# INFINITE HEARTBEAT

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Kae Saotome was selected as the winner of the 2026 *Broad Street Scientific* Essay Contest. Her award included the opportunity to interview Felice Frankel, research scientist at the Massachusetts Institute of Technology in the Department of Chemical Engineering with additional support from Mechanical Engineering.

In a glass chamber filled with translucent red liquid, a single, delicate heart tissue the size of a walnut beats at a steady rate, capturing the whole world's attention. The 2025 World Expo, held in Osaka, Kansai, Japan, showcased the world's first "artificial heart" developed entirely from induced pluripotent stem cells (iPSCs)—living human cells (The Yomiuri Shimbun, 2025). This groundbreaking innovation attracted a plethora of visitors from around the world, eager to view the promising symbol of life.

By definition, iPSCs are cells initially extracted from adult somatic cells—body cells that are not reproductive cells—that are modified back to their original, embryonic stem cell-like state, in which the cells can differentiate or develop into any type of cell in the body again (UCLA BSCRC, n.d.). Initially produced in 2006 by the Yamanaka Lab at Kyoto University in Japan (Ye et al., 2013), iPSCs' ability to function as any specific body cell has expanded the scope of scientific research into treatments for chronic diseases, such as Parkinson's disease and diabetes.

Each year, it is reported that approximately 17.9 million people lose their lives globally from cardiovascular diseases (World Health Organization: WHO, 2019). Until recent years, treatments for such diseases had been largely limited to drug intake or a heart transplant, which highly depends on the amount of organ donor availability, making it detrimental for fast-progressing heart failures. With iPSCs, however, stem cells can successfully differentiate into essential cardiovascular cells such as cardiomyocytes, which are cardiac muscle cells responsible for beating the heart (Cho et al., 2021). These cardiomyocytes can be injected directly into the heart using a needle, replacing dysfunctional cardiac muscle cells and enhancing the heart's performance.

However, injected cells typically have low survival rates, with only 0.1% to 5% surviving inside the heart, lowering the efficacy of iPSC-derived cardiomyocytes. This has led to the development of an iPSC-based cardiac patch—a small, thin sheet the size of a postage stamp with millions of iPSCs grown on it—designed to be implanted directly onto the surface of the human heart. The structure of these patches allows for an increase in the cell-cell interaction of cardiomyocytes, leading to a significant increase in cell survival rates (Duan, 2020). Additionally, iPSC-based cardiac patches have demonstrated improved performance of the heart compared to the direct injection method. In a 2020 study, a group of female Lewis rats experiencing heart failure was implanted with cardiac patches on their left anterior descending artery, a crucial portion of the heart that supplies the whole heart muscle with oxygen-rich blood. After the 4-week observation period, the survival of the rats showed a striking result: 100% of the rats implanted with a cardiac patch survived, along with a significantly stabilized cardiac rhythm (Yeung et al., 2019).

The iPSCs' ability to differentiate into any human body cell provides endless applications for treating patients. For example, hospitals and transfusion centers in urgent need of blood can utilize iPSC-derived blood cells, alleviating the shortage of blood donor supplies. The nearly limitless supply of iPSCs that can be created also allows thousands of chemical compounds to be tested at once, helping scientists find new medical uses for pre-existing drugs.

In 1982, Jarvik-7, the first artificial heart made from aluminum and polyurethane materials, attracted global attention as it was implanted into a human patient for the first time in history (Khan & Jehangir, 2014). 43 years later, an artificial heart created entirely from living human cells was revealed to the public at the 2025 World Expo. With the discovery of iPSCs, artificial hearts can be engineered at scales never imagined before. Innovations such as the cardiac patch are just the beginning of an era in which cardiovascular diseases can be treated in a relatively safe and ethical way. There are still challenges that remain in making an iPSC-derived treatment method more accessible to patients, however. A major obstacle is that the production process is expensive, with costs ranging from 10,000 to 20,000 USD (Del Carmen Ortuño-Costela et al., 2019). Furthermore, it takes between 4 and 6 months for the iPSC to be ready for cell differentiation, minimizing the ease of accessibility for a larger population. Currently, iPSC production is also strictly regulated within a research laboratory; nonetheless, ongoing clinical trials are expected to make the process more approachable for the public. Regardless of the intrinsic obstacles that remain in utilizing iPSC technology, being able to introduce it to the public in the near future will undeniably advance a diverse number of fields in healthcare and medicine.

The gently pulsing iPSC heart showcased at Osaka's World Expo powerfully portrayed life itself and the scientific progress of mankind. Osaka University's Emeritus Professor Yoshiki Sawa, the executive producer of the iPSC heart's display pavilion, hoped that the innovation would inspire children to reshape their future and to deeply cherish the meaning of life. As Dr. Yoshiki Sawa stated, "Seeing a living, beating heart up close will likely be a first for many people. I hope they feel the presence of life—and a sense of gratitude" (Fujii, 2025).

Today, inventions that felt like a dream decades ago are a reality, and it is our imagination that truly shapes and drives the world. With a single heartbeat, an infinite number of imaginations and ideas arise, every one of them capable of setting in motion the future's rhythm.

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