Consortium for the Barcode of Life: Support for Consortium Activities and Secretariat Office

Draft for Review

A request for continuation of support by the Alfred P. Sloan Foundation
submitted by the Smithsonian Institution on behalf of

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EXECUTIVE SUMMARY

DNA barcoding has grown rapidly since the concept was proposed in 2003, and the Consortium for the Barcode of Life has played an important role in promoting and guiding this growth. Taxonomists working on a wide variety of organisms are now using or testing DNA barcoding as a research tool, and large initiatives on plants, fungi and marine organisms are in the planning stages. The rapidly growing barcode database will soon offer biologists a unique system for comparative analysis across a broad spectrum of taxa. Based on the accumulation of positive results and refinement of analytical approaches, opposition to barcoding among taxonomists has essentially dissipated. Major barcoding facilities have been established in Canada and the US, and CBOL has developed a global network of partner labs that will accelerate barcoding activities in the coming years. Global barcoding initiatives on birds, fish, mosquitoes and fruit flies are making significant progress and the first fully operational barcode-based identification systems will be in place within two years. Beyond taxonomy, biologists interested in speciation, population biology, phylogenetics, and phylogeography have expressed interest in developing collaborative research that uses barcode data. CBOL's outreach to developing countries has sparked barcoding activities of scientific and socioeconomic importance to these regions. Several US government agencies are investing in pilot projects and may formally adopt barcoding for regulatory use in the near future. The next two years should witness a rapid growth in barcode data and their use in basic and applied research.

I. THE SCIENTIFIC AND SOCIETAL IMPORTANCE OF DNA BARCODING

DNA barcoding is taking up its position alongside two other great endeavors of biological research – genomics and phylogenetics. Genomics is providing a comprehensive view into the biology of a few, but rapidly rising number of 'model organisms'. Knowledge of an organism's entire genetic makeup allows cause-and-effect research into metabolic pathways, but the sampling of taxa is too sparse to learn much about diversity among organisms. Phylogenetics data make a different trade-off by sequencing tens of genes (or ten thousands of base-pairs) from 'exemplar species' that represent major branches of evolution within a group. The Assembling the Tree of Life program of the National Science Foundation is building a robust framework of evolutionary relationships, but the sampling still involves only a tiny percentage of the species in any taxonomic group. Barcoding therefore creates a broad foundation of standardized biodiversity data based that can connect all research programs that use sequence data. Taken together, these three research programs connect all life forms to each other and will enable researchers to navigate and explore the full range of their biologies.

In this way, barcoding is figuratively putting the full diversity of living organisms on the table (and literally it in a database table) for researchers to examine in a comparative way. Up until now, taxonomic groups have been considered too different and too idiosyncratic to compare their variability and species delimitations. Barcoding, however, is based on the observation that one or a very few short gene regions can be compared across an enormous diversity of taxa. A standardized database of this scope opens research opportunities on how selection acts on homologous gene sequences, or how species' histories correlate with the histories of their community assemblages. Using barcode data, we can now explore the patterns and limits to variation across a wide range of taxa in a formal, comparative way.

Up until recently, cytochrome b and a variety of other gene regions were used commonly

by taxonomists interested in molecular markers. GenBank now has approximately 75,000 cytb records, compared to 150,000 records for cytochrome c oxidase 1 (COI), the barcode gene region for most animal groups. The Barcode of Life Data System (BOLD*, www.barcodinglilfe.org; see Ratnasingham and Hebert, 2007) at the University of Guelph was launched in 2004 and it now contains more than 333,000 COI records representing approximately 35,000 species. Barcoding has clearly catalyzed the growth of an enormous data resource.

Miller (2007) described the role of barcoding in "the renaissance of taxonomy". In his view, the rapidly growing public database of barcode data is providing taxonomists with a *lingua franca* with which they can describe, discuss, and delineate species and the boundaries between them. Taxonomists are now beginning to gather barcode data for holotype specimens and to include these data in the published descriptions of new species (e.g., Victor, 2007). In a recent description of new dogfish species (Last, White and Pogonoski, 2007), researchers *"supplemented this approach [rapid description of new taxa followed by electronic publication] with DNA barcoding to add a new level of taxonomic rigor. Newly described and the re-described species had unique coxI barcodes and these can be linked with full confidence to type material and validated identifications of these taxa."* Ecologists, ecosystem scientists and others are gaining the ability to identify species using public barcode data which act as an effective proxy for the expert taxonomists who are in short supply. In ecology, for example, Smith, et al. (2007) used barcodes to distinguish ecological generalists from specialists and Hajibabaei et al. (2006) discovered new patterns of host plant fidelity among tropical Lepidoptera using barcoding. Robins, et al. (2007) used barcoding to study the biogeographic histories of rat species with the goal of understanding their relation to the history of human migration.

Barcoding is also becoming a more commonly used tool to detect and manage species of

* See Appendix 1 for a glossary of all acronyms

concern to society. Assefa, et al. (2007) used barcode data to correctly identify the species of stemborer, an important agricultural pest, using larval specimens found in sugarcane. Timm, et al. (2007) published barcode data alongside diagnostic morphological data for pest species of African moths that endanger fruit crops. Greenstone, et al. (2005) used barcoding on eggs and larvae to explore the predator-prey relationships between spiders and carabids, with an eye toward biocontrol of crop pests. Dawnay, et al. (2006) validated the laboratory protocols used in barcoding, opening the door to the use of barcode data for forensic analysis. As described below, a number of US government agencies are now testing barcoding as a regulatory tool for environmental protection, food safety, and conservation.

II. BACKGROUND: DNA BARCODING AND CBOL

Since the first DNA barcoding publication in 2003 the Barcode of Life Initiative (BOLI) has gone through three stages of growth and is embarking on a fourth. Like the growth of a tree, BOLI went through an initial phase of germination following the original publications (Hebert et al. 2003a and 2003b) and it then sprouted rapidly thanks to two 2003 planning workshops at the Banbury Conference Center, supported by the Sloan Foundation. The concept also encountered early skepticism and resistance that would persist for several years.

BOLI then entered a second phase of rapid growth in early 2004 when the Sloan Foundation granted support to the Smithsonian to create the Consortium for the Barcode of Life (CBOL; www.barcoding.si.edu). Substantial studies began to appear, demonstrating the effectiveness of barcoding in a few taxonomic groups (e.g., Hebert et al., 2004a on birds; Paquin and Hedin, 2004 on cave spiders; Hebert et al., 2004b on butterflies). High-throughput labs began to develop at the University of Guelph and the Smithsonian, and BOLD was constructed as BOLI's online workbench. CBOL held the First International Barcode of Life Conference in London in February 2005 (http://www.barcoding.si.edu/London.html). The conference made

barcoding highly visible and publications critical to barcoding continued to appear, based largely on misconceptions about barcoding and methodological conservatism (e.g., Moritz and Cicero, 2004; Will, Mishler and Wheeler, 2005). At the same time, CBOL's Working Groups were engaging taxonomists, database specialists, and potential users in a variety of activities. CBOL's two largest campaigns were launched on birds and fish, and through them members of the taxonomic community gained a better appreciation for the effectiveness of barcoding.

By early 2006, objections to and concerns about barcoding began to wane (Dasmahapatra and Mallet, 2006) and BOLI began a third phase of sturdy, woody growth, supported by a second Sloan Foundation grant to the Smithsonian for CBOL. BOLI began to branch out to new taxa (e.g., Greenstone et al., 2005 on beetles and spiders; Scheffer, Lewis and Joshi, 2006, on leafminer flies; Smith et al., 2007 on parasitic flies; Seifert et al., 2007 on fungi; Robins et al., 2007 on rats; Siddall et al., 2007 on leeches. See Appendix 2, abstracts of five recent barcoding articles). CBOL held a Second International Conference (the first barcode meeting in Asia) as well as outreach meetings to build participation in developing countries. Workshops were held to promote collaborative research with population and evolutionary biologists and to connect barcode data to global biodiversity databases. New initiatives were launched on mosquitoes and fruit flies, and potential users, especially government agencies, began to invest in pilot projects to test barcoding for formal adoption as a regulatory and forensic tool.

BOLI is now ready to enter its fourth phase of growth. Most taxonomists now recognize the value of barcodes as a research tool and as a part of the information infrastructure of biodiversity science (Padia and De La Riva, 2007). Until now, barcoding has been highly distributed with funds coming from diverse sources for coordinated but loosely federated projects. Researchers linked to the Canadian Centre for DNA Barcoding at the University of Guelph envision a five-year CAN$150 million International Barcode of Life Project ("iBOL")

that would greatly expand the barcode library, advance barcoding technology and informatics, and increase cohesion among projects. Genome Canada has expressed interest in receiving a $25 million challenge grant proposal under its International Consortium Initiative Program and the University of Guelph is preparing its proposal for submission in early 2008. If the proposal is successful, CBOL would serve as its Secretariat for international networking (see Appendix 3). With continued support from the Sloan Foundation, the next two years will produce a burst of growth that establishes barcoding as a standard, accepted technique.

III. CBOL'S LONG-TERM STRATEGY

CBOL's January 2006 proposal to the Sloan Foundation stated: ***"CBOL plans to make DNA barcoding a standard practice in taxonomy by 2010, and a practical, reliable approach to specimen identification for non-taxonomists."*** This remains our goal. At the end of the proposed award period, barcoding will be well-established and CBOL will begin a two-year transition (2010-2012) that will make BOLI sustainable without support from the Sloan Foundation. CBOL proposes to continue the four-part strategy that has produced the results described below and to add a fifth: ***Promoting Adoption of Barcoding as a Standard Protocol***.

CBOL has set the following strategic objectives for the proposed award period**:**

A. Enabling the universal application of DNA barcoding. CBOL's Leading Labs Network will be a global system for technical assistance and training to barcoding projects. Software, training materials, and analytical protocols will be developed and disseminated in several languages.

B. Populating a global database of reference DNA barcode records. Barcode data will be generated in a few high-throughput labs and in smaller facilities around the world in association with CBOL-led initiatives and a rapidly expanding set of projects launched by others. Barcodes from plants, fungi, marine taxa and other new taxonomic groups will be accumulating rapidly.

C. Developing a complete and operational demonstrator system for species identification in a group of interest. Real-world tests of the barcode reference databases of mosquitoes and/or fruit flies will be underway, and regulatory agencies will be considering their formal adoption.

D. Promoting global participation in the Barcode Initiative. Barcoding projects that began with CBOL's outreach efforts will be active and working with CBOL's Leading Labs Network.

E. Promoting adoption of barcoding as a standard protocol. This new strategy emerged from CBOL's success in attracting the attention and investment in barcoding of several US government agencies. By April 2010, barcoding will be formally validated and recognized by an international certifying body. Several US government agencies will have adopted barcoding for routine regulatory work and several others will be considering adoption. CBOL's outreach efforts will generate pilot testing by government agencies outside the US.

IV. RESULTS UNDER SLOAN FOUNDATION SUPPORT, 2006-2008 AND GOALS FOR 2010

A. SUMMARY. During the current award period, CBOL conducted an ambitious program of meetings, workshops and conferences (see Appendix 4) and outreach (Appendix 5). Membership increased to 164 Member Organizations in 46 countries (see Appendix 6). Projects launched by CBOL attracted $1,502,999 and the seven largest CBOL meetings cost more than $600,000, of which 60% came from non-Sloan sources. Taken together, CBOL has garnered support from non-Sloan sources that exceeds the current grant amount (see Appendix 7). CBOL's Executive Committee recently revised its organizational structure to better manage its expanded scope of activities and revised its Terms of Reference (Appendix 8).

B. OUTPUTS. The January 2006 CBOL proposal to the Sloan Foundation specified the following deliverables, virtually all of which have been, or will be produced, on schedule. New

goals are stated below and new deliverables are described under Proposed Program of Work.

1. Public barcode records. CBOL's last proposal set a goal of increasing the number of barcode records from 50,000 representing 10,000 species in January 2006 to 500,000 by July 2008. As of January 2008, BOLD held approximately 333,000 records from 35,000 species. There are many sequence records for plants that are not included in this total because of delays in the final selection of the plant barcode region. At the present rate of data accumulation, BOLD could contain more than 400,000 records by July 2008. Whether or not the goal of 500,000 barcode records is reached by July 2008, CBOL has learned that a potentially significant volume of barcode data has been gathered but not entered into BOLD or any other public database. CBOL plans to address this problem.

2010 Goals: 1 million barcode records representing 100,000 species.

2. The BARCODE data standards have been implemented by GenBank and the other members of the International Nucleotide Sequence Database Collaborative. Information on the standards has been disseminated and data records that meet these standards are being submitted to GenBank. Records are given the keyword BARCODE if they: contain a minimum of 500 bp; are bidirectionally sequenced from the COI region; include the primer sequence data; are linked to sequencer trace files stored in the NCBI Trace Archive, a voucher specimen in the approved structured format, and a species name that can be traced to its source. BOLD is able to upload BARCODE records to GenBank and GenBank has developed a software tool for direct submission of BARCODE records. CBOL has developed an online registry of biorepositories to enable global linkage of BARCODE records to their vouchers (see www.biorepositories.org).

2010 Goals: 100,000 records that comply fully with the BARCODE data standards.

3. Demonstrator Projects. CBOL launched two "Demonstrator Projects" in 2006 on mosquitoes and fruit flies, but has been unable to complete the proposed reference libraries. As

of September 2007, specimens from 20% of all mosquitoes and one third of all economically important fruit flies have been barcoded. Fund-raising efforts by these projects have started more slowly than anticipated but completion of both demonstrator systems is expected in 2009.

2010 Goals: 50% completion in 2008; 80% completion by the end of 2009.

4. All Birds and All Fish Barcoding Initiatives. The All Birds Barcoding Initiative (ABBI, http://www.barcodingbirds.org/) has reached and surpassed the goals set in CBOL's 2006 proposal to the Sloan Foundation. As of November 2007, ABBI had barcoded 11,433 specimens representing 2,157 species, surpassing the goals of 10,000 specimens and 2,000 species set in the proposal. The Fish Barcode of Life Initiative (FISH-BOL, www.fishbol.org) set the goal of barcoding 30,000 specimens representing 6,000 fish species by July 2008. As of January 2008, FISH-BOL has obtained barcodes from approximately 23,000 specimens representing 4,300 species.

2010 Goals: Regional Working Groups will be submitting more funding proposals; barcodes will be known for 15,000 fish species (50%) and 6,000 bird species (60%).

5. Leading Labs Network. CBOL's DNA Working Group has evolved into the Leading Labs Network which consists of 15 labs in nine countries, plus GenBank (see Appendix 9). The Network has held three planning meetings and conducted a one-day short-course on barcoding protocols for approximately 150 participants at the Second International Barcode Conference in Taipei in September 2007. The Network has begun compiling training material that will make initiation of barcoding in new labs much simpler. These training materials will be made available through the CBOL website and BOLI Data Portal and will be used in training courses conducted by the Network in the next two years.

2010 Goals: Enable barcoding in 10-15 medium and small facilities outside N. America.

6. The Data Analysis Working Group (DAWG) held three workshops during the current

award period and the Center for Discrete Mathematics and Theoretical Computer Science (DIMACS) at Rutgers University formed a regional working group in the New York area and established a web portal to advertise DAWG's activities. These efforts culminated in 12 technical presentations of new analytical methods at the Taipei conference that employ Bayesian statistics, optimized logic, phylogenetic models, and other new approaches. The contributors are preparing their presentations for publication and they have agreed to submit their analytical software to the BoLI Data Portal.

2010 Goals: Produce finished analytical software that is available for public use.

7. BOLI Data Portal. CBOL created a BOLI website (www.dnabarcodes.org) as well as a standard website template that barcoding initiatives are following (e.g., All Birds Barcoding Initiative, http://www.barcodingbirds.org/; and the European Consortium for the Barcode of Life, http://www.ecbol.org/). The BOLI website now hosts the Case Studies Portal, a collection of user-submitted descriptions of barcoding projects that are underway or in the planning stages. The Case Studies Portal is being developed as a social network and information dissemination system for BOLI participants around the world.

2010 Goals: A fully operational online environment for analyzing barcode data, comparing analytical approaches, and developing and testing new analytical software.

8. Increased participation by developing countries. CBOL held regional outreach meetings in southern Africa (Cape Town, South Africa, April 2006), eastern Africa (Nairobi, Kenya, in October 2006), Central and South America (Campinas, Brazil, March 2007) and Asia (Taipei, Taiwan, September 2007). These meetings led to planning for barcoding projects on agricultural pests, commercial fish species, and several endangered groups. CBOL has met its goal of doubling the number of developing country Member Organizations. In January 2006, CBOL had 107 Member Organizations from 40 countries, of which 24 Member Organizations

were from 17 developing countries. CBOL now has 164 Member Organizations from 46 countries, of which 54 Member Organizations are in 24 developing countries (see Appendix 6).

2010 Goals: Active projects in all participating regions; doubling of CBOL Member Organizations in western and central Africa, India and China.

9. International Barcode Conference. CBOL held the Second International Barcode of Life Conference at Academia Sinica in Taiwan in September 2007. It was attended by 350 participants from 44 countries, including 15 from China and many from Asian countries that have never been represented at barcoding meetings before.

2010 Goals: Hold a Third International Barcode of Life Conference in mid- to late 2009.

C. OUTCOMES. The outputs described above produced five far-reaching outcomes:

1. Increased acceptance by mainstream taxonomists. Several years of rapidly accumulating research have now demonstrated that barcoding can successfully separate and identify more than 95% of the well-established species in a well-studied group. In other groups with a less than fully developed species taxonomy, barcoding still produces correct identification in more than 70% of cases. For those taxa in which COI, the established animal barcode region, does not work as an effective barcode (e.g., plants, fungi, scale insects), researchers are using CBOL's protocols to identify a different standard barcode region. This attests to the robustness of barcoding's basic tenet – that a short, standardized sequence can be used for species-level diagnosis and identification. The abstracts of five significant barcoding papers published during the award period are presented in Appendix 2.

2. Expansion of barcoding to new taxonomic groups. CBOL has catalyzed and facilitated planning and outreach activities that led to the launch of new barcoding projects:

a. A CBOL/Census of Marine Life workshop led to a 50,000 marine species project;

b. CBOL organized and held two planning meetings for a Fungal Barcoding Initiative and is

working with an FBI Steering Committee to develop funding proposals;

c. CBOL conducted an outreach event at the CITES Conference of Parties and helped the American Museum of Natural History prepare a successful funding proposal for a DNA Barcoding Initiative for Conservation; and

d. CBOL provided assistance in planning a successful proposal from the NY Botanical Garden for an initiative to barcode 10,000 tree species (TreeBOL).

3. Engagement and excitement beyond taxonomy. As the volume and taxonomic diversity of barcode data has grown, CBOL has brought this new corpus of scientific data to the attention of other fields of biology. Three "intellectual outreach" meetings have been held to explore the utility of barcode data in research fields beyond taxonomy and to seek new research areas that could expand the impact of barcoding. Molecular evolutionists met with BOLI participants in a workshop sponsored by the European Molecular Biology Organization (EMBO) to discuss the behavior of molecular markers over long timespans. The National Evolutionary Synthesis Center (NESCENT) at Duke University brought together participants in Assembling the Tree of Life (AToL) program with counterparts in BOLI to discuss possible collaboration between the Tree and Barcode of Life. Most recently, population and evolutionary biologists met with BOLI participants at the Banbury Conference Center at Cold Spring Harbor Laboratory to discuss how barcode data could be used to study speciation and phylogeography.

4. Early adoption by government agencies. Several US government agencies are supporting pilot projects that are testing barcoding for possible adoption for regulatory use.

a. The US Environmental Protection Agency has awarded $250,000 from its Advanced Monitoring Initiative to test barcoding as a water quality assessment tool.

b. The Federal Aviation Administration is continuing its support for barcoding birds as a tool for preventing collisions with aircraft.

c. NOAA's National Marine Fisheries Service has approved a pilot barcode survey of the fish of the Gulf of Maine, to be conducted as part of FISH-BOL.

d. USDA's Animal and Plant Health Inspections Service (APHIS) is providing pilot funds for CBOL's tephritid fruit fly Demonstrator Project.

e. The US Food and Drug Administration (FDA) is testing barcoding for regulatory use for food quality and consumer protection. Barcode data were critical in confirming a case of species substitution and the issuance of an FDA Health Advisory.

5. Heightened public awareness. Media coverage of barcoding reached a new level following the Second International Barcode of Life Conference in Taipei in September 2007. Wire services, newspapers and magazines responded especially strongly to potential applications of barcoding to food safety and the control of disease vectors, and to the interest being shown by government regulatory agencies (see Appendix 10 for examples of media coverage).

6. Expansion of investment in barcoding. As outlined in its 2006 proposal, CBOL has used Sloan Foundation funds to build partnerships and networks which have conducted jointly-funded activities. Virtually all of CBOL's activities have been co-funded by non-Sloan sources. The cost of CBOL's seven largest meetings was more than $670,000, of which $426,463 (63.5%) came from non-Sloan sources and $244,800 (36.5%) was provided by Sloan Foundation funds through CBOL. Barcoding projects launched by CBOL attracted more than $1.28 million from non-Sloan contributors, bringing the non-Sloan contribution to CBOL activities to $1.7 million, or 110% of the current Sloan grant to the Smithsonian for support of CBOL. New barcoding grants approved during the current award for non-CBOL activities total more than $14.25 million (see Appendix 7 for a full list of co-funding).

V. PROPOSED PROGRAM OF WORK AND DELIVERABLES FOR 2008-2010[+]

A. ENABLING THE UNIVERSAL APPLICATION OF BARCODING. As interest in barcoding and demand from potential users increase, CBOL wants to lower barriers to entry into barcoding by:

1. Expanding barcoding lab capabilities. The Leading Labs Network proposes to make barcoding technology, technical information, and training opportunities more widely available, both to labs that are already barcoding and to labs that are just beginning. Members of the Network are developing useful tools that will help in different sections of "the barcoding pipeline". The Moorea BIOCODE project is developing data capture tools for use in the field, and the Smithsonian's LAB is championing the use of automated extractors in the field. These and similar contributions to the Network will produce a start-to-finish series of protocols that will provide new barcoders with efficient turn-key systems. The Network proposes to hold several meetings each year during which they will agree on standard protocols for sample processing and data management. Between these meetings, CBOL would support travel among Network members for the development of standard procedures and training material. The Network also proposes to obtain several equipment kits for field sampling and DNA extraction. The kits would be used for on-site training courses and could be loaned to barcoding projects.

Deliverables for the award period. A set of instructional materials and standard procedures disseminated through the BOLI Data Portal and training courses conducted in several regions; instrument kits for loan to barcoding projects; and increased production of barcode data at participating Leading Labs and their partner facilities.

2. Connecting BARCODE data to other biodiversity databases. CBOL's Database Working Group (DBWG) proposes two workshops and follow-on efforts to strengthen and broaden the links between BARCODE records and databases of (1) voucher specimens and (2)

[+] See Appendix 11, Chart of milestones

species names. The first workshop, planned for mid-2008, would bring together representatives of the major museum database software systems (e.g., KE-EMu, Arctos, Specify, ZIMS) to develop a roadmap for connecting them to GenBank and BOLD. The second workshop, planned for late 2008, would engage representatives of the major databases of taxonomic names in implementing seamless connectivity to GenBank and BOLD. Participants would include Species2000, Integrated Taxonomic Identification System (ITIS), Global Biodiversity Information Facility (GBIF), ZooBank, Biodiversity Information Standards (TDWG), and taxon-specific databases such as FishBase and the International Plant Names Index (IPNI). CBOL will provide follow-on support after both workshops that will allow participants to meet to implement workshop recommendations.

The Encyclopedia of Life has proposed a global conference on biodiversity informatics in 2009 and CBOL has agreed, in principle, to be a co-organizer. This meeting would be the venue for demonstrating the higher levels of database interoperability achieved with BARCODE data.

Deliverables for the award period. BARCODE records in GenBank will be interoperable with data in the other major biodiversity informatics platforms and there will be 100,000 fully compliant BARCODE records in GenBank.

***3. Improving data management and promoting public data release*.** Barcode data are now distributed across three different environments: GenBank holds about 14,000 records that adhere to most or all of the BARCODE data standards; BOLD has 333,000 COI records, of which 74,000 are publicly available. Of these, only about 14,000 records have been submitted to GenBank with the potential to be fully compliant BARCODE records. In addition to these, an unknown number of records are held by individual researchers in an unknown number of private databases. BOLD and GenBank have created tools that make it relatively easy for researchers to upload their barcode data and to make them public but obstacles clearly remain. CBOL's

Database Working Group proposes to conduct an informal survey of users to identify obstacles to data sharing and publication. CBOL's new data manager will work with BOLD, GenBank and others to develop solutions and implement them and to develop software tools for managing barcode data that will be posted on the BOLI Data Portal.

Deliverable for the award period. Software tools for creating and checking records for compliance with the BARCODE data standards will be available on the BOLI Data Portal.

4. Increasing the range and assessment of analytical methods and improving data visualization. The Data Analysis Working Group proposes to hold two workshops in 2008-2009. The first will bring together DAWG participants and members of the Leading Labs Network for a discussion of user needs, selection of standardized test datasets to be posted on the BOLI Data Portal, and development of performance metrics for analytical software. The second will bring together statisticians, population biologists, and computer scientists for presentation and discussion of the new analytical approaches being built for the BOLI Data Portal, evaluated according to the performance metrics discussed in the previous meeting.

Based on input gained in these workshops, DAWG will develop a Software Development Kit (SDK), assisted by CBOL's Data Manager and a website development contractor. The SDK will be used to promote the development and integration of data analysis tools for a multitude of logical and statistical programming languages. As a first demonstration of the utility of such an SDK, DAWG also proposes to hold a well-advertised competition for the best new software for the display and visualization of barcode data.

Deliverables for the award period. DAWG participants will publish technical papers based on presentations at the Taipei conference and will develop and refine data analysis software for use on the BOLI Data Portal. The BOLI Data Portal will be an online environment for assembling barcode data and other gene sequence data from BOLD, GenBank and other

sources, analyzing them using an array of approaches and software, utilizing new tools for data display and visualization, and developing, testing, and comparing new software tools.

5. Promoting technology development. CBOL proposes to hold a conference/workshop in late 2008 that will bring technology developers for DNA sampling and analysis together with potential major users of barcoding. The meeting will be devoted to a discussion of user needs and specifications and will provide technology developers with a clearer picture of market potential and user requirements. The developers will represent a range of technologies, including but not limited to DNA chips, pyrosequencing, and microfluidics. Users will include government agencies, major research labs, and international regulatory agencies and NGOs.

Deliverables for the award period. Heightened interest among technology developers, leading to new instruments. CBOL's near-term goal is that technology developers will reduce the time needed to barcode a specimen to 30 minutes using a transportable table-top device.

B. POPULATING A GLOBAL BARCODE DATABASE. CBOL proposes to expand its administrative support for the major initiatives it has already launched, and will promote the launch of initiatives on fungi and several other groups.

Deliverables for the award period. Each of the major barcoding initiatives will be contributing their data to BOLD and will have begun submitting BARCODE records to GenBank. A total of 1 million barcode records representing 100,000 species will exist.

1. ABBI and FISH-BOL. CBOL proposes to continue it support of the administrative and networking needs of ABBI and FISH-BOL. Based on the past two years of experience, maintaining the highest level of confidence in BARCODE data quality will require new effort. CBOL's largest campaigns need to design and support projects that will obtain fresh or frozen specimens and will validate their species identifications. The Regional Working Groups of each campaign need to raise funds for these projects. For this reason, CBOL proposes to continue its

support for: meetings of Regional Working Groups; outreach to regulatory agencies and other potential users; interns hired for data entry and management; technical training fellowships; travel to museum collections; and consultations by expert taxonomists. CBOL also proposes to conduct proposal-writing workshops. ABBI also proposes to hold a meeting of approximately 20 curators of the world's largest collections of frozen bird tissue to enlist their participation.

Deliverables for the award period. Increased submission of funding proposals; ABBI will barcode 6,000 species of birds and FISH-BOL will barcode 15,000 species of fish.

2. Promoting plant barcoding. During 2006-7, research teams identified several viable barcode strategies for vascular plants (Newmaster, Fazekas and Ragupathy, 2006; Kress and Erickson, 2007; Chase et al., 2007; Kim, 2007). An international effort to barcode all trees that CBOL helped catalyze commenced 1 January 2008. Meanwhile, CBOL's Plant Working Group will continue to compile and analyze data about plant barcode regions to encourage convergent and consistent practice among practitioners. The plant community will hold a conference in late 2008 to review progress and to plan and promote additional plant barcoding projects.

Deliverables for the award period. Diffusion of agreed plant barcode regions in 2008 and launch of multiple plant barcoding projects in 2009.

3. Fungal Barcoding Initiative. CBOL proposes to build on the momentum it has established through two planning meetings for a Fungal Barcoding Initiative (FBI) by convening a Steering Committee and facilitating the development of an action plan and funding proposals.

Deliverables for the award period. FBI will identify the barcode regions to be used across the range of fungal groups and begin to submit proposals for funding.

4. All-taxon barcode inventory. Most barcoding projects focus on a single taxonomic group while only a few sample and analyze all the taxa in a habitat (e.g., Moorea Project in

French Polynesia; CMarZ on marine zooplankton). CBOL proposes to increase the production of barcode data by promoting all-taxon barcode inventories of single sites.

Deliverables for the award period. The first all-taxon barcode inventories will begin contributing data to BOLD, and new inventories will be launched in diverse habitats

5. iBOL, ECBOL, TreeBOL, DBIC, MarBOL, FBI and other new barcoding initiatives. New initiatives such as those listed above (see Appendix 1) are coming online with increasing frequency and they represent important new sources of BARCODE records. CBOL proposes to facilitate and promote the flow of barcode data into the public domain through outreach to these initiatives and by engaging them in the work of the Leading Labs Network.

Deliverables for the award period. New initiatives will be represented on CBOL's Implementation Board and will begin to submit their data to BOLD and GenBank in 2009.

C. DEMONSTRATOR DEVELOPMENT PROJECT. CBOL proposes to continue its support of the administrative and coordinating activities of both Demonstrator Projects – the Mosquito and Tephritid Barcode Initiatives (MBI and TBI), including meetings among specialists, travel to major museum collections to obtain samples, and consultations with expert taxonomists. All funds for laboratory barcoding activities will be obtained from non-Sloan sources.

1. Mosquito Barcoding Initiative (MBI) and Tephritid Barcode Initiative (TBI). In addition to mining samples from museum collections, MBI is testing the effectiveness of a partnership with The Scholar Ship, a floating education center on which a small barcoding lab has been installed. The lab's first two-month leg (Panama, Ecuador, New Zealand, Australia) yielded more than 5,000 specimens from 175 species provided by curators in the region who brought samples to the ship to be barcoded, as well as 4,000 fresh collections. MBI proposes to combine this approach with sampling from museum collections.

2. Tephritid Barcode Initiative (TBI). TBI will be hiring a post-doctoral fellow who

will devote full-time efforts to obtaining and processing samples. Major museums that have agreed to participate will be visited and most sample processing will be done at the Smithsonian.

Deliverables for the award period. MBI and TBI will submit proposals for funding all costs that cannot be supported by CBOL. MBI will barcode five specimens from 2850 species (80% of all known species), including all disease vectors. TBI will barcode 10,000 specimens from 2,000 fruit fly species, including all economically important species, the majority of congeneric species, and representative species of genera without economically important species.

D. PROMOTING GLOBAL PARTICIPATION.

1. First outreach to four developing regions. CBOL will also organize and conduct first outreach meetings in India, China, and western and central Africa, each of which has high biodiversity and low levels of barcoding activity. Planning has already begun in China and western Africa where host sites have been selected. The regional meetings will raise awareness, identify priority applications in the region, and initiate planning and implementation. CBOL will assist regional partners in their efforts to obtain funding and implement their priority initiatives.

2. Ongoing collaboration following first outreach. CBOL will conduct "Phase 2" activities in regions in which first outreach meetings have already been held (southern and eastern Africa, South America, and Asia). These activities will include: proposal-writing and planning workshops; technical training and assistance provided through the Leading Labs Network; and researcher exchange visits among barcoding labs.

Deliverables for the award period. Plans for new initiatives will develop in western and central Africa, India and China and the number of CBOL Member Organizations in those regions will double from 20 to 40.The projects initiated as a result of CBOL's regional outreach meetings in 2006-2007 will submit funding proposals and will begin to ramp up their activities.

3. Improving national and international policies on biodiversity research. Concerns about exploitation of genetic resources have led to restrictions on biodiversity research, without distinction between commercial and basic research. CBOL proposes to convene an international workshop to explore the implications of these restrictions for barcoding and other non-commercial biodiversity research, and to construct an action plan to promote more pro-research policies. The ethics of biodiversity research, open access to biodiversity data, and the IPR implications of barcode data will be major topics of discussion. CBOL will invite international biodiversity initiatives such as GBIF, Diversitas, and BioNET to act as co-organizers.

Deliverables for the award period. Outreach materials and an action plan for improving international policies, and engagement with Parties to the Convention for Biological Diversity.

4. Third International Barcode Conference. The Third International Barcode of Life Conference will be held in late 2009 and will have 500 participants from at least 50 countries.

E. PROMOTING ADOPTION OF BARCODING AS A STANDARD PROTOCOL. CBOL's activities promote barcoding from both the supply side (driven by taxonomists) and the demand side (fueled by societal/governmental needs). The new fifth strategy addresses the demand side.

1. Formal method validation. CBOL proposes to convene a workshop with five US government agencies (EPA, USDA, NOAA, FAA, and FDA) that are testing barcoding and several Leading Labs. The goal of the workshop will be to develop a testing plan that will lead to validation of barcoding under an internationally recognized certification system.

2. Outreach to non-US government agencies. CBOL proposes to work with representatives of it Member Organizations, including those in developing countries, to develop and disseminate outreach materials aimed at government officials. These efforts have already started with the European Commission, UN's Food and Agriculture Organization, the Consultative Group on International Agricultural Research, and others (see Appendix 7).

Deliverables for the award period. Barcoding will be an internationally validated laboratory method. Several US government agencies will formally adopt barcoding as a regulatory tool, and several non-US government agencies will begin pilot testing.

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Appendix 1. Glossary of Acronyms

ABBI: All Birds Barcoding Initiative (www.barcodingbirds.org), a project organized and supported by CBOL to barcode all 10,000 species of birds

BIO: The Biodiversity Institute of Ontario, a new institute and building at the University of Guelph which is host to the Canadian Centre for DNA Barcoding (CCDB)

BOLD: Barcode of Life Data Systems (www.barcodinglife.org), a database of barcode data and related data management software developed and hosted by the University of Guelph in Ontario

BOLI: Barcode of Life Initiative (www.dnabarcodes.org), a global movement to develop and use DNA barcoding. BOLI includes all CBOL initiatives and many other activities not directly catalyzed by CBOL

CBOL: Consortium for the Barcode of Life (www.barcoding.si.edu), an international initiative hosted by the Smithsonian Institution's National Museum of Natural History and supported by the Alfred P. Sloan Foundation. CBOL's mission is to develop and promote DNA barcoding as a global standard for identifying species in research and applications.

CCDB: The Canadian Centre for DNA Barcoding, the world's leading barcoding lab, located at the University of Guelph

DAWG: The Data Analysis Working Group of the Consortium for the Barcode of Life

DBIC: DNA Barcoding Initiative for Conservation is a new grant recently awarded by the Sloan Foundation to the American Museum of Natural History in New York. The project will develop reference barcode libraries for selected groups of endangered species and promote the use of barcoding for species protection.

DBWG: The Database Working Group of the Consortium for the Barcode of Life

ECBOL: European Consortium for the Barcode of Life (www.ecbol.org), an activity within EDIT that is developing plans for European barcoding initiatives and infrastructure

EDIT: European Distributed Institute for Taxonomy (http://www.e-taxonomy.eu/), a Network of Excellence supported by the European Commission and coordinated by the Muséum National d'Histoire Naturelle in Paris. EDIT's participants include the major natural history museums and herbaria of Europe and its program of work includes DNA barcoding.

FBI: Fungal Barcode Initiative which CBOL is promoting

FISH-BOL: Fish Barcode of Life campaign, an initiative launched and supported by CBOL that is dedicated to barcoding all 30,000 species of marine, freshwater and estuarine fish

iBOL: International Barcode of Life, a proposal that is being developed at the University of Guelph for submission to Genome Canada. It would generate a CAN$25 million grant to Guelph contingent on $75 million of coinvestment by foreign partners.

LAB: The Laboratory for Analytical Biology, a facility of the Smithsonian Institution's National Museum of Natural History, located at the Museum Support Center in Suitland, MD

NSERC: Canada's National Science and Engineering Research Council, a major source of support for barcoding in Canada

MarBOL is an initiative to barcode 50,000 marine species, in collaboration with the Census of Marine Life and several major museum collections

MBI: Mosquito Barcoding Initiative, a CBOL Demonstrator Project aimed at creating an operational system for identifying mosquitoes around the world.

SDK: Software Development Kit, a collection of software tools developed by the Data Analysis Working Group that programmers can use in developing analytical software for barcode data.

TBI: Tephritid Barcoding Initiative, a Demonstrator Project launched and supported by CBOL to create an operational global identification system for fruitflies, a major agricultural pest.

TreeBOL is a new grant recently awarded by the Sloan Foundation to the NY Botanical Gardens to barcode 10,000 species of trees around the world.

Appendix 2. Abstracts of five significant barcoding publications, 2006-2007

Hajibabaei, M., Janzen, D.H., Burns, J.M., Hallwachs, W. and Hebert, P.D.N. 2006. DNA barcodes distinguish species of tropical Lepidoptera. PNAS 103 (4): 968–971

Although central to much biological research, the identification of species is often difficult. The use of DNA barcodes, short DNA sequences from a standardized region of the genome, has recently been proposed as a tool to facilitate species identification and discovery. However, the effectiveness of DNA barcoding for identifying specimens in species-rich tropical biotas is unknown. Here we show that cytochrome *c* oxidase I DNA barcodes effectively discriminate among species in three Lepidoptera families from Area de Conservacion Guanacaste in northwestern Costa Rica. We found that 97.9% of the 521 species recognized by prior taxonomic work possess distinctive cytochrome *c* oxidase I barcodes and that the few instances of interspecific sequence overlap involve very similar species. We also found two or more barcode clusters within each of 13 supposedly single species. Covariation between these clusters and morphological and/or ecological traits indicates overlooked species complexes. If these results are general, DNA barcoding will significantly aid species identification and discovery in tropical settings.

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Siddall, M.E., Trontelj, P., Utevsky, S.Y. 2007. Nkamany, M. and Macdonald, K.S., Diverse molecular data demonstrate that commercially available medicinal leeches are not *Hirudo medicinalis*. Proc. R. Soc. B 274, 1481–1487

Abstract: The European medicinal leech is one of vanishingly few animal species with direct application in modern medicine. In addition to the therapeutic potential held by many protease inhibitors purified from leech saliva, and notwithstanding the historical association with quackery, Hirudo medicinalis has been approved by the United States Food and Drug Administration as a prescription medical device. Accurate annotation of bioactive compounds relies on precise species determination. Interpretations of developmental and neurophysiological characteristics also presuppose uniformity within a model species used in laboratory settings. Here, we show, with mitochondrial sequences and nuclear microsatellites, that there are at least three species of European medicinal leech, and that leeches marketed as H. medicinalis are actually Hirudo verbana. Beyond the obvious need for reconsideration of decades of biomedical research on this widely used model organism, these findings impact regulatory statutes and raise concerns for the conservation status of European medicinal leeches.

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Smith, M.A., Wood, D.M., Janzen, D.H., Hallwachs, W., and Hebert, P.D.N. 2007. DNA barcodes affirm that 16 species of apparently generalist tropical parasitoid flies (Diptera, Tachinidae) are not all generalists. PNAS 104 (12): 4967–4972.

Abstract: Many species of tachinid flies are viewed as generalist parasitoids because what is apparently a single species of fly has been reared from many species of caterpillars. However, an ongoing inventory of the tachinid flies parasitizing thousands of species of caterpillars in Area de Conservacion Guanacaste, northwestern Costa Rica, has encountered >400 species of specialist tachinids with only a few generalists. We DNA-barcoded 2,134 flies belonging to what appeared to be the 16 most generalist of the reared tachinid morphospecies and encountered 73

mitochondrial lineages separated by an average of4%sequence divergence. These lineages are supported by collateral ecological information and, where tested, by independent nuclear markers (28S and ITS1), and we therefore view these lineages as provisional species. Each of the 16 apparently generalist species dissolved into one of four patterns: (*i*) a single generalist species, (*ii*) a pair of morphologically cryptic generalist species, (*iii*) a complex of specialist species plus a generalist, or (*iv*) a complex of specialists with no remaining generalist. In sum, there remained 9 generalist species among the 73 mitochondrial lineages we analyzed, demonstrating that a generalist lifestyle is possible for a tropical caterpillar parasitoid fly. These results reinforce the emerging suspicion that estimates of global species richness are likely underestimates for parasitoids (which may constitute as much as 20% of all animal life) and that the strategy of being a tropical generalist parasitic fly may be yet more unusual than has been envisioned for tachinids.

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Seifert, K.A., Samson, R.A., deWaard, J.R., Jos Houbraken, J., Levesque, C.A., and Moncalvo J-M. 2007. Prospects for fungus identification using CO1 DNA barcodes, with Penicillium as a test case. PNAS 104;3901-3906.

Abstract: DNA barcoding systems employ a short, standardized gene region to identify species. A 648-bp segment of mitochondrial cytochrome *c* oxidase 1 (*CO1*) is the core barcode region for animals, but its utility has not been tested in fungi. This study began with an examination of patterns of sequence divergences in this gene region for 38 fungal taxa with full *CO1* sequences. Because these results suggested that *CO1* could be effective in species recognition, we designed primers for a 545-bp fragment of *CO1* and generated sequences for multiple strains from 58 species of *Penicillium* subgenus *Penicillium* and 12 allied species. Despite the frequent literature reports of introns in fungal mitochondrial genomes, we detected introns in only 2 of 370 *Penicillium* strains. Representatives from 38 of 58 species formed cohesive assemblages with distinct *CO1* sequences, and all cases of sequence sharing involved known species complexes. *CO1* sequence divergences averaged 0.06% within species, less than for internal transcribed spacer nrDNA or tubulin sequences (*BenA*). *CO1* divergences between species averaged 5.6%, comparable to internal transcribed spacer, but less than values for *BenA* (14.4%). Although the latter gene delivered higher taxonomic resolution, the amplification and alignment of *CO1* was simpler. The development of a barcoding system for fungi that shares a common gene target with other kingdoms would be a significant advance.

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Dove, C.J., Rotzel, N.C., Heacker, M. and Weigt, L.A. In Press. Using DNA barcodes to identify bird species involved in birdstrikes. J. Wildlife Management

Abstract: We determined the effectiveness of using mtDNA 'barcodes' (*cytochrome c oxidase, subunit I, cox I,* CO1) to identify birdstrike cases that lacked sufficient feather evidence for morphological diagnosis. From September through December 2006, 821 samples from birdstrike events occurring in the United States were submitted for DNA analysis. A CO1 DNA barcode product was successfully amplified from 554 (67.5%) of the samples; 267 (32.5 %) did not contain viable DNA and depended on morphological methods (microscopy) for Order or Family level identification. Nineteen cases were deemed inconclusive either because the DNA barcode recovered from the sample did not meet our 98% match criteria when compared to the Barcode of Life Database (BoLD) or because the DNA barcode matched to a set of 2 or more

closely-related species with overlapping barcodes, preventing complete species identification. The age of the sample (up to 6 months) did not affect DNA viability, but the initial condition of the sample and the collecting method was critical to DNA identification success. DNA barcoding has great potential in aiding in the identification of birds (and wildlife) for airfield management practices, particularly in regions of the world that lack the vast research collections and individual expertise for morphologic identifications.

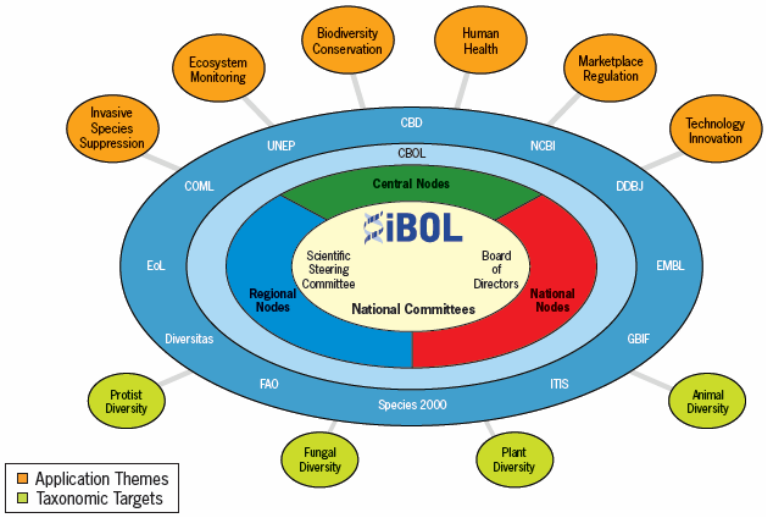
Appendix 3. CBOL and the International Barcode of Life Project (iBOL)

Genome Canada supports genomics and proteomics through regional Genome Centers, national competitions, and other instruments using funds provided by the Canadian national government. The International Consortium Initiative (ICI; http://www.genomecanada.ca/xresearchers/intlInitiatives/index.asp?l=e) is a Genome Canada challenge grant program that can provide up to 25% of the costs of major research programs so long as they are:

- Led by a Canadian researcher whose principal work will be done in Canada;
- Have a minimum duration of 3 years and a total cost of at least CAN$50 million;
- Include international partners and international visibility; and
- Gain matching funds of at least 75% of total costs from sources other than Genome Canada.

Dr. Paul Hebert of the University of Guelph is preparing an ICI proposal for "iBOL", the International Barcode of Life Project (see http://www.DNAbarcoding.org). In 2008, Dr. Hebert will request CAN$25 million from Genome Canada and CAN$25 million from other Canadian funding sources. An additional CAN$100 million will be sought from 25 participating countries, most of which will act as Central Nodes (Canada, US, European Union), Regional Nodes (Australia, Brazil, China, India, Korea, Mexico, South Africa), or National Nodes (Argentina, Costa Rica, Kenya, Madagascar, Sri Lanka). New Zealand and Norway will lead a polar barcoding program.

The University of Guelph and Genome Canada convened a planning conference in Guelph in June 2007 in which more than 70 attendees from 21 countries participated. CBOL's Executive Secretary gave a presentation on its activities and its international network of partners. There was general agreement that iBOL should build on CBOL's international network and that CBOL should be a principal participant in iBOL. As currently envisioned, CBOL would expand its activities in collaboration with iBOL and would continue to act as a principal catalyst for international collaboration in barcoding, as illustrated below. CBOL's Executive Committee has endorsed the idea of developing a close collaboration with the iBOL Project.



Organisational Structure

(From the International Barcode of Life Project prospectus)

This proposal to the Sloan Foundation for renewal of support to CBOL has no direct connection to the iBOL proposal. At this time, CBOL does not assume that the iBOL project will be funded and the program of work described in this proposal is not contingent on funding for iBOL from Genome Canada. The iBOL proposal will be submitted to Genome Canada in early- to mid-2008 and if successful, funding would start in early 2009.

If the iBOL Project is funded by Genome Canada and its international partners, CBOL will develop a revised program of work and budget that reflects its collaboration with iBOL, and will submit it to the Sloan Foundation.

Appendix 4. CBOL-sponsored conferences, workshops and meetings during the current grant period

1. Regional Barcode meeting for southern Africa, Cape Town, South Africa, 7-8 April 2006
2. Tephritid Barcoding Initiative Steering Committee meeting, Royal Museum of Central Africa, Tervuren, Belgium, 27-28 April 2006
3. National Research Council workshop "Path to Effective Recovering of DNA from Formalin-Fixed Biological Samples in Natural History Collections", Washington, DC, 8-9 May 2006
4. FISH-BOL Regional Working Group Chairs, Amsterdam, 14 May 2006
5. Marine Barcoding Workshop, Census of Marine Life, Amsterdam, 15-17 May 2006 (supported by a separate grant from the Sloan Foundation to the Univ. of Connecticut)
6. Data Analysis Working Group workshop, Muséum National d'Histoire Naturelle, Paris, 6-8 July 2006
7. DNA barcoding session at Associations of Zoos and Aquariums Annual Conference, Tampa, FL, 27 September 2006
8. Regional Barcode meeting for eastern Africa, Nairobi, Kenya, 18-19 October 2006
9. Protist barcode meeting, Portland, Maine, 6 November 2006 (supported by a separate grant from the Sloan Foundation to Bigelow Laboratory for Ocean Sciences)
10. Leading Labs Network planning meeting, NCBI, Bethesda, MD 22 February 2007
11. Scale Insects Barcoding Initiative Steering Committee, Stellenbosch, South Africa, 13-14 February 2007
12. ABBI Indomalayan Regional Working Group, National University of Singapore, 8-9 March 2007
13. ABBI and FISH-BOL Neotropical Regional Working Groups, Buenos Aires, 14-16 March 2007
14. Regional barcode meeting for South and Central America, Campinas, Brazil, 19-20 March 2007
15. Leading Labs Network planning meeting, University of Guelph, Ontario, 12 April 2007
16. CBOL-Assembling the Tree of Life workshop, National Evolutionary Synthesis Center, Duke University, Durham, NC, 19-20 April 2007 2006 (supported by a separate grant from the Sloan Foundation to Duke University)
17. Fungal Barcoding Workshop, Smithsonian Institution Center for Research and Conservation, Front Royal, VA, 14-15 May 2007 2006 (supported by a separate grant from the Sloan Foundation to Rutgers University)
18. European Molecular Biology Organization workshop "Molecular Biodiversity and DNA Barcode", Rome, Italy, 17-19 May 2007
19. Leading Labs Network, Smithsonian Institution National Museum of Natural History, Washington, DC, 10-11 July 2007
20. "Statistical methods for DNA barcode data" at the symposium of the Interface between Statistics and Computer Science, Philadelphia, May 25 2007.
21. Barcoding Short Course by Leading Labs Network, Academia Sinica, 17 September 2007
22. Fungal Barcoding Workshop, Academia Sinica, 17 September 2007
23. FISH-BOL workshop with fisheries management agencies, Academia Sinica, 17 September 2007
24. Second International Barcode of Life Conference, Academia Sinica, Taipei, Taiwan, 18-20 September 2007

25. Regional barcode meeting for Asia, Academia Sinica, Taipei, Taiwan, 21 September 2007
26. Plant Working Group meeting, Academia Sinica, 21 September 2007
27. Marine barcoding workshop, Academia Sinica, 21 September 2007
28. Banbury 3 Conference "Using DNA Barcode Data in Studies of Molecular and Evolutionary Dynamics", Cold Spring Harbor, NY, 28-31 October 2007 (supported by a separate grant from the Sloan Foundation to the Banbury Conference Center)

Appendix 5. CBOL outreach activities during the current grant period

The CBOL Executive Secretary gave the following outreach presentations:

1. Maryland Dept. Natural Resources, Annapolis, 17 April 2006
2. European Commission Directorate General for Fisheries and Maritime Affairs, Brussels, 15 May 2006
3. American Museum of Natural History, New York, 9 June 2006
4. Special Libraries Association Conference, session on biodiversity data, Baltimore, 12 June 2006
5. Census of Marine Life Barcoding Conference, Amsterdam
6. USDA Invasives Compendium conference, Washington, DC, 16 November 2006
7. Freshwater macroinevertebrate barcode workshop, Utah State University, 29 November 2006
8. Academia Sinica, Taipei, Taiwan, 16 January 2007
9. Taiwan National Museum of Natural Science, Taichung, 18 January 2007
10. Korea Ocean Research and Development Institute, Seoul, 22 January 2007
11. Korea Research Institute for Bioscience and Biotechnology, Daejeon, 23 January 2007-12-04
12. Korea Ministry of Maritime Affairs and Fisheries, Seoul, Korea, 24 January 2007
13. University of Kansas, Lawrence, Kansas, 6 March 2007
14. Species2000 conference, Reading, UK, 29 March 2007
15. University of Edinburgh, 2 April 2007
16. University of Glasgow, 3 April 2007
17. UN Food and Agriculture Organization (FAO), Fisheries Division, Rome, Italy, 16 May 2007
18. FAO Agriculture Division, Rome, Italy, 21 May 2007
19. UN Convention on International Trade of Endangered Species (CITES) Convention of Parties, The Hague, Netherlands, 8 June 2007
20. Genome Canada/ICI conference, Guelph, 18 June 2007
21. NOAA Enforcement and Litigation Workshop, Portland, Maine, 12 September 2007
22. National Marine Fisheries Research Directors, Silver Spring, MD, 27 September 2007
23. European Consortium for the Barcode of Life, Leiden, Netherlands, 3 October 2007
24. GBIF Science Symposium, Amsterdam, 18 October 2007
25. Seafood Science and Technology Conference, Punta Cana, Dominican Republic, 8 November 2007

The following outreach presentations were made by members of CBOL's Executive Committee:

26. S. Miller to Association of Zoos and Aquariums, Tampa, FL, 27 September 2006
27. S. Miller to Multiple government agencies, Nigeria, 2006
28. S. Miller to International Institute for Tropical Agriculture (IITA), Benin, 2006
29. S. Miller to Bioversity, Rome, Italy, 21 May 2007
30. J. Alves-Gomes to the IIIrd Reunión Ciencia, Technologia, y Sociedad. Joint meeting of the Argentinian, Brazilian and Uruguayan Societies for the Progress of Science, Montevideo, Uruguay, 22 June 2007
31. S. Miller to BECA and ILRI, Nairobi, June 2007
32. S. Miller to Consultative Group for International Agricultural Research, Beijing, 4 December 2007

33. S. Miller to Institute of Botany, Chinese Academy of Sciences, Beijing, December 2007
34. S. Miller to Center for Tropical Forest Science "interactions workshop", Panama, 2007

The following outreach presentations were made by members of CBOL's Scientific Advisory Board:

35. R. Hanner to South African Institute Aquatic Biodiversity, Grahamstown, South Africa, 5 April 2006
36. R. Hanner to Rhodes University, Grahamstown, South Africa, 4 April 2006
37. R. Hanner to European Commission Directorate General for Fisheries and Maritime Affairs, Brussels, 15 May 2006
38. R. Hanner to SPNHC, Albuquerque, 22 May 2006
39. R. Cowan to The sixth conference of the Southern African Society for Systematic Biology (SASSB VI), July 2006
40. P. Tubaro to Reunión de la Red Iberoamericana de biogeografía y Sistemática (RIBES), Museo de la Universidad Nacional de La Plata, 5-8 December 2006.
41. R. Hanner to Metals in the Human Environment Research Symposium, Canadian Network of Toxicology Centres, Gatineau, QC, Canada, 24 January 2007
42. R. Hanner to Flowers Canada (Ontario) Research Symposium, Niagara College, Niagara-on-the-Lake, ON, Canada. 25 January 2007
43. R. Hanner to Centre for Earth and Environmental Technologies (CEET) Symposium, Ontario Centres of Excellence, Guelph, ON, Canada, 7 February 2007
44. F. Bakker and Michel Veuille to AETFAT Congress, Cameroon, March 2007
45. R. Hanner to BioRep Invited Seminar, University of Milan, Milan, Italy, 21 May 2007
46. R. Hanner to workshop on "Biodiversity Informatics and the Barcode of Life", Danish Biodiversity Information Facility and the Danish Natural History Museum, Aarhus University, Aarhus, Denmark. 29 May 2007
47. R. Hanner to Toronto Biotechnology Initiative Invited Lecture Series, Ryerson University, Toronto, ON, Canada, 1 May 2007
48. A. Perera to Linnaeus conference, Univ. of Chitagong, Bangladesh, May 2007
49. R. Cowan to a meeting at the botanic garden of Gran Canaria ("international meeting of experts to implement SAGE, a web database for molecular population genetic data about biological diversity within the framework of the GBIF") June 2007
50. F. Bakker to Society of Botanists & Zoologists of Leuven University, Netherlands, December 2007

Appendix 6. CBOL Member Organizations (as of 15 December 2007)

Country	Location	Organization
Africa: 17 MOs in 8 countries		
Democratic Republic of Congo	Kisangani	Laboratoire d'Ecologie et Gestion des Ressources Animales (LEGERA)
Cameroon	Beau	University of Beau
Ghana	Legon	University of Ghana, Legon
Kenya	Nairobi	International Centre for Insect Physiology and Ecology
	Nairobi	National Museums of Kenya
Morocco	Agdal	Institut Scientifique
Nigeria	Ibadan	Forestry Research Institute of Nigeria
	Ibadan	National Centre for Genetic Resources and Biotechnology (NACGRAB)
	Abuja	National Biotechnology Development Agency
	Ile-Ife	Natural History Museum, Obafemi Awolowo University
South Africa	Eastern Cape	University of Fort Hare
	Grahamstown	South African Institute for Aquatic Biodiversity
	Johannesburg	University of Johannesburg
	Pretoria	ARC - Plant Protection Research Institute
	Pretoria	South African National Biodiversity Institute (SANBI)
	Pretoria	SAFRINET
Uganda	Entebbe	National Agricultural Research Organization
East Asia-Pacific: 21 MOs in 8 countries		
China	Kunming	Kunming Institute of Zoology, Chinese Academy of Scie
	Beijing	Chinese Academy of Sciences, Institute of Zoology, Zoological Museum
	Beijing	Beijing Genomics Institute, Chinese Academy of Sciences
	Guizhou	Guizhou University, Department of Entomology
	Shandong	Plant Protection College, Shandong Agricultural University
	Tolo Harbour	Department of Biology & Simon F.S. Li Marine Science Lab, The Chinese University of Hong Kong
Taiwan	Shanhua, Tainan	AVRDC The World Vegetable Center
	Kaohsiung	Department of Biological Sciences, National Sun Yat-Sen University

Country	Location	Organization
	Taipei	Research Center for Biodiversity, Academia Sinica
Japan	Shizuoka	National Institute of Genetics, ROIS
	Sapporo	Hokaido University
	Tokyo	The Union of the Japanese Society for Systematic Biology
Korea	Daejeon	Korea Research Institute of Bioscience and Biotechnology (KRIBB)
	Seoul	Korea Research and Development Institute
	Seoul	Plant DNA Bank in Korea and Korea University Herbarium (KUS)
	Incheon	National Institute of Biological Resources
	Gyeonggi Province	Korea National Arboretum
Malaysia	Sardang	Faculty of Forestry, University of Putra Malaysia
Papua New Guinea	Madang	Papua New Guinea Binatang Research Center (PNG)
Philippines	Maligaya	Philippine Rice Research Institute (PhilRice)
Singapore	Singapore	Raffles Museum of Biodiversity Research, National University of Singapore
Eurasia: 67 MOs in 20 countries		
Bangladesh	Rajshahi	University of Rajshahi, Department of Botany
		Biodiversity Research Group of Bangladesh
Belgium	Brussels	Royal Belgian Institute for Natural Sciences
	Tervuren	Royal Museum for Central Africa
Denmark	Copenhagen	Global Biodiversity Information Facility
	Copenhagen	Natural History Museum of Denmark
France	Paris	Institut National de la Recherche Agronomique (INRA)
	Paris	Muséum National d'Histoire Naturelle
Germany	Berlin	Botanic Garden Berlin (Botanischer Garten und Botanisches)
	Bonn	Alexander Koenig Zoological Research Museum
	Braunschweig	Technical University Braunschweig Zoological Institute
	Frankfurt	Senckenberg Research Institute and Natural History Museum
	Hannover	ITZ, Ecology and Evolution
	Jena	Institute of Systematic Botany with Herbarium Haussknecht (JE) and Botanical Garden

Country	Location	Organization
	Munich	Knebelsberger and Miller Bioservices
	Munich	Staatliche Naturwissenschaftliche Sammlungen Bayerns
Greece	Crete	Natural History Museum of Crete
	Heraklion	Institute of Marine Biology and Genetics (IMBG)
India	Dona Paula	National Institute of Oceanography, Gene Lab
	Gujarat	Indian Institute of Advanced Research, Puri Foundation
	Kerala	Rajiv Gandhi Center for Biotechnology, Thiruvananthapuram
	Pune	National Chemical Laboratory
	Mumbai	St Peter's College & MEWS
	Pondicherry	Vector Control Research Centre
	Thiruchirappalli	Bharathidasan University, Department of Animal Science
	Virudhunagar	Department of Biotechnology, Kamaraj College of Engineering and Technology
Iran	Tehran	Plant Pest and Disease Research Institute
Italy	Bari	Institute of Biomedical Technologies
	Genova	Istituto Zooprofilattico Sperimentale del Piemonte
	Milan	Universita degli Studi di Milano-Bicocca, Department of Biotechnology and Bioscience
	Modena	University of Modena and Reggio Emilia
	Rome	Department of Animal and Human Biology, "La Sapienza" Rome University - Faculty of Science
	Rome	Department of Biology, University of Roma Tor Vergata
	Trieste	International Centre for Genetic Engineering and Biotechnology
	Udine	Dipartimento Di Scienze Agrarie ed Ambientali, Universita Di Udine
Netherlands	Amsterdam	Consortium of Netherlands Taxonomic Facilities
	Amsterdam	Zoological Museum of the University of Amsterdam
	Leiden	National Museum of Natural History Naturalis
	Utrecht	CBS Fungal Biodiversity Centre
Norway	Oslo	Norwegian Institute of Public Health
	Bergen	University of Bergen, Bergen Museum
	Oslo	Natural History Museum, University of Oslo

Country	Location	Organization
	Tromso	Tromso Univeristy Museum
	Trondheim	Norwegian University of Science and Technology, Museum of Natural history and Archaeology
Poland	Warsaw	Museum and Institute of Zoology- Polish Academy of Sciences
Portugal	Coimbra	Institute of Marine Research (IMAR)
Russia	Moscow	Zoological Museum of Moscow University
Spain	Barcelona	Universitat de Barcelona, CERTFEM
	Canarias	Jardin Botanico Canario Viera Y Clavijo
Sri Lanka	Peradeniya	University of Peradeniya
Sweden	Goteborg	Goteborg University, Department of Zoology
	Stockholm	Swedish Museum of Natural History
Switzerland	Waedenswil	Agroscope FAW
UK	Aberdeen	Fisheries Research Service
	Bangor	University of Wales, Bangor
	Edinburgh	Royal Botanic Garden Edinburgh
	Hull	University of Hull
	London	The Natural History Museum, London
	London	The Scholar Ship
	Reading	The University of Reading
	Reading	Species 2000
	Surrey	BioNET-International
	Surrey	Royal Botanic Garden, Kew
	Swansea	School of Biological Sciences, Univ of Wales Swansea
	York	The Central Science Laboratory
United Arab Emirates	Dubai	Advanced Biotechnology Centre
North America: 35 MOs in 3 countries		
Canada	Guelph	University of Guelph
	New Brunswick	Connell Memorial Herbarium, University of New Brunswick
	Nova Scotia	Acadia University
	Ottawa	Tropical Conservancy
	Ottawa	Canadian Museum of Nature
Mexico	Mexico City	Instituto de Biologia, Universidad Nacional Autonoma

Country	Location	Organization
		de Mexico
USA	California	California Academy of Sciences
	California	Natural History Museum of Los Angeles County
	California	San Diego Supercomputer Center at UCSD
	California	Scripps Institution of Oceanography
	California	Zoological Society of San Diego
	California	Coastal Marine Biolabs
	Connecticut	University of Connecticut, Marine and Technology Center
	Florida	Florida Fish and Wildlife Conservation Commission
	Florida	Florida Museum of Natural History
	Hawaii	Bishop Museum
	Illinois	The Field Museum
	Kansas	University of Kansas, Biodiversity Institute
	Massachusetts	Museum of Comparative Zoology, Harvard University
	Massachusetts	New England Biolabs, Inc.
	Massachusetts	Ocean Genome Legacy Foundation
	Michigan	NSF International (formerly National Sanitation Foundation)
	Missouri	Missouri Botanical Garden
	Minnesota	International Species Information System
	New Hampshire	University of New Hampshire
	New Jersey	Coriell Institute for Medical Research
	New York	American Museum of Natural History
	New York	The City University of New York, Kinbsborough Community College
	New York	Olive Natural Heritage Society, Inc
	New York	The New York Botanical Garden
	Pennsylvania	Academy of Natural Sciences, Philadelphia
	Virginia	National Biological Information Infrastructure (NBII)
	Washington DC	Integrated Taxonomic Information System (ITIS)
	Washington DC	Smithsonian Institution
	Wisconsin	OPGEN Inc.
Oceania: 12 MOs in 3 countries		

Country	Location	Organization
Australia	Adelaide	Plant Biodiversity Centre, Adelaide Botanic Gardens
	Hobart TAS	Commonwealth Scientific and Industrial Research Organisation (CSIRO)
	Lismore	Australian Plant DNA Bank
	Melbourne	National Herbarium of Victoria at Royal Botanic Gardens Melbourne
	New South Wales	Department of Primary Industries, NSW
	Sydney	Australian Museum
	Sydney	Botanic Gardens Trust, National Herbarium of NSW
	Sydney	MacQuarie University
French Polynesia	Moorea	UCB Gump South Pacific Research Station
New Zealand	Canterbury	National Centre for Advanced Bio-Protection Technologies
	Lincoln	Landcare Research
	Palmerston North	Allan Wilson Centre for Molecular Ecology and Evolution, Massey University
South and Central America: 12 MOs in 4 countries		
Argentina	Buenos Aires	Museo Argentino de Ciencias Naturales
Brazil	Bahia	Universidade Estadual de Feira de Santana
	Campinas	Centro de Biol. Mol. E Engenharia Genetica-CBMEG/UNICAMP
	Manaus	Instituto Nacional de Pesquisas da Amazonia
	Pampulha	Universidad Federal de Minas Gerais
	Rio de Janeiro	Instituto de Pesquisa Jardim Botânico de Rio de Janeiro
Colombia	Bogota	Molecular Biology Center, Gimnasio Campestre
	Bogota	Instituto de Ciencias Naturales Universidad Nacional de Colombia
	Bogota	Universidad de los Andes
	Ibagué	Universidad del Tolima
Costa Rica	Santa Rosa	Area de Conservacion Guanacaste
	Santo Domingo de Heredia	Instituto Nacional de Biodiversidad (INBio)

Appendix 7. Co-investments in CBOL-sponsored activities and barcoding during the current award period

1. Co-funding for CBOL's workshops, conferences, regional meetings, and other activities. The total cost of the following seven activities was $671,263, of which $244,800 (36.5%) was provided by CBOL and $426,463 (63.5%) came from non-Sloan Foundation sources.

A. Regional meeting in Cape Town, South Africa, April 2006 (CBOL investment $25,000):
- $25,000 from BioNET-INTERNATIONAL and Swiss Agency for Development and Cooperation
- $9,900 from the South African Department of Science & Technology
- $10,000 from the JRS Biodiversity Foundation
- $4,850 in-kind contribution from host institution (South African National Biodiversity Institute)

B. Workshop on recovery of DNA from formalin-fixed specimens, May 2006, Washington, DC (CBOL investment $15,000)
- $10,000 from US Department of Agriculture
- $10,000 from US Environmental Protection Agency
- $10,000 from Harvard University Museum of Comparative Zoology
- $10,000 from Duke University National Evolutionary Synthesis Center
- $10,000 from New England Biolabs
- $10,000 from Sigma-Aldrich, Inc.

C. Data Analysis Workshop, July 2006, Paris (CBOL investment $1900)
- $27,842 from US National Science Foundation grant to Rutgers University, NJ
- €15,000 from European Science Foundation to Muséum National d'Histoire Naturelle, Paris

D. Regional meeting in Nairobi, Kenya, October 2006 (CBOL investment $25,000):
- $25,000 from BioNET-INTERNATIONAL and Swiss Agency for Development and Cooperation
- $6,600 from RPSUD (Research Programme on Sustainable Use of Dryland Biodiversity)
- $5,000 from regional BOZONET network
- $7,500 in-kind contribution from host institution (National Museums of Kenya)
- $3,000 in-kind contributions from the Kenya Wildlife Service, Africa Online and Kenya Airlines

E. Regional meeting in Campinas, Brazil, March 2007 (CBOL investment $30,000):
- $10,000 from BioNET-INTERNATIONAL and Swiss Agency for Development and Cooperation
- $10,000 from IABIN (Inter-American Biodiversity Information Network)
- $2,700 from Ministry of Science & Technology and Brazilian Society for the Progress of Science
- $7,300 in-kind contributions from host institution (University Sao Paolo) and organizer's institution (National Inst. Amazonian Research)

F. European Molecular Biology Organization (EMBO) workshop on "Molecular Biodiversity and DNA Barcode (CBOL investment $10,900)

- $36,439 from EMBO
- $13,116 from Accademia delle Scienze
- $13,000 from Accademia dei Lincei
- $11,927 from CNR, the Italian National Research Council
- $7,287 from IBM Italy
- $7,287 from SPACI, the Southern Partnership for Advanced Computational Infrastructures

G. Regional meeting in Taipei, Taiwan, September 2007 (CBOL investment $25,000):
- $25,000 from BioNET-INTERNATIONAL and Swiss Agency for Development and Cooperation
- $10,000 Taiwan Council of Agriculture, Forestry Bureau and Fisheries Agency

H. Second International Barcode of Life Conference, Taipei, Taiwan, September 2007 (CBOL Investment $112,000)
- $18,200 from Academia Sinica
- $18,200 from Taiwan National Science Council
- $6,100 from Taiwan Council of Agriculture, Bureau of Animal and Plant Health Inspection and Quarantine
- $4,200 from Taipei City government
- $3,000 from Taiwan Museum
- $1,500 from Ministry of the Interior
- $14,200 from Taiwan Council of Agriculture, Forestry Bureau and Fisheries Agency

2. External grants to CBOL initiatives during the current Sloan Foundation grant, 1 April 2006 to present. The following investments from non-Sloan sources total $1,280,900.

- $250,000 from the US Environmental Protection Agency's Advanced Monitoring Initiative for a two-year project on water quality bioassessment using barcodes for freshwater macroinvertebrates
- $200,000 from the US Federal Aviation Administration for two years of support to the Smithsonian for bird barcoding; cumulative FAA investment in barcoding to date is $620,000
- $120,000 from Genome Canada/Canadian Barcode of Life Network for a two-year postdoctoral fellow for bird barcoding at the Royal Ontario Museum
- $120,000 from Genome Canada/Canadian Barcode of Life Network for a two-year postdoctoral fellow for fish barcoding at the University of Guelph
- $100,000 from the US National Oceanic and Atmospheric Administration (NOAA) for a barcode survey of the fish species of the Gulf of Maine
- £50,000 from private donors to the Natural History Museum London for the Mosquito Barcoding Initiative
- $89,000 from Pennsylvania State University for a two-year post-doc fellowship for the Tephritid Barcoding Initiative
- €50,000 from the Belgian Royal Museum for Central Africa and the Royal Belgian Institute for Natural Sciences for a four-year barcoding effort on tephritid fruit flies

- $58,000 from the Richard Lounsbery Foundation to the Argentine Museum of Natural History for "Barcoding the birds of Argentina: building an operational system for species identification, monitoring and discovery"
- $50,000 from US Department of Agriculture/Animal Plant Health Inspection Service (USDA/APHIS) for the Tephritid Barcoding Initiative
- $44,000 from the Brazilian Governmental Agency (CNPq) to J. Alves-Gomes for DNA Barcode as an identifying tool for biological species: a case study for the commercially important catfish in the Amazon
- $35,000 from the Brazilian Governmental Agency (CNPq) to J. Alves-Gomes for DNA Barcode of Amazonian electric fish used in biomonitoring research
- $24,000 from the European Commission's Marie Curie Fellowship Program to Filipe Costa for EUROFISHCODE
- $10,000 from the British Council/Italian Research Council Exchange for travel and subsistence pertaining to a barcode study of European fishes (coordinated by Gary Carvalho)
- $6,900 from Comisión de Investigaciones Científicas de la Prov. de Buenos Aires, Argentina, for a specimen collecting survey of the fish species of the Mar Chiquita coastal lagoon (a World Biosphere Reserve)

3. In-Kind Contributions to CBOL initiatives during the current Sloan Foundation grant, 1 April 2006 to present:

A. The US National Library of Medicine / National Institutes of Health has provided significant support for numerous activities of the DBWG. This includes hosting a meeting during the current grant period (February 2007) and providing accommodations & travel support for numerous participants through the "NCBI Visitors Program." Additional funding was provided for the creation of the "Barcode Submission Tool" simplifying the deposition of electropherogram files to the NCBI Trace Archive. Finally, staff resources have been committed to handle annotation of compliant COI sequence submissions with the reserved keyword BARCODE.

B. The US Food and Drug Administration (FDA) provided supplies and reagents to the Canadian Centre for DNA Barcoding (CCDB) to aid barcoding fish species of commercial interest in North American markets.

4. Other Investments in DNA Barcoding.. The following represent more than $14.5 million invested in barcoding by non-Sloan sources during the current award period:

A. The Gordon and Betty Moore Foundation provided $250,000 during the current award period to support a pilot barcoding survey of Moorea and recently approved a three-year $5.2 million grant to continue the survey.

B. The Smithsonian Institution has made the following investments in the barcoding projects and capabilities of the National Museum of Natural History and its Laboratory for Analytical Biology. A total of $693,000 was invested during the current award.
   - $350,000 for a 96 capillary DNA sequencer (ABI)
   - $160,000 for four automated DNA extractors
   - $30,000 for PCR machines
   - $28,000 for technician salary
   - $65,000 for operating expenses related to barcoding activities

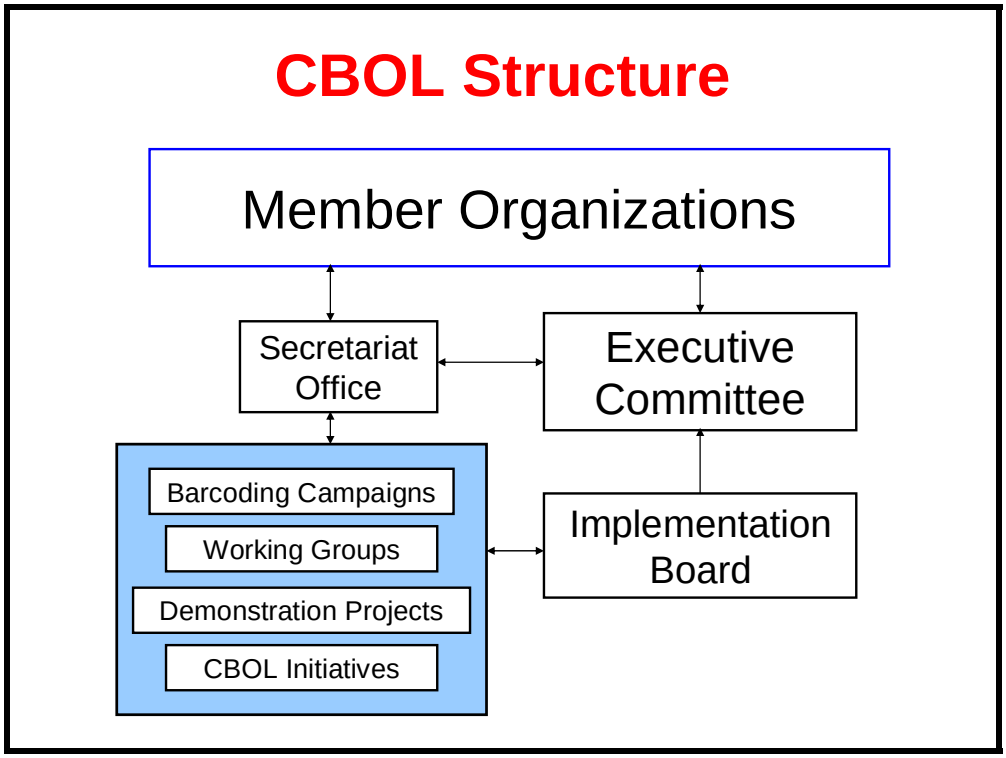
- $60,000 for plant barcoding at the international Consortium for Tropical Forest Science and SIGEO.

C. Researchers at the Canadian Center for DNA Barcoding (CCDB) and the Biodiversity Institute of Ontario (BIO) received the following support during the current grant period (reported in Canadian dollars). The total investment in CCDB and BIO during the current award period has been approximately $5.62 million.
   - $1 million from the Ontario Research Foundation to P. Hebert for operational support of CCDB
   - $1.7 million to P. Hebert and M. Hajibabaei to develop protocols for environmental barcoding using massively parallel 454/Flex sequencing capabilities ($800,000 from Genome Canada; $400,000 from the Ontario Ministry of Research and Innovation, and $250,000 each from Environment Canada and the Moore Foundation)
   - $600,000 from the National Science and Engineering Research Council (NSERC) to P. Hebert for an all-species barcode inventory of Churchill, Canada
   - $595,000 from NSERC to P. Hebert for barcoding North American and Australian Lepidoptera
   - $465,000 from NSERC to R. Hanner and B. Kraatz (University of Western Ontario) to develop an electrochemical strategy for high-throughput DNA barcoding
   - $400,000 from NSERC to P. Hebert for international activities by the Canadian Barcoding Network
   - $238,000 from six Canadian agencies (Ontario Centres of Excellence, Flowers Canada Ontario, Canadian Greenhouse Conference, Ontario Greenhouse Vegetable Growers, Horticultural Crops Ontario, and Ontario Ministry of Agriculture Food and Rural Affairs) to R. Hanner for barcoding agricultural pests
   - $176,000 from Safeguard Biosciences to M. Hajibabaei for development of micro-array technology for species detection in fish and stream biotas
   - $150,000 from the Ontario Ministry of Research and Innovation to P. Hebert for international networking
   - $120,000 from NSERC to P. Hebert to accelerate barcoding of North American and Australian Lepidoptera
   - $95,000 to P. Hebert for an international conference on the International Barcode of Life Project (iBOL) ($55,000 from Genome Canada; $40,000 from the University of Guelph)
   - $50,000 from the Total Foundation to Dirk Steinke to support barcoding the fishes of Lizard Island
   - $30,000 from the Norwegian Research Council to T. Ekrem (Trondheim Natural History Museum) for Polar barcode planning

D. €800,000 from the Belgian Federal Government, Ministry of Science Development for four years of support for barcoding activities

E. The Canadian Centre for DNA Barcoding (CCDB) has developed the Barcode of Life Data System (BOLD) which serves as the open access workbench for CBOL-related and other barcoding projects. Support for BOLD comes from grants to the Canadian Barcode of Life Network from the Canada Foundation for Innovation, NSERC and Genome Canada. During the current award period, the Network provided $500,000 in capital support to BOLD and approximately $400,000 per year in personnel support.

Appendix 8. Revised CBOL Organizational Structure and Terms of Reference



Consortium for the Barcode of Life
Terms of Reference

PREAMBLE

"DNA barcoding" was proposed by Dr. Paul Hebert in 2002 as a standardized technique for assigning biological specimens to their correct species using a short gene sequence. The number of interested researchers and potential users grew quickly, and the Alfred P. Sloan Foundation recognized the importance of DNA barcoding to science and society. The concept of an international Barcode of Life Initiative (BoLI) and an international Consortium for the Barcode of Life (CBOL) emerged during two planning workshops held in 2003 with support from the Sloan Foundation.

Recognizing that

- DNA barcode data are proving highly effective in assigning specimens to known species;
- DNA barcode data, used in conjunction with traditional taxonomic characters such as morphology, behavior, and ecological habits, will allow taxonomists to make species delimitations more precise;
- Barcode data complement traditional data by integrating pre-adult stages and highly dimorphic sexes into more comprehensive species definitions;
- Barcode data can be extremely useful to fields of science beyond taxonomy such as applied biology and ecosystem science that rely on accurate and reliable species identifications;
- DNA barcoding can create a global library of reference records that can be used by non-taxonomists to identify specimens, thereby freeing taxonomists from routine identification services and reducing the "Taxonomic Impediment"; and

Aware that

- Taxonomy is a scientific discipline with a long and rich history and well-established norms and standards;
- Many global initiatives are underway to reduce the Taxonomic Impediment, thereby increasing access to taxonomic information;
- The use of molecular data in taxonomy is widespread and increasing; and

Desiring to

- Explore the potential of DNA barcoding as a research tool and as a practical system for assigning biological specimens to their correct species;
- Make taxonomic data more accessible and valuable to society at large;
- Promote DNA barcoding as a global standard for specimen identification;
- Promote global participation in BoLI; and
- Create mutually beneficial partnerships with ongoing initiatives, thereby avoiding unnecessary duplication of effort,

The Member Organizations of the Consortium of the Barcode of Life affirm the importance and potential value of BoLI and agree to participate in the activities described in these Terms of Reference.

MISSION AND OBJECTIVES

CBOL's mission is to explore and develop the potential of DNA barcoding as a practical tool for species identification in taxonomic research, biodiversity studies and conservation, and for diverse applications that use taxonomic information in service to science and society.

In pursuing its mission, CBOL has the following objectives:

- Creating a public database of reference barcode data that are linked to voucher specimens, valid species names and associated information;
- Populating the barcode database with records from all taxonomic groups and geographic regions, starting with the groups and regions for which a species identification system is most needed;
- Expanding the community of researchers involved in BoLI;
- Increasing the community of users who are applying barcode data to scientific and practical problems; and
- Promoting the development of protocols, instruments, techniques and other tools needed by researchers who want to produce barcode data and the diverse stakeholders who want to use them.

ORGANIZATION AND PROCEDURES

CBOL will operate as a catalyst for distributed activities that are planned and conducted by its members, usually in partnership with other initiatives in biodiversity, taxonomy and systematic research. Very few CBOL activities will be overseen entirely and only by CBOL. Accordingly, CBOL will operate with the smallest possible bureaucracy and will conduct its projects as distributed, collaborative activities. CBOL will conduct most of its administrative business through electronic mail and telephone conference calls.

PARTICIPANTS

CBOL will consist of Member Organizations, an Executive Committee, an Implementation Board, and a Secretariat Office.

Member Organizations. CBOL encourages diverse organizations from around the world to become CBOL Member Organizations, and to become active participants in BoLI through CBOL's activities. Membership in CBOL is open to natural history museums, zoos, herbaria, botanical gardens, universities and their constituent departments and institutes, other research bodies, conservation organizations, government agencies, NGOs, private companies, and other organizations with an interest in biodiversity and species identification. Organizations join CBOL when a senior official of that organization signs a Memorandum of Cooperation, a legally non-binding statement that expresses the organization's interest in BoLI and CBOL's activities, and its willingness to submit its barcode data to a public repository. The Memorandum of Cooperation that is currently in place expires on 31 August 2009.

Membership in CBOL involves no financial contribution to CBOL or other commitment of resources. Member Organizations nominate potential members of CBOL's Executive Committee. CBOL will hold meetings of the representatives of Member Organizations in conjunction with International Barcode Conferences, which are held approximately every two years. CBOL will provide Member Organizations with quarterly newsletters to keep them

informed of CBOL activities and will promote their active participation through ongoing communications through a list-serve and electronic meetings.

Executive Committee. CBOL will be directed by an Executive Committee which will meet twice yearly and will be responsible for:

- Setting the strategic direction, policies, and priorities of CBOL, developed with input from Member Organizations and the Implementation Board;
- Representing the interests of CBOL's Member Organizations while pursuing CBOL's mission;
- Overseeing the preparation and submission of grant proposals (including the CBOL grant to the Sloan Foundation), and meeting all the terms and conditions of grants received by CBOL;
- Creating and overseeing CBOL's major activities, described below;
- Approving all major expenditures of grant funds;
- Appointing members to the Implementation Board; and
- Overseeing the work of the CBOL Secretariat Office, including the selection of the CBOL Executive Secretary.

CBOL's Executive Committee will consist of:

- A Chair, who will be the Principal Investigator of the primary grant supporting CBOL. For 2004-2008, this is the grant from the Alfred P. Sloan Foundation;
- CBOL's Executive Secretary;
- Five individuals selected from candidates nominated by the Member Organizations; and
- *Ex officio* members invited by the Executive Committee to address specific issues.

The Chair's term of appointment coincides with the duration of funding for CBOL from the Sloan Foundation. The Executive Secretary will be a full-time employee of CBOL, supported by the Sloan Foundation grant, selected by the Executive Committee, and hired on fixed-term contracts. Initially, the other five members of the Executive Committee were approved by the Member Organizations as a slate of candidates selected by the Chair and Executive Secretary from among nominees from Member Organizations. To stagger terms of appointment to the Executive Committee and avoid discontinuity, the initial terms of appointment were for one year (two members) or two years (three members). These initial terms of appointment may be renewed once for two years. Subsequent to the initial appointees, members of the Executive Committee will be appointed for a term of two years, renewable once for a second two-year term.

Following the initial appointments, all appointees to the Executive Committee will be selected using the following procedure:

- Nominations will be solicited from Member Organizations by the Secretariat;
- The nominees will be screened by the Secretariat with the goal of ensuring a balance on the Executive Committee with respect to geographic region, scientific expertise, taxonomic coverage, and gender;
- The resulting slate of candidates will be presented to the Executive Committee, including those members whose terms are coming to an end, for review, adjustment, and preliminary approval; and

- The slate of candidates will then be presented to the Member Organizations via electronic mail for their approval. The slate of candidates will be considered approved if objections by fewer than 20% of the Member Organizations are received within two weeks.

Members of the Executive Committee and their terms of appointment are presented in Appendix A.

Implementation Board. CBOL's Executive Committee will appoint an Implementation Board that will meet annually and will:

- Act as a meeting ground for the Chairs of each of CBOL's major activities and the leaders of selected barcoding activities outside of CBOL;
- Facilitate information exchange and coordination across CBOL activities and barcoding initiatives outside of CBOL;
- Provide the Executive Committee with annual reports of the progress being made by each of CBOL's major activities;
- Provide the Executive Committee with advice on scientific and technical matters, including suggestions for new CBOL activities and priorities; and
- Respond to requests from the Executive Committee for information and reviews of proposals for new CBOL activities.

The Implementation Board will consist of:

- The Chair of, or other designated representative, of the Leading Labs Network and each CBOL Working Group, Campaign, and Demonstrator Project;
- The Chair of, or other designated representative of major barcoding initiatives outside CBOL selected by the Executive Committee; and
- Representatives of other significant biodiversity initiatives that, in the Executive Committee's judgment, are essential CBOL partners.

Members of the Implementation Board and their terms of appointment are presented in Appendix B.

Secretariat Office. CBOL's Executive Committee will oversee a Secretariat Office that will:

- Implement the strategies and priorities established by the Executive Committee;
- Prepare proposals to the Executive Committee for new activities, and for CBOL's overall Program of Work;
- Provide the Member Organizations, Executive Committee and Implementation Board with regular reports of activities and progress;
- Perform outreach that will expand participation in CBOL and the Barcode Initiative in both developed and developing countries;
- Provide administrative support to CBOL's major activities;
- Carry out the administrative functions of CBOL, including financial and programmatic management of grants to CBOL; and
- Assist the participants in major CBOL activities in their efforts to obtain funding for their activities.

The Secretariat Office will consist of an Executive Secretary and an Administrator, and any additional staff members whose positions will be approved by the Executive Committee.

Members of the Secretariat Office staff will be employed on term appointments subject to the availability of funding and will report to the Chair of the Executive Committee.

CBOL ACTIVITIES

CBOL's Major Activities will include:

- Working Groups that address large-scale problems that many, if not all, barcoding projects will encounter. Working Groups will be open and inclusive and will focus on technical issues. CBOL has commissioned the following Working Groups:
  - Database Working Group, created in Washington, DC in May 2004;
  - Plant Working Group, created in Washington, DC in May 2004; and
  - Data Analysis Working Group, created in London in February 2005;
- The Leading Labs Network, created in Washington, DC in July 2007, consisting of the most active barcoding labs around the world and dedicated to protocol development, technical assistance, promoting the establishment and success of barcoding centers in all regions of the world, and increasing the flow of barcode records into the public domain;
- Barcoding "campaigns" and "demonstrator projects" that obtain representative barcodes for large numbers of species in particular taxonomic groups;
- Networks that promote communication and cooperative barcoding projects among groups of individuals and organizations that share an interest that can be served by barcoding; and
- *Ad hoc* committees formed to address a specific issue related to DNA barcoding.

Each CBOL activity will provide the Executive Committee, through the Secretariat Office and Implementation Board, with:

- An initial statement of goals and mission;
- A nominated leader and list of 5-10 core members;
- A brief description of its program of work; and
- Periodic reports of progress towards its goals.

The Executive Committee will be responsible for assessing the effectiveness of all activities and may decide to reconstitute or discontinue an activity.

CBOL's major activities may request financial and administrative support from the Secretariat Office. Support from the Sloan Foundation grant may be used for catalytic activities such as planning meetings and for partial support of workshops and conferences. Sloan Foundation funds cannot be used for research, research infrastructure, training courses, or capacity building. In most cases, leaders of CBOL activities will need to seek support of their activities from funding sources other than CBOL and the Sloan Foundation.

CBOL will also encourage the initiation of smaller barcoding projects, but CBOL will not be involved in the administrative or financial support of these smaller projects.

CHANGE OF STATUS

The current version of the Memorandum of Cooperation signed by each CBOL Member Organization expires on 31 August 2009. Prior to that date, CBOL's Executive Committee will review CBOL's progress towards its goals. Based on the results of that evaluation, the Executive Committee may propose an extension of the Memorandum of Cooperation to the Member Organizations which would extend CBOL's operation beyond that date.

It is the responsibility of each Member Organization to inform the CBOL Secretariat of a change in its membership status as outlined in these Terms of Reference. It is the responsibility of each member of the CBOL Executive Committee and Implementation Board to inform the CBOL Secretariat of changes in his or her participation as outlined in these Terms of Reference.

ADOPTION AND AMENDMENT

These Terms of Reference were adopted by CBOL's Executive Committee at its meeting in Cape Town, South Africa, on Sunday, 9 April 2006.

Amendments to the Terms of Reference were approved by email on 30 November 2007. These amendments:

- updated terms of appointment of Executive Committee (see membership, Appendix A);
- gave the Executive Committee the ability to appoint *ex officio* members to the Executive Committee and appoint *ad hoc* advisory committees;
- established the Implementation Board (see membership, Appendix B);
- disestablished the Scientific Advisory Board (see membership, Appendix C);
- updated the list of Major CBOL activities by disestablishing the DNA Working Group (May 2004-November 2007) and establishing the Leading Labs Network; and
- specified new activities that improve communication with and among CBOL's Member Organizations.

Appendix A. Members of CBOL's Executive Committee

Dr. José Alves-Gomes, Instituto Nacional de Pesquisas da Amazônia, Manaus
(initial term 20 June 2005 to 19 June 2007; renewed and served through 31 December 2007)

Dr. James Edwards, Global Biodiversity Information Facility, Copenhagen
(initial term 20 June 2005 to 19 June 2006; renewed through 19 June 2008)

Richard Lane, The Natural History Museum, London
(initial term 20 June 2005 to 19 June 2006; renewed through 19 June 2008)

Dr. Helida Oyieke, National Museums of Kenya, Nairobi
(initial term 20 June 2005 to 19 June 2007; renewed through 19 June 2009)

Simon Tillier, Muséum National d'Histoire Naturelle, Paris
(initial term 20 June 2005 to 19 June 2007; renewed through 19 June 2009)

Appendix B. Members of CBOL's Implementation Board (awaiting approval)

George Amato, American Museum of Natural History, Chair of DNA Barcoding for Conservation Initiative

Ken Cameron, NY Botanical Garden, Chair of TreeBOL (appointed 1 January 2008)

Scott Federhen, National Center for Biotechnology Information, Head of GenBank Taxonomy

Robert Hanner, University of Guelph, Canada; Chair of Database WG and FISH-BOL Coordinator

Paul Hebert, University of Guelph, Chair of iBOL Initiative (appointed 1 January 2008)

Peter Hollingsworth, Royal Botanic Gardens Edinburgh, UK; Chair of Plant WG

Yvonne Linton, Natural History Museum London, Mosquito Barcoding Initiative Coordinator

Bruce MacPheron, Pennsylvania State University, Chair of Tephritid Barcoding Initiative

Chris Meyer, Smithsonian Institution, liaison to BIOCODE Project in French Polynesia

Sujeevan Ratnasingham, Biodiversity Institute of Ontario, Lead for BOLD

Neil Sarkar, Marine Biological Laboratory, Woods Hole, MA, USA; Chair of Data Analysis WG

Pablo Luis Tubaro, Museum of Natural Sciences, Argentina, ABBI Chair

Lee Weigt, Smithsonian Institution, Washington, DC, USA; Chair, Leading Labs Network

Appendix C. Members of CBOL's Scientific Advisory Board

Term Members:

Freek Bakker, National Herbarium, Netherlands, Chair of SAB (initial Vice-Chair of SAB, term 1 August 2005 to 30 July 2007; renewed through 30 July 2009)

Karen Armstrong, Lincoln University, New Zealand, Vice-Chair of SAB (initial appointment 1 August 2005 to 30 July 2007; renewed through 30 July 2009)

Paul De Barro, CSIRO, Sydney, Australia (initial term 4 May 2006 to 3 May 2007; renewed through 30 July 2009)

Paul Hebert, University of Guelph, Canada; (appointed Chair of DNA WG, 1 August 2005; replaced on 21 October 2006; initial term 21 October 2006 to 20 October 2008)

Peter Ng, National University of Singapore (initial term 4 May 2006 to 3 May 2008)

Daniel Masiga, ICIPE, Nairobi, Kenya (initial term 4 May 2006 to 3 May 2007; renewed through 30 July 2009)

Athula L.T. Perera, University of Peradeniya, Sri Lanka (initial appointment 1 August 2005 to 30 July 2007; renewed through 30 July 2009)

Cecilia Saccone, CNR Institute of Biomedical Technologies, Italy (initial term 1 August 2005 to 30 July 2006 ; renewed through 30 July 2008)

Ole Seberg, University of Copenhagen, Denmark (initial term 1 August 2005 to 30 July 2006 ; renewed through 30 July 2008)

Pablo Luis Tubaro, Museum of Natural Sciences, Argentina (initial term 1 August 2005 to 30 July 2006 ; renewed through 30 July 2008)

Working Group Chairs:

Robyn Cowan, Royal Botanic Gardens Kew, UK; Chair of Plant WG (appointed 1 August 2005)

Michel Veiulle, National Museum of Natural History, Paris, France ; Chair of Data Analysis WG (appointed 1 August 2005)

Robert Hanner, University of Guelph, Canada; Chair of Database WG (appointed 1 August 2005)

Lee Weigt, Smithsonian Institution, Washington, DC, USA; Chair, DNA Working Group (appointed 21 October 2006)

Former SAB Members:

James Hanken, Harvard University, USA; (initial Chair of SAB, term 1 August 2005 to 30 July 2006 ; declined renewal)

Sandro Luis Bonatto, Pontifícia Universidade Católica do Rio, Brazil (initial term 1 August 2005 to 30 July 2006 ; declined renewal)

Appendix 9. Members of Leading Labs Network

1. Canadian Centre for DNA Barcoding, University of Guelph, Ontario
2. Laboratory for Analytical Biology, National Museum of Natural History, Smithsonian Institution, Washington, DC
3. Biocode Project, University of California Berkeley, California
4. Smithsonian Tropical Research Institute, Panama
5. National Center for Biotechnology Information, National Institutes of Health, Bethesda, Maryland
6. Australia Museum, Sydney
7. Muséum National d'Histoire Naturelle, Paris
8. Universidad Nacional Autonoma de Mexico (UNAM), Mexico City
9. Academia Sinica and Chinese Culture University, Taiwan
10. Natural History Museum London
11. New York Botanical Garden
12. Royal Botanic Gardens Kew
13. Scripps Institute of Oceanography, La Jolla, California
14. American Museum of Natural History, New York
15. CBS Fungal Biodiversity Centre, Utrecht, Netherlands
16. South Africa National Biodiversity Institute (SANBI), Cape Town, South Africa

Appendix 10. Sample of media coverage of DNA barcoding

Magazines:

Grant, Bob. "Cataloging Life" *The Scientist* Dec. 2007: 36

Guynup, Sharon. "Cracking the Code" *Audubon Magazine* Nov. 2007

Pennisi, Elizabeth. "Wanted: A Barcode for Plants" *Science* 11 Oct. 2007: 318

Evers, Marco. "Catalogue of Life" *Der Spiegel* 7 Oct. 2007: 166

"Name, rank and serial number" *The Economist* 22 Sept. 2007: 98

Barker, Veronique. "Wrestling with Biodiversity" *Innovation Canada* Sept-Oct. 2007

"Check, Erika. "Rival Genetics Projects Build Bridges" *Nature* 26 April 2007: 446

Roberts, Siobhan. "Barcoding Life" *Canadian Geographic* March-April 2007

Jones, Chris. "Bar-coding Life" *Esquire* Dec. 2006: 284-285.

Atkinson, Nick. "Cracking the Code" *Entangled* 25 May 2006: 50-51

Marris, Emma. "Gardens in Full Bloom" *Nature* 13 April 2006: 440

Holloway, Marguerite. "Democratizing Taxonomy" *Conservation in Practice* April-June 2006: 7

Internet and Newspapers:

"DNA Barcoding: From fruit flies to puffer fish" *Google AFP* 15 Sept. 2007 <http://afp.google.com/article/ALeqM5g7iBJqJkZERj5Vy2bg3oIwkZmmLQ>

Aguilar, Eva. "Africa: DNA Barcodes Tackle Disease, Protect Biodiversity" *SciDev.net* 21 Sept. 2007. http://allafrica.com/stories/200709210953.html

"Check out plan to barcode world's species" 19 Sept. 2007. *The Sydney Morning Herald*

"DNA Barcode to identify world's species" *The Hindu* 18 Sept. 2007. <http://www.hindu.com/thehindu/holnus/008200709180365.htm>

"How DNA Barcoding can help science" *Science Daily* 17 Sept 2007.

Ogilvie, Megan. "New frontier for DNA team: A barcode for every animal" *The Toronto Star* 15 September 2007

"Scientists caught up in a great bloodsucker blunder" *Taipei Times* 22 April 2007

"DNA Barcoding - a breakthrough for invasive species detection?" *The Global Invasive Species Program News* Jan 2007:7

Strauss, Stephen. "Everytime a butterfly flaps its wings in Guelph…" *The Globe and Mail* 26 Sept 2006: B10.

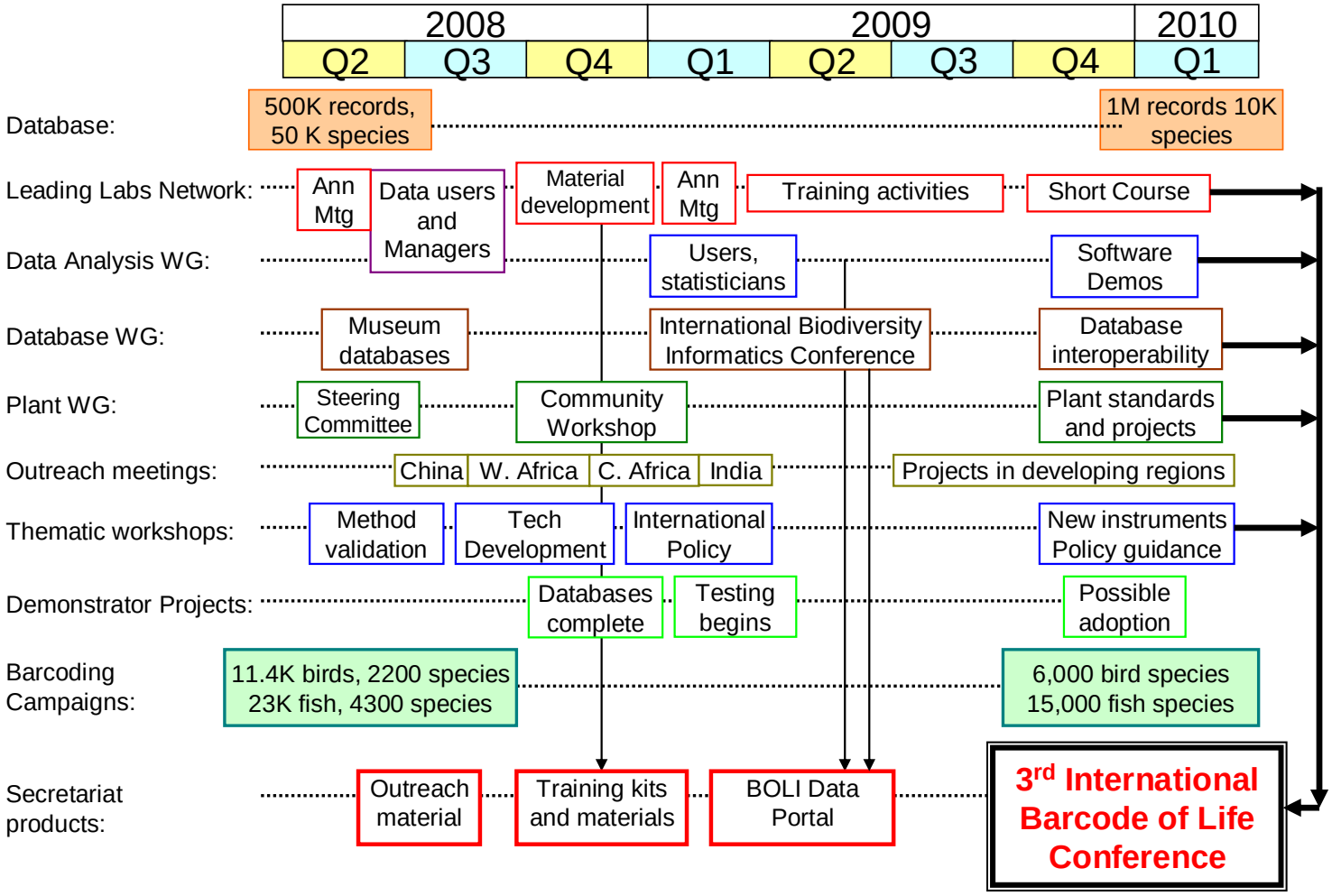
Radio:

"Backing up the planet" Quirks and Quarks. Host Bob McDonald. CBC Radio. 25 Nov. 2006 <http://www.cbc.ca/quirks/archives/06-07/nov25.html>

"The Barcoding of Life" Isla Earth. Carlos de la Rosa. Isla Earth Radio Series. Nov. 2006 <http://www.islaearth.org/radio/show.php?_sid=1164700800>

"Expert: DNA Barcoding project just begun" Host Jorge Salazar. Earth and Sky. 18 May 2007 < http://www.earthsky.org/clear-voices/51118/expert-dna-barcoding-project-just-begun>

Appendix 11. Chart of Milestones for 2010



SCOTT E. MILLER

Senior Program Officer, Office of the Under Secretary for Science, Smithsonian Institution, and Research Entomologist, Smithsonian National Museum of Natural History, Box 37012, Washington, DC 20013-7012, USA. Phone: 202-633-5135. Fax: 202-633-8942, millers@si.edu

Professional Preparation:
University of California, Santa Barbara, B.A. Biology, 1981
Harvard University, Cambridge, Massachusetts, Ph.D. Biology, 1986

Prior Professional Appointments:
Smithsonian Institution, Washington, DC
Associate Director, National Zoological Park, 2004-2006
Supervisory Research Entomologist, NMNH, 1998-2004 (on leave 1998-1999)
International Centre of Insect Physiology and Ecology (ICIPE), Nairobi
Principal Scientist and Programme Leader, 1998-1999
Bernice Pauahi Bishop Museum, Honolulu, Hawaii
Research Associate, 1998-
Chair, Department of Natural Science, 1993-1997; Chair, Department of Entomology, 1986-1993
University of Maryland, College Park, Affiliate Graduate Faculty, Dept. of Entomology, 2002-

Grants, Fellowships and Contracts (over 7.5 million dollars total):
National Science Foundation, Research Grants
DEB 0515678 (coPI 2005-2008) [insect herbivore ecology in Papua New Guinea]
DEB 0211591 (coPI 2002-2005) [insect herbivore ecology in Papua New Guinea]
DEB 9707928 (PI 1997-2002) [insect herbivore ecology on Rubiaceae in Papua New Guinea]
DEB 9629751 (PI 1996-1997) [insect herbivore ecology on euphorbs in Papua New Guinea]
DEB 9528025 (PI 1996-1999) [systematics and biogeography of aquatic insects in New Guinea]
DEB 9407297 (PI 1994-1996) [insect herbivore ecology on *Ficus* in Papua New Guinea]
National Science Foundation, Research Collections in Systematics and Ecology Grants,
BSR 8511669, 8706426, 8913871, DEB 9423814 (PI 1986-1997) [Bishop Museum entomology]
BSR 8912364 and supplement (PI 1993-1994) [Bishop Museum herbarium]
BSR 8313189 (PI 1988-1989) [Catalog of Australasian and Oceanic Flies]
National Science Foundation, Database Activities Grants,
DBA 9631091 (co-PI with John Helly *et al.* 1996-1999) [WWW based data management]
National Institutes of Health, ICBG, Co-PI with Louis Barrows et al., 2003-2008
Conservation and sustainable use of biodiversity in Papua New Guinea
Sloan Foundation, Consortium for the Barcode of Life Secretariat [2004-2008]

Representation on significant committees and review panels:
International (representing US Government and/or Smithsonian): Convention on Biological Diversity (especially Global Taxonomy Initiative), Global Biodiversity Information Facility, Global Invasive Species Program, BioNet International
Federal government: Inter-agency Working Group on Scientific Collections (co-chair), Committee on Environment and Natural Resources, National Invasive Species Council working groups, others
Private: National Geographic Society, Travelers Conservation Foundation
Board of Directors: American Entomological Institute, Consortium for the Barcode of Life (chair), Indo-Pacific Conservation Alliance, Xerces Society

Honorary membership in professional organizations:
American Association for the Advancement of Science (Fellow); Royal Entomological Society of London (Fellow)

Related publications (150 in total):

Novotny, V., S. E. Miller, J. Hulcr, R. A. I. Drew, Y. Basset, M. Janda, G. P. Setliff, K. Darrow, A. J. A. Stewart, J. Auga, B. Isua, K. Molem, M. Manumbor, E. Tamtiai, M. Mogia, and G. D. Weiblen. 2007. Low beta diversity of herbivorous insects in tropical forests. *Nature* 448:692-695.

Hulcr, J., S. E. Miller, G. P. Setliff, K. Darrow, N. D. Mueller, P. D. N. Hebert, and G. D. Weiblen. 2007. DNA barcoding confirms polyphagy in a generalist moth, *Homona mermerodes* (Lepidoptera: Tortricidae). *Molecular Ecology Notes* 7: 549-557.

Novotny, V., P. Drozd, S. E. Miller, M. Kulfan, M. Janda, Y. Basset, and G. D. Weiblen. 2006. Why are there so many species of herbivorous insects in tropical rainforests? *Science* 313: 1115-1118.

Novotny, V., S. E. Miller, Y. Basset, L. Cizek, K. Darrow, B. Kaupa, J. Kua, and G. D. Weiblen. 2005. An altitudinal comparison of caterpillar (Lepidoptera) assemblages on Ficus trees in Papua New Guinea. *Journal of Biogeography* 32: 1303-1314.

Novotny, V., Y. Basset, S. E. Miller, R. L. Kitching, M. J. Laidlaw, P. Drozd, and L. Cizek. 2004. Local species richness of leaf-chewing insects feeding on woody plants from one hectare of a lowland rainforest. *Conservation Biology* 18: 227-237.

Other significant publications (150 in total):

Miller, S. E. 1994. Systematics of the Neotropical moth family Dalceridae (Lepidoptera). *Bulletin of the Museum of Comparative Zoology* 153: 301-495.

Sekhran, N. & Miller, S.E. (eds) 1995. *Papua New Guinea Country Study on Biological Diversity*. Papua New Guinea Department of Environment and Conservation, Waigani. xl + 438 pp.

Keast, A. & Miller, S.E. (eds) 1997. *The origin and evolution of Pacific island biotas, New Guinea to Eastern Polynesia: Patterns and processes*. SPB Publications, Amsterdam. viii + 531 pp.

Holloway, J.D., Kibby, G. Peggie, D., Carter, D. & Miller, S.E. 2001. *Families of Malesian moths and butterflies*. Fauna Malesia Handbook Series. Brill, Leiden. xii + 456 pp.

Basset, Y., V. Novotny, S. E. Miller, and R. L. Kitching, eds. 2003. Arthropods of tropical forests: Spatio-temporal dynamics and resource use in the canopy. Cambridge University Press, Cambridge. xvi + 474 pp.

Synergistic Activities:

- Promoting collaboration between the agricultural and biodiversity/environment sectors, including 2 years at an international agriculture research center (http://www.icipe.org/) and participation in international panels for Secretariat of Convention on Biological Diversity and FAO.
- Promoting linkage between biodiversity research and conservation applications, including reports for Government of Papua New Guinea (Sekhran and Miller 1995) and Conservation International.
- Promotion of an integrated approach to conservation including leading the development team for a major project at Kakamega Forest, Kenya (http://www.nmnh.si.edu/kakamega).
- Contributing to building the infrastructure for understanding global biodiversity through the Consortium for the Barcode of Life (http://www.barcoding.si.edu), Global Biodiversity Information Facility, Global Taxonomy Initiative, and others.

Collaborators & Other Affiliations:

Recent Collaborators: A. Allison (Bishop Museum); Y. Basset (STRI); V.O. Becker (Brazil); J. Brown (USDA); L. Cizek (Czech Academy of Sciences); P. Drozd (Czech Academy of Sciences); J.D. Holloway (Natural History Museum); R. Kitching (Griffiths Univ.); W. Lwande (ICIPE); V. Novotny (Czech Academy of Sciences); L. Rogo (NMNH); D. Schindel (NMNH); G. Weiblen (Univ. Minn.)
Graduate and Post Doctoral Advisors: E. O. Wilson, Harvard University (Graduate Advisor)
Thesis Advisor and Postgraduate-Scholar Sponsor:
Former Graduate Students: Hide Chiba (Ph.D.), Curtis Ewing (Masters), Amanda Heddle (Masters), Caitlin O'Connell (Masters), John Strazanac (Ph.D.), Sabina Swift (Ph.D.) (all University of Hawaii); Serigine Tacko Kandji (Ph.D.), Kenyatta University; Alfred Ochieng (Masters), University of Nairobi
Former Postdoctoral Fellow: Yves Basset; Daniel Perez; Diana Percy

David E. Schindel, Ph.D.

Education

University of Michigan, B.S. in Geological Sciences	1973
Harvard University, Ph.D. in Geological Sciences	1979
Federal Executive Institute: Leadership for a Democratic Society	1995

Experience

Smithsonian Institution, November 2006 to present:

Executive Secretary, Consortium for the Barcode of Life	November 2006-present

National Science Foundation, July 1986 to November 2006:

Executive Secretary, Consortium for the Barcode of Life (on detail from NSF to the Smithsonian Institution)	September 2004-November 2006
Head, National Science Foundation's Europe Office	July 1998-August 2004
Executive Associate, Office of Integrative Activities	January-June 1998
Legislative Fellow for Senator Jeff Bingaman (D-NM; on detail from NSF to the United States Senate during a one-year developmental assignment)	January-December 1997:
Senior Science Advisor, Office of Science & Technology Infrastructure	1993-1996
Program Director, Elementary, Secondary, and Informal Education	1991-1993
Program Director, Biological Research Resources	1989-1991
Associate Program Director, Systematic Biology	1986-1989

Yale University, 1978-1986

Associate Professor, Department of Geology & Geophysics	1984-1986
Assistant Professor Department of Geology & Geophysics	1978-1984
Curator of Invertebrate Fossils, Yale Peabody Museum	1978-1986

Smithsonian Institution, 1977-1978

Predoctoral Fellow in Paleobiology, US National Museum of Natural History

Awards

NSF Director's Award for Management Excellence	1999
NSF Director's Meritorious Service Award	1997
NSF Director's Superior Accomplishment Award	1995

Other Relevant Experience

Advisor on elementary school science to Montgomery County Public Schools (Maryland)	1990
Member of a Maryland State Department of Education task force on graduation requirements	1992

Publications

Most important articles:

Schindel, D.E. and S.J. Gould. 1977. Biological interaction between fossil species: character displacement in Bermudian land snails. Paleobiology 3:259-269.

Schindel, D.E. 1980. Microstratigraphic sampling and the limits of paleontologic resolution. Paleobiology 6:408-426.

Vermeij, G.J., D.E. Schindel and E. Zipser. 1981. Predation through geologic time: evidence from gastropod shell repair. Science 214:1025-1026.

Schindel, D.E. 1982. Resolution analysis: A new approach to the gaps in the fossil record. Paleobiology. 8:340-353.

Schindel, D.E. 1982. Punctuations in the Pennsylvanian evolutionary history of Glabrocingulum (Mollusca: Archaeogastropoda). Bull. Geol. Soc. Amer. 39:400-408.

Schindel, D.E., G.J. Vermeij and E. Zipser. 1982. Frequencies of repaired shell fractures among the Pennsylvanian gastropods of north-central Texas. Jour. Paleontol., 56:729-740.

Schindel, D.E. 1982. The Gaps in the Fossil Record. Nature., 297:282-284.

Schindel, D.E., 1991, Unoccupied Morphospace and the Coiled Geometry of Gastropods: Architectural Constraint or Geometric Covariation?, in Allmon, W.D. and Ross, R., eds., Causes of Evolution, Univ. Chicago Press, 270-304.

Most recent articles:

Schindel, D.E., 2001, The American Academic Marketplace, in "German and American Higher Education: Educational philosophies and Political Systems", conference convened by the Bavarian-American Academy, Transaction Press, Rutgers University, Piscataway, NJ, pp.163-172.

Schindel, D.E. and S.E. Miller, 2005, Barcoding a useful tool for taxonomists, letter to Nature letter, 435:17

Schindel, D.E., in press, Consortium for the Barcode of Life: A rapid, cost-effective system for species identification, Proceedings of the International Conference on Biodiversity, Paris, 24-28 January 2005 under the patronage of the Ministry delegated to Research and of UNESCO.

Proposed Budget, 1 April 2008 to 31 March 2010

	2008	2009	2010	TOTAL
TOTAL:	**$1,292,031**	**$1,456,106**	**$250,203**	**$2,998,340**
Salaries and benefits	**$441,781**	**$606,606**	**$161,953**	**$1,210,340**
Meetings	**$307,500**	**$277,500**	**$0**	**$585,000**
Executive Committee (2/yr)	$50,000	$50,000		$100,000
Implementation Board (2/yr)	$50,000	$50,000		$100,000
Ad hoc scientific advisory panels	$7,500	$7,500		$15,000
International Conference, 4th quarter, 2009		$100,000		$100,000
Regional Outreach Meeting, West Africa	$25,000			$25,000
Regional Outreach Meeting, Central Africa	$25,000			$25,000
Outreach Meeting, China	$20,000			$20,000
Outreach Meeting, India	$20,000			$20,000
Proposal writing workshops (2/year)	$40,000	$40,000		$80,000
Three thematic workshops	$50,000			$50,000
Planning meetings for emerging opportunities	$20,000	$30,000		$50,000
Campaigns and Demonstration Projects	**$233,000**	**$278,000**	**$65,000**	**$576,000**
All Birds Barcoding Initiative (ABBI)	$68,750	$65,000	$16,250	$150,000
Fish Barcoding Initiative (FISH-BOL)	$56,250	$75,000	$18,750	$150,000
Tephritid Barcoding Initiative (TBI)	$48,750	$65,000	$16,250	$130,000
Mosquito Barcoding Initiative (MBI)	$59,250	$73,000	$13,750	$146,000
Working Groups and Others	**$195,000**	**$160,000**	**$0**	**$355,000**
Leading Labs	$75,000	$70,000		$145,000
Database WG	$35,000	$45,000		$80,000
Data Analysis WG	$35,000	$45,000		$80,000
Plant WG	$50,000	$0		$50,000
Central Secretariat Support	**$114,750**	**$134,000**	**$23,250**	**$272,000**
Staff travel	$35,000	$45,000	$10,000	$90,000
Training	$2,000	$2,000		$4,000
Office equipment	$8,000	$6,000	$2,000	$16,000
Office supplies	$2,500	$3,000	$500	$6,000
Printing and publication	$20,000	$30,000		$50,000
Online access rights for barcoding publications	$10,000	$5,000	$10,000	$25,000
Public Relations and Outreach	$10,000	$15,000		$25,000
Voice Communication	$2,250	$3,000	$750	$6,000
Website development and management	$25,000	$25,000		$50,000
Totals:	**$1,292,031**	**$1,456,106**	**$250,203**	**$2,998,340**
	Year 1	Year 2		
Estimated Calendar Year Requests:	**$1,631,058**	**$1,367,282**		**$2,998,340**

Budget Justification[+]

Secretariat Office Staff ($1,210,340). For most of the current award period, the CBOL Secretariat Office included three people: the Executive Secretary, Administrator, and a Project Manager. In light of the ambitious program of work proposed here, CBOL proposes to add several staff positions, described below.

- **Executive Secretary**, D. Schindel, would continue in his role for two years. He will be responsible for strategy development and implementation in all areas of CBOL activity. The addition of a Deputy Director would allow him to increase his fundraising activities and outreach to potential users and decrease his involvement in daily operations.
- **Deputy Executive Secretary.** CBOL proposes to add a Deputy Executive Secretary to the Secretariat Staff at the GS-12 level. CBOL would seek a Deputy with a Ph.D. in biology and international experience. The Deputy would have lead responsibility for outreach to developing countries and relations with CBOL's Member Organizations. The Deputy would act as back-up and understudy to the Executive Secretary and would provide CBOL with a trained successor.
- **Administrator**, M. Fritzsche, would continue in her role in charge of financial management and daily operations of the Secretariat Office. She supervises the Program Assistant and has lead responsibility for the logistics for all CBOL meetings, including the international conference.
- **Program Assistant**, A. Balla, would continue as a member of the Secretariat Office until August 2008, when she plans to enter medical school. CBOL is in the process of hiring a second Program Assistant who would begin in February 2008 and would work alongside Ms. Balla until her departure. The Program Assistant provides critical support for all logistics associated with CBOL meetings, develops outreach materials, and manages CBOL's websites and contacts database.
- **Project Manager.** The Program Assistant would be promoted from a GS-7 to a GS-9 Project Manager position after one year. This is a change in grade and title, not an addition to the Secretariat Office staff.
- **Data Manager.** CBOL hired M. Trizna as a summer intern in 2007 and during his tenure he obtained an extensive understanding of BOLD and barcode data and developed a number of very useful data management programs. He has completed an M.S. in bioinformatics and has been offered a full-time position as CBOL's Data Manager. In this position, he will have lead responsibility for developing the BOLI Data Portal. He will also work with BOLD, GenBank and all major CBOL activities to solve data management and interoperability problems.
- **Interns.** CBOL requests support for interns who will assist with projects in the Secretariat Office and on CBOL activities outside the Smithsonian. In general, the interns assisted with data entry and management of barcode records. They also assisted in managing CBOL's websites, developing outreach materials, preparing for CBOL meetings, and assisting the Administrator with daily operations. During the current award period, CBOL supported a total of 13 interns in Kenya, London, Argentina, Brazil, and Canada, as well as in the Secretariat Office.

[+] See Appendix 11, Chart of milestones

Meetings ($585,000). CBOL requests support for the following meetings of its leadership committees and for outreach activities.

- **Executive Committee ($100,000).** CBOL proposes to continue holding two meetings of the Executive Committee per year. Each year, one of these meetings is normally held in conjunction with a CBOL outreach meeting or conference.
- **Implementation Board ($100,000).** The Executive Committee agreed to a restructuring of CBOL and revision of its Terms of Reference in late 2007 (see Appendix 8). This resulted in creation of the Implementation Board which would meet twice per year. The Implementation Board consists of the heads of all major CBOL activities and their meetings are critical to the coordination and integration of the program of work.
- **Ad hoc advisory committees ($15,000).** CBOL's recent restructuring eliminated the Scientific Advisory Board, and the Executive Committee agreed to convene *ad hoc* advisory committees instead. It is likely that proposals for plant and fungal barcode regions will be submitted during the proposed award period, so CBOL anticipates the need to convene one such committee each year.
- **International Conference ($100,000).** CBOL proposes to hold the Third International Barcode of Life Conference in the fourth quarter of 2009. Possible venues in Canada, South or Central America, or Oceania are being considered. CBOL requests $100,000 for partial support of the conference. Non-Sloan sources provided approximately 52% of the total cost of the Second International Conference in Taipei in September 2007 (see Appendix 7). A similar level of cost-sharing will be sought for the Third International Conference.
- **Regional Outreach Meetings ($50,000).** CBOL proposes to hold outreach meetings for the countries of western Africa and for the Francophone countries of central Africa. These two biodiversity-rich regions have had very little exposure to or involvement in barcoding. CBOL requests $25,000 for partial funding of each regional meeting. Based on past experience, each regional meeting costs between $60,000 and $70,000. The balance will be raised from non-Sloan sources. CBOL's Deputy Executive Secretary would have lead responsibility for these meetings.
- **Outreach to China and India ($40,000).** Both China and India have enormous technological capacity as well as high biodiversity. Representative of each country have started to participate in CBOL activities and they attended the Taipei International Conference. They expressed keen interest in establishing national barcoding programs and centers. CBOL requests $20,000 for each of these meetings, with the balance to be obtained from national agencies. CBOL's Deputy Executive Secretary would have lead responsibility for these meetings.
- **Proposal-writing workshops ($80,000).** CBOL launched many activities during the current award period, including two barcoding campaigns, two Demonstrator Projects, and activities catalyzed by regional outreach meetings to developing countries. To help these activities obtain funding from non-Sloan sources, CBOL proposes to organize and hold four workshops devoted to generating funding proposals. CBOL's Executive Secretary gained hands-on experience in running proposal-writing workshops during his 20 year career at the National Science Foundation. A total of $80,000 is requested for these four workshops.

- **Thematic workshops ($50,000).** CBOL requests partial support of the following workshop that will be co-organized with partner organizations. The following requests will cover approximately 30% of the total costs of these workshops:
  - Workshop for technology developers and potential users ($10,000)
  - International workshop on restrictions to biodiversity research ($30,000)
  - Interagency planning workshop toward international validation of the barcoding method ($10,000)
- **Emerging Opportunities ($50,000).** CBOL requests support for planning meetings to be organized and convened in response to emerging opportunities in both barcoding research and applications. During the current award period, CBOL used funds in this manner to support outreach to the Census of Marine Life, the conservation community, international agricultural research organizations, and the molecular evolution research community.

Campaigns and Demonstrator Projects ($576,000). CBOL is now coordinating and promoting four major barcoding activities. Each of them is obtaining some support from non-Sloan sources and the proposal-writing workshops proposed above should increase the level of co-funding. To increase momentum of these projects and accelerate the accumulation of barcode records, CBOL requests the following support to mobilize samples into the barcoding pipeline, assist with data management and quality assurance, and promote acceptance and wider participation among taxonomists. All support for laboratory procedures involving PCR and sequencing will be obtained from non-Sloan sources.

- **ABBI ($150,000).** ABBI proposes to convene a meeting of the curators in charge of the world's largest frozen bird tissue collections, and to develop agreements with them to sample and barcode their collections. CBOL requests $20,000 for the meeting and $25,000 per year for technician support for sampling the tissue and creating high-quality DNA extracts that will be used for barcoding and returned to the collections. CBOL also requests $15,000 per year to support three training fellowships per year for students, post-docs or researchers from developing countries who will learn barcoding and will process samples at Guelph or the Smithsonian. Other requests for ABBI include meetings of the African and Australian Regional Working Groups ($15,000 each), support for ABBI technical sessions at professional meetings and travel support for the ABBI Steering Committee to meet and to give presentations at conferences ($10,000 per year)
- **FISH-BOL ($150,000).** Data management, editing, and coordination have been critical rate-limiting factors and $15,000 per year is requested for a part-time data coordinator to work with FISH-BOL Coordinator R. Hanner at the University of Guelph. Most activities in FISH-BOL are coordinated through Regional Working Groups (RWGs) which have been meeting to develop and implement their strategies for gathering and processing samples. CBOL requests $40,000 per year for partial support of four regional meetings each year, with co-funding provided by local sources. Travel support in the amount of $20,000 per year is requested for visits to and from museums for tissue sampling and for expert identification of voucher specimens. All laboratory procedures for PCR and sequencing will be supported from non-Sloan sources.
- **TBI ($130,000).** The tephritid fruit fly Demonstrator Project has obtained permission to sample tissue from virtually all major museums but TBI has not yet been able to hire a full-time technician to harvest samples and enter data. CBOL requests $30,000 per year

for partial funding of the technician's salary, to be supplemented by the host institution of whichever TBI leader hires the technician (Penn State University, Smithsonian, or the Royal Museum of Central Africa in Tervuren, Belgium). Travel support in the amount of $20,000 per year is requested for travel to museums to obtain samples. All laboratory procedures for PCR and sequencing will be supported from non-Sloan sources. An additional $15,000 per year is requested for meetings of the Steering Committee, outreach through professional conferences, and visits to potential funding agencies.

- **MBI ($146,000).** MBI requests 50% support for one research assistant ($30,000 per year), to be sited at and co-funded by the Natural History Museum London. This assistant will be responsible for MBI data management and submission. MBI also requests $25,000 per year to support travel to museum collections by MBI staff and to the Scholar Ship by curators who are donating specimens to MBI. MBI plans to hold Steering Committee meetings in April 2008 and 2009 and requests $18,000 for each.

Working Groups ($355,000).

- **Leading Labs Network ($145,000).** CBOL requests support for an annual meeting of members of the Leading Labs Network ($30,000 each) in years 1 and 2 of the proposed award period. These meetings will enable the Network to assemble (a) their designs for user kits, protocols, and suggested instrument lists, and (b) information resources for users. Network members have already accepted assignments of different resources they will develop, and CBOL's Program Assistant will be assigned to work with them. CBOL requests $20,000 in Year 1 and $40,000 in Year 2 for training workshops and technical assistance that will be provided by members of the Network to barcoding projects and regional networks, especially in developing countries. CBOL requests $25,000 to assemble several user kits that will be used during Network training workshops and will be loaned to barcoding projects in developing countries. These loaner kits will enable them to collect preliminary data that will strengthen their funding proposals to non-Sloan sources. CBOL will support development of teaching materials, the Network's website, the BOLI Case Study Portal, and other outreach materials from funds requested for Secretariat Office operations.
- **Data Analysis Working Group ($80,000).** CBOL requests support for two DAWG workshops and for a $5,000 prize for the best new visualization and display software for barcode data. In 2008, DAWG proposes a workshop to define user needs that will include statisticians, computer scientists, and data managers of the Leading Labs Network ($35,000). In 2009, a second workshop will bring together statisticians, computer scientists and population biologists for a presentation and critique of prototype software proposed for the BOLI Data Portal ($40,000). CBOL's Data Manager will provide extensive technical support for development of the BOLI Data Portal and CBOL's Secretariat Office will provide administrative support for DAWG's workshops.
- **Database Working Group ($80,000).** The DBWG plans to hold a workshop on barcode data and database interoperability in 2008 to bring together representatives of the major museum database systems and CBOL requests $25,000 for this meeting. The 2008 workshop will set the stage for a session on barcode data during the 2009 Encyclopedia of Life Biodiversity Informatics Conference. CBOL requests $10,000 for a planning meeting to prepare for the Conference and $25,000 to support CBOL's session at the Conference. Travel for consultations and small meetings with representatives of other

database initiatives will require an additional $10,000 per year. Significant staff support for DBWG will be provided by CBOL's Data Manager and Program Assistant.

- **Plant Working Group ($40,000).** CBOL requests $10,000 for meetings of the Plant Working Group's Steering Committee during Year 1 for consultation to finalize selection of the consensus regions for plant barcoding, and to develop their proposal to CBOL for approval of the selected regions. CBOL also requests $30,000 for partial support of an international workshop (estimated cost: $80,000) that will be held in late 2008 to announce the approved plant barcode region and to promote plant barcoding. Co-funding for the workshop will be sought from non-Sloan sources.

Central Secretariat Support ($272,000). The following requests are based on CBOL's expenditures during the current award period and the assumption that a Deputy Executive Secretary and Data Manager will be added to the Secretariat Staff.

- **Staff travel ($90,000).** Funds are requested to allow members of the Secretariat staff to attend CBOL meetings and for outreach. Support for attendance by CBOL staff have not been included in the requests for activities and meetings described above.
- **Training ($4,000).** The Smithsonian will provide intramural training on administrative systems for all new CBOL staff members. However, funding is requested for website maintenance courses for the Program Assistant and advanced informatics instruction for the Data Manager. This instruction is not available in-house at the Smithsonian. Extramural training in fundraising will also be needed for CBOL's Administrator.
- **Office equipment ($16,000).** Funds are requested for new computers and laptops for the two new staff members proposed here (Data Manager and Deputy Executive Secretary). In addition, two of CBOL's laptops are now more than two years old and should be replaced during the proposed award period.
- **Office supplies ($6,000)**
- **Printing and publication ($50,000).** CBOL proposes to produce printed and video resources for technical assistance to barcoders (developed and disseminated by the Leading Labs Network) and general outreach material. A significant portion of these costs will be related to the Third International Barcode Conference in 2009.
- **Online access rights for barcoding publications ($25,000).** Following the First International Barcode of Life Conference, a proceedings volume was published as a Royal Society Philosophical Transactions in Biology. CBOL purchased the rights to post the full content of the issue online. Funds are requested to do the same for proceedings volumes from the Second and Third International Conference, and for other CBOL-related publications.
- **Public Relations and Outreach ($25,000).** Funds are requested to hire a media consultant who will prepare press releases and manage press relations for the Third International Barcode Conference in 2009. In addition, funds are requested for graphic design of outreach material.
- **Voice Communication ($6,000)**
- **Website development and maintenance ($50,000).** All of CBOL's websites are designed and developed by a contractor. This will include the extensive effort needed to create the BOLI Data Portal and its connections to BOLD. Routine maintenance is conducted by members of the Secretariat staff.

Review #1

Consortium for the Barcode of Life : Support for Consortium Activities and Secretariat Office

Submitted by : Smithsonian Institution on behalf of **Scott E. Miller Ph.D.**

I strongly believe the Consortium for the Barcode of Life merits the supports of the Sloane Foundation for several reasons :

a) CBOL has brought together the interests of many biologists in different disciplinary fields in this project.
b) It has established clear objectives in a mega project for the bar-coding of thousands of species worldwide.
c) The Consortium has mobilized the interest of governments and agencies for a project that complements capacities and infrastructure between centers and promotes capacity building among the less developed.
d) It has helped the dissemination of molecular tools and protocols among taxonomists solving questions about species identification and clearing the path for its technological use in the future.
e) In our particular experience at the level of government organizations but also private donors in Argentina , the participation in CBOL was crucial in the decision to allocate funds to co-finance the local projects and its insertion in the CBOL initiative .

Regarding the feasibility of the project , I believe the project is highly feasible. Considering the Proposed Program of Work and Deliverables for 2008-2010 , I consider that the goals proposed are going to be fulfilled at a high rate. The barcode approach to taxonomy and biodiversity research and the use of information technology constitute a real impulse to taxonomy, promoting them almost to a stage of a “frontier science” and surely able to address more directly the concerns on the environment. For these reasons , I believe that many research groups will join the projects in different countries assuring the achievements of the goals.

Concerning the characters of the Goals , I consider that they are ambitious but realistic at the same time. The goals are proposed on the basis of a proven articulated work between the different levels of the CBOL structure, between central facilities and local projects , and through fluent dialog between committees representing historical discrepancies or methodologies. The goals are also proposed on assured cooperation between organizations as demonstrated in every single meeting organized by CBOL.

Regarding the plans to achieve the goals , they have proved to be an effective strategy so far. CBOL has been able to achieve an interesting part of the goals proposed and I consider they were particularly successful in covering the expectations of different groups and agencies sometime with their own different strategies.

I believe that the teams and networks of people meet two conditions that are crucial when we think of paradigmatic changes in science. On one side they are internationally recognized scientists and program managers of the most prestigious institutions worldwide. This is central

when an important condition for the success of the project is the ability to incorporate other taxonomists to this new technology. A second aspect is the multidisciplinary conformation of the teams. Some fields may develop independently, such as the establishment of new standard protocols for sample preservation or sample collection, or the development of new databases and imaging processing for the specimen. Other fields , on the other hand, are highly interdependent particularly those related to the development of new technology for real time and portable DNA sequencers. CBOL has proved to be an efficient facilitator for the dialog between these teams.

Regarding the budget I consider it sufficient. CBOL initiative actually help allocate much larger funds in direct and indirect contributions from other agencies and other governments to campaigns , central and local labs , information systems and meetings. Taking this into account , a professional management is crucial for the success of such initiative. The salaries contemplated in the budget cover that need. The funds allocated to meetings are sufficient and, considering the outcome, they are cost effective. As for the funds allocated to the campaigns and projects, they have to be considered as “flagship” projects that generally promote the allocation of direct or contributions or even in kind contribution by other institutions and agencies. This was our particular experience with CBOL projects in Argentina.

For all these reasons I strongly support the funding for this proposal

Review #2

Brief review on the proposal, "Consortium for the Barcode of Life: Support for Consortium Activities and Secretariat Office"

General Comments

This proposal is based on the substantive achievement of the preceding project, Barcode of Life Initiative. Further successful accumulation of data for cytochrome c oxidase I (COI) sequences and possible applications of the data to rapid species identification, species speciation and phylogenetics will be carried out with the clustered projects, which are all very attractive challenge. Such challenge will create synergy in taxonomy and other biological sciences and will contribute to various sectors including quarantine, environmental monitoring, disease control and others.

Clear setting of the goals by 2010 seems to ensure further progress of barcoding and its use in wide range of sciences and applications. Which also contributes to reduce "taxonomic impediments" in the process of implementation of the programmes under the Convention on Biological Diversity.

Amongst numbers of "omics" projects, barcoding has a unique position that supports pure scientific research by providing large volume of sequence data, and at the same time, assists many of practical technology developments to draw a global picture of biodiversity.

Large projects, however, commonly face the obstacles in the integration of data, which is collected and managed in distributed institutions. Diverse requirements of data analysis and gaps of understanding of the projects between the participating institutions are sometimes hinder in the project. The proposed consortium is designed carefully to overcome these by providing standards, tools, and communication opportunity with current leading organizations in taxonomy, bioinformatics and others.

To further accelerate the barcoding and to facilitate broader understanding of biodiversity it is foreseen that Consortium of Barcode of Life can take very important role. In addition, this project may strongly assist the implementation of the CBD by providing opportunities for biodiversity rich developing countries to collaborate with experts in major museums and to help filling the gaps of data and capacity in biodiversity research.

Strength of this proposal

- Achievements shown in the Barcode of Life Project and continuing participation of the experts
- Development of data standards and tools to enable global data integration
- World wide coverage of participants including the laboratories locating in developing countries
- Development of analytical tools and provision of them to the public
- Strong linkage with the major museums and leading organizations in bioinformatics
- Opportunities of capacity-building for partners in developing countries
- Proposal writing workshop to sustain the project for longer term
- Demonstration projects that prove the usefulness of barcode

- Actual co-funding obtained from varieties of donors

Potent weakness of this project

- In the experiences from 16SrDNA sequences for bacteria, secondary and tertiary structure of the sequences are significantly meaningful to distinguish taxa. However, short COI(x) sequence has limited potential to apply to wider varieties of taxa.
- Identifying barcode region in fungi may take sometime
- Those organisms which do not carry mitochondria cannot be subjected to barcoding. Such limit of application of barcoding is not clearly stated.
- With above reason, "All-taxon barcode inventory" cannot be of all-taxon, in theory.
- Access to the specimen and shipping across the boundary is strictly regulated in some countries listed in Appendix 6.

Suggestions

Although the accomplishment of Barcode of Life project is outstanding, objective analysis and description on the rational of applying barcode to wide varieties of taxa is necessary. Clear indication about the limit of barcode application and specific targeting of organisms to incorporate in this project will bring substantive products in time.

Designing analytical tools need to be described in more details. Currently, the existing tools are mostly GIS based visualization tools. Statistical treatment on the data prior to throwing into the visualization process seems to improve the accuracy of species distribution prediction, which is highly expected by environment protection and pest control sectors.

Access to the specimen in some developing countries needs appropriate communication and reasonable measure to bring benefits for the participating countries. If this project has a plan to deal with Access and Benefit Sharing which is one of the mandates under the CBD, include some text on such into the supplement. Inviting Swiss Academy of Science and World Federation for Culture Collections to the workshop would be useful to collate their lessons learned on this regard.

Proposal writing workshop is a key to make barcording project sustainable in developing countries. Concerning mutual benefit in science and technology on biodiversity, strong support for the proposal writing workshop may significantly improve the national and international politics on biodiversity research. Allocation of adequate budget for this should meet to the CBD decision of the Conference of the Parties VIII/3 paragraph 15, which states, "to convene, with the support of relevant organizations and donors, a project development seminar…and to explore potential benefits of developing new, and enhancing existing, regional or global projects to address common taxonomic needs that have already been identified"

Submission date: 25 February 2008

Review #3

Review of "Consortium for the Barcode of Life: Support for Consortium Activities and Secretariat Office"

Does CBOL merit continued support?

CBOL has filled an important organising role to develop and promote DNA barcoding around the world and across the taxonomic spectrum. I am certain that DNA barcoding (especially in "difficult" taxa) would not be as far along as it is now without CBOL's focused working group strategy. There have been some frustrations along the way (e.g. resistance to the concept of barcoding and difficulty identifying a plant barcode) and some major challenges still need to be addressed. Thus CBOL's work is not yet done.

The application under review successfully identifies several of these challenges and, fittingly, proposes to devote resources to addressing them (e.g., establishing DNA barcoding as a standard method in taxonomy). However, there are also some challenges that are not given the weight nor the resources that are warranted (e.g. continued efforts to establish and develop DNA barcoding in plants and other recalcitrant taxa). A failure to adequately address these challenges poses a risk to the overall success of CBOL's objectives.

Thus in the more detailed portion of the review below, I try to highlight some areas that deserve more attention (and funding) for 2008-2010.

Ways in which the likelihood of success or the quality of the efforts might be lifted:

As my research area is plant barcoding, I would like to briefly turn my attention specifically to the plant section of the proposal (p. 17, "2. Promoting plant barcoding"). While I am largely optimistic about plant barcoding and specifically about the prospects of identifying a region or regions to use as a universal (land) plant barcode, I am concerned that the proposal brushes over some important remaining challenges.

For example, the proposal asserts, "During 2006-7, research teams identified several viable barcode strategies for vascular plants," and yet while I believe these advances represent a good starting point, experience tells me that the plant barcoding community at large has not yet been convinced that these strategies are indeed "viable".

While I was slightly reassured by the follow-up statements ("CBOL's Plant Working Group will continue to compile and analyze data about plant barcode regions to encourage convergent and consistent practice among practitioners" and "the plant community will hold a conference in late 2008 to review progress and to plan and promote additional plant barcoding projects"), I note that this proposal allocates less than one year's worth of funding to the Plant Working Group. I address this below under the "budget" question.

This oversight is compounded by the similarly premature stoppage of Data Analysis Working Group funding at the end of 2009. It is widely understood that plants will demand a multi-locus

DNA barcode and one of the main candidates (*trnH-psbA)* is known to have complex evolution and profound level of length variation. These realities raise data analysis questions that have not yet been adequately addressed. Even in an optimisitic scenario in which a plant barcode is "decided" by the end of 2009, a significant amount of data analysis work will still need to be carried out to address the plant barcode analysis situation adequately. Again, more on this below in answer to the "budget" question.

Are the goals appropriately ambitious? Is the strategy to achieve the goals sound?

In addition to those recommendations noted elsewhere in this review, I also feel that not enough attention is being paid to the data that are affiliated with DNA. For example, CBOL's Database Working Group (DBWG) proposes two workshops and follow-on efforts to strengthen and broaden the links between BARCODE records and databases of (1) voucher specimens and (2) species names. However, it is my understanding from curators' anecdotes that more work needs to be done to create the physical space, the institutional will, and not least a favorable funding environment, to deposit voucher specimens for all of these millions of expected barcodes that will be rolling in in the near future.

Furthermore, based on this proposal the DBWG will not be addressing the need for (not to mention enormous potential in) linking barcode databases with other DNA data. For example, to identify hybrid plants, a system that takes the nuclear genome into account will need to be developed. While such a system may not need to be called "barcode" it will be needed nevertheless as supplementary data to achieve a specific outcome. Thus the working groups, as well as thet BoLD team, should consider more carefully the integration of "non-barcode" DNA data for use in both species-identification pipelines (to facilitate tricky identifications) and also to create an integrated resource for more in-depth studies utilising barcode data as part of a larger whole of molecular information.

Are the teams and networks of people capable of carrying out the work.

Yes, I believe so.

Is the budget sufficient and intelligently allocated?

While I am indeed optimistic that the Plant Working Group (PWG) will reach a workable solution for standardised land plant barcoding, I am not convinced that this is so close at hand as to warrant less than one year of funding (less than any of the other working groups!). Based on the lack of consensus at the PWG meeting in Taiwan, and moreover the absence of any unifying publications since that time (including the recent paper from Lahaye et al. in PNAS), it is folly to think that a truly workable decision on the identity of the plant barcoding loci will be reached by the end of calendar year 2008.

Thus I recommend that the PWG be resourced at least through the end of calendar year 2009. As a corrolary to this (as mentioned above), the Data Analysis Working Group should be funded through the end of the grant to address the plant-specific data analysis issues that are likely to emerge throughout 2009.

In summary…

CBOL's work is not yet done, and I would advise that this application under review should be funded with the proviso that the risks I identify above be considered very carfully before the budget is finalised.

Review #4

The application consists of a report on achievements for the years 2006-2008, descriptions of goals and deliverables for 2010, and a proposed budget.

In general, CBOL has had a strong and globally felt impact on the attitude of biologists towards barcoding. The fact that CBOL exists has encouraged many institutes to start with barcoding projects, to test and improve protocols, and to reconsider the current way of inventorying and assessing biodiversity. From the point of view of future users and of those who are currently trying to bring about a paradigm change it is extremely important to keep CBOL alive and in a productive state.

Achievements: It is true that opposition to barcoding is crumbling, however, there are still many taxonomists that fear they will lose their jobs, because they do not understand that barcoding can have the opposite effect: the discovery of a diversity that can only be understood if specialists for species do basic research at species-level. CBOL has catalyzed the international cooperation of institutes. Now it is important to keep the community together, it seems that divergent initiatives (ECBOL, iBOL etc) need a roof to ensure cooperation and synergy.

The international conference organized by CBOL contributed enormously to the popularity of barcoding in developed countries as well as in less developed countries. The interest to contribute to inventories helps to overcome barriers to field work in the tropics.

The number of barcoded species is growing rapidly. The goals defined for 2008 could not be reached in all cases, but the order of magnitude has not been missed and the general concept proved to be realistic. The many cases of co-funding prove that barcoding is of high interest.

Goals for 2010: In general, the goals are realistic and important for the scientific community. To link BOLD, Genbank and data bases with species information would be a major success and at the same time a prerequisite for a real acceleration of monitoring.

Part of the goals depend on the success of third parties, who have to raise funds for their projects. CBOL can offer supporting arguments and protocols.

Recommendations: CBOL could play a more active role in the development and distribution of software. This is on the list of desiderata in the present application and it deserves support to avoid the impression that CBOL is only a PR institution. It would also be helpful to offer more well written arguments and descriptions of case studies that can be used for political work. The web page has been prepared for this purpose, but the contents are still meager.

An important strategy that is still missing is "reverse taxonomy barcoding". This theme is provocative for traditionalists, but it is unavoidable to start doing this. Reverse taxonomy barcoding means that we start with barcoding of unidentified organisms. Since probably 80-90% of tropical insects are still unnamed, we can not wait for formal descriptions. We need the following workflow: sorting of samples to morphospecies, barcoding, imaging and vouchering of specimens, documenting the link between barcode and specimens, and publication of these data. If years later some taxonomist publishes a formal description, the Linnean name can be added. The Linnean name has the function of a global unique identifier. But the barcode has the same function and is available much faster. Thus ecological studies at species level are possible *now*, and not after years of taxonomical work.

Review # 5

Review of: Smithsonian Institution proposal to advance the efforts of the Consortium for the Barcode of Life.

First, the proposal needs to distinguish between “barcoding” and CBOL “Barcoding”. That is, the idea of “barcoding”—having diagnostic DNA sequence data—is fine. The CBOL “Barcoding” idea that COI is going to be THE answer is not necessarily fine. Clearly there is much value in getting data from one or a few genes across many taxa, but it is not clear that one gene will be the optimal gene for “barcoding”. Rather, we should think this through a bit better, because *we are unlikely to confuse birds with fishes, or sea urchins with earthworms*. As such, it is not critical that the same gene(s) be used between groups. Within major groups, however, ideal genes can be chosen empirically.

Second, many of the claims the proposal makes about the utility of barcoding to address evolutionary problems are unnecessary hype and reduce the credibility of the proposal. For example:

> “A standardized database of this scope opens research opportunities on how selection acts on homologous gene sequences, or how species’ histories correlate with the histories of their community assemblages. Using barcode data, we can now explore the patterns and limits to variation across a wide range of taxa in a formal, comparative way. “

This is very doubtful. The gene segment is too short to be of much utility in, for example, constructing trees connecting higher taxa; further, variability in mitochondrial sequences is tied to the length of the sequence as much as to any intrinsic variability along one particular gene that might be symptomatic of overall variability (isozymes are probably the best measure in this regard). Anyone interested in studying such variability would not use a little snip of COI. They require rigorous phylogenetic frameworks based on several genes. The research questions posed here are complex and are being addressed with far more appropriate data sets, which the proposal should, but does not acknowledge.

Another example is the proposal’s characterization of phylogenetics. It is not limited to "...sequencing tens of genes (or ten thousands of base-pairs) from ‘exemplar species’ that represent major branches of evolution within a group." The unfortunate insinuation is that molecular systematists have not been looking at species/population level relationships for some time.

A third example of hype is the claim that, "Substantial studies began to appear, demonstrating the effectiveness of barcoding in a few taxonomic groups (e.g., Hebert et al., 2004a on birds;...". Unfortunately, the resulting publications claiming to "discover" new species are not respected in the ornithological community, whose systematists had already identified structure within those species.

Hype, in turn, leads to a serious a PR problem for CBOL. In the abstract, the proposal claims that "Based on the accumulation of positive results and refinement of analytical approaches, opposition to barcoding among taxonomists has essentially dissipated." Among ornithologists, ichthyologists, entomologists and many other taxonomists this is simply not true. COI does not work for ALL organisms, so the claim for universality is overstated. Indeed, COI might be one of the least informative genes.Major biocollections institutions are still hesitant about CBOL precisely because of questions about intellectual honesty, overstated claims, and scientific rigor and utility. Frankly, many institutions have been alienated by what they perceive as CBOL's less than candid public relations and tactics, which is unfortunate, because 'barcoding' is an extremely worthwhile endeavor (see below).

Another example of this PR misstep is the statement further down that "ABBI also proposes to hold a meeting of approximately 20 curators of the world's largest collections of frozen bird tissue to enlist their participation." Such a meeting was already held and ABBI apparently did not listen to any of the recommendations.
The strategy of ABBI might be more successful, both operationally and politically, if small grants were made to researchers and students working on various taxonomic groups, which might be more productive than the centralized, top-down approach—a working barcoding "wikipedia".

Finally, the proposal pays insufficient attention to vouchering of the barcoded material. The proposal requires much more detail on crosslinking barcode data with specimen/voucher data in archival and accessible databases. The proposal cites www.biorepositories.org , which is apparently in collaboration with GBIF, but does not mention the LSID initiatives, and really use dated means of referring to repositories. Established community-networked and NSF-supported voucher databases (e.g., FishNet, MaNIS, HerpNet, ORNIS) are cited only vaguely and tangentially, It is not evident that the critical value of and networked IT for vouchered data is recognized.

All that said, and on the positive side, is barcoding worthwhile? Yes! But the proposal should be unabashedly forthright that barcoding (and CBOL) is a tool and mechanism for species ID (if it works), not a tool to do genomic evolutionary research. That does not mean that barcoding is unworthy, just that we should be focused on and honest about its true limits and utility, both for scientific and political reasons.

Also on the positive side, the taxa proposed for barcoding focus are appropriate. Skeeters and fruit flies are IDEAL groups, and some of the others would be excellent. The focus on birds (and some other groups) has, frankly been puzzling, because the need for a barcode ID ability for those groups is pretty minimal. But the need for ID enabling for economically/medically important groups is very high.

In sum, the proposal as conceived and written is unnecessarily overstated and less than completely intellectually honest about the benefits and shortcomings of barcoding. This brings into question not whether "the teams and networks of people [are] capable of carrying out the work" but whether their strategies fit the requisite focus (and budgets) that the barcoding initiative should maintain.

My recommendation is to decline this proposal and demand one that will advance barcoding to its best, most effective and focused utility, and engage a willing community in a bottom-up networked manner.

Consortium for the Barcode Of Life (CBOL)
Response to Reviews, March 2008

The main comments provided by five reviewers reflect both CBOL's success and the challenges it faces. In almost all cases, the reviewers' comments are accurate, helpful, and aligned with activities that CBOL is planning but could not describe within the length limits of the proposal. Reviewers' comments address three important areas, discussed below.

1. Taxonomic coverage. Barcoding began with well-known macro- and megafaunal groups like birds, fish, and Lepidoptera, but it is expanding into more difficult, less well known taxonomic groups like fungi, protists and nematodes. Reviewer 2 pointed out that by relying entirely on COI as a barcoding region, species identification for some groups would be impossible and All-Taxa Biodiversity Inventories couldn't be done. Reviewer 5 appears to believe (incorrectly) that DNA barcoding is based on the belief that COI is a universal barcode region that works in all groups. In fact, CBOL agrees completely with these two reviewers that COI is not an effective barcode region in all groups. For that reason CBOL has established a protocol for proposing and approving optimal non-COI barcode regions in groups where they are needed. Reviewer 2 pointed out that selecting the barcode region for fungi may be a long process, and in anticipation of that challenge CBOL held in May 2007 the first in a series of meetings devoted to this issue. CBOL also intends to support a Steering Committee for a Fungal Barcoding Initiative that will work toward selection of the fungal barcode region.

Reviewer 3 focused on the Plant Working Group and questioned the feasibility of selecting the plant barcode region by the end of 2008. This reviewer suggested extending the period of support (and presumably the funding level) through 2009. In planning its program of work, the Plant Working Group's new chair, Peter Hollingsworth, confirmed that the research teams working on the plant barcode problem were willing to share their data for a collaborative

analysis. Based on the number of gene regions and samples already analyzed, he concluded that little additional sequencing would be needed. CBOL has already provided matching funds for a post-doctoral fellow working with Dr. Holingsworth who will conduct the data analysis. This information was not in the proposal so Reviewer 3 was unaware that there is additional support already in place for this project. CBOL is fully committed to identifying the optimal plant barcode region and will work with the chair of the Plant Working Group to find additional funds, if they are needed.

Reviewer 4 urged CBOL to promote the use of barcoding for uncovering new species in poorly explored groups. The 'reverse taxonomy' endorsed by this reviewer would start by sorting specimens according to barcode data and then work toward formal taxonomic description of new species. The goal of adopting this approach is to accelerate exploration and description of poorly known groups. CBOL supports this goal strongly and is an active partner with major initiatives such as the Encyclopedia of Life and the European Distributed Institute of Taxonomy.

'Mainstream' barcoding proceeds in the other direction, starting with specimens sorted into known species groups on the basis of morphology and then gathering barcode data that either corroborate, refine, or refute these morphospecies clusters. The 'reverse taxonomy' approach has been criticized vocally by many taxonomists who reject the idea that molecular data are somehow intrinsically better than morphological characters, and CBOL has agreed. However, the 'barcode-first' procedure makes more sense for those taxonomic groups with few diagnostic morphological features such as nematodes, fungi and protists. CBOL organized and held a 'Banbury 3' conference on the use of barcode data in studies of evolutionary processes and the participants endorsed the 'barcode-first' approach. Participants concluded that in those cases where morphological features are lacking, nuclear gene sequences should be used to test

the reliability of specimen clusters and species boundaries based on barcode data. CBOL will be convening a small workshop with participants from the Banbury 3 conference with the goal of developing project plans and proposals to fund this type of 'reverse taxonomy' project.

2. International participation. From its origin at the University of Guelph and CBOL's launch at the Smithsonian, barcoding is becoming increasingly international and engaged with biodiversity studies in developing countries. Reviewer 1 noted specifically that CBOL had helped catalyze Argentina's participation and investment in barcoding, and other reviewers (especially Reviewer 2) noted CBOL's efforts to engage developing countries. Reviewer 4 expressed the need for outreach documents that will explain barcoding to government officials in developing countries. Participants in most of CBOL's outreach meetings in developing regions have expressed this same desire to provide clear explanations of barcoding to government officials. In response to these requests, CBOL is now completing a draft outreach brochure that will be circulated for comment. CBOL plans to revise, print, and distribute the brochure at the upcoming Conference of the Parties to the Convention on Biological Diversity (19-30 May in Bonn, Germany). Reviewer 2 recommended contacting the Swiss Academy of Sciences (a leading proponent of basic biodiversity research in developing countries) and CBOL recently partnered with the Swiss Academy in organizing a roundtable discussion at a recent CBD meeting.

Reviewer 5 asked why the All Birds Barcoding Initiative is proposing a workshop of the curators of 20 leading collections. This reviewer felt that the original ABBI inaugural meeting at Harvard in September 2005 should have been sufficient. In fact, it was the participants in the Harvard ABBI meeting that called for the curators' meeting, for the purpose of discussing how access to frozen tissue collections in museums should be managed. Reviewer 5 went on to

criticize the ABBI's leadership for not having implemented a bottom-up strategy of making small grants to researchers and students for barcoding projects on specific taxonomic groups. Adopting this strategy would have violated the terms of support from the Sloan Foundation, which state that CBOL should play a catalytic role in organizing and launching activities, and should not re-grant Sloan funds in response to bottom-up proposals.

3. Barcode data analysis. The core use of barcoding is for specimen identification; its standard application uses clustering software for data analysis and display. The volume and diversity of barcode data have increased rapidly, creating demand for more sophisticated tools for data analysis and visualization.

Reviewers 2, 3 and 4 all strongly endorsed the need for more sophisticated analytical software designed specifically for barcode data and species identification. Reviewer 2 asked for greater detail concerning the software tools that are being developed for data analysis and visualization, but space was not available within the length limits of the proposal. There were about 10 new analytical software systems presented and/or demonstrated at the September 2007 barcode conference in Taipei and they encompassed a range of statistical and computational approaches. The next step in CBOL's work program will be to have the developers benchmark their software on a few standard datasets so users can compare their performance and results.

Reviewer 3 asked why the program of work for the Data Analysis Working Group stops with the ***e-Biosphere 09*** International Biodiversity Informatics Conference in June 2009. This conference will be the major milestone in the Working Group's efforts, and it hopes to unveil the completed suite of software capabilities at that time. Members of the Working Group plan to write scientific papers based on their conference presentations and this will occupy their time immediately before and after the conference. CBOL will organize a Working Group meeting at

the ***e-Biosphere 09*** conference during which participants can discuss next steps. At this point, none of the members of the Data Analysis Working Group could anticipate the research priorities beyond the conference.

4. The relationship of barcode data to other fields of biology The rising tide of barcode data has also stimulated interest in exploring how the corpus of barcode data can be used in cognate fields of research. Researchers working on evolutionary processes below the species level (population biology, speciation processes) and above the species level (primarily Tree of Life projects) are now exploring how barcode data might fit into their research programs. CBOL agrees completely with Reviewer 5 who stated emphatically that the single barcode gene, by itself, will be insufficient for analysis of deep phylogenetic relationships or selective processes. This reviewer argued that barcoding should be limited to species identification, and CBOL agrees that this is its core mission. The proposal stated that barcode data could be useful for exploration of patterns, and there was no intent to imply that barcode data were sufficient for confirmation of patterns or their causal explanations. CBOL agrees that a full analysis will require information from additional gene regions. Nevertheless, the broad and dense sampling of taxa being done by barcoders creates the opportunity for exploratory research. With that goal in mind, CBOL organized and held workshops with macroevolutionary researchers involved in the Assembling the Tree of Life program, and microevolutionary researchers from population biology. CBOL plans to convene a proposal-writing effort with selected participants from those two workshops, with the goal of launching synergistic research projects in which barcode data play an important role and is supplemented by nuclear markers on an as-needed basis.