International Conference - Biological knowledge discovery in Biotechnology, Bioinformatics & Biomedicine

Biomaterials for sustainable development

BY

BY

DR.P.MARIE AROCKIANATHAN

Associate Professor & Head,

PG &Research Department of Biochemistry,

St.Joseph's College of Arts & Science (Autonomous),Cuddalore-607001, Tamil Nadu.

Biomaterials

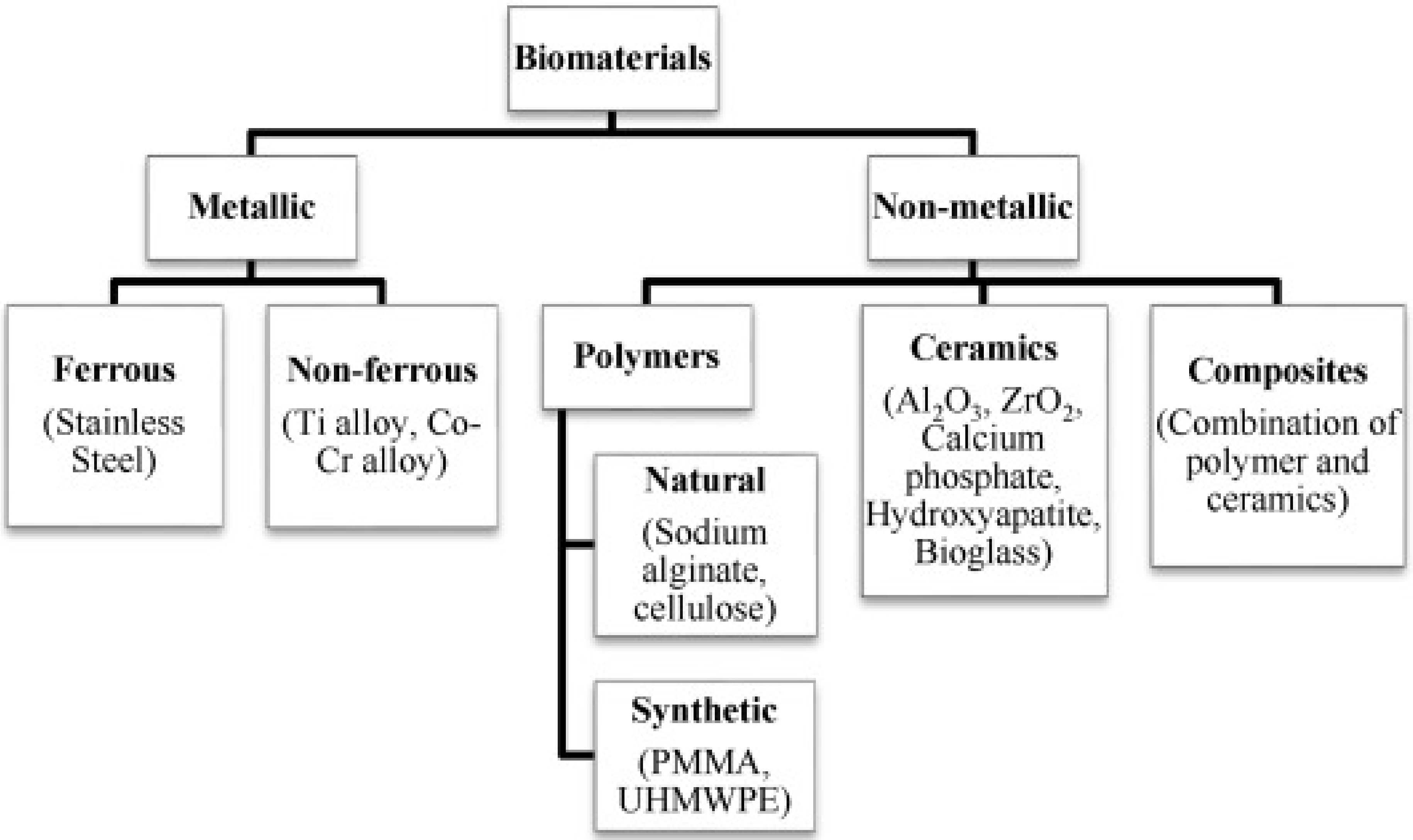
- Biomaterials may be natural or synthetic and are used in medical applications to support, enhance, or replace damaged tissue or a biological function.

- Biomaterials can be derived either from nature or synthesized in the laboratory using a variety of chemical approaches utilizing metallic components, polymers, ceramics or composite materials.
- They are often used and/or adapted for a medical application, and thus comprise the whole or part of a living structure or biomedical device which performs, augments, or replaces a natural function.

TYPES

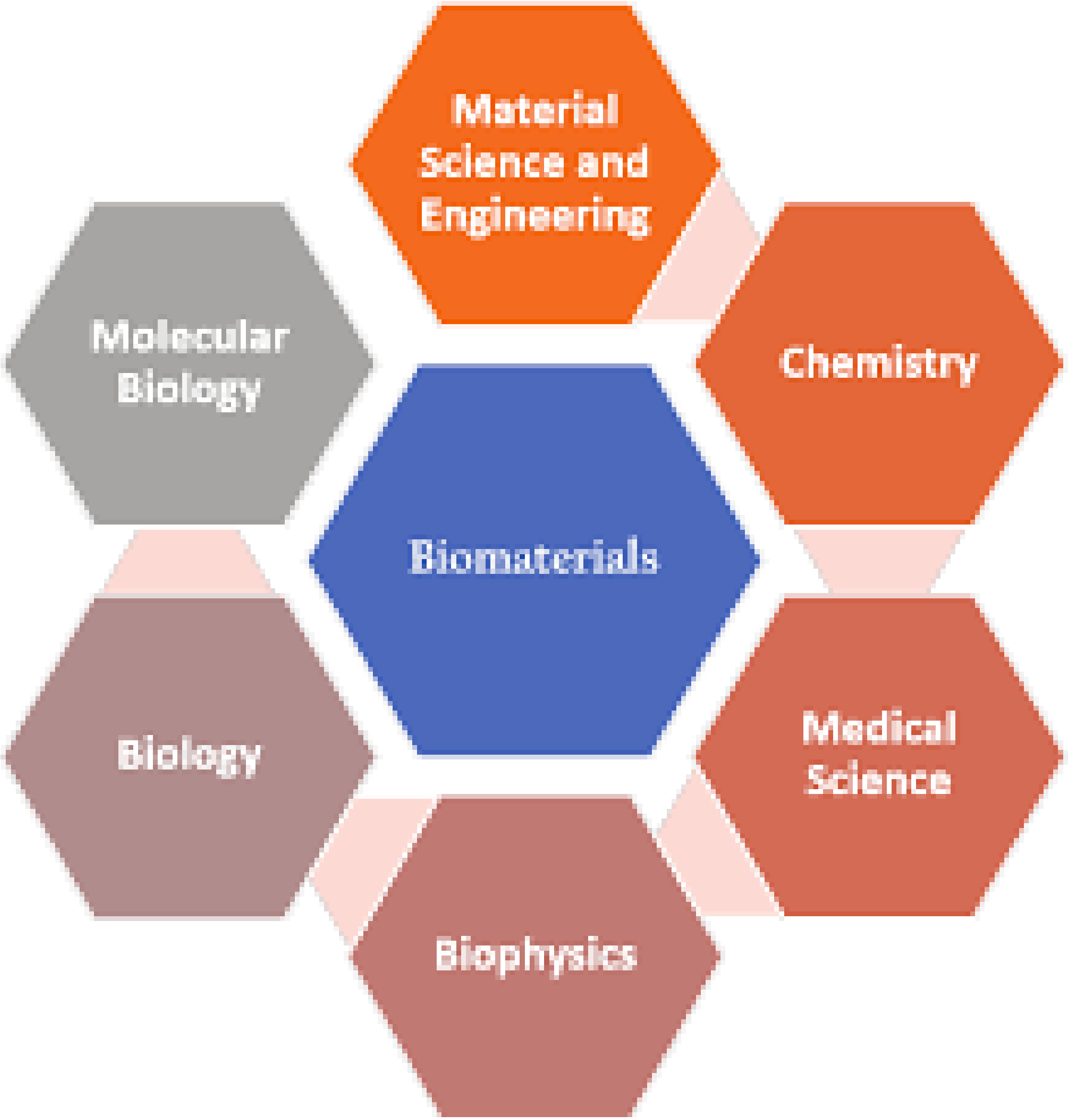
Biomaterials have been classified into 4 different types.

- i) Metals
- ii) Polymers
- iii) Ceramics
- iv) Composites

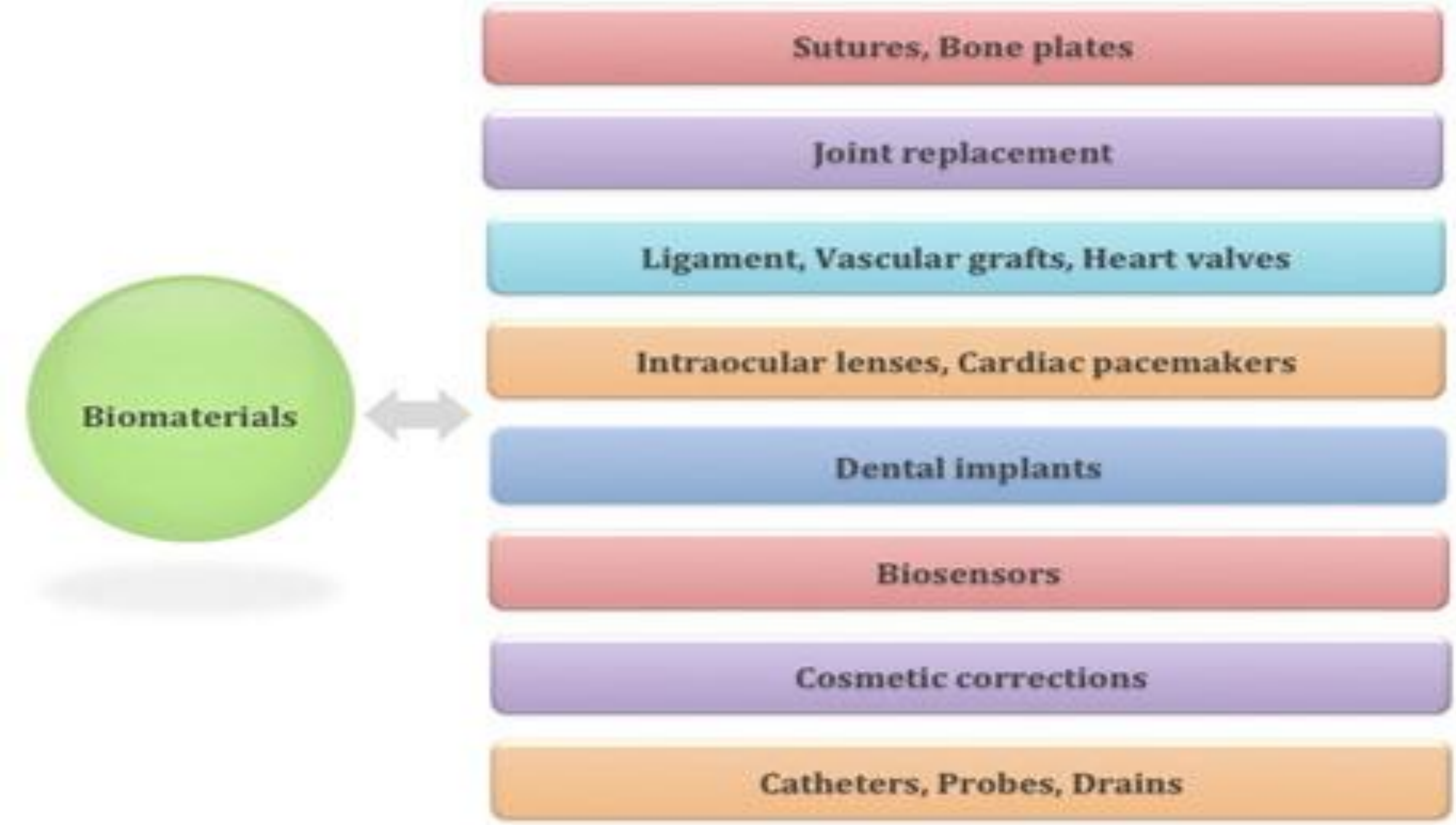


Biomaterials
Metallic
Non-metallic
Ferrous
(Stainless Steel)
Non-ferrous
(Ti alloy, Co-Cr alloy)
Polymers
Natural
(Sodium alginate, cellulose)
Synthetic
(PMMA, UHMWPE)
Ceramics
(Al_2O_3, ZrO_2, Calcium phosphate, Hydroxyapatite, Bioglass)
Composites
(Combination of polymer and ceramics)

- **Metals:** Widely used for load bearing implants. Wire, screw, plates, artificial joint for hip, knee, shoulder etc. Metal used as stainless steel, titanium and its alloy and cobalt based alloy.
- **Polymers** : Polymers resembles soft tissues and their application range from facial prosthesis to tracheal tubes, bladder, lens, tendons, etc. It can be used as sutures, catheters.
- **Ceramics** :Ceramics have been widely used in restorative materials in dentistry. The includes materials for crown (baby), cement, dentures (adult).
- **Composites**:The most successful composite are used in the field of dentistry as restorative material or dental cement.
- Carbon – carbon and carbon – reinforce polymer composites are used for bone repair and joint replacement because of the low elasticity modulus level.



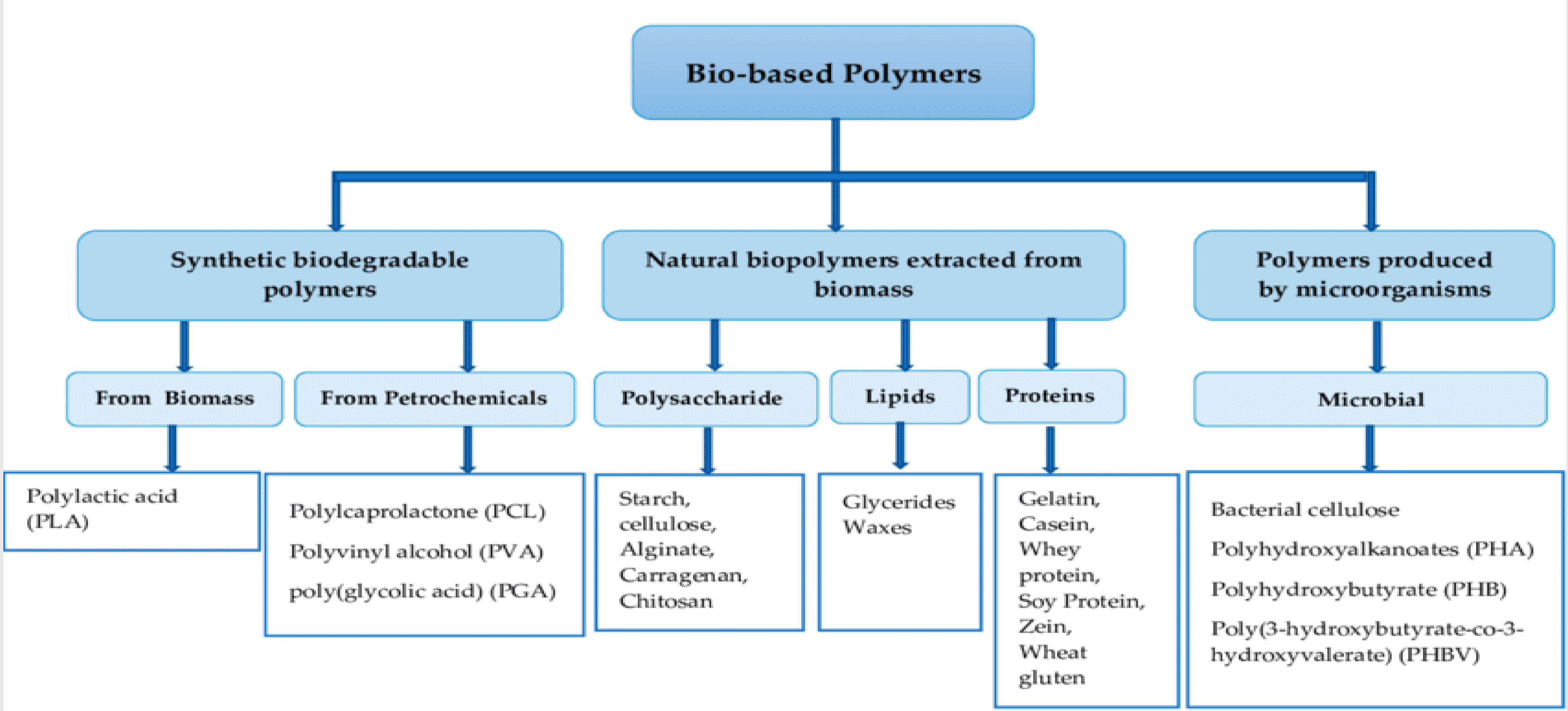
INTERDISCIPLINARY


Biomaterials
Sutures, Bone plates
Joint replacement
Ligament, Vascular grafts, Heart valves
Intraocular lenses, Cardiac pacemakers
Dental implants
Biosensors
Cosmetic corrections
Catheters, Probes, Drains

BIOPOLYMERIC MATERIALS

- Biopolymers are polymers produced from natural sources.
- They can either be chemically synthesised from biological materials or biosynthesised by living organisms.
- Biopolymers are derived from living organisms like plants and microbes- renewable resource.
- Most polymers which are petroleum-based polymers- non renewable.

Types of Biopolymers



Biodegradable synthetic polymers

Polyglycolide Acid (PGA)

- ❖It is a highly crystalline polymer (45–55% crystallinity).
- ❖ It exhibits high tensile modulus with a very low solubility in organic solvents .
- ❖The currently most commonly used in synthetic biodegradable polymer are considered to be poly (glycolic acid) and poly (lactic acid).
- ❖Resorbable sutures because of its excellent fiber forming ability(in progress).
- ❖Polyglycolides are broken down into glycine or converted into carbon dioxide and water via the citric acid cycle

Polylactide Acid (PLA)

- It is also a crystalline polymer (37% crystallinity).
- It has a glass transition temperature of 60–65° C and a melting temperature of approximately 175° C.
- Poly (L-lactide) is a slow-degrading polymer compared to polyglycolide.
- L-lactide (LPLA) homopolymer is a semicrystalline polymer with high tensile strength exhibition, low elongation, and have a high modulus.
- Suitable to be used in orthopedic fixation and sutures that have wild applications like load-bearing.

Poly (lactide-co-glycolide) & Polycaprolactone

- Different ratios of poly (lactide co-glycolides) have been commercially developed and are being investigated for a wide range of biomedical applications
- Polycaprolactone - a semicrystalline polymer with high solubility of polycaprolactone and low melting point (59- 64°C) can stimulate its biomaterial application research .
- Due to the short halflife, there is a problem with delivery of bioactive agent, therefore, a proper transport of the bioactive agents like drug; enzyme etc. a vehicle is needed.
- Starch-poly-epsilon-caprolactone microparticles were developed in some applications such as drug delivery and tissue engineering applications.

Biodegradable Natural polymers

Sugar based Biopolymers-

Lactic acid polymers (Polyactides) are created from milk sugar (lactose) which is extracted from maize, potatoes, wheat and sugar beet

Starch based Biopolymers

- Starch acts as natural polymer and can be obtained from vegetables like wheat, tapioca, potatoes and maize

Cellulose based Biopolymers

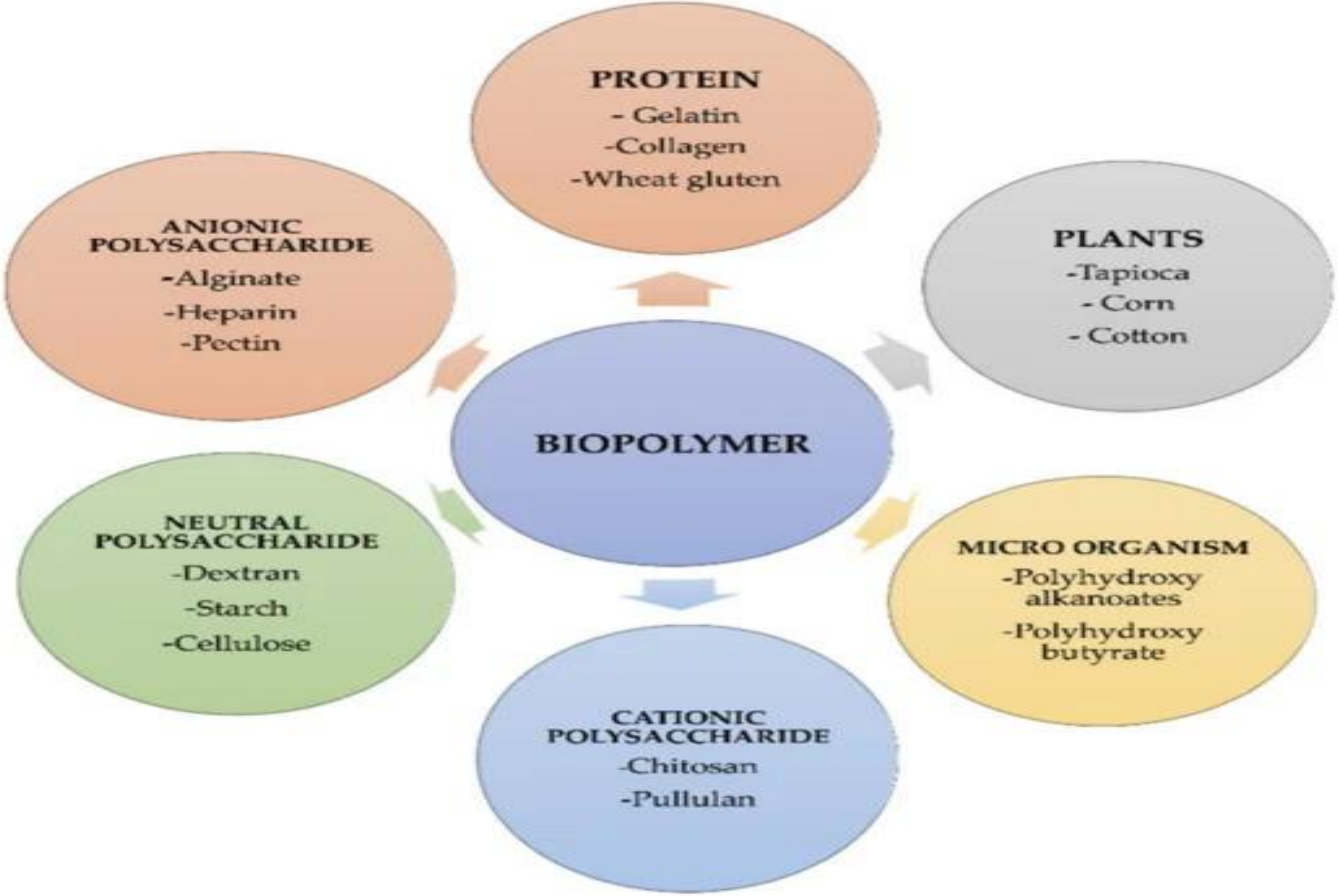
  - Cellulose are used for packing cigarettes, CDs and confectionary. This polymer is composed of glucose and is the primary obtained from natural resources, plant cellular walls, like cotton, wood, wheat and corn

Why we need biopolymers?

- Environmental concerns,
- sustainability,
- controls on pollutants and
- municipal solid waste disposal.
- It also minimizes carbon dioxide emissions, municipal solid waste, and reliance on petroleum-based resources

Sources of biopolymers

- Plants, animals, microorganisms, and agricultural wastes are examples of natural biological sources of biopolymers.
- Plant sources, such as rice, maize , wheat , sorghum , yams , cassava, potatoes , banana, tapioca , corn , cotton , and barley
- Biopolymers can be produced chemically from monomeric components, such as oils, sugars, and amino acids.
- Cattles are the most common animal sources.
- Corals, sponges, fish, lobster, and shrimp are the most common marine sources. Algae, fungus, and yeasts are the most common microbiological sources.
- Agro leftovers, paper wastes, crops, green wastes, and wood wastes are carbohydrate-rich biomass-based sources. Triglycerides are found in vegetable oils, such as sunflower, soybean, safflower, jojoba, rapeseed, castor, and meadowfoam oil


PROTEIN
- Gelatin
-Collagen
-Wheat gluten
ANIONIC POLYSACCHARIDE
-Alginate
-Heparin
-Pectin
PLANTS
-Tapioca
- Corn
- Cotton
BIOPOLYMER
NEUTRAL POLYSACCHARIDE
-Dextran
-Starch
-Cellulose
MICRO ORGANISM
-Polyhydroxy alkanoates
-Polyhydroxy butyrate
CATIONIC POLYSACCHARIDE
-Chitosan
-Pullulan

Gelatin

- One of the most popular protein biopolymers.
- Absence of an appreciable odour and the random configuration of polypeptide chains in an aqueous solution.
- They have good functional properties, such as water binding capacity, cross-linking possibility, and foaming, emulsifying and film-forming abilities.
- Gelatin can be produced from collagen from different animal sources including pigskin, bovine hides, pig and cattle bones, and other (including marine sources).
- Safe additive in the food industry.
- Chitin, chitosan, phenols (main compounds of the essential oils and natural extracts), organic acids, and enzymes , or inorganic compounds, including metallic and metal oxide nanoparticles (NPs) (e.g., silver (Ag), magnesium (Mg), zinc oxide (ZnO), titanium oxide (TiO), etc.) and clays (e.g., montmorillonite (MMT), laponite, etc.) --- fillers used to modify gelatin for various uses.

Chitin/chitosan

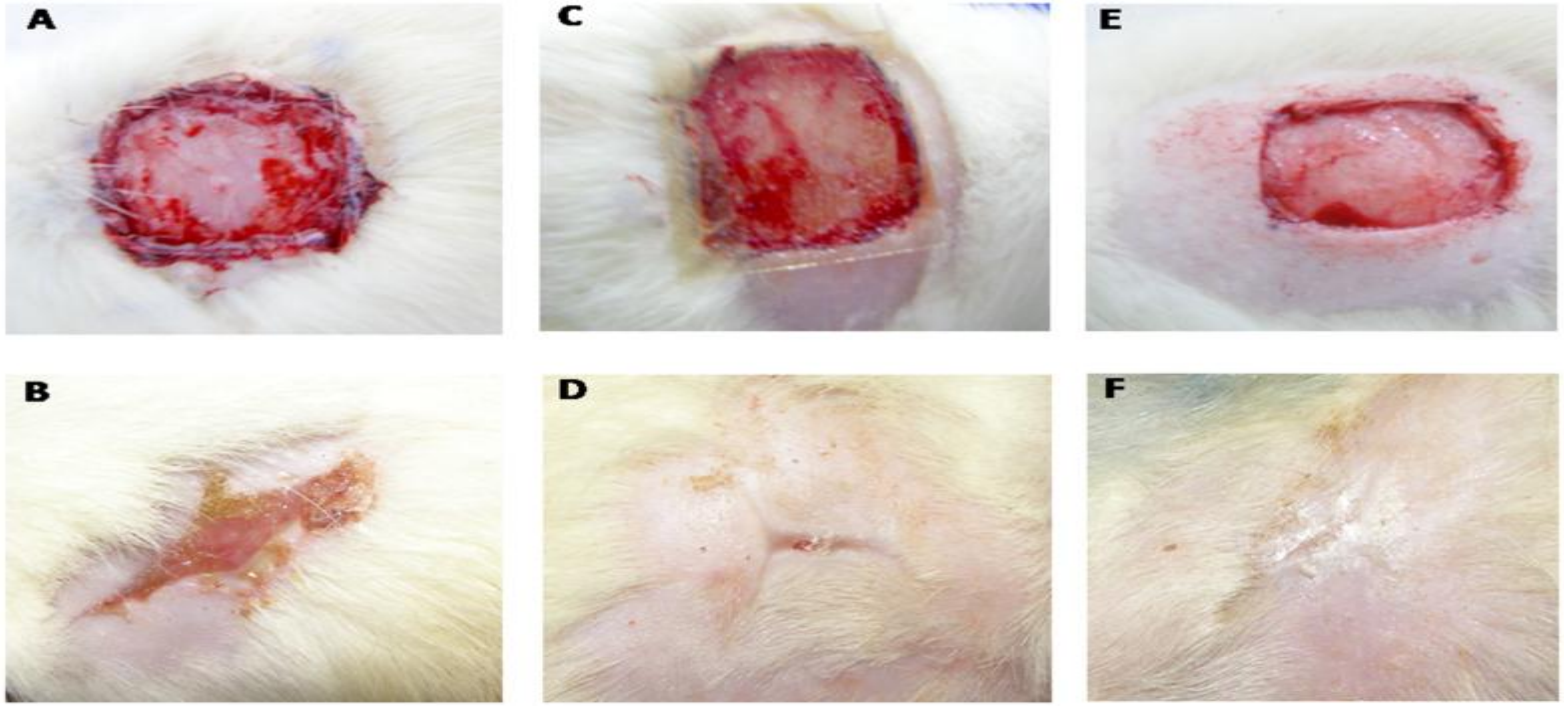
- Chitin is the second most abundant polysaccharide found in nature.
- It is present in cell walls of fungi and yeasts, the hard shells of shell fish and marine invertebrates such as crab, shrimp, lobster, oysters, etc.
- It consists of repeating units of N acetyl-D-glucosamine.
- nontoxicity, biocompatibility, and biodegradability.
- It shows a strong crystalline character owing to its linear structure and the functional groups present on the surface (insoluble in common solvents).
- Chitosan is obtained from chitin after deacetylation process.
- It has repeated units of glucosamine and N-acetyl glucosamine units linked by β-(1-4) glycosidic bonds.
- It is used extensively in various biological applications and can be processed into different forms such as nanofibers, nanoparticles, sponges, beads, membranes, and films similar to chitin.

Preparation, characterization and evaluation of biocomposite films containing chitosan and sago starch impregnated with silver nano particles

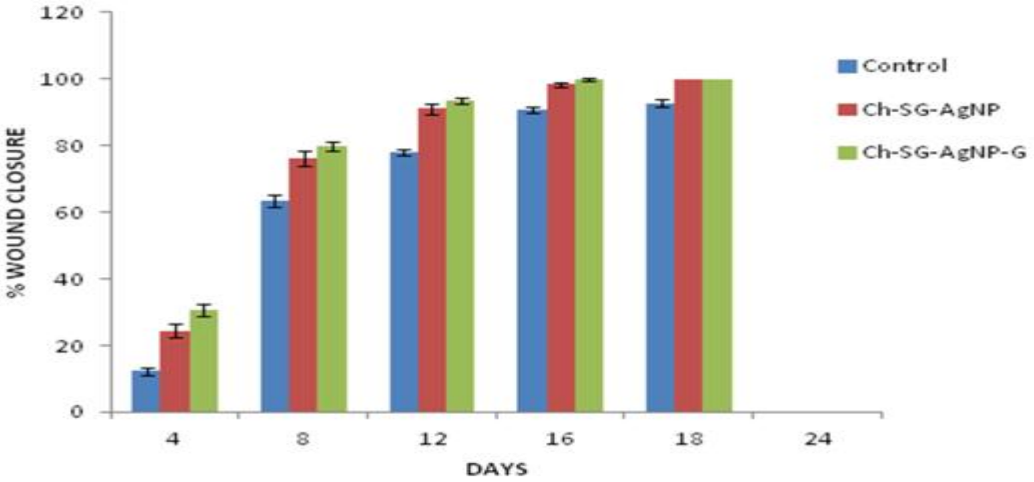
Chitosan-Sago-Ag nano film

- Chitosan extracted from crab shells
- Different films were made
  - Sago starch film
  - Chitosan-sago starch film
  - Chitosan-sago-AgNPs film

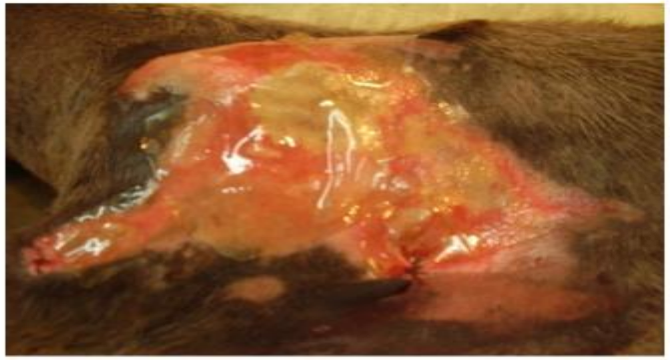
Each prepared films were tested for its mechanical properties and the films with good tensile properties were characterized using FTIR,TGA,SEM,EDAX,Water absorption studies and TEM.



Photographic representation of wound contraction rate on different days of healing: A, C & E are control, Ch-SG-AgNP and Ch-SG-AgNP-G treated groups on 0th day, respectively. B, D & F are control, Ch-SG-AgNP and Ch-SG-AgNP-G treated groups on 16th day, respectively.



The rate of contraction in control, Ch-SG-AgNP and Ch-SG-AgNP-G treated groups on different days of healing. Results are presented as mean ±SD; statistically significant data are given as $p < 0.05$.







Silk fibroin

- Silk fibroin (SF), a natural polymer that derives from the silkworm cocoons, has been used in textile industry for many centuries.
- Used as suture material for wound ligation due to its biocompatibility and strong mechanical strength.
- SF has been developed as substitution of human bodies for tissue regeneration and engineering, including vascular, neural, skin, bone, ocular, and cardiac tissues.
- SF-based materials are also attractive for targeting drug delivery and controllable release.
- Applications - vehicles for delivery drug, tissue engineering, stabilizing other nanoparticles (NPs), signaling pathways activation, and SF composite materials are introduced

Lignin

- Lignin is one of the available biopolymers found in nature at higher quantities containing a large portion of carbon.
- Naturally, lignin shows glue properties remaining in the cellular wall and in intercellular space in plant bodies and provide them with strength.
- In spite of the high abundance of lignin in nature, a very limited amount of it is being used due to its unstable lignin structure, high polydispersity, and immiscibility with host matrix.
- Lignin-based hydrogels have several applications in delivering drugs for agricultural and medicinal purposes, remediation of water, and sensor because the lignin is biocompatible and biodegradable

Alginate

- It is a natural anionic carbohydrate and a linear polysaccharide derived from marine algae.
- It has irregular blocks of β-D-mannuronic acid (M) and 1-4 linked α-L-guluronic residues (G).
- It shows properties --- biocompatibility, low toxicity, relatively low cost, and simple gelation, make it a perfect biomaterial for various applications, associated with the food, chemical, medical, and agricultural industries.

Applications :

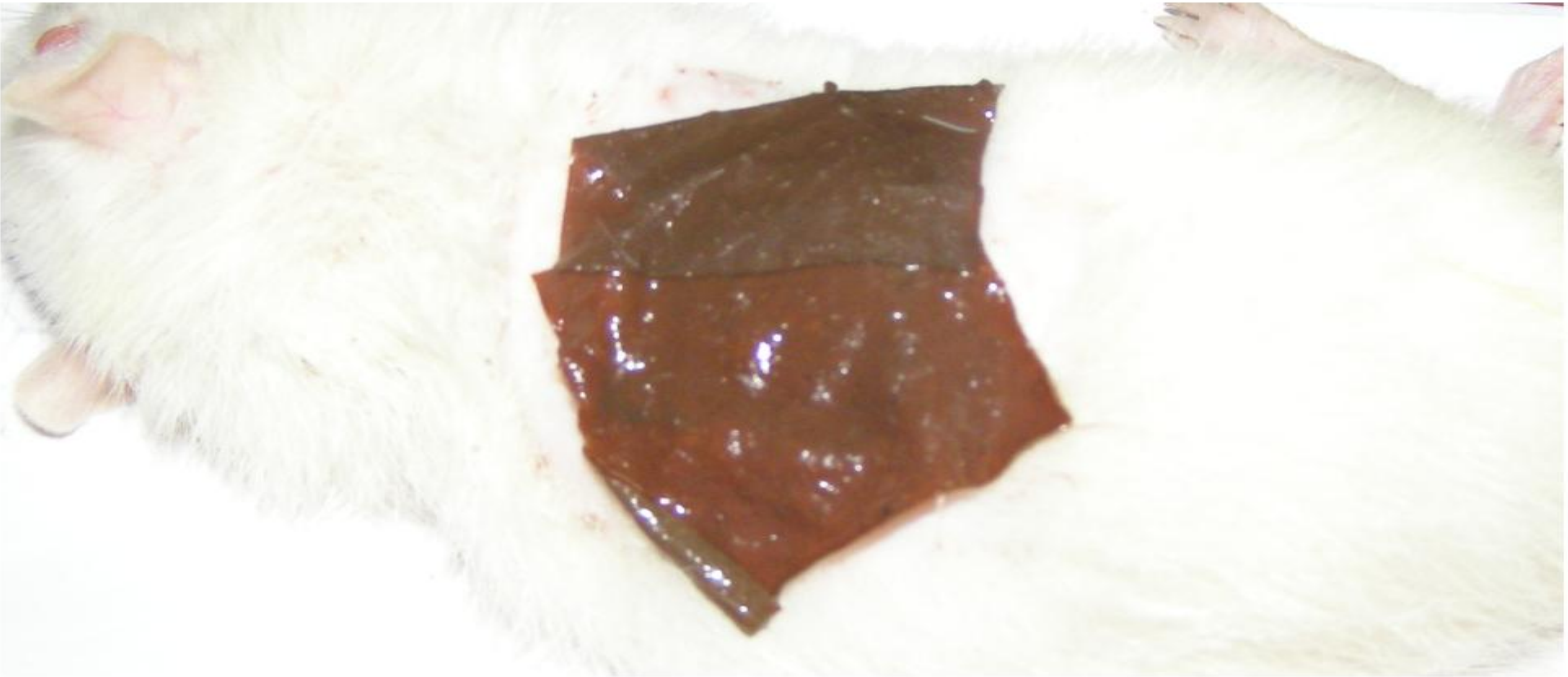
biomedical engineering (controlled drug release, cells encapsulation, immunostimulatory agents, scaffolds, etc.),

- in the pharmaceutical industry (e.g., cosmetic, toothpaste) ,
- in agriculture as elicitation of plant growth ,
- in textiles (e.g., additives for textile prints), and
- in medical textiles
- ALG fibers are used as a wound management material (wound dressing), bandages, pill disintegrators and dental impression material, tissue engineering, etc.

Starch

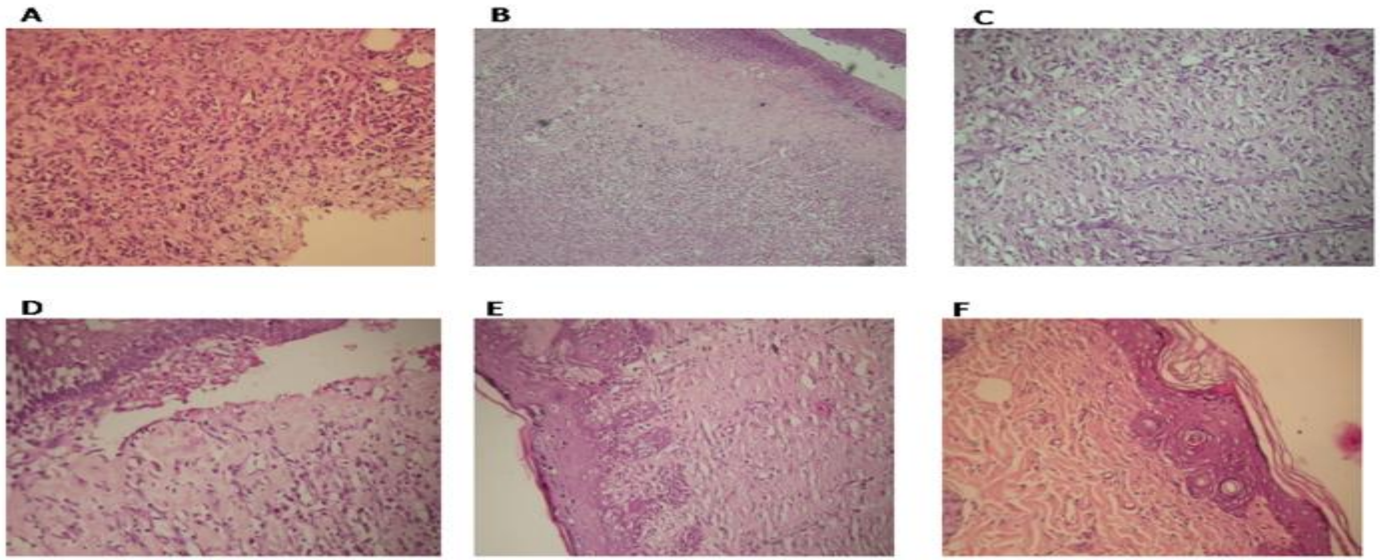
- Starch is a promising polysaccharide from abundantly available renewable sources
- It is replacement raw material for fossil fuel-based plastics or as an additive in agriculture
- Starches can be extracted from edible plant sources such as potato (*Solanum tuberosum*), cassava (*Manihot esculenta*), corn (*Zea mays*), rice (*Oryza sativa*), wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), etc.
- Chemical modifications, surface functionalization, blends, and composites with other synthetic and biopolymers may turn starch into a viable alternative for petrochemical plastics.
- Starch and starch-based composites are a feasible techno-commercial strategy for agricultural films and other packaging materials due to their favorable low-cost factors, natural abundance, and inherent capacity to degrade readily in natural and aquatic environments.

Preparation, characterization and evaluation of biocomposite films containing Alginate and sago starch impregnated with silver nano particles

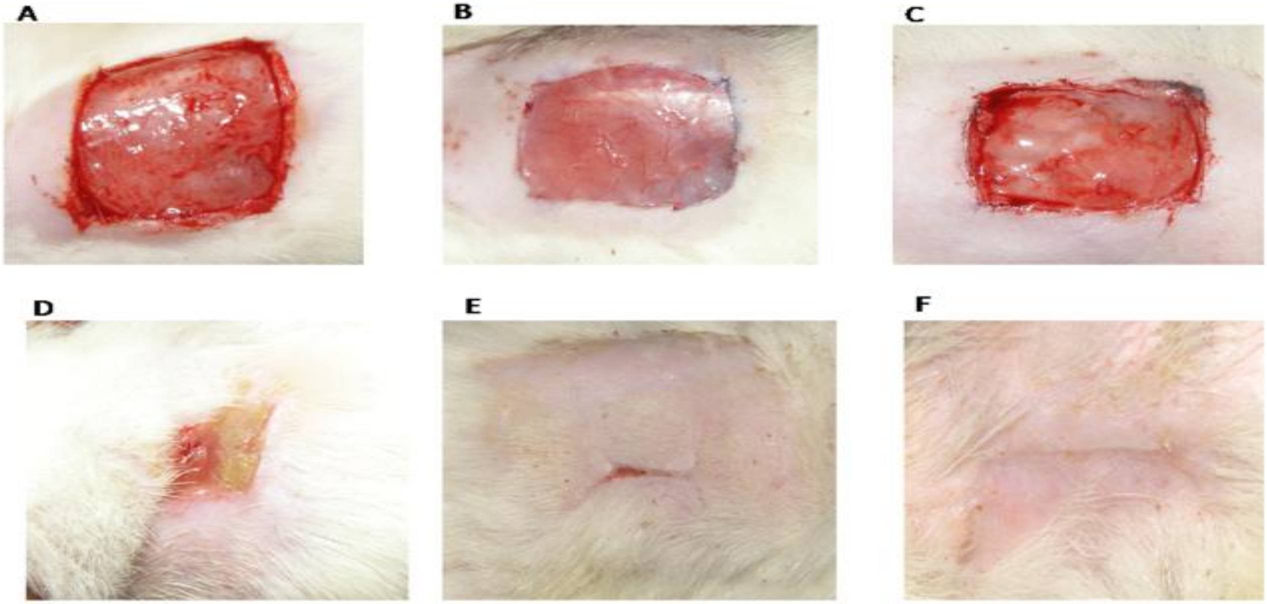


Preparation and characterization of Alginate sago starch impregnated with silver nano particles

- Alginate-sago starch composite films impregnated with silver nanoparticles were prepared with improved mechanical strength and characterized for its physicochemical properties.



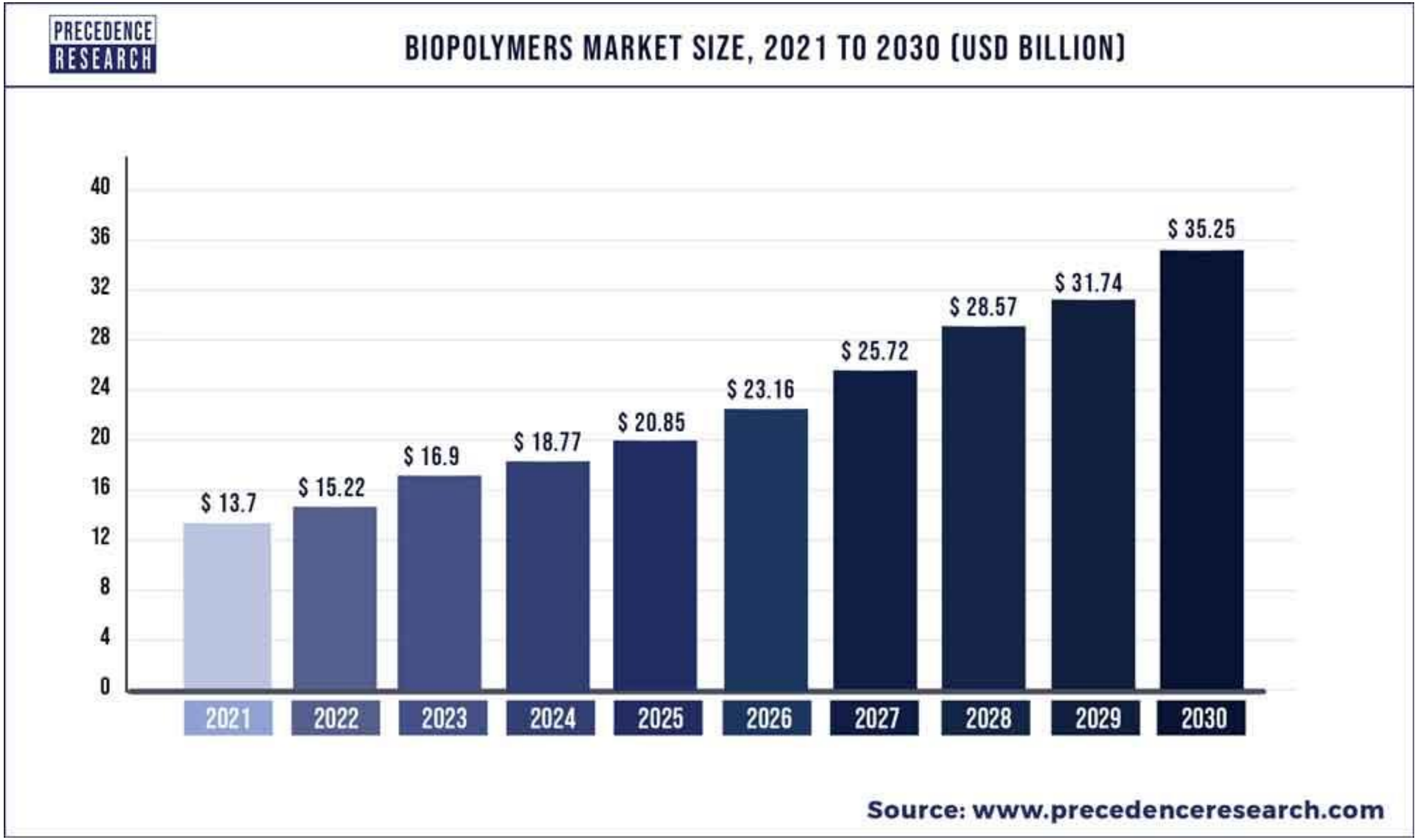
Hematoxylin and eosin stained sections of the granulation tissue at different time intervals. (A) and (D) are control group on day 8 and 16 respectively,(B) and(E) are the AL-SG-AgNP treated group on day 8 and 16 respectively and (C) and (F) are the AL-SG-AgNP-G treated group on day 8 and 16 respectively.(A),(C),(D),(E) and (F) are at similar magnification (20X) and (B) is at 10X.



Photographic representation of wound contraction rate on different days of healing: (A), (B) & (C) are control, AL-SG-AgNP and AL-SG-AgNP-G treated groups on 0th day, respectively. (D), (E) & (F) are control, AL-SG-AgNP and AL-SG-AgNP-G treated groups on 16th day, respectively.

Cellulose

- Cellulose is the most abundant biopolymer found in plants, few algal, bacterial, and fungal species.
- Cellulose produced by plant and bacteria is identical in structure; however, bacterial cellulose does not contain lignin and hemicelluloses and hence, does not require extensive purification.
- It possesses desirable properties such as biodegradability, biocompatibility, good mechanical strength, high waterabsorbing capacity, etc. and thus, finds its relevance in soft and hard tissue engineering.
- Cellulose has been widely used for the engineering of bone, cartilage, blood vessels, skin, neural tissues, adipose tissues, and many more.


PRECEDENCE RESEARCH
BIOPOLYMERS MARKET SIZE, 2021 TO 2030 (USD BILLION)
40
36
32
28
24
20
16
12
8
4
0
$ 13.7
$ 15.22
$ 16.9
$ 18.77
$ 20.85
$ 23.16
$ 25.72
$ 28.57
$ 31.74
$ 35.25
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
Source: www.precedenceresearch.com

Value added products from waste

- Plant and animal based wastes into value added products for sustainable development.
- Making products which are eco friendly, cost effective and biocompatible.

Single use plastic from starch

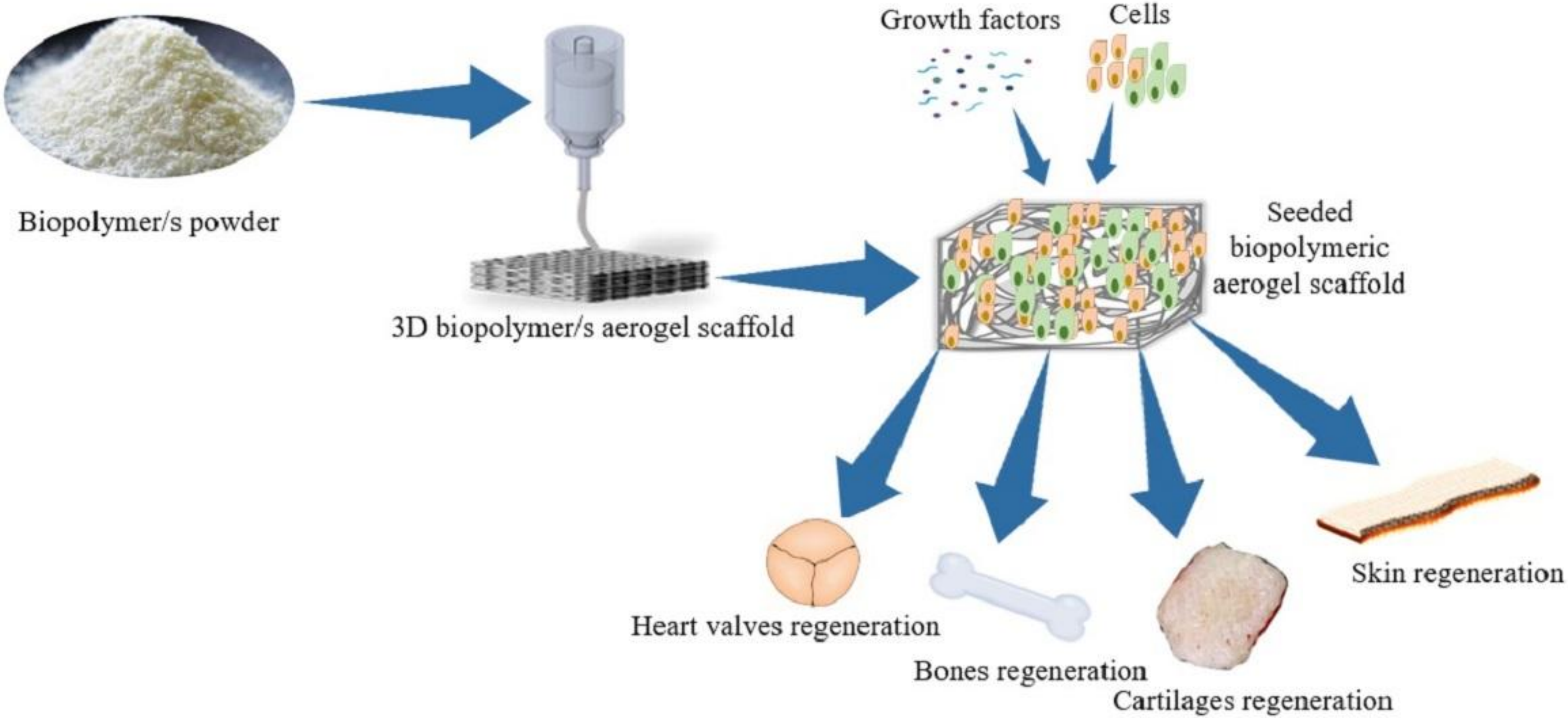

1% w/w Gellan Gum


1% w/w Gellan Gum


Mater-Bi


MATER-BI
BIODEGRADABILE
E COMPOSTABILE
come la buccia del kiwi
WWW.MATERBI.COM
Questo sacco in MATER-BI contenente materie prime rinnovabili è completamente biodegradabile e compostabile: riutilizzato per la raccolta differenziata dell'organico, si trasforma in compost.


NOVAMONT
MATER-BI
BIODEGRADABILE E COMPOSTABILE
GETTALO CON I RIFIUTI ORGANICI,
DIVENTERÀ FERTILE COMPOST
ENTRO UN MASSIMO DI 90 GIORNI.
BIODEGRADABLE AND COMPOSTABLE
THROW IT INTO THE ORGANIC WASTE BIN.
AFTER 90 DAYS AT MOST IT WILL BECOME
FERTILE COMPOST.
www.materbi.com
www.novamont.com


Biopolymer/s powder
3D biopolymer/s aerogel scaffold
Growth factors
Cells
Seeded biopolymeric aerogel scaffold
Heart valves regeneration
Bones regeneration
Cartilages regeneration
Skin regeneration

Biopolymer from tuber used in cosmetics

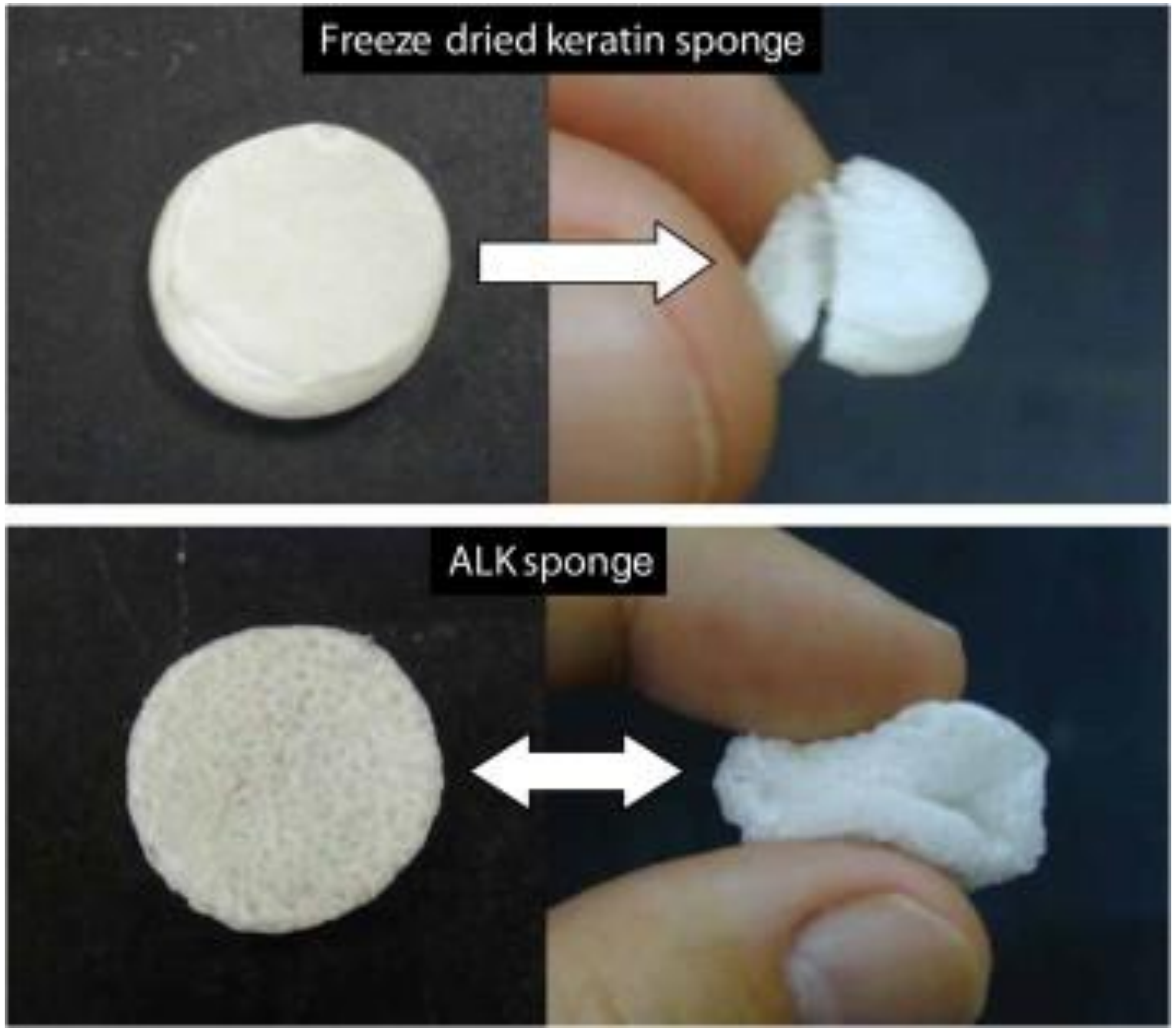
NANOGRAFI EXPLAINS

Nanocellulose as a Perfect Alternative to Plastics

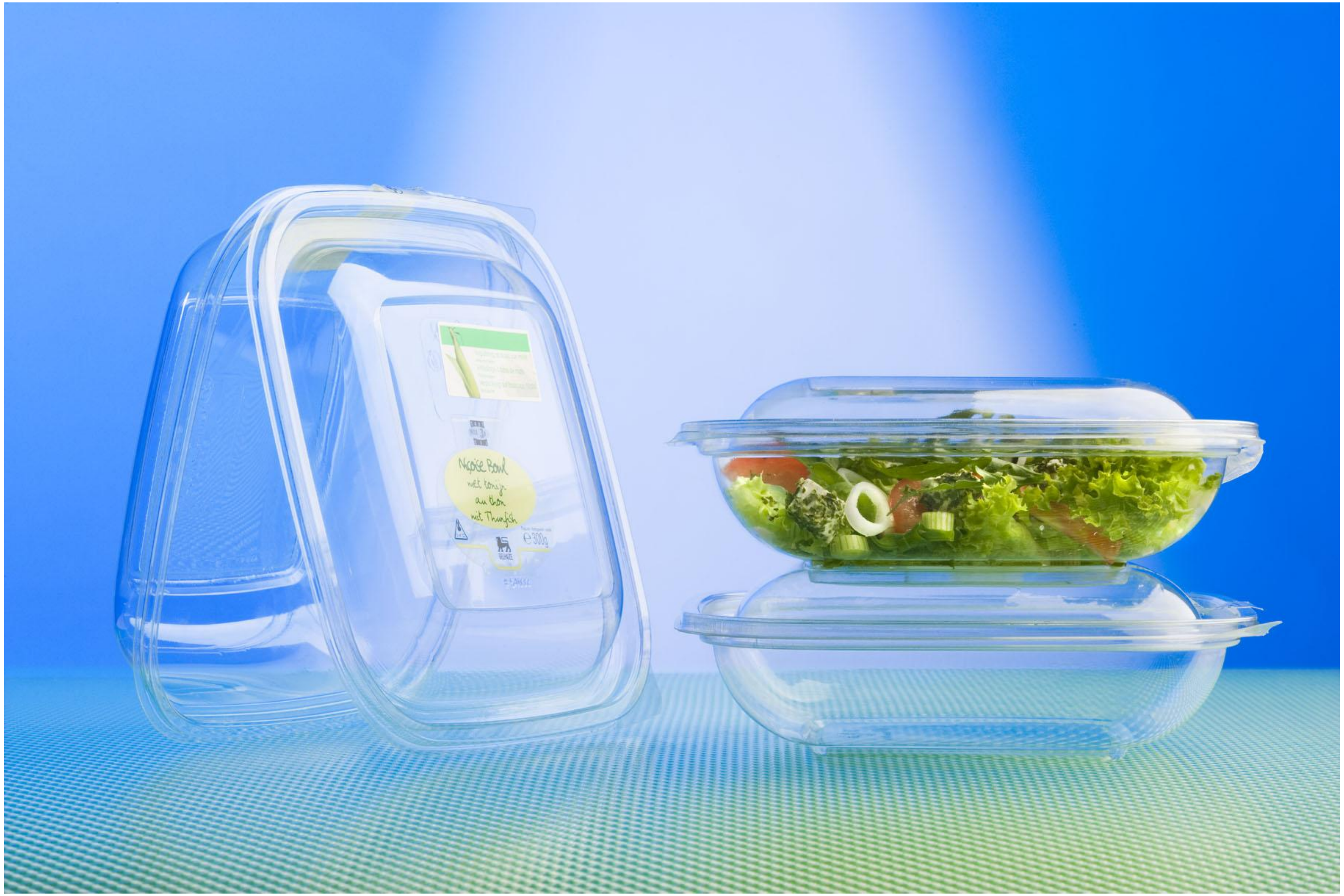

ColloSkin
MESHED
[BIOLOGICAL DRESSING]
Sterlised By
GAMMA IRRADIATION
Store at Room Temperature not exceeding 40 °C
A WHO-GMP CERTIFIED PRODUCT
ColloSkin M
[BIOLOGICAL DRESSING]
A WHO-GMP CERTIFIED PRODUCT
FOR EXTERNAL USE ONLY
Contents:
One Sterile Collagen sheet in preserving medium containing Isopropyl alcohol and water

SkinTemp™ II
Collagen Sheets
Triple Helical Matrix
Conforms to FDA Quality System Requirements.
Manufactured as per cGMP standards.
Our Quality System is ISO 13485 certified.
Kollagen™
Because the body heals itself.
SkinTemp - ST 1002
Five Sheets, 3" x 4"
Product Information:
• This device is intended for single use only.
• All open and unused pouches must be discarded.
• Sterility guaranteed in unopened, undamaged package only.
• Store at temperatures between 50ºF and 80ºF.
Human BioSciences


Dengen Dental
Absorbable Gelatin Sponge USP
DENGOFOAM
32 Sponges | Gamma Sterile | Ready to use
For Dental Use
Dental SL
(10 x 10 x 10 mm)

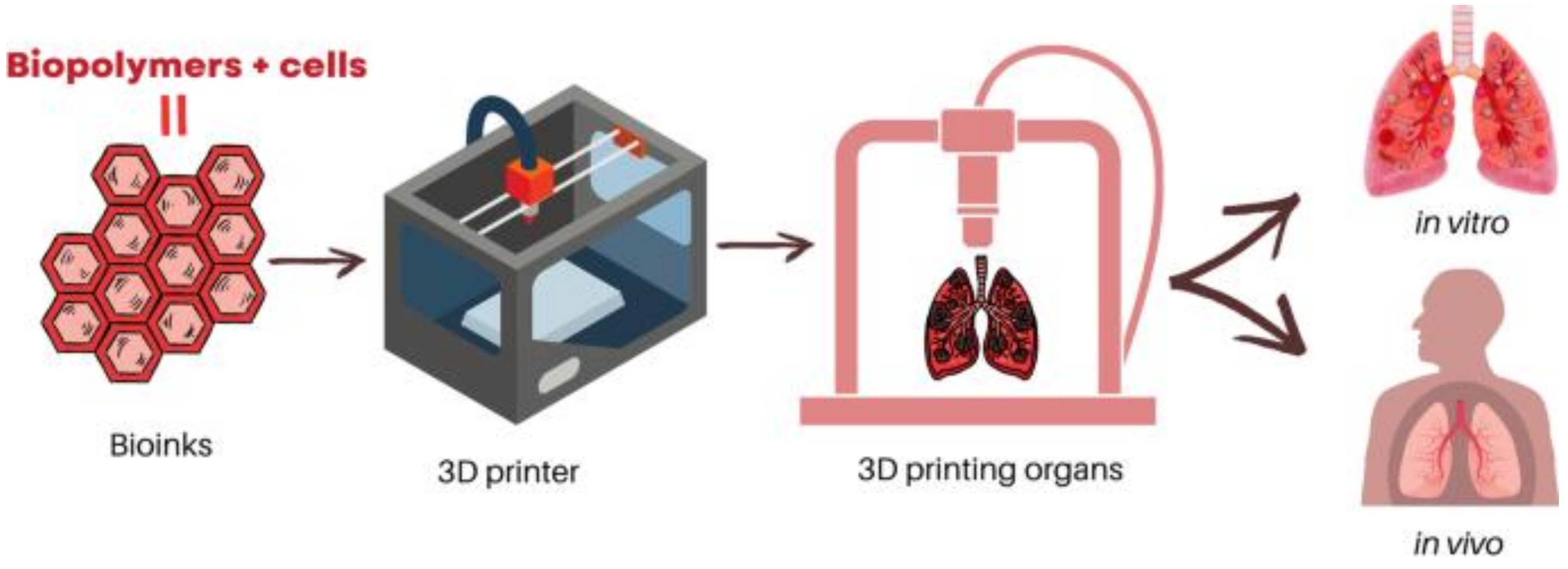


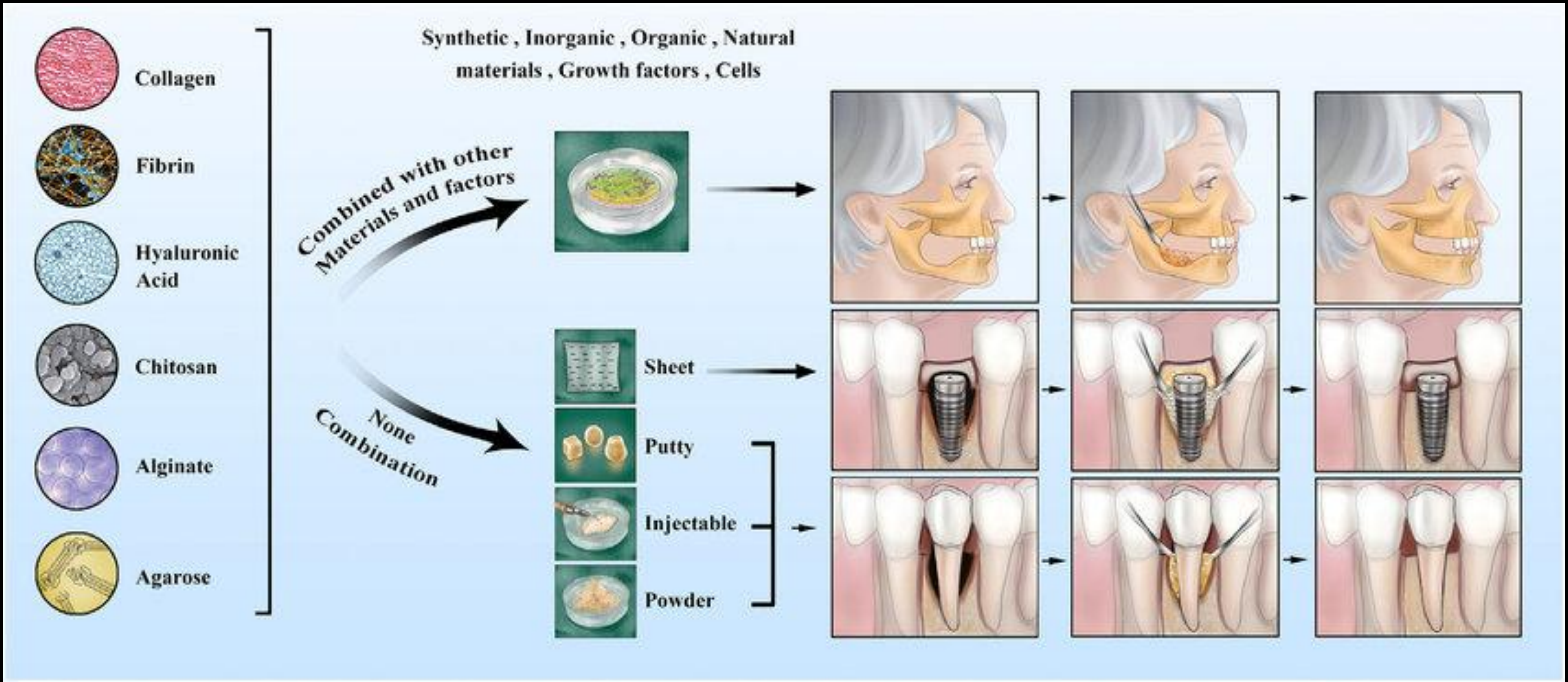
Freeze dried keratin sponge
ALK sponge



PLA
PRODUCTS

PULLULAN CAPSULE


Biopolymers + cells
Bioinks
3D printer
3D printing organs
in vitro
in vivo


Collagen
Fibrin
Hyaluronic Acid
Chitosan
Alginate
Agarose
Synthetic , Inorganic , Organic , Natural materials , Growth factors , Cells
Combined with other Materials and factors
None Combination
Sheet
Putty
Injectable
Powder


HYGITECH
Haemostatic sponge
fr – Eponge hémostatique résorbable
en – Haemostatic absorbable sponge
pt – Esponja hemostática absorvível
it – Spugna emostatica riassorbibile
x10
1 x 1 x 1 cm
HYGITECH
HAEMOSTATIC SPONGE

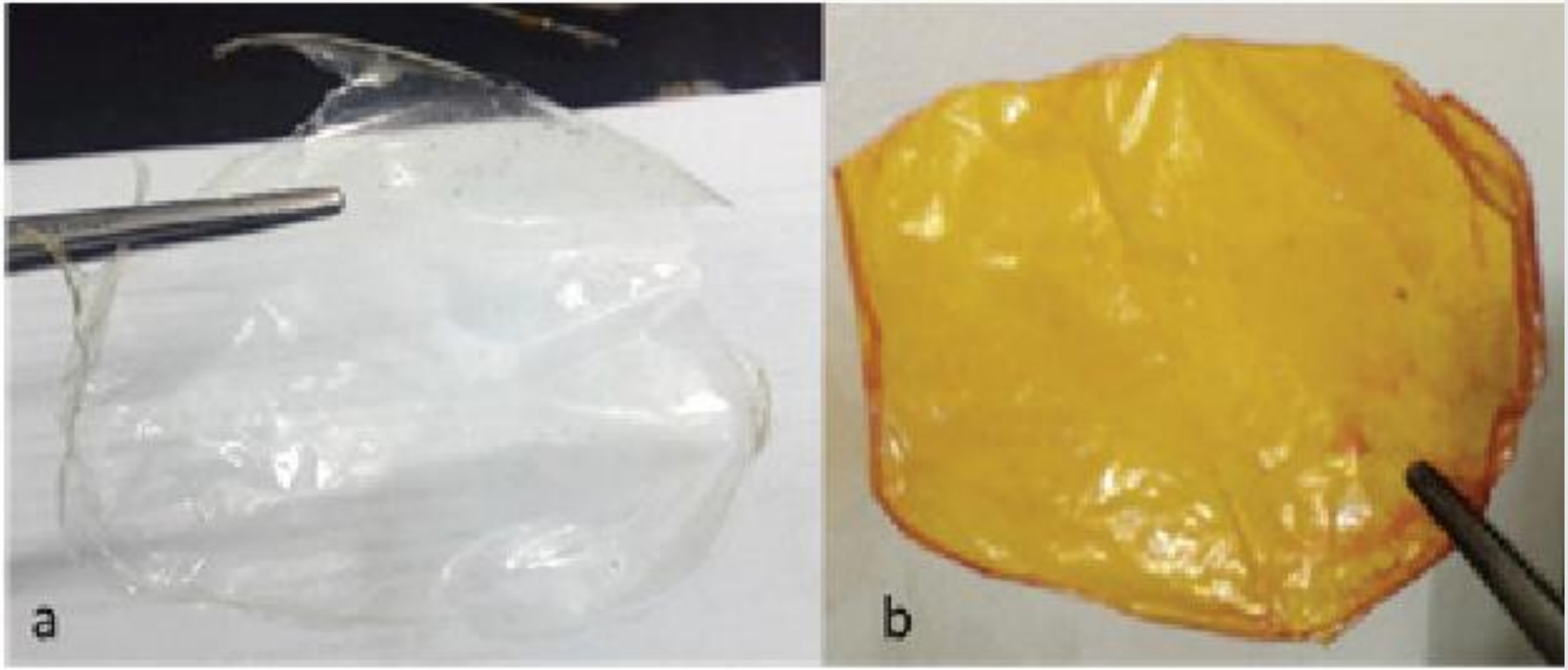
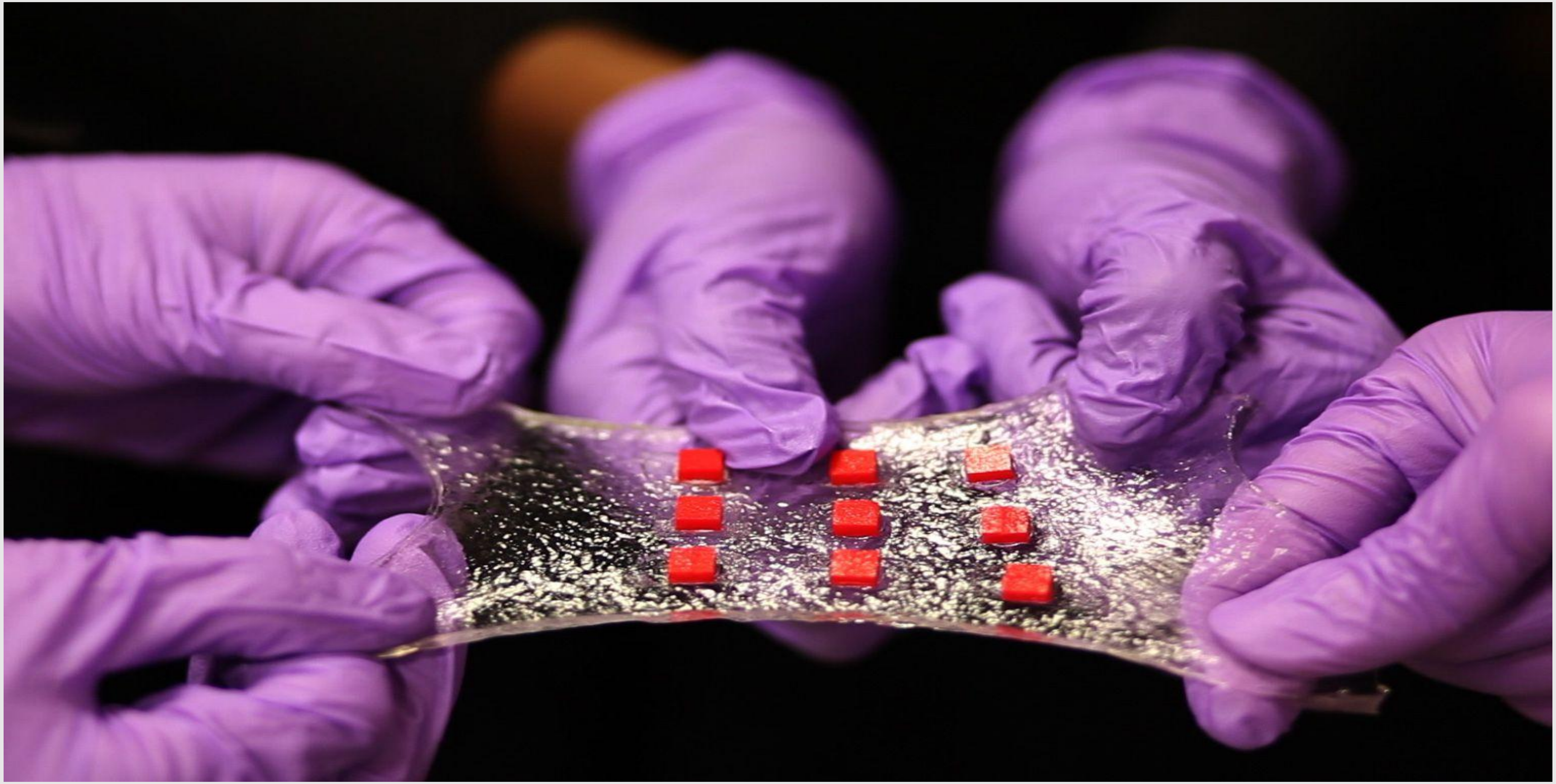


Figure 1. a) Chitosan film; b) cur-chi film.

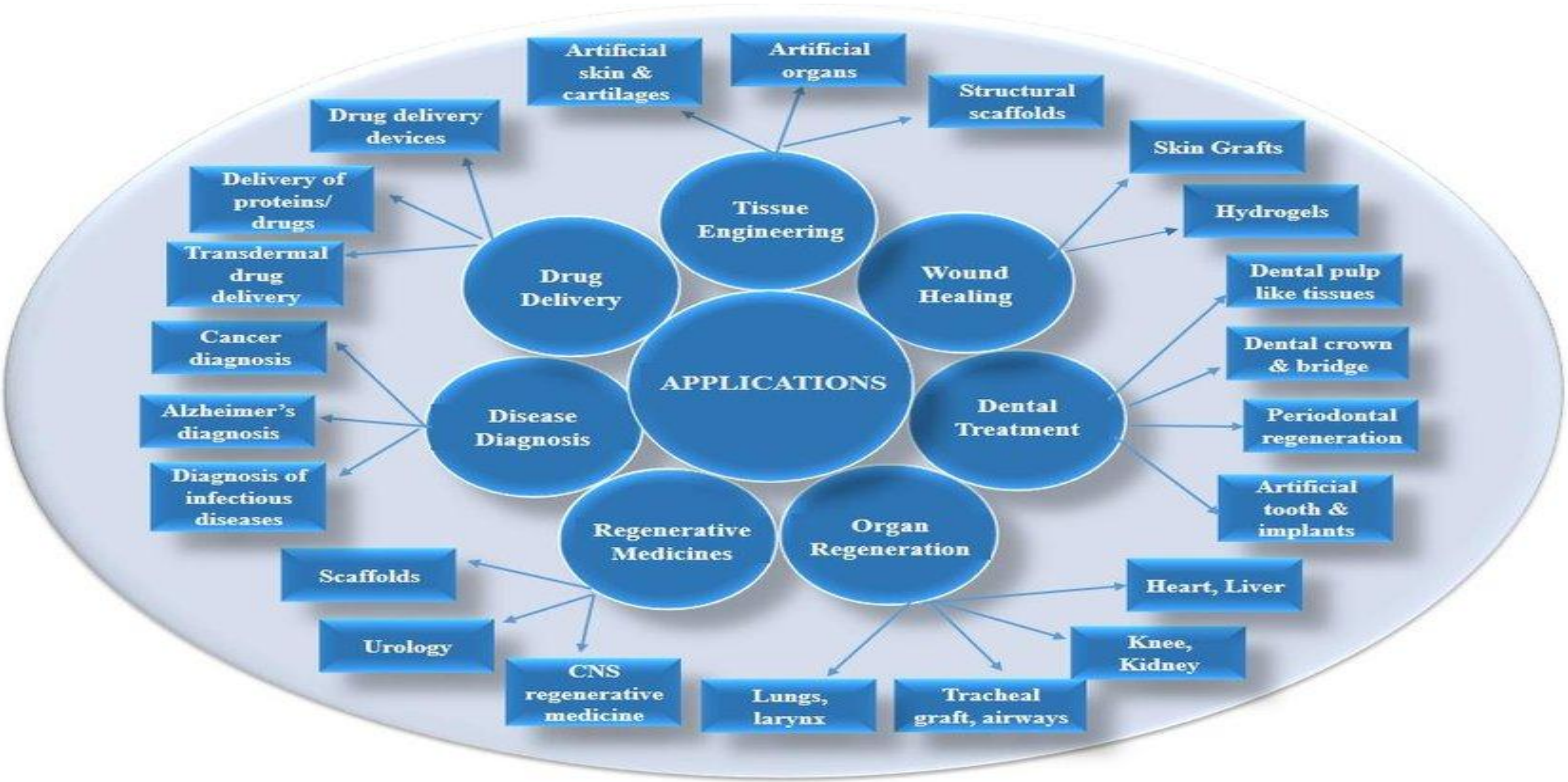
Sensor for p-nitrophenol



Stretchable electronics

Hydrogel in agriculture


EMERGING APPLICATIONS
Tissue Engineering
Drug Delivery
Food Packaging
Bone Scaffolds
Artificial Organs
Bioface Mask
NATURAL BIOPOLYMERS
Starch
Collagen
Alginate
Chitosan
SYNTHETIC BIOPOLYMERS
PCL
PGA
PVA
PBS
BIOPOLYMER'S EMERGING APPLICATIONS
DEGRADABILITY
Photocatalytic degradation
Hydrolytic degradation
Microbial degradation
Thermal degradation
BIOCOMPOSITES
Biopolymers matrix-based composites


APPLICATIONS
Tissue Engineering
Artificial skin & cartilages
Artificial organs
Structural scaffolds
Wound Healing
Skin Grafts
Hydrogels
Dental Treatment
Dental pulp like tissues
Dental crown & bridge
Periodontal regeneration
Artificial tooth & implants
Organ Regeneration
Heart, Liver
Knee, Kidney
Tracheal graft, airways
Lungs, larynx
Regenerative Medicines
CNS regenerative medicine
Urology
Scaffolds
Disease Diagnosis
Diagnosis of infectious diseases
Alzheimer's diagnosis
Cancer diagnosis
Drug Delivery
Transdermal drug delivery
Delivery of proteins/ drugs
Drug delivery devices

Sustainable developmental goals

Biomaterials contribute to:

- **SDG 3** – Good health (biomedical applications)
- **SDG 6** – Clean water (water purification)
- **SDG 7** – Clean energy (biofuels)
- **SDG 12** – Responsible consumption (bioplastics)
- **SDG 13** – Climate action (reduced emissions)

Future Perspectives

- Development of **nanobiomaterials** (e.g., CNC for dye removal)
- Smart biomaterials (stimuli-responsive)
- Industrial-scale green manufacturing
- Integration with **biotechnology and nanotechnology**

CONCLUSION

Biomaterials are crucial for achieving sustainability by replacing conventional materials with eco-friendly alternatives, promoting environmental protection, and enabling innovative solutions across multiple sectors.

THANK YOU