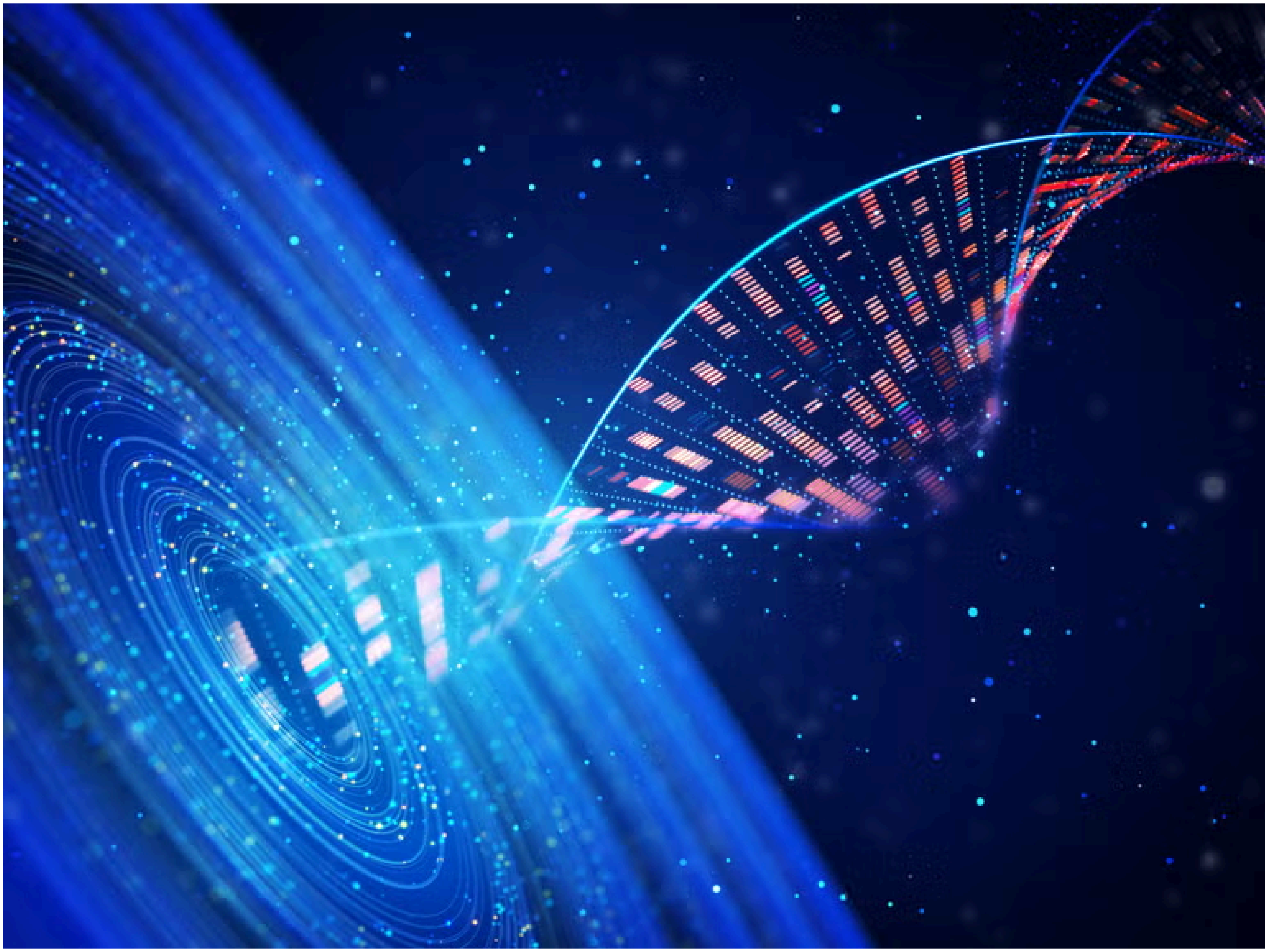

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We're Running Out of Room for Our Data—But the Raw Power of DNA Could Save Us, Scientists Say

This radical new method could preserve our entire knowledge base for thousands of years, in a storage medium the size of a coffee cup.

BY MELISSA GASKILL PUBLISHED: NOV 19, 2025 10:33 AM EST

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Here's what you'll learn when you read this story:

- We are generating staggering amounts of data every day. Data centers just can't keep up with the demand.
- With data storage needs expected to soar in the future, scientists have discovered that binary data can be translated into DNA sequences. Eventually, we could have the entirety of our data stored cheaply and safely for millennia.
- Yet, DNA synthesis remains wildly expensive. We need a breakthrough in basic research to overcome this obstacle.

Scientific fields from astronomy to zoology. Industries from health care to entertainment and finance. Social media, the arts, and **AI**. These are just a drop in the ocean of data that accumulates from nearly every aspect of our daily lives.

By the end of 2025, humans will have generated about 33 zettabytes of data—that's 3.3 followed by 22 zeros. Every day we add another 2.5 million gigabytes (GB). Much is stored in data centers that take up the space of several football fields, cost billions of dollars to run, and simply can't keep up with the demand.

But scientists have discovered another way to store data: putting it in deoxyribonucleic acid or **DNA**. This technology theoretically could fit all that data in your coffee cup–and store it for thousands of years.

Researchers have taken great strides toward making this a reality. But producing the DNA remains wildly expensive—by one **estimate**, $1 trillion for one petabyte (1 million GB) of data.

They aren't giving up, though.

"From what I know, DNA is the only material with the storage density and properties that could conceivably meet the hunger for data storage," says Mark Bathe, PhD, professor of biological engineering at MIT. "There is no other contender. The molecule that nature chose for storing its information is a pretty incredible choice despite its current cost."

How Raw Data Converts Into DNA

For billions of years, living things have stored their genetic information in DNA, an organic chemical made of unique orders of four chemical units or bases: adenine (A), thymine (T), guanine (G), and cytosine (C).

Scientists first demonstrated using DNA to store data in the 1980s. In 1999, **researchers** encoded a 23-character message into DNA; by 2013, the amount had **jumped** to 739 kilobytes and included text, images, and sounds. In 2018, it **exceeded** 200 megabytes.

And this past April, the Library of Congress awarded a **grant** to write 1.5 GB of information in DNA.

The process involves converting data into binary language (the ones and zeroes that computers use) and then into sequences of the ATGC bases, which are used to synthesize new DNA on an existing template. A sequencer, which reads and converts the DNA back into digital data, retrieves the information.

DNA Storage Offers Vast Benefits

That **high density**—coffee cup versus massive data center—is a big advantage over traditional storage.

Another is that storing DNA costs almost nothing. According to **researchers** in Beijing, keeping 109 GB on tape for ten years costs $1 billion and uses hundreds of millions of kilowatts of electricity.

DNA storage could reduce that energy expenditure by three orders of magnitude.

"Once you make the DNA polymer, it doesn't consume any energy," Bathe says. It can be stored for millenia at **room temperature**. By contrast, the US Department of Energy **predicts** data center energy use tripling by 2028, accounting for up to 12 percent of U.S. electricity use.

DNA is extremely stable, too. "Under the proper conditions, it might be stable for hundreds of thousands of years plus," says Jeff Nivala, PhD, an assistant professor at the University of Washington Paul G. Allen School of Computer Science and Engineering. DNA in thousand-year-old fossils can still be read, and some research suggests DNA data could **survive** for a million years. By contrast, tape is **rated** for only 10 to 30 years.

Further, DNA technology will never become obsolete. Digital storage methods have constantly changed, rendering a lot of data pretty much inaccessible (think floppy discs). But as long as DNA-based life exists on Earth, humans have strong incentives to maintain technologies to read and manipulate it.

DNA Synthesis Is Still Costly

Research still must overcome several challenges to implementing DNA storage, including the cost of synthesis.

"Breakthroughs in synthesis are always coming soon, but fundamentally, it is stuck at an unsustainable peak," says University of Texas Department of Molecular Biosciences professor Ilya Finkelstein, PhD.

In 2018, the Potomac Institute for Policy Studies **predicted** synthesis falling to about $21,000 per MB of data by 2027. But even at that rate, synthesizing an entire human genome, requiring about 715 MB, would cost $14 million.

One reason for that high cost is the expensive chemicals required, according to Bathe. He estimates that the cost needs to drop by about six orders of magnitude to be competitive.

"There is no doubt the cost is going to drop," he says. "The question is how much and when, and that is always hard to predict."

The field needs a breakthrough in basic research, much like the giant leap from vacuum tubes and punch cards to semiconductors, he adds.

Researchers have made **progress** on error rates in DNA synthesis and sequencing, currently on the order of 1 percent per base sequence. For example, in 2020, Finkelstein and his colleagues developed an **error-correction code** for petabyte-scale data.

Retrieval methods keep improving, too. Right now, entire stored DNA pools must be sequenced to read a single byte. But Bathe's team developed "**barcodes**" that enable random access. In a pending paper they unveil a system much like those used to search, say, all of Google for a specific image. Nivala's team recently reported a search and retrieval **method** using CRISPR-Cas9 gene editing techniques.

Data's Future May Be Beyond Our Imagining

DNA technology could help solve a common dilemma, whether to save or discard data. The choice usually is to discard, because there simply isn't anywhere to store it.

"It could enable a world where we never have to delete anything," Bathe says.

DNA storage may prove **most useful** for archives, data kept long-term but seldom accessed, such as government and medical records and scientific archives like **CERN**. It also could help quench **AI**'s huge thirst for data, theoretically improving its accuracy and expanding its capabilities.

Besides storing data, DNA could let us use it in new and different ways. One possibility, Nivala says, is processing information the way parallel electronic computing does. That process breaks down large problems into smaller ones that massive processors solve simultaneously, communicating with each other using shared memory. And DNA could do this using much less energy.

Scientists expect there are other possibilities that we'll only discover once we start using the technology.

"In basic research, we ask what is next, how can we invent new systems and new materials to transform the technology and the world," Bathe says. "When the internet was first invented, everyone wondered, what the heck is this good for? Today, I think we know."

If scientists can make DNA storage work, we could save orders of magnitude more data and use it in ways we can't yet imagine. And who knows what that might be good for?

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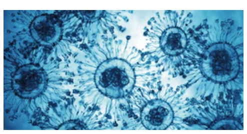

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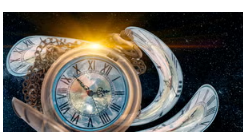

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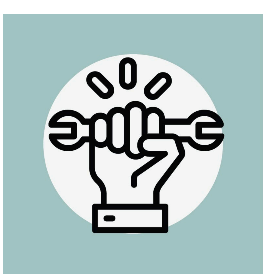

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SCIENCE WRITER

Austin-based science writer and author Melissa Gaskill focuses on ocean issues, endangered wildlife, the environment, and space. She has written for dozens of publications including Mental Floss, Scuba Diving Magazine, Men's Journal, Alert Diver, Stardate, and Scientific American.

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