

A close-up photograph of a 3D printer nozzle extruding a red filament into a glass vial containing a red liquid. The nozzle is positioned at the top center, and the filament is being deposited into the vial. The background is a blurred laboratory setting.

# 3D printing and personalized medicine in Tissue Engineering

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# Outline

- **Tissue Engineering (TE)**
- **Scaffolds in TE and their manufacturing**
- **3D printing techniques and their classifications**
- **Personalized medicine**
- **Personalized medicine in TE & 3D printing**

# Definition of TE

- Trauma, diseases or congenital abnormalities sometime cause a portion of or a whole tissue requires repair.
- **Vacanti & Langer:**

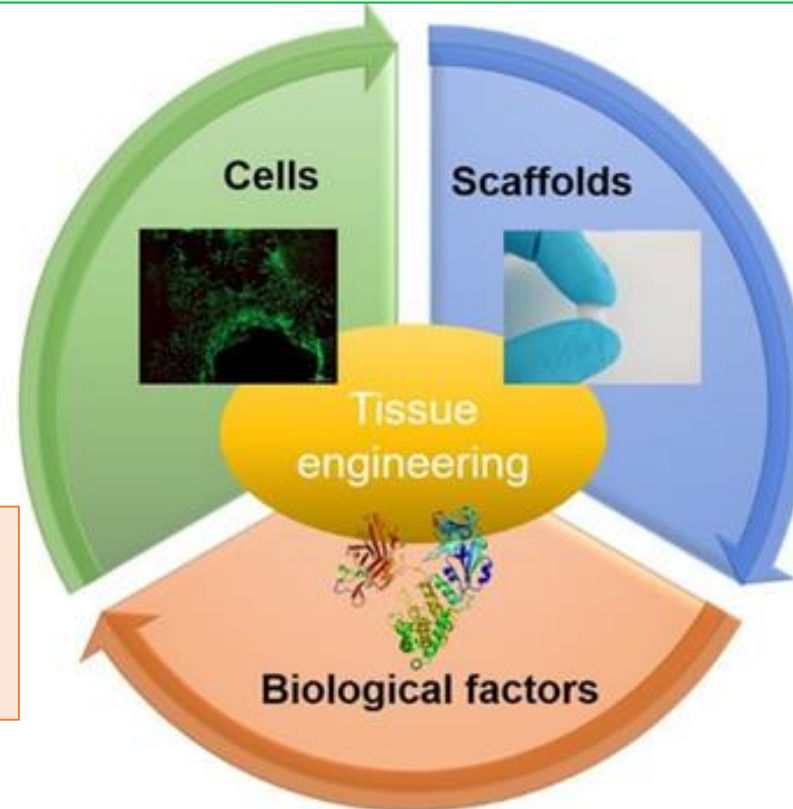


*“A combination of the principles & methods of **life sciences** with that of **engineering**, to develop materials & methods to **repair damaged or diseased tissues**, & to **create tissue replacements**”*

# Components of TE

Scaffolds provide cells with substrate for growth and mechanical integrity post implantation

- ❖ Autologous
- ❖ Heterologous
- ❖ Stem cells
- ❖ Differentiated cells



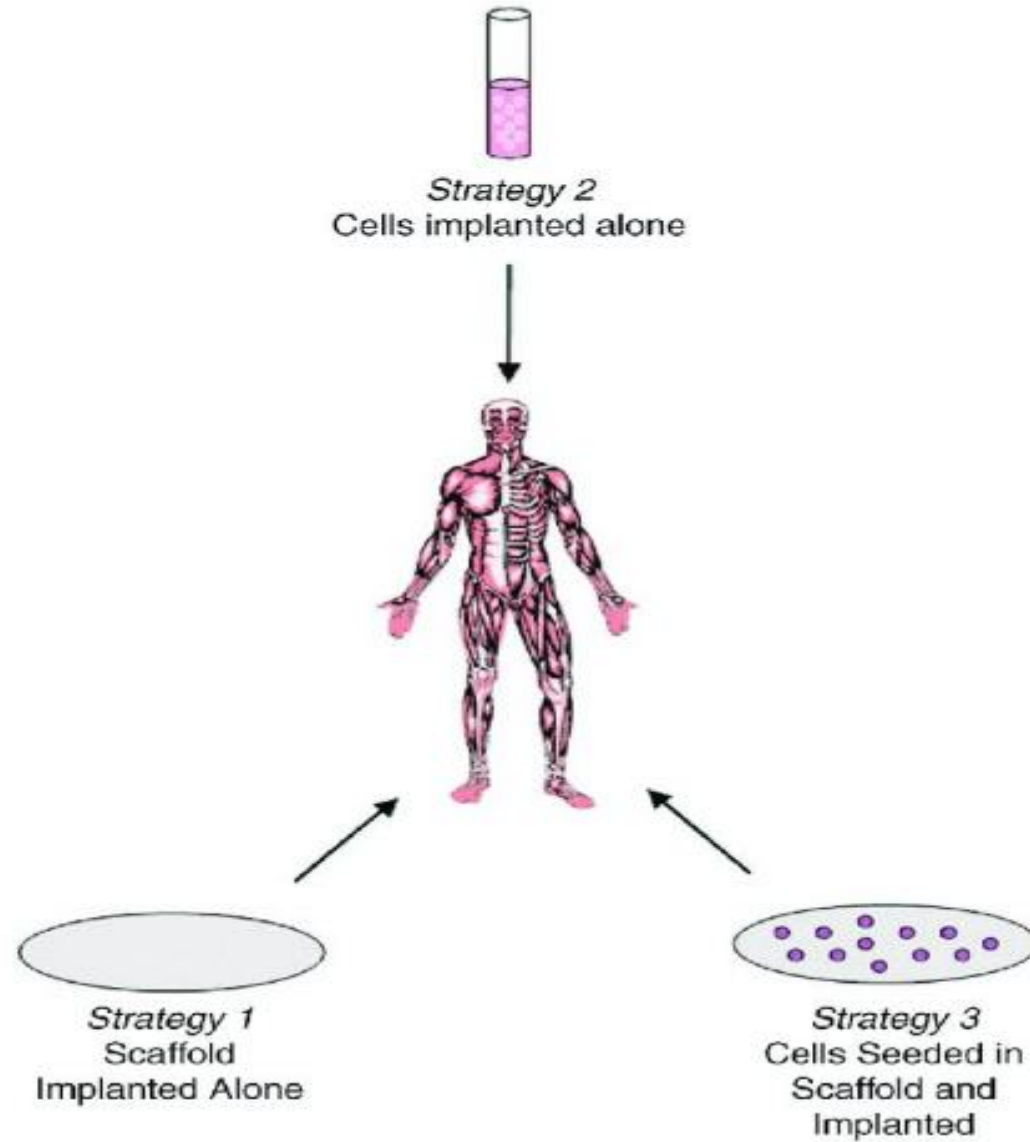
- ❖ Synthetic
- ❖ Natural
- ❖ Metals, ceramic, polymer, composites
- ❖ Foam, fibers, gels, films

Biological factors induce cell proliferation, dedifferentiation and metabolic activity

Scaffolds carry biological factors to induce or enhance repair in vivo or act as a drug delivery system

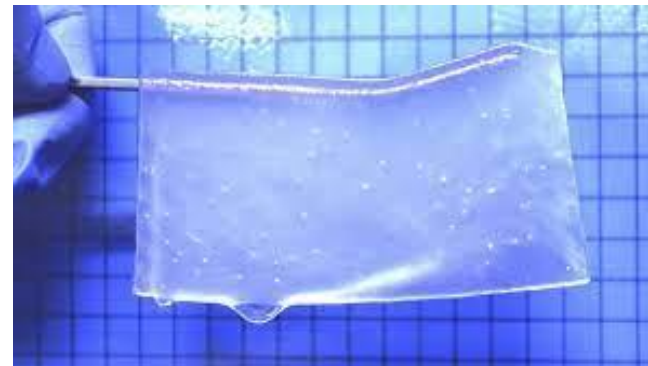
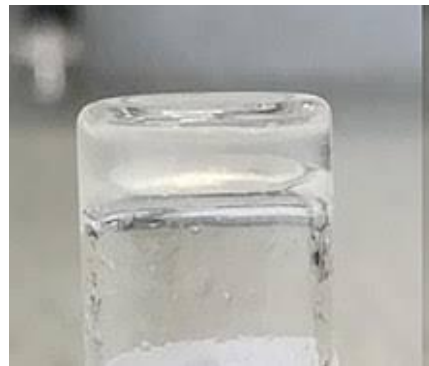
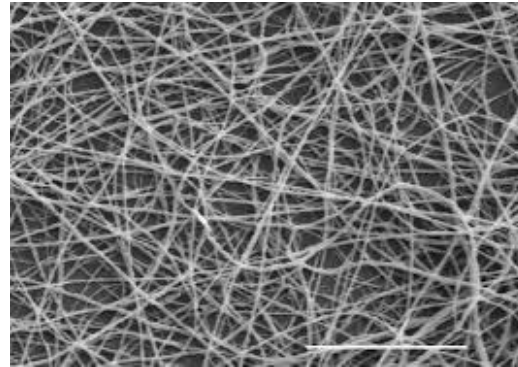
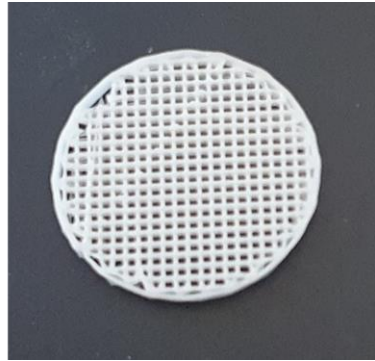
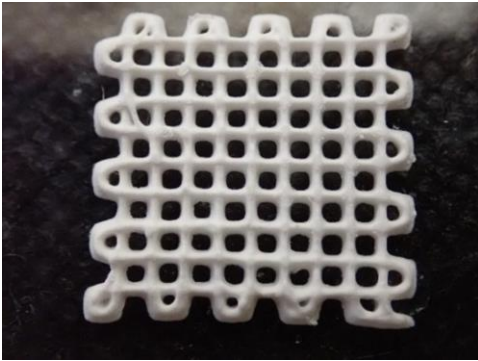
- ❖ Growth factors
- ❖ Proteins
- ❖ Extracellular vesicles
- ❖ iRNA
- ❖ Drug

# Strategies in TE

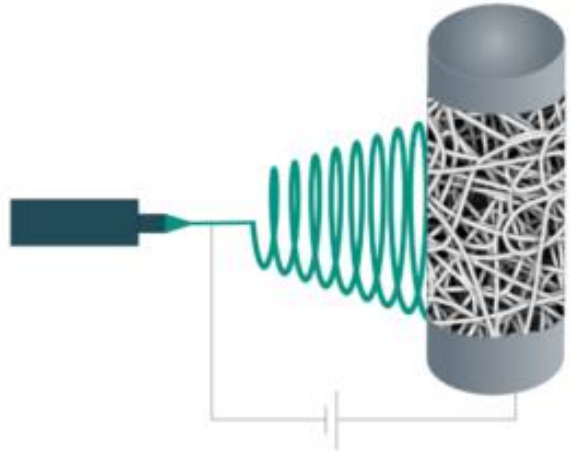


# Scaffolds

- Are 3D structures, usually porous, used for new tissue regeneration and made up of biomaterials.



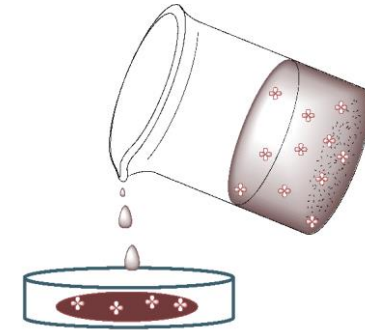
# Scaffold manufacturing approaches



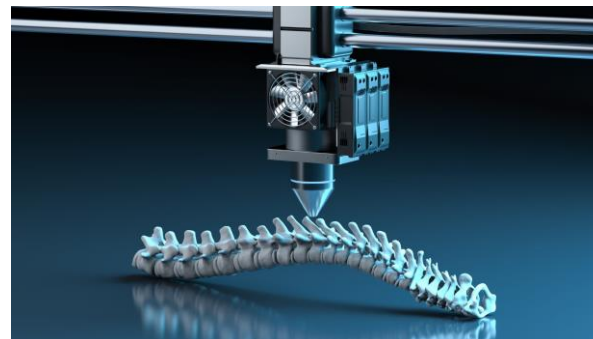
**Electrospinning**



**Freeze drying**



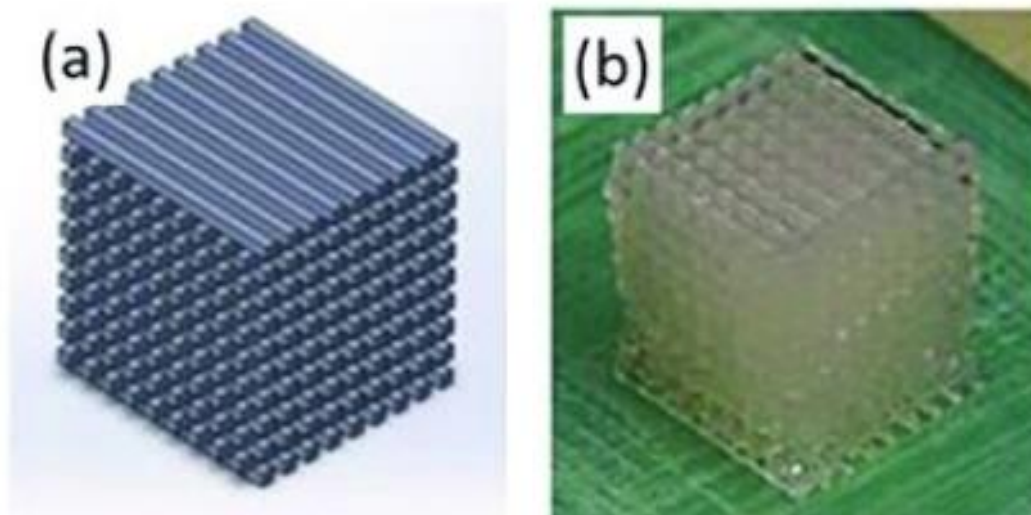
**Casting**



**3D printing**

## 3D printing or Additive manufacturing (AM)

- The physical objects are built **layer-by-layer** through the continuous addition of material, based on **a computer model**.



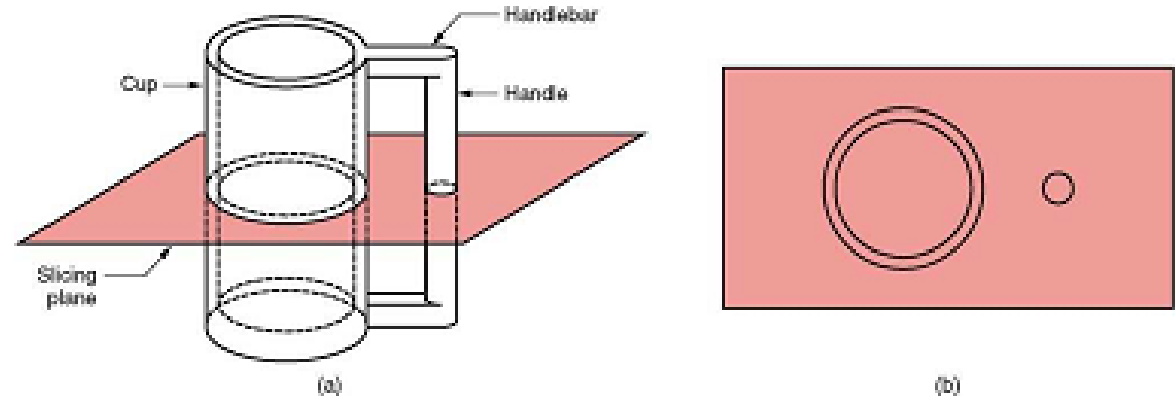
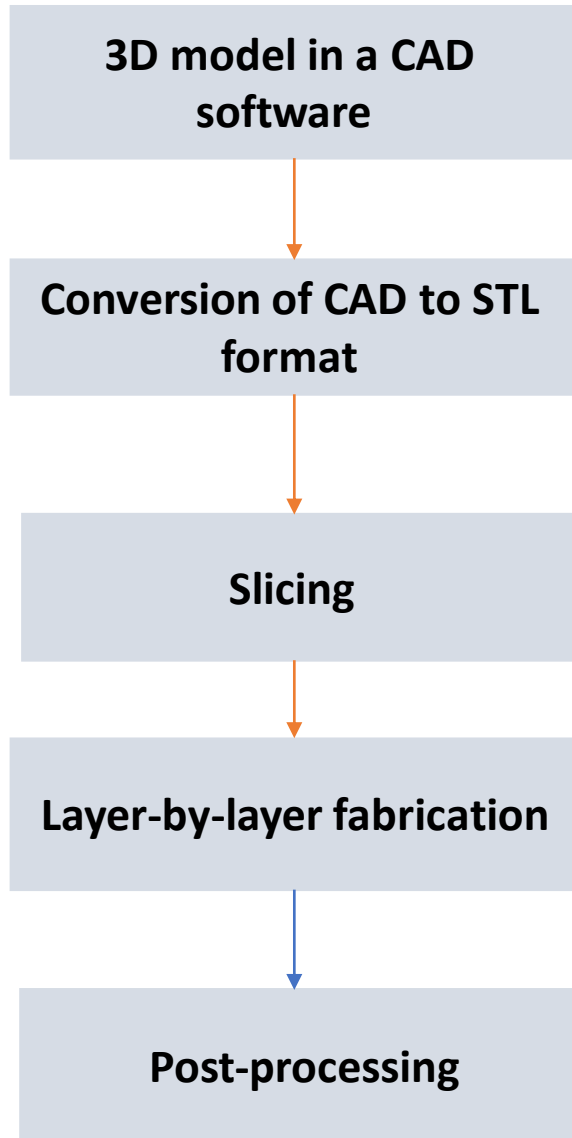
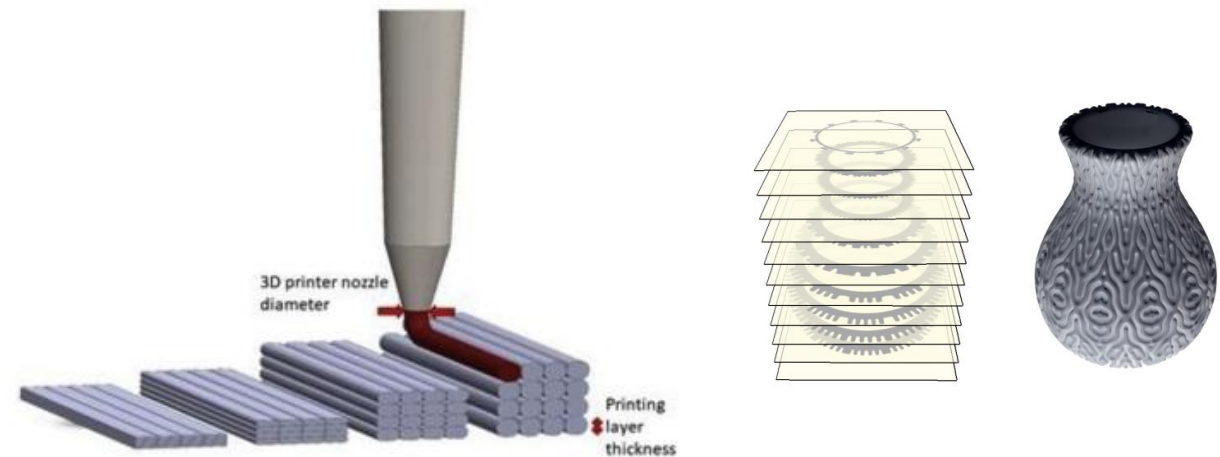


Figure above: Conversion of a solid model of an object into layers (only one layer is shown)

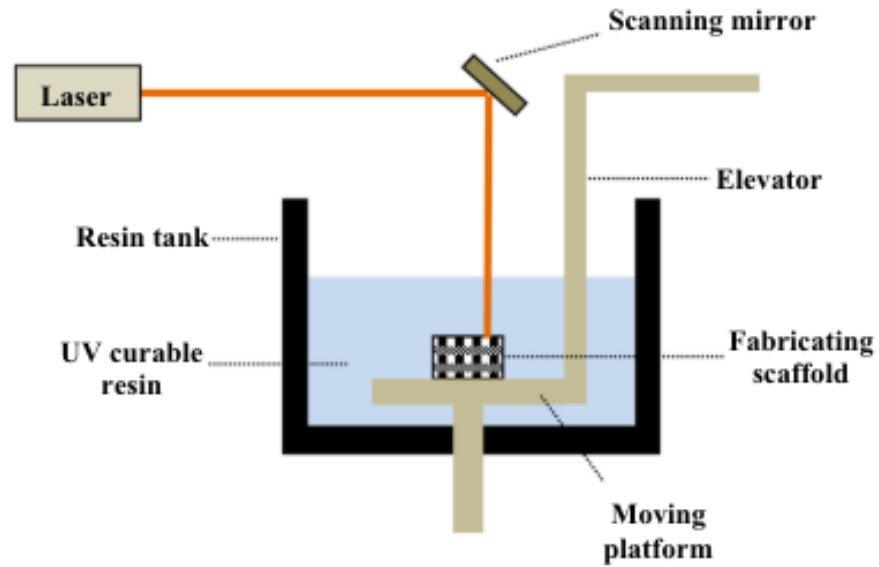


# Different types of 3D printing technologies

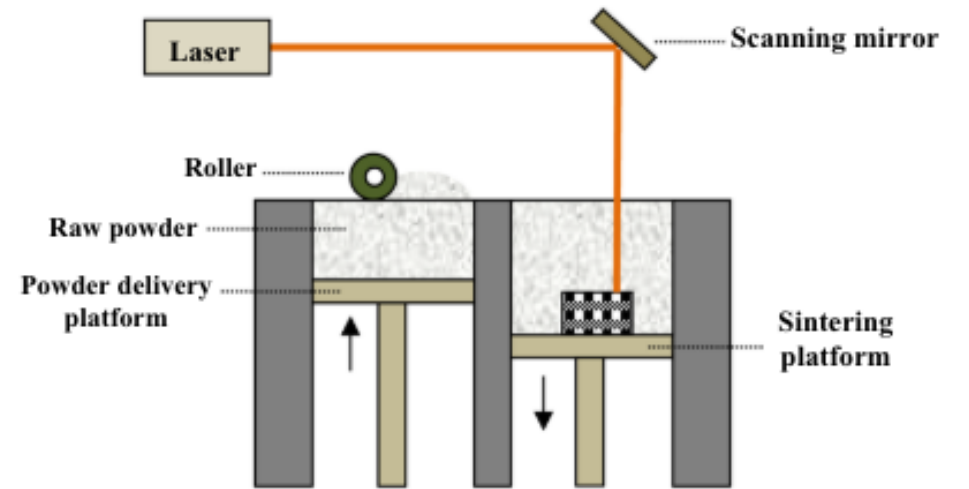
The 3D printing machines, based on the *stimulation used for integrating matter*:

- **Laser-based** 3D printing technologies
- **Extrusion-based** 3D printing technologies
- **Ink-based** 3D printing technologies

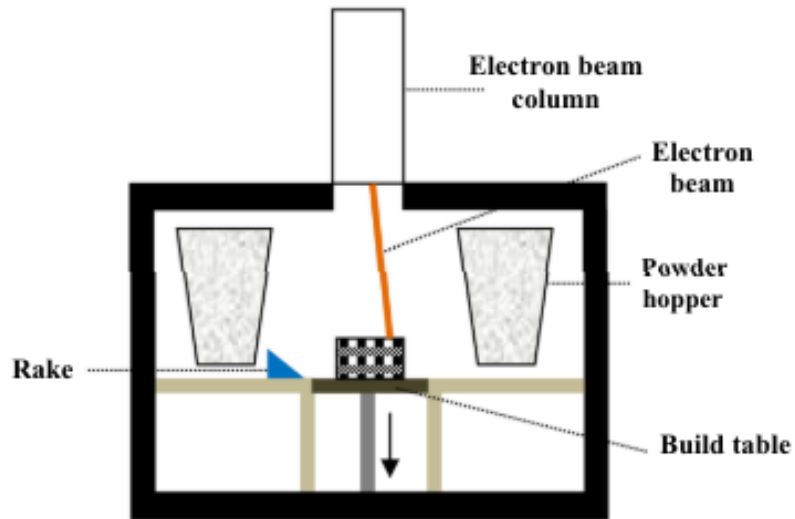
laser stimulation  
to bond either  
material  
powders or fluid  
medium



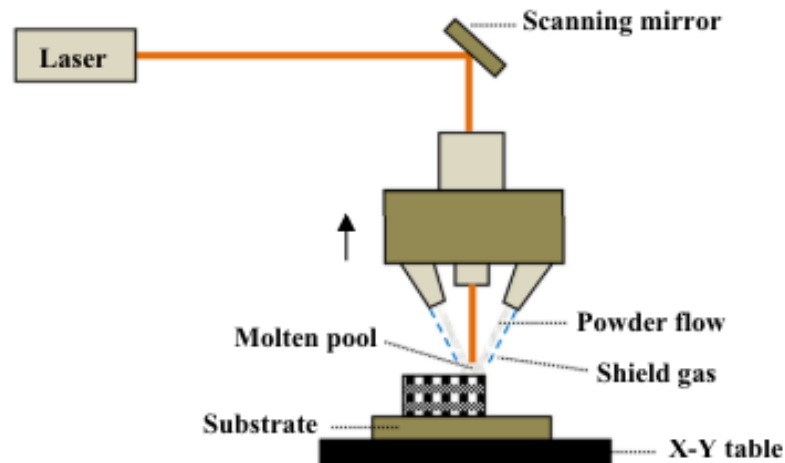
SLA



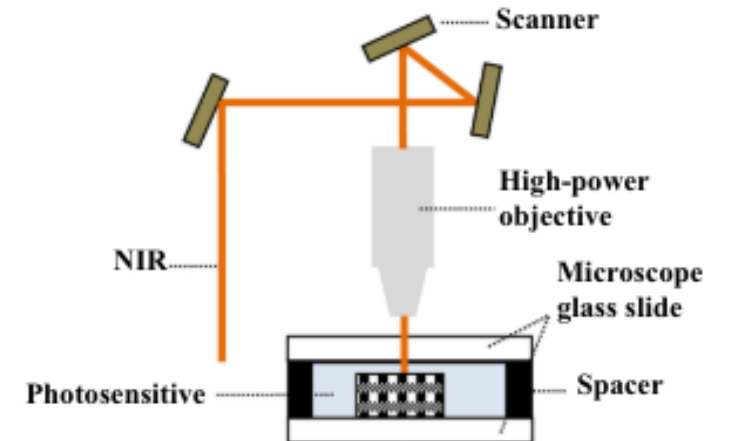
SLS/ SLM



EBM

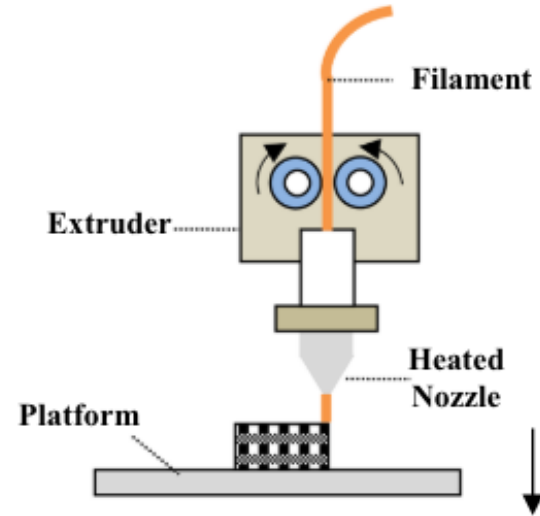


LENS

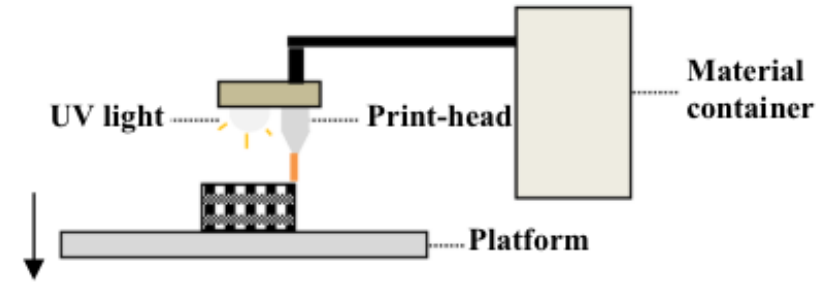


2PP

molten materials  
are cooled and  
physically bond  
or further  
solidified by UV  
stimulation

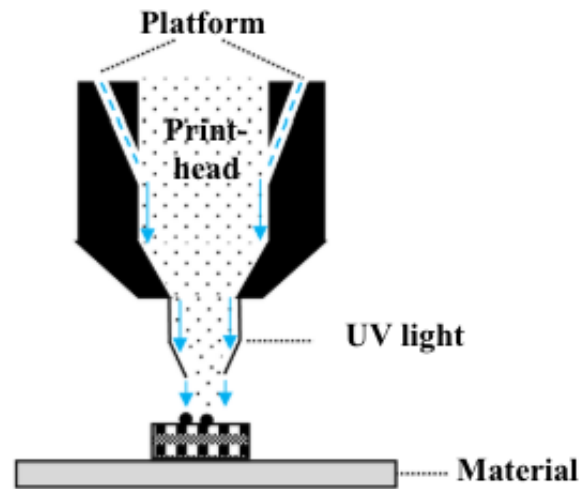


FDM

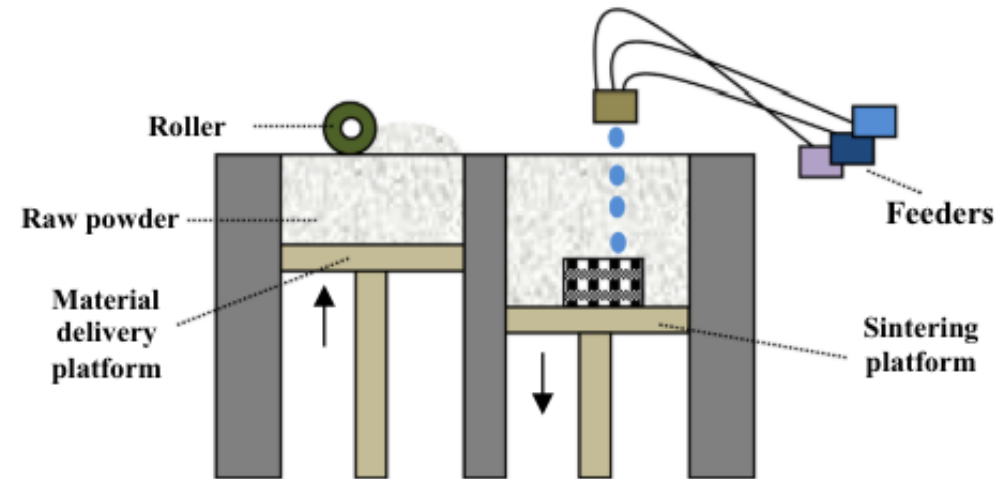


MJ

print liquid or  
aerosol chemical  
binders to  
chemically bond  
the material  
powders  
together



AJP

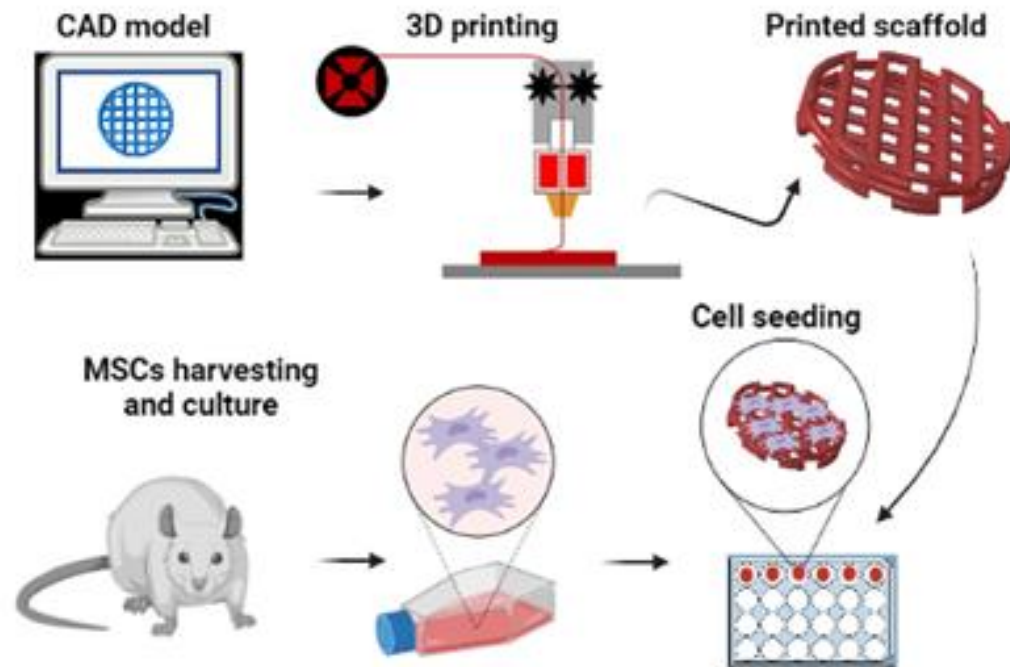


IJP

# Different types of 3D printing

## ➤ 3D printing technologies based on cell inclusion

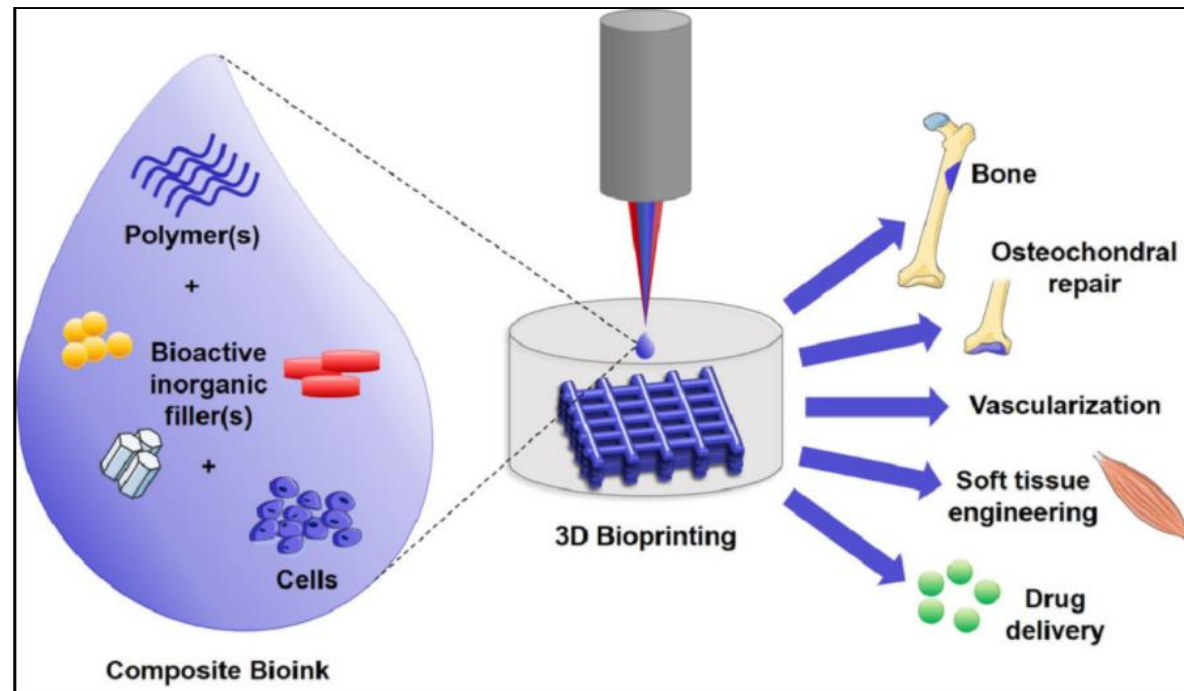
1. The scaffolds from the biomaterials solely with the cell seeding done as a post-processing task.



✗ Non-uniform cell distribution

✗ Poor cell attachment

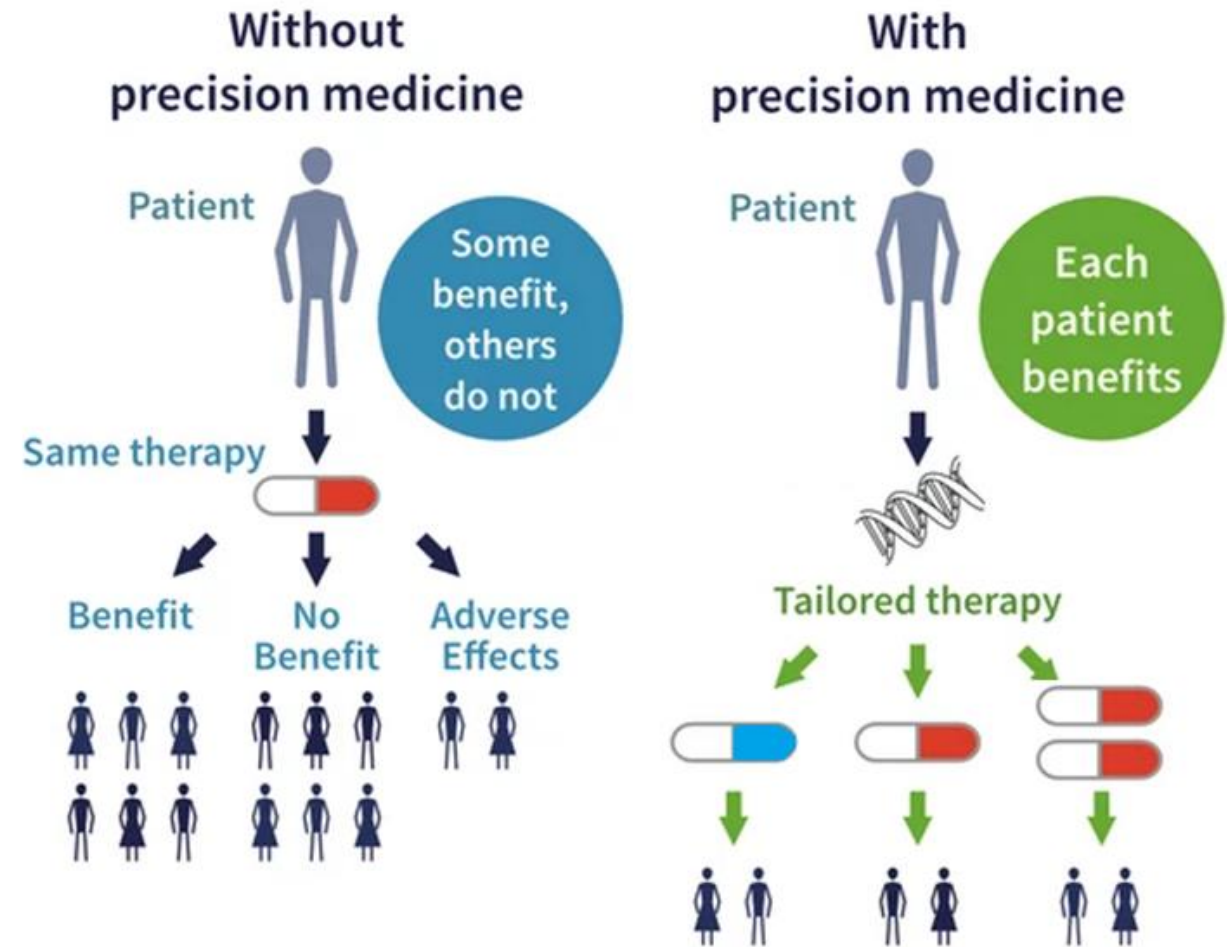
2. The so-called bioprinting (living cells is incorporated into the fabrication process) to produce **organ-like or tissue structures in 3D**
- Uses **bio-inks** (often *one or more biomaterials + living cells*).
  - **Hydrogels** are typical **bio-inks** for printing cells, morphogens, and growth factors.



# Personalized medicine (Precision medicine or customization)

➤ A specific therapy based on the patients specific own characters (such as particular anatomy, physiology, metabolic, genes, proteins, or other substances in their own body.)

➤ Considers the differences between patients with the same disease, (change from the “one size fits all” concept).



## Personalized medicine in TE & 3D printing

- Patient-specific scaffolds for regenerative purposes (models based on the patient's defect anatomy or biological factors derived from the individual)
- Drug delivery systems according to the patient's needs
- Disease modeling for disease study, drug screening and treatment based on pathophysiological conditions

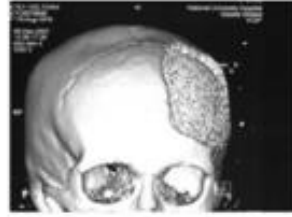
# 3D printing of personalized scaffolds (defect shape)



- **Reverse engineering** approach using image processing techniques and combining it with 3D printing
- **Anatomical data acquisition** by medical imaging:
  - **computed tomography (CT)**
  - **magnetic resonance imaging (MRI)**
  - **3D scanner**

## Manufacture of craniofacial scaffold by AM

CT scan data obtained from the defected bone of patients



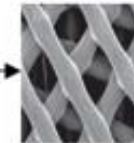
Creating a computer-based 3D model



Extracting the defect geometry and importing it into manufacturing system software to be sliced into thin horizontal layers using tool path specified for each layer

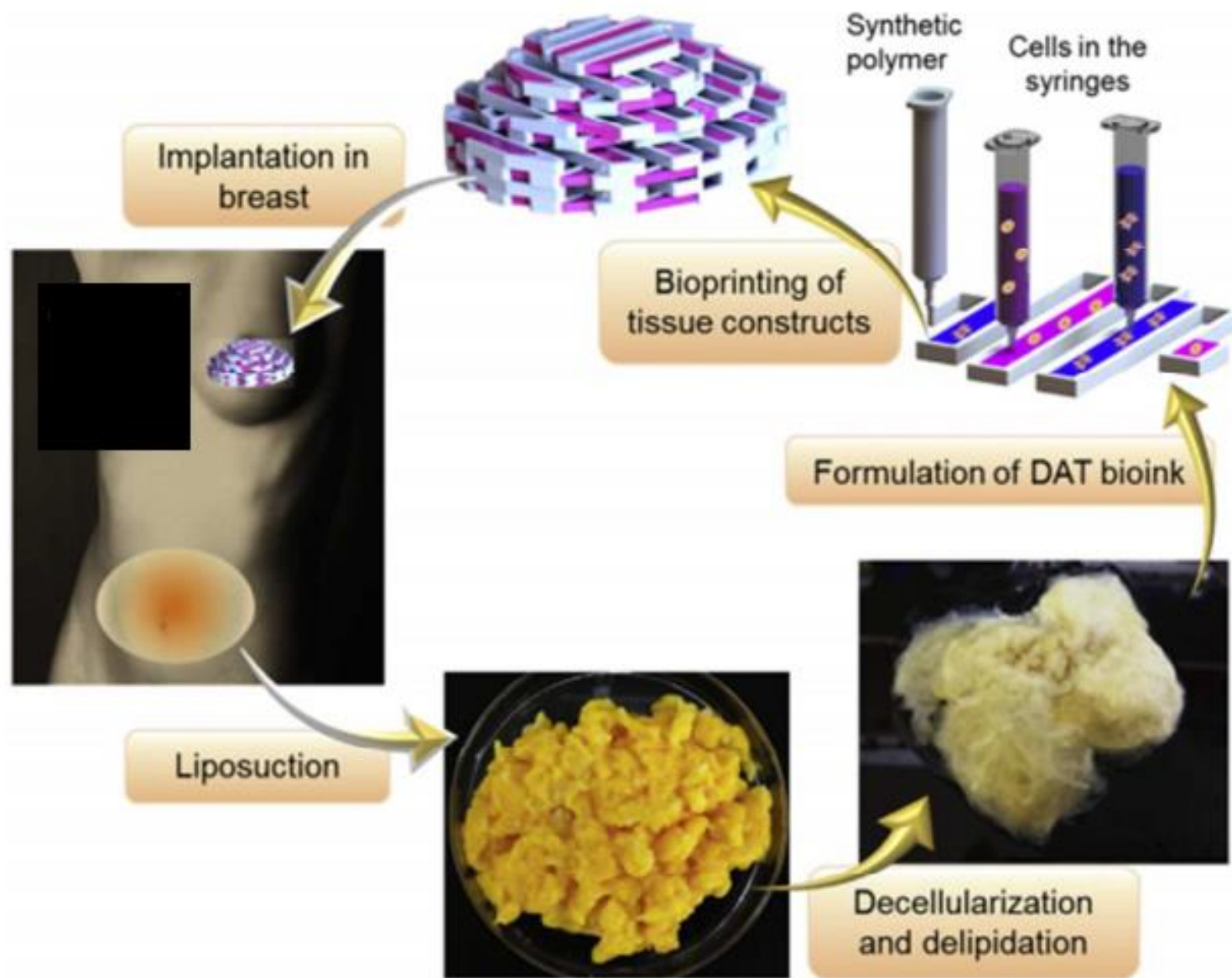


Building the scaffold layer by layer, according to the actual shape of the scaffold in the computer model



## 3D printing of personalized scaffolds (patient's biological factors)

- Patient's own cells, tissue ECM, genes, ... are used as components of bio-inks for 3D bioprinters.
- The allocation and distribution of bio-printed live cells tends to be more precise, and the final 3D scaffold is **biomimetic** (similar to native tissue).
- Different types of cells can be used



# Drug delivery system for patient's need

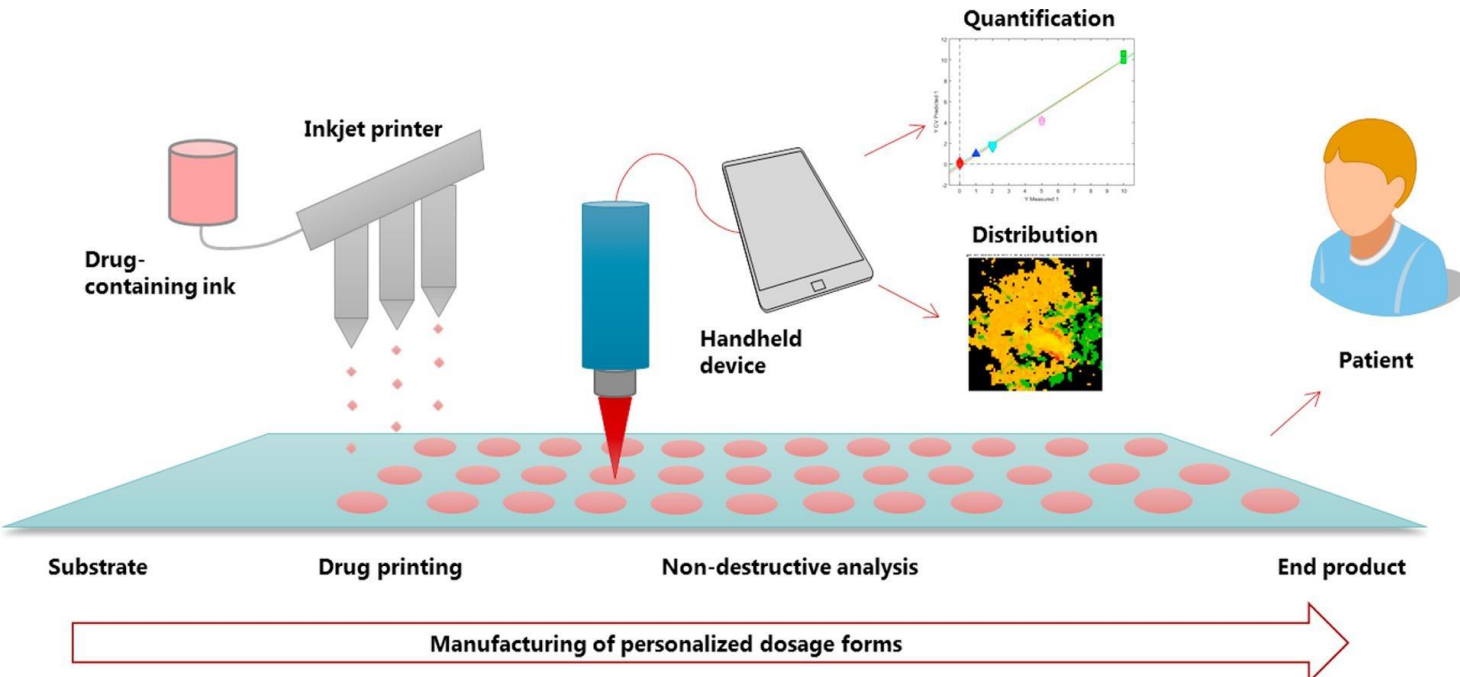
Can be designed to accommodate individual patient preferences or limitations:

1. Transdermal patches offer an alternative to conventional oral medications, for patients who have difficulty in swallowing oral formulations.

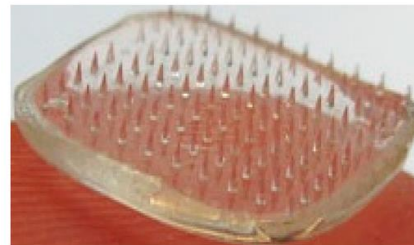


## 2. Customized oral dosage forms :

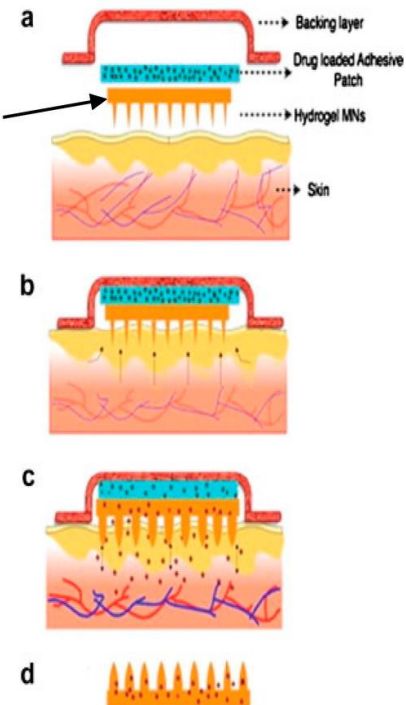
- Some patients may require specific doses deviated from standard formulations, due to factors such as age, weight, renal or hepatic function, drug interactions, or pediatric needs.
- Personalized dosing schedules appropriate for individual patients.



3. Controlled drug release over an extended period (consistent drug concentration and reducing the frequency of dosing).
4. Combination of multiple drugs in a single formulation (simplified dosing regimens for patients with multiple medications)



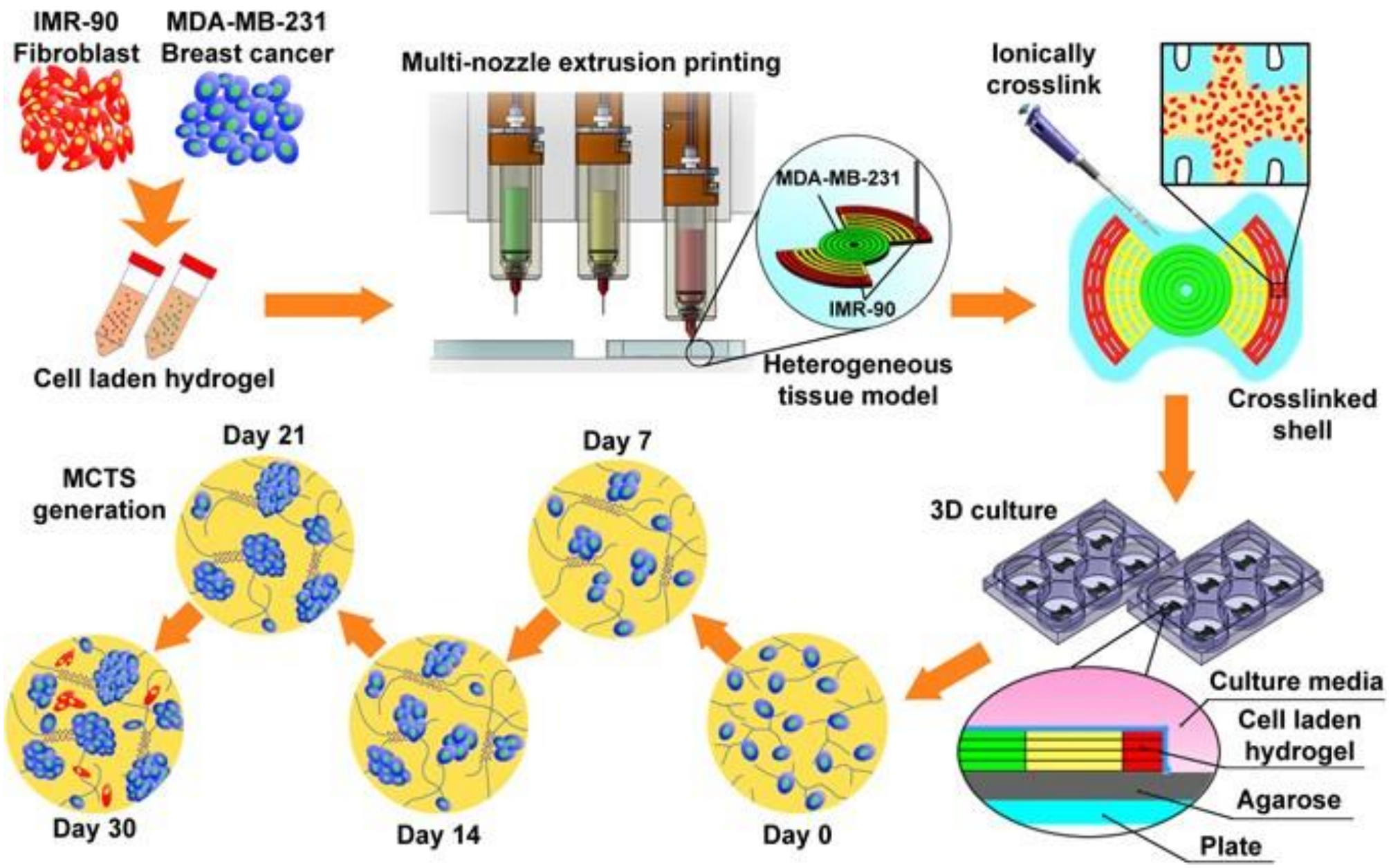
**Skin patch with patient-specific dosage, and controlled penetration and release**



**Modified-release tablets**

# Disease modeling & drug screening

- 3D printed tissues can be utilized for drug screening.
- Patient-specific cells and tissues are used to create models of diseases and effectiveness of potential treatment.
- The unique genetic and molecular characteristics of individual's disease are considered.
- *Prediction of drug response*
- *Reduced number of animals*
- *Accelerated drug discovery*





**THANK YOU!**