3-D Bio-Printing

Part of: GS-III- S&T (PT-MAINS-PERSONALITY TEST)

The development of 3D bio-printers has raised the prospects of making tissues and organs in a more affordable way and consistent way. Bangalore based start-up Next Big Innovation Lab has made human skin with its own 3D bio-printer using 3D bio-printing with a secret bio-ink.

History of bio-printing

Creation of human skin in a lab for commercial use dates back to 1993 when MatTek, a company founded by two chemical engineering professors at MIT, launched Epiderm. They took live tissue cells from cosmetic surgeries and circumcisions, and then cultured them in petri dishes to produce skin. EpiDerm is a proven in vitro model system for chemical, pharmaceutical and skin care product testing.

- **Bio-printing** is an additive manufacturing process where biomaterials such as cells and growth factors are combined to create tissue-like structures that imitate natural tissues.
  - A material known as **bio-ink** is used to create these structures in a layer-by-layer manner.
- **Bio-ink**: Bio-ink is a combination of living cells and a compatible base, like collagen, gelatine, hyaluronan, silk, alginate or nanocellulos. A compatible base provides cells with scaffolding to grow on and nutriment to survive on. The complete substance is based on the patient and is function-specific.

Next Big Innovation Lab (NBIL) case: The NBIL has made human skin with its own 3D bio-printer using 3D bio-printing with a secret bio-ink. It has filed for patents related to its 3D bio-printing process and its bio-ink formulation is a trade secret. Using its internally developed 3D bio-printer gives NBIL a cost advantage.

The process of bio-printing

- **Similar to conventional 3D printing**: Here a digital model becomes a physical 3D object layer-by-layer. However, a living cell suspension is utilized instead of a thermoplastic or a resin.
- **Caution**: In order to optimize cell viability and achieve a printing resolution adequate for a correct cell-matrix structure, it’s necessary to maintain sterile printing conditions. This ensures accuracy in complex tissues, requisite cell-to-cell distances, and correct output.
- **Key steps in bio-printing**: Several bio-printing methods exist, based on extrusion, inkjet, acoustic, or laser technologies. But the process principally involves **preparation, printing, maturation, and application** which can essentially be summarized into **three key steps**:
  1. **Pre bio-printing** involves creating the digital model that the printer will produce. The technologies used are computed tomography (CT) and magnetic resonance imaging (MRI) scans. The 3D imaging should provide a perfect fit of the tissue. Further, 3D modelling is done where the blueprint includes a layer-by-layer instruction in high detail.
  2. **Bio-printing** is the actual printing process, where bio-ink is placed in a printer
cartridge and deposition takes place based on the digital model. This process involves depositing the bio-ink layer-by-layer, where each layer has a thickness of 0.5 mm or less.

3. **Post bio-printing** is the mechanical and chemical stimulation of printed parts so as to create stable structures for the biological material. As deposition takes place, the layer starts as a viscous liquid and solidifies to hold its shape. This happens as more layers are continuously deposited. The process of blending and solidification is known as crosslinking and may be aided by UV light, specific chemicals, or heat (also typically delivered via a UV light source).

**Application**

- **Medicine and Bio-engineering:** The technique is widely applicable in fields of medicine and bioengineering. Recently, the technology has even made advancements in the production of cartilage tissue for use in reconstruction and regeneration.
  - The process can eradicate the need of organ donation and transplantation.
  - While *organ replacement* is the main objective, but *tissue repair* is also possible in the meantime.
  - With bio-ink, it’s much easier to **solve problems on a patient-specific level**, promoting simpler operations.
  - Bone tissue regeneration as well as prosthetics and dental applications.

- **Pharmaceutical testing and reduced need for animal trials:** The bio-printed tissue-like structures mimic the actual micro- and macro-environment of human tissues and organs. This is critical in drug testing and clinical trials, with potential, for example, to drastically reduce the need for animal trials.
  - Treatment for diseases can be tested using artificially affected tissues.
  - This is a more cost-effective and ethical option.

- **Cosmetic surgery:** Cosmetic surgery, particularly plastic surgery and skin grafting, also benefits from this technology. Victims of burns and other wounds could get relief from its commercial availability, once it is developed further to be good enough for grafting.

**Concerns**

- **Regulatory concerns:** The future of 3D bio-printed tissues and organs depend on regulatory clearances and getting the technology right.

- **Moral and ethical concern:** The entire process is also criticized from a moral and ethical perspective.

- **Hype:** Many new developments are over-hyped as the ultimate and ready-to-use breakthroughs in the field of 3D bio-printing, when in fact there are many unsolved problems in tissue engineering before complex organs like the heart, kidney and liver can be bio-printed.

- **Vasculature:** The vasculature—network of blood vessels that feeds the organ—is still a challenge. The vasculature still has to be developed to allow lab skin to integrate with the human body’s blood vessels.

Stem cell engineering to grow all the cells of an organ in a personalised way to avoid rejection by the recipient’s immune system is another challenge. Researchers still have to ensure that a lab organ will work with all the other organs in a human body.