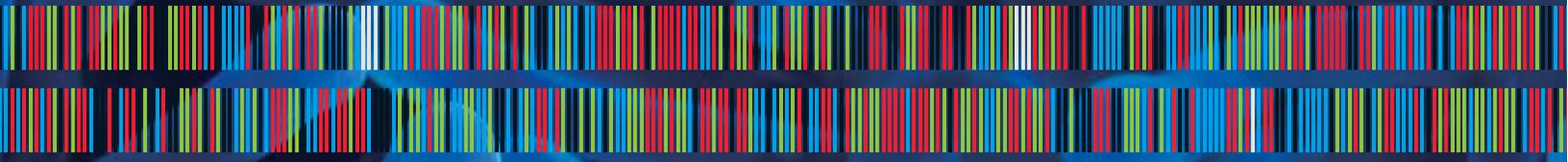




**BARCODING** *life*  
HIGHLIGHTS 2011

STICHODACTYLA  
ANEMONE



AMPHIPRION PERCULA  
ORANGE CLOWNFISH

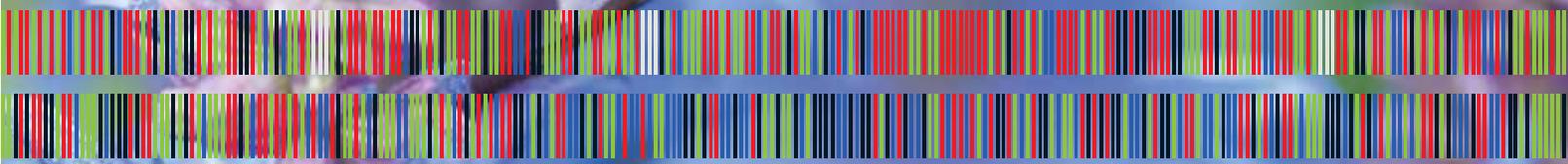
**BUILDING THE DNA BARCODE SYSTEM FOR  
THE WORLD'S ANIMALS, PLANTS, AND FUNGI**



Understanding life on Earth—what lives where, how life interacts, and how life is changing—begins with identifying species. DNA barcodes—short DNA sequences from a uniform location on the genome—distinguish animal, plant, and fungal species.

A simple, standardized identification system, DNA barcoding assists researching, monitoring, and appreciating Earth's changing biodiversity.

*XYLOCOPA VIRGINICA*  
EASTERN CARPENTER BEE



*SALVIA OFFICINALIS*  
GARDEN SAGE

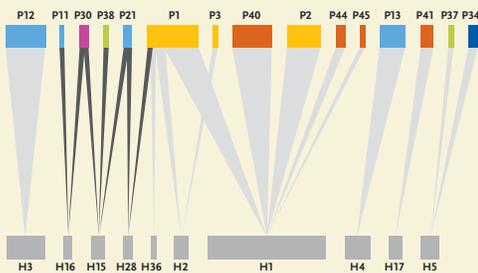


# BARCODE-BASED DISCOVERIES



**Cataloguing hidden diversity.** Some groups with simple external features may seem lacking in diversity, but DNA tells another story. In red algae (Phylum Rhodophyta), common seaweeds around the world, COI barcodes point to dozens of unrecognized species hidden among the 1,200 analyzed so far. The widespread and invasive common earthworm, *Lumbricus terrestris*, named by Linnaeus and studied by Darwin, is revealed by barcoding to be two distinct species, previously unrecognized due to overlapping variation in size and shape.

(GW SAUNDERS ET AL, BOTANY 2010; SW JAMES ET AL, PLOS ONE 2011)



**Targeting pests naturally.** Barcoding speeds the search for natural insect predators by accurately identifying potential biocontrol agents, usually tiny, otherwise-hard-to-identify parasitic wasps or flies, including those still developing inside larvae. This approach revealed unexpected parasitic insect diversity for spruce budworm moth (*Choristoneura fumiferana*), the most economically destructive insect in North America. Parasitic insects, or parasitoids, are also key components of natural ecosystems. In New Guinea, barcodes identified 93 hitherto unknown connections among lepidopteran hosts and their multiple parasitoids.

(MA SMITH ET AL PLOS ONE; HRCEK ET AL, MOL ECOL RES 2011)



**Safeguarding public health.** In East Africa, researchers analyzed blood meals of tsetse flies (*Glossina swynnertoni*), the vector of trypanosomiasis, documenting geographic differences in animal hosts, helping inform local control strategies.

(CN MUTURI ET AL, PLOS ONE 2011)



LEFT: LITTLE BROWN BAT (*MYOTIS LUCIFUGUS*)  
RIGHT: INSECT PARTS IN BAT GUANO

**Finding facts from fragments.** Gut contents and feces reveal hidden predator-prey relationships and help trace the network of interactions that make up a food web. Researchers in Africa and Canada used DNA sequences from bat guano to reveal unanticipated diversity of prey and roosts specializing in different hunting grounds.

(BOHMANN ET AL, PLOS ONE 2011; EL CLARE ET AL, MOL ECOL 2011;  
PHOTOS: EL CLARE, UNIVERSITY OF BRISTOL)



**Rediscovering lost species.** The Barcoding Fauna Bavarica project (Germany) turned up several rarely-seen species, including the predatory water beetle *Graphoderus bilineatus*, thought locally extinct for 26 years.

(A HAUSMANN, BARCODING FAUNA BAVARICA)



**Untangling names.** Every scientific name is based on a particular *type specimen* archived in a museum or herbarium, which serves as a permanent reference for the species name. When the type specimen degrades over time or is damaged, diagnostic features may be lost. This makes difficult classifying similar-looking specimens, sometimes resulting in misidentifications or multiple names assigned to the same species. Researchers are barcoding type specimens, like the moth shown above, anchoring the species name to a DNA code, widely-accessible even when morphologic features of the defining original are lost.

(PDN HEBERT, BIODIVERSITY INSTITUTE OF ONTARIO;  
PHOTO: STUART HUMPHREYS, AUSTRALIAN MUSEUM)



**Discovering diagnostic differences.** DNA barcodes sort specimens into unequivocal categories, helping experts discover distinguishing features. This approach prompted recognition of a new European liverwort, *Herbertus norenus*, from specimens previously misclassified under two other names. Correcting classifications enabled taxonomists to discern diagnostic features for *H. norenus* and its once confusing close relatives, strengthening species descriptions for the entire group.

(D BELL ET AL, MOL ECOL RES 2011)

# HELPING SOCIETY AND SCIENCE



**Protecting consumers.** In the past year, barcode surveys in Canada, Ireland, Spain, United Kingdom, and United States documented 10 – 50 percent mislabeling of fish products, including those sold at prominent restaurants and stores. In all studies, inaccuracies involved substitution with less expensive or less desirable species. Mislabelings include selling imported, farmed fish as locally caught, and selling species at risk of decline as sustainably harvested fish. Responding to calls for improved monitoring, the US Food and Drug Administration (FDA) formally adopted DNA barcoding for seafood identification in October 2011.

(CONSUMER REPORTS, DECEMBER 2011; BOSTON GLOBE, OCTOBER 23, 2011; R HANNER ET AL, PLOS ONE 2011; D MILLER ET AL, FISH FISHERIES 2011; OCEANA, REPORT MAY 25, 2011; PEW CENTER FOR PUBLIC INTEGRITY, REPORT JULY 12, 2011; WWW.FDA.GOV/FOOD/FOODSAFETY/PRODUCT-SPECIFICINFORMATION/SEAFOOD/DNASPECIATION)



**Engaging young minds.** At Coastal Marine Biolabs, Ventura, California, high school students are collecting reference barcodes for marine life in the kelp forest and near-shore areas in a federally-funded project. In New York City, high school students found 35 percent of commercial herbal teas contained unlisted ingredients, ranging from chamomile to common weeds. The TeaBOL students co-authored an article in Nature's *Scientific Reports* in June 2011, sparking global news coverage and inquiries from tea manufacturers.

(R IMONDI, COASTAL MARINE BIOLABS (CMB); MY STOECKLE ET AL, SCIENTIFIC REP 2011; PHOTOS: CMB, COLD SPRING HARBOR LABORATORY)



**Helping threatened species.** Illegal fishing practices threaten sharks and rays (Class Elasmobranchii). Many species are protected by law, but enforcement of regulations rests on recognizing dried fins and other fragmentary specimens. The Pew Ocean Environment Group highlighted DNA barcoding as a “rapid, reliable, inexpensive method of identifying shark body parts in trade.” As of September 2011, researchers have barcoded nearly 9,000 specimens from over 500 elasmobranch species, establishing inextinguishable identifiers for 50 percent of the world's sharks and rays.

(PEW ENVIRONMENTAL GROUP OCEAN SCIENCE REPORT, MARCH 2010; D STEINKE, MARBOL)



**Exciting educators.** The TeaBOL student investigators helped inspire Cold Spring Harbor's Urban Barcode Project, a science competition open to all public and private school students in New York City, with \$10,000 prizes. Here teachers attend an Urban Barcode workshop at GenSpace, a community science laboratory in Brooklyn, New York.

(D MICKLOS, COLD SPRING HARBOR LABORATORY (CSHL); PHOTO: CSHL)



**Improving environmental monitoring.** Finding out what lives in the water is the most accurate way to measure the health of streams, rivers, lakes, wetlands and oceans. Traditional bioassessment with microscopes and morphologic keys often takes months and often identifies only to genus or family level. Barcoding of invertebrates in marine and freshwater samples is accelerating identifications and improving accuracy. The Southern California Coastal Water Research Project (SCCWRP) together with US Environmental Protection Agency, Stroud Water Research Center (SWRC), and Canadian Centre for DNA Barcoding, is developing standardized barcoding methods for bioassessment.

(B SWEENEY ET AL, J N AMER BENTHOL SOC 2011; PHOTOS: B SWEENEY, SWRC; P MILLER, SCCWRP)



**Inspiring artists.** A video installation on species and barcodes was chosen for “Unnamed,” an exhibition of unsung design. The exhibition, curated by the Chinese artist and political activist Ai Weiwei, was part of the Gwangju Design Biennale in South Korea in October 2011.

(NEW YORK TIMES, OCTOBER 2, 2011)

# BUILDING THE LIBRARY



**Collecting in collections.** Natural history museums and herbaria are organized hotspots of biodiversity, thanks to decades of expeditions and countless hours of curating. Demonstrating their enormous value, a team of researchers barcoded 28,000 moth and butterfly specimens in just ten weeks at CSIRO's Australian National Insect Collection (ANIC) in Canberra, representing about 65 percent of the country's 10,000 known species. Even though many were older than 20 years, over 80 percent of the ANIC specimens produced barcode records. In the past year, researchers at Smithsonian Institution's National Museum of Natural History (NMNH) in Washington, DC, have barcoded more than 3,000 frozen bird tissues, each backed up by a permanent voucher specimen like those shown above, from over 1,400 species, adding more than 1,000 new species to the global avian barcode library.

(PHOTOS: ANIC; C DOVE, NMNH)

## Making headway on hyperdiverse groups.

Many groups are too populous and too diverse for any specialist to know in detail. DNA barcodes provide the specialist and generalist alike with a standardized identification tool of unlimited capacity. Butterflies and moths (order Lepidoptera) are the largest well-analyzed group so far, with over 500,000 barcode records from from 60,000 named and provisional species, a large fraction of the world's 170,000 total. ([www.lepbarcoding.org](http://www.lepbarcoding.org); iBOL Working Group 1.9—Terrestrial Bio-Surveillance).

([WWW.LEPBARCODING.ORG](http://WWW.LEPBARCODING.ORG))



## Establishing accessible, permanent identifiers.

Translating specialist knowledge into the simple language of DNA helps share taxonomic expertise with a broad audience. Recording identifications in DNA may be particularly critical for the less charismatic groups with few taxonomic experts. Researchers recently barcoded 2,334 marine annelid worms at eight locations in the Atlantic, Arctic, and Pacific oceans ranging from tidal flats to ocean floor sediments at 60 meters—some of the incredible diversity is shown above. 145 named and 200 provisional marine annelid species are now firmly linked to barcodes.

(CM CARR ET AL, PLOS ONE 2011)



**Completing regional inventories.** For most applications, a regional barcode library answers the question “what organism is this?” Researchers recently completed a library that characterizes 1,264 of the 1,338 species (94 percent) of butterflies and large moths of Germany. Local agricultural pests and invasive species can now be identified by DNA and distinguished from non-harmful relatives. In Japan, botanists established a library of *rbcL* barcodes for 689 of the 783 local ferns and horsetails (94 percent), creating a naming tool that works for all life stages, including gametophyte forms often indistinguishable by appearance.

(A HAUSMANN ET AL, SPIXIANA 2011; A EBHARA ET AL, PLOS ONE 2010; PHOTOS: A HAUSMANN, JESMOND DENE).



**Spawning new expeditions.** A group of Argentine and Bolivian scientists is collecting Bolivian insect and bird specimens for traditional and barcode study. Many of these will become part of local biorepositories and the rapidly growing research infrastructure for barcoding. Springtime in South Africa launches the annual *Toyota Enviro Outreach* expedition—researchers with a fleet of specially equipped 4x4 vehicles head to remote biodiversity hotspots to gather specimens for DNA barcoding. The 2011 expedition collected fish, molluscs, insects, spiders, and plants in iSimangaliso Wetland Park, a 332,000 hectare World Heritage Site containing most of South Africa's remaining swamp forests.

(PHOTOS: P TUBARO, TOYOTA ENVIRO OUTREACH)

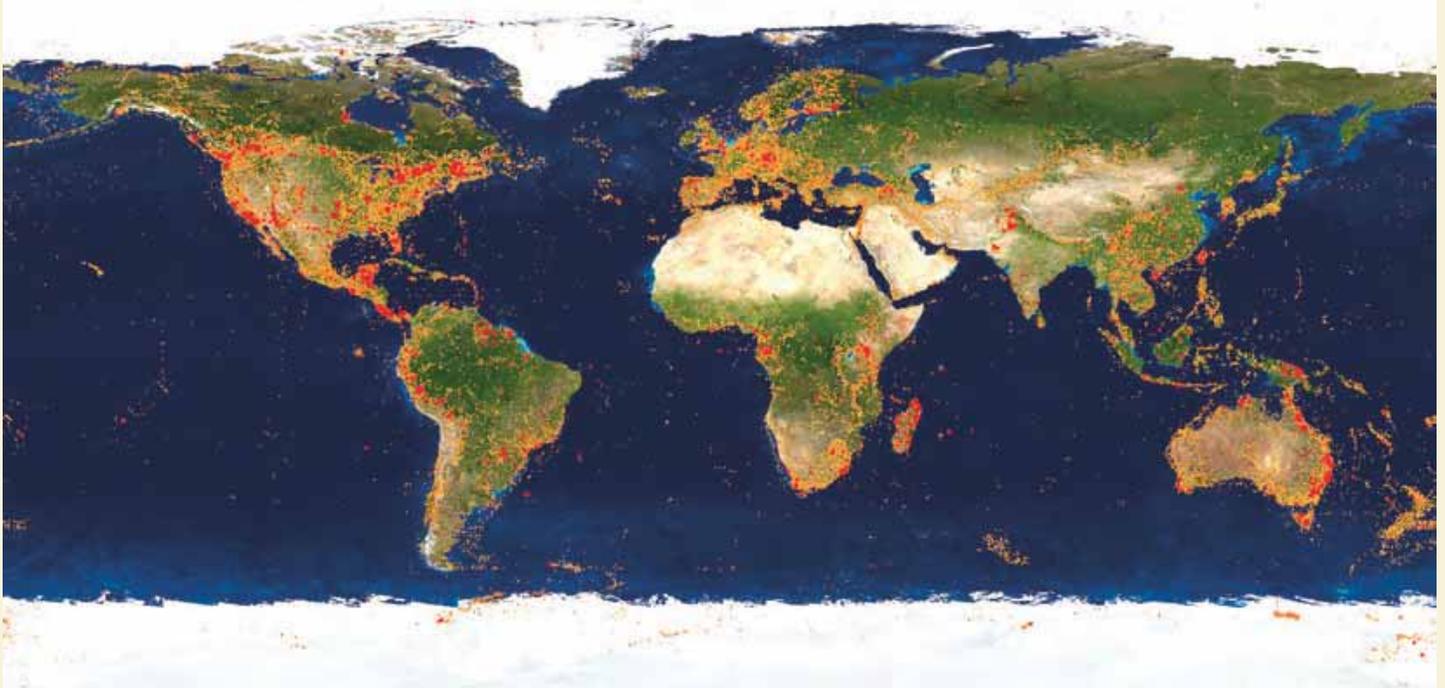


(LEFT: EIMERIA, A PATHOGENIC PROTIST  
RIGHT: AMINITA MUSCARIA, A FATAL FUNGUS)

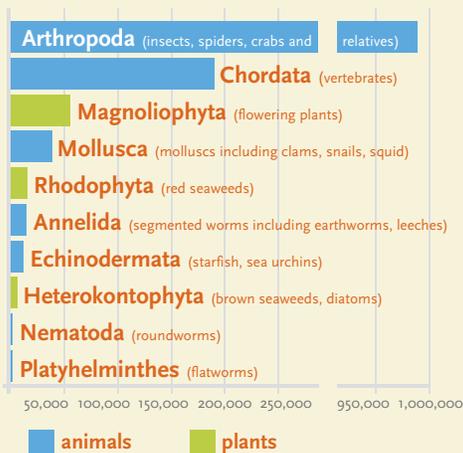
**Mapping two of the largest, darkest realms of biodiversity.** Protista (single-celled animals) and Fungi are comprised of many deeply divergent evolutionary lineages—for example, two fungi may relate more distantly than a fish to an insect. The communities of researchers that work on these phyla have identified a single gene region that promises to document the vast unstudied diversity, opening new research areas, ranging from rapid assessment of water quality to diagnosis of disease caused by indoor mold.

(BTM DENTINGER, PLOS ONE 2011; JD OGEDENGBE ET AL, INT J PARASITOL 2011; PHOTOS: M MAGGS, JD OGEDENGBE)

# THE BIODIVERSITY CHALLENGE

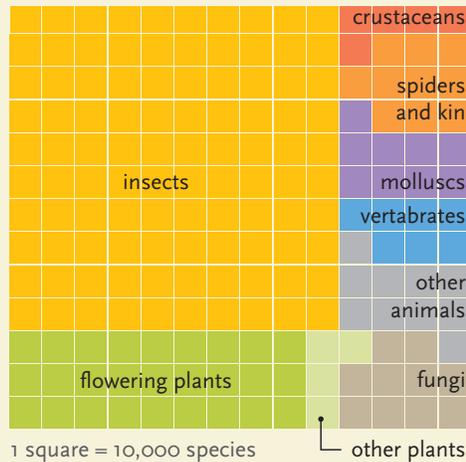


The global map shows the wide distribution of collection locations for the 1.3 million specimens representing 114 thousand known and 53 thousand provisional species recorded in Barcode of Life Data Systems (BOLD) as of September 2011. Red indicates the highest density of sampling and orange indicates lower density. (WWW.BOLDSYSTEMS.ORG)



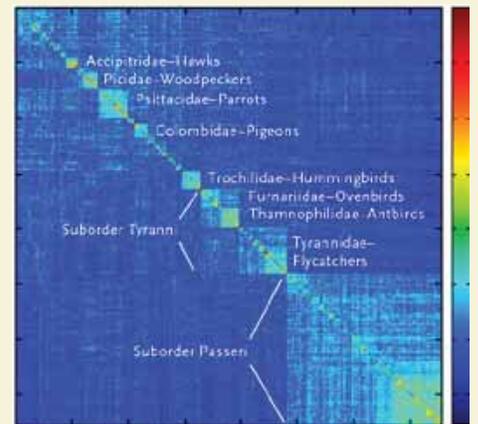
**Top Ten Phyla.** Number of barcoded specimens in Barcode of Life Data Systems (BOLD).

(WWW.BARCODINGLIFE.ORG)



**How big is the challenge?** About 1.9 million species of animals, plants, and fungi are known and about 167 thousand named or provisional species have been barcoded so far. The International Barcode of Life Project (iBOL) aims to expand the library to 500 thousand species, including most of those of established importance to society such as food sources, endangered and threatened species, disease vectors, and invasive species.

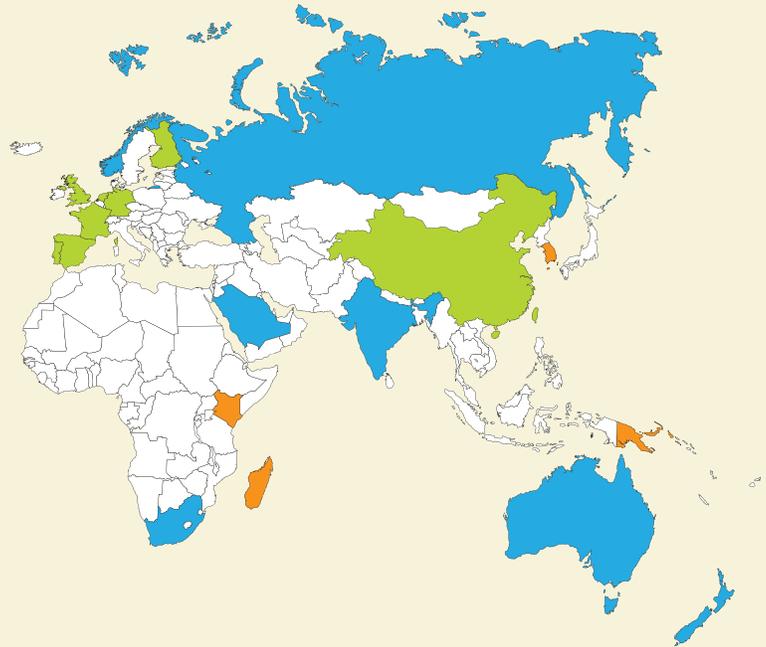
(ATLAS OF LIVING AUSTRALIA)



**Building a biodiversity macroscope.** Just as telescopes help see the Very Far and microscopes the Very Small, barcoding can be a *macroscope* that helps see the Very Large—patterns in the enormous diversity of life on Earth. The ‘Klee diagram’ above condenses 3,000 barcodes from 1,400 bird species into a ‘heat map.’ The lighter blocks along the diagonal indicate groups of species with similar barcodes, and correspond to evolutionary divisions that biologists have recognized through 250 years of study. Focusing the barcoding macroscope on the growing Library promises to reveal structural patterns across the diversity of animal, plant, and fungal life.

(SIROVICH ET AL, PLOS ONE 2010; FIGURE: MY STOECKLE).

# GROWING ORGANIZATIONS



## iBOL and CBOL join forces with UN.

Ahmed Djoghlaif, Executive Secretary of the UN Convention on Biological Diversity (CBD) Secretariat and Christian Burks, former board chair of iBOL, signed a memorandum of cooperation at the October 2010 CBD conference in Nagoya, Japan. iBOL supports CBD's work to protect and enhance biodiversity at national and international levels. CBOL's involvement in the CBD Working Group on Access and Benefit Sharing is helping to develop an international regime that differentiates commercial and non-commercial research, simplifying access to specimens for public-good projects like barcoding.

(PHOTO: UNCBD)

## IBOL PARTICIPANTS

### ■ CENTRAL NODES

Canada, China, European Union (France, Finland, Germany, Netherlands, Portugal, Spain, United Kingdom), and United States

### ■ REGIONAL NODES

Argentina, Australia, Brazil, India, Mexico, New Zealand, Norway, Russia, Saudi Arabia and South Africa

### ■ NATIONAL NODES

Colombia, Costa Rica, Kenya, Korea, Madagascar, Panama, Papua New Guinea and Peru



"free and open access to biodiversity data"



"providing access to biomedical and genomic information"



"global access to knowledge about life on Earth"

**Opening access and linking to e-Biosphere.** The acceleration of biomedical science during the past decade owes much to adoption of policies and practices of promptly sharing observations and data. Barcoders and others interested in biodiversity are taking similar steps to share knowledge about life on Earth. Publishing in open access journals, promptly uploading genetic data to NCBI's GenBank, and establishing links among major biodiversity databases are putting taxonomy on an global information platform and speeding the process of documenting biodiversity for society and science.

(WWW.GBIF.ORG; WWW.NCBI.NLM.NIH.GOV; WWW.EOL.ORG)

# TWO GLOBAL ORGANIZATIONS WITH SHARED GOALS



The International Barcode of Life (iBOL) is the largest biodiversity genomics initiative ever launched. By the end of 2015, iBOL aims to build a reference library of 5 million standardized DNA sequences capable of identifying 500 thousand species, more than a quarter of all known species on Earth. Headquartered in Canada, iBOL is the creation of more than 100 scientists from more than 20 countries. Launched in 2010 with support from Genome Canada and Ontario Genomics Institute, iBOL participants commit resources—financial support, human effort, and specimens—toward the 5M/500K goal.



The Consortium for the Barcode of Life (CBOL), free and open to all, develops DNA barcoding as a global standard for species identification. With more than 200 member organizations from more than 50 countries, CBOL builds global participation, sets community standards, organizes and supports working groups, workshops, networks, training opportunities, and international conferences held every two years. CBOL promotes general awareness of barcoding through an information website ([www.barcodeoflife.org](http://www.barcodeoflife.org)) and information sharing through Connect (<http://connect.barcodeoflife.net>), the Barcode of Life social network.

CBOL and iBOL share the goals of building, disseminating, and promoting the use of a public DNA Barcode Library. They jointly sponsor production and distribution of Highlights 2011.

## SPONSORS include

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Ministry of Science and Technology (Brazil)  
CONACYT and CONABIO (Mexico)  
University of Guelph  
Smithsonian Institution

**COVER** DNA barcodes help protect marine life.  
(D STEINKE ET AL, BARCODING NEMO: DNA-BASED IDENTIFICATIONS FOR THE ORNAMENTAL FISH TRADE. PLOS ONE, 2009)

**HIGHLIGHTS 2011** Compiled and edited by Mark Stoeckle, John Chenery, and David Schindel.

