The Science World
A Monthly e Magazine
ISSN:2583-2212
Popular Article
July 2024 Vol.4(7), 2727-2731

DNA Barcoding and Its Applications

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https://doi.org/10.5281/zenodo.13198809

Abstract

DNA barcoding is a method designed for swift and precise species identification, enhancing accessibility within ecological systems. It employs abbreviated DNA sequences from specific genome regions known as markers, rather than analyzing entire genomes. Each species utilizes a distinct marker: CO1 for animals, matK for plants, and Internal Transcribed Spacer (ITS) for fungi. DNA barcoding finds extensive application across diverse domains such as conservation of biodiversity, safeguarding endangered species, managing agricultural pests, pinpointing disease carriers, assessing water purity, confirming the authenticity of natural health products, and identifying medicinal plants.

Keywords— CO1, matK, DNA Barcode, Identification, ITS, Marker.

INTRODUCTION

The biological impacts of global climate change underscore the critical need to identify organisms for species preservation due to escalating habitat destruction. Estimates suggest Earth hosts between 5 to 50 million species of plants and animals, yet fewer than 2 million have been formally identified. Extinction rates for both animals and plants are rising annually, resulting in the loss of thousands of species each year, with the majority still awaiting identification (1). The degradation and threat to the ecosystem has resulted in a better system for species identification. DNA barcoding is a novel ecological technique that has been presented recently for species identification and ecology study (2) (3). An approach for quick and precise species identification called DNA barcoding will increase accessibility to ecological systems (4). The scientific community first took notice of DNA barcoding in 2003 when a research team led by Paul Hebert at the University of Guelph published a landmark paper titled "Biological Identifications through DNA Barcodes". While the concept of using molecular markers for taxonomic research isn't new—Carl Woese pioneered it with rRNA and other markers to discover archaea (prokaryotes) and establish evolutionary relationships—DNA barcoding represents a novel approach. Unlike analyzing entire genomes, DNA barcoding focuses on short DNA sequences specific to eukaryotes, extracted from standardized genomic regions to create unique identifiers known as DNA barcodes. These barcodes consist of sequences composed of the four nucleotide bases: A (Adenine), T (Thymine), C (Cytosine), and G (Guanine), each visually represented by a distinct color (Figure 1). This method enables even non-specialists to identify species from small, damaged, or heavily processed samples efficiently (5).

Figure 1. DNA Barcode (11)

The standardized genomic region utilized to create DNA barcodes is referred to as a marker. Different species utilize distinct markers, such as COI (Cytochrome C Oxidase 1 or cox1), located in the mitochondrial gene of animals. Proposed by Paul Hebert and endorsed by the International Barcode of Life (IBOL), COI is recognized as the official marker for animals due to its significant variability between species (inter-specific) and minimal variability within species (intra-specific). However, COI is not suitable for other groups of organisms due to its uniformity among them. For fungi, ITS (Internal Transcribed Spacer) and for plants, two chloroplast genome genes, rbcl and matK, are acknowledged as barcode markers by IBOL (8)(9).

The sequencing data obtained from a specified area is used to identify species and create a phylogenetic tree. In this tree, related individuals are grouped together, revealing a wealth of information about species (7)(10).

APPLICATIONS

DNA barcoding is used for more than just research- it can also help address problems with broad impacts on all areas in which society interacts with biodiversity. Some practical applications include pest and disease control, food production and safety, resource management, biodiversity conservation and education

1) Managing Agricultural Pests

Farmers may avoid paying billions of dollars in insect damage costs by using DNA barcoding to identify pests at any stage of their life cycle and facilitate easier pest management measures. By giving instruments to identify and prevent fruit flies at borders, the worldwide tephritid barcoding program helps control fruit flies.

2) Recognizing the Vectors of Disease

Non-ecologists can identify the vector species that can cause significant infectious illnesses in humans and animals, understand these diseases, and find cures for them thanks to DNA barcoding. An international effort to barcode mosquitoes is creating a reference barcode library that will assist public health professionals in managing these disease-carrying vector species more successfully and with the least amount of pesticide usage.

3) Keeping Natural Resources Alive

Natural resource managers can track the illicit trade in goods derived from natural resources, such as hardwood trees, by using DNA barcoding.

Fishbol is a hardwood tree reference barcode library designed to enhance natural resource management and conservation.

4) Protecting Endangered Species

Because to bush meat hunting, the population of primates in Africa has decreased by 90%. Law enforcement can employ DNA barcoding to identify bush meat, which is bought from local marketplaces.

5) Keeping an Eye on Water Quality

Water for drinking is a crucial resource for all living things. It is possible to gauge or ascertain the health of the organisms that inhabit lakes, rivers, and streams by researching them. These species can be challenging to identify, thus a library of them has been created using DNA barcoding. Environmental authorities may utilize barcoding to better determine quality and develop better rules that can guarantee a safe supply of drinking water.

6) Regular Natural Health Product Authentication

Authenticity of natural health products is an important legal, economic, health and conservation issue. Natural health products are often considered as safe because of their natural origin.

Official Website
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Published 28.07.2024

7) Identifying of plant leaves even if flowers or fruit are not available

8) Identification of medical plants (13).

PROCEDURE OF DNA BARCODING

The DNA barcoding process comprises two primary stages: First, a barcode library is established by identifying species, and second, the barcode sequence of an unknown sample is aligned with this library (known as sequence alignment) to determine its identity.

To initiate the first stage, ecological expertise is crucial for selecting one or more individuals per species as reference samples for the barcode library. Tissue samples can be collected either from live specimens in the field or from preserved specimens in museums. These samples undergo laboratory procedures including tissue sampling, DNA extraction, and sequencing to generate a DNA barcode in the form of a chromatogram.

A chromatogram is a visual representation of the DNA sequence produced by a sequencer. This barcode sequence can be stored in a database for future reference or used as a query sequence to compare with sequences already present in the database (6).

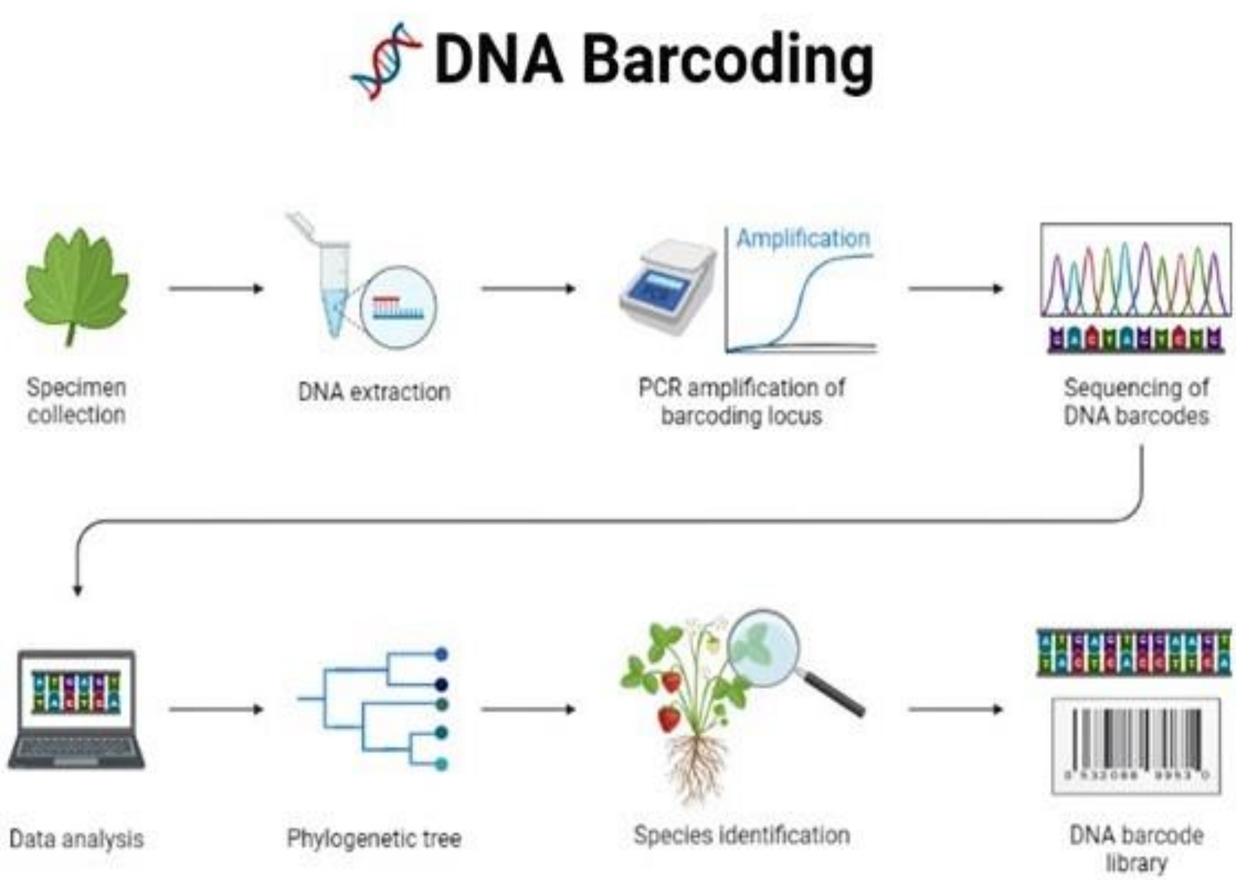

Figure 2. DNA Barcoding Procedure (Google)

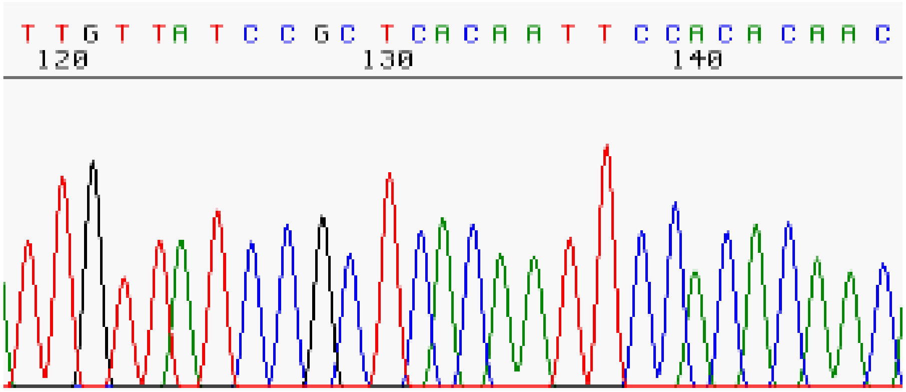

Figure 3. Chromatogram of DNA barcode generated by sequencer (12)

CONCLUSION

DNA barcoding is a rapid and precise method for identifying species, enhancing accessibility within ecological systems. It finds numerous applications across diverse fields such as managing agricultural pests, conserving biodiversity, safeguarding endangered species, monitoring water quality, and identifying medicinal plants.

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Published 28.07.2024