# Barcode of Life Initiative

www.dnabarcodes.org

*DNA Barcoding:* ***An emerging global standard for species identification***

# THE BARCODE OF LIFE INITIATIVE (BOLI)

## Developing DNA Barcoding as a Global Standard for Identifying Species

Knowing the species to which a plant or animal belongs can be an enjoyable hobby, but it is also a core issue in biological sciences and can be of critical importance to society. Birdwatchers, mushroom hunters, wildflower enthusiasts and other amateur naturalists are always seeking specimens that will add species to their "life lists". Taxonomists and biodiversity researchers are studying and documenting all life forms on earth, and the names of species provide the framework for organizing this knowledge. Species identification can also be critically important to our environment, food supply, and economy. Two insects can appear identical, but while one could be benign the other could be an agricultural pest that could endanger food supplies and cause significant economic hardships. There are tens of thousands of species of fungi, many of which are hard to tell apart. Some are responsible for food-borne diseases and other serious human health problems. Most species of fish are reasonably easy to tell apart as adults. Once they have been processed for sale to consumers as filets or canned products they can become nearly indistinguishable. The same is true for many endangered species that are imported illegally as food products, folk medicines, leather goods, and other exotica.

Until now, people have relied principally on morphological features to identify biological specimens. In many cases this can be difficult or impossible because eggs, larval forms, damaged or incomplete specimens, or derived products may not have diagnostic features. Which insect eggs are pests or benign? If I order broiled grouper in a restaurant, is this really what I'm being served? Is my watchband made from the skin of an endangered shark? DNA may offer the only clues.

In recent years, researchers have been testing the idea that all biological species could be identified using a short gene sequence from a standardized position in the genome – a 'DNA barcode' - analogous to the black stripes of the Universal Product Code used to distinguish commercial products. In study after study, DNA barcoding is proving effective in:

- Assigning specimens to known species using only a tiny piece of tissue,
- Discovering new variation within what were presumed to be single species, and
- Documenting the biodiversity of poorly known taxonomic groups and poorly sampled geographic areas.

Since 2003, researchers around the world have joined together to form the Barcode of Life Initiative (BOLI). They have adopted DNA barcoding as an everyday tool for their research, and they are demonstrating the cost effectiveness of barcoding as an applied system of species identification. Government agencies are now testing barcodes as a front-line approach for regulation and enforcement. Here are a few of the BOLI's major activities:

Canadian Barcode of Life Network

The Canadian Barcode of Life Network is the first national barcoding network. The Network includes approximately 50 researchers from 42 institutions and has set the goal of assembling barcode records for more than 10,000 Canadian animal, plant fungal and protist species over the next 5 years. www.bolnet.ca

Canadian Centre for DNA Barcoding

DNA barcoding was first proposed at the University of Guelph in Ontario, Canada. Barcoding at the University has expanded into the Canadian Centre for DNA Barcoding which now barcodes more than 100,000 specimens per year. www.barcodeoflife.org

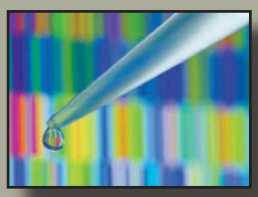
ABBI

ABBI, the All Birds Barcoding Initiative, has engaged ornithologists around the world in an effort to barcode the world's 10,000 bird species by 2010. Bird barcodes can be used to monitor changes in environmental quality and to help aviation officials prevent bird strikes on aircraft. www.barcodingbirds.org

FISH-BOL

FISH-BOL, the global Fish Barcode of Life Initiative, plans to collect DNA barcodes from at least five representatives of all 30,000+ species of marine and freshwater fish. Barcoding will improve our understanding of the world's fish populations and our ability to manage fisheries sustainably. www.fishbol.org

The Gump Marine Station of the University of California, Berkeley, has launched the Biocode project on the island of Moorea, French Polynesia. This Anglo-French collaboration will be the first to obtain barcodes for all species in a tropical ecosystem, from terrestrial insects and plants to marine invertebrates. http://moorea.berkeley.edu/



# HOW DNA BARCODING WORKS...

**Virtually all species have distinct barcode gene sequences. Building a public library of barcode sequences from museum reference specimens is the first step. After that, unknown specimens can be identified by 'looking up' their sequences in the reference library.**

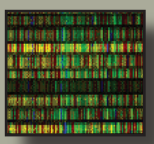
## Building the Global Reference Barcode Library

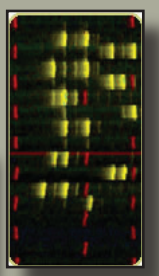
### From Voucher Specimens in Museums...

Over the past 300 years, taxonomists have collected and described more than 1.7 million species of plants, animals and microbes. They have built collections of hundreds of millions of representatives of these species. These reference specimens have been studied, identified, cataloged, and now reside in museums, herbaria, zoos and other repositories.

### ...To DNA Sequences...

Voucher specimens in museums provide tissue samples that will produce a reference barcode for that species. Using the standard and widely available tools of molecular biology, DNA is extracted from the tissue of these specimens, the barcode region is isolated, replicated by PCR amplification, and sequenced.



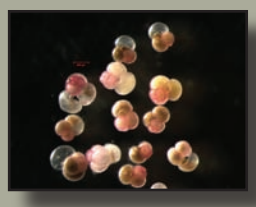




### ...To a Public Global Barcode Database

BARCODE records contain the DNA sequence, data on the voucher specimen, and the species name. These records are stored in the three global databases of gene sequences: GenBank, EMBL, and DDBJ, where they are available without charge.

## Identifying Unknowns With Reference Records



In building the reference library we have gone from identified specimens to barcode sequences. We can also work in the opposite direction. Tissue can be taken from unidentified specimens - even specimens impossible to identify by traditional means. The tissue produces a barcode sequence that can be matched to the sequence of a known species in the reference library. This process of barcoding an unidentified specimen and matching it to a known species now takes only a few hours and less than US$2. In the next few years the process will take minutes and will cost pennies.

# SPECIES IDENTIFICATION REALLY MATTERS!

## BOLI Projects are addressing applied problems....

"To what species does this organism belong?" It is probably the most commonly asked question in biology. It is not just professional taxonomists who ask. Amateur naturalists, border inspectors, public health officials, ecologists, resource managers, and many others ask the same question. The answer is often critical to the health and prosperity of society. Projects in the Barcode of Life Initiative are underway in many areas of practical importance.

### Protecting Endangered Species

The bushmeat trade is a significant threat to many primate and other mammal species in Africa. Bushmeat is sold locally and exported as raw butchered meat and as dried and smoked meat. In these forms, it is often difficult to make reliable species determinations using morphological features. DNA barcoding can be used in local markets and at ports of entry to identify bushmeat taken from protected species. Barcode data set the stage to stop illegal hunting and international trade, and to prosecute poachers and traffickers.

### Basic Research in Taxonomy

***Can you tell these apart?*** Very few specialists can, but using DNA barcodes, even non-taxonomists can identify them. Lepidoptera includes butterflies and moths, and is one of the most diverse orders of insects on earth, with about 180,000 known species. The All-Leps Barcoding Initiative will assemble DNA barcodes for nearly 20,000 of them within the next 5 years. Work is currently focused on the Lepidoptera of Australia, Canada, Costa Rica and the United States.

### Sustaining Natural Resources

Population growth continues to put pressure on natural resources such as wild fish stocks and timber forests. Managing these resources is crucial to their long-term sustainability. Barcoding can improve monitoring of population size and growth because barcode data can be used to identify larvae, seeds, and juveniles. Barcoding also enables resource managers and government regulators to monitor how much of each species is being used because processed proucts such as fish filets and lumber can be identified using barcode data. Enforcement officials can also use barcoding to identify and prosecute illegal harvesting. Data on population growth and use form the basis of wiser policies for sustainable harvesting.

### Exploring Marine Biodiversity

The Census of Marine Life is a long-term effort to document the populations of the world's oceans. Zooplankton are a critical part of the marine food chain, but they can be extremely difficult to identify and characterize, especially in their juvenile stages. CMarZ, the Census of Marine Zooplankton, is using DNA barcoding as a critical element in their study of 6,800 marine species.

## Controlling Agricultural Pests

Agricultural pests do not just attack crops. They endanger the livelihoods of farmers, the sustainability of cultures, the success of agricultural companies, and friendly trade relations among nations. Any decision involving agricultural pests starts with the fundamental question: What species is it? Without a reliable identification, effective counter-measures cannot be taken in the field, sound decisions cannot be made at ports of entry, and governments cannot establish well-informed trade agreements and restrictions.

Fruit flies are among the world's most economically important insect pests of fruits, seeds, and vegetables, costing billions of US dollars annually in crop damage, pest control, and lost markets. The Tephritid Barcode Initiative (TBI), has been launched with the goal of constructing a global identification system of all pest fruit flies and their nearest relatives by 2008. TBI is an international effort developed by the Consortium for the Barcode of Life.

## Stopping Disease Vectors

As global trade and travel increase, public health officials face a growing challenge. Every incoming shipment and traveler can be a vector carrying an infectious disease. Once a disease has been introduced into a country, containment and eradication are even greater challenges.

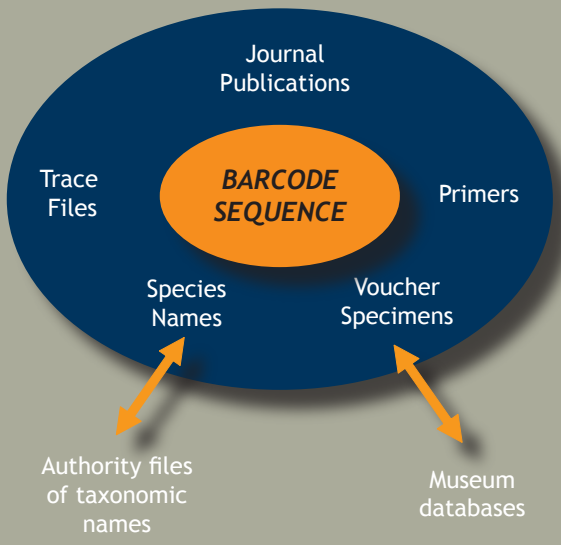
Mosquitoes transmit some of the deadliest diseases that affect humans – malaria, dengue fever, West Nile fever, yellow fever, encephalitis, filariasis and many other maladies. Mosquitoes arrive as eggs and larvae which can be difficult to identify, even for expert taxonomists.

The Consortium for the Barcode of Life has organized the Mosquito Barcoding Initiative (MBI), dedicated to developing a system for the unambiguous identification of more than 85% of all known mosquitoes. MBI will become an invaluable resource for preventing the spread of disease-bearing mosquitoes. In addition, more accurate identification using barcodes can minimize the use of insecticides by eradication programs.

## Monitoring Environmental Quality

'Bioassessment' is an accepted system for monitoring the health of natural environments such as streams, rivers, and wetlands. Biological samples are collected, the plant and animal species are identified, and the number of individuals per species are counted, from which an index of environmental health is calculated. Specimens in the samples have been identified using morphology-based identification keys but only a small fraction of the species can be identified this way. Most of the specimens in the samples are juveniles or have been damaged and can only be assigned to a genus or family. The US Environmental Protection Agency is conducting a two-year test of DNA barcoding as part of its Advanced Monitoring Initiative. Samples from the Maryland Stream Survey will be analyzed using morphology and barcodes to test the accuracy and cost-effectiveness of barcoding.

# DNA BARCODE DATA ARE...




## ...Standardized and High Quality

The Consortium for the Barcode of Life created a Database Working Group that has worked with Global Biodiversity Information Facility (GBIF) and others to set data standards for DNA barcode records. Data that meet these standards carry the BARCODE flag. Every BARCODE record is assigned a recognized species name and is linked electronically to a voucher specimen in a museum or other repository. Each record includes the PCR primers used and the trace file from the DNA sequencer. These data standards ensure that BARCODE records will be the best basis on which to identify biological specimens.

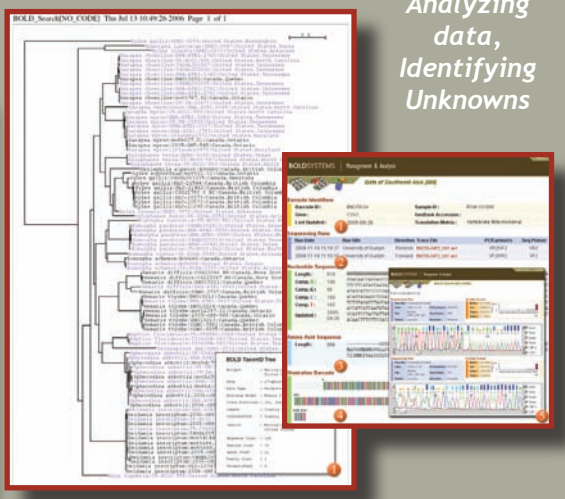
## ....Accessible and Secure in a Permanent Home

The International Nucleotide Sequence Data Collaboration (www.insdc.org) includes GenBank at the US National Institutes of Health, the European Molecular Biology Laboratory in Germany, and the DNA Data Bank of Japan. These public databases have agreed to be the global repository for DNA barcode data and have approved the BARCODE data standards.

## BOLD is an Open Access Workbench for Preparing and Submitting Barcode Data

The Barcode of Life Data Systems (BOLD) www.boldsystems.org at the University of Guelph is a web-based informatics workbench for use by the Barcode of Life Initiative. BOLI participants can use BOLD, without charge, to assemble, store, analyse, and upload their data to the global barcode data repository.

*Integrating data on Biological samples & Barcode sequences*



*Analyzing data, Identifying Unknowns*

# THE CONSORTIUM FOR THE BARCODE OF LIFE (CBOL)

**CBOL is an international collaboration devoted to developing DNA barcoding as a research tool in taxonomy and a global standard for species identification.**

CONSORTIUM FOR THE BARCODE OF LIFE


## CBOL's Major Barcoding Initiatives

- All Birds Barcoding Initiative (ABBI)
- Fish Barcode of Life (FISH-BOL)
- Mosquito Barcoding Initiative (MBI)
- Tephritid Barcoding Initiative (TBI)

## CBOL's Goals Are:

- Developing standards for the BOLI community
- Building partnerships with other biodiversity initiatives
- Promoting global participation in BOLI through regional meetings, networking, and research training
- Developing and supporting global barcoding campaigns
- Catalyzing new BOLI projects


- Accelerating the growth of the global barcode reference library
- Disseminating information about BOLI

## CBOL has more than 150 Member Organizations from 50 countries, representing:

- Natural history museums, Zoos
- Herbaria, Botanical gardens
- University departments
- Biodiversity organizations
- Governmental/intergovernmental organizations
- NGOs
- Private biotech companies
- Other research organizations

ALFRED P. SLOAN FOUNDATION

Smithsonian Institution

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Barcode of Life Initiative

www.dnabarcodes.org

*BOLI is a global initiative with many partners and supporters, among them:*

NCBI

*National Center for Biotechnology Information*

www.ncbi.nlm.nih.gov

*Global Biodiversity Information Facility*

www.gbif.org

bionet

*bioNET-INTERNATIONAL*

www.bionet-intl.org

Canadian Barcode of Life Network

www.bolnet.ca

Canadian Centre for DNA Barcoding

*University of Guelph, Ontario*

www.barcodeoflife.org

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