تفريغ فيزيكال 2

محاضرة: Polymers

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لجان الدُّفعات

Soul Academy

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Science

Physical Pharmacy II
Pharmaceutical polymers

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Pharmaceutical polymers

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objectives

At the conclusion of this chapter student should be able to:

- Know the basic concepts of polymers, definitions, and descriptive terms.
- Understand the thermal, physical, and mechanical properties of polymers in general.
- Explain the glass (T_g) transition temperature and factors affecting the T_g.
- Understand how polymer molecular weight affects its properties.
- Know what types of polymers are generally used in the pharmaceutical area.
- Explain why polymers are used in drug delivery applications.

Introduction

- **History of polymers**
- **In the 20th century**: More advanced technologies and opened new fields of application in the pharmaceutical & biomedical sectors.
- **In recent years**, polymers have been used to develop devices for controlling drug delivery or for replacing **failing natural organs**.
- In oral delivery, polymers are used as coatings, binders, taste maskers, protective agents, drug carriers, and release controlling agents.
- **In tansdermal patches**, polymers are used as backings, adhesives, or drug carriers in matrix or membrane products.
- **Controlled delivery** of proteins and peptides has been made possible using biodegradable polymers.
- ***The key difference between early polymers and pharmaceutical polymers is the biocompatibility.***

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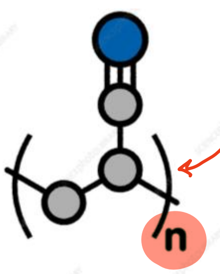
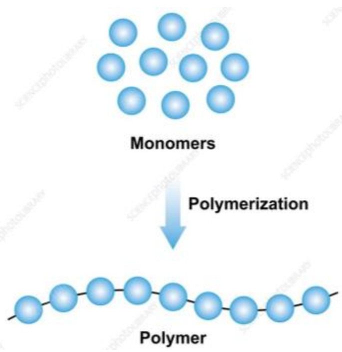
Introduction

- **POLYMERS IN GENERAL**
- The word "polymer" means "many parts."
- A polymer is a large molecule made up of many small repeating units
- A monomer is a small molecule that combines with other molecules of the same or different types to form a polymer
- The structure of a polymer is displayed by showing the repeating unit (the monomer residue) and an "n" number that shows how many monomers are participating in the reaction

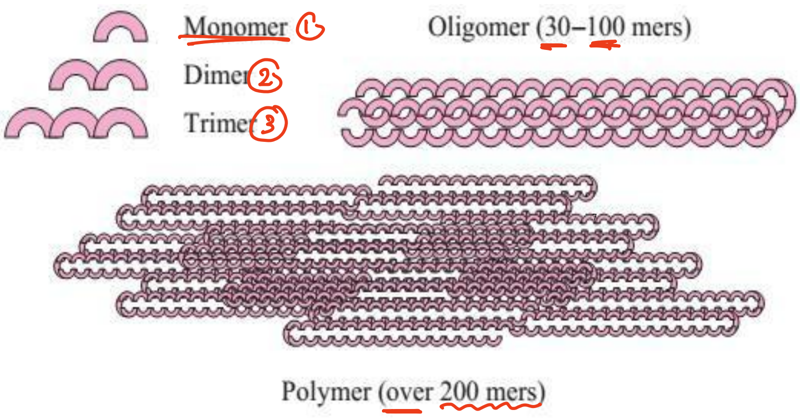


polyacrylonitrile



Introduction

•POLYMERS IN GENERAL



Degree of Polymerization (DP) = Number of monomers in a chain (n)

Fig. 20–1. Polymer anatomy.

Characteristics اهم الـ
او الـ Attributes
الي بوصف فيهم الـ Polymers

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Introduction

- **POLYMERS IN GENERAL**
- From a thermodynamic perspective, polymers cannot exist in the gaseous state because of their high molecular weight. ← مهمة
- They exist only as **liquids or high solid** materials

دائمًا بالحالة الصلبة او السائلة
ولو حتى سخنتهم ما بصيروا غاز

- Molecular weight of polymers can be adjusted for a given application
- Silicone polymer — lubricant
  - –as vacuum grease (low molecular weight), and
  - –as durable implants (very high molecular weight)

بقدر اتحكم بكمية وعدد الـ Mono على حسب الـ Application
الزرعات الي بالعمليات

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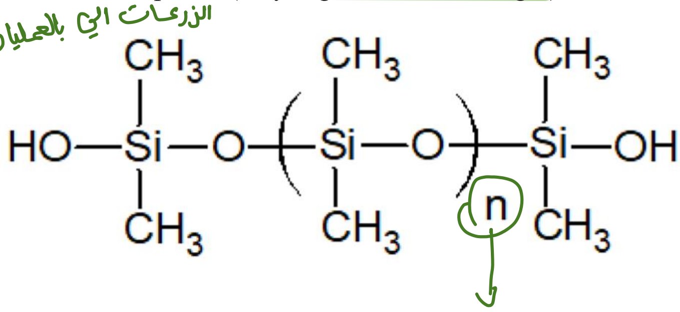

نفس الـ Monomers
لكن تغير n بعطي لكل Polymer خصائص
واستخدامات غير

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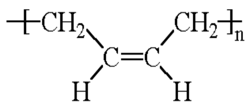
Introduction

- **POLYMERS IN GENERAL**
- The physical and mechanical properties of the polymers can also be modified by blending them with other polymers. Blending polymers can achieve superior properties that are unattainable from a single polymer

– polystyrene is not resistant against impact, so a polystyrene cup can be easily smashed into pieces if compressed between your fingers.

– However, polystyrene blended with polybutadiene is an impact resistant product.



Polystyrene + polybutadiene

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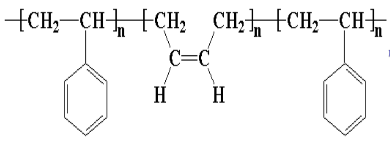
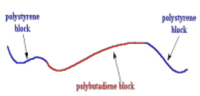
Introduction

- **POLYMERS IN GENERAL**

Alternatively, monomers of styrene and butadiene can be copolymerized to make a new copolymer of styrene and butadiene: Poly(styrene-butadiene-styrene), or SBS





- SBS is a hard elastomer used for things like soles of shoes, tire treads, and other places where durability is important. It's a “block copolymer”.
- Polystyrene is a tough hard plastic, and this gives SBS its durability. While polybutadiene is a rubbery material, and this gives SBS its rubber-like properties.
- Since SBS contains rubber and plastic, it acts like both materials.

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POLYMER SYNTHESIS

- There are two types of polymerization processes, depending on the structure of the polymer (depends on the monomers structure)
  - –Addition Polymerization (Chain, free radicals, vinyl) polymerization
  - –Condensation Polymerization step polymerization

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POLYMER SYNTHESIS

- **Addition Polymerization**
  - –For an unsaturated polymer, polymerization starts at the double bond site (π bond) by the addition of a free radical on the monomer
  - –Free-radical polymerization is also known as chain or addition polymerization
  - –Free-radical polymerization is known as "chain" or "addition polymerization".
  - –Sometimes referred to as "vinyl polymerization".
  - –It also occurs by "ring opening" of cyclic monomers.

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Free Radical → π Bond — Attack

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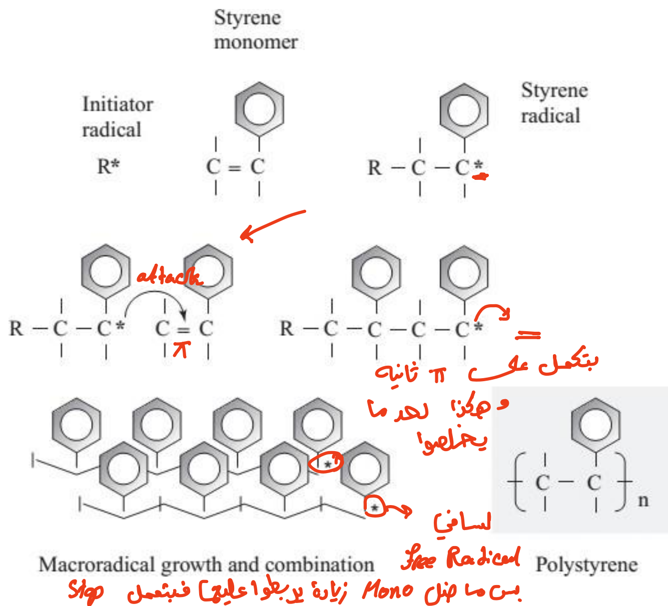
POLYMER SYNTHESIS

- **Addition Polymerization (steps)**



Addition or free-radical polymerization of styrene

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POLYMER SYNTHESIS

- **Condensation Polymerization**
- For monomers possess functional groups such as hydroxyl, carboxyl, or amines
  - For example, a monomer containing a reactive hydrogen from the amine residue can react with another monomer containing a reactive hydroxyl group (a residue of carboxyl group) to generate a new functional group (amide) and water as a side product
- In condensation polymerization, also called step polymerization, two or more monomers carrying different reactive functional groups interact with each other.
- The reaction product can grow by reacting with another monomer generating a macromonomer.
- There are no radicals involved in this reaction.

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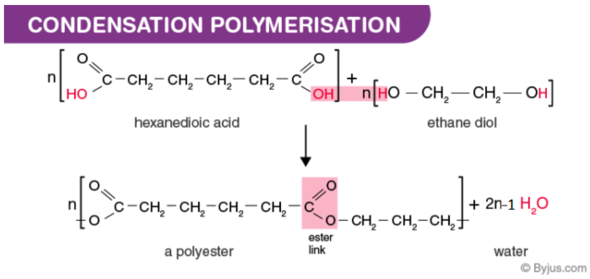
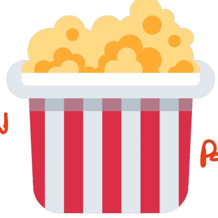
POLYMER SYNTHESIS

- **In comparison**
- Free-radical polymerization is an addition reaction that is characterized by **fast growth of macroradicals**.
- There is a high chance that high–molecular-weight chains are formed in free-radical polymerization
- Condensation polymerization is a **stepwise reaction** in which smaller species are initially formed first and then combined to make higher-molecular-weight specie
- Condensation polymerization tends to be slow generally lasting for several hours



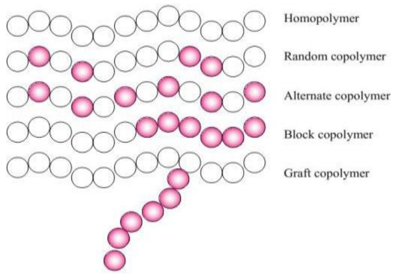
POLYMERIZATION METHODS

- **Homogeneous Polymerization**
- **Bulk polymerization**
  - –Only monomer and initiator are used - no solvents or additives.
  - –The process is "homogeneous" because everything is uniformly mixed.
  - –water-soluble monomers produce water soluble polymers, and oil soluble monomers produce oil soluble polymers.
  - –Sometimes water-swellable polymer is prepared.
  - –Water-swellable polymer occurs due to excessive exothermic heat resulting in hydrogen abstraction from the polymer backbone, which promotes cross-linking reactions at the defective site.
  - –The cross-linked polymer obtained without using any chemical cross-linker is called a **popcorn** polymer and the reaction is called "**popcorn polymerization**." (e.g., Crospovidone is a cross-linkedpolymer of vinyl pyrrolidone)



COPOLYMERS AND POLYMER BLENDS

- Polymer systems can be physically blended or chemically reacted in order to modify their properties
- **Polymer Blends**: are simply made by physical blending of two different polymers in molten or in solution state
- **Copolymerization**: refers to a polymerization reaction in which more than one type of monomer is involved. Generally, copolymerization includes two types of monomers.



*A **terpolymer** (less common; involves 3 monomer types).*

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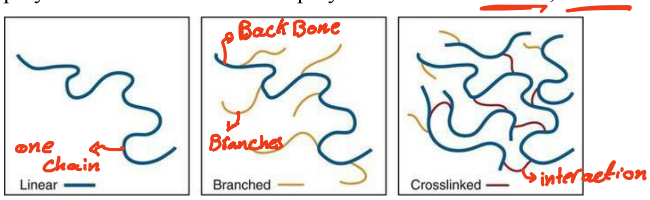
TOPOLOGY

- The topology of a polymer refers to the overall shape, structure, and arrangement of its molecular chains. It describes how the polymer chains are organized and interconnected, which can significantly influence the physical properties and behavior of the polymer.
- The topology of a polymer describes whether the polymer structure is linear, branched, or cross-linked



- **Linear polymers**
  - –Weak intermolecular forces hold the polymer chains together.
  - –Linear polymer can show dual behavior, where:
    - Chains can freely move, offering the polymer a **low melting temperature**,

      or
    - Chains may have a higher chance of approaching each other in their solid state, which increases their crystallinity and melting temperature.

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TOPOLOGY AND ISOMERISM

- A branched polymer might display better solvent permeability compared to its linear counter part due to its side groups (e.g., gum Arabic is a highly branched polymer with very high solubility in water).
- If a linear polymer is cross-linked, its solubility will be sacrificed at the expense of swellability. Therefore, a cross-linked polymer can swell in a solvent to an extent that is inversely related to the amount of cross-linker.

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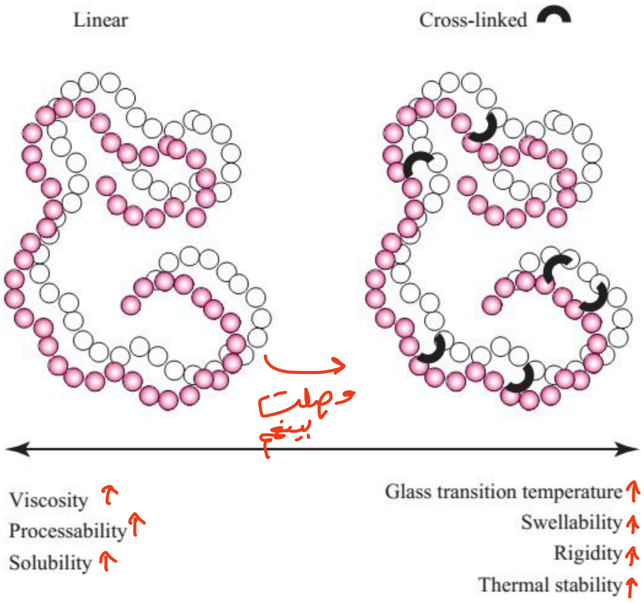
TOPOLOGY



THERMOPLASTIC AND THERMOSET POLYMERS

1- • Thermoplastic polymers

- **Linear or branched** polymers generally behave as thermoplastics
- Can undergo melting, which is potentially useful in processes such as compression molding, injection molding, and thermoforming
- Gain more freedom to move as temperature increases (i.e., high processability).
- Generally dissolves in an appropriate solvent.
- Examples include: 1- polystyrene, 2- polyethylene, and 3- poly (vinyl chloride).

THERMOPLASTIC AND THERMOSET POLYMERS

2- • Thermosetting polymers

- Are **cross-linked** polymers.
- Do not soften upon heating and decompose with further application of heat.
- Since there is no reversible melting and solidifying in thermoset polymers, they are very useful when a thermo-resistant polymer is desirable.
- Addition of cross-links to a polymer structure will hinder its chain movement and reduce its solubility, and
- Thus cross-linked polymers swell (rather than dissolve) when they are placed in a compatible solvent.

POLYMER PROPERTIES

- **Crystalline and Amorphous polymers**

- Polymers display different thermal, physical, and mechanical properties depending on their structure, molecular weight, linearity, intra- & inter- molecular interactions.
- Polymers can exist in either crystalline (regular packing) or amorphous states (irregular packing).
- The ***optical properties*** of a polymer are changed from transparent (amorphous) to opaque (semicrystalline), due to differences in their refractive indices.

POLYMER PROPERTIES

- **Crystalline and Amorphous polymers**
- Crystallinity increases polymer **strength & stiffness** (as a result of increased intermolecular interactions).
- Crystallinity also increases the **barrier properties** of the polymer (drugs usually cannot penetrate or diffuse through crystalline domains).
  - Crystalline polymers display better barrier properties and durability in the presence of attacking molecules.
  - A less crystalline or an amorphous polymer is preferred when the release of a drug or an active material is intended.

POLYMER PROPERTIES

• Thermal Transitions

- Thermal transitions in polymers differ due to their molecular structures: crystalline polymers have an ordered, tightly packed arrangement that results in a distinct melting temperature (Tm) where they transition from solid to liquid as the intermolecular forces are overcome. In contrast, amorphous polymers have a disordered structure and exhibit a glass transition temperature (Tg), where they transition from a hard, glassy state to a soft, rubbery state over a range of temperatures due to increased molecular mobility. This difference arises because crystalline polymers undergo a sharp phase change involving latent heat, while amorphous polymers experience a gradual increase in free volume and chain movement without a distinct phase change.

- Thermal transitions in polymers can occur in 2 different ways
  - Crystalline polymer melts, and show *melting temperature* (T_m).
  - Amorphous polymer shows glass transition temperature (T_g).

الخاصية	البوليمرات البلورية	البوليمرات اللامتبلورة (غير البلورية)
التركيب الجزيئي	منتظم ومرتّب	غير منتظم وعشوائي
نوع الانتقال الحراري	درجة انصهار (Tm)	درجة انتقال زجاجي (Tg)
طبيعة الانتقال	انتقال حاد ومفاجئ	انتقال تدريجي
التغير في الحالة	من صلب إلى سائل	من صلب زجاجي إلى مطاطي
السبب	كسر القوى بين الجزيئات	زيادة الحركة وسعة الفراغ بين السلاسل
وجود حرارة كامنة	نعم	لا

• Thermal Transitions

- The glass transition (T_g) of a polymer depends on many factors

• *Length of polymer chains:*

- Longer chains provides smaller free volume (the space between the polymer chain ends) than shorter ones, and thus corresponds to higher T_g values.

• *Polymer chain side group*

- Bulkier side group corresponds to higher T_g values (due to steric hindrance causing lower segmental motion in the polymer).
- Polar side groups provide stronger intermolecular interactions that also affect the motion of polymer chains, and the polymer displays a higher Tg.

POLYMER PROPERTIES

- ***Polymer chain flexibility*:**
  - Flexible polymer chains displays higher desire to move (and thus lower T_g) than rigid chains.
- ***Polymer chain branching***
  - Linear polymer chains possess smaller free volume as opposed to branched ones, thus, higher T_g is expected for linear polymers.
  - Branches in branched polymers impose hindrance to chain motion, for which higher T_g is expected.

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POLYMER PROPERTIES

- ***Polymer chain cross-linking***
  - Cross-linking limits chain movement resulting in higher T_g values.
- ***Processing rate***
  - Rate of processing (as heating & cooling) can affect molecular motion in polymers. In fast processes, the chains cannot move to the extent that they are expected to and may display a high T_g for the same polymer

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- ***Plasticizers***
  - A plasticizer is added to a polymer to enhance its flexibility and help its processing; it facilitates the movement of polymer chains against each other.
  - Plasticizers results in *reduction in the T_g* of the mixture (i.e., lower the T_g).

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✅ أولاً: الانتقالات الحرارية (Thermal Transitions)

ملحق

📌 الانتقال الزجاجي (Tg) يتأثر بعدة عوامل:

العامل	التأثير على Tg
طول السلاسل الجزيئية	سلاسل أطول → فراغ حر أقل → **Tg أعلى**
المجموعات الجانبية bulky	مجموعات أكبر → إعاقة حركية أكثر → **Tg أعلى**
المجموعات الجانبية القطبية	تفاعل بين الجزيئات أقوى → **Tg أعلى**
مرونة السلسلة الجزيئية	سلاسل مرنة أكثر → حركة أكبر → **Tg أقل**
تشعب السلاسل	- سلاسل خطية → فراغ أقل → **Tg أعلى** - التشعب يعيق الحركة → **Tg أعلى**
الروابط العرضية (Cross-linking)	تمنع الحركة → **Tg أعلى**
سرعة المعالجة (التسخين/التبريد)	عمليات سريعة → تقليل الحركة → **Tg أعلى**
المُلدّنات (Plasticizers)	تزيد مرونة البوليمر → **Tg أقل**

العامل	التأثير على Tg	التفسير
طول السلسلة الجزيئية	يزيد Tg	السلاسل الأطول → فراغ حر أقل → حركة أقل
المجموعة الجانبية bulky	يزيد Tg	تعيق حركة السلسلة (Steric hindrance)
المجموعة الجانبية القطبية	يزيد Tg	تفاعلات بين جزيئية أقوى تقلل الحركة
مرونة السلسلة الجزيئية	يقل Tg	سلاسل مرنة → حركة أسهل
تشعب السلسلة	غالبًا يزيد Tg	فروع تعيق الحركة رغم وجود فراغ
الروابط العرضية (Cross-linking)	يزيد Tg	تمنع حركة السلاسل الجزيئية
سرعة المعالجة (تسخين/تبريد)	يزيد Tg في العمليات السريعة	الحركة لا تأخذ وقتها الكافي
المُلدّنات (Plasticizers)	تقلل Tg	تزيد مرونة السلاسل

POLYMER PROPERTIES

Molecular weight

- A polymer batch may contain polymer chains with different lengths (molecular weights) and hence different molecular weight distributions.
- The molecular weight of all chains should be considered and must be averaged to have a more realistic figure for molecular weight of a given polymer.

POLYMER PROPERTIES

• *Mechanical properties weight*

- Depending on their structure, molecular weight, an intermolecular forces, polymers resist differently when they are stressed
- **They can resist against:**
  - Stretching (tensile strength)
  - Compression (compressive strength)
  - Bending (flexural strength)
  - Sudden stress (impact strength)
  - Dynamic loading (fatigue)

Type of Stress	Mechanical Property	Description
📏 Stretching	Tensile Strength	Resistance to pulling apart (e.g., rubber bands, fibers)
🔻 Compression	Compressive Strength	Resistance to being squeezed or flattened (e.g., packaging foams)
➰ Bending/Flexing	Flexural Strength	Resistance to bending or snapping (e.g., plastic rulers)
💥 Sudden Impact	Impact Strength	Resistance to shock or sudden force (e.g., helmets, safety glasses)
🔁 Repeated Load	Fatigue Resistance	Ability to withstand many cycles of stress (e.g., tires, gears)

✅ الخصائص الميكانيكية للبوليمرات

نوع القوة	ماذا تقيس؟	ملاحظات
الشد	مقاومة التمدد (Tensile Strength)	البوليمرات المرنة أفضل
الانضغاط	مقاومة الانضغاط (Compressive Strength)	البوليمرات الصلبة أفضل
الانحناء	مقاومة الانحناء (Flexural Strength)	تعتمد على الصلابة
الصدمة	مقاومة الصدمة المفاجئة (Impact Strength)	مهمة في المواد المعرضة للسقوط
الإجهاد الدوري	مقاومة التحميل المتكرر (Fatigue Strength)	مهمة في التطبيقات المتكررة مثل المفصلات

POLYMER PROPERTIES

- ***Mechanical properties weight***
  - By increasing the molecular weight and hence the intermolecular forces, polymers display superior properties under an applied stress.
  - As far as structure is concerned, a flexible polymer can perform better under stretching whereas a rigid polymer is better under compression.
  - A polymer is loaded and its deformation is monitored to measure its strength
- ***Viscoelastic Properties***
  - Polymers are neither a pure elastic nor a pure fluid material
  - They have the ability to store energy (display elastic behavior) and to dissipate it (display viscous behavior)
  - Over time, the polymer intermolecular forces will essentially become weaker and hence, the **polymer becomes softer**.

POLYMER AND MOLECULAR WEIGHT

- The mechanical properties of a given polymer generally increase with an increase in molecular weight
- As molecular weight increases, polymer chains are more likely entangled into each other at certain molecular weights.
  - Poor polymer flow either in solid state (as a melt) or in solution state (as a solution)

CLASSIFICATION OF POLYMER

- Polymers may also be classified according to their solubility into
- Water insoluble polymers
- Water soluble polymers
- Hydrogels

CLASSIFICATION OF POLYMER

- Water insoluble polymers
  - –Oil or organic soluble
  - –Ethyl cellulose and a group of cellulose esters such as cellulose acetate butyrate or phthalate are organic soluble
  - –Used in fabrication of membranes, containers, and tubing
  - –Diffusion of solutes from non-porous solid polymer is govern by Fick's first law
  - –Permeability is a function of a crystallinity and molecular weight
  - –Permeation of drug is a function of drug solubility in the polymer
  - –Permeability to gases:
    - ▪ Packaging material
    - ▪ Depends on the polarity of the polymer-more polar polymers are more ordered and less porous thus less oxygen permeability

CLASSIFICATION OF POLYMERS

• Hydrophilic polymers

- Polymer dissolves in water to form a polymer solution or hydrosol
- The cellulose ethers with methyl and hydroxypropyl substitutions are water- soluble
- The synthetic water-soluble polymers have extensive applications in pharmaceutical industries
  - Polyethylene glycol
  - Polyethylene glycol vinyl alcohol polymers,
  - Polyethylene oxide
  - Polyvinyl pyrrolidone
  - Polyacrylate
  - Polymethacrylate esters containing anionic and cationic functionalities

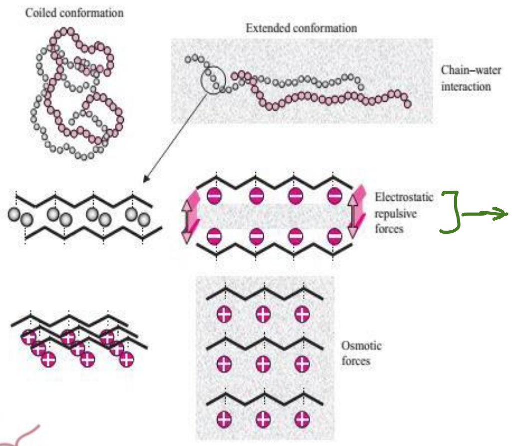
CLASSIFICATION OF POLYMER

• Hydrogels

- Swellable polymers
- when placed in excess water, are able to swell rapidly and retain large volumes of water in their structures
  - Such aqueous gel networks are called hydrogels
- These are usually made of a hydrophilic polymer that is cross- linked either by chemical bonds or by other cohesion forces such as ionic interaction, hydrogen bonding, or hydrophobic interactions.

CLASSIFICATION OF POLYMER

- **Hydrogels**
- Mechanism of swelling
  - –Polymer-solvent interactions
  - –Electrostatic repulsive forces
    - Similar charges on the polymer backbone will repel each other upon ionization in an aqueous medium. This creates more spaces inside the hydrogel
  - – Osmosis
    - The presence of ions inside the gel and the absence of the same ions in the solvent trigger a diffusion process (osmosis)



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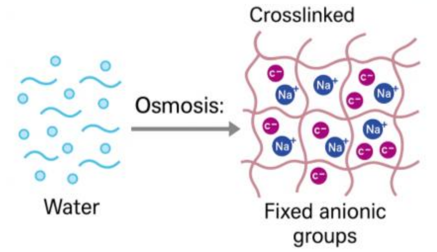

Osmosis: water enters gel due internal ionic pressure

PHARMACEUTICAL APPLICATIONS OF POLYMERS

- **Water-Soluble Synthetic Polymers**
- **Poly (acrylic acid):** Cosmetic, pharmaceuticals, immobilization of cationic drugs, base for Carbopol polymers
- **Poly (ethylene oxide):** flocculent, very high molecular-weight up to a few millions, swelling agent
- **Poly (ethylene glycol):** Mw <10,000; liquid (Mw <1000) and wax (Mw >1000), plasticizer, base for suppositories
- **Poly (vinyl pyrrolidone):** Used to make betadine (iodine complex of PVP) with less toxicity than iodine, , tablet granulation
- **Poly (vinyl alcohol):** Water-soluble packaging, tablet binder, tablet coating
- **Polyacrylamide:** Absorbent

مش لازم بالتفصيل حكيت اعرفوهم وممكن تجيبس عليهم سؤال بورنس 🐸

PHARMACEUTICAL APPLICATIONS OF POLYMERS

- **Cellulose-Based Polymers**
- **Ethyl cellulose:** Insoluble but dispersible in water, aqueous coating system for sustained release applications
- **Carboxymethyl cellulose:** Superdisintegrant, emulsion stabilizer
- **Hydroxyethyl and hydroxypropyl celluloses:** Soluble in water and in alcohol, tablet coating
- **Hydroxypropyl methyl cellulose:** Binder for tablet matrix and tablet coating, gelatin alternative as capsule material
- **Cellulose acetate phthalate:** Enteric coating

PHARMACEUTICAL APPLICATIONS OF POLYMERS

- **Hydrocolloids**
- **Alginic acid:** Oral and topical pharmaceutical products; thickening and suspending agent in a variety of pastes, creams, and gels, as well as a stabilizing agent for oil-in-water emulsions; binder and disintegrant
- **Carrageenan:** Modified release, viscosifier
- **Hyaluronic acid:** Cosmetics
- **Pectinic acid:** Drug delivery

PHARMACEUTICAL APPLICATIONS OF POLYMERS

- **Water-Insoluble Biodegradable Polymers**
- **(Lactide-co-glycolide) polymers:** Microparticle– nanoparticle for protein delivery
- **Starch-Based Polymers**
- **Starch:** Glidant, a diluent in tablets and capsules, a disintegrant in tablets and capsules, a tablet binder
- **Sodium starch glycolate:** Superdisintegrant for tablets and capsules in oral delivery

PHARMACEUTICAL APPLICATIONS OF POLYMERS

- **Plastics and Rubbers**
- **Polyurethane:** Transdermal patch backing (soft, comfortable, moderate moisture transmission
- **Silicones:** Therapeutic devices, implants, medical grade adhesive for transdermal delivery
- **Polychloroprene:** Plungers for syringes
- **Polyisobutylene**: Pressure sensitive adhesives for transdermal delivery
- **Polycyanoacrylate:** A drug carrier in nano- and microparticles
- **Poly (vinyl acetate):** Binder for chewing gum
- **Polystyrene**: Petri dishes and containers for cell culture
- **Polypropylene:** Tight packaging, heat shrinkable films, containers

PHARMACEUTICAL APPLICATIONS OF POLYMERS

- **Plastics and Rubbers**
- **Poly (vinyl chloride):** Tubing
- **Polyethylene:** Transdermal patch backing for drug in adhesive design, wrap, packaging, containers
- **Poly (methyl methacrylate):** Hard contact lenses
- **Poly (hydroxyethyl methacrylate):** Soft contact lenses
- **Acrylic acid and butyl acrylate copolymer:** High Tg pressure–sensitive adhesive for transdermal patches
- **2-Ethylhexyl acrylate and butyl acrylate copolymer:** Low Tg pressure–sensitive adhesive for transdermal patches
- **Vinyl acetate and methyl acrylate copolymer:** High cohesive strength pressure–sensitive adhesive for transdermal patches

PHARMACEUTICAL APPLICATIONS OF POLYMERS

- **Plastics and Rubbers**
- **Ethylene vinyl acetate and polyethylene terephthalate:** Transdermal patch backing (occlusive, heat sealable, translucent)
- **Ethylene vinyl acetate and polyethylene:** Transdermal patch backing (heat sealable, occlusive, translucent)
- **Polyethylene and polyethylene terephthalate:** Transdermal patch backing (when ethylene vinyl acetate copolymer is incompatible with the drug

POLYMERIC DRUG DELIVERY SYSTEMS

- Coating
  - –Those that **dissolve rapidly**
  - –Those that allow **slow diffusion** of solute or some **delayed diffusion** by acting as gel layers
  - –Materials that have been used as film formers include
    - Cellulose acetate phthalate
    - Glyceryl stearates
    - Paraffins
      cellulose acetate phthalate
    - A range of anionic and cationic polymers such as the Eudragit polymers

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POLYMERIC DRUG DELIVERY SYSTEMS

- **Matrices**
- A non-eroding matrix: passage of water through pores of insoluble polymer or water soluble polymer(swelling and gelation) followed by diffusion
- A reservoir system : drug contained in the reservoir releases by leaching or slow diffusion through the wall of the retaining polymer membrane
- An eroding matrix: drug is released when the polymer matrix in which a drug is dissolved or dispersed erodes by either bulk erosion or surface erosion
- **Microcapsules, Microsphere, Nanocapsules, NanoSpheres**

POLYMERIC DRUG DELIVERY SYSTEMS