BIOCOMPUTING: THE FUTURE OF TECHNOLOGY OR JUST ANOTHER BEAR MARKET?

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Abstract. Biocomputing integrates biological components like DNA and proteins for computation, offering a revolutionary alternative to traditional silicon-based systems. Technologies such as Organoid Intelligence (OI) use lab-grown brain organoids for cognitive tasks, showcasing biocomputing's potential for energy-efficient processing. Recent studies reveal that biocomputers can be up to 90% more energy-efficient than silicon circuits. Despite challenges in reliability and integration, advances in synthetic biology are accelerating progress. They promise significant advancements in personalized medicine and environmental monitoring. With the potential to replace conventional silicon data centers, biocomputing could transform technology by providing more efficient and adaptable systems.

Keywords: biocomputing, DNA computing, brain organoids, neural cells, organoid intelligence, synthetic biology, silicon alternatives

Picture This: Computers Made of Life That sounds like the plot to a sci-fi movie, but this is not so far from becoming real life. The relatively new field of biocomputing — an intersection between biology and computers, is greatly changing the landscape on how we view technology …and future processing power.

Biocomputing works by using the intrinsic nature of biological systems to execute computations. Rather than traditional transistors and circuits, biocomputers process information using DNA molecules, proteins and other biological components. Such living systems can make decisions, process huge amounts of information and even adapt to be more efficient.

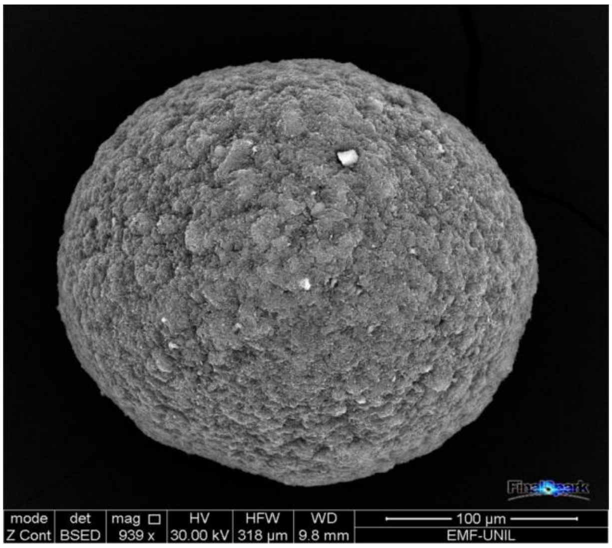

Figure 1. Image of brain organoids: 3D clusters of neural cells mimicking brain structure and function, used to study brain development and disorders. [1]

One of the most groundbreaking developments in this field is Organoid Intelligence (OI), a novel approach that involves using brain organoids—miniature, simplified versions of the brain grown in the lab—to achieve cognitive functions and computations. This concept has opened new avenues in biocomputing, demonstrating how biological intelligence can be harnessed for computational tasks. Recent studies have shown that these organoids can perform basic cognitive functions, offering a glimpse into how living systems could be used for advanced computing. [2]

Superficially, both biological and machine learning/AI by an intelligent agent can be thought to construct internal representations of the world around it, through which they are then able to conduct decision making or appropriate actions in order based on responses executed. Nevertheless, the fact that bio-algorithms and machine-learning operate in entirely different modalities (mechanisms of implementation) has created fundamentally distinct efficiencies.[3] For example, one supposes that a larval zebrafish can adapt its own movement to navigate effectively and complete tasks noiselessly at only 0.1 microwatts; meanwhile the human brain operates smoothly at an estimated efficiency of around 1 exaFlop but requires just over 20 watts (**Table 1**) for cognition while burning through dearly little power overall 100 watts total. Whereas the USA's world leading Frontier supercomputer reaches 1102 petaFlops (**1.102 exaFlops**) on LINPACK benchmarks in June, 2020 but consumes 21 megawatts which is a huge map to show how power prices are lagging far behind human brain.[4]

Table 1. Comparison of the latest supercomputer (June 2022) and the human brain.

	Frontier supercomputer (June 2020)	Human brain
Speed	1.102 exaFLOPS	~1 exaFLOPS (estimate)
Power requirements	21 MW	10-20 W
Dimensions	680 m^2 (7,300 sq ft)	1.3–1.4 kg (2.9–3.1 lb)
Cost	$600 million	Not applicable
Cabling	145 km (90 miles)	850,000 km (528,000 miles) of axons and dendrites
Memory	75 TB/s read; 35 TB/s write; 15 billion IOPS flash storage system, along with the 700 PB Orion site-wide Lustre file system	2.5 PB (petabyte)
Storage	58 billion transistors	125 trillion synapses, which can store 4.7 bits of information each

The Hewlett Packard Enterprise Frontier, or OLCF-5, is the world's first exascale supercomputer, hosted at the Oak Ridge Leadership Computing Facility (OLCF) in Tennessee. It is compared here with the human brain. For sources see (6–11).

The potential applications of biocomputing are vast. In the medical field, on the other hand, biocomputers could make it possible to reach a level of personalization in treatments that was previously unimaginable. They have the potential to process genetic data on an unprecedented level, which could allow therapies to be tailored specifically or mostly towards a person's unique genetic code. As a drug discovery aid, they could accelerate the identification of new drugs by modeling how various compounds interplay with biological systems.

Biocomputing extends well beyond the healthcare sector also reinventing our approach to environmental science. Biocomputers could be incorporated into plants or microbes that continuously monitor environmental conditions, detect chemicals in soil and water supplies, synthesize energy. These natural systems might provide the sustainable solutions to many intractable global problems.

FinalSpark is one of the earliest proponents in this area and has been a leader in biocomputing research. In their most recent tests, biocomputers have shown that they can perform a specialized function as much as 1 billion times more efficiently than the counterpart in traditional computers powered by semiconductor silicon circuits. One of the most important studies was published by FinalSpark in 2023, which revealed that a biocomputer using DNA-based circuits required almost (use)90% less energy than its silicon alternative. The discovery is extremely important for the future of low-energy computing. As one of their key researchers — Elara Quinn, PhD says “We are not just creating more efficient machines; we are redefining the fundamental principles of computing by tapping into the elegance and efficiency of nature itself.”[5]

With data centers contributing an increasing amount to the planet's emissions, the energy efficiency of biocomputing is noteworthy. Data centers, which contain the sprawling servers that make our digital lives possible, are responsible for using massive amounts of electricity. FinalSpark aims to cut this vastly unsustainable energy usage by using biocomputing technologies — thereby promoting a cleaner, more sustainable approach to future tech. Still, getting to completely working biocomputers is not without its challenges. Designing these life-saving systems is a tough problem due to the subtlety of biological system which ranges from reliability and scalability issues to how well they can integrate into existing patient management among others. Progress, however, is being made in the research field.Realizing the full potential of biocomputing is closer thanks to recent developments in synthetic biology, which have made it possible for scientists to build and construct biological systems with previously unheard-of accuracy.

As we approach the precipice of such a revolution, it's clear this biocomputing could disrupt industries and fundamentally shift the understanding of what computers are. We may be able to develop computers that outperform the ones we have today by instead harnessing biology, making them not only faster and more powerful but also capable of evolving and adapting in ways current technology cannot. " Just as the Moon’s shadow during a solar eclipse has drawn skywatchers for centuries, the shadow of biocomputing's potential has captivated researchers and innovators around the world " said Dr. Quinn during an interview earlier this year.

The potential use of these living machines is wide and varies, but as biocomputing advances further it could very well become a regular part of the human lifestyle.

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