The Relentless Pursuit of Digital Storage

For over 80 years, some of the world's brightest minds have been working to advance digital storage technologies, driven by an insatiable thirst for greater capacity, speed, and reliability. This journey, starting in the 1940s, has been marked by a series of groundbreaking innovations that have transformed the way we store and access information.

From the early days of punch cards and magnetic tapes to the present-day cloud-based solutions, the evolution of digital storage has been nothing short of remarkable. Each decade has brought new breakthroughs, pushing the boundaries of what was once thought possible and laying the foundation for the data-driven world we now inhabit.

Goals of Digital Storage

Reliability

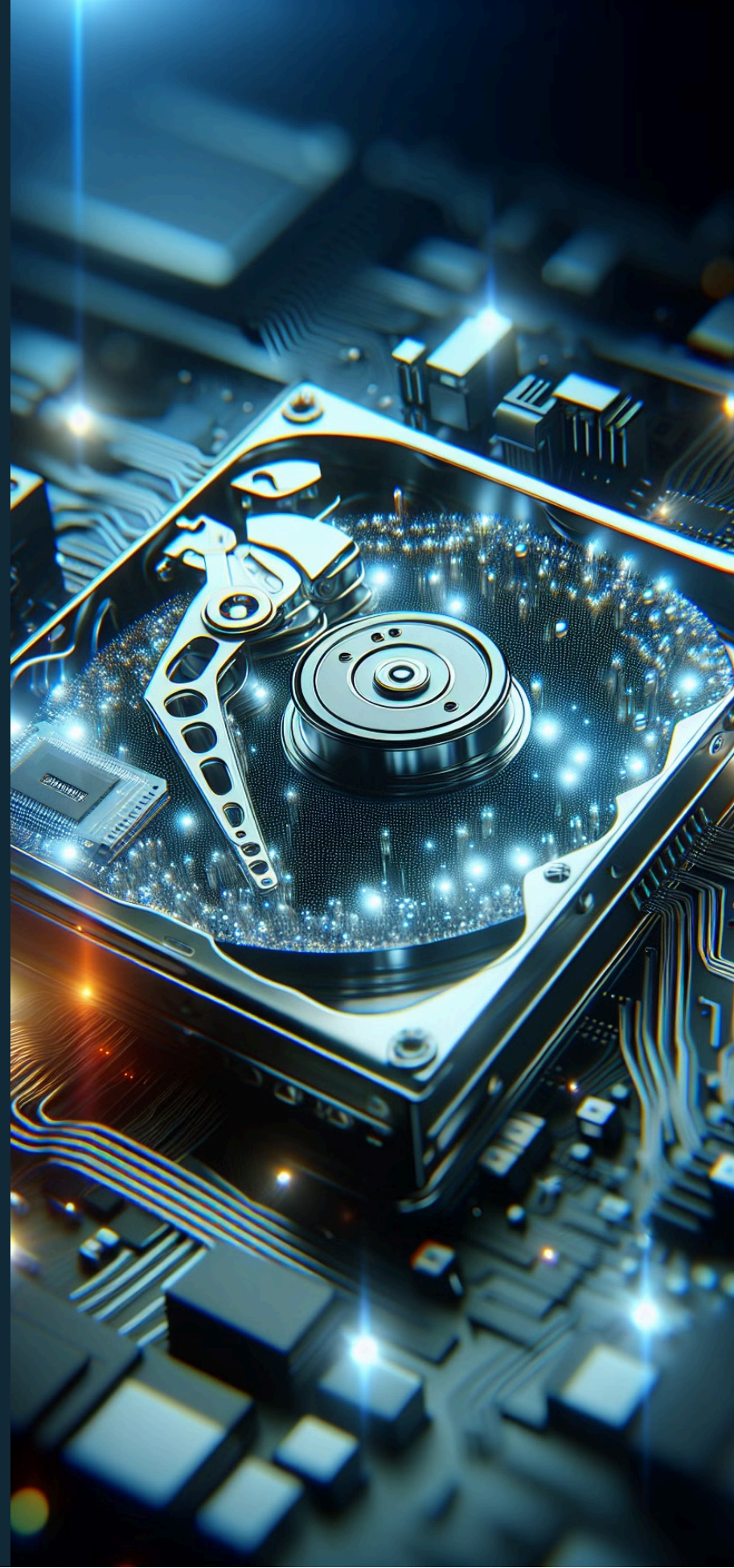
Ensuring data is securely stored and accessible when needed.

Efficiency

Optimizing storage systems for speed, cost, and energy use.

Density

Packing more data into smaller physical spaces.



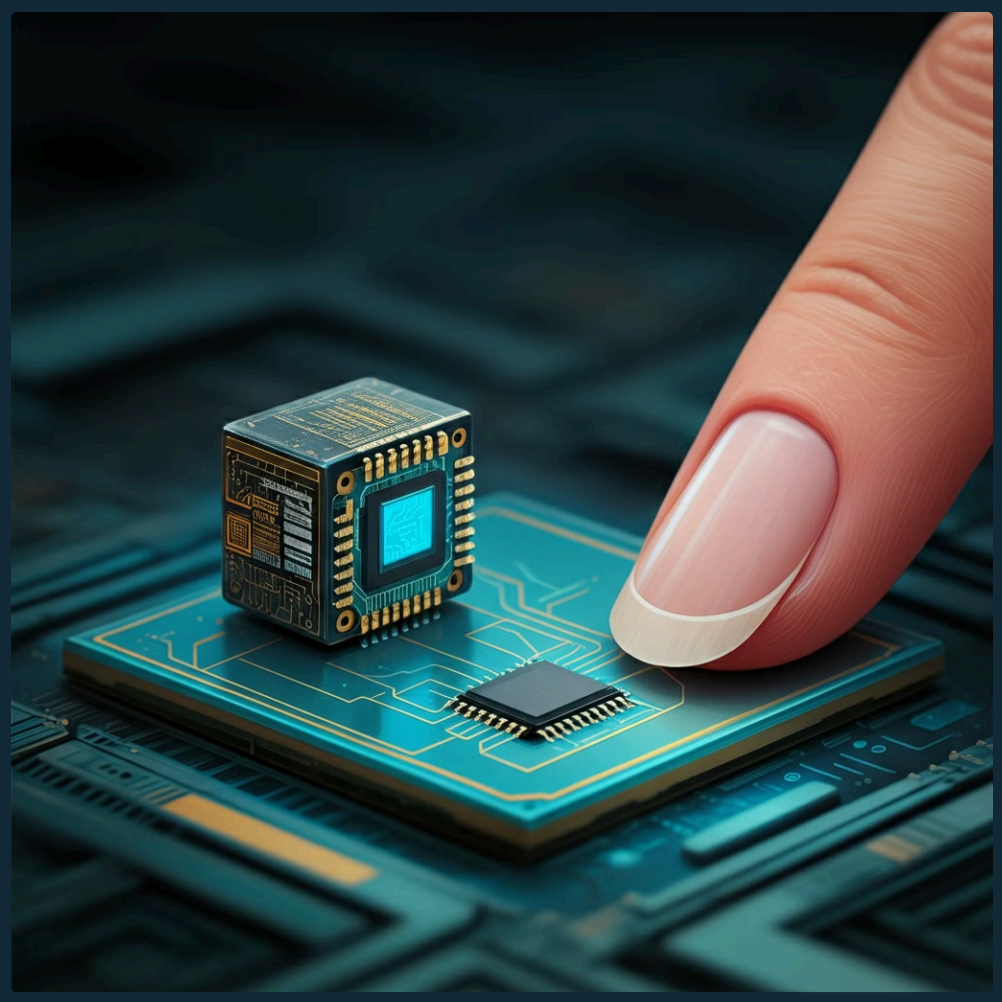
Storage Capacity Evolution

70 years ago

The **IBM 305 RAMAC**, a revolutionary device for its time, had a storage capacity of only **5 megabytes**. It was a behemoth, requiring approximately **350 square feet** of space.

Today

In contrast, a terabyte of data can be stored in a device smaller than a fingernail. This incredible shrinking of storage technology is a testament to the relentless progress in the field.



65 years ago

A five-megabyte hard drive could barely fit in a cargo plane.

Today

1 Terabyte can be stored in a device as small as a fingernail.

Current Storage Challenges

Data Growth	175 zettabytes of digital data are expected by 2025, growing exponentially.
Energy Consumption	Data storage centers consume 1.5% of the world's electricity, equating to 200 million metric tons of CO2 per year.
Physical Footprint	If unresolved, large data centers would cover the surface of the earth by 2060.

See Link to Source

Building a 175 Zettabyte Data Center

9B

Hard drives needed

20 TB hard drives

226M

Server racks

453M

Floor space

square meters

175

Equivalent in

square miles

Adding floor space for infrastructure

Power, Cooling, Access Corridors:

Adds 131 square miles

Data Center footprint

306 square miles

New York City (all five boroughs)

303 square miles

A Revolutionary Storage Technology

The Power of DNA

Mankind has discovered a storage technology that is vastly superior to our current technology, like a rocket compared to a bicycle in design and function. This revolutionary technology is DNA storage.

The Human Genome

The human genome was largely sequenced by 2003, but **2022** marked the true completion of the entire genome.

Vast Potential

DNA storage holds incredible potential for archiving vast amounts of data in a way that is both compact and durable.

The Vital Role of DNA in Life

DNA, or deoxyribonucleic acid, is the fundamental building block of all living organisms. It contains the complete genetic instructions required to create and maintain life, from the simplest single-celled organisms to the most complex multicellular lifeforms like humans.

DNA stores and transmits the instructions that guides the growth, development, function, and reproduction of every living thing.

DNA Storage in Nature

Hereditary Information

DNA stores the hereditary information for almost all life on Earth.

Two Copies

Each cell of most organisms contains a complete copy of the genome, with two copies in most cells. One copy is from each parent.

Millions of Species

There are between 10 million and 100 million species of life on Earth with the same DNA structure and storage capability.

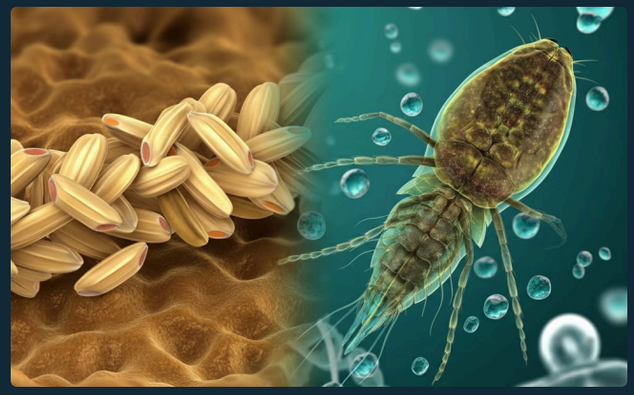
Human Genome Complexity

Composition

The human genome contains 3.2 billion base pairs and around 20,000-25,000 protein-coding genes.

Genes vs. Base Pairs

While seemingly complex, other organisms have larger genomes, such as the axolotl (salamander) with 10 times more base pairs and the *Paris japonica* (a plant) with 50 times more.



Number of Genes

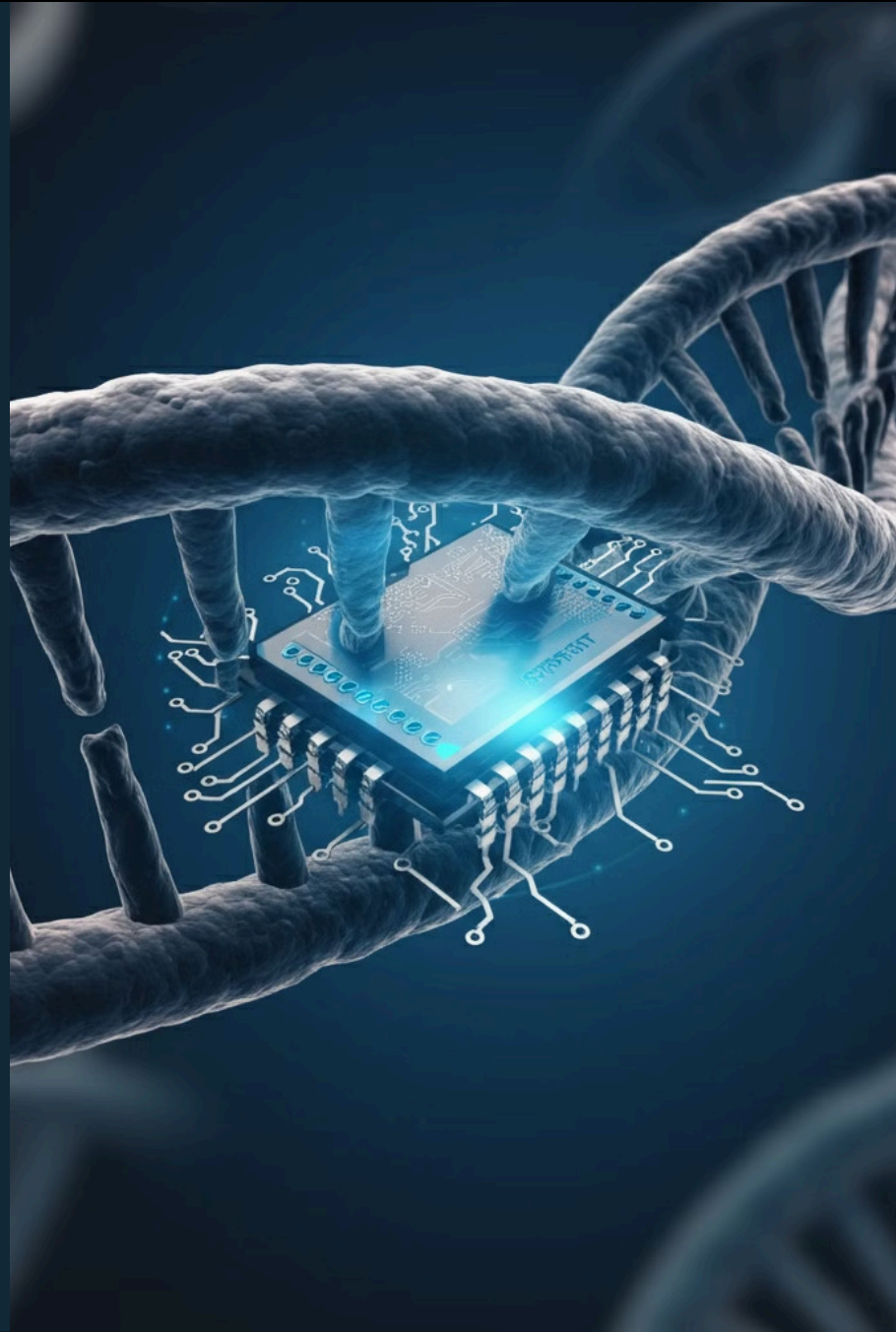
Surprisingly, some simpler organisms like rice and water fleas have more genes than humans, with over 40,000 and 31,000 respectively.

Surpisingly, the human genome, is not the most complex when compared to other life forms on Earth.

The Size of the Human Genome

The human genome, depending on the method of calculation, takes up between 3 and 90 gigabytes of storage space. If each letter of the genome is considered a byte, the total size is closer to 90 gigabytes.

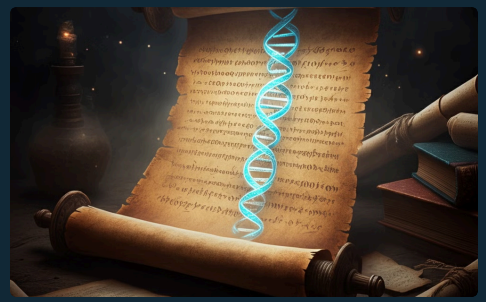
DNA's natural structure allows for highly efficient data storage, far surpassing our current digital methods.



Advantages of DNA Storage

High Density

DNA has the ability to store immense amounts of data in a very small space.



Stability and Reliability

Dried DNA can endure for thousands of years in cool environments. The oldest DNA sequenced has been dated back over 700,000 years.

Energy-Efficiency

DNA storage is remarkably energy-efficient and requires minimal space for upkeep.

Relevancy

DNA is an integral part of biological systems, ensuring its enduring importance.

Pioneering DNA Data Storage

In 2019, Harvard and MIT professor George Church led a groundbreaking project, encoding a complete book into synthetic DNA. This demonstrated the immense potential of using DNA as a long-term digital storage medium, with far greater capacity and longevity than current electronic formats.

Church's team converted 5.27 megabits of text and images into binary code, then stored it in DNA, and successfully decoded it using next-generation sequencing technology.

MIT/Harvard DNA Storage Project

How much DNA to store 175 Zettabytes?

814

Kilograms

The amount of DNA required to store 175 Zettabytes of data

35

Cubic Feet

Approximately the size of a large refrigerator in DNA is needed to hold 175 Zettabytes.

10

Square Feet

Being generous we will assume the same footprint as **IBM 305 RAMAC** (**350 sq ft**) of data center floor space required for 175 Zettabytes of DNA storage.

1/170M

Fraction

The size of the **350 sq ft** DNA storage compared to the 306 sq mile Data Center scenario in the previous slide.

Storing 175 Zettabytes of data on traditional digital media would require an immense physical footprint. However, by leveraging the incredible storage density of DNA, the same data might be housed in a remarkably compact space that includes generous space for supporting infrastructure.

DNA Data Storage Capacity

Petabyte Storage

A single gram of DNA can store up to 215 petabytes of data, far exceeding the capacity of traditional digital storage mediums.

Compact Storage

The DNA storage capacity is astounding considering 1 gram of DNA is about the weight of a common paper clip or thumbtack.

Ongoing Research

As researchers continue to push the boundaries, the upper limits of DNA data storage capacity are still being discovered.

DNA Data Storage Alliance

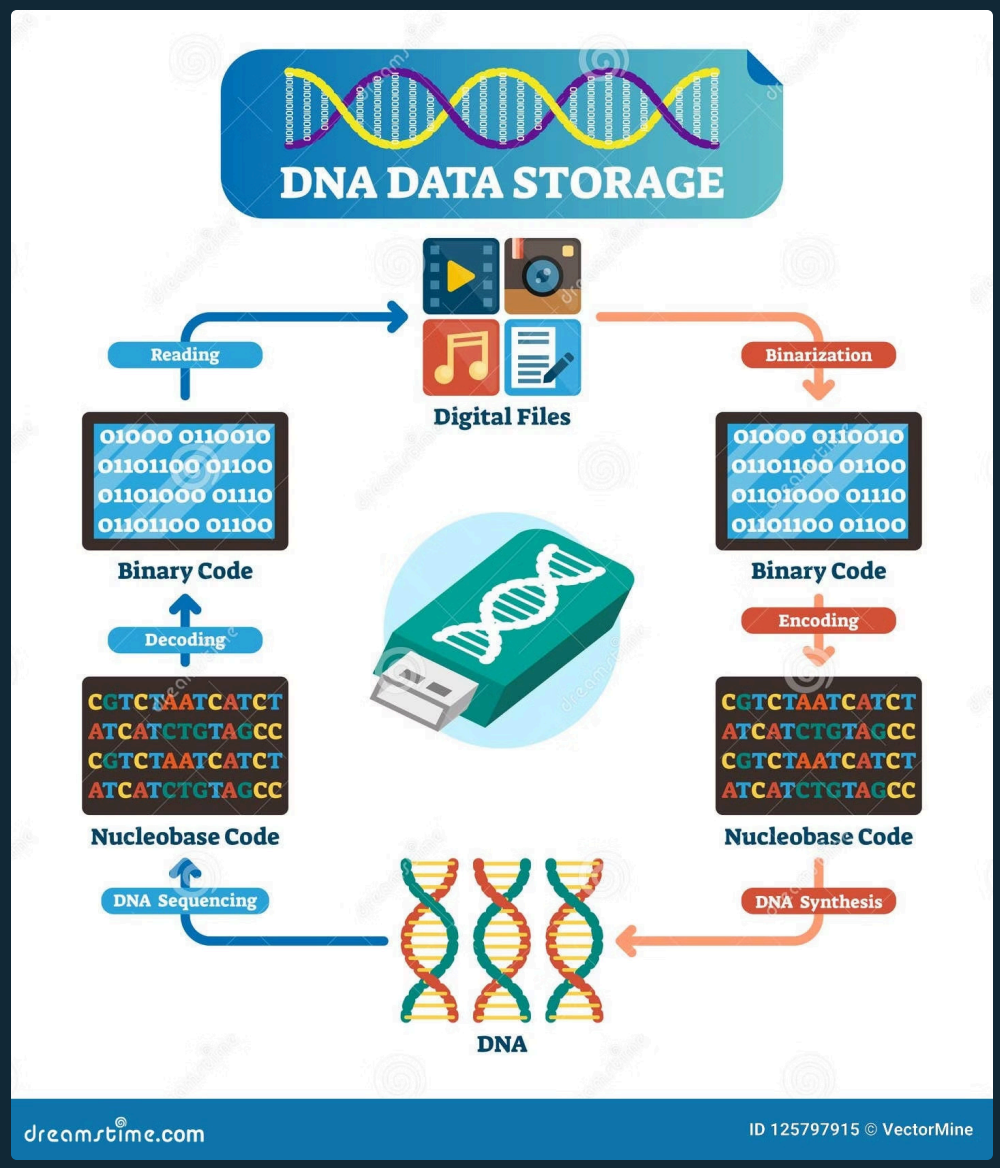
[DNA Data Storage Alliance Current Members]

In 2020, a group of leading technology and biotechnology companies formed the DNA Data Storage Alliance.

The founding members of the alliance include industry giants like **Illumina, Twist Bioscience, Microsoft, and Western Digital.** By combining their expertise, the alliance hopes to unlock the full potential of DNA storage and integrate it seamlessly into existing data management ecosystems.

On April 20, 2020 Netflix show stored in DNA

[Twist Bioscience Synthetic DNA Stores New Netflix Original Series 'BIOHACKERS']



More DNA Storage Research

July 4, 2024 A company in Lithuania, Genomika, is developing an autonomous solution for archiving data in DNA structures. Researchers aim to create a reliable, high-density, and sustainable data storage system using the enormous potential of DNA molecules.

Mindaugas Bulota, the Head of KTU's National Innovation and Entrepreneurship Center (NIEC), **views DNA storage technology as a groundbreaking advancement in the market. This innovative approach has the potential to revolutionize data archiving and create a new era of sustainable and long-lasting data preservation.**

Genomika archiving data in DNA

Planning the Path Forward

April 3, 2024

"**DNA is an intelligent data storage medium due to its stability and high density. It has been used by nature for over 3.5 billion years.** Compared with traditional methods, DNA offers better compression and physical density. DNA can retain information for thousands of years."

"**Biocybersecurity must be prioritized to prevent attacks with synthetic DNA** that could encode malware triggered during DNA sequence analysis."

"**Standardization of the coding and decoding process is necessary for long-term accessibility**. Errors in methodology can lead to data loss, emphasizing the need for a reliable protocol for handling samples."

"**Inclusion of identifying features in the DNA is crucial for future recognition of it as data storage**. Markers or sequences can indicate that the DNA is synthetic, not biological."

Trends in Biotechnology.

More on the Path Forward

BIOMEMORY is selling a DNA Storage System, right now!

December 2, 2021

Microsoft is edging closer to making DNA storage a reality

November 21, 2023

DNA storage could provide dense, flexible, more sustainable form factors for archival use cases. One company plans on commercializing its offering by 2026.

March 12, 2024

DNA Data Storage Alliance Releases First Specifications for Digital Data in DNA

The Mysteries of DNA Remain

Despite 150 years of intense study, the DNA data itself still holds many mysteries. While we have made significant progress in understanding DNA's structure, the genetic code, and basic gene functions, much remains unknown.

Areas such as **non-coding DNA, epigenetic regulation, gene networks, complex genetic diseases, and even the origins of life continue to puzzle scientists**.

Research in genetics and molecular biology continues to reveal new layers of complexity, indicating that while we have made significant strides, there is still much more to learn about DNA.

Remarkable Complexity of DNA

The storage density of DNA surpasses the most advanced digital storage media by a magnitude of over 170 million, demonstrating the remarkable complexity found in every detail of DNA. This extraordinary level of sophistication points to a design that is both intricate and efficient.

According to evolutionary scientists, the same DNA data and storage system is present in the early species of all three domains of life on Earth: Bacteria, Archaea, and Eukarya. This shared characteristic suggests that these organisms were either created with DNA or descended from a common ancestor with complex DNA. The answer leads to the origin of life on our planet.

The LUCA Problem

The theory of LUCA, the Last Universal Common Ancestor, was proposed by evolutionists to explain the origins of life on Earth.

In July of 2024, *Science* magazine confidently reported, "The last ancestor shared by all living organisms was a microbe that lived 4.2 billion years ago, had a fairly large genome encoding some 2600 proteins, enjoyed a diet of hydrogen gas and carbon dioxide, and harbored a rudimentary immune system for fighting off viral invaders."

That's quite a statement that details an unknown creature living somewhere on this planet 4.2 billion years ago.

Problem: Age of Earth and DNA

4.54B

Billion Years

Estimated age of the Earth based on radiometric dating

4.2B

Billion Years

Timeframe evolutionists claim DNA emerged in simple creatures

The estimated age of the Earth is 4.54 billion years, while evolutionists claim that the incredible design of DNA emerged in simple creatures 4.2 billion years ago. This discrepancy raises questions about the validity of the evolutionary timeline for the origin of DNA's intelligent storage system and the complex instructions for creating and maintaining life.

Faith in Design

The remarkable complexity and sophistication of DNA's data storage system challenges the notion that it could have arisen through the blind, unguided forces of natural selection. **As the Psalmist declared, we are "fearfully and wonderfully made" (Psalm 139:14)** - a testament to the genius of the divine Designer who knit together the intricate biomolecule that forms the foundation of all life.

The evidence of intelligent design in DNA, coupled with the discrepancy between the Earth's age and the timeline for DNA's emergence, raises serious questions about evolutionary explanations. *It is far more reasonable to trust in the wisdom of the Creator who "formed our inmost being"* than to have faith in an unguided, random process.