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A Bright Future for Extrusion-based 3D Bioprinting

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Bioprinting is science fiction come to life. Although 3D bioprinting was first demonstrated nearly 40 years ago in 1986, it is still considered relatively new technology. There's no doubt that bioprinting will change the face of regenerative medicine and cancer research, so why is it virtually unheard of by the general public? The truth is that most people haven't been given a comprehensive explanation of what bioprinting is or how it could drastically change their lives in the near future. To understand why 3D bioprinting is one of the most promising up-and-coming forms of experimental testing, one has to understand the science behind it.

Bioprinting is an emerging technology with the primary purpose of fabricating human tissue by 3D printing it. The process involves a mixture of one or multiple types of cells and hydrogel, an artificial replacement for the extracellular matrix (ECM) that eventually forms once the bioprinted material has been inserted. This mixture, called bioink, can be shaped into tissue through multiple methods, the cheapest and most common method being extrusion (Gungor-Ozkerim et al. 2018). Extrusion-based bioprinting forces the bioink out of a nozzle using pneumatic pressure to form a continuous filament approximately the thickness of a strand of hair. The filament is slowly layered, in a manner not unlike 3D printing using plastic, into the desired shape. Inkjet-based bioprinting, a higher resolution form of extrusion-based bioprinting, uses a small burst of pressure to force a precise droplet of bioink out of the nozzle (Panja et al. 2022). Though bioprinted tissue can be used to regenerate any body part in theory, researchers are limited to using bioink that can "accurately represent the tissue architecture needed to restore organ function post-printing" (Daly et al. 2021). And though extrusion is one of the most advantageous bioprinting technologies, the challenge of developing bioinks with "suitable rheological behavior" (similar to the consistency of toothpaste) and sufficient organ cell density is a disadvantage unique to the method. Because of the nature of 3D bioprinting, the technology is best suited for flat or hollow forms. Once the bioink has been printed, it must be stabilized by a cross-linking agent that strengthens the bioink's polymers and helps the artificial tissue retain its structure.

3D bioprinting is, without a doubt, one of the most promising forms of experimental testing on the frontier of modern medicine. Cancer researchers have been taking advantage of the complexity of 3D bioprinted "mini-brain model[s]", compared to much simpler traditional culture methods, to study how glioblastoma interacts with endothelial cells (Daly et al. 2021). Scientists studying tubular diseases modeled tiny, winding renal kidney tubules in "tight juxtaposition along non-linear paths" by 3D bioprinting the tubules in sacrificial (or self-eroding) bioink, and casting them in hydrogel (Daly et al. 2021). Once the hydrogel solidified, the scientists simply flushed the bioink out, revealing perfusable microchannels. In an even more exciting trial, Freeform Reversible Embedding of Suspended Hydrogels (or FRESH) 3D bioprinting enabled scientists to print extremely delicate structures like mini, "organ-scale neonatal heart[s]" by supporting the "fragile cardiomyocyte-laden collagen bioinks" with sacrificial gel. After just fourteen days the heart could spontaneously 'beat' (Daly et al. 2021).

From an ethical standpoint, bioprinting could eliminate the moral dilemma of animal testing for pharmaceutical scientists by providing them with an alternative that will more accurately replicate the human condition and thus the effects of the drug they are developing on humans. Outside of the lab, bioprinted tissue can reproduce the taste and texture of animal proteins without the negative environmental impact of livestock emissions or the risk of parasitic infections from improperly prepared meat. Bioprinted tissue could be the answer to a more ethical, easily accessible source of protein that environmentalists and scientists alike are looking for.

Particularly promising, though, is bioprinting's massive potential to relieve the global organ shortage. Entire organs can be fabricated using bioink with blank stem cells and, if made from the patient's own cells, greatly reduce the chance that their immune system will reject it. Though there is yet to be a 3D bioprinted heart transplant, less complicated organs like skin and kidneys have already been successfully transplanted. The ability to manufacture perfect matches for patients awaiting an organ transplant could eliminate the time sensitive and costly aspect of organ donorship as well as the potential moral or religious complications of accepting an organ from another human. Rapid developments in the technology have left little time for policymakers to set proper guidelines on 3D bioprinting and transplantation. "[T]aking into consideration the cultural and religious view of its population. . .", says engineer S. Vijayavenkataraman, "might be a good starting point" (Vijayavenkataraman et al. 2016).

Before I'd properly researched bioprinting, I had imagined it to be– though interesting– some very nascent, obscure technology that would never affect me. In reality, 3D bioprinting holds relevant and exciting potential for current generations, especially in the latest scientific scrambles to slow aging, meet the overwhelming demand for organ donors, and provide alternative protein sources to the world. Aside from policy-making concerns, anyone invested in the future of regenerative medicine, cancer research, and environmentally sustainable agriculture should commit to keeping the bioprinted treatment and research accessible to the general public, especially as the price of bioprinting technology decreases.

Works Cited

"3D Bioprinting Is Medicines Next Frontier | Sam Wadsworth | TEDxEastVan." *Youtube*, uploaded by Tedx Talks, 8 June 2016, www.youtube.com/watch?v=YHi2IH2SgJI. Accessed 6 Mar. 2023.

"3D Organ Bioprinting Gets a Breath of Fresh Air." *Department of Bioengineering*, U of Washington, 2 May 2019, bioe.uw.edu/3d-organ-bioprinting-gets-a-breath-of-fresh-air/. Accessed 6 Mar. 2023.

Aydin, Levent, et al. *A Universal Self-eroding Sacrificial Bioink That Enables Bioprinting at Room Temperature*. 20 Mar. 2020. *Wiley Online Library*, https://doi.org/10.1002/pat.4892. Accessed 6 Mar. 2023.

Daly, Andrew C., et al. *Bioprinting for the Biologist*. CellPress, 7 Jan. 2021. *ScienceDirect*, https://doi.org/10.1016/j.cell.2020.12.002. Accessed 6 Mar. 2023.

Fuest, Matthias, et al. *Prospects and Challenges of Translational Corneal Bioprinting*. 6 July 2020. MDPI, https://doi.org/10.3390/bioengineering7030071. Accessed 6 Mar. 2023.

Gungor-Ozkerim, P. Selcan, et al. "Bioinks for 3D Bioprinting: An Overview." *Royal Society of Chemistry*, 2018, pubs.rsc.org/en/content/articlehtml/2018/bm/c7bm00765e. Accessed 6 Mar. 2023.

Panja, Nabanita et al. “3D Bioprinting of Human Hollow Organs.” AAPS PharmSciTech vol. 23,5 139. 10 May. 2022, doi:10.1208/s12249-022-02279-9

Patel, Prachi. *The Path to Printed Body Parts*. PubMed Central, 19 Sept. 2016. *National Library of Medicine*, https://doi.org/10.1021/

acscentsci.6b00269. Accessed 6 Mar. 2023.

Vijayavenkataraman, S., et al. *3D Bioprinting – An Ethical, Legal and Social Aspects (ELSA) Framework*. Elsevier, 2016. *ScienceDirect*, https://doi.org/10.1016/j.bprint.2016.08.001. Accessed 6 Mar. 2023.

https://www.sciencedirect.com/science/article/pii/S009286742031624X#fig3

https://pubs.rsc.org/en/content/articlehtml/2018/bm/c7bm00765e

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9088731/

https://bioe.uw.edu/3d-organ-bioprinting-gets-a-breath-of-fresh-air/

https://www.youtube.com/watch?v=YHi2IH2SgJI

https://onlinelibrary.wiley.com/doi/abs/10.1002/pat.4892

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5043457/

https://www.sciencedirect.com/science/article/pii/S2405886616300021

https://www.mdpi.com/2306-5354/7/3/71