UNIT-II

2 MARKS:

1. **Write a note on Ti based alloys. (Dec. 2018, May 2017)**
   - Commercially pure **Ti (CPTi) and Ti–6Al–4V** are two dominant Ti-based materials used in joint replacement.
   - Ti-based implants have excellent corrosion resistance and biocompatibility. And the credit goes to the oxide layer, which spontaneously forms in the presence of oxygen. It has been shown that Ti-based alloys promote osteoblast activities.
   - Ti-based biomaterials with tailored porosity are important for cell adhesion, viability, differentiation and growth.
   - There have been numerous research investigations about different porous coatings and fully porous matrixes.
2. **List out the drawbacks of ceramic implant materials. (Dec. 2018, May 2017)**
   - Some ceramic materials are also biodegradable.
   - Difficulty in manufacturing forms the main disadvantage.
   - They also can minimize bone ingrowth.
   - Sometimes, implants can loosen over time and become dislodged.
3. **Write a note on resorbable and non resorbable ceramics. (Dec. 2019)**
   - Bioceramics and bioglasses are ceramic materials that are biocompatible and it is an important subset of biomaterials.
   - Bioceramics range in biocompatibility from the ceramic oxides, which are inert in the body, to the other extreme of resorbable materials, which are eventually replaced by the body after they have assisted repair.
   - Whereas, the ceramics which are not replaced by the body after they have assisted repair are non resorbable ceramics.
4. **Give the chemical composition of HAP. (Dec. 2017, Dec. 2019)**

Chemical formula	$Ca_{10} (PO_4)_6 (OH)_2$
Molecular weight	1004.6 g/mol

- Hydroxyapatite (HAP) is a calcium phosphate similar to the human hard tissues in morphology and composition.
- Particularly, it has a hexagonal structure2, 3 and a stoichiometric Ca/P ratio of 1.67, which is identical to bone apatite.
- An important characteristic of hydroxyapatite is its stability when compared to other calcium phosphates.
- Thermodynamically, hydroxyapatite is the most stable calcium phosphate compound under physiological conditions as temperature, pH and composition of the body fluids.

5. Define Austenite phase of stainless steel. (May 2019)

- Surgical stainless steel is a grade of stainless steel used in biomedical applications. The most common "surgical steels" are austenitic SAE 316 stainless and martensitic SAE 440, SAE 420, and 17-4 stainless steels.
- SAE 316 and SAE 316L stainless steel, also referred to as marine grade stainless, is a chromium, nickel, molybdenum alloy of steel that exhibits relatively good strength and corrosion resistance.
- 316L is the low carbon version of 316 stainless steel. 316L in particular is biocompatible when produced to ASTM F138 / F139. It is a common choice for biomedical implants, as well as body piercings and body modification implants.

6. What is Allotropic transformation in Ti alloy? (May 2019)

- Titanium undergoes an allotropic transformation at 882 °C from close-packed hexagonal structure (CPH) a-phase to a body-centered cubic structure β-phase.
- Below this temperature, it exhibits a hexagonal close-packed (HCP) crystal structure, known as the α phase, while at a higher temperature, it has a body-centered cubic (BCC) structure, the β phase.
- The latter remains stable up to the melting point of 1,670 °C.

7. Why degradation effect on metal takes place? (Nov. 2016)

- Corrosion or degradation involves deterioration of material when exposed to an environment resulting in the loss of that material.

- Most metals are found in nature as ores. The manufacturing process of converting these ores into metals involves the input of energy. During the corrosion reaction the energy added in manufacturing is released, and the metal is returned to its oxide state.
- In the marine environment, the corrosion process generally takes place in aqueous solutions and is therefore electrochemical in nature.

8. Mention the advantages of ceramic implants. (Nov. 2016)

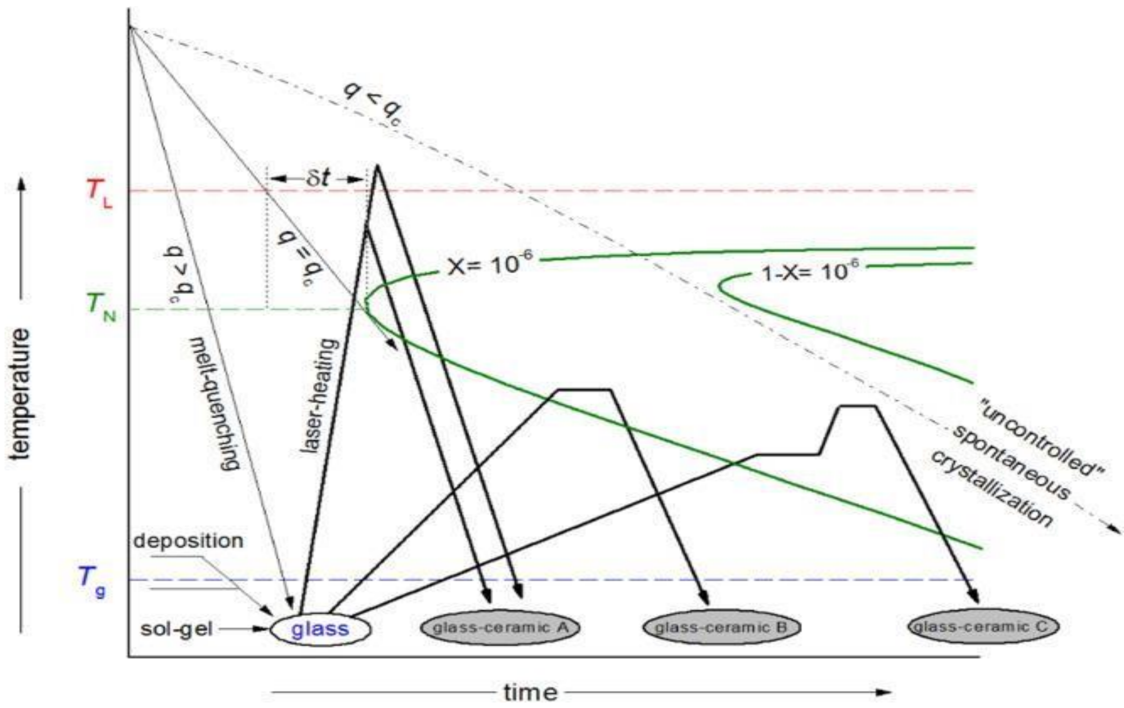
- Ceramic implants withstand chemical erosion that occurs in other materials subjected to acidic or caustic environments.
- Ceramics generally can withstand very high temperatures, ranging from 1,000 °C to 1,600 °C (1,800 °F to 3,000 °F).
- The ceramic implants are proving to be very durable and an excellent alternative to metal implants.
- The mechanical strength of ceramic dental implants has improved greatly over time. Another advantage of ceramic dental implants is that unlike any metal, ceramic are not subject to corrosion over time.

9. List out the medical applications of metallic implant materials (May 2018)

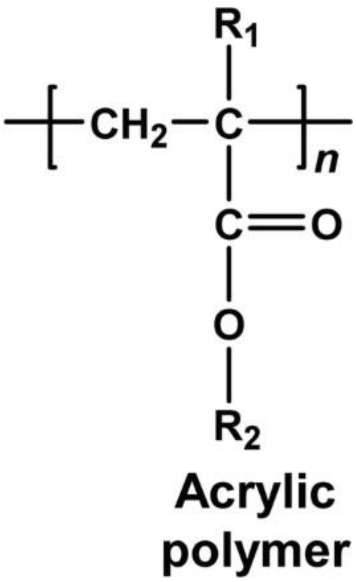
- Metallic implants are the primary biomaterials used for joint replacement and becoming increasingly important.
- The metallic implants used for orthopedic applications can be categorized as stainless steel, CoCr alloys, and Ti and Ti alloys.

Division	Example of implants	Type of metal
Cardiovascular	Stent Artificial valve	316L SS; CoCrMo; Ti Ti6Al4V
Orthopaedic	Bone fixation (plate, screw, pin) Artificial joints	316L SS; Ti; Ti6Al4V CoCrMo; Ti6Al4V; Ti6Al7Nb
Dentistry	Orthodontic wire Filling	316L SS; CoCrMo; TiNi; TiMo AgSn(Cu) amalgam, Au
Craniofacial	Plate and screw	316L SS; CoCrMo; Ti; Ti6Al4V
Otorhinology	Artificial eardrum	316L SS

10. Draw the temperature time cycle for a glass ceramic. (May 2018)



11. Draw the structure of acrylic polymers. (Dec. 2017)



11 MARKS:

1. **Illustrate in detail about chemical composition of polymers, ceramics and composites as biomaterials for implantation with their application. (Dec. 2018, May 2017)**

   POLYMERS

- A polymer is a useful chemical made of many repeating units. A polymer can be a three dimensional network or two-dimensional network a one-dimensional network. Repeating units are often made of carbon and hydrogen and sometimes oxygen, nitrogen, sulfur, chlorine, fluorine, phosphorous, and silicon.
- These polymers are specifically made of carbon atoms bonded together, one to the next, into long chains that are called the backbone of the polymer. Because of the nature of carbon, one or more other atoms can be attached to each carbon atom in the backbone.
- There are polymers that contain only carbon and hydrogen atoms. Polyethylene, polypropylene, polybutylene, polystyrene and polymethylpentene are examples of these. Polyvinyl chloride (PVC) has chlorine attached to the all-carbon backbone. Teflon has fluorine attached to the all-carbon backbone.
- A ceramic material is an inorganic, non-metallic, often crystalline oxide, nitride or carbide material. Some elements, such as carbon or silicon, may be considered ceramics. 1. Oxides: alumina, beryllia, ceria, zirconia

  2. Non-oxides: carbide, boride, nitride, silicide

  3. Composite materials: particulate reinforced, fiber reinforced, combinations of oxides and nonoxides.
- A substance which has a molecular structure built up chiefly or completely from a large number of similar units bonded together, e.g. many synthetic organic materials used as plastics and resins. A polymer is basically synthesized by joining small molecules or substances into a single giant molecule by a chemical process.
- The small molecules which are used in synthesizing a polymer is called as monomer.
- Polymers are used as biomaterials and that can be of the following types,

1. **Synthetic Polymers** like Polyvinylchloride (PVC), Polypropylene, Polymethyl methacrylate are used in implants, medical disposable supplies, dressings, etc.
2. **Biodegradable Biomaterials:** Polyactide, Polyglycolide, etc. It is valuable as it regenerates tissue and does not leave residual traces on implantation. Mostly used for tissue screws, cartilage repair and drug delivery systems.
3. **Biopolymers / Natural polymers** are those which are established from the living organisms. Some of the examples are DNA, RNA, proteins, carbohydrates, etc.

APPLICATIONS:

•Polymer composites are widely used for preparing medical implants.

•Polymers for Biomedical Applications

•Biodegradable polymers as Biomaterials

•Implanted polymer composites

•Polymers as Biomaterials

•Biopolymers for food packaging

•Micro and nan blends based on natural polymers

CERAMICS

- Ceramics are used as biomaterials due to their high mechanical strength and biocompatibility
- Types of Bio-ceramic materials are tri calcium phosphate, Metals oxides such as Al_2O_3 and SiO_2 ,Apatite ceramics, Porous ceramics, Carbon and Alumina
- Advantage:
  - High compression strength
  - Wear & Corrosion resistance
  - Can be highly polished
- Disadvantage
  - High E modulus (stress shielding)
  - Brittle -Low fracture toughness
  - Difficult to fabricate

APPLICATIONS OF CERAMICS

- Al_2O_3 and SiO_2 - used to make femoral head
- Tri calcium Phosphate - bone repairs
- Alumina used in orthopedic applications.

- Porous alumina used in teeth roots
- Apatite ceramics - bio active ceramics-used as synthetic bone
- Carbon good biocompatibility, wide application in heart valves
- Percutaneous carbon – stimulation of cochlea and visual cortex for artificial hearing and aid the blind respectively

COMPOSITE BIOMATERIALS

- The term "composite" is usually reserved for those materials in which the distinct phases are separated on a scale larger than the
- Biomaterial applications are:
    - dental filling composites
    - reinforced methyl methacrylate bone cement and ultra-highmolecular- weight polyethylene, andorthopedic implants with porous surfaces

2. **Describe the properties and applications of 2 widely used metals in the manufacture of orthopedic implant devices. (Dec. 2017, Dec. 2019)**

- Metallic implants are the primary biomaterials used for joint replacement and becoming increasingly important.
- The metallic implants used for orthopedic applications can be categorized as stainless steel, CoCr alloys, and Ti and Ti alloys.
- These metallic materials have several properties such as high strength, high fracture toughness, hardness, corrosion resistance and biocompatibility, which make them an excellent choice for total joint replacement.
- The disadvantage with metallic implants is their high elastic modulus, which causes stress shielding.
- Toxic effects caused by ions released from metallic implants are also a major concern.
- **Stainless steel alloys** were the first metals to be used for orthopedics.
- Stainless steel alloys contain carbon, chromium, nickel, molybdenum, and manganese, phosphorus, sulfur, and silicon as trace elements.
- These components affect the mechanical properties of steel by alteration of its microstructure.
- A high nickel content (10–14%) in stainless steel can cause toxicity.
- This has prompted research in the development of Ni-free stainless steel alloys.

- **Cobalt-based alloys** are the other metallic implants used for joint replacement.
- CoCrMo and CoNiCrMo are the two main cobalt based alloys generally used in orthopedics.
- Especially for joint replacement where low frictional resistance is desired, CoCrMo alloys are preferred over CoNiCrMo alloys.
- Commercially pure **Ti (CPTi) and Ti–6Al–4V** are two dominant Ti-based materials used in joint replacement.
- Ti-based implants have excellent corrosion resistance and biocompatibility. And the credit goes to the oxide layer, which spontaneously forms in the presence of oxygen. It has been shown that Ti-based alloys promote osteoblast activities.
- Therefore for uncemented joint replacement, Ti-based alloys are preferred over other metallic implants.
- One drawback with Ti alloys is that they are relatively softer than stainless steel alloys and cobalt-based alloys. This makes them more susceptible to wear where articulation is required.

Physical Properties of Metals:

- Luster (shininess)
- Good conductors of heat and electricity
    - The good electrical conductivityof metals favors their use for neuromuscular stimulation devices, the most commonexample being cardiac pacemakers.
    - These favorable properties (good fracture resistance,electrical conductivity, formability) are related to the metallic interatomicbonding that characterizes this class of material.
- High density (heavy for their size)
- High melting point
- Ductile (most metals can be drawn out into thin wires)
- Malleable (most metals can be hammered into thin sheets).

Chemical Properties of Metals:

- Easily lose electrons
- Surface reactive
- Loss of mass(some corrode easily)
    - The corrosion of metallic implant gives adverse effects to the surroundingtissues and to the implant itself.

- It produces chemical substances that harmful for humanorgans and deteriorates the mechanical properties of the implant.
- Therefore, corrosionresistance of a metallic implant is an important aspect of its biocompatibility.

➢ Change in mechanical properties

Biocompatibility of metals:

➢ In metals,biocompatibility involves the acceptance of an artificial implant by the surrounding tissuesand by the body as a whole.

➢ The metallic implants do not irritate the surrounding structures,do not incite an excessive inflammatory response, do not stimulate allergic andimmunologic reactions, and do not cause cancer.

3. a. What are ceramic implant materials and carbons? Discuss its properties and applications in medical field. (Dec. 2019)

b. Write in detail about carbon ceramic materials. (Dec. 2017)

➢ A ceramic material is an inorganic, non-metallic, often crystalline oxide, nitride or carbide material. Some elements, such as carbon or silicon, may be considered ceramics.

➢ Ceramic materials are brittle, hard, strong in compression, and weak in shearing and tension.

➢ They withstand chemical erosion that occurs in other materials subjected to acidic or caustic environments.

➢ Ceramics generally can withstand very high temperatures, ranging from 1,000 °C to 1,600 °C (1,800 °F to 3,000 °F).

CARBON CERAMIC

➢ Carbon ceramic composite (C/-SiC) is a carbon fiber reinforced silicon carbide ceramic composite. The main matrix component of silicon carbide determines the hardness of the composite, the effect of carbon fiber is to improve the mechanical strength and fracture toughness of the material, and its strength is 5 times higher than that of the steel.

➢ **Ceramic matrix composites** (**CMCs**) are a subgroup of composite materials and a subgroup of ceramics. They consist of ceramic fibers embedded in a ceramic matrix. The fibers and the matrix both can consist of any ceramic material, whereby carbon and carbon fibers can also be regarded as a ceramic material.

- The carbon ceramic composite material has the advantages of low density, high temperature oxidation resistance and corrosion resistance, and is a new type of high temperature structure material and functional material which can meet the use of 1650 degrees centigrade.

PROPERTIES OF CARBON CERAMICS:

- The motivation to develop CMCs was to overcome the problems associated with the conventional technical ceramics like alumina, silicon carbide, aluminum nitride, silicon nitride or zirconia – they fracture easily under mechanical or thermo-mechanical loads because of cracks initiated by small defects or scratches.
- The crack resistance is – like in glass – very low. To increase the crack resistance or fracture toughness, particles (so-called monocrystalline *whiskers* or *platelets*) were embedded into the matrix. However, the improvement was limited, and the products have found application only in some ceramic cutting tools.
- The reinforcements used in ceramic matrix composites (CMC) serve to enhance the fracture toughness of the combined material system while still taking advantage of the inherent high strength and Young’s modulus of the ceramic matrix.
- The most common reinforcement embodiment is a continuous-length ceramic fiber, with an elastic modulus that is typically somewhat lower than the matrix.
- The functional role of this fiber is

  (1) to increase the CMC stress for the progress of micro-cracks through the matrix, thereby increasing the energy expended during crack propagation; and then

  (2) when thru-thickness cracks begin to form across the CMC at higher stress (proportional limit stress, PLS), to bridge these cracks without fracturing, thereby providing the CMC with a high ultimate tensile strength (UTS).
- Generally, CMC names include a combination of *type of fiber/type of matrix*. For example, *C/C* stands for carbon-fiber-reinforced carbon (carbon/carbon), or *C/SiC* for carbon-fiber-reinforced silicon carbide. Sometimes the manufacturing

process is included, and a C/SiC composite manufactured with the liquid polymer infiltration (LPI) process is abbreviated as *LPI-C/SiC*.

- They differ from conventional ceramics in the following properties, presented in more detail below:
  - Elongation to rupture up to 1%
  - Strongly increased fracture toughness
  - Extreme thermal shock resistance
  - Improved dynamical load capability
  - Anisotropic properties following the orientation of fibers

4. Write in detail about stainless steel. (May 2019)

- Stainless steel is one of the most frequently used biomaterials for internal fixation device because of a favorable combination of mechanical properties, corrosion resistance, cost effectiveness and easily making a manufacturing.
- However, Stainless steel is not used as cement less arthroplasty implants due to their low biocompatibility because the stable oxide layer cannot be formed on the surface of stainless steel. Stainless steel is used for non-permanent implants, such as internal fixation devices, because of its poor fatigue strength and liability to undergo plastic deformation.

316L STAINLESS STEEL

- 316L stainless steel is considered as one of the attractive metallic materials for biomedical applications due to its mechanical properties, biocompatibility, and corrosion resistance.
- The mainadvantage of porous materials is their ability to providebiological anchorage for the surrounding bony tissue viathe ingrowth of mineralized tissue into the pore space.

MANUFACTURING PROCESS:

- The manufacture of stainless steel involves a series of processes.
- First, the steel is melted, and then it is cast into solid form. After various forming steps, the steel is heat treated and then cleaned and polished to give it the desired finish. Next, it is packaged and sent to manufacturers, who weld and join the steel to produce the desired shapes.

1. MELTING AND CASTING:

- The raw materials are first melted together in an electric furnace.
- This step usually requires 8 to 12 hours of intense heat.

2. FORMING:

- The semi-finished steel goes through forming operations, beginning with hot rolling, in which the steel is heated and passed through huge rolls.
- Blooms and billets are formed into bar and wire, while slabs are formed into plate, strip, and sheet.

3. HEAT TREATMENT:

- After the stainless steel is formed, most types must go through an annealing step.
- Annealing is a heat treatment in which the steel is heated and cooled under controlled conditions to relieve internal stresses and soften the metal.

4. DESCALING:

- Annealing causes a scale or build-up to form on the steel. The scale can be removed using several processes.
- One of the most common methods, pickling, uses a nitric-hydrofluoric acid bath to descale the steel.

5. CUTTING:

- Cutting operations are usually necessary to obtain the desired blank shape or size to trim the part to final size.
- Mechanical cutting is accomplished by a variety of methods, including straight shearing using guillotine knives, circle shearing using circular knives horizontally and vertically positioned, sawing using high speed steel blades, blanking, and nibbling.

6. FINISHING:

- Surface finish is an important specification for stainless steel products and is critical in applications where appearance is also important.
- Certain surface finishes also make stainless steel easier to clean, which is obviously important for sanitary applications.

CHEMICAL COMPOSITION:

Element	Type 316 (%)	Type 316L (%)
Carbon	0.08 max.	0.03 max.
Manganese	2.00 max.	2.00 max.
Phosphorus	0.045 max.	0.045 max.
Sulfur	0.03 max.	0.03 max.
Silicon	0.75 max.	0.75 max.
Chromium	16.00-18.00	16.00-18.00
Nickel	10.00-14.00	10.00-14.00
Molybdenum	2.00-3.00	2.00-3.00
Nitrogen	0.10 max.	0.10 max.
Iron	Balance	Balance

5. **Discuss about Ti-based alloys with biomedical application. (May 2019)**

- Metals and their alloys are widely used as biomedical materials. On one hand, metallic biomaterials cannot be replaced by ceramics or polymers at present.

PROPERTIES OF Ti BASED ALLOYS:

- Biomedical implants are desired to satisfy various requirements demanded by human body, because they could be applied to approximately any organ of human body. The basic properties are biomechanical properties and biomedical properties.

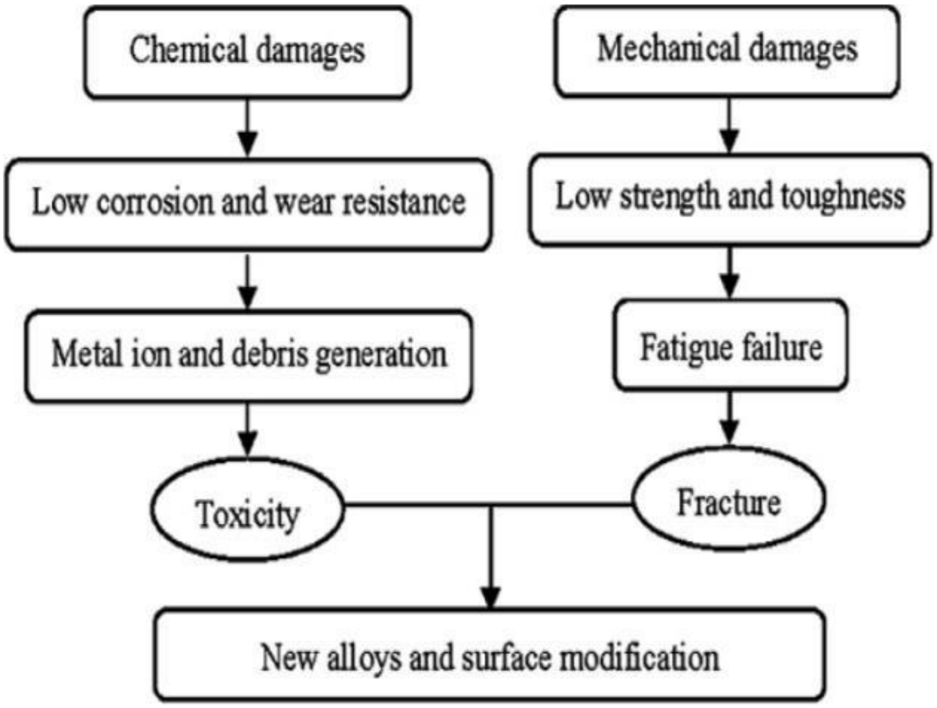
BIOCOMPATIBILITY OF Ti BASED ALLOYS:

- Ideally, biomedical implants are required to be highly innocuous without any inflammatory or allergic reactions in human body. At present, issues concerning biocompatibility are thrombosis, including blood coagulation and adhesion of blood platelets to biomaterial surface, and the fibrous tissue encapsulation of biomaterials that are implanted in soft tissues.

FABRICATION OF Ti BASED ALLOYS:

1. KROLL'S PROCESS:

Pure titanium is produced using several methods including the Kroll process. This process produces the majority of titanium primary metals used globally by industry today. In this process, the titanium is extracted from its ore rutile—TiO2 or titanium concentrates.

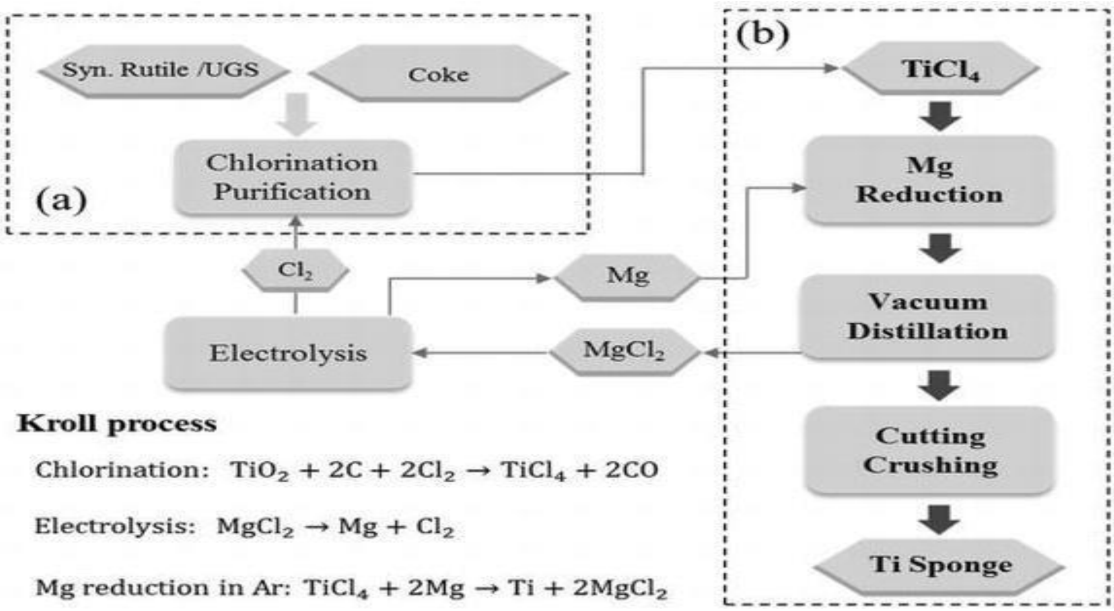


2. ARMSTRONG PROCESS:

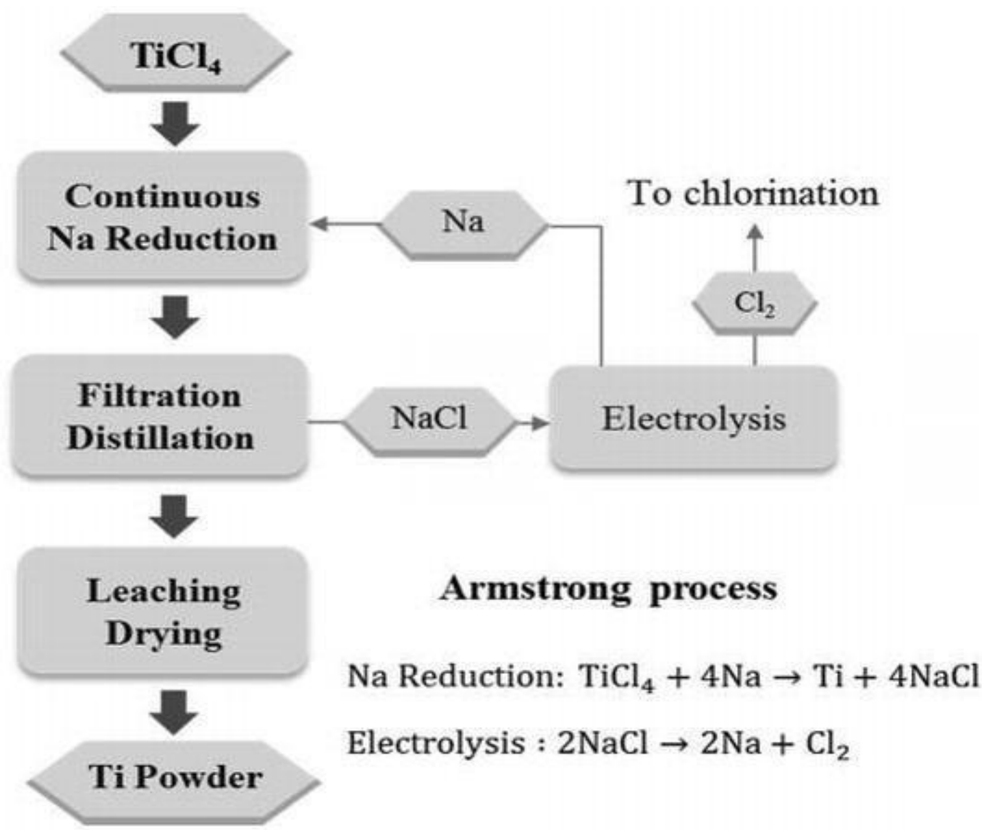
This process is capable of producing commercially pure titanium (Ti) powder by the reduction of titanium tetrachloride (TiCl4) and other metal halides using sodium (Na). This process produces powder particles with a unique properties and low bulk density.

3. HYDRIDE DEHYDRIDE PROCESS:

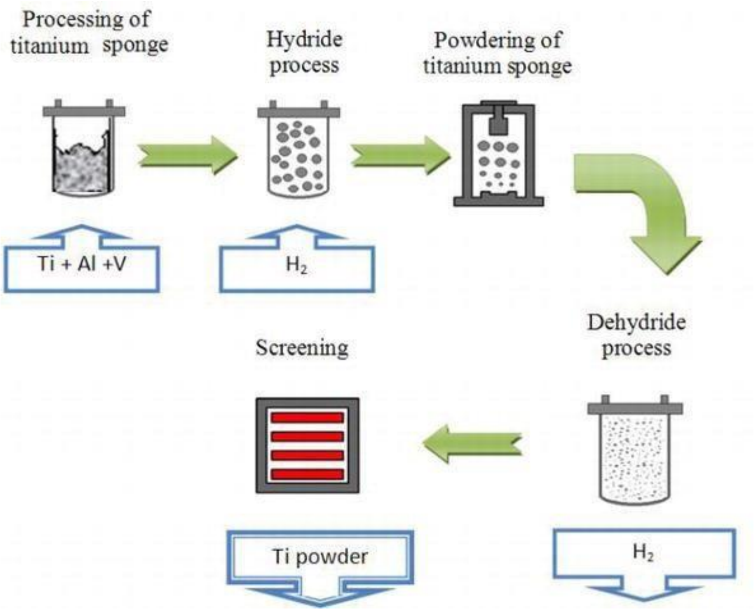
The hydride-dehydride (HDH) process, illustrated in fig, is used to produce titanium powder using titanium sponge, titanium, mill products, or titanium scrap as the raw material.



KROLL'S PROCESS



ARMSTRONG PROCESS



HYDRIDE DEHYDRIDE PROCESS

6. a. Explain the different classes of biomaterials used for implants. (Nov. 2016)

b. Give examples and medical applications of stainless steel, ceramic and composite implants. (Nov. 2016)

- The Materials which are used for structural applications in the fields of medicine are known as biomaterials.
- These materials are used to make devices to replace damaged body parts. A variety of devices and materials are used in the treatment of disease or injury.Common place examples include suture needles, plates, teeth fillings, etc

REQUIREMENTS OF BIOMATERIALS:

- Technical functionality through mechanical properties tuned to the specific implant
- Sufficient stability against physiological media
- Residue-free metabolization for biodegradable biomaterials
- High biocompatibility
- Simple processing

CLASSIFICATION OF BIOMATERIALS

1)METAL AND ALLOYS

- Metals and alloys are used as biomaterials due to their excellent electrical and thermal conductivity and mechanical properties. The types of Metal and alloys are cobalt based alloys, titanium, stainless steel , protosal from cast alloy, conducting metals such as platinum

- The advantage of metal
  - High strength
  - Fatigue resistance
- Disadvantages are
  - High elastic modulus
  - Corrosion

APPLICATIONS OF METAL AND ALLOY

- Metals and alloys biomaterials are used in implant and orthopedicapplication
- Stainless steel Predominant implant alloy

CERAMICS

- Ceramics are used as biomaterials due to their high mechanical strength and biocompatibility
- Types of Bio-ceramic materials are tri calcium phosphate, Metals oxides such as Al2O3 and SiO2 ,Apatite ceramics, Porous ceramics, Carbon and Alumina
- Advantage:
  - High compression strength
  - Wear & Corrosion resistance
- Disadvantage
  - High E modulus (stress shielding)
  - Brittle -Low fracture toughness

APPLICATIONS OF CERAMICS

- Al2O3 and SiO2 - used to make femoral head and Tri calcium Phosphate - bone repairs

BIOPOLYMERS

- Biopolymers are macromolecules (protein, nuclei ,acids and polysaccharides) formed in nature during the growth cycles of all organism
- Advantages
  - Easy to make complicated items
  - Tailor able physical & mechanical properties
- Disadvantages
  - Leachable compounds Absorb water & proteins etc.

   - Surface contamination

APPLICATION OF BIOPOLYMERS

- Medical disposable supplies, prosthetic materials, dental materials, implants, dressings, extracorporeal devices, encapsulates, polymeric drug delivery systems, tissue engineered products

COMPOSITE BIOMATERIALS

- The term "composite" is usually reserved for those materials in which the distinct phases are separated on a scale larger than the
- Biomaterial applications are:
  - dental filling composites
  - reinforced methyl methacrylate bone cement and ultra-highmolecular- weight polyethylene, andorthopedic implants with porous surfaces.
- The Materials which are used for structural applications in the fields of medicine are known as biomaterials.
- These materials are used to make devices to replace damaged or diseased body parts in human and animal bodies.
- A variety of devices and materials are used in the treatment of disease or injury.
- Common place examples include suture needles, plates, teeth fillings, etc

STAINLESS STEEL

- Stainless steel is one of the most frequently used biomaterials for internal fixation device because of a favorable combination of mechanical properties, corrosion resistance, cost effectiveness and easily making a manufacturing.
- However, Stainless steel is not used as cement less arthroplasty implants due to their low biocompatibility because the stable oxide layer cannot be formed on the surface of stainless steel.
- Stainless steel is used for non-permanent implants, such as internal fixation devices, because of its poor fatigue strength and liability to undergo plastic deformation.

316L STAINLESS STEEL

- 316L stainless steel is considered as one of the attractive metallic materials for biomedical applications due to its mechanical properties, biocompatibility, and corrosion resistance.

- This inatcrial is popular metal for use as acetabula cup (one half of an artificial hip joint) applications.
- Highly porous 316L stainless steel parts were produced by using a powder metallurgy proceses, which includes the selective laser sintering(SLS) and traditional sintering.

7. **Explain in detail about the composition, properties and methods by which implants are manufactured for stainless steel and cobalt based alloys. (May 2018)**

- Stainless steel is one of the most frequently used biomaterials for internal fixation device because of a favorable combination of mechanical properties, corrosion resistance, cost effectiveness and easily making a manufacturing.

316L STAINLESS STEEL

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CHEMICAL COMPOSITION:

Element	Type 316 (%)	Type 316L (%)
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Silicon	0.75 max.	0.75 max.
Chromium	16.00-18.00	16.00-18.00
Nickel	10.00-14.00	10.00-14.00
Molybdenum	2.00-3.00	2.00-3.00
Nitrogen	0.10 max.	0.10 max.
Iron	Balance	Balance

MANUFACTURING PROCESS:

- The manufacture of stainless steel involves a series of processes.
- First, the steel is melted, and then it is cast into solid form.

- After various forming steps, the steel is heat treated and then cleaned and polished to give it the desired finish.
- Next, it is packaged and sent to manufacturers, who weld and join the steel to produce the desired shapes.

1. MELTING AND CASTING:

- The raw materials are first melted together in an electric furnace. This step usually requires 8 to 12 hours of intense heat. When the melting is finished, the molten steel is cast into semi-finished forms. These include blooms, billets, slabs, rods, and tube rounds.

Table 4. Mechanical properties of various Co alloys

Technical name	Yield strength (MPa)	Ultimate tensile strength (MPa)	Young's modulus (GPa)	Percentage elongation (%)	Hardness (HV)	Poisson's ratio
Cast Co–Cr–Mo	448–517	660	280	10	298	0.3
Wrought Co–Cr–Mo	448–648	858	210	30	239	0.3
	1606	1500	210	9	245	0.3
	965–1000	1000	232	12	280	0.3
Wrought Co–Ni–Cr–Mo	240–655	794–1000	210	50	–	0.3
	1585	1794	232	8	–	0.3

2. FORMING:

- The semi-finished steel goes through forming operations, beginning with hot rolling, in which the steel is heated and passed through huge rolls. Blooms and billets are formed into bar and wire, while slabs are formed into plate, strip, and sheet.

3. HEAT TREATMENT:

- After the stainless steel is formed, most types must go through an annealing step. Annealing is a heat treatment in which the steel is heated and cooled under controlled conditions to relieve internal stresses and soften the metal.

4. DESCALING:

- Annealing causes a scale or build-up to form on the steel. The scale can be removed using several processes. One of the most common methods, pickling, uses a nitric-hydrofluoric acid bath to descale the steel.

5. CUTTING:

- Cutting operations are usually necessary to obtain the desired blank shape or size to trim the part to final size.

6. FINISHING:

- Surface finish is an important specification for stainless steel products and is critical in applications where appearance is also important. Certain surface finishes also make stainless steel easier to clean, which is obviously important for sanitary applications.

8. a. Write a detailed note on hydroxyapatite glass organic as biomaterials for human implant. (Dec. 2018, May 2017)

b. Explain the structure, properties and manufacturing methods of hydroxyapatite. (May 2018)

- **Hydroxyapatite**, also called **hydroxylapatite**(**HA**), is a naturally occurring mineral form of calcium apatite with the formula $Ca_5(PO_4)_3(OH)$, but it is usually written $Ca_{10}(PO_4)_6(OH)_2$ to denote that the crystal unit cell comprises two entities.
- Hydroxyapatite is the hydroxyl end member of the complex apatite group. The OH^- ion can be replaced by fluoride, chloride or carbonate,producing fluorapatite or chlorapatite.

STRUCTURE

- HAp structure is formed by a tetrahedral arrangement of phosphate (PO_4^{3-}), which constitute the "skeleton" of the unit cell.
- Two of the oxygens are aligned with the c axis and the other two are in a horizontal plane.

PROPERTIES

- CaPs are in general brittle in nature due to their high strength ionic bonds.
- The mechanical properties of CaPs are defined by their crystallinity, grain size, grain boundaries, porosity and stoichiometry.
- When the microstructure is comprised of small grains, the number of grain boundaries also decreases significantly, leading to increased mechanical strength.

BIOLOGICAL PROPERTIES

- HA bioceramics have been widely used as artificial bone substitutes because of its favourable biological properties which include: biocompatibility, bio-affinity, bioactivity, osteoconduction, osteointegration, as well as osteoinduction.HA contains only calcium and phosphate ions and therefore no adverse local or systemic toxicity has been reported in any study.

SYNTHESIS OF HAP

1. Wet chemical methods (precipitation)

a) Calcium Hydroxide and Orthophosphoric Acid

- At a pH of greater than 9, orthophosphoric acid solution is added is a drpwise manner to a dilute solution/suspension of calcium hydroxide.The acid is added at a controlled rate, with stirring being maintained throughout the process. The precipitation reaction is slow.Reaction temperatures of between 25 and 90°C are common, the higher temperature producing a higher crystallinity product.

b) Calcium Nitrate, Diammonium Hydrogen Phosphate and Ammonium Hydroxide

- Another precipitation method used for producing hydroxyapatite involves calcium nitrate, diammonium hydrogen phosphate and ammonium hydroxide.This method results in a faster production rate, with ammonium hydroxide being added to maintain a constant pH.

2. Hydrothermal techniques

- After wet chemistry, hydrothermal techniques are the second most popular synthesis techniques for producing hydroxyapatite powders.This method involves reacting a mixture of calcium carbonate ($CaCO_3$) and di-ammonium hydrogen phosphate at high temperatures and pressures such as 275°C and 12000psi.

3. Hydrolysis of other calcium phosphates

- Temperature exerts a substantial effect on the rate of α-$Ca_3(PO_4)_2$ hydrolysis and also changes the morphology of the reaction products.At 40 C, the plate-like intersecting crystals of HAP grow. Their maximum size after the 24-h hydrolysis is 1–2 m.Needle like HAP crystals are formed upon boiling of the suspension.

4. Sol-gel

- Sol-gel materials can be manufactured by three different methods namely: gelation of colloidal powders, hypercritical drying and by controlling the hydrolysis and condensation of precursors and then incorporating a drying step at ambient temperature.

5. Solid state method

- The solid-state method for HA synthesis typically involves combining TCP and $Ca(OH)_2$ powders in specific ratios mixing the dry powders in water, wet milling, casting the mixture into bodies, drying and sintering.

IMPLANTATION PROCEDURE

- Implantation site is prepared with an antiseptic solution.
- A local anaesthetic is used to numb the site.
- A small incision is made at the implantation site.
- Tissue from the area is gently lifted to create a small tunnel or pocket for the implant.

- The implant is inserted and trimmed if necessary to fit the requirements of the correction.
- The implant is secured in place by suturing the incision(s).
- Sutures removed after 5-7 days.

LIFTIME OF HAP IMPLANTS

- A solid hydroxyapatite implant is permanent.
- It is thought that due to the porous nature of these implants they lack strength, but this is possibly made up for by the ease of bone tissue growth into the pores of the implant once inserted.
- Over time they are partially resorbed and replaced by natural bone.

COMPLICATIONS IN HAP IMPLANTS

- Infection of the implant site
- Extrusion (part of the implant comes through the skin)
- Induration (hardening of the area operated on)

UNIT-I

2 MARKS:

1) What are biomaterials? (Nov 2018, May 2017)

The Materials which are used for structural applications in the fields of medicine are known as biomaterials. These materials are used to make devices to replace damaged or diseased body parts in human and animal bodies. A variety of devices and materials are used in the treatment of disease or injury. Common place examples include suture needles, plates, teeth fillings, etc.

2) Define biocompatibility? (Dec 2018, May 2019. May 2017)

Biocompatibility is a general term describing the property of a material being compatible with living tissue. Biocompatible materials do not produce a toxic or immunological response when exposed to the body or bodily fluids. Biocompatible materials are central for use in medical implants and prosthetics to avoid rejection by the body tissue and to support harmonious biological functioning.

3) Is blood a viscoelastic material? Justify. (Nov 2019)

Viscoelasticity is a property of human blood that is primarily due to the elastic energy that is stored in the deformation of red blood cells as the heart pumps the blood through the body. The energy transferred to the blood by the heart is partially stored in the elastic structure, another part is dissipated by viscosity, and the remaining energy is stored in the kinetic motion of the blood. When the pulsation of the heart is taken into account, an elastic regime becomes clearly evident. It has been shown that the previous concept of blood as a purely viscous fluid was inadequate since blood is not an ordinary fluid. Blood can more accurately be described as a fluidized suspension of elastic cells (or a sol).

4) State Wolfe's law for bone remodelling. (Nov 2019)

Wolfe's law states that: "Bone in a healthy person is capable of adapting loads that is placed under. If loading on a particular bone increases, the bone will remodel itself over time to become stronger to resist the loading. Conversely, if the loading on a bone decreases, the bone will become weaker”.

5) How are biomaterials classified? (May 2019)

Based on the application in the medical field biomaterial are classified into:

- Metals and alloys biomaterials
- Ceramics biomaterials
- Polymer biomaterials
- Composite biomaterials

Based on compatibility biomaterials are classified into:

- Biotolerant
- Bioinert
- Bioactive
- Bioresorbable

6) What is the importance of surface properties of biomaterials? (Nov 2016)

The surface properties of an implantable biomaterial play an important role in biointegration and biocompatibility during a period starting with implantation and for the whole in-dwelling lifetime of the implant. Upon implantation, several biological events take place on the biointerface of material and tissue, which are mostly related with the surface properties of biomaterial.

- Some of the surface properties are:
- The surface region of a material is known to be uniquely reactive.
- The surface of a material is inevitably different from the bulk
- Surface readily contaminate.
- The surface structure of a material is often mobile.

7) What are the factors on which wound healing depends on? (Nov 2016)

Many factors controlling the efficacy, speed, and manner of wound healing fall under two types: local and systemic factors.

- **Local factors**
- Moisture
- Mechanical factors
- Oedema
- Ionizing radiation
- Faculty technique of wound closure
- Ischemia and necrosis
- Foreign bodies.
- Low oxygen tension
- Perfusion
- **Systemic factors**
- Inflammation
- Diabetes
- Nutrients Metabolic diseases
- Immuno suppression
- Connective tissue disorders
- Smoking
- Age
- Alcohol

8) What are the factors from the choice of material can affect local tissue response to an implant? (May 2018)

- **Local effect of implant on host:**
- Blood material interaction
- Toxicity
- Modification of normal healing
- Infection
- Tumorigenesis
- Protein absorption, coagulation, fibrinolysis, platelrt adhesion, complement activation, leukocyte adhesion, hemolysis
- Encapsulation, foreign body reaction, pannus formation
- **Local events following implantation:**
- Injury

- Acute inflammation
- Chronic inflammation
- Granulation tissue
- Foreign body reaction
- Fibrosis

9) Define viscoelasticity. (Nov 2017, May 2018)

Viscoelasticity is the time-dependent and elastic behaviour of materials. This means that the response to a stimulus is delayed, and there is a loss of energy inside the material. Viscoelastic behaviour normally occurs at different time scales (relaxation times) in the same material.

Viscoelasticity is the property of materials that both viscous and elastic characteristics when undergoing deformation.

10) Define creep. (Nov 2017)

Creep (sometimes called cold flow) is the tendency of a solid material to move slowly or deform permanently under the influence of persistent mechanical stresses. It can occur as a result of long-term exposure to high levels of stress that are still below the yield strength of the material.

11 MARKS

1) a. Elaborate in detail about the classification of biomaterials and their biomedical applications (Nov 2018)

b. Classify the biomaterials giving emphasis on the properties and applications of each. (Nov 2019)

c. How are biomaterials classified? Mention the merits and demerits of each category with their application in detail. (May 2018)

The Materials which are used for structural applications in the fields of medicine are known as biomaterials. These materials are used to make devices to replace damaged or diseased body parts in human and animal bodies. Common place examples include suture needles, plates, teeth fillings, etc.

CLASSIFICATION OF BIOMATERIAL

Based on the application in the medical field biomaterial are classified into following 4 types:

i) METAL AND ALLOYS

- Metals and alloys are used as biomaterials due to their excellent electrical and thermal conductivity and mechanical properties. Types of Metal and alloys are cobalt based alloys, titanium, stainless steel, protosal from cast alloy, conducting metals such as platinum.

Advantages

- High strength
- Fatigue resistance
- Easy to sterilize

Disadvantages

- Corrosion
- Toxicity
- Wetting

Applications of Metal and Alloy

- Metals and alloys biomaterials are used in implant and orthopaedic application
- Stainless steel Predominant implant alloy
- Protosal from cast alloy of Co ,Cr, Mo used for implant hip Endo prosthesis and advance version of this protosal are widely used in hip joints

ii) CERAMICS

They are used as biomaterials due to their high mechanical strength and biocompatibility. Types of Bio-ceramic materials are tri calcium phosphate, Metals oxides such as Al_2O_3 and SiO_2, Apatite ceramics, Porous ceramics, Carbon and Alumina.

Advantage

- High compression strength
- Wear & Corrosion resistance

Disadvantage

- High E modulus

- Brittle -Low fracture toughness

Applications of Ceramics

- Al_2O_3 and SiO_2 - used to make femoral head
- Apatite ceramics - bio active ceramics-used as synthetic bone
- Carbon good biocompatibility, wide application in heart valves
- Percutaneous carbon – stimulation of cochlea and visual cortex for artificial hearing and aid the blind respectively.

iii) BIOPOLYMERS

- Biopolymers are macromolecules (protein, nuclei ,acids and polysaccharides) formed in nature during the growth cycles of all organism

Advantages

- Surface modification
- Biodegradable

Disadvantages

- Surface contamination
- Difficult to sterilize

Application of Biopolymers

- Synthetic polymeric materials have been widely used in medical disposable supplies, prosthetic materials, dental materials, implants, dressings, extracorporeal devices, encapsulates, polymeric drug delivery systems, tissue engineered products

iv) COMPOSITE BIOMATERIALS

- The term "composite" is usually reserved for those materials in which the distinct phases are separated on a scale larger.

Biomaterial applications of composite biomaterials

- Dental filling composites
- Orthopedic implants with porous surfaces

CLASSIFICATION OF BIOMATERIALS BASED ON COMPATIBILITY

1. Biotolerant

Implant separated from the surrounding bone by a layer of soft tissue over the interface. No contact in the osteogenesis. The layer is induced by the implant release of monomers, ions, and/or corrosion products. Almost all synthetic polymers and most metals are this category.

2. Bioinert

Implants in direct contact with bone tissue, occurring involvement in the osteogenesis. However, there is no chemical reaction between the tissue and the implant. There is not, at least in amounts detectable by cells, the release of any component. Examples of bioinert biomaterials are: alumina, zirconia, titanium, tantalum, niobium, and carbon.

3. Bioactive

There is the interaction between the implant and the bone tissue, interfering directly in the osteogenesis. By chemical similarity, the mineral part of bone tissue binds to the implant, promoting osteoconduction. The main materials of this class are: Ca-phosphate, vitro-ceramic, and hydroxyapatite.

4. Bioresorbable

Materials that, after a certain period of time in contact with the tissues, end up by being degraded, solubilized, or phagocytosed by the body. They are of interest in clinical applications where it is inadvisable the reoperation to remove the implant. Representative of this class are tricalcium phosphate (TCP) and PLLA (poly-L-lactic acid).

2. **List and discuss the sequence of steps occurring during wound healing and examine the tissue response to body implants. (Nov 2019)**

Wound healing refers to a living organism's replacement of destroyed or damaged tissue by newly produced tissue.

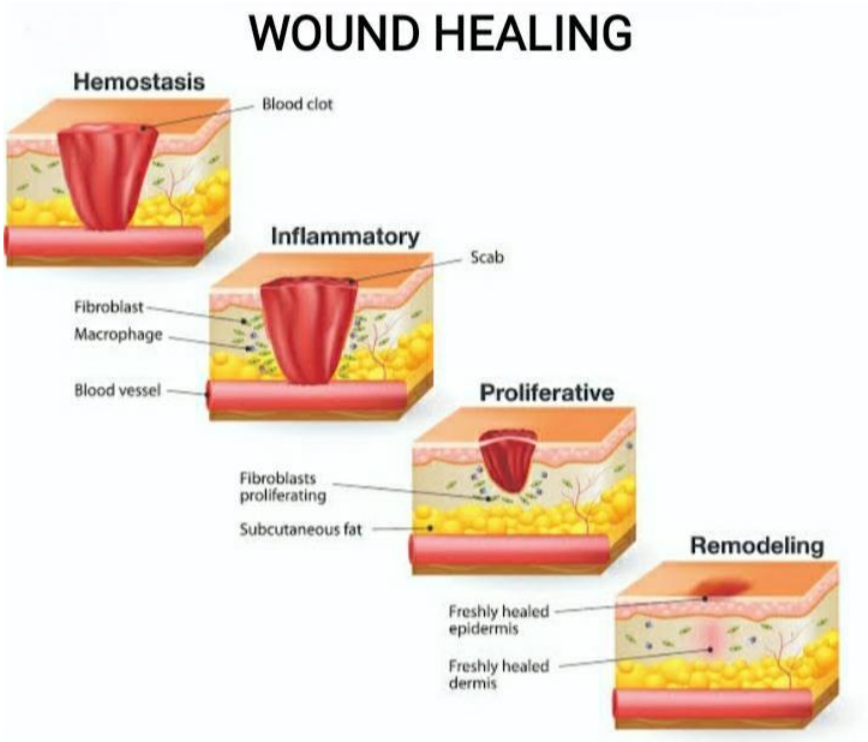
Phase 1: Hemostasis Phase (Stop the bleeding)

Hemostasis, the first phase of healing, begins at the onset of injury, and the objective is to stop the bleeding. In this phase, the body activates its emergency repair system, the blood clotting system, and forms a dam to block the drainage. During this process, platelets come into contact with collagen, resulting in activation and aggregation. An enzyme called thrombin is at the center, and it initiates the formation of a fibrin mesh, which strengthens the platelet clumps into a stable clot.

Phase 2: Defensive/Inflammatory Phase (Clotting)

If Phase 1 is primarily about coagulation, the second phase, called the Defensive/Inflammatory Phase, focuses on destroying bacteria and removing debris—essentially preparing the wound bed for the growth of new tissue.

During Phase 2, a type of white blood cells called neutrophils enter the wound to destroy bacteria and remove debris. These cells often reach their peak population between 24 and 48 hours after injury, reducing greatly in number after three days. As the white blood cells leave, specialized cells called macrophages arrive to continue clearing debris. These cells also secrete growth factors and proteins that attract immune system cells to the wound to facilitate tissue repair. This phase often lasts four to six days and is often associated with edema, erythema (reddening of the skin), heat and pain.



Phase 3: Proliferative Phase (New cell growth)

Once the wound is cleaned out, the wound enters Phase 3, the Proliferative Phase, where the focus is to fill and cover the wound.The Proliferative phase features three distinct stages: 1) filling the wound; 2) contraction of the wound margins; and 3) covering the wound (epithelialization). During the first stage, shiny, deep red granulation tissue fills the wound bed with connective tissue, and new blood vessels are formed. During contraction, the wound margins contract and pull toward the center of the wound. In the third stage, epithelial cells arise from the wound bed or margins and begin to migrate across the wound bed in leapfrog fashion until the wound is covered with epithelium. The Proliferative phase often lasts anywhere from four to 24 days.

Phase 4: Maturation Phase (Strengthening)

During the Maturation phase, the new tissue slowly gains strength and flexibility. Here, collagen fibers reorganize, the tissue remodels and matures and there is an overall increase in tensile strength (though maximum strength is limited to 80% of the pre-injured strength). The Maturation phase varies greatly from wound to wound, often lasting anywhere from 21 days to two years. The healing process is remarkable and complex, and it is also susceptible to interruption due to local and systemic factors, including moisture, infection, and maceration (local); and age, nutritional status, body type (systemic). When the right healing environment is established, the body works in wondrous ways to heal and replace devitalized tissue.

TISSUE RESPONSE TO BODY IMPLANTS

- All implants interact with the biological environment around them. Effects go both ways "Effects of tissue on the implant and Effects of implant on the tissue".
- All materials intended for application in humans as biomaterials, medical devices, or prostheses undergo tissue responses when implanted into living tissue.
- These actions involve fundamental aspects of tissue responses including injury, inflammatory and wound healing responses, foreign body reactions, and fibrous encapsulation. Secondly the in vivo evaluation of tissue responses to these materials is important for performance, safety, and regulatory reasons.

MECHANICAL EFFECTS OF HOST ON IMPLANTS

1. Abrasive wear
2. Fatigue
3. Stress-corrosion
4. Cracking
5. Corrosion
6. Degeneration and dissolution

BIOLOGICAL EFFECTS OF HOST ON IMPLANTS

1. Absorption of substances from tissue
2. Enzymatic degradation

3. Calcification

LOCAL EFFECT OF IMPLANT ON HOST

1. Blood material interaction
2. Toxicity
3. Modification of normal healing
4. Infection
5. Tumorigenesis
6. Protein absorption, coagulation, fibrinolysis, platelet adhesion, complement activation, leukocyte adhesion, hemolysis
7. Encapsulation, foreign body reaction, pannus formation

SYSTEMATIC EFFECT OF IMPLANT ON HOST

1. Embolization
2. Hypersensitivity
3. Elevation of implant elements in blood
4. Lymphatic particle transport

3. Explain the surface properties of biomaterials. (May 2019)

Biomaterial Surface

- Biomaterial surfaces exhibit remarkable heterogeneity in physical structure:
- Material dependant: Metals vs. Polymers vs. Ceramics vs. Gels
- Chemistry: Polar vs. Apolar, Charge, Reactivity
- Morphology: Smooth, Rough, Stepped, Patterned, Diffuse
- Order: Crystalline, Amorphous, Semi-Crystalline, Phasic
- Environment: Hydration, Solvent Quality

SURFACE PROPERTIES

- The surface region of a material is known to be uniquely reactive
- The surface of a material is inevitably different from the bulk
- Surfaces readily contaminate
- The surface structure of a material is often mobile.

SURFACE INTERACTION WITH MOLECULES

- Nonspecific interaction
- Specific bonding

⦿ Surface topology

1. NON-SPECIFIC INTERACTION

⦿ Dipole-dipole type interactions;

⦿ Electrostatic forces resulting from charged molecules

⦿ Hydration or solvation force that results from expulsion of water between the two surfaces

⦿ Hydrophobic effects that non-polar molecules tend to form intermolecular aggregates in an aqueous medium

⦿ Repulsive steric forces that arise due to proteins on both surfaces forming spikes of up to 10 nm.

2. SPECIFIC BONDING

⦿ The electronic and atomic structures, and almost all the physical properties, of solids depend on the nature and strength of the inter-atomic bonds:

1. Ionic Bonding
2. Covalent Bonding
3. Metallic Bonding
4. Weak Bonding – Vander Waals and hydrogen bonding

3. SURFACE TOPOLOGY

⦿ Topological features occur at different length scales:

1. Sub-cellular level (< 10 μm)
2. Cellular level (10-100 μm)
3. Multi-cellular level (>100 μm)

⦿ Modulate protein adsorption

⦿ Constrain receptor binding and related signaling pathways – cell attachment, spreading, migration, and function

⦿ Porosity

SURFACE CHARACTERISATION

⦿ Contact Angle Methods

⦿ Electron Spectroscopy for Chemical Analysis (ESCA)

⦿ X-ray Photoelectron Spectroscopy (XPS)

⦿ Secondary Ion Mass Spectrometry (SIMS)

⦿ Infrared Spectroscopy (IRS)

⦿ Scanning Electron Microscopy (SEM)

⦿ Scanning Tunneling Microscopy (STM)

⦿ Atomic Force Microscopy (AFM)

SUPERHYDROPHOBICITY

⦿ **Ultrahydrophobic** (or **superhydrophobic**) surfaces are highly hydrophobic, i.e., extremely difficult to wet.

⦿ The contact angles of a water droplet on an ultrahydrophobic material exceed 150°.

⦿ This is also referred to as the lotus effect, after the superhydrophobic leaves of the lotus plant. A droplet striking these kinds of surfaces can fully rebound like an elastic ball.

⦿ In the biomedical arena this property is used as substrates to control protein adsorption, cellular interaction, and bacterial growth, as well as platforms for drug delivery devices and for diagnostic tools.

- **SURFACE ADSORPTION**

⦿ SURFACE ENERGY

⦿ SURFACE HYDROPHOBICITY

⦿ SURFACE CHARGE

1. SURFACE ENERGY

⦿ Surface energy is a term used to describe the surface of a given substrate; surface energies range from high to low.

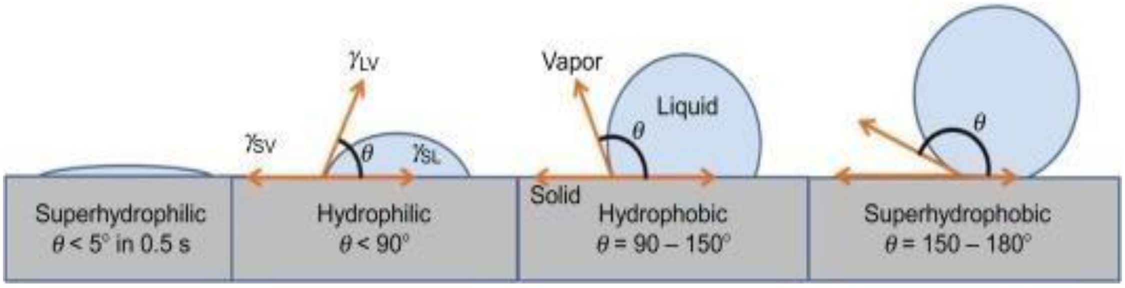
⦿ The molecular force of attraction between unlike materials determines their adhesion.

⦿ The strength of attraction is depends on the surface energy of the substrate. High surface energy means a strong molecular attraction, while low surface energy means weaker attractive forces.

2. SURFACE HYDROPHOBICITY

⦿ Hydrophobic surface is a surface that has the ability to repel water.

Surface hydrophobicity is a structure-related function, dependent on the size and shape of protein molecule, amino acid composition, and sequence, as well as any intramolecular or intermolecular cross-links.



3. SURFACE CHARGE

⦿ It is the electrical potential difference between the inner and outer surface of a material.

⦿ Surface charge on biomaterials is emerging as a crucial determinant of regulating cells responses impacting cells signaling in tissue treatment.

⦿ Charges allocated at the surface determine cells adhesion and later tissue development.

4. a. Discuss about viscoelastic property of biomaterials. (May 2019)

b. With an example explain and describe the components of stress strain curve of a ductile metal. (Nov 2016)

➢ Viscoelasticity is the time-dependent and elastic behaviour of materials. This means that the response to a stimulus is delayed, and there is a loss of energy inside the material.

➢ Viscoelastic behaviour normally occurs at different time scales (relaxation times) in the same material.

➢ Viscoelasticity is the property of materials that both viscous and elastic characteristics when undergoing deformation.

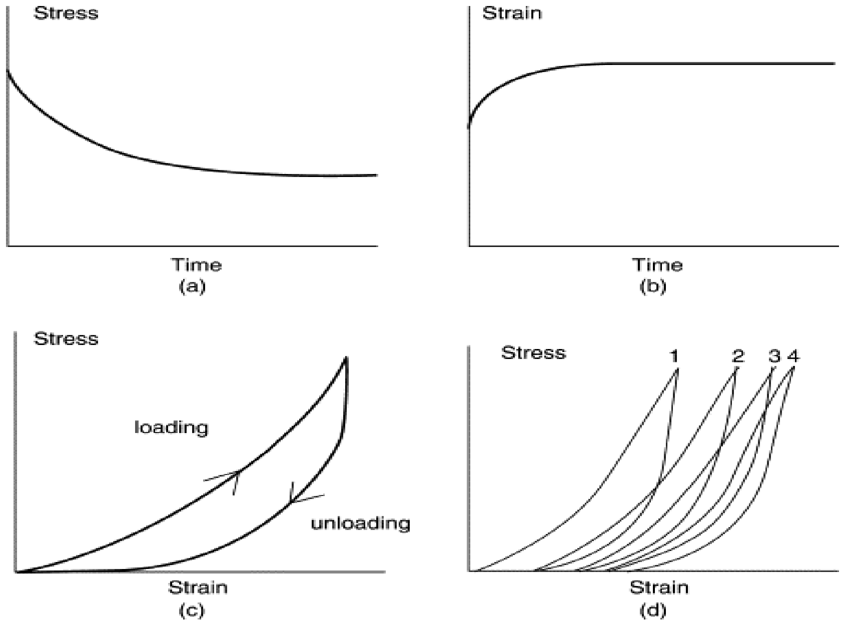
➢ Viscous materials, like water, resist shear flow and strain linearly with time when a stress is applied.

➢ Elastic materials strain when stretched and immediately return to their original state once the stress is removed.

➢ Viscoelastic materials have elements of both of these properties and, as such, exhibit time-dependent strain.

➢ Whereas elasticity is usually the result of bond stretching along crystallographic planes in an ordered solid, viscosity is the result of the diffusion of atoms or molecules inside an amorphous material.

➢ Depending on the change of strain rate versus stress inside a material the viscosity can be categorized as having a linear, non-linear, or plastic response.



➢ When a material exhibits a linear response it is categorized as a Newtonian material. In this case the stress is linearly proportional to the strain rate. If the material exhibits a non-linear response to the strain rate, it is categorized as Non-Newtonian fluid.

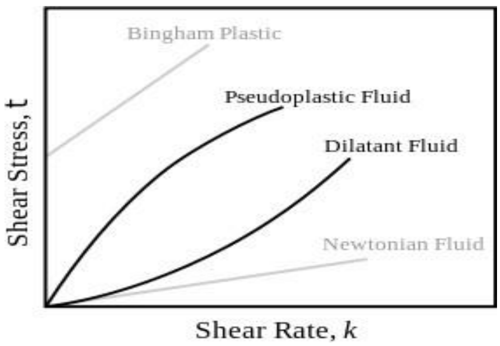
➢ There is also an interesting case where the viscosity decreases as the shear/strain rate remains constant. A material which exhibits this type of behavior is known as thixotropic.

➢ In addition, when the stress is independent of this strain rate, the material exhibits plastic deformation. Many viscoelastic materials exhibit rubber like behavior explained by the thermodynamic theory of polymer elasticity.

➢ Some examples of viscoelastic materials include amorphous polymers, semicrystalline polymers, biopolymers, metals at very high temperatures, and bitumen materials.

➢ Cracking occurs when the strain is applied quickly and outside of the elastic limit.

➢ Ligaments and tendons are viscoelastic, so the extent of the potential damage to them depends both on the rate of the change of their length as well as on the force applied.



- A viscoelastic material has the following properties:
- hysteresis is seen in the stress–strain curve
- stress relaxation occurs: step constant strain causes decreasing stress
- creep occurs: step constant stress causes increasing strain

TYPES OF VISCOELASTICITY

- **Linear viscoelasticity** is when the function is separable in both creep response and load. All linear viscoelastic models can be represented by a Volterra equation connecting stress and strain:Linear viscoelasticity is usually applicable only for small deformations.
- **Nonlinear viscoelasticity** is when the function is not separable. It usually happens when the deformations are large or if the material changes its properties under deformations.

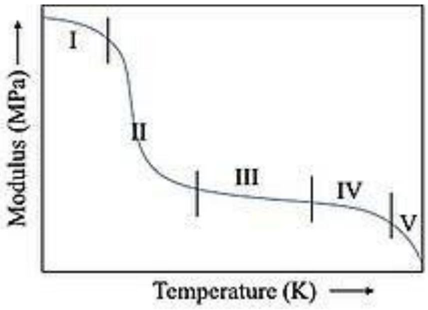
DYNAMIC MODULUS

- Viscoelasticity is studied using dynamic mechanical analysis, applying a small oscillatory stress and measuring the resulting strain.
- Purely elastic materials have stress and strain in phase, so that the response of one caused by the other is immediate.
- In purely viscous materials, strain lags stress by a 90 degree phase.
- Viscoelastic materials exhibit behavior somewhere in the middle of these two types of material, exhibiting some lag in strain.

EFFECT OF TEMPERATURE ON VISCOELASTIC BEHAVIOUR

- The secondary bonds of a polymer constantly break and reform due to thermal motion. Application of a stress favors some conformations over others, so the molecules of the polymer will gradually "flow" into the favored conformations over time.

- Because thermal motion is one factor contributing to the deformation of polymers, viscoelastic properties change with increasing or decreasing temperature.
- In most cases, the creep modulus, defined as the ratio of applied stress to the time-dependent strain, decreases with increasing temperature. Generally speaking, an increase in temperature correlates to a logarithmic decrease in the time required to impart equal strain under a constant stress.
- In other words, it takes less work to stretch a viscoelastic material an equal distance at a higher temperature than it does at a lower temperature.
- More detailed effect of temperature on the viscoelastic behavior of polymer can be plotted as shown.



- There are mainly five regions (some denoted four, which combines VI and V together) included in the typical polymers
- **Region I:** Glassy state of the polymer is presented in this region. The temperature in this region for a given polymer is too low to endow molecular motion. Hence the motion of the molecules is frozen in this area. The mechanical property is hard and brittle in this region
- **Region II:** Polymer passes glass transition temperature in this region. Beyond Tg, the thermal energy provided by the environment is enough to unfreeze the motion of molecules. The molecules are allowed to have local motion in this region hence leading to a sharp drop in stiffness compared to Region I.
- **Region III:** Rubbery plateau region. Materials lie in this region would exist long-range elasticity driven by entropy. For instance, a rubber band is disordered in the initial state of this region. When stretching the rubber band, you also align the structure to be more ordered. Therefore, when releasing the rubber band, it will spontaneously seek higher entropy state hence goes back to its initial state. This is what we called entropy-driven elasticity shape recovery.

- **Region IV:** The behavior in the rubbery flow region is highly time-dependent. Polymers in this region would need to use a time-temperature superposition to get more detailed information to cautiously decide how to use the materials. For instance, if the material is used to cope with short interaction time purpose, it could present as 'hard' material. While using for long interaction time purposes, it would act as 'soft' material.
- **Region V:** Viscous polymer flows easily in this region. Another significant drop in stiffness.

VISCOELASTIC CREEP

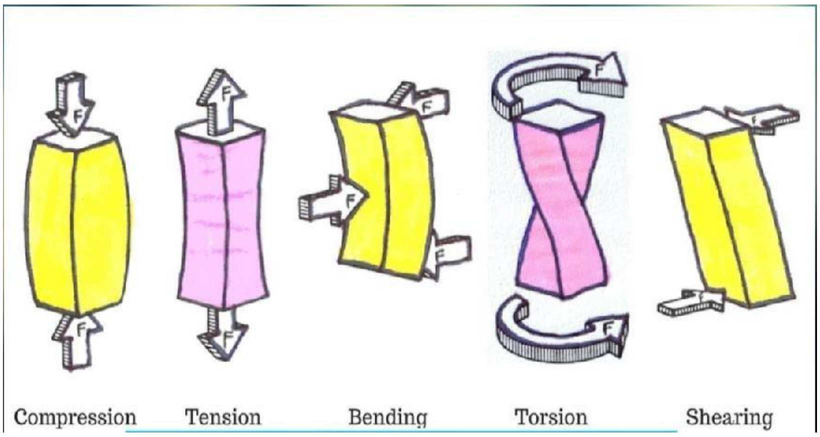
- When subjected to a step constant stress, viscoelastic materials experience a time-dependent increase in strain. This phenomenon is known as viscoelastic creep.
- Viscoelastic creep data can be presented by plotting the creep modulus (constant applied stress divided by total strain at a particular time) as a function of time. Below its critical stress, the viscoelastic creep modulus is independent of stress applied. A family of curves describing strain versus time response to various applied stress may be represented by a single viscoelastic creep modulus versus time curve if the applied stresses are below the material's critical stress value.

5. Write briefly about the various mechanical properties affecting biomaterials. (Nov 2016, Nov 2017)

1. **TENSILE AND SHEAR PROPERTIES**

a) Tensile Testing

- Parameters measured: **Engineering stress** (σ) and **Engineering strain** (ε).
- $\sigma = F/A$: Force applied perpendicular to the cross section of sample
- $\varepsilon = (l_i - l_0)/l_0$: l0 is the length of sample before loading, li is the length during testing.



b) Compression Testing

- Performed mainly for biomaterials subjected to compressive forces during operation. E.g. orthopedic implants.
- Stress and strain equations same as for tensile testing except force is taken negative and l0 larger than li.
- Negative stress and strain obtained.

c) Shear Testing

- Forces parallel to top and bottom faces
- **Shear stress** (τ) = F/A0
- **Shear strain** (γ)=tanθ ; θ is the deformation angle.

d) Torsion Testing

- Torsion is the twisting of an object due to an applied torque.
- The stress is perpendicular to the radius

2. BENDING PROPERTIES:

ELASTICITY:

A temporary shape change that is self-reversing after the force is removed, so that the object returns to its original shape, is called elastic deformation.

PLASTICITY:

When the stress is sufficient to permanently deform the metal, it is called plastic deformation

Material 1: Ceramics

- Stress proportional to strain.
- Governed by **Hooke's law**: σ = εE; τ=Gγ
- E **Young's modulus** G: **Shear modulus -** measure of material stiffness.
- Fracture after applying small values of strain: ceramics are brittle in nature.

Material 2: Metal

- Stress proportional to strain with small strain; elastic deformation.
- At high strain, stress increases very slowly with increased strain followed by fracture: Plastic deformation.

Material 3: Plastic deformation polymer

- Stress proportional to strain with small strain; elastic deformation.
- At high strain, stress nearly independent of strain, shows slight increase: Plastic deformation.

Material 4: Elastic polymer

- Stress increases very slowly with increasing strain.
- Do not fracture at a very high strain values.

3. TIME DEPENDENT PROPERTIES

CREEP: Defined as plastic deformation of sample under constant load over time.

- Creep at 37 deg C a significant concern for biomedical applications.
- Metals: Grain boundary movement, vacancy diffusion
- Ceramics: little or no vacancy diffusion
- Polymers: viscous response in amorphous regions.
- Creep is function of crystallinity: As % crystallinity increases, creep decreases.

Creep curve

3 distinct regions:

- Primary creep: increase in strain with time; creep rate decreases.
- Secondary creep: linear relation between creep strain and time.
- Tertiary creep: Leads to fracture.

4. ELASTIC MODULUS

- Elastic modulus is simply defined as the ratio of stress to strain within the proportional limit.
- Physically, it represents the stiffness of a material within the elastic range when tensile or compressive load are applied.
- It is clinically important because it indicates the selected biomaterial has similar deformable properties with the material it is going to replace.
- These force-bearing materials require high elastic modulus with low deflection. As the elastic modulus of material increases fracture resistance decreases. It is desirable that the biomaterial elastic modulus is similar to bone.
- The Elastic modulus of a material is generally calculated by bending test because deflection can be easily measured in this case as compared to very small elongation in compressive or tensile load.
- Another method of elastic modulus measurement is non-destructive method. It is also clinically very good method because of its simplicity and repeatability since materials are not destroyed.

5. HARDNESS

- Hardness is one of the most important parameters for comparing properties of materials. It is used for finding the suitability of the clinical use of biomaterials. Biomaterial hardness is desirable as equal to bone hardness.
- If higher than the biomaterial, then it penetrates in the bone. As above said, biomaterials sample are very small therefore, micro and nano scale hardness test (Diamond Knoop and Vickers indenters) are used.

6. FRACTURE STRENGTH

- Strength of materials is defined as the maximum stress that can be endured before fracture occurs.
- Strength of biomaterials (bioceramics) is an important mechanical property because they are brittle. In brittle materials like bioceramics, cracks easily propagate when the material is subject to tensile loading, unlike compressive loading.
- A number of methods are available for determining the tensile strength of materials, such as the bending flexural test, the biaxial flexural strength test and the weibull approach.
- In bioceramics, flaws influence the reliability and strength of the material during implantation and fabrication. There are a number of ways that flaws can be produced in bioceramics such as thermal sintering and heating. The importance is for bioceramics to have high reliability, rather than high strength.

7. FRACTURE TOUGHNESS

- Fracture toughness is required to alter the crack propagation in ceramics. It is helpful to evaluate the serviceability, performance and long term clinical success of biomaterials.
- It is reported that the high fracture toughness material improved clinical performance and reliability as compare to low fracture toughness.
- It can be measured by many methods e.g. indentation fracture, indentation strength, single edge notched beam, single edge pre cracked beam and double cantilever beam.

8. FATIGUE

- Fatigue is defined as failure of a material due to repeated/cyclic loading or unloading (tensile or compressive stresses).
- It is also an important parameter for biomaterial because cyclic load is applied during their serving life. In this cyclic loading condition, micro crack/flaws may be generated

at the interface of the matrix and the filler. This micro crack can initiate permanent plastic deformation which results in large crack propagation or failure.

- During the cyclic load several factor also contribute to microcrack generation such as frictional sliding of the mating surface, progressive wear, residual stresses at grain boundaries, stress due to shear.

6. What are the various types of tissue response to implants and what are the factors affecting the performance of implants? (Nov/Dec 2017)

- All implants interact with the biological environment around them.Effects go both ways "Effects of tissue on the implant and Effects of implant on the tissue".
- All materials intended for application in humans as biomaterials, medical devices, or prostheses undergo tissue responses when implanted into living tissue.
- These actions involve fundamental aspects of tissue responses including injury, inflammatory and wound healing responses, foreign body reactions, and fibrous encapsulation.Secondly the in vivo evaluation of tissue responses to these materials is important for performance, safety, and regulatory reasons.

MECHANICAL EFFECTS OF HOST ON IMPLANTS

1. Abrasive wear
2. Fatigue
3. Stress-corrosion
4. Cracking
5. Corrosion
6. Degeneration and dissolution

BIOLOGICAL EFFECTS OF HOST ON IMPLANTS

1. Absorption of substances from tissue
2. Enzymatic degradation
3. Calcification

LOCAL EFFECT OF IMPLANT ON HOST

1. Blood material interaction
2. Toxicity
3. Modification of normal healing
4. Infection
5. Tumorigenesis

6. Protein absorption, coagulation, fibrinolysis, platelet adhesion, complement activation, leukocyte adhesion, hemolysis
7. Encapsulation, foreign body reaction, pannus formation

SYSTEMATIC EFFECT OF IMPLANT ON HOST

1. Embolization
2. Hypersensitivity
3. Elevation of implant elements in blood
4. Lymphatic particle transport

LOCAL EVENTS FOLLOWING IMPLANTATIONS

Local events following implantations are as follows

1. INJURY

The reaction of vascularized living tissue to local injury Goals are:

- To reduce the agent or process causing injury
- To start off healing process by regenerating parenchymal cells
- The formation of fibroblastic scar tissue

2. ACUTE INFLAMMATION

- Short duration from minutes to days
- Characterized by the emigration of leukocytes especially neutrophils
- Emigration assisted by adhesion molecules on both WBC and endothelial cells
- The expression of these molecules is affected by the imflammatory response
- WBC migration controlled by chemotaxis
- Specific receptors on the leukocytes detect chemotactic agents, they also control the activation of leukocytes
- After localization of WBCs phagocytosis and the release of enzymes take place

3. CHRONIC INFLAMMATION

- Characterized by the presence of macrophages, monocytes, and lymphocytes
- Proliferation of blood vessels and connective tissue
- Could be either caused by the nature of the biomaterial or by motion in the implant
- Lymphocytes and plasma are related to the immune reaction

4. GRANULATION TISSUE

- Fibroblasts and vascular endothelial cells in the implant site proliferate and form granulation tissue “Granulation tissue from the pink soft granular appearance on the surface of healing tissue”. Seen 3-5 days after implantation

- Angiogenesis small blood vessel formation. Angiogenesis includes proliferation, maturation, and organization of endothelial cells
- At the beginning of the process proteoglycans dominate then type III collagen dominates

5. FOREIGN BODY REACTION

- Foreign body giant cells are formed by the fusion of monocytes and macrophages to phagocytose the material
- Composed of foreign body giant cells and components of granulation tissue.
- Reaction dependent on the form and topography of the implant
- Smooth surfaces have a reaction of one layer of macrophages one to two cells in thickness

6. FIBROSIS AND FIBROUS ENCAPSULATION

- Last response to biomaterials
- Repair of the implant site can be one of two: Regeneration:
  - ➢ replacement of the injured tissue with parenchymal cells of the same type
  - ➢ Replacement with fibrous capsule “Fibrous capsule: connective tissue”
- Dependent on:
  - ➢ Proliferative capacity of cells in the tissue (labile, stable/expanding, permanent/static)
  - ➢ Retention of the framework.

UNIT-III

2 MARKS:

1. **What are biopolymers?(Nov 2018, May 2017)**

- Biopolymers are natural polymers produced by the cells of living organisms.
- "Biopolymer" refers to polymers that occur in nature or are produced by biological action.
- Biopolymers consist of monomeric units that are covalently bonded to form larger molecules.
- Some of the examples are DNA, RNA, proteins, carbohydrates, etc.

2. **What is glass transition temperature?(Nov 2018, May 2017)**

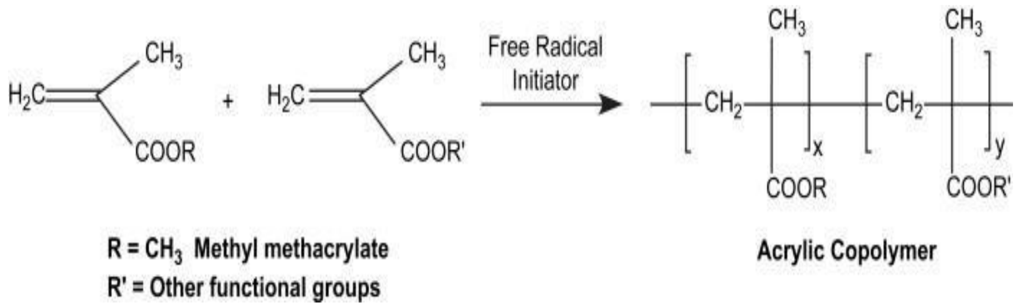
- The glass–liquid transition, or glass transition, is the gradual and reversible transition in amorphous materials from a hard and relatively brittle "glassy" state into a viscous or rubbery state as the temperature is increased.
- The glass-transition temperature T_g of a material characterizes the range of temperatures over which this glass transition occurs. It is always lower than the melting temperature, T_m, of the crystalline state of the material, if one exists.

3. **List few applications of rubber used in medical field?(Nov 2019)**

- Tubing
- Drains
- Feeding tubes
- Catheters
- Implants for long and short term use
- Seals and gaskets
- Syringe pistons
- Scar Treatment Silicone Sheets and gels.

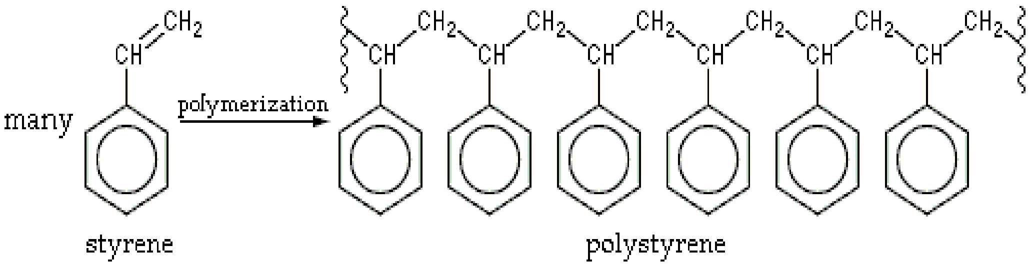
4. **Draw the structure of acrylic polymers?(Nov 2019, Nov 2017)**

Acrylic polymers containing hydroxyl groups are utilized in base coats as binders, which bind the pigments together, usually by a catalyzed cross-linking mechanism with a polyisocyanate hardener, providing a chip-resistant coating.



5. **What is polymerization & give example?(May 2019)**

❖ Polymerization is a process through which a large number of monomer molecules react together to form a polymer. The macromolecules produced may have a linear



or a branched structure.

❖ Polymerization is the chemical process of monomers joining together to form polymers, often it takes many thousands of monomers to make a single polymer.

❖ An example detailing the polymerization of the monomer styrene into the polymer known as polystyrene is provided.

6. **What is free radical polymerization?(May 2019)**

❖ Free-radical polymerization (FRP) is a method of polymerization, by which a polymer forms by the successive addition of free-radical building blocks. Free radicals can be formed by a number of different mechanisms, usually involving separate initiator molecules.

❖ Free-radical polymerization is a type of chain-growth polymerization, along with anionic, cationic and coordination polymerization.

7. **Give the classification of synthetic polymers with example.(Nov 2016)**

Synthetic polymers can be classified into four main categories:

❖ Thermoplastics-eg. Polystyrene

❖ Thermosets-eg. Polyester

❖ Elastomers-eg. Buna -s and Buna -s

❖ Synthetic fibers-eg. Nylon

8. Give the application of biodegradable polymers.(Nov 2016)

- Polymer system for gene therapy.
- Biodegradable polymer for ocular, tissue engineering, vascular, orthopedic, skin adhesive & surgical glues.
- Bio degradable drug system for therapeutic agents such as anti tumor, antipsychotic agent, anti-inflammatory agent.
- Many biomaterials, especially heart valve replacements and blood vessels, are made of polymers like Dacron, Teflon and polyurethane.

9. What are homo polymers? Give examples.(May 2018)

- A **homopolymer** is defined as a polymer that has the same monomer unit in the chain. It can be noted that polymerizations involving only one type of monomer are called homopolymerizations whereas those involving more than one type of monomer are called copolymerization processes.
- Examples of **homopolymer** are PVC with vinyl chloride units, polypropylene with propylene units, Polymethyl-methacrylate.

10. Give the medical application of high strength thermoplastics.(May 2018)

- Applications that require abrasion resistance, wear or a low friction coefficient, these engineering plastics offer superior performance when compounded with lubricants such as PTFE and graphite.
- Heat and shock resistant applications in the glass and aerospace industries.
- Sterilisation and hydrolysis proof parts for medical devices.
- Emission proof and radiation resistant components for vacuum technology and applications in the areas of X-ray technology and nuclear energy.
- Components for the chemical industry.

11. What are monomers?(nov 2017)

- Monomers are small molecules, mostly organic, that can join with other similar molecules to form very large molecules, or polymers. All monomers have the capacity to form chemical bonds to at least two other monomer molecules.
- Example: Glucose

11 MARKS:

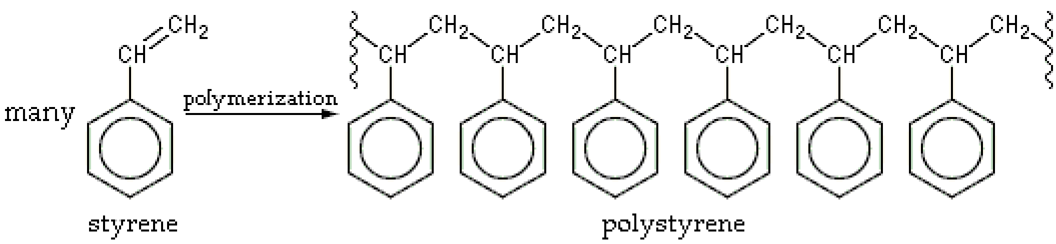
1. **Narrate in detail on different techniques used to produce polymers with advantages and disadvantages. (Nov 2018, May 2019, May 2017)**

Polymer

- A polymer is basically synthesized by joining small molecules or substances into a single giant molecule by a chemical process.
- Polymers are of two types: naturally occurring and synthetic or man made.
- Natural polymeric materials such as hemp, shellac, amber, wool, silk, and natural rubber have been used for centuries. A variety of other natural polymers exist, such as cellulose, which is the main constituent of wood and paper.
- The list of synthetic polymers, roughly in order of worldwide demand, includes polyethylene, polypropylene, polystyrene, polyvinyl chloride, synthetic rubber, phenol formaldehyde resin , neoprene, nylon, polyacrylonitrile, PVB, silicone, and many more.

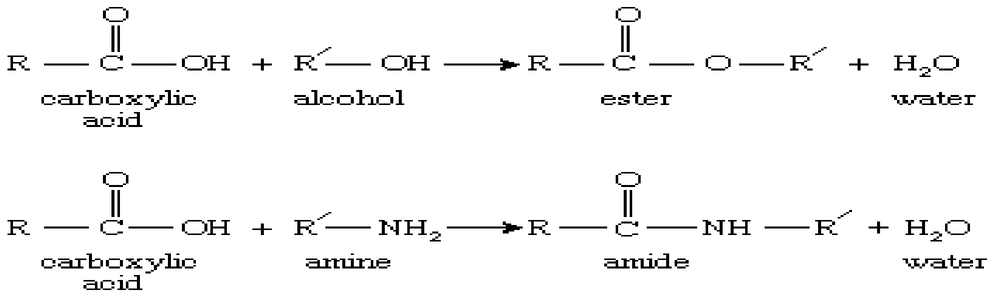
Polymerization

- Polymerization is a process through which a large number of monomer molecules react together to form a polymer.
- The macromolecules produced from a polymerization may have a linear or a branched structure.
- They can also assume the shape of a complex, three-dimensional network. There exist several different categories of polymerization reactions, the most notable of which being step-growth polymerization, chain-growth polymerization and condensation polymerization.



Step Growth Polymerization

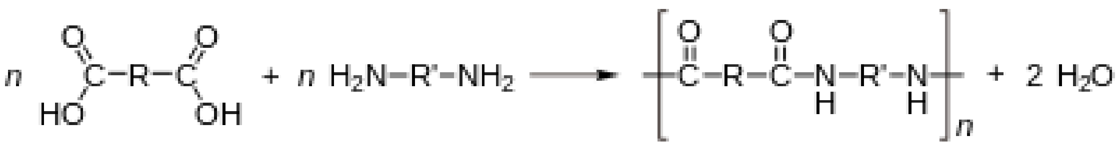
- In step-growth polymerization, the polymers are formed by the independent reaction between the functional groups of simple monomer units. In step-growth, each step may consist of a combination of two polymers having a different or same length to form a longer length molecule.



- The reaction is a lengthy process and the molecular mass is increased at a very slow rate. An example of step-growth polymerization is condensation polymerization where a water molecule is evolved in the reaction when the chain is lengthened.

Condensation Polymerization

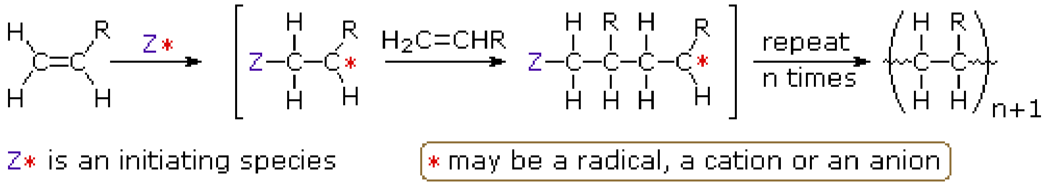
- In condensation polymerization, the formation of the polymer occurs when there is a loss of some small molecules as byproducts through the reaction where molecules are joined together. The byproducts formed may be water or hydrogen chloride. Polyamide and proteins are examples of condensation polymers.



Chain-growth polymerization

- All the monomers from which addition polymers are made are alkenes or functionally substituted alkenes. The most common and thermodynamically favored chemical transformations of alkenes are addition reactions.
- Many of these addition reactions are known to proceed in a stepwise fashion by way of reactive intermediates, and this is the mechanism followed by most polymerizations.
- A general diagram illustrating this assembly of linear macromolecules, which supports the name chain growth polymers, is presented here.
- Since a pi-bond in the monomer is converted to a sigma-bond in the polymer, the polymerization reaction is usually exothermic by 8 to 20 kcal/mol. Indeed, cases of

explosively uncontrolled polymerizations have been reported. It is useful to distinguish four polymerization procedures fitting this general description.



- ❖ Radical Polymerization The initiator is a radical, and the propagating site of reactivity (*) is a carbon radical.
- ❖ Cationic Polymerization The initiator is an acid, and the propagating site of reactivity (*) is a carbocation.
- ❖ Anionic Polymerization The initiator is a nucleophile, and the propagating site of reactivity (*) is a carbanion.
- ❖ Coordination Catalytic Polymerization The initiator is a transition metal complex, and the propagating site of reactivity (*) is a terminal catalytic complex.

2. Write a note on biopolymer. Explain in detail about polyamicles and acrylic with biomedical application.(Nov 2018, May 2017)

- ❖ Biopolymers are natural polymers produced by the cells of living organisms.
- ❖ “Biopolymer” refers to polymers that occur in nature or are produced by biological action.
- ❖ Biopolymers consist of monomeric units that are covalently bonded to form larger molecules.
- ❖ There are three main classes of biopolymers, classified according to the monomers used and the structure of the biopolymer formed: polynucleotides, polypeptides, and polysaccharides.
- ❖ Polynucleotides, such as RNA and DNA, are long polymers composed of 13 or more nucleotide monomers.
- ❖ Polypeptides and proteins, are polymers of amino acids and some major examples include collagen, actin, and fibrin.
- ❖ Polysaccharides are linear or branched polymeric carbohydrates and examples include starch, cellulose and alginate.
- ❖ Natural Polymers are those substances which are obtained naturally.

- These polymers are formed either by the process of addition polymerization or condensation polymerization.

Polyamide/polyamicles:

- **Polyamide**, any polymer (substance composed of long, multiple-unit molecules) in which the repeating units in the molecular chain are linked together by amide groups. Amide groups have the general chemical formula CO-NH.
- They may be produced by the interaction of an amine (NH_2) group and a carboxyl (CO_2H) group, or they may be formed by the polymerization of amino acids or amino-acid derivatives (whose molecules contain both amino and carboxyl groups).
- Broadly defined, the polyamides include proteins and peptides, which are naturally produced polymers consisting of amino-acid repeating units. (In molecular biology the amide linkage is usually referred to as the peptide bond.) More narrowly defined, the polyamides are an important group of industrially produced synthetic polymers.
- The most important is nylon, actually an extremely versatile class of polymers that are made into indispensable fibres and plastics.
- Another class of polyamides made into fibres is the so-called aramids, or aromatic polyamides—amide polymers that contain phenyl rings in their repeating units.
- Some nylons also contain phenyl rings, so the two classes are actually distinguished by the number and frequency of the rings. When 85 percent or more of the amide groups are linked directly to phenyl rings, the polyamide is classified as an aramid. When the rate is lower than 85 percent, the polymer is classified as a nylon.

Applications

- Polyamides (PA, nylon)PA 6 : $[NH-(CH2)5-CO]n$ made from ε-Caprolactamhigh degree of crystallinityinterchain hydrogen bonds provide superior mechanical strength (Kevlar fibers stronger than metals)plasticized by water, not good in physiological environmentUsed as sutures

Acrylics

- Acrylate polymers are a group of polymers prepared from acrylate monomers.
- These plastics are noted for their transparency, resistance to breakage, and elasticity.
- They are also commonly known as acrylics or polyacrylates.

- Acrylate polymer is commonly used in cosmetics, such as nail polish, as an adhesive.
- Materials having the ability to hold water within the voids of acrylic-based polymeric chain are special class materials used for biomedical applications in different therapeutic applications such as drug diffusivity, tissue engineering, gene delivery and pharmaceutical applications of various poly (acrylic acid) hydrogels and nanohydrogels.
- Acrylic polymers containing hydroxyl groups are utilized in base coats as binders, which bind the pigments together, usually by a catalyzed cross-linking mechanism with a polyisocyanate hardener, providing a chip-resistant coating.
- Acrylic, or more properly acrylate polymer, a group of polymers (plastics) noted for transparency and elasticity
- Acrylic resin, a group of related thermoplastic or thermosetting plastic substances.Acrylic fiber, a synthetic fiber of polyacrylonitrile
- Acrylic is a transparent plastic material with outstanding strength, stiffness, and optical clarity.
- Acrylic sheet is easy to fabricate, bonds well with adhesives and solvents, and is easy to thermoform.

Applications

- Acrylic-based polymers have many currently important biomedical applications such as contact lenses, corneal prosthesis, bone cements, tissue engineering, etc. due to their excellent biocompatibility and suitable performance in mechanical properties, among many other applications.
- the potential uses of these polymeric materials in the biomedical industry could be increased exponentially if some of their acrylic properties (mechanical strength, electrical and/or thermal properties, water sorption and diffusion, biological interactions, antibacterial activity, porosity, etc.) are enhanced.
- Thus, acrylics have been fabricated as multicomponent polymeric systems in the form of interpenetrated polymer networks or combined with other advanced materials such as fibers, nanofibers, graphene and its derivatives and/or many other kinds of nanoparticles to form composite or nanocomposite materials, which are expected to exhibit superior properties.

3. **Discuss about any four different types of polymers.(Nov 2019, Nov 2017)**

Elastomer :

- An **elastomer** is a polymer with viscoelasticity and with weak intermolecular forces, generally low Young's modulus and high failure strain compared with other materials
- Elastomers are amorphous polymers maintained above their glass transition temperature, so that considerable molecular reconformation, without breaking of covalent bonds, is feasible.
- Elastomers are usually thermosets but may also be thermoplastic. The long polymer chains cross-link during curing, i.e., vulcanizing.
- The elasticity is derived from the ability of the long chains to reconfigure themselves to distribute an applied stress. The covalent cross-linkages ensure that the elastomer will return to its original configuration when the stress is removed
- Elastomers that have cooled to a glassy or crystalline phase will have less mobile chains, and consequentially less elasticity, than those manipulated at temperatures higher than the glass transition temperature of the polymer.
- Example Styrene-butadiene rubber, Butyl rubber,etc.

Thermoplastic :

- A thermoplastic, or thermosoftening plastic, is a plastic polymer material that becomes pliable or moldable at a certain elevated temperature and solidifies upon cooling
- Thermoplastics differ from thermosetting polymers, which form irreversible chemical bonds during the curing process. Thermosets do not melt when heated, but typically decompose and do not reform upon cooling
- Above its glass transition temperature and below its melting point, the physical properties of a thermoplastic change drastically without an associated phase change. Some thermoplastics do not fully crystallize below the glass transition temperature, retaining some or all of their amorphous characteristics
- Amorphous and semi-amorphous plastics are used when high optical clarity is necessary, as light is scattered strongly by crystallites larger than its wavelength. Amorphous and semi-amorphous plastics are less resistant to chemical attack and environmental stress cracking because they lack a crystalline structure.

- Example:nylon,acrylic,etc.

Thermosetting polymer:

- A **thermosetting polymer, resin, or plastic**, often called a **thermoset**, is a polymer that is irreversibly hardened by curing from a soft solid or viscous liquid prepolymer or resin.
- Curing results in chemical reactions that create extensive cross-linking between polymer chains to produce an infusible and insoluble polymer network.
- The starting material for making thermosets is usually malleable or liquid prior to curing, and is often designed to be molded into the final shape. It may also be used as an adhesive.
- Once hardened, a thermoset cannot be melted for reshaping, in contrast to thermoplastic polymers which are commonly produced and distributed in the form of pellets, and shaped into the final product form by melting, pressing, or injection molding.
- Example : Bakelite,resin etc.

Fiber

- **Fiber** or **fibre** is a natural or man-made substance that is significantly longer than it is wide. Fibers are often used in the manufacture of other materials. The strongest engineering materials often incorporate fibers, for example carbon fiber and ultra-high-molecular-weight polyethylene.
- Synthetic fibers can often be produced very cheaply and in large amounts compared to natural fibers, but for clothing natural fibers can give some benefits, such as comfort, over their synthetic counterparts.
- Example : rayon,polyamide,etc.

4. Write notes on (Nov 2019, Nov 2017)

a) High strength thermoplastics

b) Silicone Rubber

HIGH STRENTH THERMOPLASTICS

- High-performance plastics are plastics that meet higher requirements than standard or engineering plastics.
- They are more expensive and used in smaller amounts.

- ❖ High performance plastics differ from standard plastics and engineering plastics primarily by their temperature stability, but also by their chemical resistance and mechanical properties, production quantity, and price.
- ❖ There are many synonyms for the term high-performance plastics, such as: high temperature plastics, high-performance polymers, high performance thermoplastics or high-tech plastics.
- ❖ The name high temperature plastics is in use due to their continuous service temperature (CST), which is always higher than 150 °C.
- ❖ The term "polymers" is often used instead of "plastics" because both terms are used as synonyms in the field of engineering.
- ❖ If the term "high-performance thermoplastics" is used, it is because both standard and technical as well as high-performance plastics are always thermoplastics.
- ❖ Thermosets and elastomers are outside of this classification and form their own classes.
- ❖ It is this material class that brings the superior properties of polymers - such as sliding friction characteristics, weight saving and chemical resistance - to bear, especially, a high permanent operating temperatures.

RUBBER

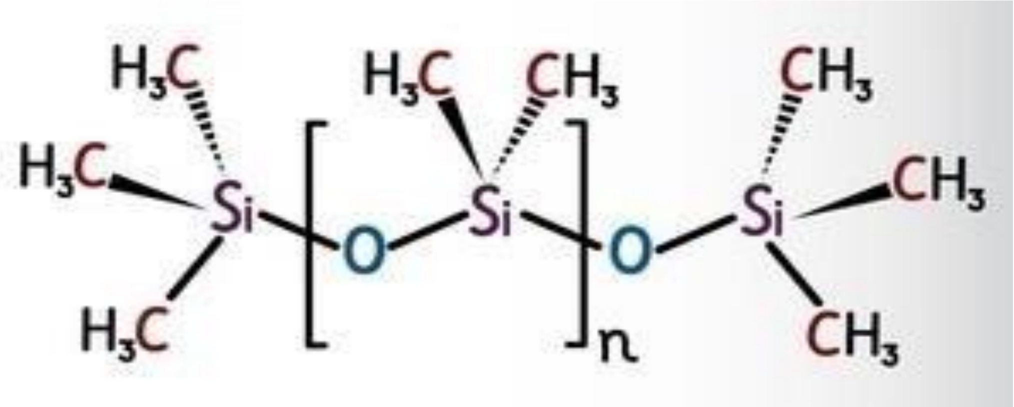
- ❖ Biomaterials are materials which are used to replace a part or a function of the body in safe, reliable, economical and physiologically acceptable manner.
- ❖ Polymers are used as biomaterial for a long time due to its light weight and biocompatibility.
- ❖ Natural and synthetic rubber are mainly used because of their inertness and bicompatible nature.
- ❖ Silicone rubber are widely used and natural rubber as of yet found limited applications.

Natural, silicone and polyurethane rubbers are considered as three important biomaterials which have found widespread applications in medical technology.

SILICONE RUBBER:

- ❖ Silicone rubber is a durable & highly-resistant elastomer (rubber-like material) composed of silicone (polymer) containing silicon together with other molecule like carbon, hydrogen and oxygen.

- ❖ Its structure always comprises siloxane backbone (silicon-oxygen chain) and an organic moiety bound to the silicon.
- ❖ Hence, the properties of silicone rubber can vary greatly depending on the:
  1. Organic groups (methyl, vinyl, phenyl, trifluoropropyl or other groups)
  2. Chemical structure
- ❖ As compared to organic rubber, silicone rubber has Si-O bond in its structure, and hence, it has better:
  1. Heat resistance
  2. Chemical stability
  3. Electrical insulation
  4. Abrasion resistance
  5. Weatherability as well as Ozone resistance
- ❖ Silicone rubbers can withstand temperature ranging from -50°C to 350°C (depends in duration of exposure).
- ❖ Parts made of silicone rubber when exposed to wind, rain and UV rays for long periods result in virtually no change in physical properties.
- ❖ Unlike most organic rubbers, silicone rubber is not affected by ozone as well.
- ❖ Silicone Rubber's special features, are hence, originated from its unique molecular structure that they can carry both inorganic and organic properties.
- ❖ Overall silicone rubbers are used various applications as elastomers, adhesives & sealants, potting, and encapsulating compounds as well as in coatings, lubricants etc.



- ❖ Silicone rubbers are classified as:
  1. Methyl Group
  2. Methyl and Phenyl Groups.
  3. Methyl and Vinyl Groups

4. Methyl, Phenyl and Vinyl Groups
5. Fluoro, Vinyl and Methyl Groups

- Apart from its molecular structure, another factor for classifying silicone rubber are viscosity and method employed for their processing. Silicone rubber is available in three main forms:
  1. **Solid Silicone Rubber or High Temperature Vulcanized, HTV**
  2. **Liquid Silicone Rubber, LSR**
  3. **Room Temperature Vulcanized, RTV**

APPLICATIONS OF SILICONE RUBBER:

- Tubing
- Drains
- Feeding tubes
- Catheters
- Implants for long and short term use
- Seals and gaskets
- Syringe pistons & Respiratory masks
- Scar Treatment Silicone Sheets and gels.

5. Write in detail about polyamide and its applications. (May 2019)

- **Polyamide**, any polymer (substance composed of long, multiple-unit molecules) in which the repeating units in the molecular chain are linked together by amide groups. Amide groups have the general chemical formula CO-NH.
- They may be produced by the interaction of an amine (NH_2) group and a carboxyl (CO_2H) group, or they may be formed by the polymerization of amino acids or amino-acid derivatives (whose molecules contain both amino and carboxyl groups).
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- The most important is nylon, actually an extremely versatile class of polymers that are made into indispensable fibres and plastics.

- Another class of polyamides made into fibres is the so-called aramids, or aromatic polyamides—amide polymers that contain phenyl rings in their repeating units.

1. **ARAMIDS:**

- Aramid fibers are a class of heat-resistant and strong synthetic fibers. They are used in aerospace and military applications, for ballistic-rated body armor fabric and ballistic composites, in marine cordage, marine hull reinforcement, and as an asbestos substitute. The name is a blend of "aromatic polyamide".
- The chain molecules in the fibers are highly oriented along the fiber axis. As a result, a higher proportion of the chemical bond contributes more to fiber strength than in many other synthetic fibers. Aramides have a very high melting point (>500 °C).
- Common aramid brand names include Kevlar, Nomex, and Twaron.
    - Appearances
    - Fiber
    - Chopped fiber
    - Powder
    - Pulp

Aramid

- good resistance to abrasion
- good resistance to organic solvents & nonconductive
- very high melting point (>500 °C) &low flammability
- good fabric integrity at elevated temperatures
- sensitive to acids and salts &sensitive to ultraviolet radiation
- prone to electrostatic charge build-up unless finished
- high tenacity & low creep

Uses

- flame-resistant clothing
- heat-protective clothing and helmets
- body armor
- composite materials
- mechanical rubber goods reinforcement

- ❖ fiber-reinforced concrete
- ❖ reinforced thermoplastic pipes
- ❖ Asphalt reinforcement

2. KEVLAR:

- ❖ Kevlar is a heat-resistant and strong synthetic fiber, related to other aramids such as Nomex and Technora.
- ❖ Kevlar has many applications, ranging from bicycle tires and racing sails to bulletproof vests, because of its high tensile strength-to-weight ratio; by this measure it is five times stronger than steel.
- ❖ It also is used to make modern marching drumheads that withstand high impact. It is used for mooring lines and other underwater applications.
- ❖ Kevlar is synthesized in solution from the monomers 1,4-phenylene-diamine (para-phenylenediamine) and terephthaloyl chloride in a condensation reaction yielding hydrochloric acid as a byproduct.
- ❖ The result has liquid-crystalline behavior, and mechanical drawing orients the polymer chains in the fiber's direction.

APPLICATIONS OF KEVLAR:

Cryogenics

Kevlar is often used in the field of cryogenics for its low thermal conductivity and high strength relative to other materials for suspension purposes.

Armor

Kevlar is a well-known component of personal armor such as combat helmets, ballistic face masks, and ballistic vests..

Personal protection

Kevlar is used to manufacture gloves, sleeves, jackets, chaps and other articles of clothing] designed to protect users from cuts, abrasions and heat.

6. **Explain the biodegradation properties of biodegradable polymers.(Nov 2016).**
    - ❖ Biodegradable polymers are a special class of polymer that breaks down after its intended purpose by bacterial decomposition process to result in natural byproducts such as gases (CO2, N2), water, biomass, and inorganic salts.
    - ❖ In order for a biodegradable polymer to be used as a therapeutic, it must meet several criteria:

1) be non-toxic in order to eliminate foreign body response;

2) the time it takes for the polymer to degrade is proportional to the time required for therapy;

3) the products resulting from biodegredation are not cytotoxic and are readily eliminated from the body;

4) the material must be easily processed in order to tailor the mechanical properties for the required task;

5) be easily sterilized & have acceptable shelf life.

- The biodegradable polymers are polyglycolide, polylactide, polyhydroxobutyrae, hyaluronic acid, and hydrogels.
- Polyglycolide or poly(glycolic acid) (PGA), also spelled as polyglycolic acid, is a biodegradable, thermoplastic polymer and the simplest linear, aliphatic polyester.
- It can be prepared starting from glycolic acid by means of polycondensation or ring-opening polymerization.
- Currently polyglycolide and its copolymers are widely used as a material for the synthesis of absorbable sutures and are being evaluated in the biomedical field.
- It has the advantages of high initial tensile strength, smooth passage through tissue, easy handling, excellent knotting ability, and secure knot tying.
- It is commonly used for subcutaneous sutures, intracutaneous closures, abdominal and thoracic surgeries.
- Polylactic acid, or polylactide (PLA) is a thermoplastic polyester formally obtained by condensation of lactic acid with loss of water.
- It can also be prepared by ring-opening polymerization of lactide , the cyclic dimer of the basic repeating unit.
- PLA can degrade into innocuous lactic acid, so it is used as medical implants in the form of anchors, screws, plates, pins, rods, and as a mesh.
- This gradual degradation is desirable for a support structure, because it gradually transfers the load to the body as that area heals.
- HYALURONIC ACID'S chemical structure is based on two disaccharide units polymerized into large macromolecules of up to 30,000 repeating units.
- HA is biodegradable, biocompatible, nontoxic, nonthrombogenic, nonimmunogenic, and noninflammatory.

- Hyaluronic acid (HA) has been widely used for viscosupplementation of diseased or aged articular joints
- Hyaluronic acid-based conjugates could solve the solubility problems, improve a drug's blood plasma half-life, and form viscoelastic hydrogels.
- Hydrogels can be classified into two categories based on their origins, including synthetic polymers and natural polymers.
- In comparison to synthetic hydrogels, natural hydrogels are more safe, and also possess good biocompatibility and biodegradability.
- Hydrogels are mainly formed from biopolymers and/or polyelectrolytes.
- Hydrogels can be obtained by radiation technique in a few ways, including irradiation of solid polymer, monomer (in bulk or in solution), or aqueous solution of polymer.
- Hydrogels are used for manufacturing contact lenses, hygiene products, tissue engineering scaffolds, drug delivery systems and wound dressings.

Biodegradation property:

- **Biodegradation** is the **property** of a material that can be completely converted into water, CO_2, and biomass through the action of microorganisms such as fungi and bacteria. **Biodegradable** plastics have the ability to be degraded by microorganisms present in the environment by entering the microbial food chain.
- Biodegradable polymers have numerous applications, there are properties that tend to be common among them. All biodegradable polymers should be stable and durable enough for use in their particular application, but upon disposal they should easily break down.
- Polymers, specifically biodegradable polymers, have extremely strong carbon backbones that are difficult to break, such that degradation often starts from the end-groups. Since the degradation begins at the end, a high surface area is common as it allows easy access for either the chemical, light, or organism.
- Crystallinity is often low as it also inhibits access to end groups. A low degree of polymerization is normally seen, as hinted at above, as doing so allows for more accessible end groups for reaction with the degradation initiator. Another commonality of these polymers is their hydrophillicity.

- Hydrophobic polymers and end groups will prevent an enzyme from easily interacting if the water-soluble enzyme cannot easily get in contact with the polymer.
- Other properties of biodegradable polymers that are common among those used for medicinal usages include being:
  1. non-toxic
  2. capable of maintaining good mechanical integrity until degraded
  3. capable of controlled rates of degradation
- These are important as biodegradable polymers are used for drug delivery where it is critical to slowly release the drug into the body over time instead of all at once and that the pill is stable in the bottle until ready to be taken.
- Factors controlling the rate of degradation include percent crystallinity, molecular weight, and hydrophobicity. The degradation rate depends on the location in the body, which influences the environment surrounding the polymer such as pH, enzymes concentration, and amount of water, among others. These are rapidly decomposed.

7. Explain about the advantages, disadvantages and application of polyamides, polyethylene and polyacrylates. (Nov 2016,May 2018)

1) POLYETHYLENE

- **Polyethylene** is one of the most widely used thermoplastic and its ever increasing demand is due to availability of monomer ethylene from naphtha and Gas cracker plant.
- First polyethylene plant in India was based on ethylene from molasses. Some of the other deriving force for fast growth and use of polyethylene are ease of processing the polymer, its relative cost, resistance to chemicals and its flexibility.
- A wide variety of polyethylene varying intensity and characteristics for wide range of application is available.

Advantages of polyethylene:

- Polyethylene has many useful properties which make it suitable for several applications. It has low strength and hardness, but is very ductile and has good impact strength; it will stretch rather than break.

- Polyethylene is water resistant and durable, so it is longer lasting when exposed to the elements compared to other polymers.

Disadvantages of polyethylene:

- The polymer, like many other plastics, takes a long time to break down, and as such can end up in landfill sites for decades, which we are running out of space for.
- Another way to dispose of polyethylene is incineration, which can result in harmful gas emissions.
- Polyethylene is mainly extracted from petroleum or natural gas, of which there is a finite amount.

2)POLYAMIDES

- **Polyamide**, any polymer (substance composed of long, multiple-unit molecules) in which the repeating units in the molecular chain are linked together by amide groups. Amide groups have the general chemical formula CO-NH.
- They may be produced by the interaction of an amine (NH_2) group and a carboxyl (CO_2H) group, or they may be formed by the polymerization of amino acids or amino-acid derivatives (whose molecules contain both amino and carboxyl groups).

Advantages of polyamides:

- High Abrasion Resistance – Higher levels of resistance to wear by mechanical action
- Good Thermal Resistance – Special grades of nylon can have a melting point of almost 300°C
- Good Fatigue Resistance – This makes it ideal for components in constant cyclic motion like gears
- High Machineability – Cast billets can be machined into various components that would be too costly to cast into intricate shapes
- Noise Dampening – Nylon is a very effective noise dampener

Disadvantages of polyamides:

- Water Absorption – Water absorbed results in lower mechanical properties. Nylon 6/12 is specially formulated to resist moisture absorption
- Chemical Resistance – Nylon has low resistance to strong bases and acids
- High Shrinkage – High percentages of shrinkage in cast applications

- The table below indicates some of the main nylon grades used in industry.

Applications of polyamides:

Polyamides (PA, nylon)PA 6 : [NH−(CH2)5−CO]n made from ε-Caprolactamhigh degree of crystallinityinterchain hydrogen bonds provide superior mechanical strength (Kevlar fibers stronger than metals)plasticized by water not good in physiological environment. Used as sutures.

3) POLYACYLICS:

- Acrylate polymers are a group of polymers prepared from acrylate monomers.
- These plastics are noted for their transparency, resistance to breakage, and elasticity.
- They are also commonly known as acrylics or polyacrylates.

Advantages of polyacylics:

- Excellent optical clarity
- Excellent weatherability and resistance to sunlight
- Rigid, with good impact strength
- Excellent dimensional stability and low mould shrinkage
- Stretch forming increases bi-axial toughness

Disadvantages of polyacylics:

- Poor solvent resistance; attacked especially by ketones, esters, chlorocarbons and aromatic hydrocarbons, freons
- Subject to stress cracking
- Combustible
- Continuous service temperature limited to about 200 F degrees
- Flexible grades unavailable

Applications of polyacylics:

- Major applications are coatings, paints, textiles, leather finishing, automotive products, tape adhesives, and oil-resistant and high-temperature-resistant elastomers.
- They are also used as comonomers to increase the plasticity of rigid and brittle plastics.

- Besides paints, inks, and coatings, acrylics are used in pressure sensitive adhesive formulations. They can be formulated with a large variety of adhesion properties, from low adhesion (barely tacky) to very high tack that bond permanently to surfaces.
- Acrylic-based polymers have many currently important biomedical applications such as contact lenses, corneal prosthesis, bone cements, tissue engineering, etc. due to their excellent biocompatibility and suitable performance in mechanical properties, among many other applications.

8. Describe the following polymers with their properties and their specific applications(May 2018)

a) Polyoefin

Polyoefin

- Polyolefinsis family of polymers derived from a particular group of base materials known as olefins, are the world's fastest growing polymer family.
- Polyolefins such as polyethylene (PE) and polypropylene (PP) are commodity plastics found in applications varying from house hold items such as grocery bags, containers, carpets, toys and appliances, to high tech products such as engineering plastics, industrial pipes, automotive parts, medial appliances and even prosthetic implants.

Physical and mechanical properties

- Polyolefins are milky white in appearance and waxy to the touch. Polyolefins are opaque when thick and transparent when in the form of film. Although often used as a container or as packing, polyolefins are not completely impervious to water, air or hydrocarbons, but this implies the notion of time and amount of loss tolerated.
- At ambient temperature (23°C), PE and PP, partially crystalline, are above their vitreous transition temperature, thus their uncrystallized phase is rubbery. The vitreous transition temperature of PP is very close to ambient temperature. PEbd is, at ambient temperature, more sensitive to creep than PEhd and PP.

Chemical properties

- Polyolefins have very good chemical stability. At temperatures below 60°C, they are practically insoluble. They are attacked neither by acids nor bases, nor salt solutions. They are insoluble in water and even have little affinity for water.

- Polyolefins are, in their natural state, very sensitive to the action of ultraviolet rays (UV) in the presence of oxygen (air), but there are effective photo-stabilizers, as for example black carbon, the ultimate use of a black dye.

Electrical properties

- Polyolefins are excellent electrical insulators for various ambient conditions. This explains their tendency to be electrostatic. They have a very high resistivity and a high dielectric strength.
- The low dielectric loss factor (tan δ) that represents the energy lost, converted to heat in the dielectric, prohibits high-frequency welding.

Thermal properties

- PE and PP burn, even when the igniting flame is no longer present, with a bluish flame and they "drip". In incomplete combustion (fire), carbon monoxide and small quantities of hydrocarbon are formed.
- Polyolefins are, in general, rated HB by UL94, but some flame-retardant grades of PP can be V0 or V2..

Dimensional properties

Stability is independent of the ingress of humidity (low < 0.2 %) (little affinity for water). These highly-crystalline polymers thus undergo extensive retraction when molded.

Printing and marking properties

- Polyolefins have a surface on which adhesion is difficult. However, each manufacturer provides solutions and a surface preparation for printing, painting, marking, and even vacuum-system metallization.
- Polyolefins are pleasant to the touch. Certain grades of copolymer are specially provided for "pleasant contact" applications
- Implementation properties
- Polyolefins are very difficult to glue together. It is necessary to carry out a flame-type surface preparation or chemical attack. Infrared, contact, ultrasonic or hot-air welding is no problem.
- Induction welding is not applicable directly as the energy spreading through the material is insufficient for heating it. This drawback can be corrected by embedding a metal insert in the material. Heating of this metal in the plane of the joint will melt the polyolefin to be welded.

Unit IV

2 Marks

1. What is adhesive? Give its applications. (Nov 2018)

- Surgical glue -also called “tissue adhesive” or "liquid stitches" to close both major and minor wounds, such as lacerations, incisions made during laparoscopic surgery, and wounds on the face or in the groin.
- Benefits of surgical glue include:
    - Lower rates of infection
    - Less time in the operating room
    - Less scarring
- Five main types of adhesives or sealants are available for surgeons to use, including:
    - Fibrin sealants;
    - Cyanoacrylates

2. What are the biomedical applications of surgical tapes?(Nov 2018)

- When used with implantable staples, surgical staplers may be used in gastrointestinal, gynecologic, thoracic, and many other surgeries. Examples of these uses include:
- Removing part of an organ (resection)
- Cutting through organs and tissues (transection)
- Creating connections between structures (anastomoses)

3. How are suture materials are classified?(Nov 2019)

- Broadly, sutures can be classified into absorbable or non-absorbable materials. They can be further classified: synthetic or natural sutures, monofilament or multifilament sutures.
- The ideal suture is the smallest possible to produce uniform tensile strength, securely hold the wound for the required time for healing, then be absorbed. It should be predictable, easy to handle, produce minimal reaction, and knot securely.

4. List few blood interfacing implants.(Nov 2017, Nov 2019)

- Heat valves.
- Blood vessel implants.
- Total artificial hearts(TAH).
- Cardiovascular assisted devices and grafts.

5. Name two suture materials. List the different wound dressing materials.(May 2019)

Nylon. A natural monofilament suture.

- Polypropylene (Prolene). A synthetic monofilament suture.
- Silk. A braided natural suture.
- Polyester (Ethibond). A braided synthetic suture.

Wound Dressing Materials

- Gauze Dressings. Gauze dressings are made of woven or non-woven materials and come in a wide variety of shapes and sizes.
- Transparent Films.
- Hydrocolloids.
- Alginates.
- Composites.

6. State the conditions at which biodegradability increases.(May 2019)

- Biodegradation is the decay or breakdown of materials that occurs, when microorganisms use an organic substance as a source of carbon and energy.
- Biodegradation can occur under aerobic conditions, where oxygen is the electron acceptor, and under anaerobic conditions, where nitrate, sulfate, or another compound is the electron acceptor.

7. Point out the factors to be considered for skin substitute.(Nov 2016)

- Over the past two decades, bioengineered skin substitutes have become a mainstream therapy for wound management.
- Originally designed to replace skin grafts for patients with severe burns, they are now also used in the treatment of chronic venous and chronic diabetic ulcers.
- It is likely that applications for these products will broaden as they become more advanced. The ideal skin substitute would:
    - Adhere to the wound bed rapidly
    - Be inexpensive
    - Avoid immune rejection by the host

8. Give some examples of absorbable synthetic sutures.(Nov 2016)

Absorbable suture materials include the original catgut as well as the newer synthetics polyglycolic acid, polyactic acid, polydioxanone, and caprolactone.

9. What are the minimum requirements for soft tissue implants?(May 2016)

- Exhibit physical properties (flexibility and texture) which are equivalent or comparable to those called for in the product profile.

- Maintain the expected physical properties after implantation for a specific period.
- Elicit no adverse tissue reaction
- Display no carcinogenic, toxic, allergenic, and or immunogenic effect Achieve assured sterility without compromising the physiochemical properties.

10. List out types of total joint replacement.(May 2016)

JOINT	TYPES
Hip	Ball and socket
Knee	Hinged,semiconstrained,surface replacement. Unicompartment or bicompartment
Shoulder	Ball and socket
Ankle	Surface replacement
Elbow	Hinged,semiconstrained,surface replacement.
Wrist	Ball and socket, space filler
Finger	Hinged, space filler

11.What is surgical tape?(Nov 2017)

- **Surgical tape** or **medical tape** is a type of pressure-sensitive adhesive tape used in medicine and first aid to hold a bandage or other dressing onto a wound.
- These tapes usually have a hypoallergic adhesive which is designed to hold firmly onto skin, dressing materials, and underlying layers of tape, but to remove easily without damaging the skin. They allow air to reach the skin ("breathable").
- Some breathable tapes such as kinesiology tape, and other elastic bandages with adhesive are made of cotton. Surgical tape is often white because it contains zinc oxide, which is added to help prevent infections. Tapes made of porous material, such as 3M Micropore, are widely used.

11 Marks

1. Explain in detail about different materials used in suture and advantages and disadvantages.(May 2017, May 2018, Nov 2018)

- Sutures, commonly called stitches, are sterile surgical threads that are used to repair cuts (lacerations). They also are used to close incisions from surgery. Some wounds are closed with metal staples instead of sutures.

- Sutures may be used to close surface wounds or deep wounds. Surgical suture materials are used in the closure of most wound types.

CLASSIFICATION OF SUTURE MATERIAL:

- Broadly, sutures can be classified into absorbable or non-absorbable materials. They can be further classified: synthetic or natural sutures,
  and monofilament or multifilament sutures.
- The ideal suture is the smallest possible to produce uniform tensile strength, securely hold the wound for the required time for healing, then be absorbed. It should be predictable, easy to handle, produce minimal reaction, and knot securely.

ABSORBABLE SUTURES:

- Absorbable sutures are broken down by the body via enzymatic reactions or hydrolysis. The time in which this absorption takes place varies between material, location of suture, and patient factors.
- Absorbable sutures are commonly used for deep tissues and tissues that heal rapidly; as a result, they may be used in small bowel anastomosis, suturing in the urinary or biliary tracts, or tying off small vessels near the skin.

NON ABSORBABLE SUTURES:

- Non-absorbable sutures are used to provide long-term tissue support, remaining walled-off by the body’s inflammatory processes (until removed manually if required).
- Uses include for tissues that heal slowly, such as fascia or tendons, closure of abdominal wall, or vascular anastomoses.

NATURAL VS SYNTHETIC SUTURES:

Suture materials can be further categorised by their raw origin:

- Natural – made of natural fibres (e.g. silk or catgut). They are less frequently used, as they tend to provoke a greater tissue reaction.
- Synthetic – comprised of man-made materials (e.g. PDS or nylon). They tend to be more predictable than the natural sutures, particularly in their loss of tensile strength and absorption.

MONOFILAMENT VS MULTIFILAMENT SUTURES:

Suture materials can also be sub-classified by their structure:

- Monofilament suture – a single stranded filament suture (e.g nylon, PDS*, or prolene). They have a lower infection risk but also have a poor knot security and ease of handling.

- Multifilament suture – made of several filaments that are twisted together (e.g braided silk or vicryl). They handle easier and hold their shape for good knot security, yet can harbour infections.

SUTURE TYPES AND INDICATIONS:

- Nylon - Securing drains to the skin
- Silk - Repairing sutures for blood vessels, Achilles tendon repair
- Prolene - Vessel graft sutures for AAA, Femoral-Popliteal graft, or Carotid Artery grafts

2. How to choose the suitable materials for skin implant?Explain what are the materials used in skin implant?(May 2017, Nov 2018)

- Tissue-engineered skin needs to:

(a) provide a barrier layer of renewable keratinocytes (the cells that form the upper barrier layer of our skin), which is

(b) securely attached to the underlying dermis,

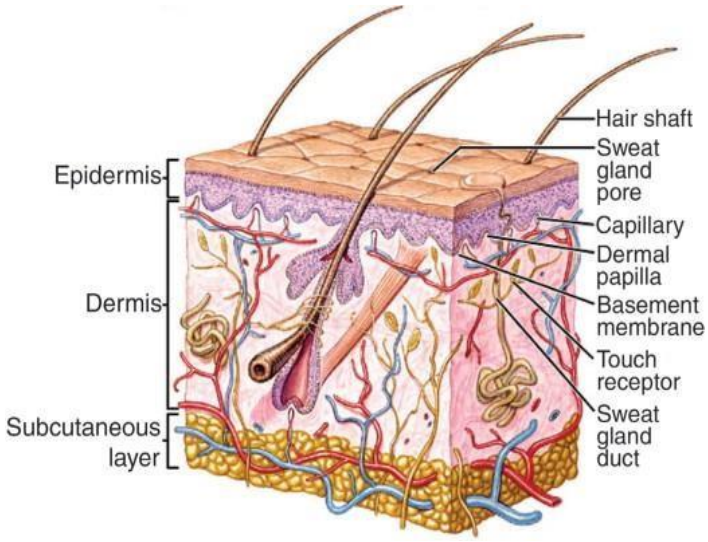
(c) provides an elastic structural support for skin.

- Skin physiology includes:

(a) spanning skin development and stem cells,

(b)skin pigmentation,

(c) sensory transduction.



- The integration of biomaterials with skin is necessary to enable infection-free access to vasculature and body cavities.
- Also, integrating plastics and metals with skin increases options for the reconstruction of surgical and traumatic defects and enables the permanent implantation of robotic

and electronic devices.

CHOICE OF MATERIALS:

- The choice of material depends on the anticipated use.
- Metal biomaterials consisting of iron, cobalt, tantalum and titanium are used extensively as surgical implant devices.
- Titanium and tantalum, have excellent mechanical properties and consequently are commonly chosen for implantation where structural strength is required (e.g. joint replacements).
- Favourable mechanical and surface chemistry properties make these metals ideal choices for skin implantation.

SURFACE FUNCTIONALIZATION:

Chemical methods of surface functionalization include

- **Self-assembled monolayers**: Single layers of phosphate groups can be bound covalently to metal oxide surfaces, such as titanium dioxide (TiO_2), niobium oxide (Nb_2O_5).
- **Polymer adlayers**: Polymers can be bonded to substrates through their vinyl ether side functional groups. The bound polymers can then be functionalized in additional steps.
- **Chemical vapour deposition:** Surfaces are exposed to volatile precursors that react on the substrate. This process is used to create artificial diamonds.
- **Silanization:** Many of the techniques to functionalize surfaces for protein binding use chemicals known as 'silanes'. Silanes are silicon analogues of alkanes.
- **Nanotechnology:** Nanotechnology involves the creation and use of materials 100 nm or smaller.The ability to create larger molecules, ''supramolecular assemblies'', is close.

CHARACTERISTICS OF MATERIALS:

Metals:

- In order to achieve the mechanical and biophysical properties desired for applications in medicine, combinations of metals (alloys) have been developed.
- These alloys are designed to be inert and withstand the corrosive environment within the human body.
- Since metals cannot repair themselves after deformation or fatigue, they must have mechanical properties that exceed the properties of the natural tissue they are

supporting or replacing.

Stainless steel:

- It has been used as a biological implant since the 1920s.
- Medical-grade stainless steel, alloys of iron–chromium–nickel, have a relatively high tensile strength but are easily deformed (bent).
- Historically, **cobalt–chromium alloys** have been one of the most significant biomaterials used in humans.
- The major disadvantage of Co-Cr-Mo alloys is the scatter artifact on computed tomography (CT) imaging.
- Because of this, and other benefits, titanium has essentially replaced Co-Cr-Mo alloys in most biomedical applications.Although gold is chemically inert, it has poor mechanical properties in its pure form.
- Platinum is an inert metal and is the material of choice for patients with gold sensitivity in need of eyelid implants for lagophthalmos.
- Polymers are molecules composed of repeating monomer subunits.
- Polytetrafluoroethylene (PTFE) also known as Teflon was accidentally invented by Roy Plunkett in 1938 while he was trying to develop a refrigerant.

IDEAL SKIN SUBSTITUTE:

Over the past two decades, bioengineered skin substitutes have become a mainstream therapy for wound management. The ideal skin substitute would:

- Adhere to the wound bed rapidly
- Recapitulate the physiologic and mechanical properties of normal skin
- Be inexpensive
- Avoid immune rejection by the host

3. **a. Write in detail about the soft tissue replacements.(Nov 2016, Nov 2017)**
   b. Explain schematically the various type of hip and knee joint replacements.(Nov 2017)
   c. Describe the biomaterials used, design and applications of joint replacement.(May 2018, Nov 2016)

Hip Joint Replacement:

- The prosthesis for total hip replacement consists of a femoral component and an acetabular component. The femoral stem is divided into head, neck, and shaft.
- The femoral stem is made of Ti alloy or CoCr alloy (316L stainless steel was used

earlier) and is fixed into a reamed medullary canal by cementation or press fitting.

- The femoral head is made of CoCr alloy, alumina, or zirionia.
- The acetabular component is generally made of ultra-high molecular weight polyethylene (UHMWPE).
- The prostheses can be monolithic when they consist of one part, or modular when they consist of two or more parts and require assembly during surgery.
- Monolithic components are often less expensive, and less prone to corrosion or disassembly.
- When the acetabular component is monolithic, it is made of UHMWPE when it is modular, it consists of a metallic shell and a UHMWPE insert.
- The metallic shell seeks to decrease the microdeformation of the UHMWPE and to provide a porous surface for fixation of the cup.
- Dislodgment of the insert results in dislocation of the hip and damage of the femoral head, since it contacts the metallic shell directly.
- The hip joint is a ball-and-socket joint, which derives its stability from congruity of the implants, pelvic muscles, and capsule.
- The prosthetic hip components are optimized to provide a wide range of motion without impingement of the neck of the prosthesis on the rim of the acetabular cup to prevent dislocation.
- The design characteristics must enable implants to support loads that may reach more than eight times body weight.
- Cells from the immune system of the host, for example, macrophages, are able to identify the polyethylene particles as foreign and initiate a complex inflammatory response.
- Numerous efforts are underway to modify the material properties of articulating materials to harden and improve the surface finish of the femoral head.

Knee Joint Replacements:

- The prosthesis for total knee joint replacement consists of femoral, tibial, and patellar components.
- Compared to the hip joint, the knee joint has a more complicated geometry and movement biomechanics, and it is not intrinsically stable.
- In a normal knee, the center of movement is controlled by the geometry of the ligaments. As the knee moves, the ligaments rotate on their bony attachments and the

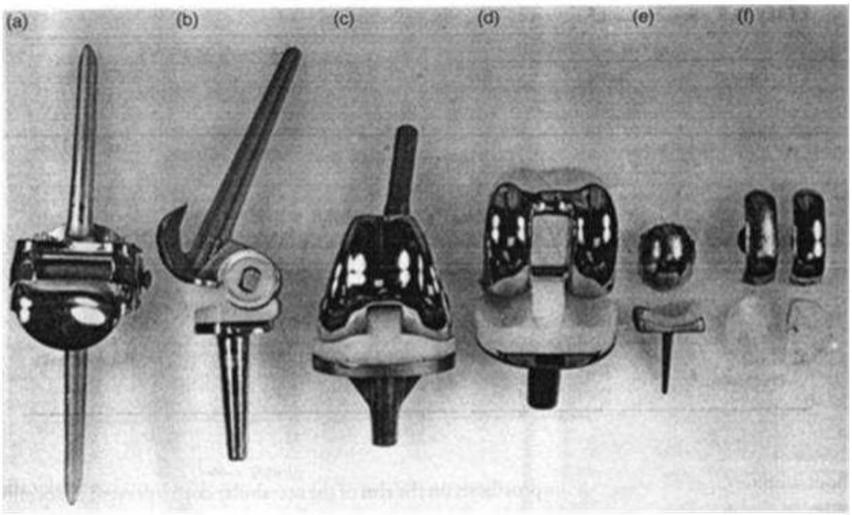
center of movement also moves.

The prostheses for total knee replacement can he divided according to the extent to which they rely on the ligaments for stability:

(1) Constraint: These implants have a hinge articulation, with a fixed axis of rotation, and are indicated when all of the ligaments are absent, for example in reconstructive procedures for tumoral surgery.

(2) Semi-constrained: These implants control posterior Semi-constrained prostheses are often used in patients with severe angular deformities of the extremities, or in those that require revision surgery, when moderate ligamentous instability has developed.

(3) Non-constrained: These implants provide minimal or no constraint. The prosthesis that provides minimal constraint requires resection of the posterior cruciate ligament during implantation, and the prosthetic constraint reproduces that normally provided by this ligament.



Joint Replacements:

- Our ability to replace damaged joints with prosthetic implants has brought relief to millions of patients who would otherwise have been severely limited in their most basic activities and doomed to a life in pain.
- It is estimated that about 16 million people in the United States are affected by osteoarthritis, one of the various conditions that may cause joint degeneration and may lead a patient to a total joint replacement.
- Joint degeneration is the end-stage of a process of destruction of the articular cartilage, which results in severe pain, loss of motion, and occasionally, an angular deformity of the extremity.Unlike bone, cartilage has a very limited capacity for

repair.

- Therefore, when exposed to a severe mechanical, chemical, or metabolic injury, the damage is permanent and often progressive.
- Under normal conditions, the functions of cartilage are to provide a congruent articulation between bones, to transmit load across the joint, and to allow low- friction movements between opposing joint surfaces.
- The sophisticated way in which these functions are performed becomes evident from some of the mechanical characteristics of normal cartilage.
- For example, due to the leverage geometry of the muscles and the dynamic nature of human activity, the cartilage of the hip is exposed to about eight times body weight during fast walking.
- Over a period of 10 years, an active person may subject the cartilage of the hip to more than 17 million weight bearing cycles.
- From the point of view of the optimal lubrication provided by synovial fluid, cartilage's extremely low frictional resistance makes it 15 times easier to move opposing joint surfaces than to move an ice-skate on ice.
- Cartilage functions as a unit with subehondral bone, which contributes to shock absorption by under going viscoelastic deformation of its tine trabecular structure.
- Although some joints, like the hip, are intrinsically stable by virtue of their shape, the majority require an elaborate combination of ligaments, meniscus, tendons, and muscles for stability.
- Because of the large multidirectional forces that pass through the joint, its stability is a dynamic process.
- Receptors within the ligaments fire when stretched during motion, producing an integrated muscular contraction that provides stability for that specific displacement. Therefore, the ligaments are not passive joint restraints as once believed.
- The extreme complexity and high level of performance o1 biologic joints determine the standard to be met by artificial implants.

JOINT	**TYPES**
Hip	Ball and socket

Knee	Hinged,semiconstrained,surface replacement. Unicompartment or bicompartment
Shoulder	Ball and socket
Ankle	Surface replacement
Elbow	Hinged,semiconstrained,surface replacement.
Wrist	Ball and socket, space filler
Finger	Hinged, space filler

- Total joint replacements are permanent implants, unlike those used to treat fractures, and the extensive bone and cartilage removed during implantation makes this procedure irreversible.
- Therefore, when faced with prosthesis failure and the impossibility to reimplant, the patient will face severe shortening of the extremity, instability or total rigidity of the joint, difficulty in ambulation, and often will be confined to a wheel chair.
- The design of an implant for joint replacement should be based on the kinematics and dynamic load transfer characteristic of the joint. The material properties, shape, and methods used for fixation of the implant to the patient determines the load transfer characteristics.
- This is one of the most important elements that determines long-term survival of the implant, since bone responds to changes in load transfer with a remodeling process, mentioned earlier as Wollff's law.
- Overloading the implant-bone interface or shielding it from load transfer may result in bone resorption and subsequent loosening of the implant.
- The articulating surfaces of the joint should function with minimum friction and produce the least amount of wear products.
- Loss of tissue, especially of bone, makes re-implantation difficult and often shortens the life span of the second joint replacement.
- In the following section. the most relevant achievenwnts in fixation methods and prosthetic design for different joints will be discussed at a conceptual level.
- Most joints can undergo partial replacement (hemiarthroplasty), that is, reconstruction of only one side of the joint while retaining the other.

- This is indicated in selected conditions when global joint degeneration has not taken place. This section will focus on total joint replacement, since this allows for a broader discussion of the biomaterials used.

4. Discuss the medical applications for metallic implants with diagram.(May 2019)

METALLIC IMPLANTS:

- Metallic implants are the primary biomaterials used for joint replacement and becoming increasingly important.
- The metallic implants used for orthopedic applications can be categorized as stainless steel, CoCr alloys, and Ti and Ti alloys.
- These metallic materials have several properties such as high strength, high fracture toughness, hardness, corrosion resistance and biocompatibility, which make them an excellent choice for total joint replacement.
- The disadvantage with metallic implants is their high elastic modulus, which causes stress shielding.
- **Stainless steel alloys** were the first metals to be used for orthopedics.
- Stainless steel alloys contain carbon, chromium, nickel, molybdenum, and manganese, phosphorus, sulfur, and silicon as trace elements.
- **Cobalt-based alloys** are the other metallic implants used for joint replacement.
- Ti-based implants have excellent corrosion resistance and biocompatibility. And the credit goes to the oxide layer, which spontaneously forms in the presence of oxygen.

Physical Properties of Metals:

- Luster (shininess)
- Good conductors of heat and electricity
- High melting point
- Ductile (most metals can be drawn out into thin wires)
- Malleable (most metals can be hammered into thin sheets)
  - High strength and resistance
  - High strength and resistance to fracture that this class of material can provide, assuming proper processing, gives reliable long-term implant performance in major load-bearing situations.
  - Coupled with a relative ease of fabrication of both simple and complex shapes using well-established and widely available fabrication techniques (casting,

forging, machining)

- This has promoted metal use in the fields of orthopedics and dentistry primarily, the two areas in which highly loaded devices are most common

Chemical Properties of Metals:

- Easily lose electrons
- Surface reactive
- Loss of mass (some corrode easily)

i. The corrosion of metallic implant gives adverse effects to the surrounding tissues and to the implant itself.

ii. It produces chemical substances that harmful for human organs and deteriorates the mechanical properties of the implant.

iii. Therefore, corrosion resistance of a metallic implant is an important aspect of its biocompatibility.

- Change in mechanical properties

Biocompatibility of metals:

- In metals, biocompatibility involves the acceptance of an artificial implant by the surrounding tissues and by the body as a whole.
- The metallic implants do not irritate the surrounding structures, do not incite an excessive inflammatory response, do not stimulate allergic and immunologic reactions, and do not cause cancer.
- Other functional characteristics that are important for metallic device include adequate mechanical properties such as strength, stiffness, and fatigue properties; and also appropriate density.

5. Discuss the medical applications for ceramic implants with diagram.(May 2019)

CERAMIC IMPLANT MATERIALS:

- A ceramic material is an inorganic, non-metallic, often crystalline oxide, nitride or carbide material. Some elements, such as carbon or silicon, may be considered ceramics.
- Ceramic materials are brittle, hard, strong in compression, and weak in shearing and tension.
- Ceramics generally can withstand very high temperatures. Ceramics are used in many types of medical procedures. The ceramic materials used are not the same as

porcelain type ceramic materials.

- Ceramics can also be classified into three distinct material categories:
  1. Oxides: alumina, beryllia, ceria, zirconia
  2. Non-oxides: carbide, boride, nitride, silicide
  3. Composite materials: particulate reinforced, fiber reinforced, combinations of oxides and nonoxides.

CATEGORIES OF CERAMIC IMPLANT MATERIALS:

- Ceramic materials are widely used for biomedical applications because of their remarkable biological and mechanical properties.
- Hydroxyapatite (HAp) is a calcium phosphate ceramic. Hydroxyapatite (HA) has been widely used as a bone graft substitute.
- Carbon is produced by depositing silicon-alloyed carbon on a prefabricated graphite substrate.
- Similar carbon products are currently being tested for use as percutaneous implants and dental anchors.
- Carbon fiber-reinforced composites are being tested as internal bone plates.

HISTORY OF CERAMICS:

- Prior to 1925, the materials used in implant surgery were primarily relatively pure metals. The success of these materials was surprising considering the relatively primitive surgical techniques.
- The final product was a new material which he called bioglass.

PROPERTIES OF CERAMICS:

- Ceramics show numerous applications as biomaterials due to their physio-chemical properties.
- They have the advantage of being inert in the human body.
- Their hardness and resistance to abrasion makes them useful for bones and teeth replacement.
- Some ceramics also have excellent resistance to friction, making them useful as replacement materials for malfunctioning joints.
- Properties such as appearance and electrical insulation are also a concern for specific biomedical applications.
- The main advantages are a greater failure strength, and a good resistance to fatigue.
- Diamond can be used for the same application, but in coating form.

BIOCOMPATIBILITY OF CERAMICS:

- Bioceramics' properties of being anticorrosive, biocompatible, and aesthetic make them quite suitable for medical usage.
- Zirconia ceramic has bioinertness and noncytotoxicity.
- Bioactive ceramics, including bioglasses must be non-toxic, and form a bond with bone.
- The biological activity of bioceramics has to be considered under various *in vitro* and *in vivo* studies.

MANUFACTURING PROCESS:

- Technically, ceramics are composed of raw materials such as powders and natural or synthetic chemical additives, favoring either compaction, setting , or accelerating sintering processes.
- For crystalline materials, grain size and crystalline defects provide further pathways to enhance biodegradation and osseointegration, which are key for effective bone graft and bone transplant materials.

UNIT V

2 MARKS

1. Mention biomaterials used for artificial heart valves. (Nov 2016)

- Artificial heart valves can be separated into three broad classes: mechanical heart valves, bioprosthetic tissue valves and engineered tissue valves.
- Polyether urethane urea and Polysulfones are the most common polymers which are used for artificial heart valves.
- Mechanical valves are made from carbon and metal.
- Bioprosthetic valves are usually made from pig or cow tissue, or sometimes from human tissue.

2. What is an allograft? How is it different from an autograft? (Nov 2016)

- Tissues that are transplanted from one genetically distinct individual to another within the same species are called allografts.
- Allograft differs from autograft in such a way that, if tissues are transplanted from one area on an individual to another area on the same individual (e.g., a skin graft on a burn patient), then it is known as an autograft.

3. What are the materials used in dental implants? (May 2017)

- Polymers
- Ceramics
- Metals
- Composites
- Bioactive Glass
- Hydroxyapatite

4. What are dental amalgams? (Dec 2017)

- Dental amalgam is a dental filling material used to fill cavities caused by tooth decay.
- Dental amalgam is a mixture of metals, consisting of liquid (elemental) mercury and a powdered alloy composed of silver, tin, and copper.

5. What are the drawbacks of materials used as heart valves? (Nov 2017, Nov 2019)

- The major drawbacks of mechanical heart valves is that they are associated with an increased risk of blood clots. Clots formed by red blood cell and platelet damage can block blood vessels leading to stroke. People with mechanical valves need to take anticoagulants (blood thinners), such as warfarin, for the rest of their life.

- Mechanical heart valves can also cause mechanical hemolytic anemia, a condition where the red blood cells are damaged as they pass through the valve.
- Implanted mechanical valves can cause foreign body rejection.
- Bioprosthetic valves are made from cow so possible objections on religious grounds.

6. Specify some reasons for valvulardysfuction. (May 2018)

- Coronary Artery Disease
- Heart Attacks
- Syphilis
- Hypertension
- Connective Tissue Diseases
- Tumors

7. Mention the application of biomaterials in dental implants. (May 2018)

- Titanium (Ti) and its alloys (mainly Ti-6Al-4V) have become the metals of choice for dental implants.
- Grade 5 titanium, Titanium 6AL-4V (signifying the titanium alloy containing 6 percent aluminium and 4 percent vanadium alloy) is slightly harder than CP4 and used in the industry mostly for abutment screws and abutments.
- The ceramic-polymer composites are a potential way to filling of cavities replacing amalgams suspected to have toxic effects.
- Aluminosilicates are commonly used in dental prostheses, pure or in ceramic-polymer composites.

8. What are prosthetic devices? (May 2017, Dec 2018)

- A prosthetic device is any device that helps replace, correct, or support a body part or function of a body part.
- Examples of these devices include: Dentures, which help replace missing teeth and take over the function of chewing.
- This helps us gain adequate nutrition and keep healthy.

9. What are dental implants? (Dec 2018)

- A dental implant is a surgical fixture that is placed into the jawbone and allowed to fuse with the bone over the span of a few months.
- The dental implant acts as a replacement for the root of a missing tooth.

- Dental implants are replacement tooth roots.
- Implants provide a strong foundation for fixed (permanent) or removable replacement teeth that are made to match your natural teeth.

10. What is limb prosthesis? (May 2019)

- A limb prosthesis is an artificial limb that replaces a missing body part, usually because it has been amputated.
- The main causes of limb amputation are:

1. Blood vessel (vascular) disease
2. Cancer
3. Injury
4. Birth defect

11. What is the need for dental implants? (May 2019)

- Dental implants can be used to replace a single tooth, several teeth, or all of the teeth.
- The goal of teeth replacement in dentistry is to restore function as well as esthetics.
- When it comes to tooth replacement, generally, there are three options:

1. Removable dental appliance (complete denture or partial denture),
2. Fixed dental bridge (cemented), and
3. Dental implant.

- Dental bridgework was the more common restorative option prior to the relatively recent shift to dental implant treatment.

12. Compare prosthesis and implants. (Dec 2019)

Prosthesis	**Implants**
Prosthesis is an artificial replacement for a body part, either internally or externally.	Implants are devices or tissues that are placed inside or on the surface of the body.
Prosthesis can be functional, as in	Implants are surgically inserted or

the case of artificial arms and legs, or cosmetic, as in the case of an artificial eye.	grafted into the body, tend to be used therapeutically.

11 MARKS

1. **a. Explain about the types of heart valves and the complications that may occur after valve replacement. (Nov 2016)**

   b. Discuss in detail about the various types of prosthetic cardiac heart valves. (May 2018)

ARTIFICIAL HEART VALVES:

- An artificial heart valve is a one-way valve implanted into a person's heart to replace a valve that is not functioning properly (valvular heart disease).
- Artificial heart valves can be separated into three broad classes: mechanical heart valves, bioprosthetic tissue valves and engineered tissue valves.
- The main purpose of heart valve is to keep blood flowing in the proper direction through the heart, and from the heart into the major blood vessels connected to it.
- Heart valves can malfunction for a variety of reasons, which can impede the flow of blood through the valve (stenosis) and/or let blood flow backwards through the valve (regurgitation).
- Both processes put strain on the heart and may lead to serious problems, including heart failure. While some dysfunctional valves can be treated with drugs or repaired, others need to be replaced with an artificial valve.

1. **MECHANICAL HEART VALVES:**

- Mechanical valves come in three main types
- – Caged Ball,
- – Tilting-Disc And
- – Bileaflet

CAGED BALL:

- When the heart contracts and the blood pressure in the chamber of the heart exceeds the pressure on the outside of the chamber, the ball is pushed against the cage and allows blood to flow.
- When the heart finishes contracting, the pressure inside the chamber drops and the ball moves back against the base of the valve forming a seal.
- Caged ball valves are strongly associated with blood clot formation, so people who have one required a high degree of anticoagulation.

TILTING DISC:

- Tilting disc valves, a type of swing check valve, are made of a metal ring covered by an ePTFE fabric.
- The metal ring holds, by means of two metal supports, a disc that opens when the heart beats to let blood flow through, and then closes again to prevent blood flowing backwards.
- The disc is usually made of an extremely hard carbon material (pyrolytic carbon), enabling the valve to function for years without wearing out.

BILEAFLET:

- Bileaflet valves are made of two semicircular leaflets that revolve around struts attached to the valve housing.
- With a larger opening than caged ball or tilting-disc valves, they carry a lower risk of blood clots.
- They are, however, vulnerable to blood backflow.

ADVANTAGES AND DISADVANTAGES OF MECHANICAL HEART VALVES:

- The major advantage of mechanical valves over bioprosthetic valves is their greater durability. Made from metal and/or pyrolytic carbon,they can last 20–30 years.
- The major drawbacks of mechanical heart valves is that they are associated with an increased risk of blood clots.
- Implanted mechanical valves can cause foreign body rejection.

BIOPROSTHETIC VALVES:

- Bioprosthetic valves are usually made from animal tissue (heterograft/xenograft) attached to a metal or polymer support.
- Bovine (cow) tissue is most commonly used, but some are made from porcine (pig) tissue.
- The tissue is treated to prevent rejection and calcification.
- Alternatives to animal tissue valves are sometimes used, where valves are used from human donors, as in aortic homografts and pulmonary autografts.
- An aortic homograft is an aortic valve from a human donor, retrieved either after their death or from a heart that is removed to be replaced during a heart transplant.
- A pulmonary autograft, also known as the Ross procedure, is where the aortic valve is removed and replaced with the patient's own pulmonary valve.
- A pulmonary homograft (a pulmonary valve taken from a cadaver) is then used to replace the patient's own pulmonary valve.
- Bioprosthetic valves tend to deteriorate more quickly in younger patients.
- Current bioprosthetic valves lack longevity, and will calcify over time.
- When a valve calcifies, the valve cusps become stiff and thick and cannot close completely.
- Moreover, bioprosthetic valves can't grow with or adapt to the patient: if a child has bioprosthetic valves they will need to get the valves replaced several times to fit their physical growth.

TISSUE ENGINEERED VALVES:

- These tissue engineered valves involve seeding human cells on to a scaffold.
- The two main types of scaffold are natural scaffolds, such as decellularized tissue, or scaffolds made from degradable polymers.
- Cells that are used for tissue engineered heart valves are expected to secrete the extracellular matrix (ECM).
- Extracellular matrix provides support to maintain the shape of the valves and determines the cell activities.

FUNCTIONAL REQUIREMENTS:

- Minimal regurgitation
- Minimal transvalvular pressure gradient
- Non-thrombogenic
- Self-repairing

2. Explain in detail about dental implants. (Nov 2016)

DENTAL IMPLANTS

- Dental implants are replacement tooth roots. Implants provide a strong foundation for fixed (permanent) or removable replacement teeth that are made to match your natural teeth.
- A dental implant is a surgical fixture that is placed into the jawbone and allowed to fuse with the bone over the span of a few months. The dental implant acts as a replacement for the root of a missing tooth.
- In turn, this "artificial tooth root" serves to hold a replacement tooth or bridge.
- Having a dental implant fused to the jawbone is the closest thing to mimicking a natural tooth because it stands on its own without affecting the nearby teeth and has great stability.
- The process of fusion between the dental implant and jawbone is called "osseointegration."

NEED FOR DENTAL IMPLANTS:

- Dental implants can be used to replace a single tooth, several teeth, or all of the teeth. The goal of teeth replacement in dentistry is to restore function as well as esthetics.
- When it comes to tooth replacement, generally, there are three options:

    1. removable dental appliance (complete denture or partial denture),
    2. fixed dental bridge (cemented), and
    3. dental implant.

- Dentures are the more affordable option for replacement teeth but are the least desirable because of the inconvenience of a removable appliance in the mouth.
- Furthermore, dentures can affect one's taste and sensory experience with food.

- Dental bridgework was the more common restorative option prior to the relatively recent shift to dental implant treatment.
- The main disadvantage to bridgework is the dependence on existing natural teeth for support. Implants are supported by bone only and do not affect surrounding natural teeth. Deciding on which option to choose depends on many factors. Specifically for dental implants, these factors include:
  - location of missing tooth or teeth,
  - quantity and quality of the jawbone where the dental implant is to be placed,
  - health of the patient,
  - cost, and
  - patient preference.

TYPES OF DENTAL IMPLANTS:

- Historically, there have been two different types of dental implants:
  1. Endosteal
  2. subperiosteal.
- Endosteal refers to an implant that is "in the bone," and subperiosteal refers to an implant that rests on top of the jawbone under the gum tissue.
- Subperiosteal implants are no longer in use today because of their poor long-term results in comparison to endosteal dental implants.

ADVANTAGES:

- There are many advantages to dental implants, including:
  - Improved
  - Improved speech
  - Improved comfort
  - Easier eating
  - Improved self-esteem
  - Improved oral health
  - Durability
  - Convenience

DENTAL APPLICATIONS:

- Their most important applications in dentistry include:

1. Indirect restorations (in lay and onlay)
2. Post & core
3. Crown (all metal and porcelain fused to metal (PFM))
4. Telescopic crown that is used as retentive elementin over denture.
5. Bridge
6. Frame work for removable denture
7. Implants

MATERIALS USED:

POLYMERS:

- One of the most common cases is the use of polymeric base material in complete and partial denture. In addition, denture soft liners, resin cements, pit and fissure sealants contain polymer. Polymers used for denture base includes: Vulcanite, Celluloid, Phenol-formaldehyde (Bakelite), Polyvinylchloride (PVC), Poly methyl methacrylate (PMMA).

CERAMICS:

- Ceramics are considered as a combination of metal elements and non-metallic materials such as, oxides, nitrides and silicates, and can be appear in two solid crystalline and amorphous (shapeless) solid, the second group is also called glass.
- They form hard, stiff, and brittle materials due to the nature of their inter-atomic bonding, which is ionic and covalent.

METALS:

- Metallic elements commonly used in dentistry are divided into two groups, noble and base metal.
- Gold, platinum, palladium, iridium, rhodium, osmium and ruthenium are considered as noble metals. Their resistance to oxidation, tarnish and corrosion in heating and soldering and use in the mouth is excellent.

COMPOSITES:

- Composite resins are used to rebuild the tooth structure, change the color, contour correction and improvement of facial surface of the teeth beauty. Composites used in dentistry are composed of three main components organic (resin matrix, inorganic filler components and coupling agent) and other components.

COMPOSITION:

- A typical conventional implant consists of a titanium screw (resembling a tooth root) with a roughened or smooth surface.
- The majority of dental implants are made of commercially pure titanium, which is available in four grades depending upon the amount of carbon, nitrogen, oxygen and iron contained.
- Most modern dental implants also have a textured surface (through etching, anodic oxidation or various-media blasting) to increase the surface area and osseointegration potential of the implant.

3. Explain the different types of limb prosthetic devices with schematic diagram. (May 2017, Nov 2018)

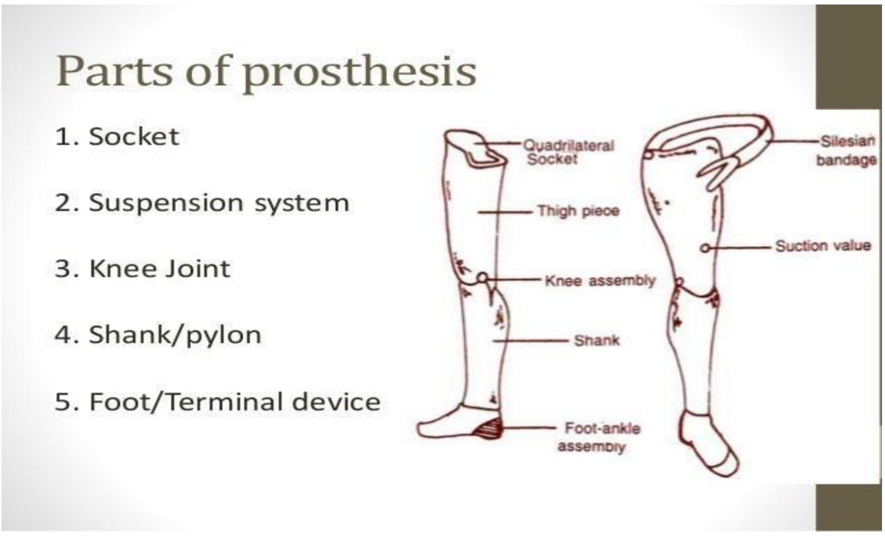
<u>LIMB PROSTHESIS</u>

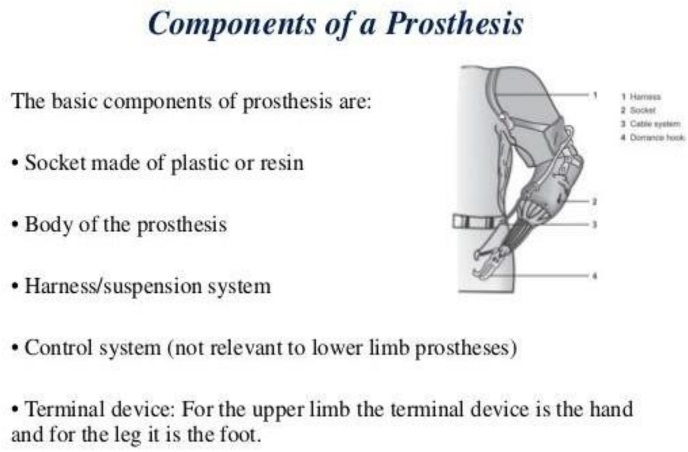
- A limb prosthesis is an artificial limb that replaces a missing body part, usually because it has been amputated.
- The main causes of limb amputation are:

  1. Blood vessel (vascular) disease
  2. Cancer
  3. Injury
  4. Birth defect

- New plastics and other materials, such as carbon fiber, have allowed artificial limbs to be stronger and lighter, limiting the amount of extra energy necessary to operate the limb. With advances in modern technology, cosmesis, the creation of life-like limbs made from silicone or PVC, has been made possible.
- There is a wide variety of prostheses that are designed to function and in many cases look -- like a natural arm, leg, hand, or foot. Although there are many different designs, most have similar parts. These include:

  1. A socket into which the stump of the amputated limb fits
  2. The suspension, which holds the prosthesis onto the stump
  3. The shaft
  4. The foot, hand, or hook
  5. A covering for cosmetic appearances





The socket is often lined with foam or silicone to protect the stump. Special socks are also worn over the stump to ensure a proper fit and improve comfort.

<u>TYPES OF PROSTHESIS:</u>

- **Lower leg and foot:** A number of prosthetic feet are available to simulate the action of a natural foot after an amputation below the knee. At least one available foot-ankle prosthesis is controlled by a microprocessor. It uses feedback from sensors to adjust joint movement, making walking more efficient and reducing the risk of falls.
- **Leg with knee:** For amputations above the knee, the prosthesis has both a knee and ankle joint. Currently there are more than 100 prosthetic ankle, foot, and knee models. Some use fluid or hydraulic-controlled devices that let users vary their walking speed. Others use computerized parts that let the user make rapid real-time adjustments while walking.

- **Arm and hand:** The oldest and most commonly used prosthetic arm is operated with the body's own movements and a harness that extends in a figure eight across the back and under the opposite arm. Others use a rechargeable battery to run small motors in the prosthetic hand or hook. The battery improves grip strength.

FABRICATION OF PROSTHESIS:

- The fabrication of the prescribed prosthesis also goes through various stages that could influence considerably the rehabilitation and the physiotherapy program planned after the first fitting.

These fabrication steps are:

1.Casting

2.Positive mould

3.Rectification

4.Assembling

5.Alignments

6.Cosmetic

- Replacing the movements of the human body with prosthetic components is a very complex and complicated task.
- Prosthetic components can imitate, with different level of complexity, these movements but never replace them.
- With the loss of sensory and proprioception, the amputee must rely solely on sensory capabilities of his stump and body, which may affect confidence during the execution of the march.
- However, modern prosthetic technologies offer a wide range of components, especially in lower limb prosthesis, which manages to replace the major movements and enable users to perform the gait.
- Below, we add some examples of common prosthetic components and correlation between the prosthetic design and the gait.

FITTING OF PROSTHESIS:

- Measuring the stump and the healthy opposite limb
- Fitting silicone liner
- Making a plaster mold
- Fashioning the socket

- Forming the plastic parts and then creating the metal parts of the limb
- Attaching the shaft
- Aligning the prosthesis

PROSTHETIC RAW MATERIALS:

- Prosthetic are made lightweight for better convenience for the amputee. Some of these materials include:

1. Plastics: Polyethylene, Polypropylene, Acrylics, Polyurethane
2. Wood (early prosthetics)
3. Rubber (early prosthetics)
4. Lightweight metals: Titanium, Aluminum
5. Composites: Carbon fiber reinforced polymers

PERFORMANCE:

- Fit – athletic/active amputees, or those with bony residua, may require a carefully detailed socket fit; less-active patients may be comfortable with a 'total contact' fit and gel liner
- Energy storage and return – storage of energy acquired through ground contact and utilization of that stored energy for propulsion
- Energy absorption – minimizing the effect of high impact on the musculoskeletal system
- Ground compliance – stability independent of terrain type and angle
- Rotation – ease of changing direction
- Weight – maximizing comfort, balance and speed
- Suspension – how the socket will join and fit to the limb

4. a. Explain in detail about working principles and mechanism of externally powered limb prosthesis. (May 2017, May 2018, Nov 2018, May 2019)

b. A person loses his upper limb in an accident and needs a prosthetic device. What are the design considerations taken into account to manufacture an externally powered limb prosthesis. (Nov 2019)

EXTERNALLY POWERED LIMB PROSTHESIS

- A prosthesis is an artificial replacement for any or all parts of the lower or upper extremities.
- It is a device that is designed to replace, as much as possible, the function or appearance of a missing limb or body part.
- A prosthesis is used to provide an individual who has an amputated limb with the opportunity to perform functional tasks, particularly ambulation (walking) which may not be possible without the limb.
- The type of prosthesis is determined by the extent of an amputation.
- Four categories of upper limb prosthetic systems:

    1. Passive system
    2. Body-powered system
    3. Externally powered system
    4. Hybrid system.

- A passive system is primarily cosmetic but also functions a stabilizer. A passive system is fabricated if the patient does not have enough strength or movement to control a prosthesis, or wears a prosthesis only for cosmoses.
- A body-powered system prosthesis uses the patient's own residual limb or body strength and ROM to control the prosthesis. An externally powered system uses an outside power source such as a battery to operate the prosthesis.
- A hybrid system uses the patient's own muscle strength and joint movement, as well as an external supply for power. An example of a hybrid system is one in which there is a body powered elbow joint but an externally powered terminal device.

Power:

1. Body-powered prostheses:
2. Cable controlled
3. Externally powered prostheses
4. Electrically powered Myoelectric prostheses
5. Switch-controlled prostheses

Body-powered prostheses

- Body powered prostheses use forces generated by body movements transmitted through cables to operate joints and terminal devices.

- Forward flexing the shoulder to provide tension on the control cable (Bowden cable) of the prosthesis resulting in opening the terminal device. Relaxing the shoulder forward flexion results in return of the terminal device to the static closed position.
- Body-powered prostheses are more durable and are less expensive and lighter than myoelectric prostheses.
- Examples
  (1) biscapular protraction,
  (2) shoulder flexion
  (3) Shoulder depression, extension, internal rotation, & abduction operate the elbow lock in trans humeral amputation.

Externally powered prostheses

- Externally powered prostheses use muscle contractions or manual switches to activate the prosthesis. Electrical activity from selected residual muscles are detected by surface electrodes to control electric motors.
- A myoelectrically controlled prosthesis uses muscle contractions as a signal to activate the prosthesis. It functions by using surface electrodes to detect electrical activity from selected residual limb muscles to control electric motors.
- Switch-controlled, externally powered prostheses use small switches to operate the electric motors. These switches typically are enclosed inside the socket or incorporated into the suspension harness of the prosthesis

LOWER LIMB PROSTHESIS

1. Preparatory (Temporary) Prosthesis
2. Definitive (Permanent) Prosthesis

1. Preparatory (Temporary) Prosthesis

- A preparatory (temporary) prosthesis is usually made prior to a definitive prosthesis. It helps in shrinking and shaping of the residual limb.
- Usually used for 3 to 6 months of post surgery (until maximal stump shrinkage has been achieved).

2. Definitive (Permanent) Prosthesis:

- When shaping and shrinking process has ended and residual limb volume has stabilized, a definitive or permanent prosthesis is made.

- It can be applied after 3-9 months of postoperative.
- Life span of 3-5 years.

Lower limb prosthesis:

Socket:

- The socket is typically custom-made for the user. The socket is constructed using a cast of the residual limb.
- In most sockets, the goal is to achieve total contact with the residual limb. Total contact does not necessarily imply equal pressure distribution.

Suspension:

- Suspension is the method by which the prosthesis is held onto a person's residual limb. Example: Pelvic belt, Supracondylar calf

Body:

(1) Exoskeletal construction

(2) Endoskeletal construction

Endoskeletal construction:

- The socket connects to the remaining components through pipes called pylons.
- Endoskeletal systems are made of carbon fiber or titanium pylons or steel.

Exoskeletal construction:

- It gains its structural strength from outer laminated shell through which the weight of the body transmitted.
- This shell is made of resin or HDPE over a filler material of wood or foam and whole prosthesis shaped to provide a cosmetic appearance of amputed limb.
- The opposite surviving leg is taken for reference for shape length and skin colour

Prosthetic feet

- Prosthetic feet are made out of many different materials including wood, plastic, foam, and carbon fiber. Example:

(1) SACH (solid ankle cushion-heel)

(2) Jaipur foot Solid-Ankle Cushion-Heel Feet

Prosthetic knee Joint

- The knee joint is aligned in the prosthesis in extension .The best knee mechanism in one that offers adequate stability in stance phase.
- If the knee mechanism does not fully extend before heel contact it buckles causing prosthetic knee to flex suddenly when weight is applied.

5. Describe the various types of mechanical heart valve prosthesis used in cardiac surgery. (Nov 2017, Nov 2019)

MECHANICAL HEART VALVES:

- Mechanical valves come in three main types

– Caged Ball,

– Tilting-Disc And

– Bileaflet

CAGED BALL:

- The first artificial heart valve was the caged ball valve, a type of ball check valve, in which a ball is housed inside a cage.
- When the heart contracts and the blood pressure in the chamber of the heart exceeds the pressure on the outside of the chamber, the ball is pushed against the cage and allows blood to flow.
- When the heart finishes contracting, the pressure inside the chamber drops and the ball moves back against the base of the valve forming a seal.
- Caged ball valves are strongly associated with blood clot formation, so people who have one required a high degree of anticoagulation.

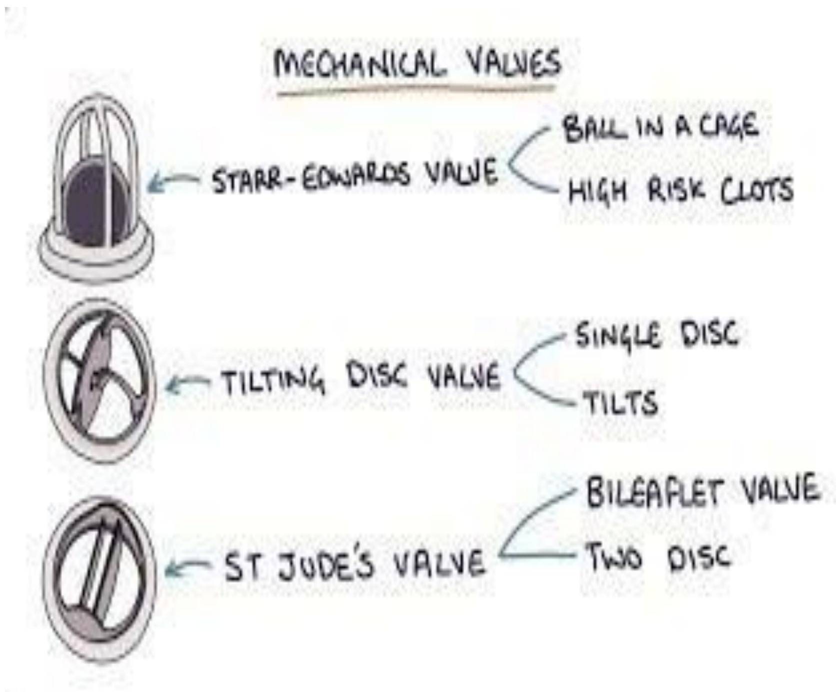
TILTING DISC:

- Tilting-disc valves, a type of swing check valve, are made of a metal ring covered by an ePTFE fabric.
- The metal ring holds, by means of two metal supports, a disc that opens when the heart beats to let blood flow through, then closes again to prevent blood flowing backwards.
- The disc is usually made of an extremely hard carbon material (pyrolytic carbon), enabling the valve to function for years without wearing out.

BILEAFLET:

- Bileaflet valves are made of two semicircular leaflets that revolve around struts attached to the valve housing.

- With a larger opening than caged ball or tilting-disc valves, they carry a lower risk of blood clots.
- They are, however, vulnerable to blood backflow.

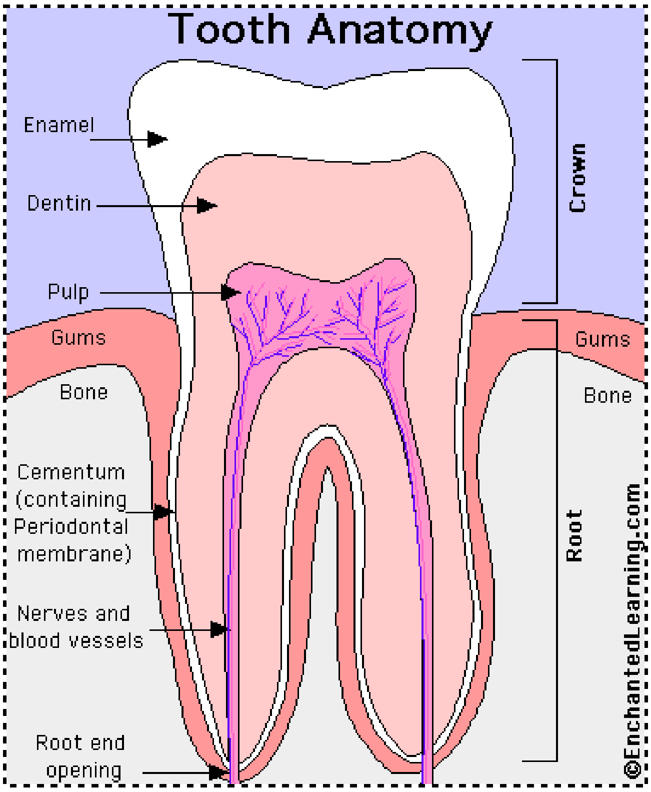


ADVANTAGES AND DISADVANTAGES OF MECHANICAL HEART VALVES:

- The major advantage of mechanical valves over bioprosthetic valves is their greater durability. Made from metal and/or pyrolytic carbon,they can last 20–30 years.
- The major drawbacks of mechanical heart valves is that they are associated with an increased risk of blood clots.
- Clots formed by red blood cell and platelet damage can block blood vessels leading to stroke. People with mechanical valves need to take anticoagulants (blood thinners), such as warfarin, for the rest of their life.
- Mechanical heart valves can also cause mechanical hemolytic anemia, a condition where the red blood cells are damaged as they pass through the valve.
- Cavitation, the rapid formation of microbubbles in a fluid such as blood due to a localized drop of pressure, can lead to mechanical heart valve failure,so cavitation testing is an essential part of the valve design verification process.
- Implanted mechanical valves can cause foreign body rejection.

➢ The blood may coagulate and eventually result in a hemostasis. The usage of anticoagulation drugs will be interminable to prevent thrombosis.

6. Draw the structure of human teeth and write about the different types of orthodontic materials. (Nov 2017)



Structure of Human Teeth

Different types of Orthodontic Materials:

1. Stainless steel

➢ Stainless steel (SS) arch wires have remained a popular choice in orthodontics; as they offer many advantages such as: formability, biocompatibility, environmental stability, stiffness, resilience, and low cost.

➢ One advantage of stainless steel is the ability to alter composition and ultimately physical properties through manipulations of formulations in the manufacturing process.

➢ Originally, stainless steel arch wires typically contained 17-25% chromium and 8-25% nickel, with the remaining being iron.

➢ A resulting important advantage of stainless steel composition, especially considering its use in the oral cavity, is its rust resistance properties.

- Further, the physical properties of stainless steel are generally regarded to have a high strength value, boosting a stiffness of 93-100% stronger than conventional carbon steels .
- Regular grade has a high degree of formability and low fracture rate; whereas, the super grade has higher yield strength, with lower deformation properties. It is through these properties, as discussed above, that stainless steel arch wire continues to offer a high degree of versatility and durability, remaining as one of the most widely used arch wires in orthodontics.

2. Cobalt-Chromium (CoCr)

- The composition of cobalt chromium is cobalt (40%), chromium (20%), iron (16%), and nickel (15%) by percentage mass.
- Cobalt-Chromium and stainless steel have similar physical properties as both have a high stiffness value; however, a main advantage of CoCr is its availability in four different tempers, made possible through the process of heat treatment.
- This is an important advantage as it gives the practitioner a variable amount of formability to work with, allowing for the ability to bend loops, place V-bends, and place various other offsets into the arch wire.
- Thus, with these properties CoCr arch wire proves useful under certain clinical circumstances in orthodontics; as its ability to be hardened by heat treatment after being shaped and its different formable states may be particular advantageous in certain cases.

3.Nickel-Titanium (NiTi) Alloys

- The advent of Nickel-Titanium alloys, which were originally intended for the space program, were found to have a place in arch wire orthodontics.
- Shortly after, Nickel-Titanium (commonly regarded as Nitinol), was introduced it quickly became highly regarded, as its physical properties allowed for a high degree of springiness.
- This was found to be very advantageous as it allowed for the ability of NiTi arch wires to exhibit a shape memory effect, in which they exhibited the potential to return to their original form after deformation.
- Further, the physical properties of NiTi, which is generally 50% nickel and 50% titanium, allowed for light continuous forces to be offered through the shape memory affect; rather than abrupt heavy forces.

- In addition to the conventional NiTi alloys, two other generic nitinol-type alloys are available, an austenitic active alloy and a martensitic active alloy.
- Martensitic and austenitic are both important as their physical properties allows for shape memory rebound after deformation.
- Martensite is generally represented by the low stiffness phase; whereas, austenite respresents the higher stiffness phase.
- A key limitation of the austenitic alloy is that wire bending is not practical clinically, as very high forces are needed for the material to undergo plastic deformation.
- Finally, some currently-marketed NiTi's have been able to enhance on these properties, allowing for the creation of an arch wire which is dead soft at room temperature, but in the environment of higher temperatures, such as the oral cavity, it becomes elastic.
- This becomes particularly advantageous for patients after an arch wire adjustment, as sipping cold water changes the properties of the elastic strain, ultimately resulting in decreased applied force.
- It is clear, current NiTi systems are beneficial in certain orthodontic circumstances, as their ability to supply a light and constant force is more predictable and efficient compared to stainless steel and cobalt chromium.

7. Discuss in detail about artificial heart. (May 2019)

ARTIFICIAL HEART

- An artificial heart is a prosthetic device that is implanted into the body to replace the original biological heart.
- It is distinct from a cardiac pump, which is an external device used to provide the functions of both the heart and the lungs.
- Thus, the cardiac pump need not be connected to both blood circuits.
- Also, a cardiac pump is only suitable for use not longer than a few hours, while for the artificial heart the current record is 17 months.
- This synthetic replacement for an organic mammalian heart (usually human), remains one of the long-sought goals of modern medicine.

- Although the heart is conceptually a simple organ (basically a muscle that functions as a pump), it embodies complex subtleties that defy straightforward emulation using synthetic materials and power supplies.
- The obvious benefit of a functional artificial heart would be to lower the need for heart transplants, because the demand for donor hearts greatly exceeds supply.
- Artificial heart, device that maintains blood circulation and oxygenation in the human body for varying periods of time.
- The two main types of artificial hearts are the heart-lung machine and the mechanical heart.

HEART LUNG MACHINE:

- The heart-lung machine is a mechanical pump that maintains a patient's blood circulation and oxygenation during heart surgery by diverting blood from the venous system, directing it through tubing into an artificial lung (oxygenator), and returning it to the body.
- The oxygenator removes carbon dioxide and adds oxygen to the blood that is pumped into the arterial system.
- The blood pumped back into the patient's arteries is sufficient to maintain life at even the most distant parts of the body as well as in those organs with the greatest requirements (e.g., brain, kidneys, and liver).
- Heart-lung machines have been greatly improved with smaller and more- efficient oxygenators, allowing them to be used not only in adults but also in children and even newborn infants.

MECHANICAL HEART:

- Mechanical hearts, which include total artificial hearts and ventricular assist devices (VADs), are machines that are capable of replacing or assisting the pumping action of the heart for prolonged periods without causing excessive damage to the blood components.
- Implantation of a total artificial heart requires removal of both of the patient's ventricles (lower chambers).
- However, with the use of a VAD to support either the right or the left ventricle, the entire heart remains in the body.

- Mechanical hearts are implanted only after maximal medical management has failed.
- They may be used for cardiac resuscitation after cardiac arrest, for recovery from cardiogenic shock after heart surgery, and in some patients with chronic heart failure who are waiting for a heart transplant.
- Occasionally, mechanical hearts have been used as a permanent support in patients who do not qualify for a heart transplant or as a bridge to recovery of the patient's own diseased heart.
- The goal is to provide a safe, effective system that allows the recipient to move about freely, thus improving the quality of life.
- Some recipients of VADs have lived several years and have returned to work and normal physical activities.