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EDITORIAL

Xenobots - the living robots - are here

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ABSTRACT

The modern age of exciting discoveries almost on a daily basis now offers an awesome breakthrough with wide implications for health and science in general. The creation of living robots, or xenobots, unparalleled in human history, allows us to control living cells effectively and program them to do as we would like them to perform. This editorial explores this futuristic technology and its possible benefits for life in general.

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INTRODUCTION

The report in November 2021 of the first ever living robots that could also reproduce, caused a sensation in the world of synthetic biology and artificial intelligence.[1] Developed in 2020 by a team of scientists from the University of Vermont, Tufts University, and the Wyss Institute at Harvard University, all three from the USA, caused a ripple that is still reverberating with the endless possibilities that this breakthrough work offers.

The authors published their seminal work in the prestigious journal *Proceedings of the National Academy of Sciences* (PNAS), elaborating that skin forming cells from frog embryos (*Xenopus laevis,* hence the name Xenobots) were used for the experiment by liberating them from their natural environment and their inherent genetic tendency to differentiate into skin cells.[2] Under the laboratory conditions, these cells were programmed to grow into spheroids, displayed the ability to move, and still later, developed the ability to reproduce themselves by interacting with other stem cells in the environment – this activity, not having been observed previously in any living system, was appropriately named as "Kinematic Replication".

By itself a fascinating phenomenon, the use of Artificial Intelligence (AI) further enhanced the Kinematic Replication potential of these organoids. Among the most important of such uses of AI was the determination of optimum shapes of the progenitor organoids that would enhance the replication efficiency. After multiple simulations, it was discovered that a semitoroid shape (resembling the Pac-Man game character) of the progenitor cells could enhance the diameters of offspring by 149% and the replicative system by 250%. Moreover, AI generated changes to the terrain on which the cells grew and replicated also enhanced the replication potential.

The organoids therefore continued to replicate and reproduce themselves as long as nascent stem cells were provided in the environment. The stem cells were ingested through the organoid "mouths" and used for growth and replication. The process could be halted if new stem cells were not supplied, thereby indicating a substrate dependent control of Kinematic Replication. Moreover, the organoids displayed the capability of exponential propagation and would continue to produce offspring as long as substrate supply was maintained.

Implications of this observed behavior could date back to prehistoric origins of life, wherein molecules such as peptides could self-assemble and propagate ultimately to give rise to biological systems and cells capable of the same behavior. Coming to more modern times, such systems would allow a deeper understanding and possibly better control of the process of cellular reproduction and growth, thereby providing a great advance for further work on control of neoplastic proliferation. Furthermore, studies of the cell-to-cell signaling systems that produced such biological cohesion and abilities would be a gold mine of knowledge.

A future area for research in healthcare would be the creation of injectable living cellular robots guided for specific work inside the body through external controlling mechanisms. This could see the development of xenobots for chipping away at atherosclerotic plaques in blood vessels, as well as directed drug delivery to cancer cells or any other location in the body. Perhaps organs could be repaired *in situ* by specific transformed replication, similar to the regenerative capacity of the human liver, so that injured or damaged tissues can be repaired and replaced.

Further ongoing developments in this field include the incorporation of different biological tissues to create Xenobots.[3] This allows further properties to be exploited, e.g., a combination of frog skin cells and contractile heart muscle cells provided the ability of more advanced movements that could be controlled and directed towards specific targets. A similar feature was developed by using ciliated cells that provided directed locomotion.

Currently developed models of xenobots, named Xenobot 2.0 offer many more advanced features compared to their predecessors.[4] They do not need additional tissues to help them with locomotion and other tasks, are much more programmable and controllable, and can even incorporate memory systems (based on mRNA) to remember assigned tasks. They have been shown to perform as microscopic garbage collectors after relevant directions were given. Moreover, they can heal themselves and have longer lifespans.

It remains to be seen how these biorobots will be accommodated in the world of science in future, and what possible uses they might be put to. Perhaps there would be ethical and legal issues to be tackled before actual commercial or medical uses are brought about. In any case, the discovery has opened up a whole new area for future research and the possibilities of further and deeper interaction with cells and biological systems. As such, it would mean a whole new mode of communications with living organisms and systems that hopefully may enable life on earth to evolve into a better future for the planet.

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