

MUSCULAR AND SKELETAL SYSTEM AS SCAFFOLDS

ARCHITECTURE

The musculoskeletal system (Locomotor system) is a human body system that provides our body with movement, stability, shape, and support. It is subdivided into two broad systems.

1. **Muscular system**, which includes all types of muscles in the body. Skeletal muscles, in particular, are the ones that act on the body joints to produce movements. Besides muscle, the muscular system contains the tendons which attach the muscles to the bones.
2. **Skeletal system**, whose main component is the bone. Bones articulate with each other and form the joints, providing our bodies with a hard-core, yet mobile, skeleton. The integrity and function of the bones and joints are supported by the accessory structures of the skeletal system. Articular, cartilage, ligaments, and bursae.

Functions of Musculo skeletal system:

1. Muscles contract and relax to enable activities such as walking, running, and lifting.
2. Muscles produce heat during metabolism, helping to regulate body temperature.
3. Stores essential minerals like calcium and phosphorus, which are crucial for bone and cell maintenance
4. Produces red and white blood cells via bone marrow.

Mechanism:

The nerve system (body's command centre) controls your voluntary muscle movements. Voluntary muscles are ones you control intentionally. Some involve large muscle groups to do activities like jumping. Others use smaller movements, like pushing a button.

Movements happen when: Our nervous system (brain and nerves) sends a message to activate your skeletal (voluntary) muscles. Our muscle fibres contract (tense up) in response to the message. When the muscle activates or bunches up, it pulls on the tendon. 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 muscles to relax or deactivate. The relaxed muscle releases tension, moving the bone to a resting position.

Scaffolds and tissue engineering:

Scaffolds play a crucial role in bioengineering solutions for both muscular and skeletal systems, providing structural support and promoting tissue regeneration. Here's how scaffolds are utilized in each context:

1. Muscle Tissue Engineering:

- **Purpose:** Scaffolds are used to create a framework that supports the growth and organization of muscle cells in vitro (in the lab) or in vivo (in the body).
- **Materials:** Biocompatible materials such as natural polymers (e.g., collagen, fibrin) or synthetic polymers (e.g., polylactic acid, polyglycolic acid) are commonly used.

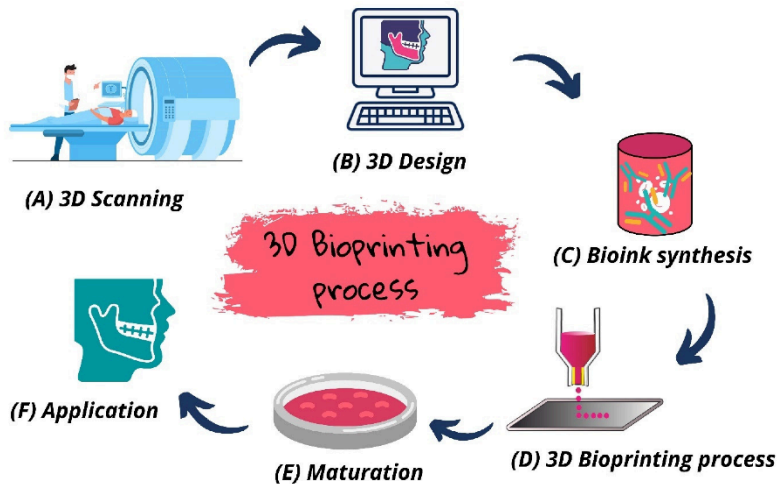
- **Function:** Scaffolds mimic the extracellular matrix (ECM) of muscle tissue, providing a framework for muscle cells to adhere, proliferate, and differentiate.
- **Applications:** Used in therapies for muscular dystrophy and muscle injuries, scaffolds can be seeded with stem cells or myoblasts to promote muscle regeneration and restore muscle function.

2. Bone Tissue Engineering:

- **Purpose:** Scaffolds are designed to support the growth of new bone tissue and aid in bone regeneration
- **Materials:** Typically made from biocompatible materials like ceramics (e.g., hydroxyapatite), polymers (e.g., polylactic acid), or composite materials.
- **Function:** Scaffolds provide a three-dimensional structure that mimics the trabecular and cortical bone architecture, facilitating cell attachment, proliferation, and differentiation.
- **Applications:** Used in treating bone fractures, osteoporosis, and bone defects, scaffolds can be loaded with growth factors or stem cells to enhance bone healing and regeneration.

BIOPRINTING TECHNIQUES AND MATERIALS

Bioprinting is a rapidly growing field that uses various techniques to produce three-dimensional (3D) functional biological medical and scientific structures and tissues for applications. The main objective of bioprinting is to mimic the structure and function of human tissues and to the development of parts for damaged or diseased organs, leading to replacement of diseased organs.



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3D BIOPRINTING

3D bioprinting is a technology where bioinks, mixed with living cells, are printed in 3D to construct natural

Aspect	3D Printers	Bioprinters
Printing Purpose	General-purpose printing of objects	Fabrication of living tissues and organs
Materials	Plastics, metals, ceramics, resins, etc.	Bioinks (hydrogels, extracellular matrices, cell aggregates, etc.)
Applications	Manufacturing, engineering, product design, architecture, etc.	Regenerative medicine, tissue engineering, drug development, etc.
Printing Process	Additive manufacturing, layer-by-layer deposition	Precise deposition of bioinks layer-by-layer
Cell Compatibility	NA	Bioinks must support cell viability and function
Challenges	NA.	Development of suitable bioinks, cell viability, vascularization, scaling up, etc.
Advantages	Versatile, wide range of applications Enables rapid prototyping Cost-effective for non-biological objects	Potential for tissue and organ transplantation Enables tissue engineering and regenerative medicine Can create tissue models for studying diseases Potential for personalized medicine and drug testing.
Limitations	Limited ability to create functional living tissues, limited choices of materials for certain applications, lack of cell compatibility and tissue functionality.	Complex and rapidly evolving technology, challenges in developing suitable bioinks and scaling up vascularization and long term functionality of printed tissues.

tissue-like three-dimensional structures. Currently, this technology can be used in various research areas, such as tissue engineering and new drug development.

BASIC PRINCIPLE OF 3D BIOPRINTING

The principle of 3D printing 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.

COMPARISON BETWEEN 3D PRINTER AND BIOPRINTER

BIOPRINTING MATERIALS

Bioprinting materials, also known as bioinks, are specifically designed to be compatible with living cells and provide a supportive environment for their growth and organization.

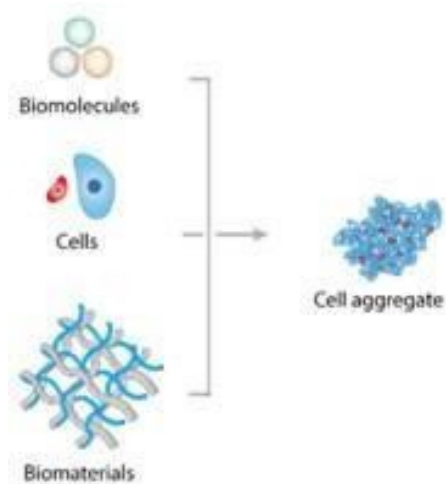
Hydrogels:

Hydrogels are water-based polymer networks that closely mimic the extracellular matrix (ECM) found in living tissues. They offer excellent biocompatibility, mechanical support, and can be formulated to have similar physical properties to native tissues.

Examples of hydrogels used as bioinks include:

- Gelatine-based hydrogels
- Alginate hydrogels
- Fibrin-based hydrogels
- Collagen-based hydrogels

Cell-laden Aggregates: In some cases, cells are first aggregated into biomolecules and biomaterials (or microtissues) before being incorporated into the bioink. These aggregates provide a more physiological environment for the cells and enhance their viability and functionality.

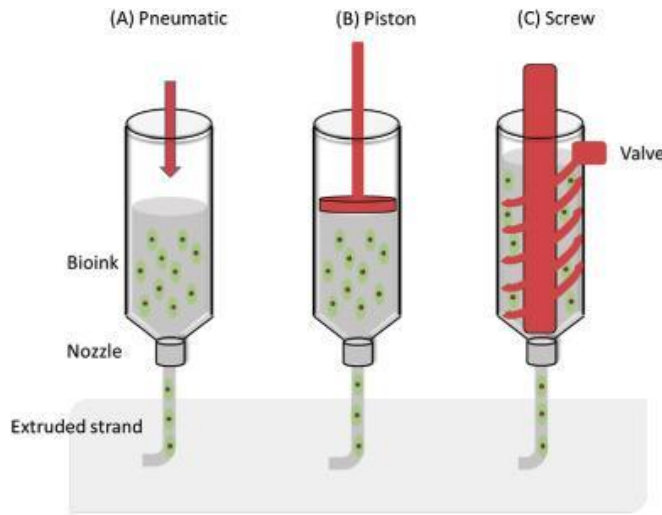


MOST COMMONLY USED BIOPRINTING TECHNIQUES

Bioprinting techniques involve the precise deposition of bioinks to create three-dimensional structures with living cells.

1. INKJET-BASED BIOPRINTING

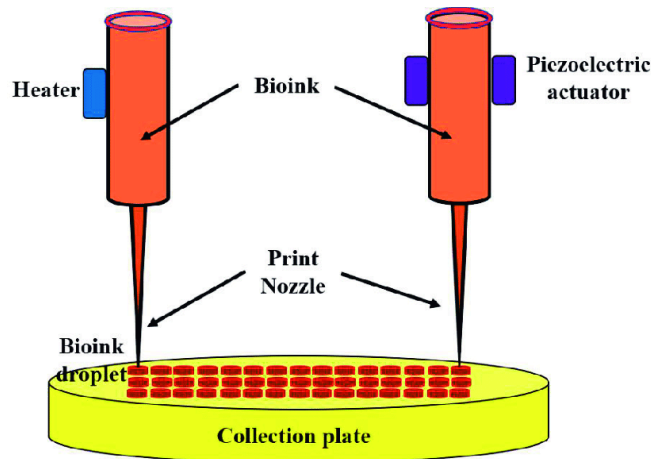
Inkjet bioprinting works similarly to standard inkjet printing. The bioink is loaded into cartridges, and ejected through fine nozzles onto a substrate. The droplets form layers, and are built by depositing subsequent layers. Inkjet bioprinting allows for high-resolution printing and precise control over droplet size, but it may be limited by the cell viability during the ejection process.



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2. EXTRUSION-BASED BIOPRINTING

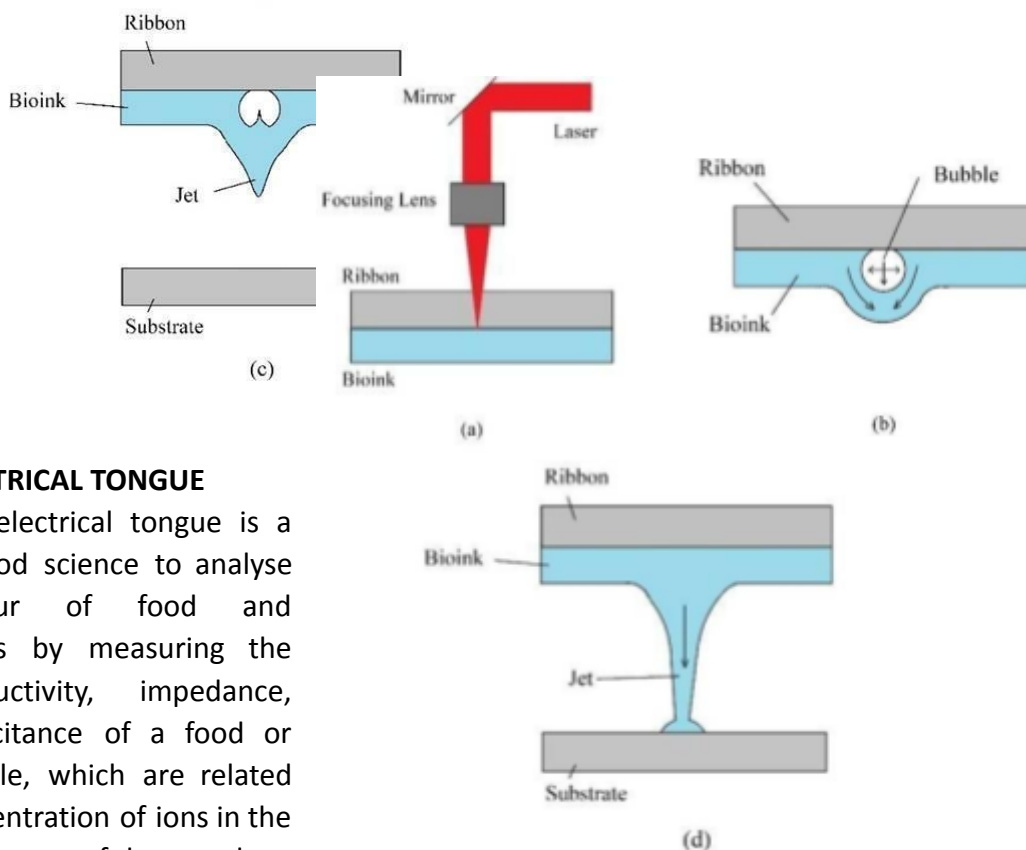
Extrusion-based bioprinting uses a syringe or a similar mechanism to extrude the bioink through a nozzle. The bioink is deposited layer-by-layer to create the desired structure. This technique is versatile and can handle a wide range of viscosities, including those with living cells or cell aggregates. It allows for high cell viability and can produce controlled porosity. However, it may have limitations in achieving high resolution and complex geometries.



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3. LASER-ASSISTED BIOPRINTING

Laser-assisted bioprinting utilizes laser energy to precisely deposit bioinks onto a substrate. The bioink is placed on an energy-absorbing layer, and the laser creates a pressure wave that propels the bioink onto the substrate in a controlled manner. This technique offers high resolution, precision, and the ability to print complex structures. It can be used with delicate bioinks and allows for cell viability. However, laser-assisted bioprinting can be relatively slow and may have limitations in terms of bioink viscosity.



ELECTRICAL TONGUE

The electrical tongue is a device used in food science to analyse the taste and flavour of food and beverages. It works by measuring the conductivity, impedance, capacitance of a food or sample, which are related to the concentration of ions in the sample and the texture of the sample.

This technology allows for the rapid and non-invasive analysis of food and beverages, as it does not require human taste testers. Instead, the electrical tongue provides a numerical representation of the taste and flavour of the sample, which can be used to compare and analyse different food and beverage products.

MATERIALS USED IN ELECTRICAL TONGUE TECHNOLOGY

Examples of biomaterials used in Electrical Tongue technology include:

device used to analyse the taste and beverages. It electrical and beverage to the sample and

1. **Polymers:** Polymers, such as polyvinyl alcohol (PVA) and polyethylene oxide (PEO), are often used as the substrate or matrix material in electrical tongue sensors, as they have high sensitivity to changes in ion concentration and are flexible.
2. **Metal Oxides:** Metal oxides, such as tin dioxide (SnO₂) and zinc oxide (ZnO), are commonly used in electrical tongue sensors because of their high sensitivity to changes in ion concentration and ability to undergo changes in electrical conductivity in response to different tastes.
3. **Carbon Nanotubes:** Carbon nanotubes are small tubes made of carbon atoms that have high electrical conductivity and sensitivity to changes in ion concentration, making them an attractive material for use in electrical tongue sensors.
4. **Dendrimers:** Dendrimers are synthetic, branched nanostructures that can be functionalized with specific receptors or enzymes to target specific tastes. They are being explored as potential materials for use in electrical tongue sensors.
5. **Microfluidic Devices:** Microfluidic devices, which are small devices that can manipulate small volumes of fluid, are being used in the development of electrical tongue sensors. These devices can be made from a variety of materials, including silicon, glass, and polymers, and can be functionalized with specific receptors or enzymes to target specific tastes.

ELECTRICAL NOSE IN FOOD SCIENCE

The electrical nose, also known as an electronic nose, is a technology used in food science for the analysis and characterization of food and beverage aromas and flavours. The electrical nose typically consists of a sensor array that is capable of detecting and quantifying volatile organic compounds (VOCs) in food and beverage samples.

Technology behind the Electronic Nose

The sensors in the electrical nose work by measuring the changes in electrical resistance or capacitance that occur when the sensors are exposed to volatile organic compounds. Each sensor in the array is designed to respond to a specific range of volatile organic compounds, and the combination of signals from all of the sensors allows for the analysis of the overall aroma and flavour profile of a sample.

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DNA ORIGAMI

DNA Origami is a technique in nanotechnology that involves folding DNA molecules into specific shapes. The process involves using a long, single strand of DNA, called the scaffold, to guide the folding of short, complementary DNA strands, called staples, into a desired shape.

The first DNA origami structures were developed in the mid-2000s and since then, the technique has been widely used in a variety of applications, including the creation of nanoscale structures, the study of molecular interactions, and the development of new drug delivery systems.

TECHNOLOGICAL IMPORTANCE OF DNA ORIGAMI

The technological importance of DNA origami lies in its potential to be used in a wide range of applications, including nanotechnology, materials science, and biomedicine. Some of the key ways in which DNA origami can impact technology include:

1. **Nanoscale manufacturing:** DNA origami can be used as a template for the precise assembly of nanoscale structures, which have applications in areas such as electronics, photonics, and materials science.
2. **Drug delivery:** DNA origami can be used to develop new approaches for drug delivery, as it can be designed to carry therapeutic agents directly to specific cells or tissues.
3. **Biosensors:** DNA origami can be used to develop new biosensors that can detect specific biological molecules and signals in real-time.
4. **Biomedical imaging:** DNA origami can be used as a tool for biomedical imaging, as it can be designed to target specific cells or tissues and provide high-resolution images.
5. **Gene therapy:** DNA origami can be used as a delivery vehicle for gene therapy, as it can be programmed to target specific cells and deliver therapeutic genes to those cells.
6. **Biocatalysis:** DNA origami can be used to develop new approaches for biocatalysis, as it can be designed to perform specific chemical reactions and act as a catalyst.
7. **Nanopatterning:** DNA origami can be used as a tool for nanopatterning, as it can be programmed to arrange and position nanoscale structures with precise control.

BIO COMPUTING

Bio-computing refers to the use of biological systems, such as cells, enzymes, and DNA, for computing and information processing. This field combines the principles of computer science, biology, and engineering to create novel systems for computing and data storage.

Technological Importance

The technological importance of bio-computing lies in its potential to provide new and innovative solutions for computing and information processing. Here are some of the key ways in which bio-computing can impact technology:

1. **Computational power:** Bio-computing systems have the potential to provide new levels of computational power, as they can perform complex tasks and calculations using biological processes.
2. **Data storage:** Bio-computing systems can be used to store and process large amounts of data, as DNA has a high information density [consider that a single gram of DNA can theoretically store up to 215 petabytes (1 petabyte = 1 million gigabytes) of data] and can be easily synthesized and amplified.
3. **Medical applications:** Bio-computing systems can be used to develop new diagnostic and therapeutic approaches in medicine, such as biosensors and gene therapies.
4. **Environmental monitoring:** Bio-computing systems can be used to monitor and track environmental conditions, such as air and water quality, in real-time.
5. **Energy efficiency:** Bio-computing systems are energy-efficient, which is becoming increasingly important as we face the challenge of climate change and the need to reduce our energy consumption.
6. **Robustness:** Bio-computing systems are highly robust, as they are less susceptible to errors and failures compared to traditional electronic systems.
7. **Versatility:** Bio-computing systems can be programmed and reprogrammed to perform different tasks, which makes them highly versatile and adaptable.

BIOIMAGING FOR DISEASE DIAGNOSIS

Bio-imaging is the use of imaging technologies to visualize biological processes and structures in living organisms. It plays a crucial role in disease diagnosis by providing detailed images of the body's internal structures and functions, and can help healthcare professionals to identify and diagnose a wide range of diseases and conditions.

Examples of Bioimaging Techniques

Some examples of bioimaging techniques used for disease diagnosis include X-rays, CT scans, MRI, PET scans, ultrasound, and optical imaging. These technologies can be used to visualize a wide range of structures and functions, including bones, tissues, organs, blood vessels, and more.

ARTIFICIAL INTELLIGENCE FOR DISEASE DIAGNOSIS

Artificial Intelligence (AI) has the potential to revolutionize the field of disease diagnosis by providing healthcare professionals with more accurate and efficient tools for identifying and treating various conditions.

Advantages

Some of the key ways in which AI is being used in disease diagnosis include:

1. **Image analysis:** AI algorithms can analyse medical images, such as X-rays, CT scans, and MRIs, to detect signs of diseases. For example, AI algorithms can identify patterns in medical images that may indicate the presence of a particular condition, such as a tumour or an injury. This type of image analysis is known as computer-aided diagnosis (CAD).
2. **Data analysis:** AI algorithms can analyse large amounts of patient data, such as electronic health records, to identify patterns and trends that may indicate a disease. This type of data analysis is known as predictive analytics.
3. **Diagnosis:** AI algorithms can be used to diagnose diseases by evaluating symptoms, test results, and other patient information. AI algorithms can help healthcare professionals make faster and more accurate diagnoses, reducing the risk of misdiagnosis.
4. **Personalized medicine:** AI algorithms can be used to create personalized treatment plans for patients based on their specific medical histories, lifestyles, and other factors. For example, AI algorithms can analyse a patient's medical history, lifestyle habits, and genetic information to recommend the best course of treatment for their condition.
5. **Clinical decision support:** AI algorithms can be integrated into electronic health records to provide healthcare professionals with real-time decision-making support. For example, AI algorithms can provide physicians with information about the best diagnostic tests to order, the most effective treatments to consider, and the best ways to manage patient care.

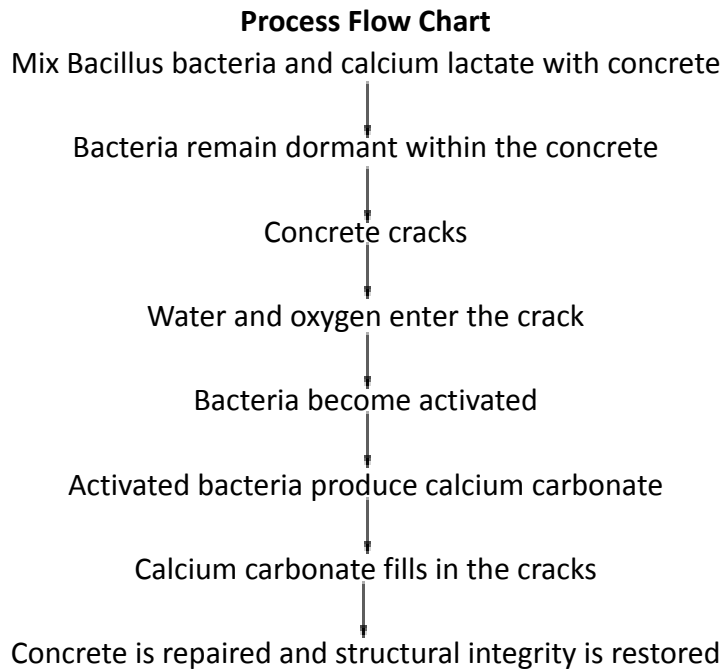
SELF-HEALING BIO- CONCRETE

Self-healing bio-concrete is a type of concrete that incorporates microorganisms, such as *Bacillus* fragments, into the mixture, along with calcium lactate as a nutrient source. The microorganisms are activated when the concrete cracks, and they produce calcium carbonate, which fills in the cracks and repairs the concrete. This process is known as bio-mineralization.

The benefits of self-healing bio-concrete include increased durability, reduced maintenance costs, and improved sustainability, as the concrete is able to repair itself without the need for human intervention.

Additionally, because the microorganisms used in the concrete are naturally occurring and non-toxic, self-healing bio-concrete is considered to be environmentally friendly.

SELF-HEALING PROCESS



Self-healing bio-concrete works by incorporating Bacillus bacteria into the concrete mixture, along with calcium lactate as a nutrient source. The bacteria are dormant within the concrete and do not become active until the concrete cracks.

When the concrete cracks, water and oxygen enter the crack and activate the Bacillus bacteria. The bacteria then produce calcium carbonate, which is a type of mineral that is commonly found in natural stone. The calcium carbonate acts as a binder and fills in the cracks, repairing the concrete and restoring its structural integrity. This process is known as biomineralization.

The Bacillus bacteria used in self-healing bio concrete are naturally occurring and non-toxic, so they are considered to be environmentally friendly. They are also able to survive in a wide range of temperatures and pH levels, making them well-suited for use in concrete.

BIOREMEDIATION AND BIOMINING VIA MICROBIAL SURFACE ADSORPTION

Bioremediation and biomining are two related but distinct processes that utilize living organisms to clean up contaminated environments or extract valuable minerals, respectively.

Bioremediation refers to the use of microorganisms, plants, or animals to clean up contaminated environments, such as soil, water, or air. This process occurs naturally over time, but can also be accelerated through the addition of specific microorganisms or other biotic agents. The goal of bioremediation is to remove contaminants from the environment and restore it to a healthy state.

Biomining, on the other hand, refers to the use of microorganisms to extract valuable minerals from ore deposits. This process involves the use of microorganisms to dissolve minerals from ore, creating a solution that can be separated and purified to obtain the valuable minerals. Biomining is often used in the extraction of metals such as copper, gold, and nickel, and has several advantages over traditional mining methods, including lower energy costs, reduced waste, and increased metal recover.

The process of removing polluting heavy metals using bioremediation or biomining via microbial surface adsorption

Identification of heavy metal-contaminated site:

Identify the site or area contaminated with heavy metals, such as soil, water, or industrial waste sites.

Isolation and characterization of metal-resistant microbial strains:

Select and isolate microbial strains that have demonstrated resistance to heavy metals. These can include bacteria, fungi, or archaea.

Culturing and enrichment of microbial strains:

Culture and propagate the selected microbial strains in a suitable growth medium under laboratory conditions. This step aims to obtain a sufficient quantity of active microbial biomass for subsequent applications.

Preparation of microbial suspension:

Harvest the microbial biomass and prepare a suspension by suspending the biomass in a carrier solution, such as water or a nutrient broth. This suspension will serve as the delivery system for the microbes during application.

Application of microbial suspension to the contaminated site:

Apply the microbial suspension to the heavy metal-contaminated area. This can be done through spraying, injection, or soil/water mixing, depending on the specific site conditions.

Microbial adsorption and sequestration of metal:

The applied microbial strains adsorb to the surfaces of metal particles or form biofilms. Through their metabolic activity, the microbes produce extracellular compounds such as organic acids or biofilm matrix components that have an affinity for binding metal ions.

Separation or removal of metals from the contaminated site can be achieved through different methods

Methods used for the Separation or Removal of Metals

After the steps of microbial adsorption and sequestration of heavy metals, the subsequent separation or removal of metals from the contaminated site can be achieved through different methods. Here are a few common approaches:

1. **Phytoremediation:** In this method, plants are used to remove heavy metals from the soil or water. The metal-accumulating ability of certain plant species, called hyperaccumulators, allows them to take up metals from the environment and store them in their tissues. After the plants have absorbed the metals, they can be harvested and disposed of properly, effectively removing the metals from the site.
2. **Chemical extraction:** Chemical agents can be applied to the contaminated area to facilitate the release of heavy metals from the microbial biomass or the surrounding matrix. Chelating agents, such as ethylenediaminetetraacetic acid (EDTA) or citric acid, can be used to form complexes with the metals, increasing their solubility and facilitating their removal.