Biology for Engineers BBOC407

MODULE-5
TRENDS IN BIOENGINEERING

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TRENDS IN BIOENGINEERING

Muscular and Skeletal Systems as scaffolds (architecture, mechanisms, bioengineering solutions for muscular dystrophy and osteoporosis),scaffolds and tissue engineering, Bioprinting techniques and materials, 3D printing of ear, bone and skin. 3D printed foods. Electrical tongue and electrical nose in food science, DNA origami and Biocomputing, Bioimaging and Artificial Intelligence for disease diagnosis. Self-healing Bio concrete (based on bacillus spores, calcium lactate nutrients and biomineralization processes) and Bioremediation and Biomining via microbial surface adsorption (removal of heavy metals like Lead,Cadmium, Mercury, Arsenic).

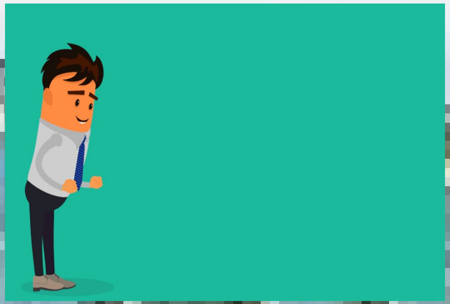
MUSCULAR AND SKELETAL SYSTEM AS SCAFFOLDS

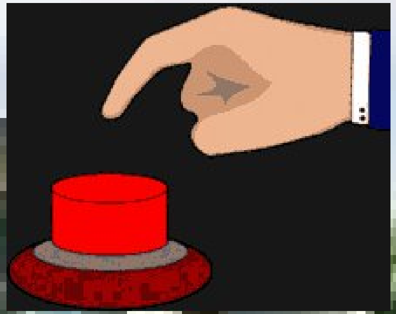
Skeletal System as the Scaffold

- In **architecture**, Scaffolds are **temporary structures used during construction**
- Similarly, the **Bones in the human body** acts as a permanent scaffold
- **Bones** in the human body serve as a permanent scaffold. They **are connected through joints**, which allow movement and flexibility
- Just as scaffolds are strategically designed to **withstand forces during construction**, the human skeleton is designed to **withstand various pressures, stresses, and loads that the body encounters during daily activities and movement.**

Mechanism of musculoskeletal system.

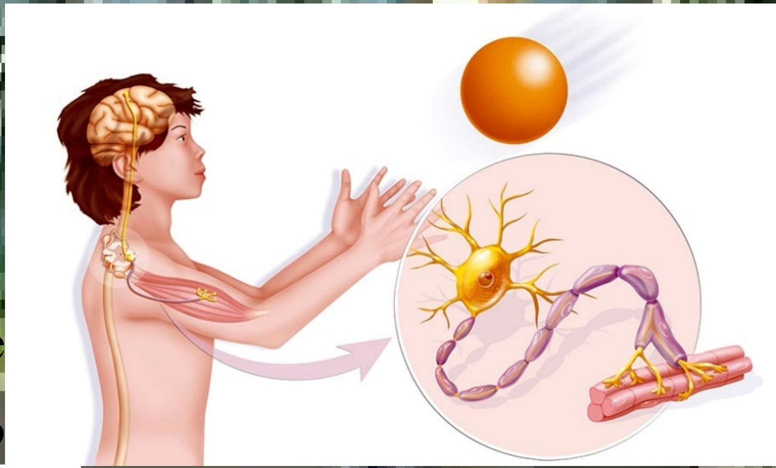
- The nerves control your voluntary muscle movements.
- Voluntary muscles are ones you control intentionally.
- Some involve jumping or pushing a button etc.

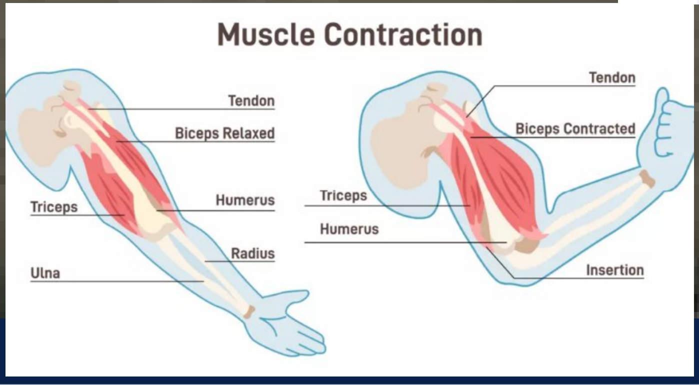




When does the moment happen?

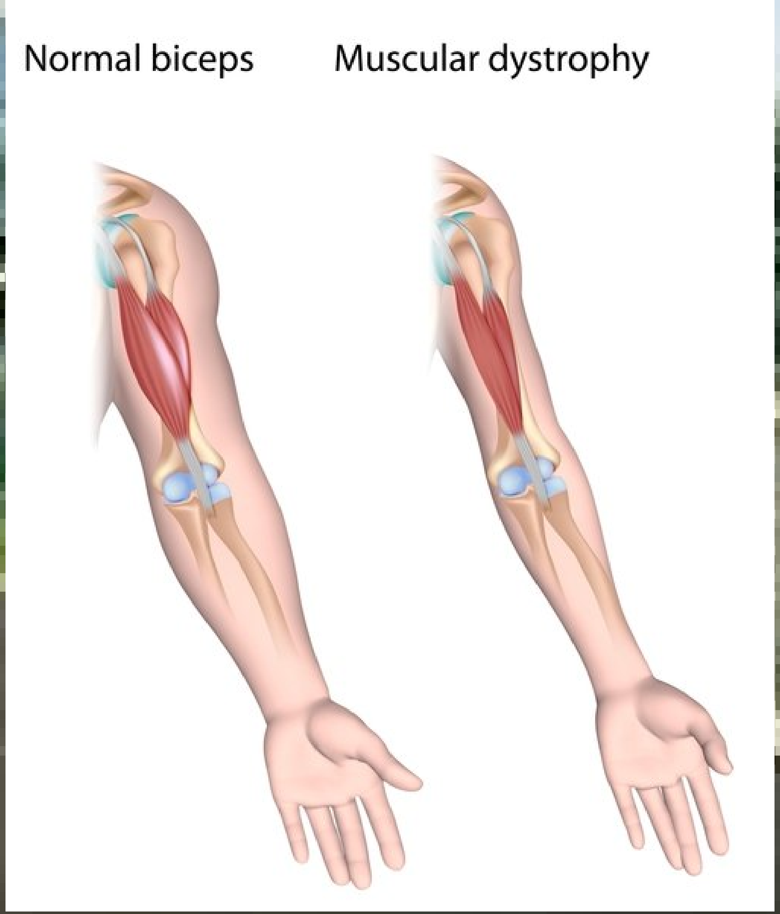
- Our nervous system **(brain and nerves)** sends a message to activate your **voluntary muscles**.
- **Voluntary muscle** takes up the muscle message and **activates itself.**
- **Tendons attach muscles to bones**. The tendon pulls the bone, making it move.
- To relax the muscle, your nervous system sends another message. It triggers the **message to relax the muscles**. The relaxed muscle releases tension, moving the bone to a resting position.





Muscular Dystrophy (MD)

- Muscular dystrophy is a group of diseases that cause progressive weakness and loss of muscle mass.
- MD is a progressive condition, which means it gets worse over time. It often begins by affecting a particular group of muscles, before affecting the muscles more widely.
- Some types of MD eventually affect the heart, or the muscles used for breathing, at that point the condition becomes life-threatening.
- There's no cure for MD, but treatment can help to manage many of the symptoms.



What causes muscular dystrophy?

- MD is caused by changes (mutations) in the genes responsible for the structure and functioning of a person's muscles.
- The mutations cause changes in the muscle fibers that interfere with the muscles' ability to function. Over time, this causes increasing disability.

SCREENING & DIAGNOSIS

Blood tests

Damaged muscles release enzymes such as creatine kinase (CK) into the blood. High blood levels of CK suggest a muscle disease such as muscular dystrophy.

Electromyography

A thin-needle electrode is inserted through the skin into the muscle to be tested. Electrical activity is measured when relaxing and gently tighten the muscle. Changes in the pattern of electrical activity can confirm a muscle disease. The distribution of the disease can be determined by testing different muscles.

Ultrasonography

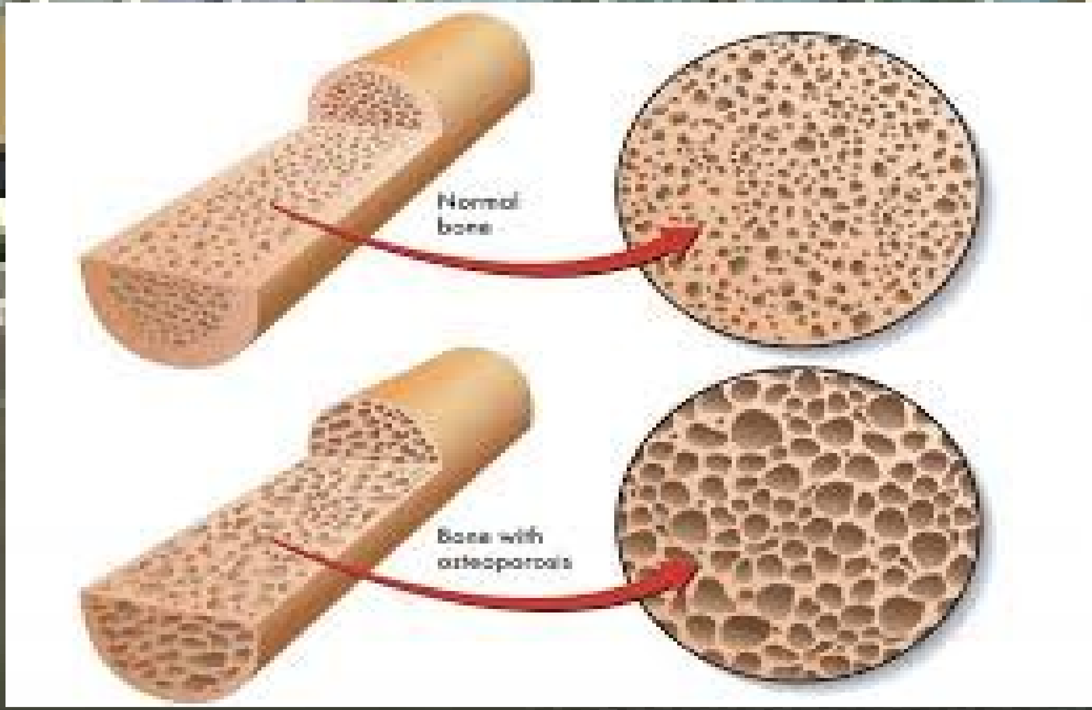
High-frequency sound waves are used to produce precise images of tissues and structures within the body. An ultrasound is a noninvasive way of detecting certain muscle abnormalities, even in the early stages of the disease.

Muscle biopsy

A small piece of muscle is taken for laboratory analysis. The analysis distinguishes muscular dystrophies from other muscle diseases. Special tests can identify dystrophin and other markers associated with specific forms of muscular dystrophy.

The osteoporosis

- Osteoporosis is a bone di



1. Targeted Drug Delivery

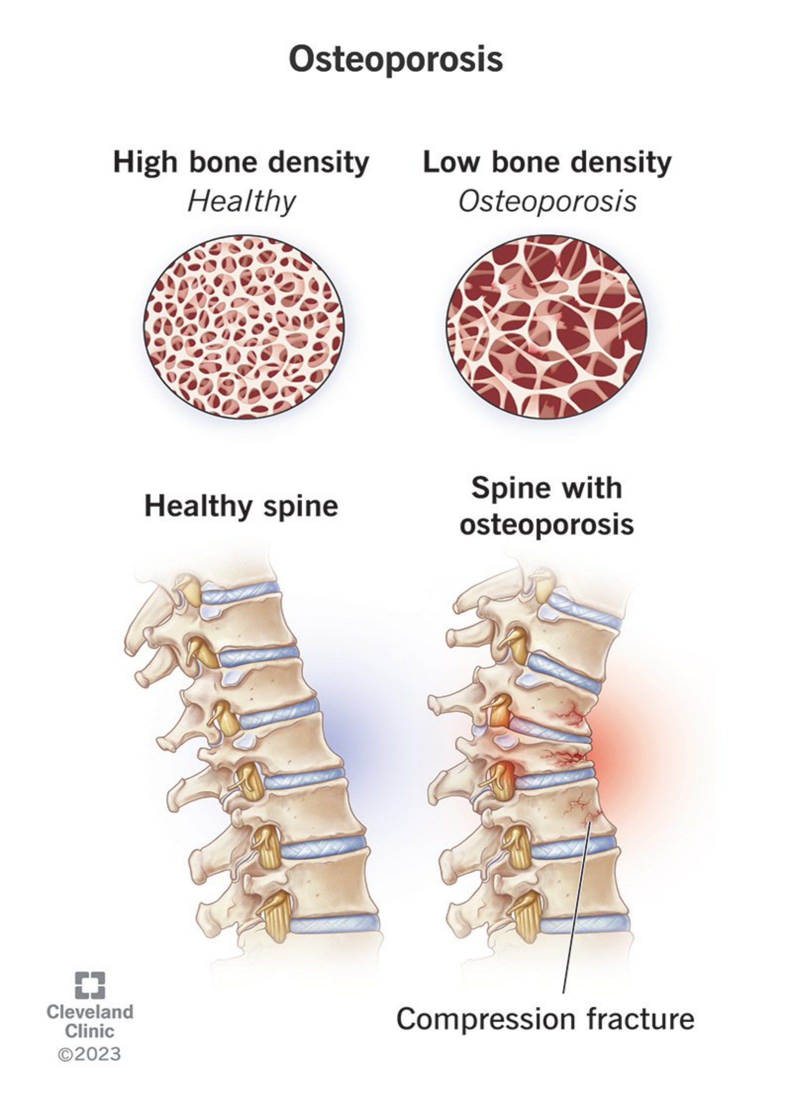
Biomedical engineers are revolutionizing drug delivery for osteoporosis treatment. They design drug delivery systems that ensure precise and controlled release of medications. This innovation not only enhances treatment efficacy but also minimizes side effects.

2. **Tissue Engineering**

Tissue engineering holds immense promise for osteoporosis patients. Biomedical engineers work on creating artificial bone tissue and scaffolds that promote bone regeneration. These bioengineered materials can repair damaged bones and improve bone density, offering hope to those affected by severe osteoporosis.

3. Assistive Devices and Robotics

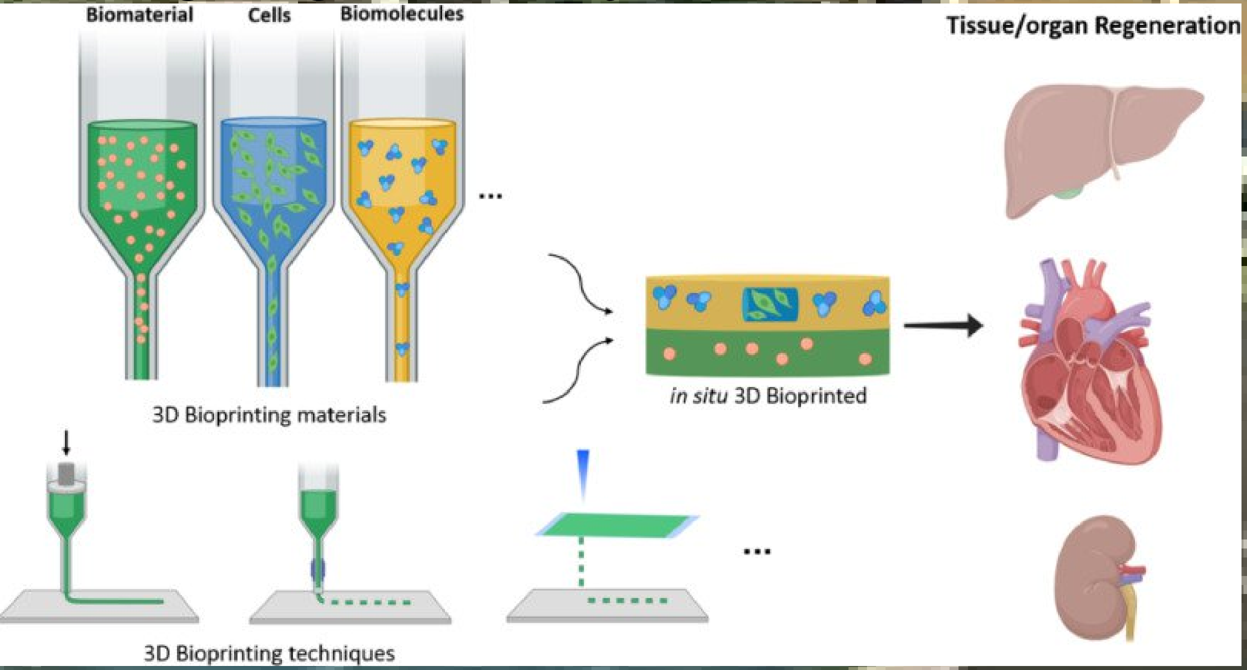
Maintaining mobility and independence is a primary concern for individuals with osteoporosis. Biomedical engineers develop assistive devices and robotics to support them. These devices aid in daily activities, reducing the risk of falls and fractures, and enhancing the quality of life for osteoporosis patients.

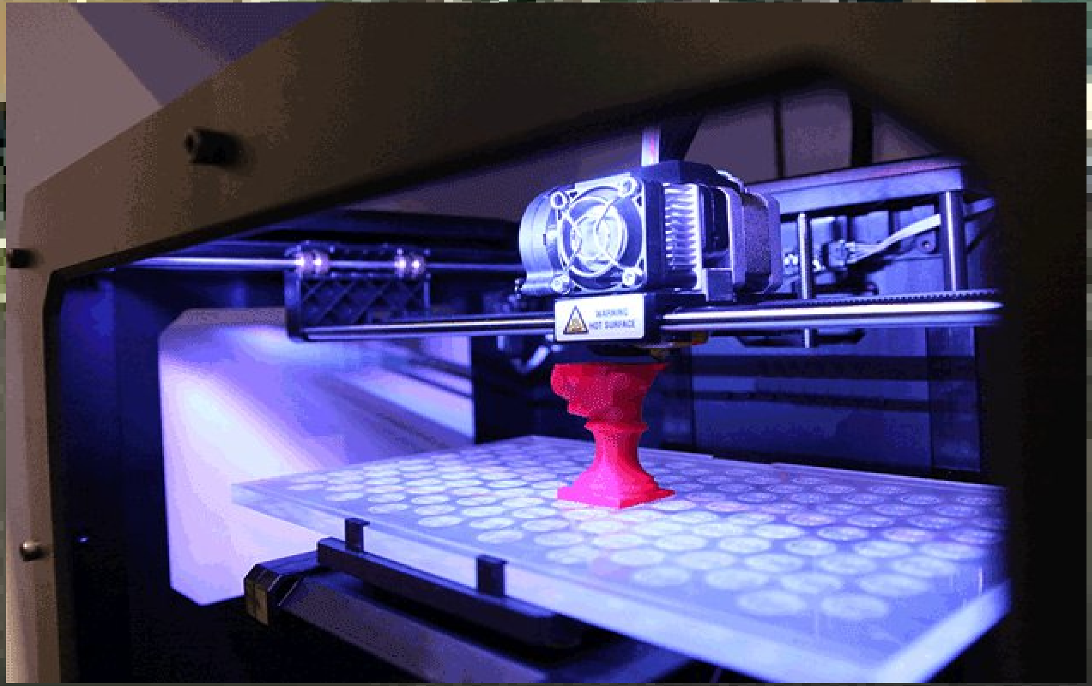


BIOPRINTINGG

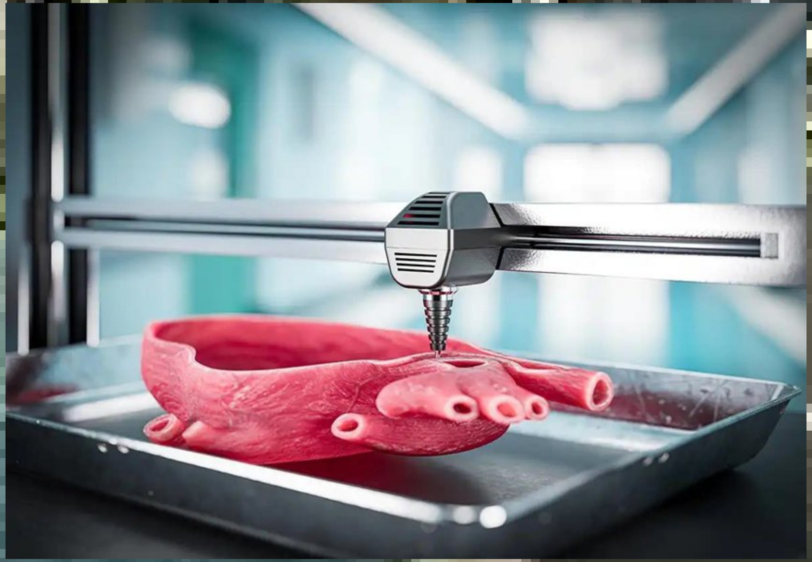
Bioprinting is an additive manufacturing process similar to 3D printing – it is an additive manufacturing process that creates a physical object from a digital design.

Bioprinters print with cells and biomaterials, creating organ-like structures that let living cells multiply and replicate parts that imitate natural tissues, bones, and blood vessels in the body. It is mainly used in connection with drug research and most recently as cell scaffolds to help repair damaged ligaments and joints.

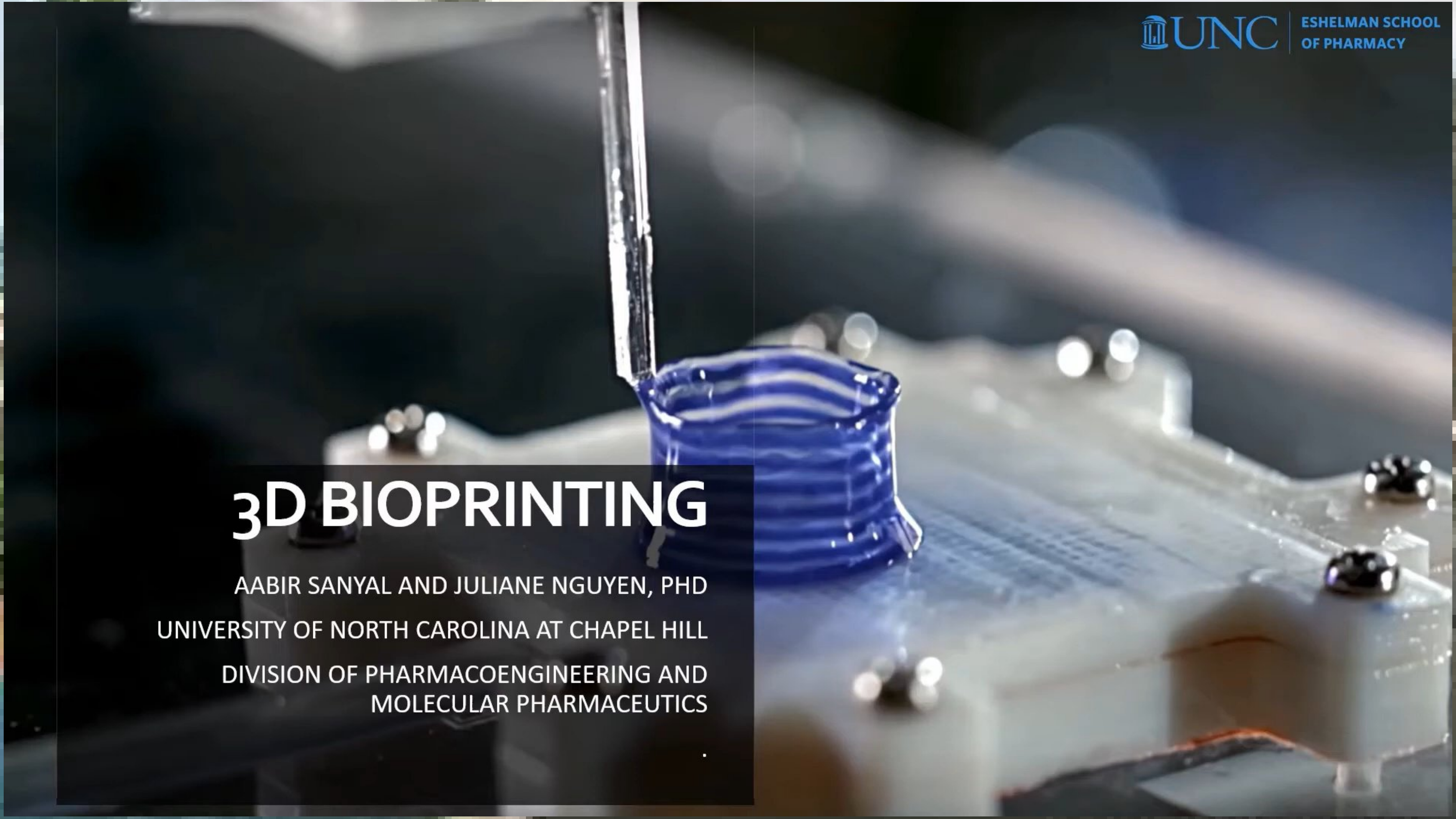




- 3D bioprinting begins with a suitable microarchitecture which is further stabilized by scaffolds of cells and tissues while considering the effect of manufacturing on cell viability.
- The most important motivation behind the development of 3D bioprinting is the limited availability of biological structures that are required for the rehabilitation of lost organs and tissues.
- The aim of the process is to provide an appropriate alternative to tissue implants and animal testing procedures during research on diseases and the development of treatments.



- The use of 3D bioprinting is limited to the formation of organs and tissues to estimate the efficiency of drugs, but 3D bioprinting has great scope in its use for replacing lost and failed organs in patients.
- 3D bioprinting is trickier than 3D printing as the cells are more sensitive and require special attention to allow the cells to grow and divide and prevent the cytotoxic(Cytotoxicity is the ability of a substance to harm cells, causing cell death) activity of solvents used during the process.
- The research on 3D bioprinting is focused on the development of approaches that allow the fabrication of 3D functional living structures of biological and mechanical importance to restore the functions of tissues and organs.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3D BIOPRINTING
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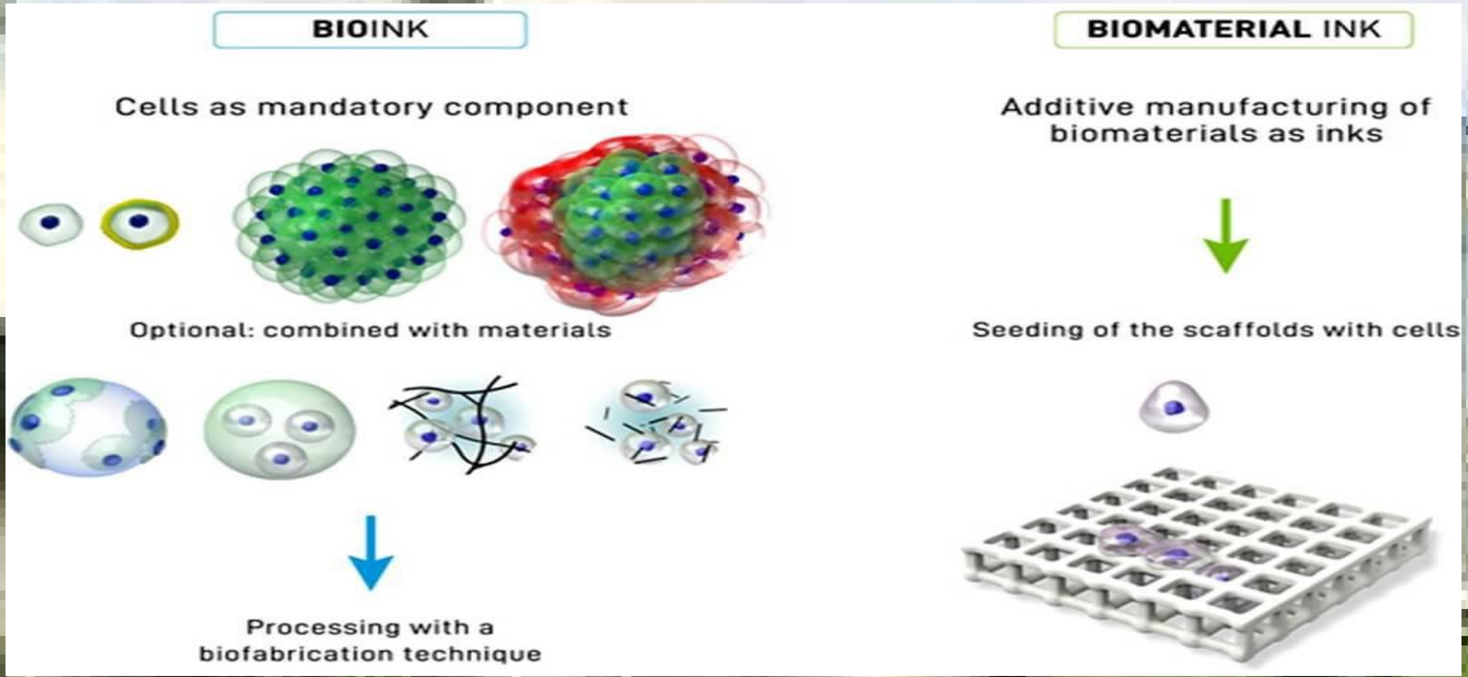
- **BIOINKS** are biological materials used in the manufacture of engineered live tissues by the process of 3D bioprinting.
- Cells: Single cells, cell pellets, cell sheets, spheroids, or tissue strands
- Biomaterials: Gels like hydrogels or microgels, nanomaterials, or fibres
- The term bioink doesn't only indicate the cells used in manufacturing, but also carrier molecules that provide support to the growing cells.
- **Common carrier materials used with cells during bioprinting are biopolymer gels that act as a 3D molecular scaffold so that cells can attach, grow, and increase**.
- The biopolymers used in bioink are essential as they retain water which provides mechanical stability to the engineered tissues.
- The selection of bioink for a particular process is an important step as the selected bioinks should have desired physicochemical properties that include mechanical, chemical, biological, and rheological characteristics.



Distinction between a bioink (left side) and a biomaterial ink (right side). In a bioink, cells are a mandatory component of the printing formulation in the form of single cells, coated cells or cell aggregates (of one or several cell types), or also in combination with materials (for example seeded onto microcarriers, embedded in microgels, formulated in a physical hydrogel, or formulated with hydrogel precursors). In the case of biomaterial ink, in principle any biomaterial can be used for printing and cell-seeding (Cell seeding is to spread cells to a culture vessel for cell culture activities) occurs post-fabrication.

The bioinks used in the bioprinting process should have the following properties:

- The bioinks used should be able to provide adequate mechanical strength and robustness while maintaining the tissue-matching mechanics in the resulting tissue constructs.
- The bioink molecules should have adjustable gelation and stabilization to result in high shape fidelity during bioprinting.
- The bioinks should be biocompatible and can undergo biodegradability according to the natural microenvironment of the tissue.
- The bioinks should be suitable for chemical modifications to form specific tissues.

Basic Principle Of 3D Bioprinting

- The principle of 3D bioprinting is based on the precise placement of biological components, biochemicals and living cells in a layer-by-layer fashion with the spatial control of the placement of functional constituents onto the fabricated 3D structure.
- The process of 3D bioprinting is based on three distinct approaches;
- Biomimicry or biomimetics, autonomous self-assembly, and mini-tissue building blocks.

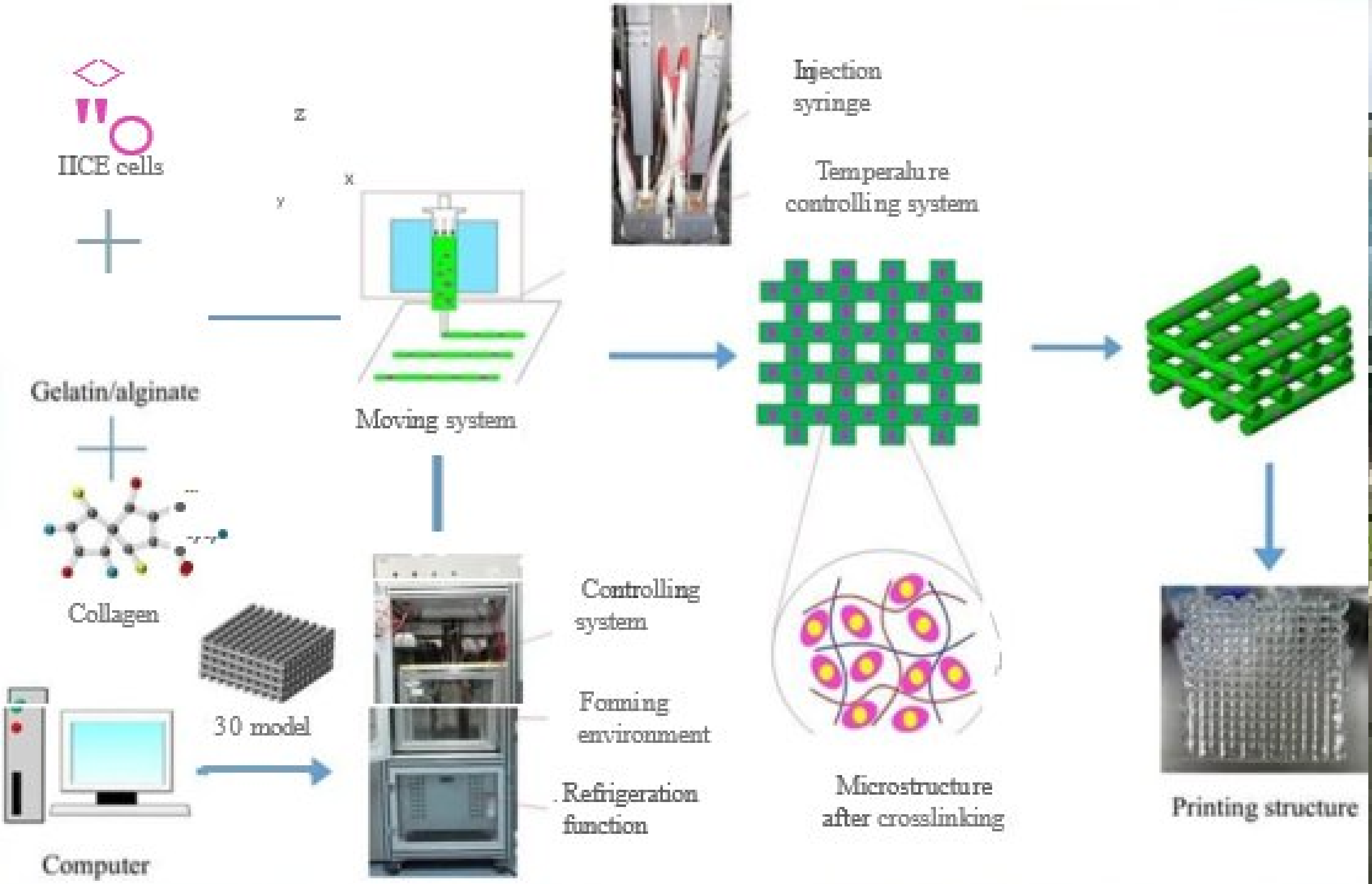
- **1. Biomimicry**
- Biomimicry is the manufacture of identical reproductions of cellular and extracellular components of tissues and organs after a detailed examination of nature itself.
- In order to achieve biomimicry, specific cellular functional components of tissues are to be precisely reproduced.
- Since the materials used in the process have a significant influence on cell attachment, cell size, and morphology, the control of proliferation and differentiation of cells is present in the scaffold.
- A detailed understanding of the microenvironment, including the arrangement of cell types, composition of the extracellular matrix, a gradient of soluble and insoluble factors, and the nature of biological forces is required.

2. Autonomous self-assembly

- Autonomous self-assembly is the approach of replicating biological tissue by using the mechanism of embryonic tissue and organ development as a guide.
- The cellular component of a developing tissue produces its own extracellular matrix and cell signals that allow autonomous organization and patterning to form the desired microarchitecture.
- During the process, a scaffold-free version is formed using self-assembling cellular spheroids that undergo differentiation and organization to form the desired tissue.
- This approach relies on the cell as the primary driver of tissue formation, which directs the localization, functioning, and structure of the resulting tissue.
- The use of this approach requires detailed knowledge of the developmental mechanism of embryonic tissues and organogenesis.

3. Mini tissues building blocks

- Mini tissue building blocks approach utilizes the method of both of the previous strategies.
- In this method of bioprinting, small functional units of tissues and organs, called mini-tissues, are formed.
- The mini tissues represent the smallest structural and functional unit of the organs, like the kidney neuron.
- These mini-tissues can then be fabricated either via autonomous self-assembly or biomimicry.
- The bioprinting begins with the assembly of mini-tissues into macro-tissues based on biologically inspired organization, which is then followed by the reproduction of tissue units that can self-assemble to form functional structures.


IICE cells
Gelatin/alginate
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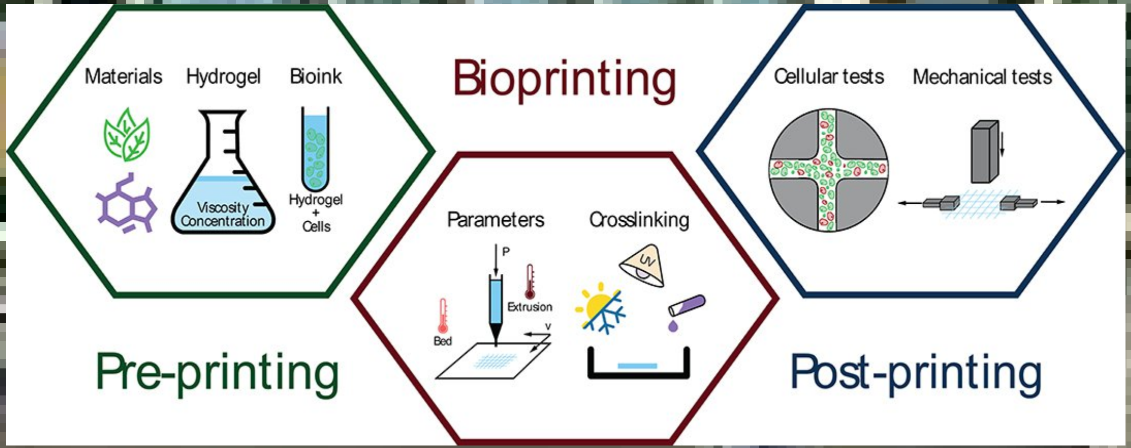
Moving system
Injection
syringe
Temperature
controlling system
Controlling
system
Forming
environment
Refrigeration
function
Microstructure
after crosslinking
Printing structure

BASIC STEPS OF 3D BIOPRINTING (PROCESS)

The overall process of 3D bioprinting can be achieved via three distinct steps, pre-bioprinting, bioprinting, and post-bioprinting.

1. Pre-bioprinting

- The first step of pre-bioprinting is the formation of a model that is used by the printer and the choosing of materials to be used during the process.
- It begins with the extraction of biopsy of a tissue which provides a biological model that is to be recreated by the 3D bioprinting method.
- Technologies like computed tomography (CT) or magnetic resonance imaging (MRI) scans are used in this step.
- The images obtained through these methods are tomographically reconstructed to obtain 2D images.
- Cells necessary for the process are then selected and multiplied. The cell mass thus formed is mixed with oxygen and other nutrients to keep them viable.



2. Bioprinting

- The second step is the actual printing process where the bioink is placed in the printer to form a 3D structure.
- The mixture of cells, nutrients, and matrix, together forming bioink, is then placed onto the printer cartridge, which then deposits the material based on the digital model prepared.
- The formation of biological constructs involves the deposition of bioink onto the scaffold in a layer-by-layer approach to generate a 3D tissue structure.
- This step of the bioprinting process is a complex process as it requires the formation of different cell types based on the type of tissues and organs to be formed.

3. Post-bioprinting

- Post-bioprinting is the last step of the bioprinting process, which is important to provide stability to the printed structure.
- In order to maintain the structure and function of the biological matter, physical and chemical stimulations are required.
- These stimulations provide signals to the cells to reorganize and maintain the growth of tissues.
- In the absence of this step, the mechanical structure of the material might be disrupted, which then affects the functioning of the material.

3D BIOPRINTING TECHNOLOGY (TYPES)

1. Extrusion based bioprinting
2. Inkjet-based bioprinting
3. Pressure-assisted bioprinting (PAB)
4. Laser-assisted bioprinting (LAB)
5. Stereolithography (STL)

What are Bioprinters?

- Bioprinters or 3D bioprinters are automated devices for the additive fabrication of 3D functional tissues and organs based on the digital models that are created via various scans using biomaterials.
- Bioprinters are automated robotic devices that work based on different mechanisms.
- 3D printers that can only print cell-free scaffolds but cannot dispense living cells are not considered bioprinters.
- The evolution of 3D bioprinters is a continuous process that involved the hybridization of new technological approaches to create new advanced forms of bioprinters.
- There are different types of bioprinters depending on the technique of bioprinting employed by the machines; inkjet bioprinters, extrusion-based bioprinters, and laser-based bioprinters.
- These bioprinters work on different mechanisms and are generally used for different purposes depending on the type of biomaterials used.

How do Bioprinter works?

- The process of bioprinting begins with the CT or MRI scans of the desired organ. The image thus obtained is loaded into a computer that builds a corresponding 3D blueprint of the organ using a software program.
- The information from the 3D data is combined with histological information based on microscopic analysis to produce a layer-by-layer model of the organ.
- The information is then fed into the printer. Besides, other information about the choice of material to be used is also entered into the printer.
- The printer then reads the blueprint and deposits the biomaterial onto the receiver in a layer-by-fashion.

- It is achieved by the movement of the print head in all directions to generate the required depth and thickness.
- Once a layer reaches the platform, it solidifies either by cooling or via a chemical reaction. To the solidified layer, a new layer is deposited to form a stable structure.
- The organ thus formed is removed from the printer and placed in an incubator to allow the structures to settle and stabilize.

Examples of 3D bioprinters

- 3D bioprinters are developed by different companies like Cellink that can create cartilages, skin, bones, and muscles.
- Depending on the mechanism of bioprinting utilized, bioprinters like inkjet printers, laser printers, etc. are used for different purposes.

Bioprinting Materials

Bioink material	Strengths
Collagen	High biological relevance
Hyaluronic acid	Cell proliferation Capable of gelation
Gelatin	High solubility in water Biocompatible Thermal reversible gelation
Chitosan	Biocompatible Antibacterial features

Limitations And Future Challenges Of 3D Bioprinting

- The primary barriers in bioprinting are suitable bioinks with high biocompatibility and mechanical strength.
- Bioprinter technology that is currently used has comparatively lower resolution and speed, which produces a challenge for future development. Similarly, the bioprinters should also be compatible with a wide spectrum of biomaterials.
- The speed of the bioprinting process should be increased to mass-produced biomaterials at a commercially acceptable level as the current speed is slow.
- Vasculature of tissue constructs is an important challenge in 3D bioprinting as the tissues require continuous oxygen and nutrients.
- There are some ethical issues with 3D bioprinting as the cost of the method might make it inaccessible to the poor.
- Because bioprinting is a novel technology, it should be studied sufficiently to ensure it is going to be safe for humans.
- Personalized 3D printing technology might lead to a serried of regulatory problems to ensure printed product supervision.

Applications Of 3

3D PRINTING OF SKIN BONE E

3D Printing Of Skin

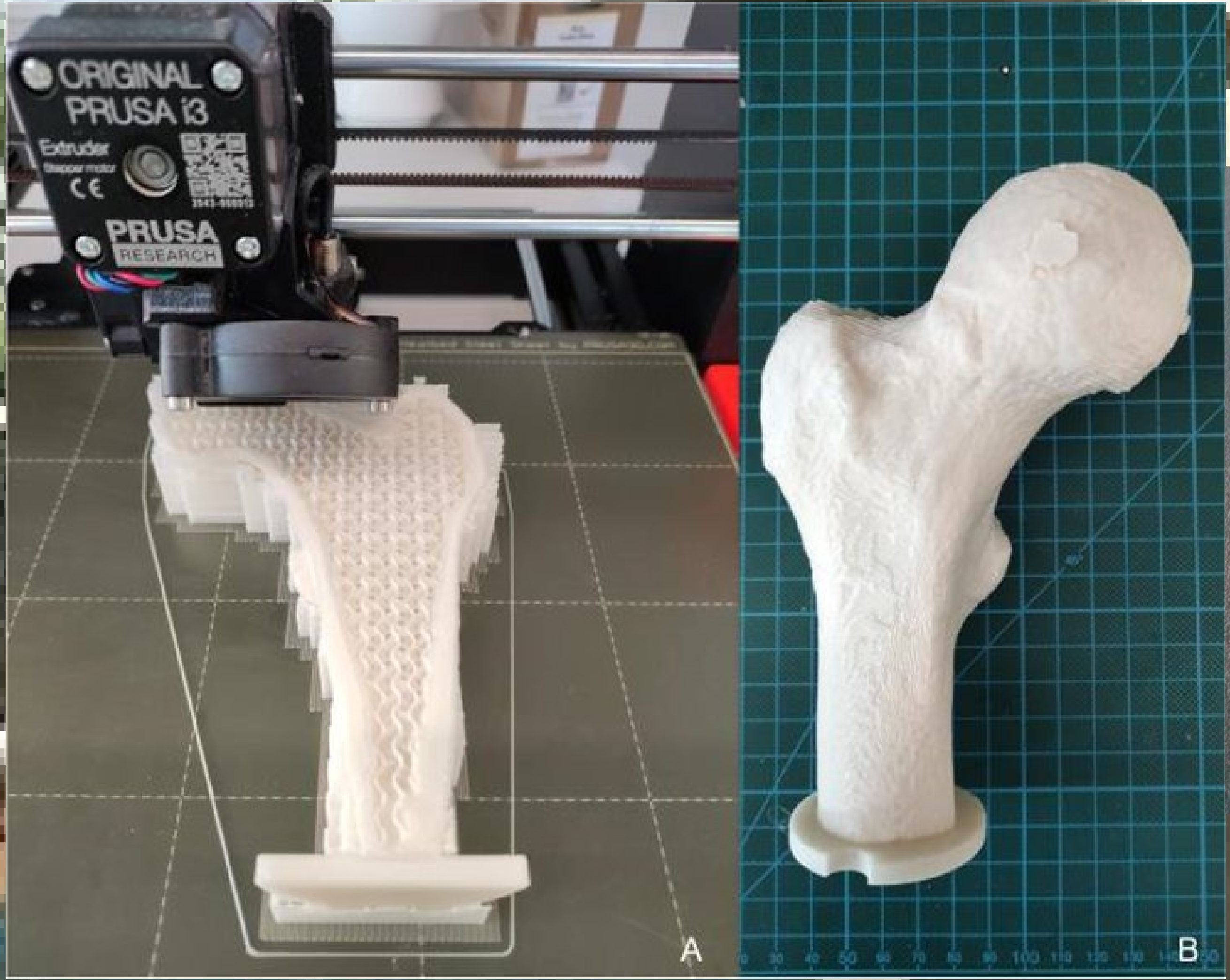
- Tissue engineering is one of the most prominent applications of 3D bioprinting. It enables the fabrication of complex tissues and organs that can replace failed or lost tissues.
- Production of functional tissues and organs at clinically relevant dimensions is challenging as the integration of the vascular network of arteries and veins and incorporation of various cell types to reinvent complex organ biology are not easy to achieve.
- Nevertheless, a wide variety of tissues have been successfully bio printed while maintaining mechanical integrity and functioning.

SKIN

- Tissue engineering can be done to produce substitutes like an autologous split-thickness skin graft, allografts, acellular dermal substitutes, and acellularized graft-like commercial products.
- Bioprinting of skin tissue can be done using an eight-channel valve-based bioprinter where a 13-layer tissue is constructed using collagen hydrogel.
- Keratinocytes are then bio printed on top of alternating layers of human foreskin fibroblasts and acellular collagen layers to fabricate constructs with densely packed cells in epidermal layers.
- The tissue constructs prepared are engrafted with the host after about 10 days in the stratified epidermis.
- This results in early signs of differentiation and formation of the stratum corneum as well as some blood vessels.
- The biomaterial used for the process might differ, but the most common cells used are keratinocytes and fibroblasts.
- Besides, skin with infections or diseases can be used as biomaterials for bioprinting to study the pathophysiology of the disease.

3D PRINTING OF BONE

- **Bone and cartilage** fabrication is the most mature use of bioprinting as the composition of such hard tissues is uncomplicated and is mostly composed of inorganic elements.
- Even though other techniques like gas foaming, salt leaching, and freeze-drying have been employed to produce such hard tissues, 3D bioprinting produces the most accurate structures.
- Thermal inkjet bioprinter is used to fabricate polymethacrylate scaffolds from bone- marrow-derived human mesenchymal stem cells.
- The cells are comprinted with nanoparticles of bioactive glass to control the spatial placement of cells.
- In cartilage tissue engineering, a printable bioink is prepared as a combination of nano fibrillated cellulose and alginate with human chondrocytes as living soft tissue.


ORIGINAL
PRUSA i3
Extruder
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3D PRINTING OF EAR

- Taking a small sample of the patient's ear to create billions of cartilage cells. The living cells are then mixed with collagen-based “bio ink,” which is safe for the body.
- The 3D bio-printer uses that ink to create an object based on a digital model that copies the patient’s healthy ear.
- Example:
- A 20-year-old woman who was born with the congenital disorder microtia and had one misshapen ear received the new appendage in March, 3D Biotherapeutics, the company that manufactured the ear. The ear was constructed from her own cells as a mirror replica of her other ear.
- Microtia patients are born without outer ears or with appendages that are smaller and different in shape. For these patient's 3D Bioprinting will be of great help.

3D PRINTED FOODS

- Typical 3D-printable foods are made of chocolate, cheese, and powdered ingredients like sugar or flour. Simulated meat, as well as cultured meat, are also possibilities.
- 3D-printed food is only a novelty that can be used to accompany existing meals.
- 3D printing in the food industry refers to the process of creating foods using 3D printing technology.
- The most commonly used technology makes use of food ingredients that are relatively viscous to ensure that, when extruded, the material keeps the intended form. The food is built up layer by layer until complete.
- 3D printers do not cook the food, but rather prepare them in the desired form. Thereafter, they may need to be cooked in an oven after the printing process is complete. Some foods, like sugar or chocolate, can be consumed directly after printing.

The first 3D-printed foods were:

- **Chocolate:** Chocolate needs to be kept in a liquid form. It cools quickly after extrusion, making it an ideal food for 3D printing.
- **Cheese:** Like chocolate, cheese must be held in its molten form prior to extrusion. It also tends to cool relatively quickly.
- **Cookie Dough:** Cookie dough is a paste that can be easily extruded into the required shape. However, the cookie must be baked in an oven after printing before it can be consumed.

The benefits of 3D printing food are listed below:

- **Automation**: 3D printing allows for the automation of the food preparation process. The machine can be left to build the food while other portions of the meal are prepared.
- **Precise Ingredient Control**: 3D food printers make use of precisely controlled stepper motors to dispense ingredients. This means that consistent ingredient accuracy is maintained while also reducing overall waste.
- **Creativity:** 3D printing allows for unmatched creativity. Complex 3D food products with impressive geometries can be created that would be impossible to construct by hand.
- **Customizable Foods:** Food products can be easily customized depending on a consumer's preferences. This can be as simple as changing the ratio of ingredients used to make the product by changing the deposition settings on the machine. Alternatively, the ingredient pods can be swapped out for different ingredient combinations.

3D printing technologies for food printing closely match their plastic-based counterparts. The main types of 3D printers used for food are listed below:

- **Extrusion:** Works similarly to an FDM (Fused Deposition Modelling) 3D printer for plastics. However, instead of an extruder and a hot end (a component of an FDM 3D printer), a food-filled syringe is used to dispense the ingredients. Some popular machine suppliers are Natural Machine, Foodini, and byFlow.
- **Binder Jetting:** Binder jetting works by laying down a powder ingredient and then spraying an edible liquid binder on top of the powder to fuse the food particles together. 3D Systems and Brill 3D Culinary Studio both produce binder-jetting 3D food printers for creating powder-based food products.
- **Inkjet:** An edible liquid is dispensed using multiple inkjet heads. Applications include edible decorative images or bio-ink for cultured meat printing. MeaTech is currently developing an advanced inkjet food printer for producing cultured meat products.

- The most common is FDM-style printing. This process works by placing an ingredient into a syringe-type dispenser. The food printer then moves the head of this dispenser around the build plate, tracing out the cross-section of the food one layer at a time, until it is complete. In some cases, the food needs to be cooked afterward.

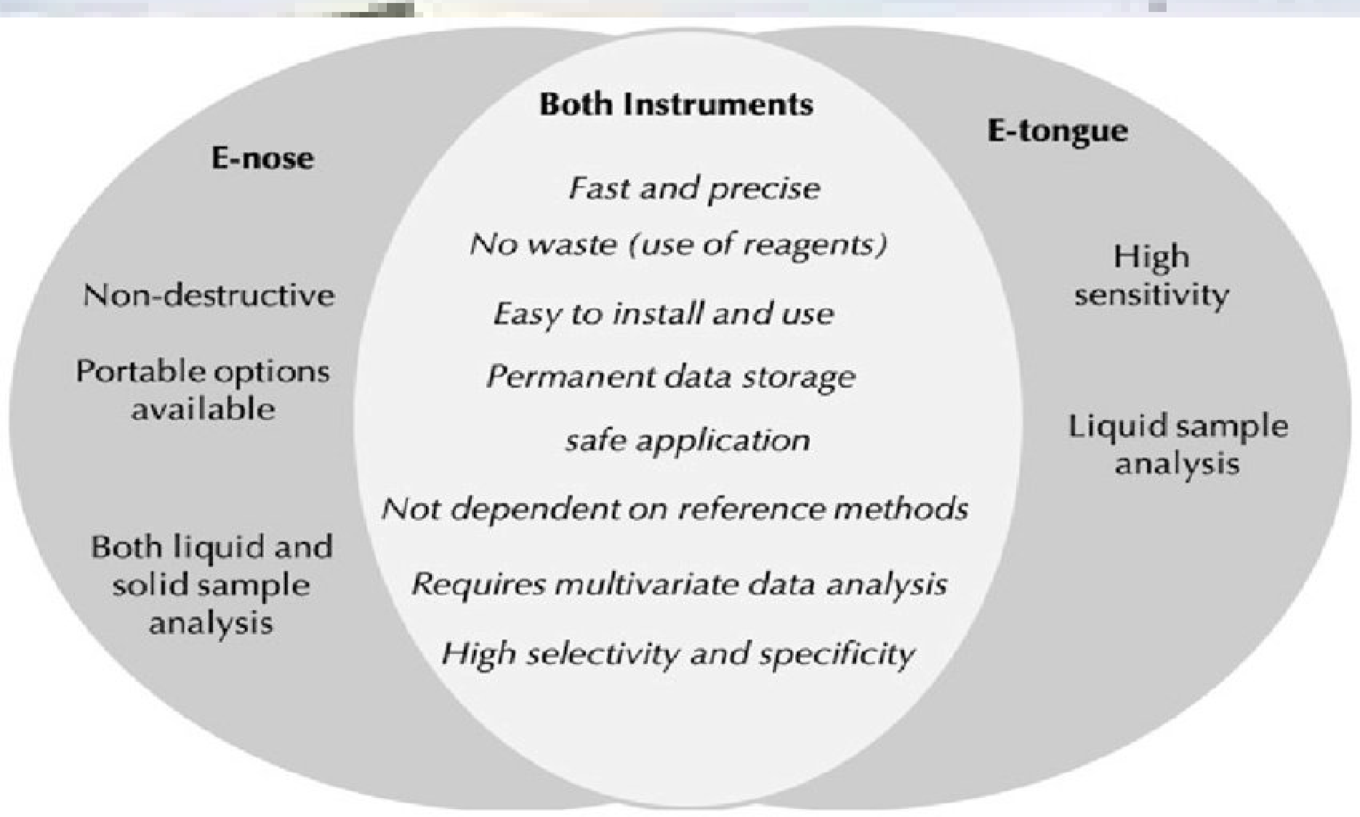
ELECTRICAL TONGUE

- The electronic tongue is an analytical instrument comprising an array of nonspecific, low-selective, chemical sensors with high stability and cross- sensitivity to different species in solution and an appropriate method of PARC and/or multivariate calibration for data processing.
- Electronic tongues are normally used to give qualitative answers about the sample studied and only in some cases to predict the concentration of individual species in the sample.
- The e-tongue is capable of determining food quantitative composition and recognizing (identifying, classifying, discriminating) different food tastes.
- Emerging applications include the detection of pathogenic the e-tongue is predominantly used to analyse liquid samples only. In the case of any solid samples, the sample needs to be extracted in any suitable electrolyte that acts as a continuous phase and maintains close contact with the electrode array.
- The mechanism in taste recognition by e-tongue occurs in three levels: (i) receptor level (chemo-sensitive metal oxide sensors), (ii) transmission level (detectors and transducers), and (iii) perception level (data analytics and chemometrics)

ELECTRICAL NOSE

- An electronic nose is "an instrument which comprises an array of electronic chemical sensors with partial specificity and an appropriate pattern recognition system, capable of recognizing simple or complex odour" and tries to distinguish dissimilar gas mixtures.
- E-noses are the systems for the automated detection and classification of odours, vapours, and gases, which have provided an excess of benefits to the agricultural, biomedical, cosmetics, environmental, food, manufacturing, military, pharmaceutical, regulatory, and various scientific research fields.
- The electronic nose (e-nose) consists of a gas sensor array to provide a fingerprint of exhaled breath (breath print, BP) by detecting VOCs through multiple sensors. The e-nose is able to give quantitative response to a comprehensive VOCs profile, but in this case individual VOCs remain unidentified.

- The electronic nose (e-nose) is designed to crudely mimic the mammalian nose in that most contain sensors that non-selectively interact with odour molecules to produce some sort of signal that is then sent to a computer that uses multivariate statistics to determine patterns in the data.
- The non-selectivity of the sensors results in many possibilities for unique signal combinations, patterns or fingerprints. The human tongue contains sensors, in the form of 10,000 taste buds of 50–100 taste cells each, for sweet, sour, bitter, salty and umami and is much less complicated than the human olfactory system. The e-tongue then uses a range of sensors that respond to salts, acids, sugars, bitter compounds, *etc.* and sends signals to a computer for interpretation.



- A disadvantage for the e-nose and e-tongue systems (as with humans) is that they are also affected by the environment including temperature for both e-nose and e-tongue and humidity for e-nose, which can cause sensor drift, although calibration systems and built-in algorithms help compensate for this.

DNA ORIGAMI

- **DNA origami** involves the folding of DNA to create 2D and 3D objects at the nanoscale.
- Origami is a Japanese art of paper folding. The goal is to fold a flat sheet of paper into a finished sculpture. No cut, glue, or markings of the paper sheet should be used. Origami practitioners use a small number of basic folds to combine them into a variety of ways.
- DNA origami can be used to construct the most complex and refined two-dimensional DNA nanostructures, which subsequently serve as a template to assemble functional nanomaterials or molecules.
- The specificity of the interactions between complementary base pairs make DNA a useful construction material, through design of its base sequences.
- DNA origami refers to an assembly technique that folds single-stranded DNA template molecules into target structures. This is done by annealing templates with hundreds of short ‘staple’ DNA strands.

- The underlying princi

- DNA origami has now emerged as a new way for the design and synthesis of defined two-and three-dimensional (2D and 3D) DNA nanostructures. The self-assembly reactions of DNA molecules enable the size expansion of the nanostructures.
- Structural DNA nanotechnology is a new technology developed during the past 30 years. The nature of DNA molecules allowing for self-assembly makes it possible to construct novel DNA-based materials. For this approach, self-assembly protocols are utilized allowing the synthesis and folding of branched DNA molecules, for example, into polyhedral structures. Also, branched DNA motifs can be designed for the production of 2D and 3D periodic lattices of DNA or DNA crystals. Furthermore, DNA has been already used to produce nanomechanical devices in which molecules can walk along strands of DNA or change their shapes.
- DNA origami is created via self-assembly. The combination of heat and chemical denaturation of double-stranded DNA scaffold strands in the presence of staple strands, followed by a sudden drop in temperature and stepwise dialysis to remove chemical denaturant favors self-assembly. For DNA origami production DNA complementary reactions are exploited for controlling DNA structures.

What is needed for the folding of DNA origami?

- Typically, a DNA scaffold or template DNA is needed. This will need to be designed first.
- Before design select the desired shape of the final nanostructure. Software tools can help with the design, the placing of needed crossover points and the design of the short DNA stables required for folding.
- Single-stranded DNA sequences can be synthesized of up to 200 bases or somewhat longer. Often, for longer DNA scaffold viral DNA is used.
- Strands are mixed in the correct ratios with an excess of staple DNA.
- Heating and cooling sometimes in combination with dialysis forms the structures via self-assembly.
- Analysis via gel electrophoresis allows detection of well-formed DNA nanostructures. DNA nanostructures are observed as sharp bands that migrate differently than the starting material.
- Further characterization can be done using electron microscopy or atomic force microscopy.

BIOCOMPUTING

- Biocomputing — a cutting-edge field of technology — operates at the intersection of biology, engineering, and computer science. It seeks to use cells or their sub-component molecules (such as DNA or RNA) to perform functions traditionally performed by an electronic computer.
- The procedure of DNA computing can be divided into three stages: encoding information, computation (molecular operations) and extraction of solution. The stage of encoding information is the first and most important step, which directly affects the formation of optimal solution.
- DNA computers will be used to solve complex problems.
- DNA computers will be able to solve problems in medicine, biology, engineering and cryptography, artificial intelligence, and data analysis

- The goal of biocomputing is to mimic some of the biological ‘hardware’ of bodies like ours — and to use it for our computing needs. From less to more complicated, this could include:
- 1. Using DNA or RNA as a medium of information storage and data processing
- 2. Connecting neurons to one another, similar to how they are connected in our brains
- 3. Designing computational hardware from the genome level up Cells Already Compute
- Cells are far more powerful at computing than our best computers. For example:
- 1. Cells store data in DNA
- 2. Receive chemical inputs in RNA (data input)
- 3. Perform complex logic operations using ribosomes
- 4. Produce outputs by synthesizing proteins
- Biocomputing’s engineering challenge is to gain a granular level of control of the reactions between organic compounds like DNA or RNA.

Overheating & High Energy Use

- Traditional computers use microchips, which heat up quickly.
- Supercomputers are usually a collection of several high-speed traditional computers, combined into a single unit. Generally, they are not qualitatively different from traditional computers. Even so, supercomputers use a lot of energy, heat up quickly, and require massive cooling units to function at full speed. On the other hand, biological matter can perform calculations and process data without using as much energy, and without heating up significantly.

Multitasking

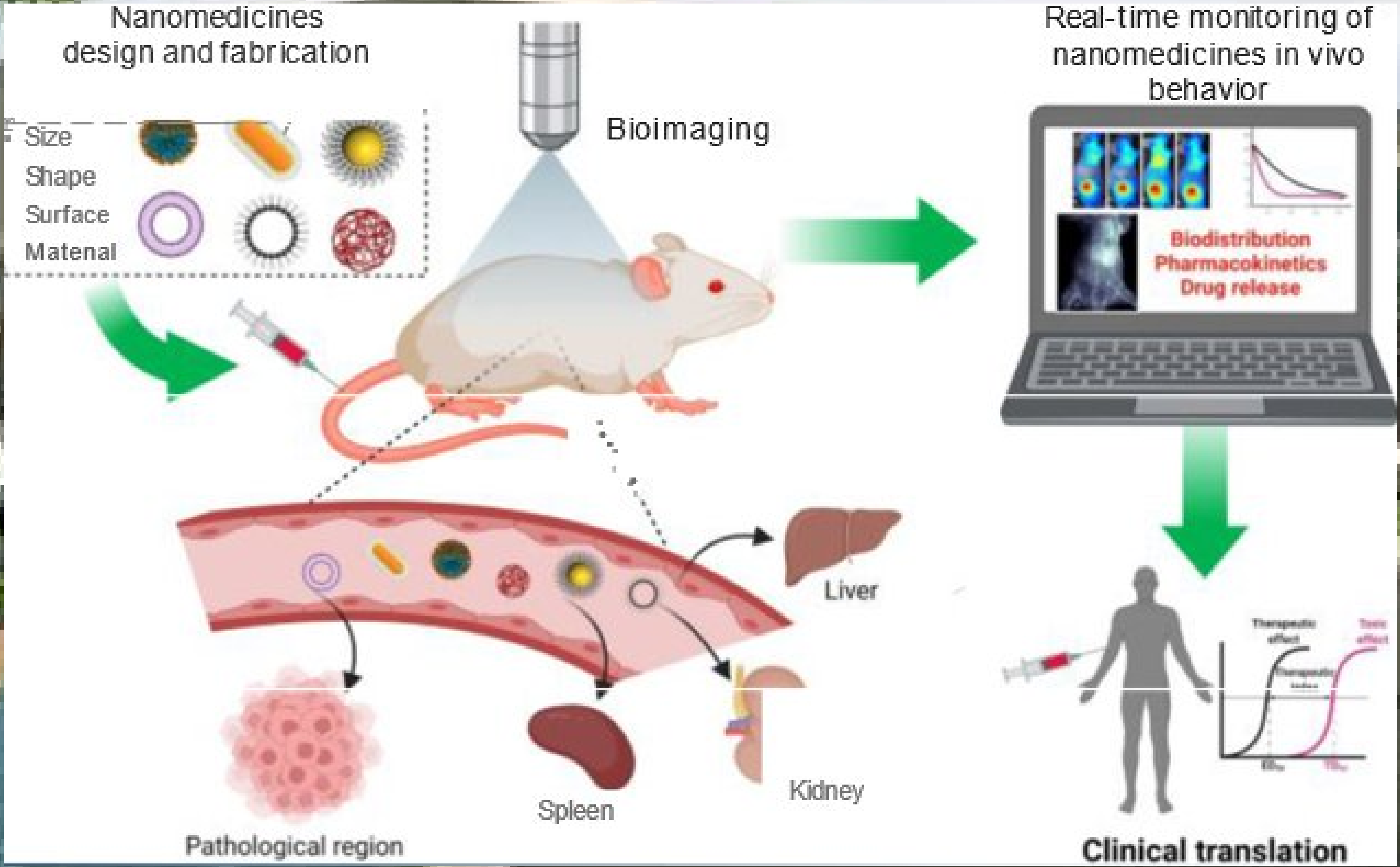
- Regular computers perform one task at a time and switch quickly between tasks to give the user a seamless experience of multiple tasks running simultaneously. Biological systems, on the other hand, engage in 'parallel computation' — whereby multiple tasks can be executed truly simultaneously.
- Early proof-of-concept work has been completed using myosin — a superfamily of motor proteins which cause muscle contraction and convert chemical energy into mechanical energy. Myosin-enabled biocomputing could perform multiple computations simultaneously.

Self-Organizing and Self-Repairing

- Biological molecules also display an intelligent ability to self-organize and self-repair. So, biocomputing engineers will have to find ways to simulate this intelligent ‘software’ on top of the biological molecule ‘hardware’ to produce, organize, and repair the biocomputing system.
- Like a living organism the “software” in biological systems is responsible for producing and assembling the hardware which in turn will help run the software.

BIOIMAGING

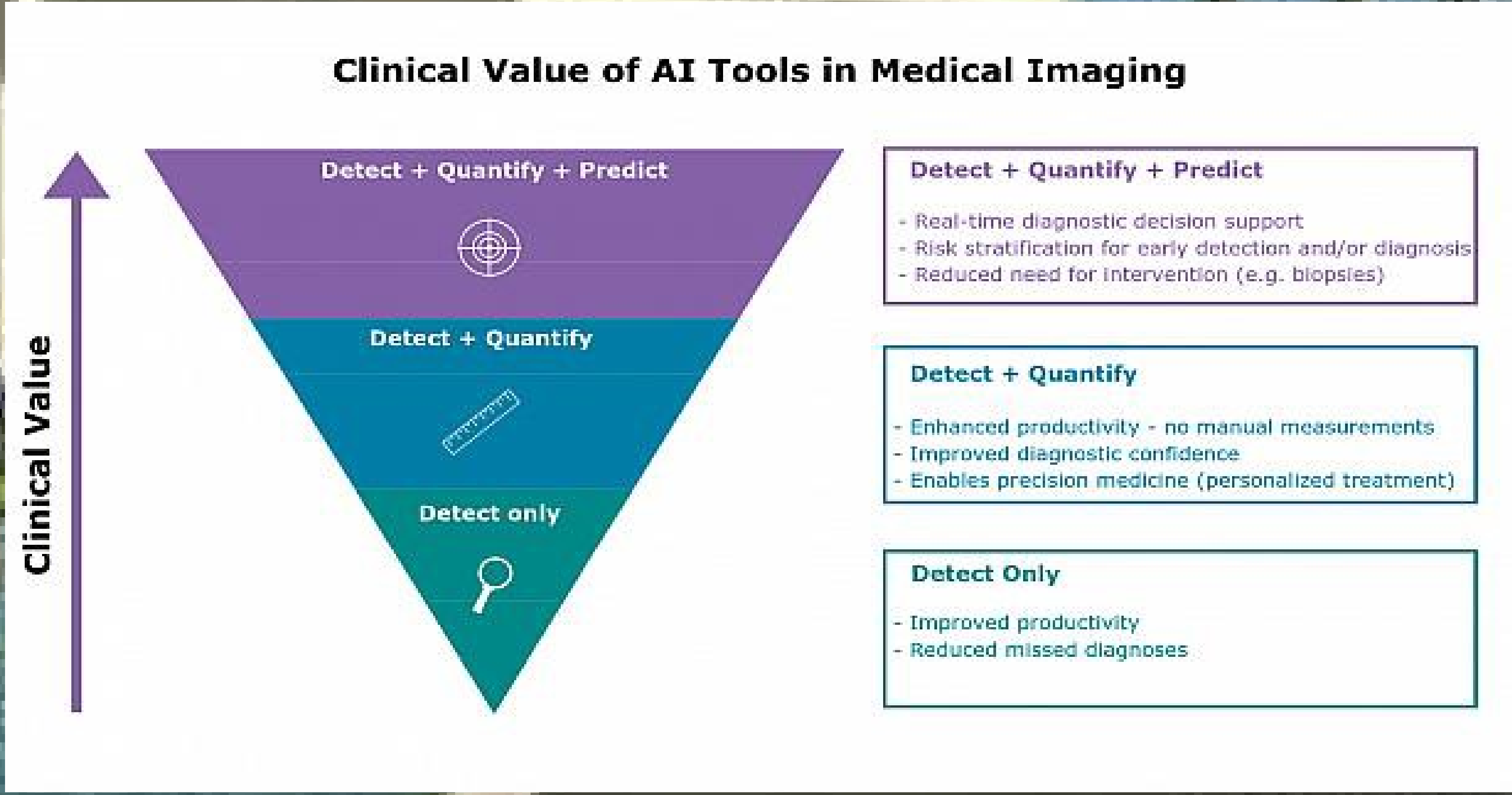
- Bioimaging refers to technologies for viewing biological substances that have been fixed for monitoring. In the fundamental and medical sciences, bioimaging can be used to examine typical anatomy and physiology and gather research data.
- There are certain medical imaging techniques including optical imaging (OI), magnetic resonance imaging(MRI), positron emission computed tomography, computed tomography (CT), radiography and conventional applied clinically.
- Bioimaging is a non-invasive process of visualizing biological activity in a specific period. It does not inhibit the various life processes such as movement, respiration, etc., and it helps to report the 3D structure of specimens apart from inferencing physically.
- Bioimaging gives clinicians a chief tool for checking patients' reactions to therapy. It promises illness detection in therapy in a non-invasive and safe manner. Bioimaging is a very important innovative imaging technology that has a lot of significance in today's world.
- The application of biomedical imaging for diagnosis and management of lifestyle-induced diseases will help to avoid disease development through lifestyle changes.


Nanomedicines
design and fabrication
Size
Shape
Surface
Matenal
Bioimaging
Real-time monitoring of
nanomedicines in vivo
behavior
Biodistribution
Pharmacokinetics
Drug release
Liver
Spleen
Kidney
Pathological region
Clinical translation

ARTIFICIAL INTELLIGENCE FOR DISEASE DIAGNOSIS

- In diagnosing the disease, the accuracy and correctness of the diagnosis is the most critical factor in the treatment process.
- AI has proven significant accuracy in the detection of image-based diseases as well as in the prediction of treatment outcomes regarding survival rate and treatment response.
- It can scan freeform text and pull data about specific symptoms, gene sequencing, or medical history. That information helps physicians screen patients for genetic conditions and diagnose rare diseases.

- AI techniques are used to predict diseases based on available patient data. Medical diagnosis requires physicians and medical laboratories for testing, while artificial intelligence-based predictive systems are used for the early prediction of diseases.



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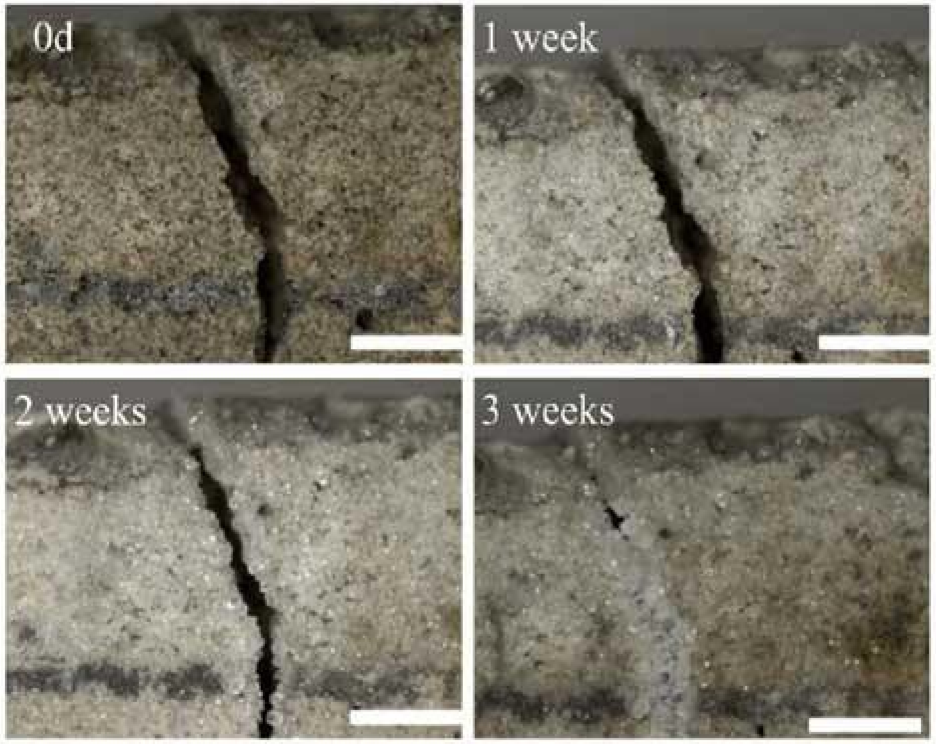
BIOCONCRETE

- Bio-concrete is a self-healing form of concrete designed to repair its own cracks.
- Bio concrete produces limestone ($CaCO_3$) crystals to fill up the cracks appearing on the surfaces. When the cracks begin to form in the concrete structure water enters the cracks After encountering water and oxygen, the inactive bacteria become active.
- Self-healing concrete is a result of biological reaction of non-reacted limestone and a calcium-based nutrient with the help of bacteria to heal the cracks appeared on the building.
- Special type of bacteria's known as Bacillus are used along with calcium nutrient known as Calcium Lactate.
- Self-healing concrete (SHC) has the capacity to heal and lowers the requirement to locate and repair internal damage (e.g., cracks) without the need for external intervention.
- This limits reinforcement corrosion and concrete deterioration, as well as lowering costs and increasing durability.


0d
1 week
2 weeks
3 weeks


BEFORE
AFTER

BasedOnBacillu

- For the creation of healable cement concrete matrix, microbial self-healing solutions are significantly more creative and potentially successful.
- The addition of bacteria, mainly of the genus Bacillus, were studied for cracks-filling and increasing the compressive strength through $CaCO_3$-precipitation
- Gram-positive "*Bacillus subtilis*" (*B. subtilis*) microorganisms can effectively repair structural and non-structural cracks caused at the nano- and microscale.
- B. subtilis bacteria greatly enhanced the compressive strength and speed up the healing process in cracked cement concrete mixture. The iron oxide nanoparticles were proven to be the best immobilizer for keeping B. subtilis germs alive until the formation of fractures.

Calcium Lactate Nutrients

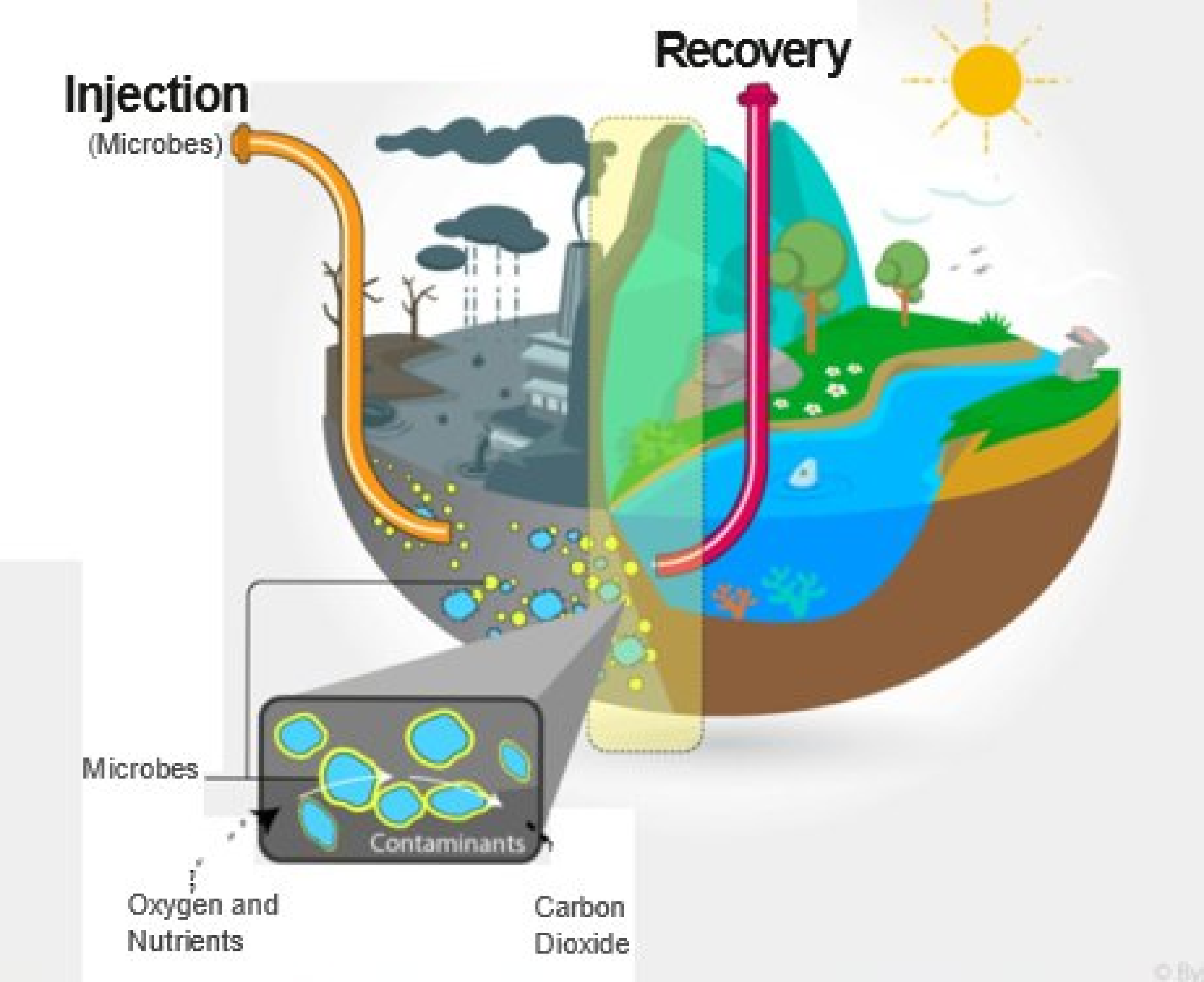
- Calcium lactate comes in a liquid form and is added as a supplement in the water used for concrete mixing.
- The bacterial liquid culture and calcium lactate are added directly to the concrete mix.
- Calcium lactate is used to enhance the compressive strength and the self- healing of cracks.

Bio Mineralization Process

- Biomineralization is the process by which mineral crystals are deposited in the matrix of living organisms , often to harden or stiffen existing tissues
- This process gives rise to inorganic-based skeletal structures such as bone during development, which is a complex and dynamic organ with both structural and metabolic functions.

BIOREMEDIATION

- Bioremediation is a biotechnical process, which cleans up contamination.
- It is a type of waste management technique which involves the use of organisms to remove or utilize the pollutants from a polluted area.
- There are several remedies where contaminated water or solid is purified by chemical treatment, incineration, and burial in a landfill. There are other types of waste management technique which include solid waste management, nuclear waste management, etc. Bioremediation is different as it uses no toxic chemicals.


Injection
(Microbes)
Recovery
Microbes
Contaminants
Oxygen and Nutrients
Carbon Dioxide

- Microorganisms like Bacteria and Fungi are the main role player when it comes to executing the process of Bioremediation.
- Bacteria are the most crucial microbes in this process as they break down the waste into nutrients and organic matter.
- Even though this is an efficient process of waste management, but bioremediation cannot destroy 100% contaminants.
- Bacteria can easily digest contaminants like chlorinated pesticides or clean oil spills, but microorganisms fail to destroy heavy metals like lead and cadmium.

Types of Bioremediation

Bioremediation is of three types –

1) Biostimulation

As the name suggests, the bacteria is stimulated to initiate the process. The contaminated soil is first mixed with special nutrients substances including other vital components either in the form of liquid or gas. It stimulates the growth of microbes thus resulting in efficient and quick removal of contaminants by microbes and other bacteria.

2) Bioaugmentation

At times, there are certain sites where microorganisms are required to extract the contaminants. For example – municipal wastewater. In these special cases, the process of bioaugmentation is used. There's only one major drawback in this process. It almost becomes impossible to control the growth of microorganisms in the process of removing the contaminant.

3) Intrinsic Bioremediation

The process of intrinsic bioremediation is most effective in the soil and water because of these two biomes which always have a high probability of being full of contaminants and toxins.

The process of intrinsic bioremediation is mostly used in underground places like underground petroleum tanks. In such place, it is difficult to detect a leakage and contaminants and toxins can find their way to enter through these leaks and contaminate the petrol. Thus, only microorganisms can remove the toxins and clean the tanks.

Advantages of bioleaching include:

- Bioleaching can stabilise sulphate toxins from the mine without causing harm to the environment.
- Poisonous sulphur dioxide emissions harm the environment and can cause health problems for miners, and bioleaching avoids this process entirely.
- Bioleaching is more cost-effective than smelting processes.
- Some Bioleaching offers a different way to extract valuable metals from low-grade ores that have already been processed.
- Bacteria, archaea and fungi are typical prime bioremediates. The application of bioremediation as a biotechnological process involving microorganisms for solving and removing dangers of many pollutants through biodegradation from the environment.

Removal Of Heavy Metals

- Bioremediation is an innovative technique for the removal and recovery of heavy metal ions from polluted areas and involves using living organisms to reduce and/or recover heavy metal pollutants into less hazardous forms, using the activities of algae, bacteria, fungi, or plants.
- Heavy metals like Lead, Cadmium, Mercury, Arsenic can be removed by bioremediation and biomining process.

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Thank You

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