Scientists develop the world's first reproducing robots

Over the years, technology has developed in ways we could never have envisioned. Humans first thought of autonomous machines for household tasks decades ago, with widespread industrial uses at present. The foundations for the invention of robots were laid following the Industrial Revolution, although the concept of robots can be traced back to ancient history. The discovery of robots represents a watershed moment in human history. It is a well thought out progression from a single-task machine to a digitally labelled artificial servant. In general, robots are a blend of science fiction and real-world engineering technology. Those like the Egyptian water clock have progressed through numerous stages of development, such as progress, design and variations, to the state-of-the-art robots based on artificial intelligence (AI) principles. Following the Egyptian clocks, Archytas constructed an extraordinary robot, a bird-like mechanism that could be propelled into the atmosphere using steam. Leonardo Da Vinci's drawings of the robot, analytical engine and automata have helped begin a new era in robotics history. In the 1950s, the first industrial robots were developed. The growing need for autonomous machines in the service industry has given rise to the expanding robotics field.

With the AI revolution, the boundary between living beings and machines has become narrow. Recently, the technology has made a huge stride by developing living robots that can reproduce. In 2020, scientists from the University of Vermont, Tufts University and Harvard University's Wyss Institute for Biologically Inspired Engineering, USA, repurposed dead cells and used stem cells from the embryos of the African clawed frog to create the world's first 'living' robots known as 'Xenobots', the name coined after the scientific name of their progenitor *Xenopus laevis*. The xenobots are less than a millimetre wide. They can move around and collaborate, as well as heal themselves after lacerations. And now according to the latest study[1], they can reproduce as well, though not in the conventional sense.

The xenobots perform 'kinetic replication', which occurs at the molecular level, but has never been identified before in complete cells or organisms. To enhance the capacity of xenobots to replicate, scientists utilized AI to examine billions of possible body configurations. They predicted which xenobot shapes will produce the most offspring using an evolutionary algorithm. The best form turned out to be C-shaped that resembled Pac-Man, the popular video game. When the scientists split spherical xenobots into C-shapes, the modified xenobots reproduced up to four generations, more than doubling the number of generations formed by spherical xenobot parents. When put in a laboratory dish, a xenobot located and accumulated hundreds of stem cells in its mouth, which it then turned into new xenobots within a few days. Stem cells are unspecialized cells with the capacity to change into several cell types. The xenobots were developed by scraping live stem cells from frog embryos and incubating them. No genetic modification was involved.

The scientists discovered that the xenobots, which were originally spherical in shape and consisted of around 3000 cells, could proliferate within five days under the right laboratory conditions. These behave as flexible oars, carrying the xenobots ahead in a corkscrew pattern. Further research indicated that groups of 12 xenobots kept in a dish containing around 60,000 single cells appeared to collaborate to generate either one or two new generations. A single xenobot parent could start a pile, and then a second parent, by chance, can add more cells to that pile, and so on, resulting in the offspring. On an average, each cycle of replication produce a little smaller xenobot progeny. Offspring with fewer than 50 cells gradually lost their ability to move and replicate. The new generation of xenobots were quicker and better than their predecessors, and they could also record data. The capacity of a robot to store information may be utilized to research and control its behaviour. Scientists hope that these single-cell robots will help them get a better understanding of evolution and data processing in living organisms. Metabolism is a blessing for biological robots. They have the capacity to absorb and break down substances, which opens a whole new area for synthetic biology.

The finding has been significant in the realm of biology and has tremendous potential for regenerative medicine. This may be exciting for some individuals while others may be concerned, by the prospect of self-replicating biotechnology. Currently, experts reveal that xenobots serve no practical role for humanity, but they enable scientists to learn how cells work together to form a complex organism. They might also help explain certain diseases like cancer. Thus, they might act as a catalyst for medical advancement. Scientists are presently studying how xenobots can benefit humans. Also, if xenobots are developed from human cells instead of frog cells, whether they can be developed into an effective medical device that can be transplanted into humans without inducing an immune reaction. Scientists are striving to learn more about this technique called replication. The environment and technology are evolving at a rapid pace. It is critical for society as a whole that they comprehend how this works.

The English philosopher Francis Bacon had said centuries ago that certain studies are too dangerous to conduct. Although the scientific community does not believe this is the case with xenobots, it may be so in future. The use of xenobots for hostile purposes, as well as the use of AI to design DNA sequences that would result in intentionally dangerous synthetic beings is prohibited by the United Nations' Biological Weapons Convention, as well as the 1925 Geneva Protocol and Chemical Weapons Convention. However, application of these inventions outside of warfare is less clearly restricted. These developments, which include AI, robots and biology, are difficult to control due to their interdisciplinary nature. However, it is necessary to consider potentially hazardous uses. There is an important precedent here. The National Academies of Science and Medicine in the US presented a joint report on the growing science of human genome editing in 2017. It highlighted the parameters under which scientists should be permitted to modify human DNA in ways that allow the alterations to be handed down to future generations. It suggested that this work be confined to 'compelling purposes of treating or preventing severe disease or disability', and also only under strict supervision. Human gene editing is currently legal in the US and the UK under certain conditions. However, creating new organisms that could self-replicate is beyond the reach of these findings.

1. Kreigman, S., Blackiston, D., Levin, M. and Bongard, J., *Proc. Natl. Acad. Sci.*, 2021; doi:10.1073/pnas.2112672118.

Arjun R. Krishnan, Science Writing Fellow, Current Science.
e-mail: arjunkriz92@gmail.com