Capgemini
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The *dual transition*

The path to a digital and sustainable economy

Conversations FOR TOMORROW

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Executive conversations with...

PROF. SUSAN HOCKFIELD

Neuroscientist and Author,
President Emerita

MIT

VALUE CREATION THROUGH SYNTHETIC BIOLOGY

Massachusetts Institute of Technology

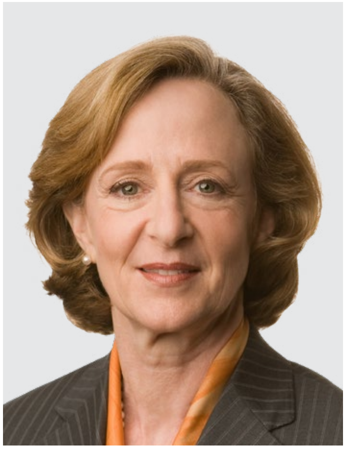
Susan Hockfield is Professor of Neuroscience and President Emerita at the Massachusetts Institute of Technology (MIT). She was the 16th president (2004-12) of MIT, and the first woman and the first life scientist to lead the institute.

Professor Hockfield's research focuses on the development of the brain and on glioma, a form of brain cancer. As a biologist, she pioneered the use of monoclonal antibody technology in brain research, identifying proteins through which neural activity early in life affects brain development.

She also helped shape national policy for energy and next-generation manufacturing, and in 2011 was appointed by President Barack Obama to co-chair the steering committee of the Advanced Manufacturing Partnership (MIT AMP).

In 2020 Professor Hockfield received a Science Communication Award from the American Institute of Physics for her book, The Age of Living Machines (2019). She is the recipient of several other prestigious awards, including the Charles Judson Herrick Award from the American Association of Anatomists; the Golden Plate Award from the Academy of Achievement; and the Amelia Earhart Award from the Women's Union.

The Capgemini Research Institute spoke to her about the role of synthetic biology in building sustainable solutions.



Prof. Susan Hockfield,
Neuroscientist and Author,
President Emerita at MIT

What drew you to a career in the life sciences, and in synthetic biology in particular?

From as early as I can remember, I always had to take things apart to understand how they worked, leaving a litter of parts behind me. I had a curiosity about how things work in the living world and learned how to take them apart to understand how living organisms work.

In my junior year in college, the opportunity to use electron microscopes to understand the different parts of cells just blew my mind. Shortly after finishing college, I started work in a medical school laboratory, where I felt a sense of belonging from the very first day. While I was doing my PhD in neuroanatomy, I had the great fortune to work at the National Institutes of Health (NIH), which had a fascinating multidisciplinary group of anatomists, physiologists, pharmacologists, psychologists, and clinicians, all thrown in together with the shared ambition of understanding how the brain perceives pain and to find ways to alleviate it.

"From as early as I can remember, I always had to take things apart to understand how they worked, leaving a litter of parts behind me."

DECODING SYNTHETIC BIOLOGY

The field of synthetic biology is complex and rapidly evolving. How would you explain its significance to a lay person?

Nature is brilliant at solving technical problems. Our role is to recognize nature's solution and adapt it to our needs. Synthetic biology is one such powerful biological tool now available to us. Genes can be reconfigured, not just in cells and cultures, but in living organisms. It is an opportunity not only to understand the different areas of biology, but also to manipulate those areas to improve human health.

Future innovations will be an amalgamation of these biological tools with physics and engineering. My particular interest is in using the different parts of biology synthetically to build things that, while not actually living themselves, use the components of living things.

> "Nature is brilliant at solving technical problems. Our role is to recognize nature's solution and adapt it to our needs."

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VALUE CREATION THROUGH SYNTHETIC BIOLOGY

In *The Age of Living Machines*, you talk about the convergence of biology and engineering. How do you see new value being created by the large-scale adoption of synthetic biology across industries?

There is a desperate and urgent need to scale the technologies we have available to us today in order to avoid being overtaken by the needs of an increasing global population. Advancements in physics, engineering, and life sciences have resulted in several interesting innovations in synthetic biology. For instance, a startup called Aquaporin[1] uses water-channel proteins[2] found in living cells to build water filters for use in residential settings and, hopefully, soon in industry. Nanotechnology has assisted the development of slow-release drugs[3], allowing controlled doses to be administered for diabetes, cancer therapies, etc. In another application, synthetic nanoparticles[4] can help for early detection of tumors or specific diseases by emitting signals in the urine.

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1 Aquaporin is a Danish biotech water-purification firm founded by Peter Holme Jensen, headquartered in Copenhagen.

2 US physician Peter Agre won the Nobel Prize in Chemistry in 2003 for the discovery of 'aquaporin' proteins, which allow water to flow in and out of living cells.

3 US chemical engineer Robert Langer is credited with the development of the technology that forms the basis for slow-release drugs.

4 MIT professor, inventor, and entrepreneur Sangeeta Bhatia is credited with designing the first synthetic nanoparticles.

THE ROLE OF SYNTHETIC BIOLOGY IN ACHIEVING SUSTAINABILITY GOALS

What role do you think synthetic biology can play in helping organizations become more sustainable?

My own view is that biological systems and parts are, by their very nature, sustainable. Synthetic biology constructs without contaminating the environment.

For example, usage of water-channel proteins for water purification is a step towards identifying sustainable solutions. Similarly, scientists have used genetically engineered viruses to build sustainable batteries. I believe using biology from the outset is likely to lessen the environmental impact more than when using chemistry alone.

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SYNTHETIC BIOLOGY: THE ETHICAL CONUNDRUM

How can governments, academics, and organizations work together to assuage ethical concerns around synthetic biology?

When gene engineering first emerged in the mid-1970s, scientists recognized the associated potential dangers. This led to the establishment of the Asilomar Conference[5], in which participants signed a pact to remain within clearly defined scientific boundaries. This constituted a remarkable collaborative commitment to protecting the world.

Cutting-edge biological research was previously limited to a small group of people within a small set of countries. Now, however, it is widespread. This does mean it may be difficult to achieve another Asilomar-like conference success, especially as we cannot even reach a consensus on existential issues such as nuclear arms. We need to set strongly enforced perimeters but, unfortunately, we do not have strong international agreement.

Are the dangers of synthetic biology greater than the dangers of climate pollution, nuclear war, and other existential crises? They are different, and, like current technologies, should be regulated to protect humanity and our ecosystem.

5 In February 1975, the International Congress on Recombinant DNA Molecules, popularly known as the Asilomar Conference, was held in California. Led by Paul Berg, David Baltimore, Sydney Brenner, Richard Roblin, and Maxine Singer, the conference attracted almost 140 attendees, including scientists, lawyers, journalists and government officials. It is often considered to have been the first step toward the formulation of public policies that address biohazards. https://www.nature.com/articles/455290a

What are your thoughts on the challenges around the application of gene engineering in life sciences?

We can't discuss gene engineering without raising the pluses and the minuses, which actually shift as you think about – and develop – them. We have identified the genes for some diseases, and we agree it is okay to eliminate those genes if that can be done safely. But what constraints should be placed on modifying embryos in terms of IQ, height, etc., once the associated genes are identified?

Similarly, genetic engineering of plants has gotten a bad name. Why would we not want a virus-resistant cassava to help solve hunger problems in third-world nations, for example? Or why would we not want to harvest more than 150 bushels of corn per acre, which would be a major lifesaver for many?

In gene engineering, it is important to think about what kind of organisms we are creating, the possibility of propagating them, and how to control their use.

"We can't discuss gene engineering without raising the pluses and the minuses, which actually shift as you think about – and develop -– them."

WOMEN IN SCIENCE

As the first woman and the first life scientist to become president of MIT, what do you see as the key to attracting more girls and young women to science?

In a perfect scientific world, gender would not be relevant – but we're not there yet. Besides the more evident limitations, there are also many more subtle barriers. For example, men often tend to group together, unconsciously leaving women out. This kind of self-segregation happens all the time and is a significant part of the problem. Such informal networks often convey information that travels around among men, with women left off the mailing list.

"We must encourage women all along the way but also provide opportunities for them to have fabulous experiences."

We must encourage women all along the way but also provide opportunities for them to have fabulous experiences. We need to give them the confidence to do unusual things, and to instill support for other pioneering women. Women must amplify each other's voice.

A recent MIT study showed that it is very rare for a woman to be part of the founding group of any company. We have started a program[6] to encourage women entrepreneurs to walk the path of company creation. It brings women into the entrepreneurial sphere, providing them with the encouragement and funding that allows them to get started. But, if you look at the numbers for venture-capital investments in companies, less than 4% of VC dollars go into women-founded companies, which means that it is just harder to get funding if you are a woman.

"LESS THAN 4% OF VC DOLLARS GO INTO WOMEN-FOUNDED COMPANIES."

6 Future Founders Initiative, a joint collaboration of MIT faculties, led by Dr. Sangeeta Bhatia, Dr. Susan Hockfield and Dr. Nancy Hopkins, to encourage female entrepreneurship, especially in biotech.

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