when it states that: “LINNE’s knowledge environment, enabled by Organizing Principles 1, 2, 3, and 4 above, shall be made available as a learning system for use by the general public.” In addition, this Report has proposed a workshop series, *LINNE As A Virtual AND Place-Based Learning System*, to further flesh out Organizing Principle 5. It has recommended that this workshop series address using LINNE in: (a) formal education through college level; (b) informal education; and (c) online outreach. Finally, as part of LINNE’s Grand Challenge destination, this Report has determined that LINNE should prioritize enabling the public to learn about the totality of organisms, that compose that portion of the Earth’s membrane of organisms that is wrapped around the United States.

2. *NSF’s Ideas Goal: Discovery across the frontier of science and engineering, connected to learning, innovation, and service to society.*

Discovery Across the Frontier of Science and Engineering

We began this Workshop, and this Report, by taking a deep breath, and plunging head first into the new century’s literature on *revolutionizing science and engineering through cyberinfrastructure*.⁸¹ It is the new revolution in cyberinfrastructure that will make possible: (a) LINNE’s virtual community; (b) LINNE’s federation of place-based systematics nodes; and (c) LINNE’s semantic web constructed around the nation’s systematics datasets and collections. This is LINNE as a *science-driven*, national systematic infrastructure, and this is LINNE as a cyberinfrastructure-based tool that will allow for far-reaching discovery. Indeed, this Report has proposed that the initial projects considered for LINNE be chosen to span discovery within all the Kingdoms of life, the

Domains of life, extinct organisms, and those ‘intracellular parasites’ that are progressively less alive in terms of being metabolically active.⁸²

Discovery Connected to Learning, Innovation, and Service to Society

LINNE is fundamentally about learning. That learning will be about organisms. It will include knowledge, to construct Earth’s tree of life and to describe Earth’s membrane of life.

But LINNE is also all about innovation. A virtual community for the nation’s geographically distributed taxonomists and systematists is a new idea. The linking of natural history museums, experimental systematics facilities, and other systematics nodes into a vast network of resources, will be a new thing. The linking of the nation’s systematics datasets and collections, and the building a semantic web around them, to further organize them, will be an unprecedented thing.

And, we must not forget, LINNE is about service to society. That service will include accurate, comprehensive, and up-to-date information about organisms that impact, or could impact, homeland or national security. It will also include accurate, comprehensive, and up-to-date information about organisms that impact, or could impact public health and our nation’s environments.

Through all of these aspects in this next century, LINNE is certain to promote new and even further scientific discoveries, new and more advanced technologies, and new and more knowledgeable kinds of scientists and technologists who are prepared to embrace them all.

3. *NSF’s Tools Goal: Broadly accessible, state-of-the-art science and engineering facilities, tools and other infrastructure that enable discovery, learning and innovation.*

LINNE, itself, will be a new, virtual tool for systematics for the 21st century. Based on cyberinfrastructure, LINNE will be a systematics infrastructure for all of the nation. Membership in LINNE’s virtual community, and access to LINNE’s information and scientific and technological capabilities, will be open to all scientists who research or study organisms. The most up-to-date information on the nation’s organisms will also be accessible to: (a) students and educators; (b) the public with an interest in organisms, including for entrepreneurial reasons; and (c) policy- and decision-makers concerned with the impact of organisms on homeland security, public health, and the environment. Finally, LINNE’s nodes, themselves, will be upgraded with such state-of-the-art technology, tools, facilities, and infrastructure that can allow their effective federation into LINNE.

C. NSF Priorities

Finally, the vision for LINNE, as reported here, integrates input from the broad-based systematics community. As such a broad-based community vision, we believe that LINNE merits consideration as a priority for NSF attention. This Report has presented, above, our input on LINNE’s intellectual merit and justifications, and on LINNE’s broader impacts. It presents, below, evidence of LINNE’s broad-based community support.

6. Development of a National Systematics Infrastructure: Evidence of LINNE's Broad-based Community Support

LINNE is the broad community's decadal vision for taxonomy and natural history collections, and for a national systematics infrastructure, for this decade and beyond. This *broad community vision* for a national systematics infrastructure was deliberated, debated, and agreed to over several days in two workshops held over a span of five weeks. NSF supported these workshops for the very purpose of providing the community with an environment that could allow broad participation in the creation of a common vision for the future.⁸³ Ninety-four scientists enunciated a collective vision for LINNE. These 94 brought their perspectives and experiences from 51 separate institutions within the United States.⁸⁴ Many of the scientists were heads of museums and/or research departments.⁸⁵ Thirty-one of the 94 were the presidents, or were nominated by the presidents, of taxon-oriented societies.⁸⁶ All demonstrated both a passion and a daily commitment to systematics. Altogether, they represented intimate knowledge of, and expertise in, non-human organisms throughout the diverse kingdoms of life.

LINNE is also a *community-selected course of action* that has resulted from several decades of ongoing dialogue to assess and make more broadly known, the systematic community's needs and priorities.⁸⁷ That ongoing dialogue has been characterized by increasing mobilization of the systematics community from within, and an increasingly focused determination of the community's own goals. As recently as 1969, the CEQ Panel on Systematics and Taxonomy could still state: "As is often the case with small, professional groups, the needs of taxonomists for support and for an opportunity to develop their full capacities may be lost or overlooked in the enormity of Government operations. The recommendations of this report are advanced to help systematists increase their contribution[s] . . ." ⁸⁸

Nevertheless, the systematics community had already begun coalition-building and its own, effective self-assessment in this period. In 1970, a core team composed of directors of systematics collections undertook an evaluation of the critical problems their own collections faced. The result of their individual assessments was a common plea to "maintain the great systematics collections as a national information resource."⁸⁹

Mobilization of the broad community then proceeded in earnest in the years from 1974 through 1994. Self-assessments became increasingly broad-based and began to include identification of research and resource priorities for the systematics community as a whole.⁹⁰ At the end of this period, Systematics Agenda 2000 represented a community consensus on framework objectives to discover, describe, and classify the world's species.⁹¹

A decade later, the systematics community has become thoroughly used to the idea of community-owned problems.⁹² It has also had ten years and more to assimilate the norms adopted by community consensus in initiatives such as SA 2000. Mobilization from within, broad-based self-assessments, acknowledgment of community problems, and consensus establishment of broad community objectives and norms has moved us very far, indeed, from a group that was once characterized as a "small, professional group . . . [that] may be lost or overlooked. . . ." ⁹³ We, ourselves, have set the stage for the next community-

owned and mature action. And our broad community has here owned the stage — and acted — when it saw the many possibilities for the future of taxonomy, and systematics, and natural history collections, inherent in LINNE.

7. Development of a National Systematics Infrastructure: LINNE's Proposed Partners

It has been clear that partnership will be a most important component of LINNE. In all likelihood, LINNE's opportunity for partnership will increase through time, and space, and disciplines, in this century.⁹⁴ With that potential increase for LINNE in mind, this Report presents an introduction to the subject of partnerships — and some of LINNE's first, clearly perceived partners.

*Regulating Bodies for the Names of Earth's Organisms*⁹⁵

Discovery and documentation of organisms throughout life and space and time, and their building into composite pictures, will call the operative nomenclatural codes into heavy use. After all, LINNE's central focus and Scientific Questions have been defined as: (1) *What are the Earth's living and extinct organisms, where do they occur, what are their taxonomic relationships, and what are their evolutionary frameworks?* and, as a priority, (2) *What are the living and extinct organisms found within the United States, where do they occur, what are their taxonomic relationships, and what are their evolutionary frameworks?* In addition, LINNE's first Organizing Principle sets out that LINNE will seek to include systematics nodes that will enable new discoveries about organisms in all of the Kingdoms of life, Domains of life, intracellular 'parasites,' extinct organisms, and organisms as yet undiscovered or undescribed. Finally, LINNE's third and fourth Organizing Principles set out that LINNE will link data about taxa into composite and dynamic pictures. This Report foresees a need for LINNE to partner with the bodies that regulate the nomenclatural codes, in order to come to agreement and coordination on general problems that will be relative to both of our work, into this next century.

LINNE's International Counterparts

Partnership with LINNE's international counterparts, from the outset, will promote international agreement on key, specific issues such as data standards and applications. It will also promote seamless integrity in documenting the organisms of the Biosphere in this next century. For example, both Europe and Australia have begun initiatives to federate regional taxonomic and systematic data and collections, and/or to link regional natural history institutions into effective networks. Other regions are also contemplating federation across systematics subdisciplines.⁹⁶

The European initiative, SYNTHESYS, is a collaboration between the Natural History Museum, London, and 19 other European natural history museums and botanic gardens. SYNTHESYS aims to “create an integrated European infrastructure for researchers in the natural sciences” through both: (a) enhanced access to collections, facilities, and expertise, and (b) several networking activities that, together, will create “a single ‘virtual’ museum service.”⁹⁷ The Australian Initiative, ABRS, brings together

taxonomic information in Australia through strategic partnerships. ABRS aims to answer three questions: (1) “What plants, animals, and other organisms occur in Australia?” (2) “Where are they found?” and (3) “How can we provide that information to you?”⁹⁸

LINNE’s *Other Relevant Partners*

LINNE’s fourth Organizing Principle sets out that LINNE will link systematics answers and systematics data in such a way as to build an observatory of the totality of organisms that make up the Earth’s membrane of organisms — with priority given to building an observatory focused on organisms in the United States. This Report has acknowledged that this aspect of LINNE will make possible: (1) a fundamental accounting of the nation’s organisms; and (2) a composite picture of the occurrences of the nation’s organisms.

The potential of this aspect of LINNE will necessarily bring LINNE into the arena of other global and regional bodies who have been concerned, for some time, with this very lack of a comprehensive accounting of the Earth’s and the nation’s organisms. This Report strongly endorses the idea that LINNE should develop *in consonance* with the good work of already existing global and regional bodies. Though there are important others, this Report sets out three examples of global and regional bodies as potential partners for LINNE. They are: (a) the Global Taxonomy Initiative of the United Nations Convention on Biological Diversity (GTI);⁹⁹ (b) the Global Biodiversity Information Facility (GBIF);¹⁰⁰ and (c) the National Biological Information Infrastructure (NBII).¹⁰¹ These potential partners work toward: (a) building taxonomic knowledge and capacity; (b) building the world’s primary data on biodiversity; and (c) building the nation’s biological resources.¹⁰²

Finally, this Report identifies the National Ecological Observatory Network (NEON) as a potential partner for LINNE. Currently in an advanced stage of planning, NEON will be a cyberinfrastructure-enabled knowledge environment for environmental issues of national importance.¹⁰³ NEON’s central focus and Scientific Question will be: *What is the pace and nature of biological change?* Consistent with this overarching question will be six, specific environmental challenges/issues that NEON will observe and understand in depth. To meet its environmental challenges, NEON will require access to accurate and comprehensive information about the identity of organisms occurring within the United States.¹⁰⁴

8. Development of a National Systematics Infrastructure: Conclusions and a Consideration of Tradition

This Report has addressed the development of a systematics infrastructure for the United States, as conceived by members of the systematics community convened in New York City, in December 2003. Our conception for a national systematics infrastructure builds upon the community’s decadal vision for taxonomy and natural history collections outlined in November 2003. LINNE, as conceived here, outlines a course of action for taxonomy, and systematics, and natural history collections — for this decade and beyond.

The conception for LINNE has been based, in part, upon the possibilities that have newly opened for systematics with the development of cyberinfrastructure. This Report has

considered LINNE in light of NSF's blue-ribbon advisory report on revolutionizing science and engineering through cyberinfrastructure [Atkins Report]. It has considered LINNE in light of the OSTP's identification of knowledge environments for science and engineering as Grand Challenges for our nation and our nation's priorities. And it has considered LINNE in light of those cyberinfrastructure-enabled knowledge environments already being planned or developed by sister research communities.

Our conception for LINNE proceeds from several decades of ongoing dialogue by the systematics community to assess our needs, acknowledge our problems, identify our priorities, and establish our norms. LINNE, it bears repeating, is not divorced from our historical process. Rather, LINNE is a course of action that *both* results from our historical dialogue *and* recognizes our possibilities for the 21st century.

This Report has recognized LINNE's intellectual justifications as a new, systematics infrastructure for the nation. It has identified LINNE's central focus and initial Scientific Questions. And it has identified an opportunity to use the answers and the data from our Scientific Questions and the linking of LINNE's systematics nodes, to build a composite picture and understanding of the Earth's organisms. This Workshop Report has proposed the broad outline of LINNE's multi-decade Grand Challenge destination to substantially discover and describe the totality of organisms that make up the Earth's membrane of organisms. And it has identified five intelligible, interdependent, and mutually-reinforcing Organizing Principles that, together, would constitute a framework and direction for beginning LINNE.

This Report proposes a series of additional workshops to: (a) further define LINNE, and (b) to continue planning and developing LINNE. It has set out the first recommendations for these proposed workshops, against the Organizing Principles here identified for LINNE. The workshops and further planning would encompass: (a) enabling new science with LINNE; (b) establishing LINNE's virtual community; (c) federating LINNE's place-based systematics nodes; (d) constructing LINNE's semantic web; (e) building LINNE's composite picture and understanding of the diversity of life; and (f) establishing LINNE's observatory focused on the Earth's membrane of organisms. This Report has also proposed two workshop series that would plan for the transfer of up-to-date systematics knowledge outside of LINNE's nodes. They would encompass: (a) establishing LINNE as a virtual *and* place-based learning system; and (b) establishing LINNE as a source of information for policy- and decision-makers.

This Report gives some consideration to LINNE's potential partners. It recognizes potential partners for LINNE among the regulating bodies for the names of Earth's organisms and among LINNE's international counterparts. It recognizes potential partners for LINNE among the global and regional bodies already working toward building taxonomic knowledge and capacity, the world's primary data on biodiversity, and the nation's biological resources. And it recognizes a potential partner for LINNE in NEON, which will address environmental challenges of national importance, and whose Central Question will be: *What is the pace and nature of biological change?*

Finally, this Report assesses all of our work against the National Science Foundation's strategic plan and goals for ensuring excellence in the nation's future science. In specific and foundational objectives for the nation's science, and in NSF's goals for people, ideas, and tools for the future, we have given evidence that this conception for LINNE reaches that excellence.

For this reason, and for all of the above, we, the systematics community convened here, believe that LINNE merits consideration as a priority for NSF attention.

A Consideration of Tradition

We close here knowing that we have spoken with passion about the need for a national systematics infrastructure. The conception for a systematics infrastructure in this Report has embraced new possibilities for the future. But it has also remained deeply rooted in those traditions of our discipline that give rise to that passion. Just as LINNE has here embraced new possibilities, so we recommend that LINNE also embrace traditional reason and experience. This Report, therefore, proposes one final workshop series to be considered by NSF and the systematics community in defining and planning for LINNE:

Proposed Workshop Series 9

Honoring America's Heritage With LINNE

Perhaps we can consider, also, beginning LINNE this way:

From the hydrosphere and the community of ichthyology:

- Federating the data and the collections for the nation's Atlantic and Pacific Salmons, *Oncorhynchus spp.* and *Salmo salar*.

From the lithosphere and the community of botany:

- Federating the data and the collections for the nation's American Oaks, *Quercus spp.*

From the atmosphere and the community of ornithology:

- Federating the data and the collections for *Haliaeetus leucocephalus* — known more familiarly to us all as the American Eagle.

Participants

Lois D. Blaine	Director of Bioinformatics American Type Culture Collection	<i>lblaine@atcc.org</i>
Christopher Brochu	Assistant Professor Department of Geoscience University of Iowa	<i>christopher-brochu@uiowa.edu</i>
Ann Budd	Professor and Chair Department of Geoscience University of Iowa	<i>ann-budd@uiowa.edu</i>
James Collins	Professor Department of Biology Arizona State University	<i>jcollins@asu.edu</i>
Daphne Fautin	Curator Natural History Museum and Biodiversity Research Center University of Kansas	<i>fautin@ku.edu</i>
Darrel Frost	Associate Dean of Science and Curator American Museum of Natural History	<i>frost@amnh.org</i>
Terrance Gosliner	Senior Curator Dept of Invertebrate Zoology and Geology California Academy of Sciences	<i>tgosliner@CalAcademy.org</i>
James Hanken	Director Museum of Comparative Zoology Harvard University	<i>hanken@oeb.harvard.edu</i>
Robert Hanner	Scientific Program Director Coriell Institute for Medical Research	<i>rhanner@coriell.umdnj.edu</i>
Maureen Kearny	Assistant Curator Division of Amphibians and Reptiles Field Museum of Natural History	<i>mkearney@fieldmuseum.org</i>
Lynn Kimsey	Director Center for Biosystematics and Bohart Museum of Entomology University of California at Davis	<i>lskimsey@ucdavis.edu</i>
Diana Lipscomb	Professor Systematics and Evolution of Protista Dept of Biological Sciences George Washington University	<i>biodl@gwu.edu</i>

Robert E. Magill	Director of Research Missouri Botanical Garden	<i>bob.magill@mobot.org</i>
Steven Manchester	Curator of Paleobotany Florida Museum of Natural History	<i>steven@flmnh.ufl.edu</i>
Michael Mares	Sam K. Viersen Jr. Presidential Professor and Research Curator of Mammals Sam Noble Oklahoma Museum of Natural History	<i>mamares@ou.edu</i>
Jody Martin	Curator Invertebrate Studies Natural History Museum of Los Angeles County	<i>martin@nhm.org</i>
Richard Mayden	Professor and Chair Department of Biology St. Louis University	<i>maydenr@slu.edu</i>
Roy McDiarmid	Curator National Museum of Natural History and Supervisory Zoologist USGS Patuxent Wildlife Research Center	<i>mcdiarmid.roy@nrmn.si.edu</i>
Scott Miller	Chair Department of Systematic Biology National Museum of Natural History	<i>miller.scott@nrmn.si.edu</i>
Thomas Moritz	Boeschenstein Chair of Library Services American Museum of Natural History	<i>tmoritz@amnh.org</i>
Maureen O'Leary	Assistant Professor Anatomical Sciences State University of New York at Stony Brook	<i>maureen.oleary@ stonybrook.edu</i>
Larry Page	Adjunct Curator of Fishes Florida Museum of Natural History	<i>lpage1@ufl.edu</i>
Townsend Peterson	Curator Museum of Natural History and Biodiversity Center University of Kansas	<i>town@ku.edu</i>
John Pipoly III	Director of Research Fairchild Tropical Garden	<i>jpipoly@ fairchildgarden.org</i>
John E. Rawlins	Associate Curator Section of Invertebrate Zoology Carnegie Museum of Natural History	<i>rawlins@ carnegiemuseums.org</i>

Tim Rowe	J. Nalle Gregory Regents Professor Department of Geology University of Texas	<i>rowe@mail.utexas.edu</i>
Scott Schaefer	Curator Division of Vertebrate Zoology American Museum of Natural History	<i>schaefer@amnh.org</i>
Michael J. Sharkey	Professor Department of Entomology University of Kentucky	<i>msharkey@pop.uky.edu</i>
Fred Sheldon	Curator Museum of Natural Science Louisiana State University	<i>fsheld@lsu.edu</i>
Dennis Stevenson	Vice President and Rupert Barneby Curator The New York Botanical Garden	<i>dvs@nybg.org</i>
Jan Stevenson	Manager of Special Projects The New York Botanical Garden and Juris Doctor Candidate, Pace Law School Biodiversity and Cultural Heritage Law	<i>jstevenson@nybg.org</i>
Barbara M. Thiers	Director William and Lynda Steere Herbarium The New York Botanical Garden	<i>bthiers@nybg.org</i>
Melissa Tulig	Bioinformatics Manager The New York Botanical Garden	<i>mtulig@nybg.org</i>
Wheeler, Ward	Curator Division of Invertebrate Zoology American Museum of Natural History	<i>wheeler@amnh.org</i>
Terry Yates	Vice Provost for Research and Professor Department of Biology University of New Mexico	<i>tyates@ sevilla.unm.edu</i>

Observers

Muriel Poston	Program Director Biological Research Collections Division of Biological Infrastructure Directorate for Biological Sciences National Science Foundation	<i>mposton@nsf.gov</i>
Evonne Tang	Program Officer Board on Life Sciences The National Academies	<i>etang@nas.edu</i>
Quentin Wheeler	Division Director Division of Environmental Biology Directorate for Biological Sciences National Science Foundation	<i>qwbeeler@nsf.gov</i>
Jim Woolley	Program Director Biodiversity Surveys and Inventories Division of Environmental Biology Directorate for Biological Sciences National Science Foundation	<i>jwoolley@nsf.gov</i>

Acknowledgments

The conception for LINNE in this Report proceeds from four main sources: (1) the ideas presented as summaries from the Workshop breakout sessions; (2) the ideas discussed in the Workshop's whole group discussion sessions; (3) the ideas presented by individual Workshop participants in their Workshop presentations; and (4) a subsequent study of several reference works cited in the Workshop grant proposal, or during the Workshop presentations, or later recommended by individual Workshop participants, as relevant to LINNE. The ideas from these main sources are presented in this Report as a cohesive whole. In presenting this cohesive whole conception for LINNE, the Report Writers have necessarily had to make some decisions about whether to omit or include some suggestions put forth by participants. We have proceeded on this basis:

- If an idea was presented to the whole Workshop group as a summary idea from a break-out session, and the whole group appeared to be in general agreement on that idea, and that idea was not challenged by the whole group, or did not receive serious challenge from a subset of the whole group, that idea was presented in this Report as an idea for LINNE.
- If an idea for LINNE was put forth in the Workshop's whole group discussion sessions, was taken up for discussion by the whole group, and the whole group appeared to be in general agreement on that idea and did not challenge that idea, the idea was presented in this Report as an idea for LINNE.
- Ideas put forth in the Workshop's whole group discussion sessions that were: (a) raised but not taken up for further discussion; (b) challenged by a subset of the whole group; or (c) challenged by the whole group, were *not* presented in this Report as an idea for LINNE.
- Ideas about emerging new opportunities and new tools, presented during invited Workshop participant presentations, were accepted at face value as ideas and opportunities for LINNE. This was so, even if these ideas were challenged by another Workshop participant or other Workshop participants.
- Information from references cited or sent to us by Workshop participants was included in this Report when helpful to provide historical background or broader context for the ideas presented during the Workshop and presented in this Report. These references are acknowledged in the endnotes section of the Report.
- Information from references cited in the grant proposal for this Workshop was included in this Report when helpful to provide historical background or broader context for the ideas for a national systematics infrastructure presented in this Report. These references are acknowledged in the endnotes section of the Report.

Thanks are due to the members of the Workshop Steering Committee for reviewing the draft of this Report. The Steering Committee members have provided much-needed advice on the organization of this Report and on the clarification of its contents. They also urged us to better convey the overall sense of excitement on the part of Workshop participants about the many new opportunities and tools that are emerging for systematics. And, so that this Report may be sure to work towards the interests of a national systematics infrastructure, the members of the Steering Committee have requested that we make clear to readers, the level of consensus that the systematics community has reached here. In incorporating these suggestions, the Report Writers take full responsibility for any remaining errors in judgment concerning the style or content of this Report.

¹ Publishers Book Description, Daniel R. Headrick, *When Information Came of Age: Technologies of Knowledge in the Age of Reason and Revolution 1700-1850*, Oxford Univ. Pr on Demand, 1st ed (December 15, 2000), at <http://www.oup.com/us/catalog/> (Accessed 01/08/2004).

² Professor William T. Stearn, "Introduction," in Wilfrid Blunt, *Linnaeus: The Compleat Naturalist*, Princeton, New Jersey: Princeton University Press (2001). Professor Stearn, a former president of the Linnaean Society, was a distinguished botanist at the British Museum of Natural History for many years. He died in 1987.

³ *Id.*

⁴ *Id.*

⁵ Daniel E. Atkins et al., *Revolutionizing Science and Engineering Through Cyberinfrastructure: Report of the National Science Foundation Blue-Ribbon Advisory Panel on Cyberinfrastructure*, January 2003 [Atkins Report], at 5, available at http://www.community/technology/nsf_ci_report/ (Accessed 01/18/2004).

⁶ *Id.* at 6, Appendix A, Executive Summary ES2.

⁷ *See generally* Daniel E. Atkins et al. *supra* note 6, at 6.

⁸ Iain McLean, *The Concise Oxford Dictionary of Politics, Federalism*, at 180, New York: Oxford University Press (1996).

⁹ *Id.* at 179-180.

¹⁰ *See generally* Daniel E. Atkins et al. *supra* note 6, at 6-7 and Executive Summary ES 2-3.

¹¹ *See* Overview, 4.1 Knowledge Environments For Science and Engineering, Interagency Working Group on Information Technology Research and Development, GRAND CHALLENGES: Science, Engineering, and Societal Advances Requiring Networking and Information Technology Research and Development [NITRD Report], November 2003, available at <http://www.hpcc.gov/> (Accessed 12/28/2003). The Office of Science and Technology Policy (OSTP), within the Executive Office of the President, which authorized this report, "serves as a source of scientific and technological analysis and judgement for the President with respect to major policies, plans, and programs of the Federal Government." *See* About OSTP, at <http://ostp.gov/html/whatwedo.html> (Accessed 01/06/2004). Selected, additional multi-decade Grand Challenges include: High Confidence Infrastructure Control Systems; Informed Strategic Planning for Long-Term Regional Climate Change; Anticipate Consequences of Universal Participation in a Digital Society; Collaborative Intelligence: Integrating Humans with Intelligent Technologies; Generating Insights from Information at Your Fingertips; Managing Knowledge-Intensive Organizations in Dynamic Environments; SimUniverse: Learning by Exploring; and Virtual Lifetime Tutor for All.

¹² *Id.* at Overview.

¹³ *See* Google's selected web definition of "systematics," at www.cmdr.ub.ca/pathogenomics/terminology.html (Accessed 01/14/2004). *See also* the definitions of "systematics" and "biosystematics" in hyperdictionary, at <http://www.hyperdictionary.com/dictionary/biosystematics> (Accessed 01/14/2003).

¹⁴ Many modern systematists consider the traditional classification of living organisms into five kingdoms to be outdated. They begin the classifications of life, instead, with a three-Domain system: Archaea (originally Archaeobacteria) – Bacteria (originally Eubacteria) – Eukaryota. *See generally* Biology:

Classification of life, at Wikipedia, The Free Encyclopedia, at <http://en.wikipedia.org/wiki/Biology> (Accessed 01/19/2004).

¹⁵ *Id.*

¹⁶ Maria Bakardjieva, Virtual Togetherness: A Perspective from Everyday (Real?) Life, abstract available at <http://www.brunel.ac.uk/research/virtsoc/eventsGRvirtual.htm#bak.ar> (Accessed 01/21/2004). Among the online (technical) practices that help to form virtual communities are: (a) newsgroups; (b) mailing lists; (c) internet relay chat (IRC); (d) MUDs/MOOs; (e) bulletin boards; and (f) computer conferencing. For a history and description of these online practices, see Communities in Cyberspace, Title Page, The Technical Layer, at http://www.ucalgary.ca/~bakardji/community/title_page.html (Accessed 01/20/2004).

¹⁷ For a tour through some existing virtual communities, see Northeastern University, Computers and Society, Virtual Community Fieldtrip, at <http://www.ccs.neu.edu/home/perrolle> (Accessed 01/22/2004). See also generally The Virtual Community, Howard Rheingold, Virtual Community Services, at <http://www.rheingold.com/index.html> (Accessed 01/22/2004). Rheingold is considered a pioneer of virtual communities (he coined the phrase when he began talking about social activity online in 1988).

¹⁸ Easy Virtual Community, Autospec, Inc., at <http://members.cruzio.com/~autospec/easy.htm> (Accessed 01/21/2004).

¹⁹ See, for example, the works of Charles Darwin (1809-1882) and his adherents, and those of Willi Hennig (1913-1976) and his adherents.

²⁰ See cyberinfrastructures and knowledge environments being planned or developed for sister research communities and research agencies within the United States, especially:

- (1) US National Virtual Observatory (NVO) for the wide astronomical community, at <http://www.us-vo.org/> (Accessed 01/19/2004)
- (2) National Ecological Observatory Network (NEON) for the environmental research community, at BioDirectorate for Biological Sciences, at <http://www.nsf.gov/bio/neon/start.htm> (Accessed 01/22/2003).
- (3) Space Physics & Aeronomy Research Collaboratory (SPARC) for the space physics and aeronomy research community, at <http://www.windows.ucar.edu/sparc/> (Accessed 01/22/2004).
- (4) NIH Biomedical Informatics Research Network (BIRN) for the biomedical research community, at www.nbirn.net/ (Accessed 01/22/2003).
- (5) Grid Physics Network (GriPhyN) for the physics research community, at <http://www.griphyn.org> (Accessed 01/22/2004).

See also cyberinfrastructures and knowledge environments being planned or developed outside the United States, especially:

- (1) European Union DataGrid Project including biology and medical imaging applications, at <http://eu-datagrid.web.cern.ch/eu-datagrid/> (Accessed 12/30/2003)
- (2) United Kingdom e-Science Grid for use by all of the UK science communities, at <http://www.escience-grid.org.uk/> (Accessed 01/09/2004).
- (3) Australia's Environmental Resources Information Network (ERIN) for the environmental community and for policy-makers, at <http://www.deh.gov.au/erin/about.html> (Accessed 12/30/2003).
- (4) Australian Biological Resources Study (ABRS) for the systematics community and for policy-makers, at <http://www.deh.gov.au/biodiversity/abrs/> (Accessed 12/30/2003).
- (5) Synthesis of Systematics Resources (SYNTHESYS). European infrastructure for researchers in the natural sciences, at <http://www.synthesys.info> (Accessed 06/10/2004).

²¹ See Introduction and Eligibility: Definition, and Project Approval for Inclusion in Budget Request: 1. MRE Panel, in Guidelines for Planning and Managing the Major Research Equipment Account, at <http://www.nsf.gov/home/about/mre01.html> (Accessed 01/15/2004).

²² This Report does not yet focus on LINNE's project management plan, life span, life-cycle cost profile, or budgetary impact.

²³ Edward O. Wilson, *The Future of Life*, Chapter One, To the Ends of the Earth, Alfred A. Knopf Incorporated, Copyright © 2002 E. O. Wilson, Chapter One available online, at the connection, at <http://archives.theconnection.org/firstchapters/wilson.shtml> (Accessed 01/16/2004).

²⁴ See generally Scope and Vision of the NVO, Building the Framework for the National Virtual Observatory, National Virtual Observatory (NVO), at <http://www.us-vo.org/docs/nvo-proj.html> (Accessed 01/17/2004).

²⁵ Aeronomy is "a branch of science that deals with the atmosphere of the Earth and the other planets with reference to their chemical composition, physical properties, relative motion, and responses to radiation from space," see Google's definition of "aeronomy" at <http://www.noaa.gov/WWHHD/Pubdocs/aeronomy.html> (Accessed 01/23/2004). See also the Space Physics & Aeronomy Research Collaboratory (SPARC) *supra* note 21.

²⁶ Edward O. Wilson *supra* note 23.

²⁷ See GRAND CHALLENGES: Science, Engineering, and Societal Advances Requiring Networking and Information Technology Research and Development [NITRD Report] *supra* note 12, at Overview. See also the site index of the Office of Science and Technology Policy (OSTP), Executive Office of the President for the relationship between the NITRD group and the OSTP, at <http://ostp.gov/html/sitemap.html> (Accessed 01/06/2004).

²⁸ Perhaps not surprisingly, other research communities also have a dual view of the *primary* justification for their cyberinfrastructure-enabled environments. LINNE will observe Earth's membrane of life, with its diversity of organisms, and LINNE will be a knowledge environment for systematics in the United States. The NVO observes the sky, with its diversity of bodies, and NVO is a datagrid for astronomy in the United States. See Ewa Deelman et al., Introduction, Grid-Based Galaxy Morphology Analysis for the National Virtual Observatory, team-member publication deposited in the US-VO (i.e., NVO) Document Repository, at Publications, at <http://www.us-vo.org/publications.html> (Accessed 01/23/2003).

²⁹ The six national priorities that the NITRD group recognized as relating to advances in science, engineering, and society, and requiring networking and information technology R&D, are: (1) Leadership in Science and Technology; (2) Homeland and National Security; (3) Health and Environment; (4) Economic Prosperity; (5) A Well-Educated Populace; and (6) A Vibrant Civil Society, see the NITRD Report *supra* note 12, at Overview. For some additional, recent commentary from the systematics community on how the work of systematists impacts national priorities, see Andrew V. Suarez and Neil D. Tsutsui, The Value of Museum Collections for Research and Society, *BioScience*, Vol. 54 No. 1 (January 2004). Biological museum collections represent a vital source of data for systematics research on many groups of organisms.

³⁰ The NITRD Report explains that all of the Grand Challenges they have identified, including knowledge environments for science "are expected to yield significant breakthroughs of practical importance to mankind." See the NITRD Report *supra* note 12, at Introduction.

³¹ See Page, Larry (Chair), Vicki Funk, Michael Jeffords, Diana Lipscomb, Michael Mares, and Alan Prather. 2004. Workshop to Produce a Decadal Vision for Taxonomy and Natural History Collections, held at the Florida Museum of Natural History, University of Florida, Gainesville, FL, 10-12 November, 2003. Report to the U.S. National Science Foundation, Biodiversity Surveys and Inventories Program. Available at the LINNE website, at http://www.flmnh.ufl.edu/taxonomy_workshop/impact.htm.

³² See NSF Proposal 0352943, *Development of a National Systematics Infrastructure: A Virtual Instrument for the 21st Century*.

³³ For a glimpse at the ways LINNE could fail, see the webpages, publications, and workshop reports of the scienceof**collaboratories** (SOC), An alliance to advance the understanding of **collaboratories**. This alliance seeks to understand why “Over the past decade there have been a series of collaborative projects . . . some successful and some less so,” and why “the design, deployment, and adoption of new collaborations remain difficult and uncertain processes.” See the Scienceof**collaboratories**, at <http://www.scienceofcollaboratories.org/AboutSOC/index.php?Mission> (Accessed 02/03/2004).

³⁴ According to the NITRD Report, LINNE should be thought of as both a journey (a multi-decade journey) and a destination (that is, arriving at a different level of human understanding of Earth’s membrane of life, and of the organisms that compose it, and having acquired, along the way, a capability to act, knowingly, on that new understanding). See the NITRD Report *supra* note 12, at Report Overview.

³⁵ That is, from our current place of only just beginning to comprehend, in any real way, that the totality of organisms we all study --- plus the countless others than no one is yet studying --- compose a seamless membrane of life, wrapped around our Earth, through both space and time.

³⁶ The reader will notice some disjunct between the way systematists frame their questions today and the way we have conceived the Grand Challenge destination for LINNE, i.e., that time, many decades away, when we have substantially discovered and described the totality of organisms that compose the Earth’s membrane of organisms.

³⁷ Put still a third way, how to proceed with best effect to the revolutionary way of doing the science of systematics for the new knowledge economy, as laid out in the Atkins Report, and to the multi-decade way of building a new knowledge environment for the science of systematics, as laid out in the NITRD Report? See *about* the Atkins Report *supra* note 6 and *about* the NITRD Report *supra* note 12.

³⁸ Intelligible means: [*that*] *that may be understood or comprehended; clear; comprehensible*. Webster’s New Universal Unabridged Dictionary, Deluxe Second Edition, New York: New World Dictionaries/Simon and Schuster (1983). The idea of providing LINNE with intelligible organizing principles, from the outset, is borrowed from an idea in administrative law, where federal agencies are given broad intelligible principles (by Congress) to guide further development. An example of an intelligible principle might be: “Agency X shall promote and develop Nation Y’s wine industry. Promotion and development by Agency X shall include promoting the use of Nation Y’s own grape cultivars, and developing the market for Nation Y’s wine both within Nation Y and outside of Nation Y.” Intelligible principles are seen as vital to the integrity and maintenance of a system. Intelligible principles also direct and authorize actions and development in conformity with those principles, and confine actions and development not in conformity with those principles. For a thorough discussion of the intelligible principle doctrine, see 1-3 Administrative Law § 3.03, Part I. Historical Background, Matthew Bender & Company, Inc., a member of the LexisNexis Group, copyright 2003.

³⁹ The inspiration for providing LINNE with Organizing Principles came from all those participants in the Workshop who kept trying to grasp at the form of a “national systematics infrastructure.” These participants kept coming back to points like, “well, aren’t we also talking about a national *organization* for systematics that would be something like a department or agency?”

⁴⁰ A goodly amount of discussion ensued at the Workshop over what should constitute a systematics “node” for LINNE. Indeed, there appear to be levels of nodes, because every organism, and every biological museum collection is, in some sense, a node. However, for the purposes of this report, a “node” is a distributed resource of the type described in the NITRD Report when referring to Grand Challenge Knowledge Environments. The NITRD Report describes a multi-decade Grand Challenge, for developing a Knowledge Environment for Science, this way: “Organize and make broadly available distributed resources such as supercomputers, data archives, distant experimental facilities, and domain-specific

research tools to enable new scientific discoveries and education across disciplines and geography.” See the NITRD Report *supra* note 12, at 4.1 Knowledge Environments for Science and Engineering.

⁴¹ This follows the NVO (National Virtual Observatory) precedent of including in its virtual observatory: “astronomers, technicians, engineers, programmers, support staff, . . .” See “What is the Virtual Observatory?”, powerpoint slide from the NVO EPO (Education and Public Outreach) Workshop, *available at* Robert Hanisch, The National Virtual Observatory, 11 July 2002 presentation, *at* <http://bill.cacr.caltech.edu/cfdocs/usvo-pubs/list.cfm> (Accessed 01/29/2003).

⁴² One example of the kind of learning system that might be developed for LINNE is at <http://www.windows.ucar.edu/sparc/> (Accessed 01/16/2004). The SPARC (Space Physics & Aeronomy Research Collaboratory) learning system was developed with guidance from the National Science Foundation. SPARC, in turn, is included in a larger internet learning system called *Windows to the Universe*. See *Windows to the Universe at* <http://www.windows.ucar.edu> (Accessed 01/16/2004). Note that some research communities which are developing cyberinfrastructure-enabled knowledge environments prefer the descriptor “education and public outreach” to “learning system.”

⁴³ The NVO’s framework for enabling new science—new astronomy was used, in part, as a conceptual model for outlining this set of Workshops for LINNE, *see* Alex Szalay and Roy Williams, 2.1 Enabling New Science---The New Astronomy, Building the Framework for the National Virtual Observatory, *available at* <http://www.us.-vo.org/docs/nvo-proj.html> (Accessed 01/17/2004).

⁴⁴ For an idea of the kinds of *social* issues that may be involved in determining LINNE’s governance model, *see* 1.3 Alternative Networking Strategies, Caledonia Centre for Social Development, *at* http://www.caledonia.org.uk/networks/section_1_3.htm. (Accessed 01/25/2004). This document discusses the creative tension that is a natural part of any thriving network and describes four possible types of decision and communication centers: hierarchy; hub or central node; autonomous and non-hierarchical; and federation. It also discusses the possibility of moving to different models of decision-making and communication, at different stages of a network’s organization.

⁴⁵ See the definition of “Virtual Community” in the Semantics section of this report and *supra* notes 17-19.

⁴⁶ See, for example, Workshops: The Social Underpinnings of Collaboration, *at* <http://www.scienceofcollaboratories.org/Workshops/WorkshopJune42001/index.php> (Accessed 02/04/2004); *see also* information on **scienceofcollaboratories** *supra* note 32.

⁴⁷ Susan H. Frost, “genesis: It’s the vision. . .,” Emory Intellectual Initiatives: Selected findings from a study of [cross-school] intellectual initiatives at Emory University, *at* http://www.emory.edu/PROVOST/IPR/ipr_faculty/initiatives_brochure.htm (Accessed 01/29/2004).

⁴⁸ *Id.* The Emory Intellectual Initiatives pamphlet gave as an example here the unpacking of the meaning of the recently mapped human genome requiring the combined talents of psychologists, molecular biologists, and neuroscientists.

⁴⁹ The reader should understand that systematics “nodes” are not necessarily synonymous with the whole institutions of which they are a component. For example, University X’s Natural History Museum might be federated as a systematics node under LINNE, whereas University X as a whole might not.

⁵⁰ Linnaeus died two years after the American Revolution, in 1778.

⁵¹ Encompassed within the nation’s heritage biological collection are:

- (a) specimen collections, preserved & living (museums, herbaria, botanical gardens, zoos, aquaria and culture collections)
- (b) derivatives and “virtual” specimens and samples
- (c) collateral collections (nests, etc.)

- (d) scientific publications & "gray literature"
- (e) images of all types (satellite to electro-micrographs)
- (f) time-based media (film, video, recorded sounds)
- (g) bibliographic indices (e.g. Zoological Record 1864-present) & Authority Files
- (h) observational data on occurrences of species
- (i) maps (analog or digital)
- (f) archives and manuscripts (field and lab notes)
- (g) expertise: the experience-based knowledge of individuals or cultures

Tom Moritz, Boeschstein Director, Library Services, American Museum of Natural History, Texts: Integration and Interoperability in the Biodiversity Commons, presentation at the National Science Foundation (NSF) Workshop at The New York Botanical Garden, "*Development of a National Systematics Infrastructure: A Virtual Instrument for the 21st Century*," Dec. 11-13, 2003. Modern systematists are actively adding to the nation's biological heritage collections.

⁵² For a more thorough discussion of the value of past scientific collections for ongoing scientific research, see Collective KNOWLEDGE, *Dinosaurs to DNA: The Power of Natural Science Collections*, Biodiversity Research Institute (2003), available at Natural Science Collections Alliance, at www.nsalliance.org (Accessed 12/01/2004).

⁵³ That is, LINNE's Grand Challenge destination.

⁵⁴ The "semantic web" has been described as *an extension of the current web in which information is given well-defined meaning, better enabling computers and people to work in cooperation*, and also as *a web of data, like a global database. The infrastructure of the Semantic Web would allow machines as well as humans to make deductions and organize information. The architectural components include semantics (meaning of the elements), structure (organization of the elements), and syntax (communication)*. See Google's definitions of the "semantic web," at <http://www.google.com/search?q=define:semantic+web>. (Accessed 02/10/2004). The semantic web is seen as necessary for federating, fusing, and exploring a large number of heterogeneous data sets. See Alex Szalay and Roy Williams *supra* note 40. That sister research community has as its ambitious goal to federate the data and information of the entire discipline of astronomy.

⁵⁵ For example:

- The Zebra is *Equus burchelli* (Kingdom Animalia)
- The Horse is *Equus caballus* (Kingdom Animalia)
- The Coffee Tree is *Coffea arabica* (Kingdom Plantae)
- Portabella Mushroom = *Agaricus bisporus* (Kingdom Fungi)
- A commonly occurring Diatom is *Eunotia serra* (Kingdom Protista) (millions of diatom skeletons form "diatomaceous earth," which is used in asphalt for road-building).
- The Tuberculosis-causing bacterium is *Mycobacterium tuberculosis* (Kingdom Monera)
- The original name for the Smallpox virus was *Orthopoxvirus variola* (an intracellular 'parasite')
(the use of binomial nomenclature for viruses is no longer common, though Smallpox still goes by the scientific name of *Orthopoxvirus*.)
- The T. rex dinosaur is *Tyrannosaurus rex* (extinct organism)

⁵⁶ The National Science Foundation has, of course, already identified this goal for the systematics community, in its calling for proposals from the community to assemble "... a framework phylogeny, or Tree of Life for all 1.7 million described species," see *Assembling the Tree of Life*, Directorate for Biological Sciences, U.S. National Science Foundation, at <http://www.nsf.gov/bioprogdes/bioatol.htm>. (Accessed 02/19/2004).

⁵⁷ In recommending the series of 9, additional workshops to begin fleshing out, and making real, the intelligible, interdependent, and mutually-reinforcing organizing principles for LINNE, we have recognized that these two series could have substantial overlap: (a) LINNE As *Semantic Web*, and (b) LINNE As

Composite Picture and Understanding of the Diversity of Life. It may be that for the most effective development of LINNE, these topics should be considered in the same series of workshops. For purposes of this report, however, we thought it best to keep them separate.

⁵⁸ See workshop reports from the three NSF-sponsored workshops, *Assembling the Tree of Life I, II, and III*, available at <http://research.amnh.org/biodiversity/center/features/tol.html> (Accessed 07/12/2004). See also, *Assembling The Tree of Life brochure*, at ucjeps.berkeley.edu/tol.pdf. (Accessed 07/12/2004).

⁵⁹ *Assembling The Tree of Life brochure supra* note 57, at 2.

⁶⁰ For a discussion of evolving ideas in intellectual property rights, especially as those rights relate to scientific information, see J.H. Reichman and Paul F. Uhler, *The Public Domain: A Contractually Reconstructed Research Commons for Scientific Data in a Highly Protectionist Intellectual Property Environment*, 66 *Law & Contemp. Prob.* 315 (2003). This article explains: (a) intellectual property rights in government generated scientific data; (b) intellectual property rights in government-funded scientific data; (c) scientific data as a private good; (d) formal data exchange in big science; and (e) informal data exchange (i.e., barter system) in small science. Already, there has been a call for a “biodiversity commons,” not in the context of LINNE, but as an imperative for conservation. These writings on a biodiversity commons, however, may provide fruitful ideas for LINNE and LINNE’s research commons. For a brief discussion of the biodiversity commons to link systematics data as an imperative for conservation, see Thomas Moritz, *Building the Biodiversity Commons*, *D-Lib Magazine*, June 2002, at <http://dlib.org/dlib/june02/moritz/06moritz.html> (Accessed 07/13/2004). For the IUCN’s *Biodiversity Commons: Statement of Principles*, see the IUCN website, at http://www.iucn.org/info_and_news/press/biodivcommons.doc. For an issues paper on the biodiversity commons, see *Sharing Information with Confidence: past experience, current trends and potential future directions* (May 2004), available at http://www.iucn.org/info_and_news/press/sharing-Information_Confidence-3rd_Draft.pdf (Accessed 07/13/2004).

⁶¹ For a discussion and explanation of cyberinfrastructure-enabled knowledge environments and this paradigm shift to teams of scholars, see *The Changing Nature of Research and the Future of the Research University*, Academic Convocation at Texas A&M University, October 1, 2003, by James J. Duderstadt, President Emeritus, University Professor of Science and Engineering, The University of Michigan, available at <http://www.tamu.edu/conv/s003/add-duderstadt.html> (Accessed 02/20/2004). Prof. Duderstadt was a major figure during the development of the cyberinfrastructure-enabled knowledge environment known as “SPARC,” (Space Physics & Aeronomy Research Collaboratory).

⁶² The NVO (National Virtual Observatory) has solved this problem by recognizing the three distinct roles of author, publisher/creator, and reader for purposes of data publication. A user of NVO data is able to complete his/her research and quickly publish the results, often within the NVO, itself. The derived data and research results, themselves, are then incorporated into the NVO, making them quickly available to the broad research community. See Paul Messina and Alex Szalay, *The NVO as Facility for Data Publication*, Project Description: Building the Framework for the National Virtual Observatory, available at <http://www.us.-vo.org/docs/nvo-proj.htm>. (Accessed 01/17/2004).

⁶³ This aspect of LINNE will perhaps be considered by some commentators to be neither strictly science-driven nor mission-oriented. LINNE, as considered here, can be likened to Thomas Jefferson’s decision to mount the Lewis and Clark expedition into the unknown, western parts of the United States. Jefferson thought that mapping and sampling unknown western organisms would *both* (a) serve basic science and (b) further a westward expansion of the nation. This mode of research project, that is “motivated by placing it in an area of basic scientific ignorance that seems to lie at the heart of a social problem” has been termed “Jeffersonian research.” See Gerald Holton and Gerhard Sonnert, *Rethinking What Research Government Should Fund: A Vision of Jeffersonian Science*, at *Issues in Science and Technology* online, Fall 1999, at <http://www.nap.edu/issues/16.1/holton.htm> (Accessed 02/20/2004) “The main goal [of Jeffersonian research] is to remove that basic ignorance in an uncharted area of science and thereby to

attain knowledge that will have a fair probability—even if it is years distant—of being brought to bear on a persistent, debilitating national (or international) problem.”

⁶⁴ Put another way, the nation lacks a fundamental accounting of the organisms that compose that portion of the Earth’s membrane of organisms, that is wrapped around the United States. Earth’s membrane of living organisms has been said to encompass parts of the “hydrosphere” (the water realm of the Earth’s surface), the “lithosphere” (the Earth’s crust), and the “atmosphere” (the thin layer of gases surrounding Earth to an altitude of less than 300 miles), *see* Earth’s Physical Systems at http://sbsi.csUMB.edu/sbsc256/sbscStuff/Chapter_2/2/4/1.html (Accessed 02/13/2004). Under the traditional, legal concept of *cujus est solum, ejus est usque ad coelum et ad inferos* (whosoever has the soil, also owns to the heavens above and to the center beneath), the nation’s “borders” extend vertically, including into the uppermost regions where organisms occur. For a thorough discussion of the history of United States ownership “to the heavens above,” *see* Major Stephen M. Shrewbury, September 11th and the Single European Sky: Developing Concepts of Airspace Sovereignty, 68 J. Air L. & Com. 115 (2003).

⁶⁵ As the systematics community has recently noted, some of the issues in which organisms are a factor are the conservation, management, understanding, and enjoyment of the natural world, Quentin D. Wheeler, Peter H. Raven, and Edward O. Wilson, Taxonomy: Impediment or Expedient?, Editorial in *Science*, 16 January 2004, available at www.sciencemag.org. “Society has a growing need for credible taxonomic information [that is, information about organisms and their taxonomic relationships] in order to allow us to conserve, manage, understand, and enjoy the natural world.”

⁶⁶ The reader should be reminded that a full and fundamental accounting of the nation’s organisms, as they occur within the nation, is part of the Grand Challenge journey for systematics (for LINNE) that is expected to take many decades. It is also important to understand that scientific fieldwork for the discovery and documentation of new organisms within the nation, will remain a necessary and vital part of systematics, in all its aspects, in all this time. (As we conceive it, information about new organisms discovered through fieldwork, along with accompanying biological heritage collections made, will be added to LINNE, through its systematics nodes, and made available for organization and analysis by LINNE’s semantic web).

⁶⁷ Whereas the fundamental accounting will produce something like a total checklist of the nation’s organisms, the composite picture of their *occurrences* will produce something like a map of each organism’s range, showing the geographic areas in which each particular organism can be found. This is possible because systematists have traditionally recorded information about the locality of origin of a biological heritage collection, when making that collection. [Here is an explanation of the historical reason for making collections of the same organism from many localities: “Before [the work of Charles Darwin], one full specimen was considered adequate to represent each . . . species. Linnaeus (circa 1753) gave his extra collections to his students, not supposing the material necessary to his own herbarium . . . However, a single specimen represents only imperfectly the natural population of which it was a part, for it depicts only one of many character combinations. One collection stands for a complex species only as well as a single [preserved] dog skin represents all the breeds . . . of *Canis familiaris*. As the complexity of species has become better understood, the necessity for many specimens has become apparent. Ideally, the herbarium is hoped to include the complete range of geographical, ecological, and other forms within each species”, Lyman Benson, *Plant Taxonomy*, at 22-23, New York: The Ronald Press Company (1962).] Because of these traditions, the nation’s systematics repositories and data archives contain millions of pieces of information about the localities in which the nation’s organisms have been found.

⁶⁸ For example, some component of the nation’s systematists is in the field every day, recording observations about organisms (using various media) and making heritage biological collections. Thus, LINNE will receive new information, from its virtual community, about the nation’s organisms every day. And LINNE will be updating its fundamental accounting, and picture, and analysis of those organisms each day. (Lest the reader think that “observatories” can only be those big, place-based buildings/machines that one is used to thinking of as “observatories,” the astronomy community, itself, has this to say: “The NVO [National Virtual Observatory] would be a ‘Rosetta Stone’ linking *the archival data sets* of space and

ground-based observatories, *the catalogs* of multi-wavelength surveys, *and the computational resources* necessary to support comparison and cross-correlation among these resources We think of the NVO as a genuine observatory that astronomers will use from their desks.” (emphasis supplied), *see* Alex Szalay and Roy Williams, Building the Framework for the National Virtual Observatory, *available at* <http://www.us.-vo.org/docs/nvo-proj.html> (Accessed 01/17/2004).

⁶⁹ It has been useful for us to think of the first 4 Organizing Principles for LINNE as www.LINNE.org and the 5th Organizing Principle — LINNE’s learning system --- as www.LINNE.edu

⁷⁰ Especially those of the NVO and SPARC. *See* the urls for NVO and SPARC *supra* note 21.

⁷¹ “Let no lesson remain unknown” is an expression that has been used by Steven Clift of DoWire – Democracies Online Newswire. DoWire is dedicated to “promoting online civic participation and democracy efforts around the world through information exchange, experience sharing, outreach, and education.” *See* Steven Clift’s use of the expression at [DW] EU’s 6th Framework Programme, *at* <http://www.mail-archive.com/do-wire@tc.umn.edu/msg00583.html> (Accessed 07/13/2004).

⁷² *See* Report section LINNE’s Intellectual Justification, *at* page 6.

⁷³ *See* NSF’s new Strategic Plan: National Science Foundation Strategic Plan, FY 2003 – 2008, at 8, *available at* <http://www.nsf.gov/od/gpra/> (Accessed 02/24/2004).

⁷⁴ E.g., botany, herpetology, entomology, virology, bacteriology, ornithology, protistology, mammalogy, among others.

⁷⁵ Funding for new research under LINNE has not yet been a focus of this Report.

⁷⁶ *Id.*

⁷⁷ National Science Foundation Strategic Plan *supra* note 72, at 9-21.

⁷⁸ That is, since Linnaeus (1707-1778).

⁷⁹ *See* Report section LINNE’s Intellectual Justification, *at* page 6.

⁸⁰ *Id.*

⁸¹ *See, for example*, Daniel E. Atkins et. al., Revolutionizing Science and Engineering Through Cyberinfrastructure: Report of the National Science Foundation Blue-Ribbon Advisory Panel on Cyberinfrastructure, January 2003 [Atkins Report], *at* note 6 and Knowledge Environments for Science and Engineering, Interagency Working Group on Information Technology Research and Development, GRAND CHALLENGES: Science, Engineering, and Societal Advances Requiring Networking and Information Technology Research and Development, November 2003 [NITRD Report], *at* note 12.

⁸² *See* Workshop Series 1– LINNE as science-driven: *Enabling New Science With LINNE*, *at* page 12.

⁸³ Workshop to Produce a Decadal Vision for Taxonomy and Natural History Collections, held at Florida Museum of Natural History, University of Florida, Gainesville, FL, 10-12 November, 2003. Funded by the U.S. National Science Foundation, Biodiversity Surveys and Inventories Program, and Workshop on Development of a National Systematics Infrastructure: A Virtual Instrument for the 21st Century, held at The New York Botanical Garden, Bronx, NY, 11-13 December, 2003. Funded by the U.S. National Science Foundation, Biodiversity Surveys and Inventories Program.

⁸⁴ Academy of Natural Sciences of Philadelphia, Allyn Museum, American Association of Museums, American Institute of Biological Sciences, American Museum of Natural History, American Type Culture

Collection, Arizona State University, Bell Museum University of Minnesota, Bishop Museum, California Academy of Sciences, Carnegie Museum of Natural History, Coriell Institute for Medical Research, Delaware State University, Fairchild Tropical Garden, Field Museum of Natural History, Florida Dept. of Agriculture and Consumer Services, Florida Museum of Natural History, George Washington University, Harvard University, Museum of Comparative Zoology, Illinois Natural History Survey, Louisiana State University, Museum of Natural Science, Maine State University, Michigan State University, Missouri Botanical Garden, Natural History Museum of Los Angeles County, Oregon State University, Sam Noble Oklahoma Museum of Natural History, Smithsonian Institution, St. Louis University, State University of New York at Stony Brook, Systematics Association (UK), Texas A&M University, Texas Memorial Museum, The New York Botanical Garden, Tulane University, University of Alabama, University of Arkansas, University of California-Berkeley, University of California-Davis, Center for Biosystematics, University of Cincinnati, University of Iowa, University of Kansas, Museum of Natural History and Biodiversity Center, University of Kentucky, University of Nebraska, University of New Mexico, University of Northern Colorado, University of Tennessee, University of Texas, University of Wyoming, US Department of Agriculture, USGS Patuxent Wildlife Research Center.

⁸⁵ Director of Bioinformatics, American Type Culture Collection; Chair, Department of Geoscience, University of Iowa; Associate Dean of Science, American Museum of Natural History; Director, Museum of Comparative Zoology, Harvard University; Scientific Program Director, Coriell Institute for Medical Research; Director, Center for Biosystematics and Bohart Museum of Entomology, University of California at Davis; Director of Research, Missouri Botanical Garden; Chair, Department of Biology, St. Louis University; Chair, Department of Systematic Biology, National Museum of Natural History; Director of Research, Fairchild Tropical Garden; Vice President for Botanical Science, The New York Botanical Garden; Director, William and Lynda Steere Herbarium, The New York Botanical Garden; Vice Provost for Research, Department of Biology, University of New Mexico.

⁸⁶ Acarological Society of America; All Species Foundation; American Association of Museums; American Bryological and Lichenological Society; American Elasmobranch Society; American Fisheries Society; American Institute of Biological Sciences; American Malacological Society; American Society of Ichthyologists & Herpetologists; American Society of Parasitologists; American Society of Mammologists; American Society of Plant Taxonomists; Belgium Frenchspeaking Association of Museums; Belgium Naturalists Society; Bergey's Manual Trust; Botanical Society of America; Entomological Society of America; Freshwater Mollusk Conservation Society; Herpetologists League; International Commission, Systematics of Prokaryotes; International Society of Hymenopterists; Lepidopterists' Society; North American Mycological Society; Paleontological Society of America; Natural Science Collections Alliance; Society for the Preservation of Natural History Collections; Society of Nematologists; Society of Systematic Biologists; Unification in the Collections Community Workshop.

⁸⁷ Scott Miller, Senior Biodiversity Advisor to the Director and Curator of Entomology, National Museum of Natural History, Smithsonian Institution, *Have We Been Here Before? A Systematics Infrastructure Vision From Zoology*, presentation at the National Science Foundation (NSF) Workshop at The New York Botanical Garden, "*Development of a National Systematics Infrastructure: A Virtual Instrument for the 21st Century*," Dec 11-13, 2003. Dr. Miller traced the community dialogue and assessment through: (a) Systematic Biology: a Survey of Federal Programs and Needs [Post Report] (1969); (b) Systematics in Support of Biological Research [Michener Report] (NAS, 1970); (c) The Systematic Biology Collections of the United States: An Essential Resource. Part I. The Great Collections—Their Nature, Importance, Condition and Future [Steere Report] (July, 1970); (d) America's Museums: The Belmont Report [Belmont Report] (1968); (e) America's Systematics Collections: A National Plan (1973); (f) Systematics '75 (ASC, 1976); (g) Stuessy Report (NSF, 1981); (g) ASC surveys and workshops (1985, 1988); (h) Biological Survey for the Nation (NAS, 1993); (i) Systematics Agenda 2000 (1994); and (j) PCAST Report (1998).

⁸⁸ Panel on Systematics and Taxonomy of the U.S. Federal Council for Science and Technology, Epilogue, Systematic Biology: A Survey of Federal Programs and Needs [POST Report], Office of Science and Technology, Executive Office of the President (1969).

⁸⁹ A report to the National Science Foundation by the Conference of Directors of Systematics Collections, Part I, The Great Collections: Their Nature, Importance, Condition, and Future, pg. 5, *in* The Systematic Biology Collections of the United States: An Essential Resource [Steere Report] (1970)

⁹⁰ See W. Hardy Eshbaugh, Systematics Agenda 2000: an historical perspective, pg. 457-458, *Biodiversity and Conservation*, Vol 4, No 5 (1995). “An early effort to establish a clearly defined systematics agenda appeared in 1974 under the title ‘Trends, Priorities, and Needs in Systematics and Evolutionary Biology’ and was later updated (1984). . . . Nonetheless, this earlier effort seemed doomed to failure because it was too broad in scope and lacked focus. . . . What has changed. . . ? Most of all it is a sense of urgency. . . . This sense of urgency and a call for the systematic biology community to define clearly its priorities and research agenda led to a meeting of . . . individuals, representing the American Society of Plant Taxonomists, the Society of Systematic Biologists, and the Willi Hennig Society . . . in March 1991. . . . One month later. . . the Systematics Agenda 2000 was established as an initiative. . . .”

⁹¹ Systematics Agenda 2000: Charting the Biosphere, A Global Initiative to Discover, Describe and Classify the World’s Species, SA2000 brochure produced by the American Society of Plant Taxonomists, the Society of Systematic Biologists, and the Willi Hennig Society, in cooperation with the Association of Systematic Biologists, and with financial support from the U.S. National Science Foundation (1994). That Systematics Agenda 2000 was a global initiative does not take away from the fact that it served to mobilize the nation’s community of systematists.

⁹² The “taxonomic impediment” is one example of a community-owned problem.

⁹³ POST Report *supra* note 87.

⁹⁴ For example, LINNE, in its aspect as observatory, will observe the organisms of the Biosphere — composed of the hydrosphere (the water realm of the Earth’s crust), the lithosphere (the Earth’s crust), and the atmosphere (the thin layer of gases surrounding the Earth to an altitude of less than 300 miles). At some stage in LINNE’s development, at some point in this Century, there may be points of partnership with other, national, cyberinfrastructure-enabled knowledge environments such as SPARC (Space Physics & Aeronomy Research Collaboratory) that observes the troposphere, the lower portion of the atmosphere, where life occurs.

⁹⁵ That is, the International Union of Biological Sciences (IUBS) and the International Union of Microbiological Sciences (IUMS). The present, operative, nomenclatural codes under the aegis of either IUBS or IUMS are:

International Code of Zoological Nomenclature

International Code of Botanical Nomenclature

International Code of Nomenclature for Cultivated Plants

International Code of Nomenclature of Bacteria

International Code of Virus Classification and Nomenclature

Also, the *Draft BioCode* (1996-1997), as a step toward the formulation of a harmonized nomenclatural code for all of Earth’s organisms. Also, the *PhyloCode* (1998) as a formal set of rules governing phylogenetic nomenclature. See Codes of Nomenclature, at BIOSIS, at <http://www.biosis.org.uk/zrdocs/codes/codes.htm>. (Accessed 02/13/2004). IUBS and IUMS issue sets of rules or codes of nomenclature governing the formation and choice of scientific names of the Earth’s taxa. They do not concern themselves with the definitions of the Earth’s taxa, *per se*. The Draft Biocode can be found at <http://www.rom.on.ca/biodiversity/biocode/biocode1997.html> (Accessed 08/02/2004). The PhyloCode can be found at <http://www.ohiou.edu/phylocode/index.html> (Accessed 02/13/2004).

⁹⁶ South Africa, for example. Pers. Comm. 07/29/2004, Dr. John Donaldson, Director, Kirstenbosch Research Centre, Capetown, the National Botanical Institute (NBI).

⁹⁷ Synthesis of Systematics Resources (SYNTHESYS), at <http://www.synthesys.info>. (Accessed 08/02/2004). *See also supra* note 21.

⁹⁸ Australian Biological Resources Study (ABRS), at <http://www.deh.gov.au/biodiversity/abrs/> (Accessed 08/02/2004). *See also supra* note 21.

⁹⁹ *See* the Global Taxonomy Initiative at the Convention on Biological Diversity website, at <http://www.biodiv.org/programmes/cross-cutting/taxonomy/> (Accessed 08/02/2004).

¹⁰⁰ Global Biodiversity Information Facility (GBIF), at <http://www.gbif.org> (Accessed 06/10/2004).

¹⁰¹ National Biological Information Infrastructure (NBII), at <http://www.nbii.gov> (Accessed 06/10/2004).

¹⁰² The NBII and GBIF are complementary initiatives. Both aspire to “design, implement, coordinate, and promote the compilation, linking, standardization, digitization, and dissemination of biodiversity data,” *see* NBII and GBIF: Biological Information Across Boundaries, International Biological Informatics Program, December 2002, *available at* <http://www.gbif.org> (Accessed 07/20/2004). The influential PCAST Report, in 1998, recommended that the NBII be elevated to a new level of capability “that can make maximal use of, and fully and openly share on a global basis, the information generated by research on biodiversity and ecosystems,” Panel on Biodiversity and Ecosystems, *Teaming With Life: Investing in Science to Understand and Use America’s Living Capital*, at Executive Summary, President’s Committee of Advisors on Science and Technology (PCAST), March 1998 [PCAST Report], *available at* http://www.whitehouse.gov/WH/EOP/OSTP/html/OSTP_Home.html (Accessed 03/20/2004). *See also supra* note 86 to understand the temporal position of the PCAST Report in the systematic community’s ongoing dialogue to assess, and make more broadly known, their needs, priorities, goals, and objectives.

¹⁰³ National Research Council of the National Academies, *NEON: Addressing the Nation’s Environmental Challenges*, pg 23, Washington, D.C.: The National Academies Press (2004).

¹⁰⁴ *Supra*, at pg. 24-25. The six, identified, major environmental challenges, for which a NEON-like national network of infrastructure would be essential for their solution, are: (1) biodiversity, species composition, and ecosystem functioning; (2) ecological aspects of biogeochemical cycle; (3) ecological implications of climate change; (4) ecology and evolution of infectious diseases; (5) invasive species; and (6) land use and habitat alteration.