Medical Biomaterials
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Lecture – 28
Polymers

Hello everyone. Welcome to the course on medical biomaterials. Today we are going to start on a different material that is polymers. Polymers are most ubiquitous and we can have different combinations blends different sizes shapes and so on. So, polymers have become very useful in the area of biomaterials next to metals I would say and sometimes may be they may even replace metals at some points because nowadays polymers of very high strength or being a designed.

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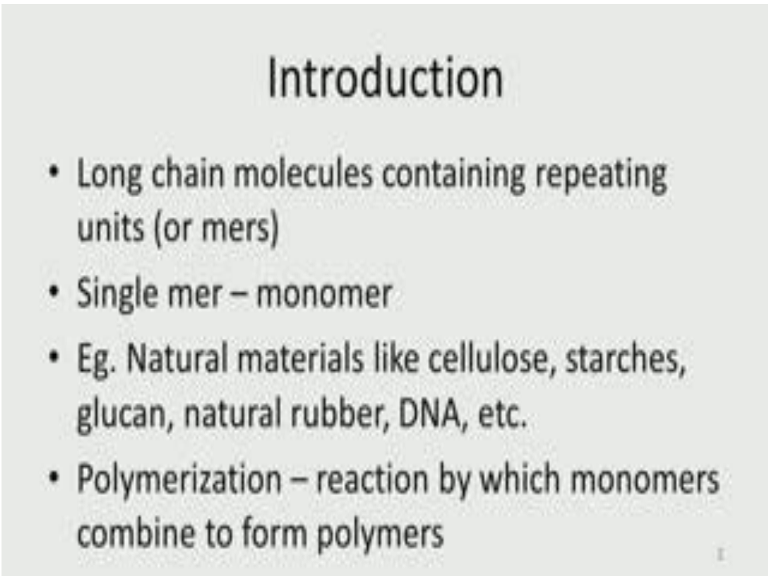

So, what are these polymers? These are long chain molecules containing repeat units. So, these are very long chain. So, the molecular weight may vary from may be about couple of 1000 going right up to 100000 200000, so 100s of kilo daltans. Polyethylenes could be in that range. We can have some glucans which are about 2000 daltans. So, polymers have wide range of molecular weights and they have repeating units which is called mers. So, that is why you have monomer oligomer and so on. So, single mer is called a monomer. So, there are natural polymers like cellulose, glucans, starches, natural, rubber even DNA would call it a natural polymer. So, many of these natural polymers are also used in biomaterial applications, because they are bio compatible, they will not exhibit any toxicity and in addition synthetic polymers hundreds of synthetic polymers have come already in to the use.

There is something called polymerization reaction. So, that is the reaction which converts these monomers in to polymers. So, we can have single monomer, so we will have polymer of the same monomer or we can have 2 monomers. So, we will have polymer of 2 of the monomers. So, we can have dimerization and so on. Monomerization and so on actually. So, we can have combinations of more than one monomer to get polymers then later on we can blend different polymers hydrophobic hydrophilic polymers to get products of different properties and that is why polymers have become very useful.

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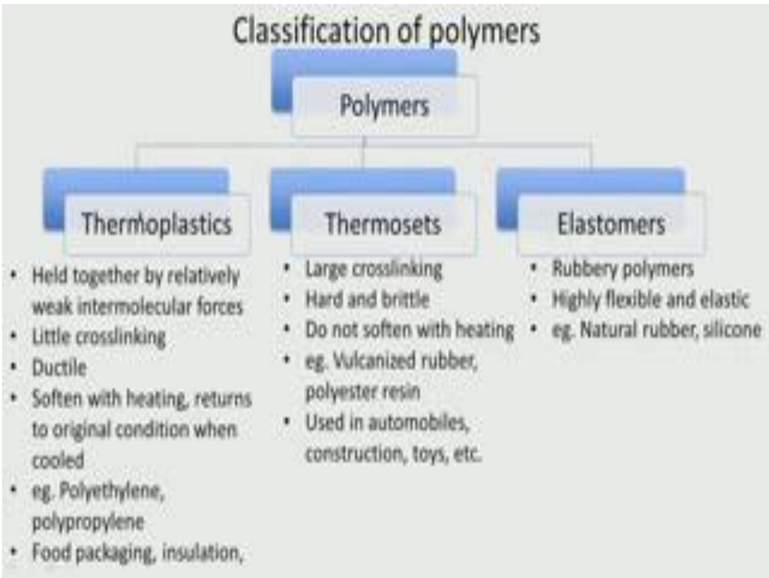

So, the polymers are classified originally thermoplastics, thermosets and elastomers thermoplastics. So, they are held together by relatively weak inter molecular forces and they have little cross linking, and they are ductile, they soften with heating and then one we when we cool it again they return back to their original conditions. So, that is the advantage we can soften it by heating where as and when you cool it they go become in the whole form like your polyethylene polypropylene linear low density polyethylene insulation material all these are called thermoplastic; that means, when I heat it thermo means temperature right plastic.

So, when I heat it becomes like a plastic and then when we cool it sets whereas, thermo sets they have large cross linking, they are very hard and brittle unlike thermo plastics, which are ductile they do not soften while heating. So, ones we set it after that we cannot change their shape. Unlike the thermoplastic thermosets we cannot change the shape once they are set like your vulcanized rubber polyester resin and so on actually.

So, they are used in auto mobile construction toys etcetera and of course, there are many applications in biomaterial where you have thermosets where you do not want to soften the material, we want hard material. Then you have elastomer these are rubbery polymer elastomers are like rubber. They are highly flexible elastic like your silicone has got lot of application historically in the area of biomaterials, because they are very rubbery flexible silicone tubes uretral tubes breast implants and so on, quite a lot of application. So, polymers are basically divided based on whether they are thermoplastic; that means, they soften and again they get hard once it is cooled or thermosets, where it does not soften once it is set and then the elastomers which are rubbery type of.

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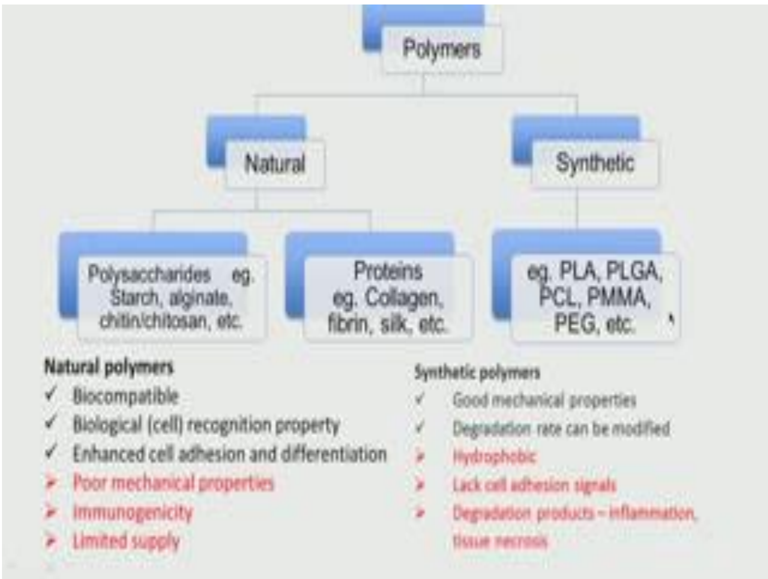

Again polymers can be divided in 2 forms, natural form natural polymers synthetic polymers like your polysaccharides, starch, alginate, chitin, chitosan, glucon. They are all sugars lot of sugars and then naturally protein collagen fibrin silk. So, as you can see these natural polymers are produced either by bacteria fungus or from plant derive sources. So, animal derived sources. So, we have all these are natural polymer and lot of natural polymers are also used in biomaterial application. For example, if you look at starch quite lot of cyclodextrin, they are used in drug delivery system chitin chitosan they are used in ligaments, polysaccharides are also used in drug delivery system, proteins are used in coating biomaterials to make the material bio compatible.

Sometimes for tissue engineering the scaffolds are made with collagen silk. So, polymers are natural polymers are used widely, but then natural polymers have lot of disadvantages also. Although they are bio compatible they have this biological recognition property; that means, when they are implant in inside the body the host system is very comfortable having that. You have good cell addition and differentiation, but they have poor mechanical properties of course, immunogenicity they have immunogenic properties because some of them could be bacterial or even animal which could cause certain immune response.

So, for example, bovine serum albumin, for example, or even your chitosan for example, or collagen for example, because they are animal derived there is always worry that there could be some contamination coming from the animal. Especially the collagen they also have limited supply. So, we cannot produce in tons and tons because they are if they are animal derived it becomes difficult because animals have to be sacrificed to get that sort of product bacterial of course, if you have very good fermentation technology bacterial derived polymers could be made in tons and tons of it. For example, linear glucan is made in large quantities using bacteria.

Now if you come to synthetic polymer they are made chemically like any organic molecule, we can make these synthetic polymers the monomers are made and then the polymerization reaction is carried out, to arrive at synthetic polymers like poly lactic acid, poly lactic glycolic acid, polycapro lactone, poly methyl methacrylate, polyethylene glycol and so on. So, all these are synthetically derived polymers and as you can see some of them are hydrophobic some of them are hydrophilic. So, we have wide range of hydrophobicity, hydrophilicity some of them have thermosetting properties, some of them are thermoplastic properties, some of them prevent bacterial addition some of them do to prevent some of them are biodegradable like your poly lactic acid some of them are non biodegradable like you are poly ethylenes.

So, we can in the same polymer family we can have different properties of course, there some of the mechanical properties, are not as good as metals, but still they can really ogment the metals, for example, synthetic polymer coating is done on drug eluting stents these stent has sensitive polymer coating the polymer degrades and elutes out the drug, if you are talking about drug delivery in some orthopedic issue then we have biodegradable polymer, we cannot have a biodegradable metal. So, we need to have a biodegradable polymer. So, for drug delivery applications slow release systems scaffolds which can completely disappear bio reabsorbed, then of course, nothing to be polymers. So, polymers have great future and great application, they have good mechanical properties of course, when compared to metals, they are nowhere degradation rate can be modified, we can make it say days or we can make it weeks or even years, that is the beauty of it.

Some polymers are hydrophobic. So, the problem is bacteria can attach. They lack cell addition signals because cells can adhere, if they if they identify their polymer as host, unlike the naturals ones degradation products. For example, if poly lactic acid degrades it may give out little bit of lactic acid which may be little bit acidic. So, that problem is there which can lead to inflammation cell death tissue necrosis and all of that. So, that also can also happen, because some polymers can degrade little bit and give out some acidic. For examples if you take poly methyl methacrylate. So, it is obtained from methyl acrylic acid methyl methacrylate for example, there could be some little bit of acrylic acid present may be in PPM or even PPB which is not fully polymerized.

So, there could be some little bit of leaching of that take poly carbonate which is a very strong. It is even called engineering plastic it is as strong as any metals. In fact, shatter proof glasses for example, are made with poly carbonate they are extremely strong even bullet proof glasses are made with poly carbonate, but the problem is poly carbonate is made up of some chemicals like diphenyl carbonate and bisphenol a and little bit of bisphenol a, even small PPM or even less than that unreacted is present and if it starts leaching out and there are some worries about the bisphenol a, causing endocrine disorders and so on actually. So, that could be one problem with synthetic polymers if there is very small amount of unreacted monomer present which could be toxic to the system or if there are any degradation products which could be toxic or leaching out leachants, which could be toxic then that could be delay problematic when it is used as a biomaterial.

So, there are lot of advantages and a few disadvantages, which needs to be addressed when you are using synthetic polymers. So, we have both the natural which are also used in biomaterial application like your collagen, starch, dextrin, polysaccharide exo polysaccharides and we have the synthetic material which are widely used.

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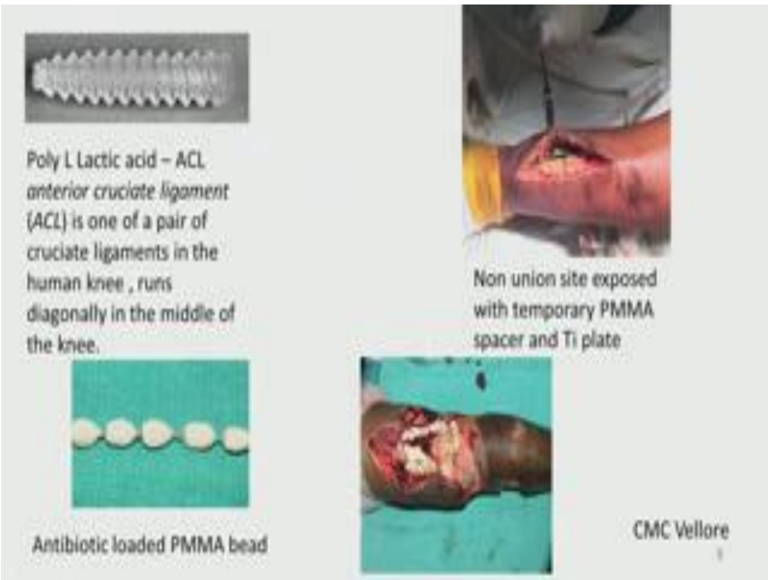

Now, I am going to show you some pictures of where polymers are used. These are curtsey from many medical centres hospitals with which I am having collaboration. For example, this is a Poly L Lactic Acid. And this is called anterior cruciate ligament screw. This is used especially if there is a ligament tare sport related injury for example. So, near the human knee actually. So, it runs diagonally in the middle of the knee. So, this is used to repair that. Look at this when there is fracture and the bones are far apart. So, non union site exposed. So, temporarily that keep poly methyl methacrylate spacer and this is the titanium plate you can see this poly methyl methacrylate.

And once it is healed that poly methyl methacrylate spacer is removed antibiotic loaded PMMA bead especially in orthopaedic surgery there is lot of problems about infection. So, they keep these poly methyl methacrylate beads impregnated with say meropenem it is a very good antibiotic as you can see here it is kept inside until all the infection for a couple of weeks may be until the infection completely goes and then these beads are removed, because poly methyl methacrylate is not degradable. So, once the drug is eluted it has to be removed. So, this is the some of these figures pictures are curtsey form Christian medical centre it is called CMC Vellore in near Chennai.

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Look at this, this is called double j polyurethane urethral stand. This is used near the bladder and ureter connection. There is an ureter here which connects the bladder ureter and the urine flows through this. And if there is a blockage and the urine does not flow they need to place this this is made up of polyurethane. So, very flexible as you can see here and it remains inside the body for couple of weeks or even going right up to 68 weeks. It faces quite lot of harsh environment here. Because of the flow urine you may have salts calcium oxalate and magnesium type of salts, you may have a e coli proteus mirabilis lico like bacteria. So, salt encrustation and bacterial infection are very serious problems here. So, these are poly lactic glycolic acid urethral stands polyurethane is not biodegradable. So, these stands have to be removed.

Once the infection is completely gone here, these are some designs of poly lactic glycolic acid urethral stand, which can slowly degrade in 4 to 6 weeks and so, hopefully you do not have to do another surgery to remove these stands. So, these are biodegradable hopefully this curtsey form C Ramachandra medical college hospital in Chennai.

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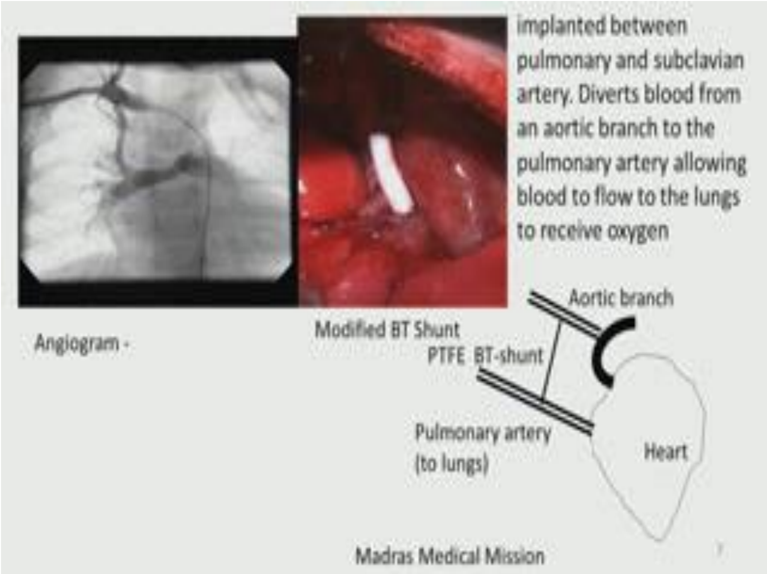

Look at this these are shunt BT-shunt it is called it is used near the heart region these are made up of this is made up of poly tetra fluoro ethylene.

So, if you take the heart here, for example, this is the pulmonary artery this is going to lungs. So, this is the we will call it the bad blood which goes to the lungs, and it gets oxygen, and then they come back to the heart and then later on the blood is pumped to the aortic branch going to various parts of the body this is going down. And this is going upward to the upper side of the body what happens is if there is a leakage inside in the heart the blood does not go to the lungs to get oxygen the blood gets shorts circuited. So, the patient does not get oxygen. And sometimes if it is a paediatric patient they become slightly blue. This is called a blue baby syndrome and this problem can arise especially in a paediatric; that means, a child could be born with this problem there could be a small hole in the connecting chambers. So, the blood, instead of going to the pulmonary artery to the lungs gets short circuited and go to aorta.

So, there might not be enough oxygen. So, what they do is they attach this PTFE poly tetra fluoro ethylene BT-shunt they call it. So, between the pulmonary and the subclavian artery, it diverts the blood from the aortic branch to the pulmonary atria along the blood to flow to the lungs to receive oxygen. So, once this is done, the blood gets enough oxygen and so the paediatric patient also recovers otherwise there is insufficient oxygen in the blood the patient looks slightly blue in colour because blood does not have enough oxygen. So, that was also called the blue baby syndrome and they discovered this new treatment or a operating procedure they were able to save lot of babies, by attaching this poly tetra fluoro ethylene shunt here.

Now, one problem with this is as the baby grows, the rest of the body grows, but this PTFE shunt size remains the same this is this to be in millimetre range. So, they may have to conduct another operation to have bigger diameter shunt. So, that is the big problem here. They do this because the baby may be too small to conduct an open heart surgery, if the child becomes older and can is able to sustain an open heart surgery, then the doctors open the heart and patch up the whole that is present inside the chamber. So, ones the whole is patched up then the blood will definitely go in to the pulmonary artery to the lungs, to get sufficient amount of oxygen. So, when operation cannot be conducted because the baby may be too small operation means I am talking about open heart surgery then they temporarily put this temporarily when I say temporarily it may last for few years, until the baby is older stronger for it to undergo and open heart surgery. So, this is made up of PTFE poly tetra fluoro ethylene this is an angiogram.

You can see that in angiogram is nothing, but they pass a dye and they are able to see the flow of the blood because the dye can be viewed from outside. This is this is curtsey form a hospital called madras medical mission in Chennai. So, as you can see I am showing you lot of pictures of polymers, where finding applications in different areas of the biomaterial research. This is a cross linked polyethylene it is used for total knee replacement surgery.

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So, we have a cobalt chromium metals, cobalt chromium molybdenum. So, we have the rotating ball and socket like and so polyethylene finds application there, because they do not want to have a metal on metal that is both ball and socket being metal and metal they have one of them as polymer. So, the attrition rate would be much less whereas metal on metal could lead to lot of metal debris like if you remember we did a problem in the previous class the amount of cobalt ions that get released per year. So, polymers are used mostly polyethylene ultra high molecular weight polyethylene is used here, as you can see in this picture for the knee replacement surgery this is the curtsey from CMC Vellore.

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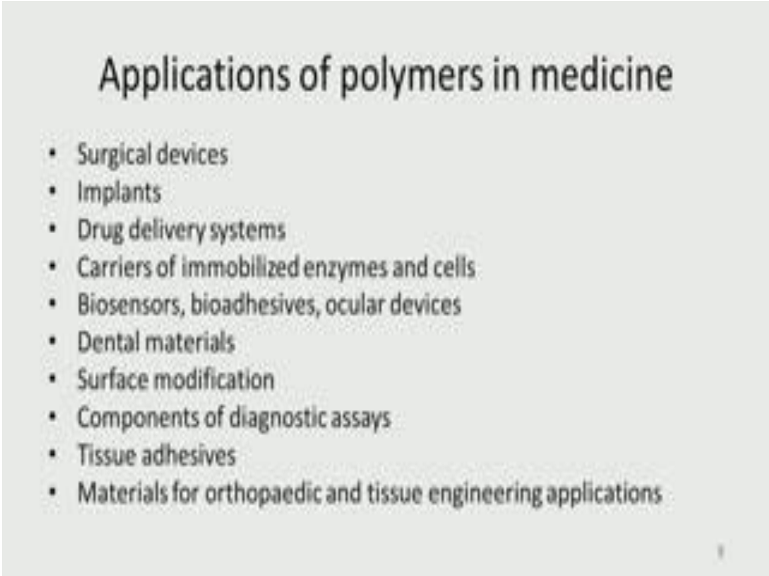

So, lot of applications polymers have surgical devises implants I showed you so many different examples drug delivery systems. So, you want to slow release antibiotics we can coat surfaces with carriers of immobilized enzymes and cells. So, we can have delivery systems we can have immuno modulators and other growth factors which needs to be delivered very targeted drug delivery, to particular cells may be cancerous cells or tumours then polymers are very important.

Bio sensors, we can have bio sensors made up of polymers bio adhesives. Nowadays there is lot of interest in can I joint after an operation surfaces of these skin rather than having a ocular devises, like your eye implant ocular implant contact lenses dental materials poly methyl methacrylate acrylic acid dental cements. So, all these are made up of polymers surface modification. So, we can modify metal surfaces by coating with polymer we can have polymer inserts to avoid metal on metal rubbing. We can have inserts to prevent dissimilar bi metallic current being produced and so on. Components of diagnostic assays tissue adhesives materials for orthopaedic and tissue engineering applications, I showed you lot of pictures related to orthopaedic and tissue applications. So, lot of applications of polymers in medicine you which cannot be carried out by any other material.

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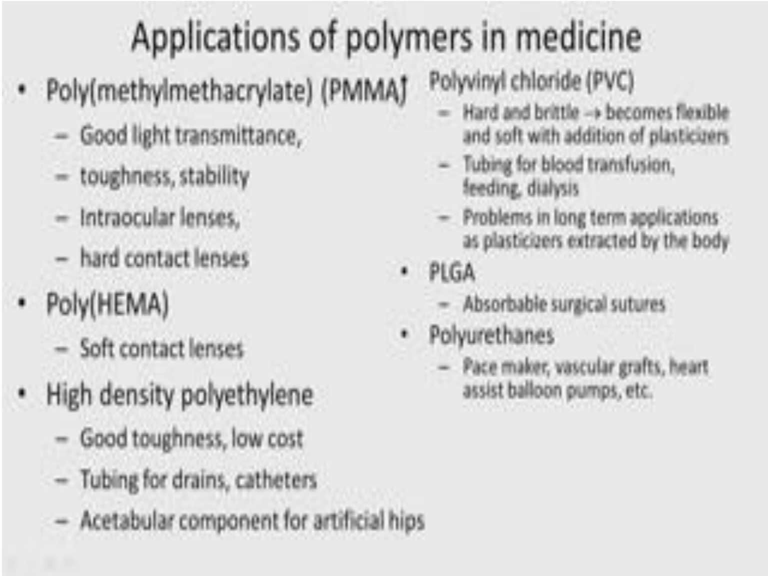

So, as I showed you we will talk about little bit on some of these polymers am poly methyl methacrylate. It is extremely useful, it is used in dental ocular applications hard contact lenses, intraocular lenses, orthodo notic applications good light transmittance. So, they are able to transmit light. So, it is quite tough stable it is very stable especially in oral environment and they also look almost like that teeth that is why in dental applications we find lot of these poly methyl methacrylate.

Poly hema hydroxy ethyl methyl, product ethyl methyl is extremely because it is hydroxy it is extremely hydrophilic. So, it is used in soft contact lenses as you know contact lenses have to be hydrophilic. And they should be able to take in lot of moisture that is why especially if the moisture content of the eyes goes down eyes can become red and irritable that is why poly hema is used. And especially in soft contact lenses because they are quite flexible unlike the hard contact lenses which can be used only for few hour then the eyes become red it has to be removed, where as soft contact lenses can be used for much longer duration. That is the advantage of poly hema high density poly ethylene it is used quite a lot in knee, especially in the area of ball and socket there you know good tough low cost it is used in tubing for drains in catheters urinary catheters different types of trackial catheters.

So, HDPE is used artificial hips HTP is used then comes poly vinyl chloride, this is extremely inert material smooth. It is hard and brittle it becomes flexible and soft by adding plasticizers as you know, especially the insulator on top of electrical cables they always have PVC. It is used in blood transfusion feeding dialysis one big problem is long duration some of the plasticizers, like phthalates are used to make it flexible they may start leaching out in to the body fluid, which may have adverse reaction with the cells it may coast toxicity, that is one big problem with PVC for long duration. It is not very advisable because the plasticizers that are added could be creating problem. So, it is good for short duration applications like your dialysis blood transfusion which may be few hours.

PLGA poly lactic glycolic acid, so contains 2 different monomers lactic acid glycolic acid. So, you produce a polymere polymer with these. So, we can have different combinations lactic to glycolic. So, if I have very large glycolic I can have a fast biodegradation, if I have more lactic I can have slow biodegradation. So, we can have different ratios and get different products. So, these are surgical sutures once upon a time sutures were made up of nylon which are very strong and they were not biodegradable. So, when there was an external wound doctors used to cow bring those skin together and suture with a nylon and once the wound has healed they will pull the nylon out.

So, the doctor have to perform more slight operation, but here PLGA is bio reabsorbable. So, it will completely dissolve disappear. So, we do not have to go to the doctor again PLGA is quite strong and tough and it is bio reabsorbed completely. So, we do not have to go again, to remove it polyurethanes extremely flexible and inert they are almost like a rubber. So, vascular grafts heart assist balloon pumps diaphragms heart diaphragms pace makers. So, everywhere PU is used polyurethane. So, there is lot of business for polyurethane also.

So, some of these polymers I would say poly methyl methacrylate polyurethanes they have good applications wide range in applications in the area of biomaterial and hema highly extremely hydrophilic and they absorb quite a lot of moisture. So, they are used in contact lenses or even wound dressings because they can swell and absorb lot of moisture especially wounds after burn hema is good, if you want very tough material like a polyethylene, which are used in knee replacement and such type of strong applications PVC is inert material and, but the problem is you have these plasticisers which may leach out. So, it is good for short duration application. So, PVC is one meant only for short duration applications where as PMMA, for example, polyurethane SDP they are used for much longer duration applications also.

So, we will continue more on the polymers in the next class also.

Thank you very much.