

EOL - Encyclopedia of Life

Executive Summary



In February 2004, internationally renowned biologists and information specialists gathered for a four-day workshop in Telluride, Colorado to assess the feasibility of assembling a web-based **Encyclopedia of Life (EOL)** .

The 35 participants agreed that a widely-known, well-integrated, easily accessible, encyclopedic source of biodiversity information providing **all significant information known about all known species** has the potential to provide a critically needed baseline of biological knowledge vital for the future of life on Earth.

From this meeting arose a consensus regarding 1) the vision of an Encyclopedia of Life , 2) the key challenges, 3) the principles of governance, and 4) necessary milestones for the development of an EOL – which are outlined in detail in the principal document.

At the conclusion of the meeting, the National Museum of Natural History (NMNH) of the Smithsonian Institution offered to provide an early leadership role in launching this global EOL initiative by hosting its infrastructure. The NMNH will host the Internet portal of the site, provide incentives so its scientists will contribute to EOL, and actively collaborate with the international taxonomic community to make the EOL a truly global initiative and resource. Ownership of the EOL will ultimately rest with those who contribute to the endeavor over the long run and to the user community.

In just five years of concentrated effort, the project seeks to implement a freely accessible internet-based system containing several hundreds of thousands of species pages that will be routinely used for a wide range of economic, educational, and scientific applications.

¹The Telluride meeting was convened by the National Museum of Natural History, Pinhead Institute, and Telluride Institute.

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1. Motivation

How much do humans know about life on Earth? We know a great deal. We have explored and mapped many regions of the planet and have described more than a million-and-a-half species in the process. However, the truth is that over the past centuries we have discovered and described only a small percentage of the species that live on our planet. Now, biologists believe that Earth has entered a period of exponentially increasing species loss resulting from impacts on the planet's natural order by our rapidly increasing human population. As habitat destruction and landscape conversion spread at an accelerating rate, we are in effect standing in a burning building feeding the flames of species loss. And our knowledge of life on Earth is far too dispersed, diluted, disorganized and desultory to know what we need to save, let alone understand how to save it.

Biologists and natural history institutions are now in a unique position to provide the world's people with universal access to all we know about species through a web-based Encyclopedia of Life. Now that information technologies are affordable, available, and widely distributed, it is high time to provide access to all significant information known about all known species.

2. The Key Challenge: Making Knowledge about Life Globally Accessible

Given the incredible richness and diversity of life on Earth, and the still somewhat nascent state of information technologies, we should not be surprised that the information we currently possess is widely scattered. Much of this information is still in paper format located in specialized libraries or on specimen labels in museums or in the minds of experts in natural history museums and research institutions. What is available in electronic form is often not shared outside the world of professional biologists or is spread across far-flung, highly heterogeneous websites. This makes it effectively impossible for the average citizen to gain much more than a spotty, almost random knowledge of life. These challenges also make it extremely difficult and costly for professional scientists to do their work. Properly organized, easily available, and scientifically vetted, what we already know about biodiversity would become enormously useful to professional scientists,

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average citizens, policy makers, and to the fields of biology, conservation, medicine, security, education, agriculture, biotechnology, sustainability, and more. Significantly, information about new discoveries can be easily added to this encyclopedia. The reaches of the Internet are rapidly expanding. Web-based human interfaces are increasingly usable and the ubiquitous Web page is becoming the most common form of global communication. This offers the perfect medium for collecting and studying knowledge about species. Many institutions around the world have already begun to put databases of information about species on-line. However, these databases, image repositories, syntheses, and even scanned portions of "the literature" are often 1) limited to particular nations or geographical areas, 2) limited to particular groups of species or interests, or 3) intended specifically for a lay, rather than scientific, audience. There are few widely employed standards for these information repositories, and interchange among them has not generally been a priority. Many different groups have attempted to address this problem, but they have not addressed a global audience nor garnered the momentum to carry the process forward.

3. The Vision of the Encyclopedia of Life

In just five years of concentrated effort, we believe it is possible to implement a freely accessible system containing over one million species pages that will be routinely used for a wide range of educational, scientific, and economic applications.

The Encyclopedia of Life project will use proven and emerging technologies to provide open, electronic access to all significant information known about all known species. This will have the equally important effect of accelerating the discovery and description of all species of our planet by making apparent the social benefits of such information, and through increased technical capabilities to support this activity.

These capabilities could ultimately transform the practice of organismic biology, and therefore the design and implementation of the EOL will be flexible enough to evolve as our understanding evolves and as technologies advance.

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THE VISION OF AN IDEAL ENCYCLOPEDIA OF LIFE

INCLUDE:

A) Integrating What We Know About Biological Diversity

The Encyclopedia will support integrated access to complex information while simultaneously encouraging individual scientists and citizens to independently submit their own information and observations about species. Thus, the EOL will synthesize information from numerous contributors around the world into an integrated portal. Very importantly, the process of constructing the EOL will transform a plethora of incompatibly-structured data sources into a standardized and highly accessible format that will allow users to efficiently query the specifics of a particular species and its place in the natural world.

B) Bringing Citizens into the World of Life Science

We have only begun to guess how widely the EOL will be used. But we know this: The more it is used, the more it will be used in various ways we cannot possibly predict. The Web itself is a prime example of this Information Age phenomenon.

But, we can safely predict some uses of the EOL. Take for instance middle school or high school students. In the near future, they will be able to visit the EOL portal, easily locate needed information, and put together reports, talks, posters, websites, etc, with high-quality images of species, concise taxonomic information, and easily understandable overviews of species. Any visitor to the EOL will be able to explore the site in-depth, accessing scientific literature for details not presented on a species page, if desired.

Or, take average citizens who discover insects chewing on bushes or rodents burrowing in the ground. The EOL can guide them through the process of identifying the creature, and supplying information about its habitat, threats, and its contribution to the great cycle of life. Importantly, citizens will be able to collect and upload information they have gathered, and will be able to engage others in discussions, sharing information.

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Some uses we can readily imagine include:

- Farmers in Africa using the system to identify crop pests and design integrated pest management plans
- Students throughout the world using the system to share observations, identifications, and range maps of butterflies, bats, or birds
- Scientists using the system to accelerate the discovery and description of new species, increasing our baseline knowledge of biology
- Environmental scientists employing the EOL to improve conservation strategies for ecosystems

C) Supporting the Needs of Scientists

The EOL will convene a professional board of highly skilled and recognized taxonomists to ensure the quality of information at the core of the Encyclopedia. The search capabilities, integrated reports, and management tools will meet the highest standards of science. There will be a platform for developing fully automated tools for field identification of species that provides an initial determination of the name (of a known species) or indicates that the specimen (of an unknown species) should be further studied by a taxonomist for a final classification.

D) Specific Capabilities of the Encyclopedia

Finally, it must be emphasized that the Encyclopedia of Life is not a single Website or database. It will be an ever-growing collection of electronic data sources, maintained by autonomous scientific authorities around the world.

Its contribution will include:

- An **internationally accepted internal data format** for providing access to electronic data on species, so that each additional site accessible via the EOL portal will have a low cost associated with putting it online
- **Highly accessible Web-based user and applications interfaces** for querying information about species, integrating, and downloading it, and producing a wide variety of outputs (such

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as reports and image collections). Various sorts of querying will be supported, including character comparisons, DNA, multi-field searching, image browsing, and geographic browsing

- A **community of experts** to guide the development and ensure the quality of the information contained in the Encyclopedia
- The support of **sophisticated software tools for managing information** about species in order to allow scientists and non-scientists to focus on the issues of life itself as opposed to the expense and time-consuming nature of locating, acquiring, and integrating information from far-flung, inaccessible and disparate sources
- The support of **software tools for visually presenting species data** that maintain professional standards and accuracy, and are easily understood by users with no professional-level training in biology; yet are rich enough to support the needs of the most sophisticated users

In Sum: A Great Enabler

The Encyclopedia of Life will thus be a great enabler. It will bring together biologists from around the world by making it dramatically easier to share knowledge. It will bring students and citizens into the fold of biological literacy. It will allow research to progress far more quickly, and in many cases lead to scientific conclusions that previously had been intractable. It will open the eyes of the world to the vast beauty, complexity and usefulness of biodiversity. It will allow monitoring of natural and human-created threats to species. It will allow us all to understand and appreciate the economic and aesthetic value of Earth's species and guide efforts to nurture Earth's natural order.

4. Principles of Governance for the Encyclopedia of Life

The Encyclopedia of Life will be constructed as a dynamic product with contributions from a growing worldwide community of taxonomic institutions, professional societies, and individuals. In recognition

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of this fundamental premise, the management approach will necessarily be distributed and incremental – adding or modifying structures, rules and incentives as required by the growing scale and changing nature of the global enterprise.

THE FOLLOWING PRINCIPLES WILL GUIDE THE MANAGEMENT OF THE ENCYCLOPEDIA OF LIFE THROUGH THIS EVOLUTIONARY PROCESS:

A) Open contributions and participation

The EOL will be open to contributions and participation from all interested parties. This includes governments, taxonomic institutions, professional societies, corporations, and individuals.

B) Representative management

The management of the EOL will be representative of the community that contributes to it. This community is expected to be broadly represented geographically, taxonomically, and generationally.

C) International

The EOL will only succeed if it is truly an international enterprise with contributions and users originating from countries around the world.

D) Proportionality

Contributors to the EOL will be credited in proportion to what they provide, while attempting to account for disparate resources.

E) Capacity building

Much of the Earth's biodiversity exists in places that have relatively little local capacity to describe it, yet high potential to use it, and even more potential to conserve it. The EOL will likely result in building local taxonomic capacity, as well as facilitating and encouraging sustainable local use and widespread appreciation of biodiversity.

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F) Open access

The EOL will provide its intellectual property to the world under open licensing, modeled after the Creative Commons, to encourage non-proprietary use by everyone. Proprietary use of specific information will be considered under licensing regimes that ensure contributors receive fair compensation and attribution for their contributed intellectual property.

G) Leadership

The EOL is an ambitious global undertaking that will require significant upfront investment in leadership resources and these early investments will most likely come from the major taxonomic institutions of the world. The initial stages of the EOL have been led by the National Museum of Natural History (NMNH) of the Smithsonian Institution in Washington, DC. However, these early efforts and investments do not confer ownership of content. Ownership will ultimately rest with those who contribute to the endeavor over the long run and to the user community.

The NMNH will play a pivotal role by hosting the initiative and the Internet portal to the EOL. Scientists at NMNH and in other science units of the Smithsonian Institution will lead by example – significantly contributing to the EOL pages while actively collaborating with the international taxonomic community to encourage their contributions.

H) A foundation in science

The EOL is fundamentally a scientific enterprise. This means that the values of science will take precedence over other considerations. Specifically, contributions will be assessed on merit as opposed to the credentials of the contributor.

5. Encyclopedia of Life: Basic Site Pages

The EOL website will have a simple structure consisting of three kinds of interfaces, each of which will be focused on delivery of different types of information, navigation, and searchability. **Species**

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Pages will contain or link to information specific to an individual species. **Family Tree Pages** will provide users with general information about a group of species, as well as the ability to navigate up or down the classification system. **The Home Page** of EOL will provide an entry point into the website, with information about the structure and purpose of the site, as well as search tools.

Species Pages

The heart of the EOL website is the Species Page. Each species will have a unique page, which is the entry point for information. The text on the Species Page will be geared to the “citizen naturalist,” an educated, non-scientist seeking information about a species. It will be as engaging as possible. The “motto” of each Species Page is, “Every species tells a story.” Links on the Species Page will direct the user to more detailed information, such as more images, natural history information, digitized scientific literature, specimen databases, maps, etc.

Content of the Species Page:

- Authentic species name and frequent synonyms, both scientific and common
- Brief diagnostic, physical description
- Brief text, directed to the citizen naturalist, telling a natural history story about the species
- Image(s)
- Generalized distribution maps
- Author and date of publication of the Species Page and sources of information

Family Tree Pages

Family Tree Pages will illustrate the groupings of species on the tree of life and provide users with a way to navigate around the classification system. Users will be directed to a Family Tree Page if their query is as general as “cat,” for example. In this case, the page would be the Felidae Page,

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where words such as “feline” and “felid” would be encountered. Users would have the option to be “more specific” or “less specific,” and would then move up or down the classification system. There will be Family Tree Pages illustrating the classification of that lineage, including Kingdom, Phylum, Class, Order, etc.

Home Page

As the top level entry point to the EOL website, this page provides basic information about the site, its purpose, and its functionality.

Content of the Home Page:

- The mission statement of the EOL, “All significant information known about all known species”
- A history and explanation of the EOL project
- An explanation and description of the Linnaean system of classification
- A definition of a species, as used within the EOL website
- A guide to using the EOL website
- Search tools
- Browse tools
- Contributor guidelines and instructions
- Application interface specifications

Home Page Links:

- Species in the news
- Glossary of terms
- FAQs
- Contributors (content providers)

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6. EOL's "If you want to learn more, click here"

The Encyclopedia of Life will contain or provide links to all significant information known about all known species on Earth. It will provide seamless access to existing knowledge from distributed sources, as well as new knowledge that will be discovered, codified, and documented by the scientific community over time. Though it is essentially impossible for any single entity to develop and maintain all content, that is the goal of the EOL, and it is vital that EOL users perceive its contents as seamless, regardless of the source of the data being accessed. The data to which the EOL provides access to will come from many different widely-distributed communities – from many databases maintained by many organizations and individuals, internationally. They will all have to be able to exchange information and provide interoperable ways to access the distributed information.

The Species Pages described above will display only a small portion of the information accessible from the EOL website. The underlying databases will convey all available information about a species; some of this information will be in the form of deep links to other sites. In addition to the content of the Species Page as listed above, the following are some of the other information that will be included in these databases:

Species characterization

- Physical descriptions, including dimensions
- Primary type specimen(s) descriptions and images
- One or more images of a representative specimen of a species, against which specimens or images can be compared for species identification
- Specimen data and databases rich in specimen-based information
- Sounds of the species
- Videos of the species

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Relationships among species, and between a species and its environment

- Conservation status of species
- Human relevance information (e.g. cultural, spiritual, and economic significance)
- Geographic distribution of the species including map, location information, atitude/longitude, city, country, or other geographic description.
- Phylogeny
- Prey, predators, parasites, and symbionts of the species
- Information about the species location and relationships within the tree of life

Stories

- Information about the discovery of the species and its publication
- Interesting stories about the species, including its way of life: what it eats, who eats it, where it rests, where it eats
- Information about the scientists who do the discovering
- Information about the cultural, spiritual, or economic significance of a species

Literature References or Links

- Collection information
- Catalog information
- Current research on the species, including names and contact information of current researchers
- Taxonomic literature
- Physiological & morphological literature
- Behavioral literature
- Ecological & natural history literature
- Genetic information

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Authorship, certification and audit trail

- Authors responsible for providing information/documentation about species for the EOL
- Certification status, indicating whether each element of information about the species has been vetted by an established scientific review process. This will also include quality assessment/control information about the content provided.
- An audit trail of changes made to the information presented in the EOL

7. Milestones for the Encyclopedia of Life Development

A) **Convene a steering committee within 2-4 months with membership representative of potential contributors and expertise.** The steering committee will be the initial governing body of the EOL. Its goal will be to oversee the first stages of development. It is likely that the steering committee will be replaced by a more robust governance structure that can accommodate rapid growth in the number of contributors and users.

B) **Develop a prototype within 6 months with which to engage potential contributors.** Readily available information for a modest number of species will be assembled into a "concept demo" prototype to engage potential sponsors and contributors. This prototype will have limited functionality, flexibility, and extensibility; but it will provide a thorough "taste" of how one particular application of the full EOL would look and feel to a user. The prototype will focus on assembling a modest number of high quality Species Pages across several taxa, and demonstrate search and portal functions; special emphasis will be to show how the full EOL will provide an incremental, accessible way to explore species data and related scientific and environmental information.

C) **Develop a business plan within 6 months.** The steering committee in consultation with the larger community will draft a 5-year business plan that can be used to attract sponsors and contributors. This business plan will provide detailed descriptions of the goals, management, content, applications, development, and operating costs.

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D) Develop a multi-institutional proof-of-concept with 3 to 5 major taxa within 18 months.

A first order system will be constructed with sufficient functionality to integrate Species Pages from multiple institutions for 3 to 5 major (e.g. mammals) taxa.

This initial system will force the Encyclopedia of Life community

to demonstrate that it can address its key management, technical, and content issues.

E) Expand the multi-institutional prototype with additional taxa and contributors within 24 months.

A key milestone for the multi-institutional prototype is a demonstrated capacity to attract and integrate content from contributors beyond the initial circle of implementers.

F) Populate the database with currently known species within five years.

The Encyclopedia of Life should contain at least one million Species Pages, of which 200,000 are considered high quality, complete Species Pages, in the Encyclopedia of Life website.

Conclusion

A widely-known, well-integrated, easily accessible, encyclopedic source of biodiversity information providing **all significant information known about all known species** has the keen potential to provide a critically needed baseline biological knowledge and increase the awareness of government officials, scientists, industry leaders, and most importantly, the general population, to the beauty and astonishing breadth of life on Earth – and to the dire need to protect and nurture this irreplaceable diversity.

The National Museum of Natural History (NMNH) of the Smithsonian Institution will play a pivotal role in launching and leading this global EOL initiative.

In just five years of concentrated effort, we believe it is possible to implement a freely accessible system containing over one million species pages that will be routinely used for a wide range of economic, educational, and scientific applications. It is an idea whose time has come.

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Participants in the Encyclopedia of Life Symposium

Keynote Speakers

Daniel Janzen, Dept of Biology, University of Pennsylvania

Peter Raven, Director, Missouri Botanical Gardens

Cristián Samper, Director, National Museum of Natural History

Participants

Terry Erwin, National Museum of Natural History

Brian Farrell, Museum of Comparative Zoology, Harvard University

Brian Fisher, California Academy of Sciences

Mark Fornwall, National Biological Information Infrastructure

Thomas Garnett, Smithsonian Institution Libraries

Anthony Gutierrez, US Army

Winnie Hallwachs, University of Pennsylvania

Diane Hillman, Cornell University

Brewster Kahle, Internet Archive

John Kineman, National Geophysical Data Center / NOAA

Roger "Buzz" King, University of Colorado

John Kunze, California Digital Library, University of California

Erick Mata, INBio

Scott Miller, National Museum of Natural History

Piotr Naskrecki, Museum of Comparative Zoology, Harvard University

Bradley Parks, Argonne National Laboratory

Tom Parris, ISCIENCES, LLC

John Pickering, University of Georgia

"Rama" Ramapriyan, EOSDIS, NASA

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Bruce Stein, NatureServe

F. Christian Thompson, USDA

Warren Wagner, National Museum of Natural History

Stu Weibel, Online Computer Library Center

Richard Wilkerson, Walter Reed Biosystematics Unit

Don Wilson, National Museum of Natural History

Special Guests

John Clute, science fiction writer

Dan Collins, artist, Arizona State University

Paul J McAuley, science fiction writer

Marsha Sitnik, EOL Symposium scribe, National Museum of Natural History

Telluride Participants and Organizers

Nana Naisbitt, Executive Director of Pinhead Institute and Smithsonian Research Collaborator

Amy Poinsett, Finance Director, Pinhead Institute

John Lifton, Founder and Director, Telluride Institute

Pamela Zoline, Founder, Telluride Institute

Robin Magee, Executive Director, Wilkinson Public Library, Telluride

Margaret Rinkevich, Chairperson, Pinhead Institute

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Host:

National Museum of Natural History, Smithsonian Institution, DC

Partners:

California Academy of Sciences, San Francisco

CANABIO, Mexico City

INBio, Santo Domingo, Costa Rica

MCZ, Harvard University, Cambridge, MA

Missouri Botanical Garden, St. Louis

MVZ, University of California, Berkeley

Partial List of Potential Partners:

American Museum of Natural History, New York

Bishop Museum, Honolulu

Conservation International, DC

Cornell University, Ithaca

CSIRO, Canberra

Field Museum of Natural History, Chicago

GBIF, ITIS, Species 2000

Museum National d'Histoire Naturelle, Paris

The Natural History Museum, London

The Nature Conservancy, DC

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June 2004 Letters of Support for the Encyclopedia of Life

From E.O. Wilson, Harvard biology professor for four decades, and winner of two Pulitzer prizes

The Encyclopedia Of Life project has great significance for science and the public interest at many levels. It is the first step in a "big science" project that will in time match the Human Genome Project in magnitude. It is extremely important to reach the goal it envisions of exploring all of life's biodiversity. At present, only as few as 10 percent of Earth's species are known to science. The information accumulated in the Encyclopedia Of Life on each species in turn can then be used to under-gird new initiatives in ecology, molecular biology, medicine, agriculture, and in fact virtually every human activity with a biological component. The database will also be a source of new ideas as the phenomenon discovered in the Encyclopedia Of Life effort come to light.

From Peter Raven, Director of the Missouri Botanical Garden

The 21st Century may be the age of biology -- a time when our knowledge about organisms makes it possible for us to use them in constructing the sustainable life-support systems of the future, and preserving those that have supported us all in the past. Towards this end, a remarkable first step has been taken with the organization of the Encyclopedia of Life.

Our degree of understanding is abysmal -- no more than one of six of all species of organisms (other than bacteria) has even been given a name, and even for the vast majority of those that we've named, we know next to nothing! A serious impediment to progress lies in our underutilization of modern information technology to retrieve the established information about organisms, and thus to add rationally to the information that we need for the future. A universal series of Web pages, evolving as knowledge increases, for all species of organisms, provides a sound means for improving the situation rapidly -- the Encyclopedia of Life.

By making this knowledge accessible to all, we will be accelerating progress greatly. Students, amateurs, and professional biologists alike -- all those who have need of such knowledge -- will find it readily, in an easily digestible form. When we have access to knowledge that we have already acquired, we shall know where to look for more. In this way, the Encyclopedia of Life represents an exciting new beginning in our millennia-old quest to understand the world around us.

The Smithsonian Institution, the national museum of the United States, is the natural leader for this project. For it to be successful, however, will require the efforts of many over the years to come -- in fact, their continuous involvement. The output will help us all, and many will participate in building it. It is a pleasure to watch this project grow, and a thrill to think of how useful it can become in the very near future.

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From Daniel Janzen, Professor of Biology, University of Pennsylvania

The anticipated Encyclopedia of Life web site has all the potential to become THE window on the biodiversity world, for the world, by the world. Humanity has long been accumulating, and forgetting, massive amounts of information about the world's wild biodiversity. We have libraries, museums and specialists packed to the hilt with wild biodiversity and understanding of it. It is all linked and collated through a marvelous code of scientific names for species and for groups of species of various degrees of relatedness. However, when am standing with a name in my hand, it is often a quite tortured trek - originally through literature and specialists, and now through them AND the internet - to find out what I want to know about a species, now, here, in real time.

As the internet was born, individual taxonomists and other managers of species-level information recognized instantly that a process was being delivered unto them that could open the world of their knowledge to the world at large, leading to a plethora of web sites and species pages, tagged by species names and sought by the Googles of the world. So, you get a million hits when you type in "squirrel", when all you wanted to know was what really IS this thing burying acorns in the lawn.

Fortunately for all of us, the world over, the rising conscience of the biodiversity information producers, as well as the information users, has finally led to the predictable collective effort to create a single window to this world of biodiversity. The Encyclopedia of Life is meant to, and will, be a welcoming window to what we know. Put in a name, any name, it takes you there. And if you want to dawdle along the route to peer off into the many nooks and crannies of the biosphere, course into well-marked detours, shortcuts, circle routes, cul-de-sacs, parking lots, lookout turnouts, and interstate shopping malls, it will help you do that. If you have only a dimly viewed idea of the name for that thing in your hand, it will even lead you off into an identification excursion, before bringing you back to the interstate where you can zoom off to where you want to go (you think).

Now think on what this window to biodiversity will mean to those who have long labored in silence in their inner sanctums, whispering to their near neighbors, puzzling over how to name species, how to find species, how to group species, and how to tackle the natural history information that steadily accumulates onto species. After many centuries of being the unseen inner workings of the science-society interface, abruptly the fruits of their labors will be globally accessible, from the farm worker to the day care center child, from the CEO on her lunch break to the crown prince of a distant country, from tropical rain forest to the arctic. And once the world knows what it holds in its hands and mind, maybe, just barely maybe, it might find itself collectively willing to think about holding on it as it slides inexorably into the craw of ravenous humanity."