

MODULE 5: TRENDS IN BIOENGINEERING (QUALITATIVE)**Syllabus**

Muscular and Skeletal Systems as scaffolds, scaffolds and tissue engineering, Bioprinting techniques and materials. Electrical tongue and electrical nose in food science, DNA origami and Biocomputing, Bioimaging and Artificial Intelligence for disease diagnosis. Bioconcrete. Bioremediation. Biomining.

Introduction:

Bioengineering is a discipline that applies engineering principles of design & analysis to biological systems & biomedical technologies.

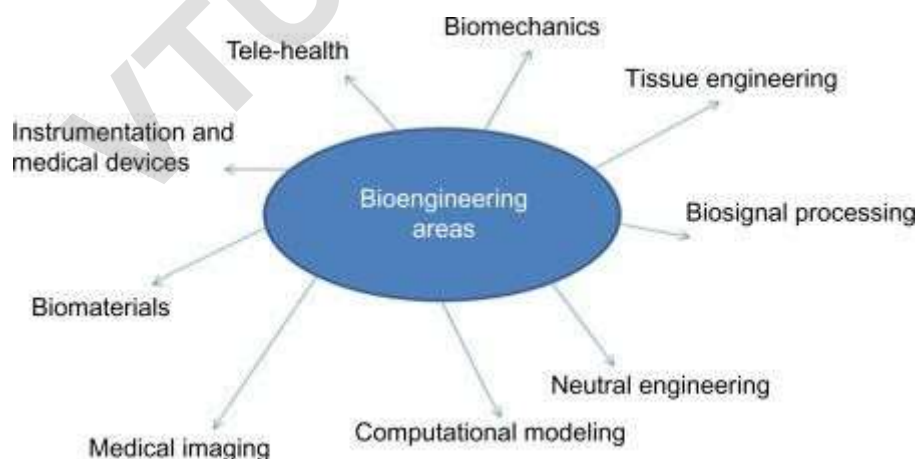
Examples of bioengineering research include bacteria engineered to produce chemicals, new medical imaging technology, portable disease diagnostic devices, & tissue engineered organs.

Examples of bioengineering research include bacteria engineered to produce chemicals, new medical imaging technology, portable and rapid disease diagnostic devices, prosthetics, biopharmaceuticals, and tissue-engineered organs. Bioengineering overlaps substantially with biotechnology and the biomedical sciences in a way analogous to how various other forms of engineering and technology relate to various other sciences (such as aerospace engineering and other space technology to kinetics and astrophysics).

In general, biological engineers attempt to either mimic biological systems to create products, or to modify and control biological systems. Working with doctors, clinicians, and researchers, bioengineers use traditional engineering principles and techniques to address biological processes, including ways to replace, augment, sustain, or predict chemical and mechanical processes.

Branches of bioengineering may be categorized as:

Tissue engineering, Transdermal patches, Wearable devices, Robotic surgeons and Rehabilitation, Nanorobots, Virtual reality, Microbubbles, Organ-on-a-chip, Mini bioreactors, gene editing.



Muscular & skeletal systems as scaffolds

The muscular and skeletal systems are two interconnected and interdependent systems in the human body.

They work together to provide support to the body, enable its movement, give protection to vital organs and carry out various physiological functions essential for human life.

Architecture of Muscular & skeletal system

The muscular and skeletal systems work together to form the framework of the body, providing support, movement, and protection for the body organs and tissues.

Muscular system is composed of muscles and tendons.

1. Muscles are responsible for movement by contracting and relaxing, and they work in pairs to produce opposing movements. For example, the biceps and triceps in the arm work together to produce flexion and extension of the elbow joint.
2. Tendons connect muscles to bones, allowing the muscles to pull on the bones and produce movement.

Skeletal system is composed of bones, cartilage, and ligaments.

1. Bones provides rigid framework for body, protecting the organs and supporting the body weight.
2. Cartilage acts as a cushion between bones reducing friction & absorbing shock during movement.
3. Ligaments connect bones to other bones, providing stability & preventing excessive movement.

Mechanism of working of muscular and skeletal system

The systems work together to produce movement and maintain stability in the body.

The mechanism involves following steps:

1. **Contraction of muscles:** When the brain sends a signal to a muscle to contract, the muscle fibers shorten and pull on the tendons, which in turn pull on the bones. This produces movement at the joint.
2. **Transmission of force:** When a muscle contracts, the force is transmitted through the tendons to the bone, causing it to move.
3. **Lever system:** The bones in the body act as levers, with joints acting as fulcrums. The arrangement of bones and joints in the body creates a system of levers that allows for efficient movement with minimal energy expenditure.
4. **Feedback mechanism:** The nervous system provides feedback to the brain about the position and movement of the body. This allows for fine-tuning of movements and helps to maintain stability and balance.

Muscular and skeletal systems as scaffolds

1. Regenerate the cells during accidents, sport-related injuries.
2. When a natural muscle is not working, scaffolds are used as temporary templates.
3. Scaffolds are 3-dimensional structures made up of biomaterials (collagen, fibrin and PLA).
4. These are designed and used to support and guide the growth of cells, tissues, or organs in human body.
5. The orientation and alignment of regenerated muscle cells are guided by the structure of scaffold.
6. The structure of regenerated muscle fibers will be similar to structure of scaffold.
7. Scaffolds are porous structures with interconnected pore networks.
8. The porosity allows for the diffusion of nutrients, oxygen and waste products.
9. The surface properties of scaffolds are modified to incorporate seed cells, bioactive molecules and growth factors.
10. These create a microenvironment for muscle action formation of new blood vessels and by tissue remodeling.

11. Scaffolds are used in regeneration of bone, cartilage, skin, nerves and organs.

Muscular dystrophy

Muscular dystrophy is a group of diseases that cause progressive weakness and loss of muscle mass.

1. It is a genetic disorder.
2. It is caused by a mutation in the dystrophin gene.
3. The main sign of muscular dystrophy is progressive muscle weakness.
4. It results in difficulty walking, frequent falls, difficulty rising from lying or sitting position, trouble running and jumping etc.

Bioengineering solutions for muscular dystrophy

Bioengineering solutions for muscular dystrophy are briefly given below:

1. **Gene Therapy:** In Gene therapy mutated gene responsible for muscular dystrophy is replaced by a functional gene. Also be used to modify the expression of genes with the genetic defect causing muscular dystrophy.
2. **Cell Therapy:** In cell therapy, the damaged cells of muscle tissue are transplanted by healthy muscle cells. Stem cells can be differentiated into muscle cells and implanted into affected muscles. These cells have the potential to regenerate muscle fibers and improve muscle strength and function.
3. **Tissue Engineering:** In this approach, stem cells or muscle precursor cells are seeded onto bioengineered scaffolds. These scaffolds are then implanted into the affected muscle tissue. The scaffold provides structural support and guidance for new tissue growth and their integration into the host tissue.

Osteoporosis

Skeletal disorder in which there is decrease in bone mineral density and bone mass.

This can lead to a decrease in bone strength that can increase the risk of fractures (broken bones).

Osteoporosis occurs when the body fails to form enough new bone, or when existing bone is reabsorbed more quickly than it is replaced.

It is commonly seen in postmenopausal women and in older men. Fractures happen most often in bones of the hip, vertebrae in the spine, and wrist.

The main causes of osteoporosis are:

- a) Hormonal imbalances, particularly a decrease in estrogen levels in women after menopause.
- b) Inadequate calcium and vitamin D intake and physical inactivity,
- c) Smoking, and excessive alcohol consumption,
- d) Taking certain steroidal medications.

Bioengineering solutions for Osteoporosis

Main bioengineering solutions for osteoporosis are briefly given below:

1. **Use of scaffolds:** Bioengineered scaffolds can be used to provide structural support and a three-dimensional environment for bone regeneration. Seed cells are attached to scaffolds and allowed proliferate and differentiate to produce new cells.
2. **Use of Growth Factors and Bioactive Molecules:** Growth factors and bioactive molecules enhance bone formation. Growth factors are the molecules that can stimulate the proliferation and differentiation of bone-forming cells and accelerate bone regeneration. Example for growth factors is morphogenetic proteins (BMPs).
3. **Use of cell therapies:** Stem cells or seed cells can be isolated from various sources like bone marrow and adipose tissue. These cells can be incorporated into scaffolds and implanted into bone defect sites. At this site, they proliferate and differentiate to produce new cells and contribute to new bone formation.
4. **Delivering Drugs to target site:** Bio engineering based modern targeted drug delivering systems can be utilized to delivery drugs directly and specifically to osteoporosis site. These systems can deliver medications, such as bisphosphonates or teriparatide, directly to the bone tissue.

Bioprinting techniques:

Bioprinting techniques has emerged as a powerful tool for building tissue & organ structures in the field of tissue engineering. The technique allows precise placement of cells, biomaterials & biomolecules in spatially predefined locations within confined three-dimensional (3D) structures. Developments in 3D bioprinting have been mostly motivated by the limited availability of organs globally, which are needed for the rehabilitation of lost or failed organs and tissues. The most challenging and demanding applications for engineered tissues include the skin, cartilage, hard tissues such as bones, cardiac tissue, and vascular grafts.

In general, bioprinting can be defined as “the automated generation of biologically functional products with structural organization from living cells, bioactive molecules, biomaterials, cell aggregates such as microtissues, hybrid cell-material constructs through bioprinting”.

The three basic steps of bioprinting:

1. Pre-bioprinting: - This involves creating a digital file for the printer to read. Today, these files are often based on CT and MRI scans. Researchers prepare cells and mix them with their bioink, using a live-cell imaging system to ensure there are enough cells to bioprint a tissue model successfully.

2. Bioprinting: - Researchers load the cell-laden bioink into a cartridge and choose one or multiple printheads, depending on the structure they’re trying to build. Developing different types of tissue requires researchers to use different types of cells, bioinks and equipment.

3. Post-bioprinting: - Most structures are crosslinked to become fully stable. Crosslinking is usually done by treating the construct with either ionic solution or UV light – the construct’s composition helps researchers determine what kind of crosslinking to use. Then the cell-filled constructs are placed inside an incubator for cultivation.

Applications of bioprinting: -

Drug development:

Many of today’s studies rely on living subjects – an inconvenient and expensive method for both academic and commercial organizations. Bioprinted tissues can be used instead during the early stages, providing a more ethical and cost-effective solution. Using bioprinted tissue can help researchers determine a drug candidate’s efficacy sooner, enabling them to save money and time.

Artificial organs:

The organ donation list is so long that patients wait years before getting the help they need. Being able to bioprint organs could help clinicians keep up with patients or eliminate the list entirely. While this solution is far down the line, it is one of the most impactful possibilities in the field.

Wound healing:

A lot of tissue-specific bioinks are available today, enabling researchers to work with artificial skin cells, neurons, hepatocytes and more. One day, clinicians could use these models for therapeutic procedures like skin grafts, bone bandages for combat wounds or even plastic surgery.

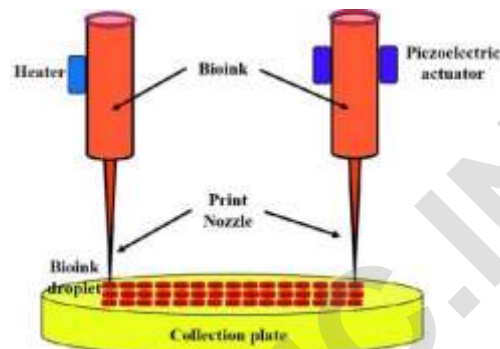
Types of bioprinting techniques: Bioprinting techniques can be broadly classified into 5 types as follows.

1. Inkjet bioprinters.
2. Extrusion based bioprinters.
3. Laser-based bioprinters.
4. Stereolithography based bioprinter.
5. Microvalve bioprinters.

Inkjet bioprinters: - It is a form of droplet-based bioprinting, in which the bioink is dropped on the stage in small portions. This working principle is the same as in some ink cartridge office printers, and those can be easily modified for bioprinting.

Principle of inkjet bioprinters:

- ✓ Inkjet bioprinting is based on the ejection of drops of liquid onto a substrate by thermal or acoustic forces.
- ✓ Thermal inkjet bioprinting can be achieved by electrically heating the print head to generate pressure that causes the release of droplets from the nozzle.
- ✓ In the case of acoustic inkjet bioprinting, a piezoelectric crystal is used that creates an acoustic wave inside the print head to break the liquid into droplets.
- ✓ When a voltage is applied to a piezoelectric substance, a rapid change in shape is induced. This, in turn, generates pressure required to force droplets out of the nozzle.
- ✓ Both of these methods have their own advantages and disadvantages; thus, the selection of inkjet bioprinting technology should be made based on the desired purpose.

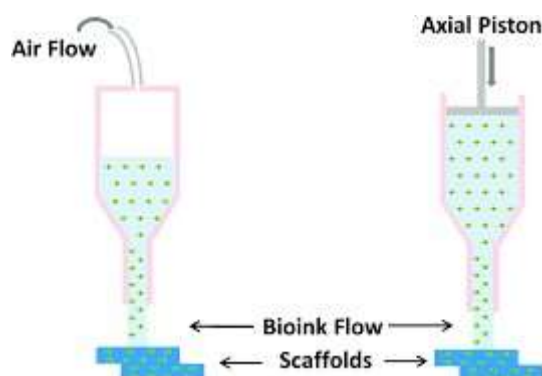
**Examples of inkjet based bioprinting**

1. Some of the common applications of inkjet bioprinting are the regeneration of functional skin and cartilage tissues where the high printing speed of this technique enables direct deposition of cells and biomaterials onto skin and cartilage lesions.
2. Besides, inkjet bioprinting also allows the deposition of primary or stem cells with uniform density onto lesions while maintaining cell viability and function.
3. Layered cartilage constructs have also been developed using a combination of inkjet bioprinting and electrospinning technology.

Extrusion based bioprinters: - In this, the bioink is extruded through a nozzle tip by pressure. The bioink extrudes as a continuous filament and is printed layer-by-layer on top of a substrate placed on the stage.

Principle of extrusion based bioprinters:

- ✓ The extrusion-based 3D bioprinting utilizes one of the two mechanisms to produce the desired result; the semi-solid extrusion (SSE) and the fused deposition modeling (FDM) based 3D printing.
- ✓ In the SSE based 3D bioprinting, pressurized air or rotating screw gear is used to extrude a continuous stream of semi-solid materials through a nozzle which is deposited in a layer-by-layer fashion to form a 3D structure.
- ✓ The FDM 3D bioprinting, however, utilizes high temperature to melt thermoplastic filaments which are then extruded through a nozzle to deposit in a layer-by-layer fashion to produce a 3D structure.
- ✓ The two principal components of all extrusion-based 3D printers include the extrusion system and the positioning system; thus, both of these systems should be accurate enough to produce a visually and geometrically accurate structure.



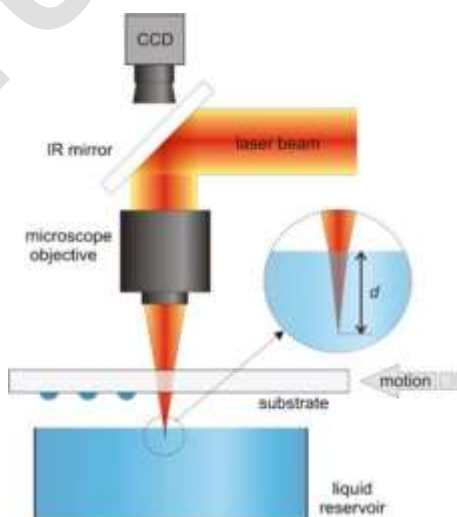
Examples of extrusion based bioprinting

1. The extrusion-based 3D bioprinting method has been widely used in various biomedical sectors ranging from the pharmaceutical industry to research sectors.
2. The technology is commonly used for single tissue applications, and to manufacture scaffolds that mimic tissue interfaces.
3. The technology is capable of producing models that mimic soft tissues and bone structures which provide an opportunity for possible implants.

Laser based bioprinters: In this, the bioink is stored in a donor slide. On top of the donor slide and in direct contact with it is an energy absorbing layer. When a strictly controlled laser is pulsed into the absorbing layer, the shockwave from the laser separates a droplet of bioink from the donor slide. The droplet then falls to the collector slide due to gravity.

Principle of laser based bioprinters:

- ✓ The principle of laser-assisted bioprinting is the use of the laser to induce forward transfer of biomaterials onto a solid surface.
- ✓ The laser present on the printer irradiates the ribbon, which causes the liquid biomaterial to evaporate and reach the receiving substrate in droplet form.
- ✓ The receiving substrate consists of biopolymers or a cell culture medium which assists cellular adhesion and sustained growth of the biomaterial.



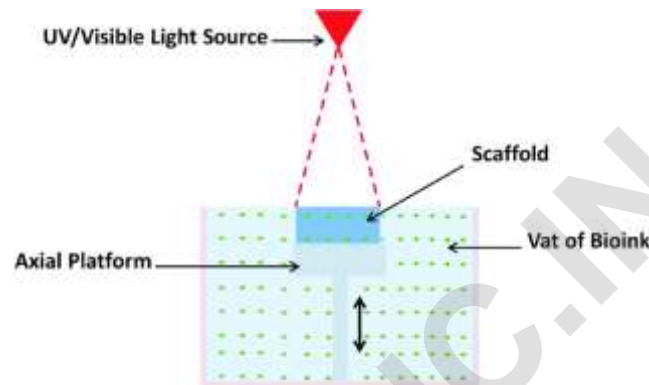
Examples of Laser-assisted bioprinting:

1. Laser-assisted bioprinting has been used to produce a cellularized skin constructs with relevant cell densities in a layered tissue construct.
2. Cells of the human dermal fibroblasts, pulmonary artery endothelial cells, and breast cancer cells can be produced via laser-assisted bioprinting.

Stereolithography based bioprinter: The stereolithography technique has the highest fabrication accuracy, and a large number of materials can be used in the process. The technique utilizes light-sensitive hydrogels that are deposited in a layer-by-layer fashion to form a 3D structure. The speed of this method is very fast (about 40,000 mm/s) with cell viability of more than 90%.

Principle of stereolithography based bioprinters:

- ✓ Stereolithography technology is based on the solidification of the liquid photosensitive polymer upon illumination.
- ✓ The technology utilizes digital micromirror arrays to control the light intensity to polymerize light-sensitive polymer materials.
- ✓ The photochemical solidification of biopolymers results in the formation of layers that together form a 3D object.



Examples stereolithography based bioprinters:

This technique has been used in several ways to produce tissues and organs of different animals, including humans.

Besides, the technique was tested upon on DNA material, but the use of UV light has chances of affecting the DNA structure. However, a custom light source can be prepared to use with DNA molecules.

Microvalve bioprinters: The microvalve-based bioprinting system is an advanced manufacturing platform that facilitates the precise deposition of bio-inks with moderate viscosities and the four key parameters that influence the printability include viscosity, density and surface tension of the printable bio-inks.

Principle of microvalve bioprinters:

- ✓ Microvalve printing is a simple droplet-based deposition mechanism, where fluids under constant pneumatic pressure are dispensed from tips by opening and closing a small valve, which can be controlled mechanically, electrically or magnetically.
- ✓ This style of deposition has been implemented in extrusion-style printing as outlined above, where the microvalve remains open for extended periods, but finds most application in drop on-demand deposition by fast actuation of the microvalve.
- ✓ The tips are usually 100-200 μm in diameter, and are capable of dispensing droplets with volumes ranging from tens of nanolitres to several micro-litres, from inks with relatively low viscosities (1-20 mPa. s).

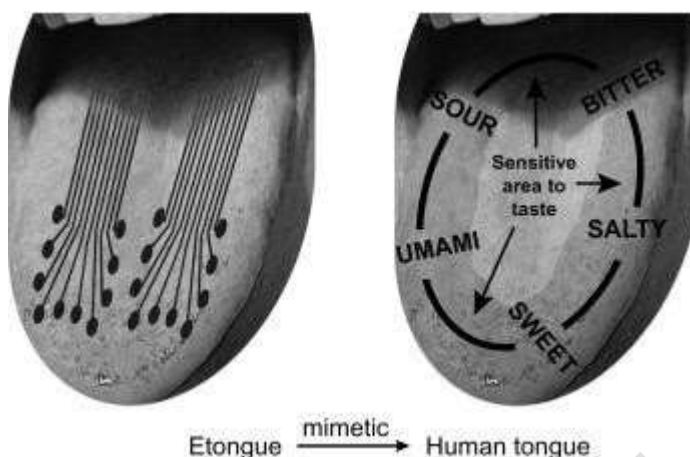


Electronic tongue (E- tongue) in food science: Electronic tongue, also known as E-tongue, is an analytical instrument that mimics the human tongue's sense of taste and is used in food science to analyze the taste and flavor of different food products.

Working and components of E-tongue:

1. **Sensor Array:** The tongue's sensor array is the heart of the instrument consisting of several sensors that are sensitive to specific taste related chemicals such as salt, some sweetness bitterness. Each sensor is designed to respond to a particular chemical or group of chemicals and together they can provide a comprehensive profile of the taste and flavor of a food sample.
2. **Sample Holder:** The sample holder is the part of the tongue that holds the food sample during testing. It is typically made of a material that is inert and does not interact with the food sample, such as glass or plastic.
3. **Signal Processor:** The tongue's signal processor is responsible for analyzing the electrical signals generated by the sensor array in response to the food sample. It converts these signals into a profile of the taste and Savor of the sample, which can be displayed on a computer screen or other output device.
4. **Data Analysis Software:** The tongue's data analysis software is used to interpret the data generated by the signal processor and create a profile of the taste and flavor of the food sample. This software can be customized to suit the specific needs of a particular application or industry,

5. **Calibration Solutions:** To ensure accurate and reliable results, E-tongue, require regular calibration using standardized solutions with known taste and flavor characteristics.



Electronic tongue (E- nose) in food science: An electronic nose, also known as an E-nose, is an analytical instrument that mimics the human sense of smell and is used to identify and analyze the aroma or odor of different substances. The e-nose consists of a sensor array that is capable of detecting and quantifying different volatile organic compounds (VOCs) based on their chemical composition.

Working and components of E-nose: The E-nose is an analytical instrument that works by detecting and analyzing the volatile organic compounds (VOCs) present in a sample.

1. **Sensor Array:** The e-nose's sensor array is composed of several sensors that are sensitive to specific VOCs. Each sensor is designed to respond to a particular chemical or group of chemicals, and together they can provide a comprehensive profile of the aroma. or odor of a sample.
2. **Sample Delivery System:** The sample delivery system is used to introduce the sample into the e-nose. Depending on the type of sample, the delivery system can vary, but it typically involves exposing the sample to the sensor array through an inlet port.
3. **Signal Processing System:** The e-nose's signal processing system is responsible for analyzing the electrical signals generated by the sensor array in response to the sample. The system converts these signals into a profile of the aroma or odor of the sample, which can be displayed on a computer screen or other output device.
4. **Data Analysis Software:** The e-nose's data analysis software is used to interpret the data generated by the signal processing system and create a profile of the aroma or odor of the sample. This software can be customized to suit the specific needs of a particular application or industry.
5. **Calibration Solutions:** To ensure accurate and reliable results, e-noses require regular calibration using standardized solutions with known aroma or odor characteristics. Calibration solutions can be used to verify the performance of the instrument and ensure that it is operating within the desired range of accuracy and precision.

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

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.

BIO-IMAGING 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.

Technological Importance

The technological importance of bio-imaging for disease diagnosis lies in its ability to provide detailed images of the body's internal structures and functions, which can help healthcare professionals to make accurate diagnoses and provide effective treatments.

1. **Improved accuracy:** Bio-imaging technologies can provide high-resolution images of the body's internal structures, which can help healthcare professionals to identify subtle changes and make accurate diagnoses.
2. **Early detection:** Bio-imaging can be used to detect diseases in their early stages, when they are often more treatable. This can lead to earlier treatment and better outcomes for patients.
3. **Multi-modality:** Bio-imaging technologies can be combined to provide a multi-modal view of the body's internal structures and functions, which can provide a more comprehensive understanding of a disease or condition.
4. **Cost-effectiveness:** Many bio-imaging technologies are relatively low-cost, which makes them accessible to a wider range of patients.
5. **Minimally invasive:** Many bio-imaging techniques are non-invasive, which means that they do not require incisions or the insertion of instruments into the body. This makes them less painful and less risky than many traditional diagnostic procedures.
6. **Improved patient outcomes:** By providing healthcare professionals with detailed images of the body's internal structures and functions, bio-imaging can help to improve patient outcomes by enabling earlier and more accurate diagnoses, and more effective treatments.
7. **Advancements in research:** Bio-imaging technologies are also important in advancing medical research, by providing detailed images of the body's internal structures and functions, which can help researchers to better understand the underlying mechanisms of diseases and develop new treatments.

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

Image analysis: AI algorithms can analyze 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 tumor or an injury. This type of image analysis is known as computer-aided diagnosis (CAD).

Data analysis: AI algorithms can analyze 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.

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.

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 analyze a patient's medical history, lifestyle habits, and genetic information to recommend the best course of treatment for their condition.

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.

Limitations

Lack of understanding of the underlying algorithms: AI algorithms can be complex and difficult to understand, making it difficult for healthcare professionals to interpret the results. This can lead to confusion and mistrust of AI-based tools, particularly among healthcare professionals who are not familiar with AI technology.

Bias: AI algorithms may be biased, leading to inaccurate or unfair diagnoses. For example, if an AI algorithm is trained on data from a predominantly male population, it may not accurately diagnose conditions that affect women differently.

Regulation: The use of AI in healthcare is heavily regulated, and it can be challenging to get approval for new AI technologies. In many countries, AI algorithms must undergo a rigorous evaluation process before they can be used in healthcare.

Cost: The development and implementation of AI algorithms can be expensive, which may limit access to these technologies for some patients and healthcare facilities. This is particularly true in low- and middle-income countries, where access to healthcare is already limited.

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 bio-concrete is still a relatively new technology and is currently in the research and development phase.

However, initial studies have shown promising results and have demonstrated the potential for self-healing bio-concrete to be a viable alternative to traditional concrete in certain applications.

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 bioconcrete are naturally occurring and nontoxic, 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.

In addition to repairing cracks, self-healing bioconcrete also has the potential to improve the overall durability of concrete by reducing the amount of water that is able to penetrate the surface.

This can help to prevent the development of further cracks and increase the longevity of the concrete.

Self-healing Process process:

1. Mix Bacillus bacteria and calcium lactate with concrete
2. Bacteria remain dormant within the concrete
3. Concrete cracks
4. Water and oxygen enter the crack
5. Bacteria become activated
6. Activated bacteria produce calcium carbonate
7. Calcium carbonate fills in the cracks
8. Concrete is repaired and structural integrity is restored

BIOREMEDIATION AND BIOMINING VIA MICROBIAL SURFACE ADSORPTION

(Removal of heavy metals like Lead, Cadmium, Mercury, Arsenic)

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 recovery.

Bioremediation and biomining via microbial surface adsorption is a process that utilizes microorganisms to remove heavy metals like lead, cadmium, mercury, and arsenic from contaminated environments or ore deposits, respectively.

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

Process of removing polluting heavy metals using bioremediation

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.

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.

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.

Biosorption: In this method, the metal-loaded microbial biomass or biofilms can be harvested and separated from the site. The biomass can then be processed to recover the metals through techniques such as acid leaching or thermal treatment. The metals can be further purified or recycled for various industrial applications.

Physical removal: In some cases, physical methods such as sedimentation, filtration, or membrane separation can be employed to separate the metal-loaded microbial biomass or biofilms from the surrounding environment. These techniques rely on the physical properties of the biomass or biofilms, such as size, density, or adsorption capacity, to separate them from the water or soil.

Electrochemical methods: Electrochemical techniques, such as electrokinetic remediation or electrocoagulation, can be utilized to remove heavy metals from the contaminated site. These methods involve the application of an electric field or the

generation of metal precipitates through electrochemical reactions, resulting in the migration or precipitation of metal ions, which can then be collected and removed.

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