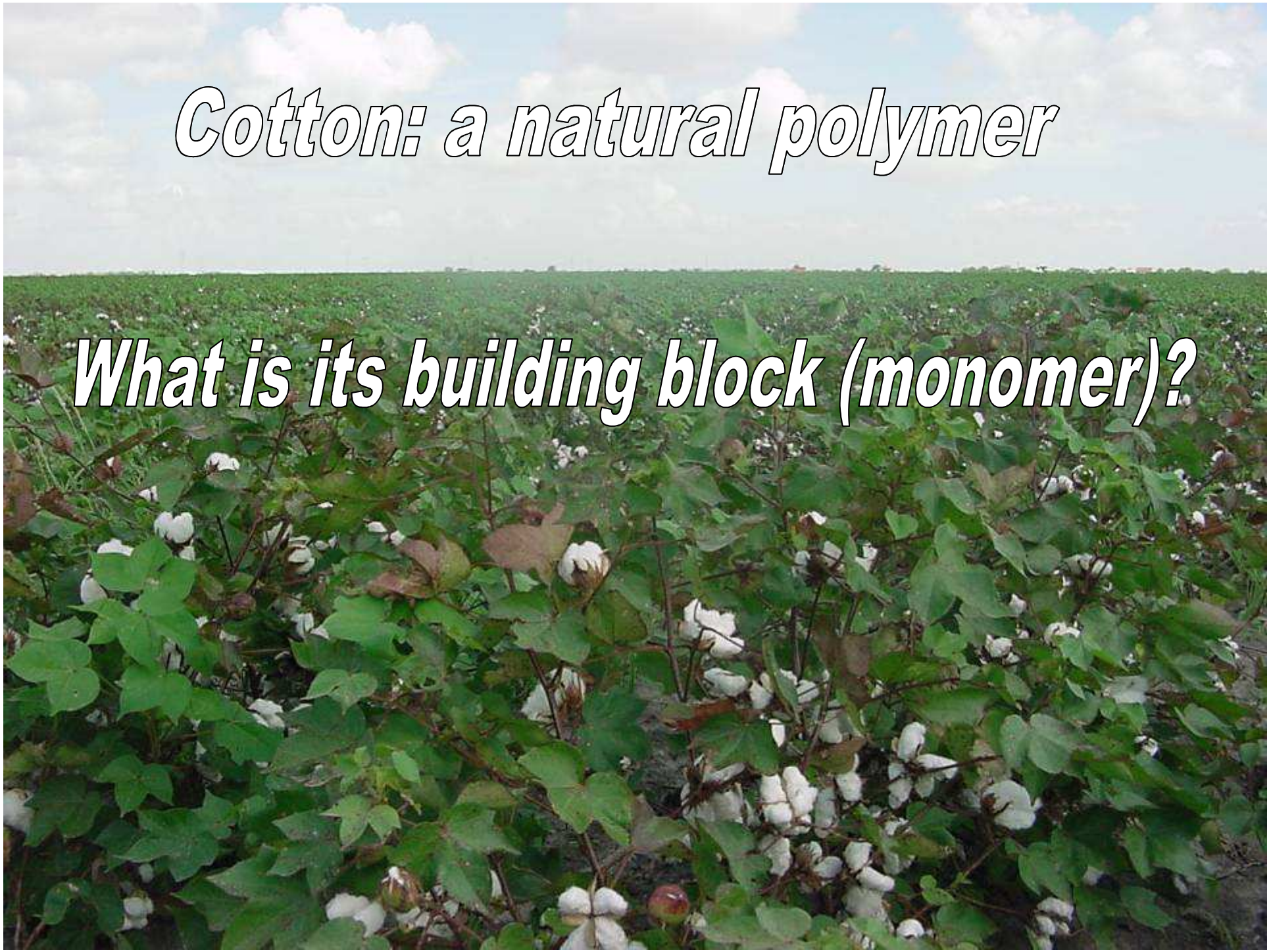
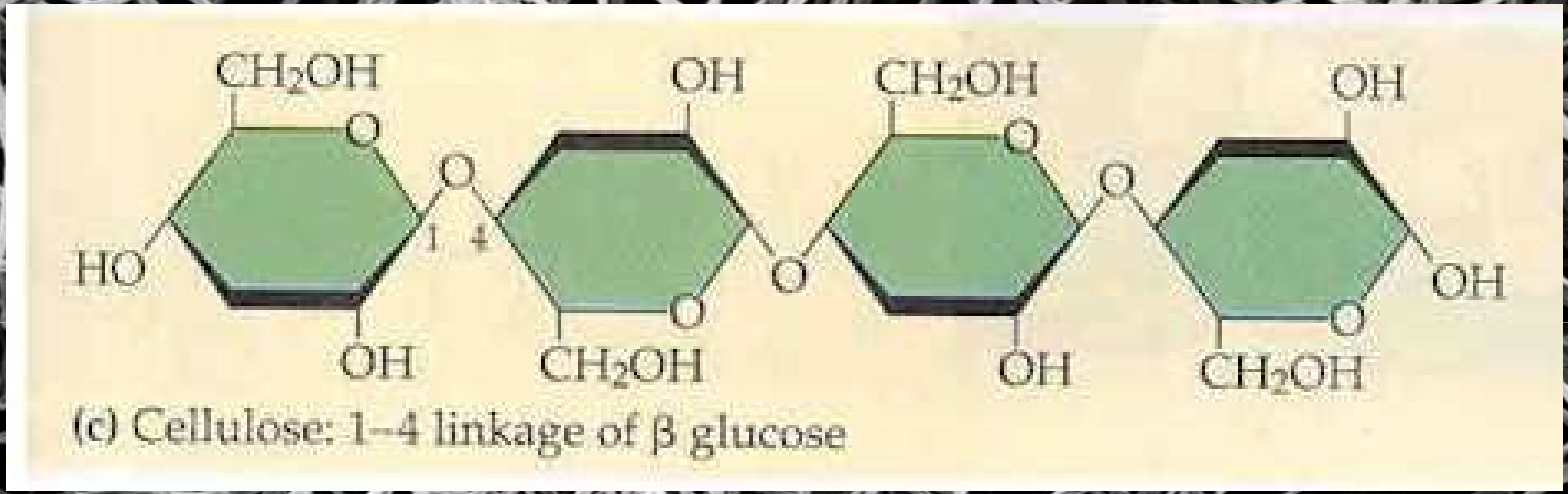

WELCOME TO
POLYMER
PLANET


Cotton: a natural polymer
What is its building block (monomer)?

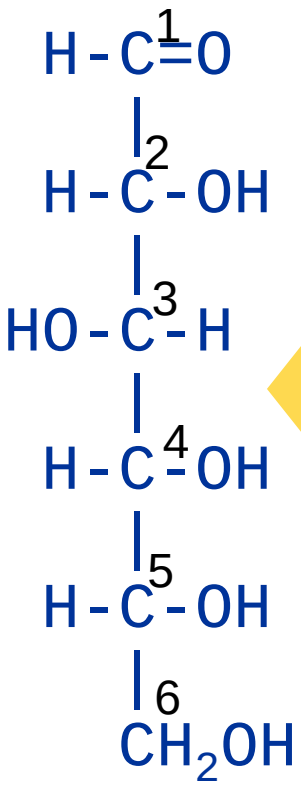
Cotton fiber is mostly cellulose, and cellulose is made of chains of the sugar, glucose linked together a certain way.



(c) Cellulose: 1–4 linkage of β glucose

Glucose

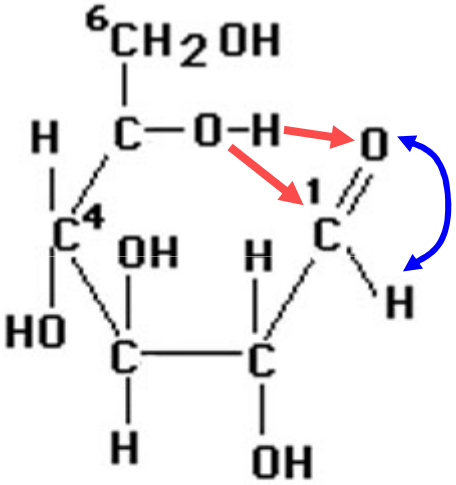
Structural formula.
Straight chain glucose



bends

Glucose

glucose bending

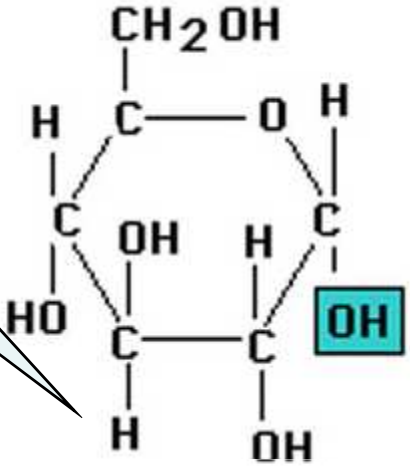


flips either way

Glucose

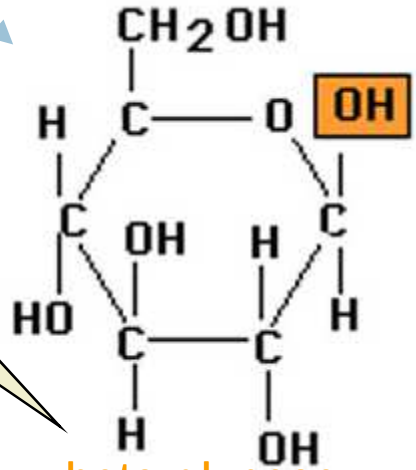
Two ring-shape versions

Used in making starch



alpha-glucose

Used in making cellulose



beta-glucose

Glucose bends itself into 4 different shapes **millions** of times a second

Nylon is used in clothes, shoes, jackets, belts, and accessories. It's not surprising a magazine is named after this polymer. Where did nylon get its name?

Nylon was discovered in 1935. The name nylon is derived from two cities where it was discovered namely New York (NY) and London (LON).

Polymer Chemistry

Part 1

Polymer Characteristics and Classifications

Definitions

- Polymer – A very long molecule composed of repeating units connected by covalent bonds

- Monomer – A repeated unit in a polymer. The reactant for the polymerization reaction.

Characterizing a Polymer

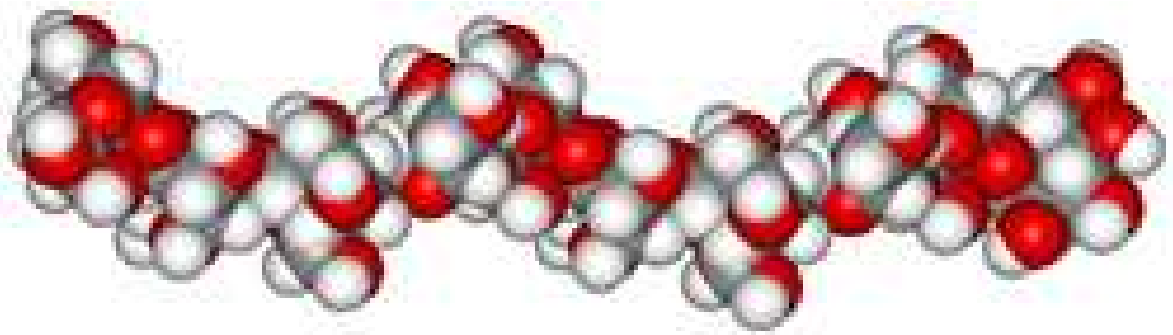
- Structure
- Classification
- Synthesis

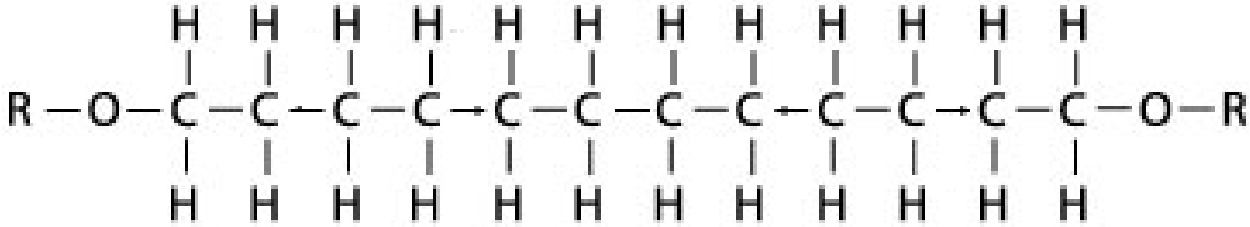
Structure of a Polymer

- Skeletal Structure
- Chemical Structure

Skeletal Structure

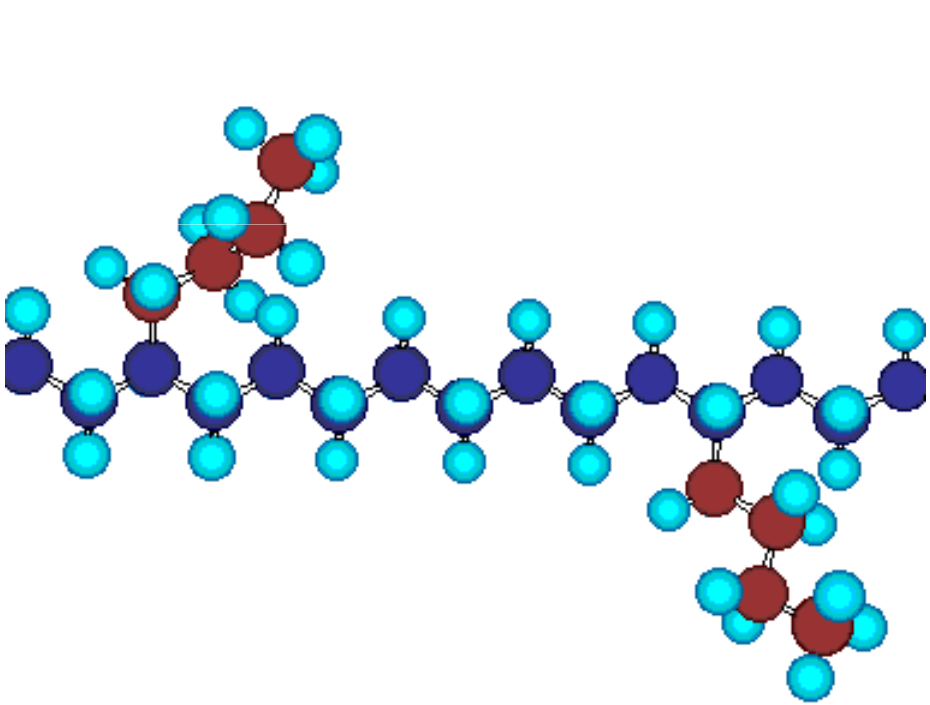
- Linear – a chain with two ends

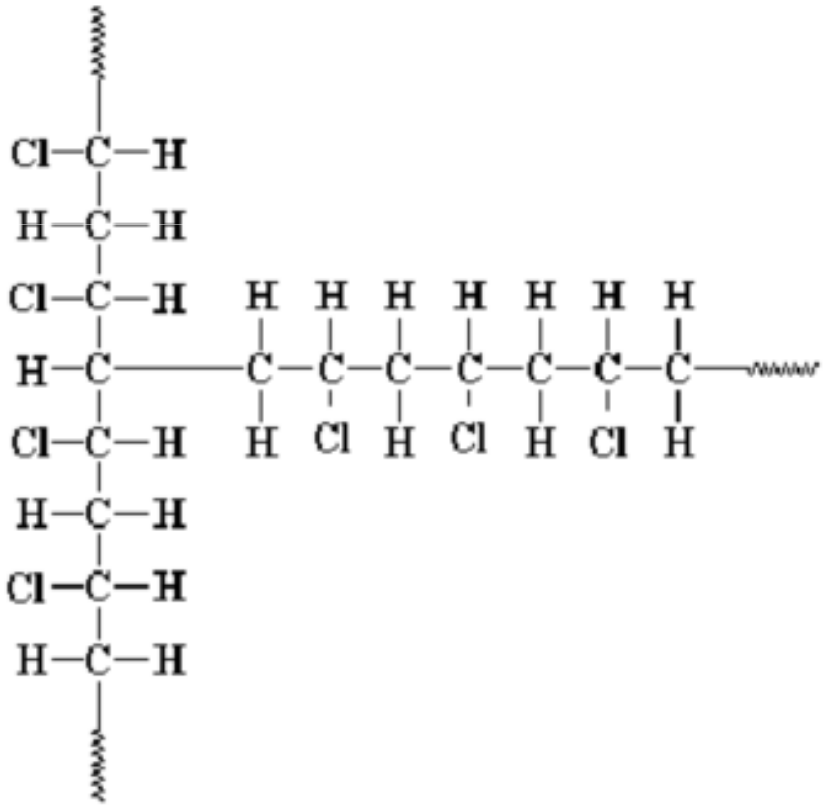




Skeletal Structure

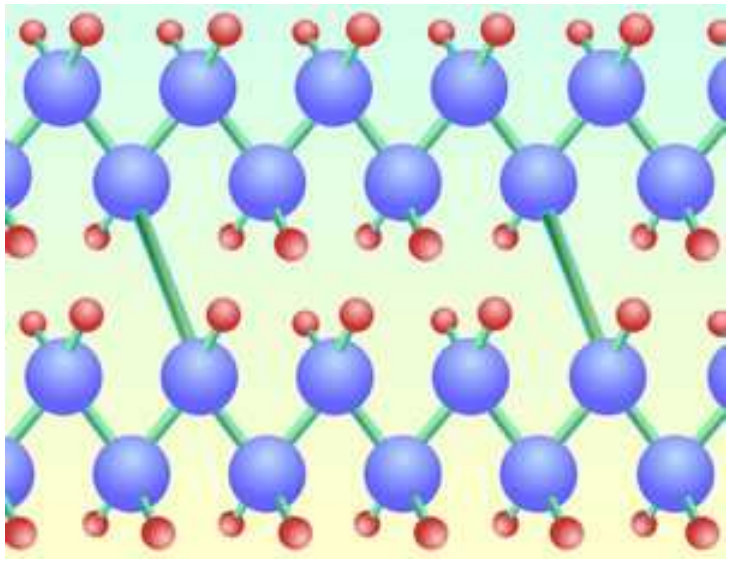
- Branched – have side chains

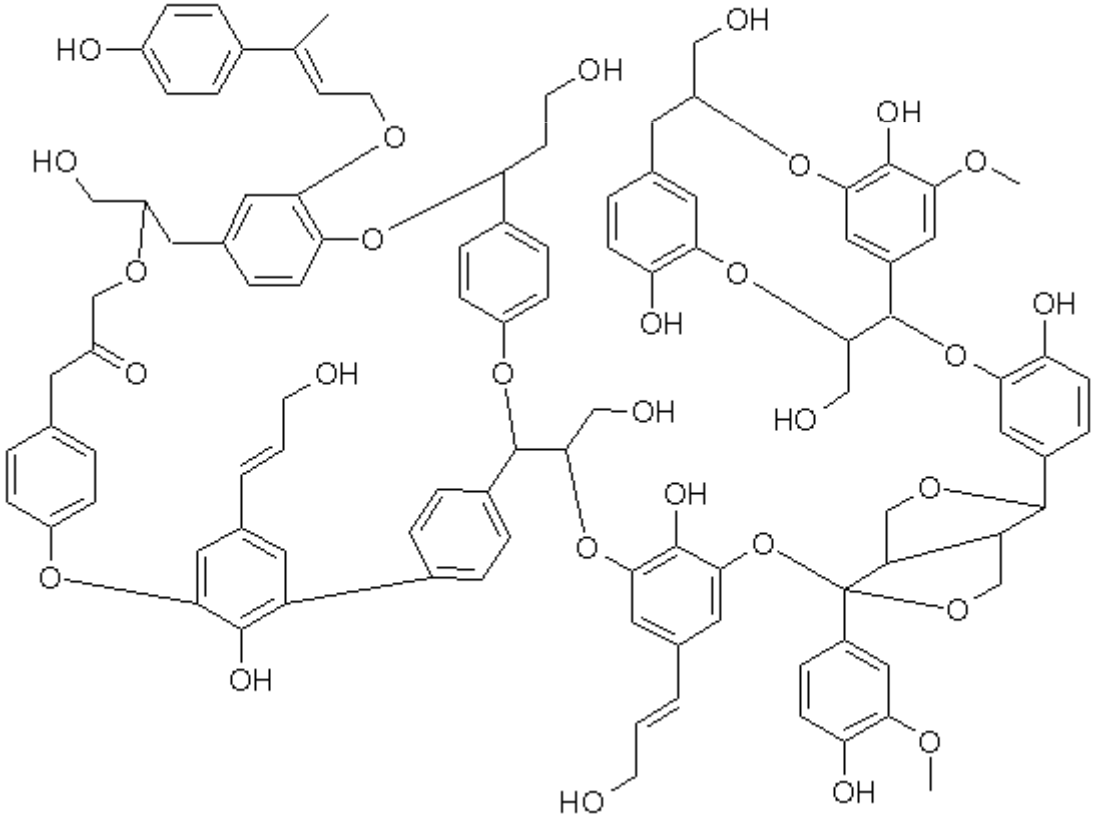




Skeletal Structure

- Crosslinked (Networked) – chains are connected to other chains





Chemical Structure

- Homopolymer – only one monomer (repeating unit)

- A – A – A – A – A – A – A -

- Copolymer – more than one monomer

Copolymers

- Alternating

  - A – B – A – B – A – B – A – B -

  - A – A – B – B – A – A – B – B -

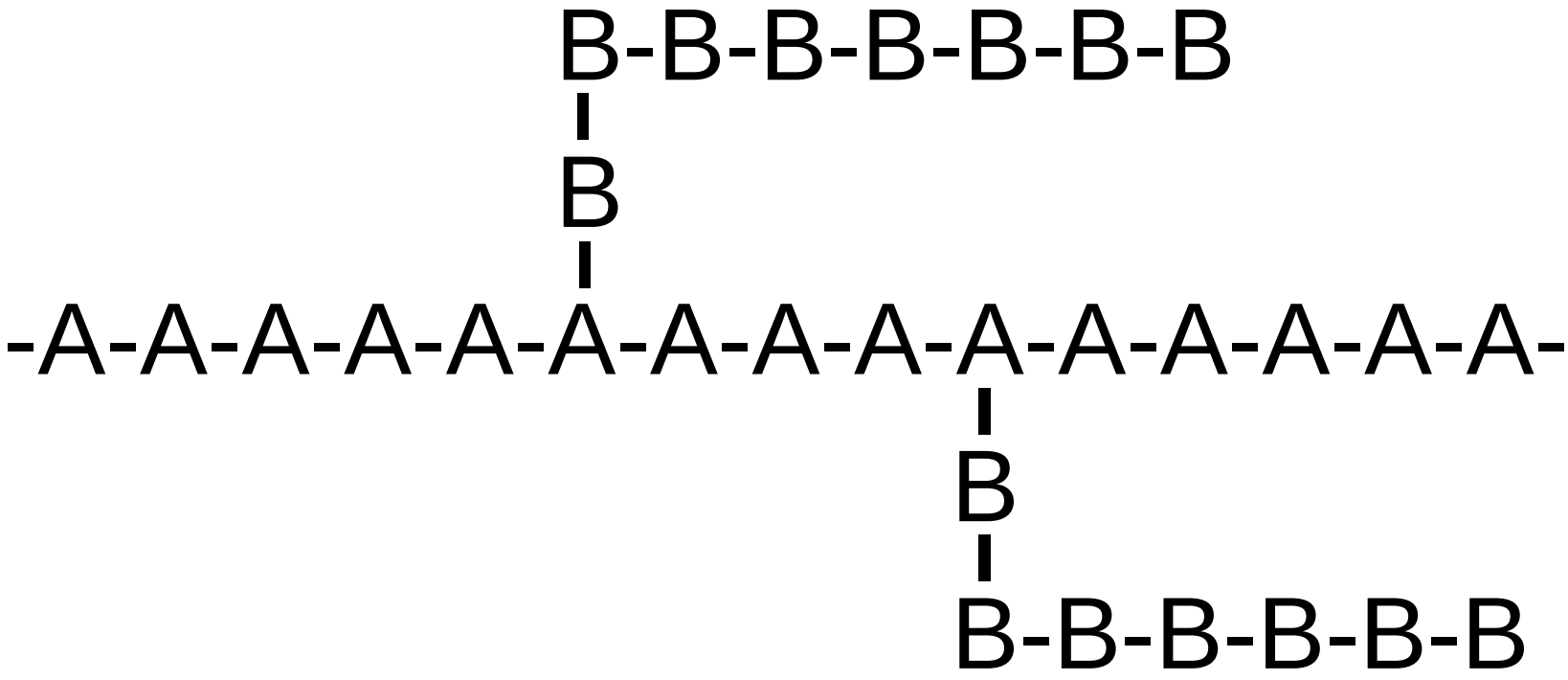
- Block

-A-A-A-A-A-B-B-B-B-B-A-A-A-A-A-

-A-A-A-A-A-A-A-B-B-B-B-B-B-B-

Copolymers

- Graft



Classifications

- Thermoplastic
- Thermoset

Thermoplastics

- Linear or branched polymers which can be melted when heat is applied.
- Can be molded into any shape with processing techniques such as injection molding or extrusion.
- Most common “plastics”

Thermoplastics

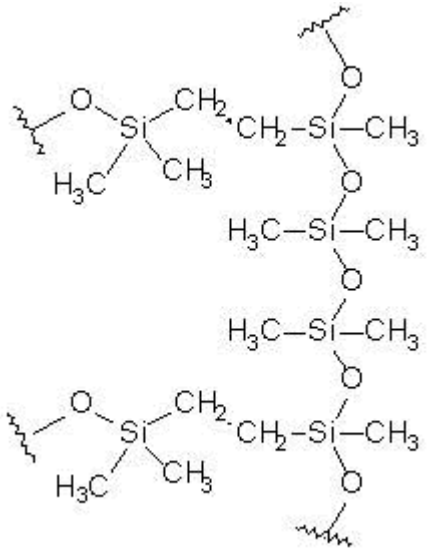
- Plastics – bottles, grocery bags, water piping, rope, fishing line, car parts
- Most are recyclable
- Natural thermoplastics – silk, cellulose (proteins), polylactic acid

Codes for Plastics

- 1 – PETE(polyethylene terephthalate) – soft drink bottles
- 2 – LDPE (Low-density polyethylene) – plastic bags, toys
- 3 – PVC (polyvinylchloride)– water pipes
- 4 – HDPE (High-density polyethylene) – milk jugs
- 5 – PP (Polypropylene)– bottle caps
- 6 – PS (Polystyrene)– styrofoam

Elastomers

- Crosslinked (networked) rubbery polymers that can be stretched easily (3-10x original size)
- Rapidly recover original dimensions when applied stress is released.
- Low degree of crosslinking



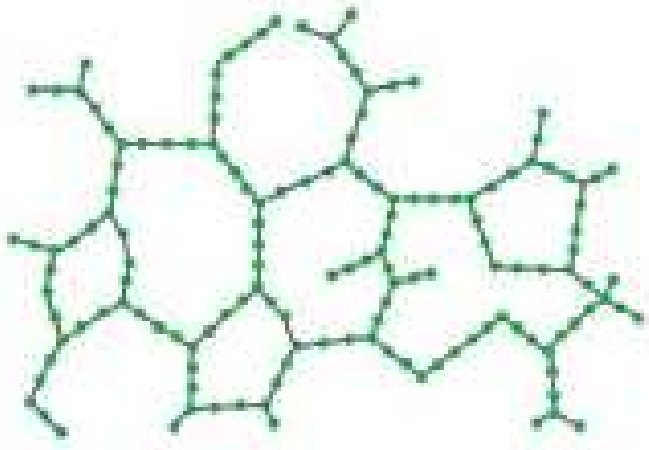
Elastomers

- Uses – examination gloves, rubber bands, bouncing balls
- Not recyclable
  - Degrades (burns/scorches) when heat is added
- Natural elastomers – natural rubber, latex

Thermosets

- Normally are rigid materials.
- Network polymers in which chain motion is greatly restricted by a high degree of crosslinking.
- Cannot be reshaped once formed.

epoxy



Thermosets

- Uses – high temperature electrical applications, super glue, counter top laminates, epoxy resins, tires (vulcanized rubber)
- Cannot be recycled (burn/scorch with heat)
- Natural* thermosets – vulcanized rubber

Polymer Chemistry

Part 2

Polymer Synthesis

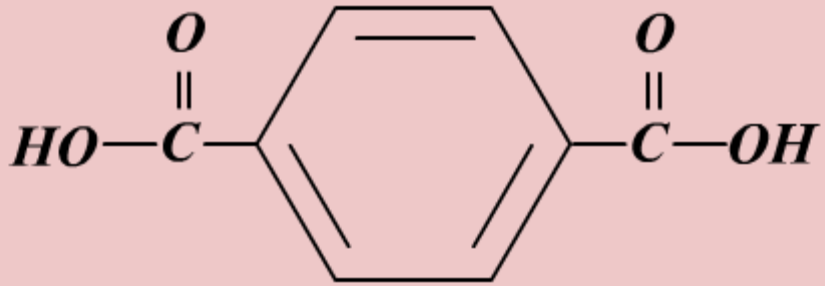
Condensation Polymer

- The polymer in whose synthetic reactions small molecules (H_2O, HCl) are eliminated when the monomers combine. Also called as copolymer.

Condensation Polymerization

Formation of polyethylene terephthalate (PET)

By Mohan Karulkar (karulkar@uiuc.edu)

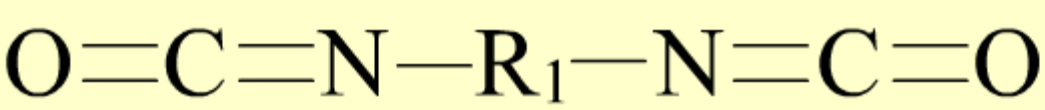


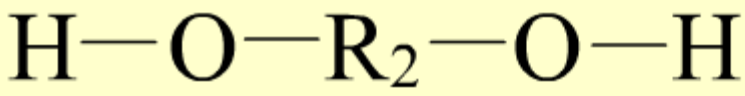
NEXT

Addition Polymer

- Reactions in which monomers combine without the elimination of a small molecule.
  - Usually involves the breaking of a double bond.

Polyaddition





Start Polymerization

Created by Jennifer Younker jyounker@uiuc.edu

Polyaddition with Radicals

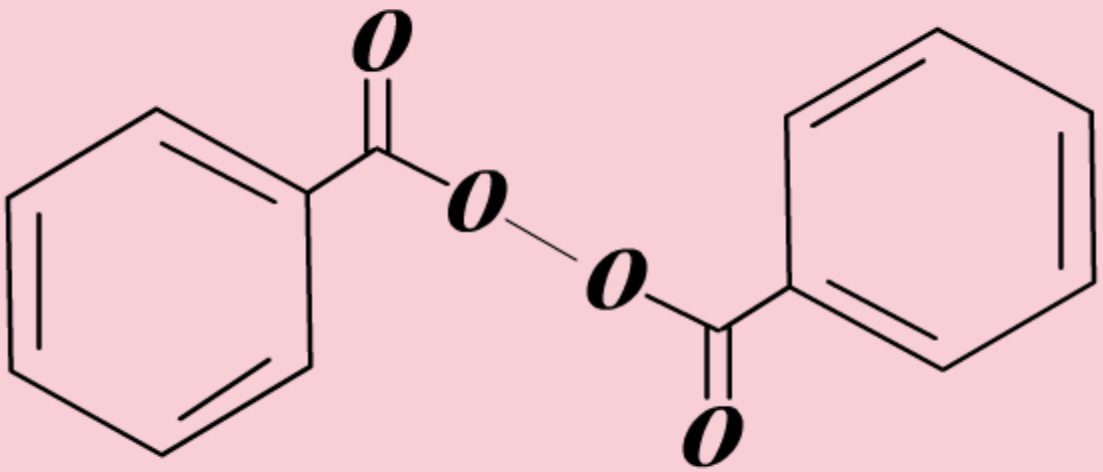
- Initiation – Creation of an active site (free radical).
- Propagation – Growth of polymer chain by addition of a monomer to an active site and the creation of a new active site.

Polyaddition with Radicals

- Termination – Growth of chain stops.
  - Combination – Two growing chains collide.
  - Disproportionation – A hydrogen atom is added to the end of a growing chain.

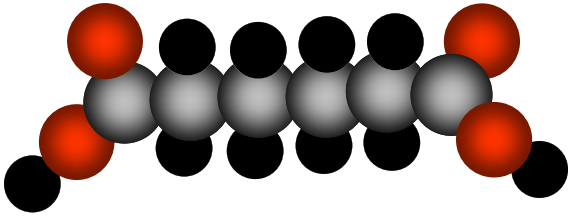
Addition Polymerization

By Mohan Karulkar (karulkar@uiuc.edu)

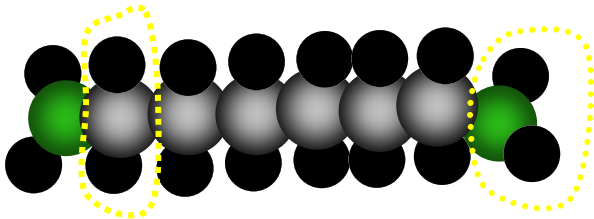


Form Initiator

Tetramethylene dicarboxylic acid (adipic acid)



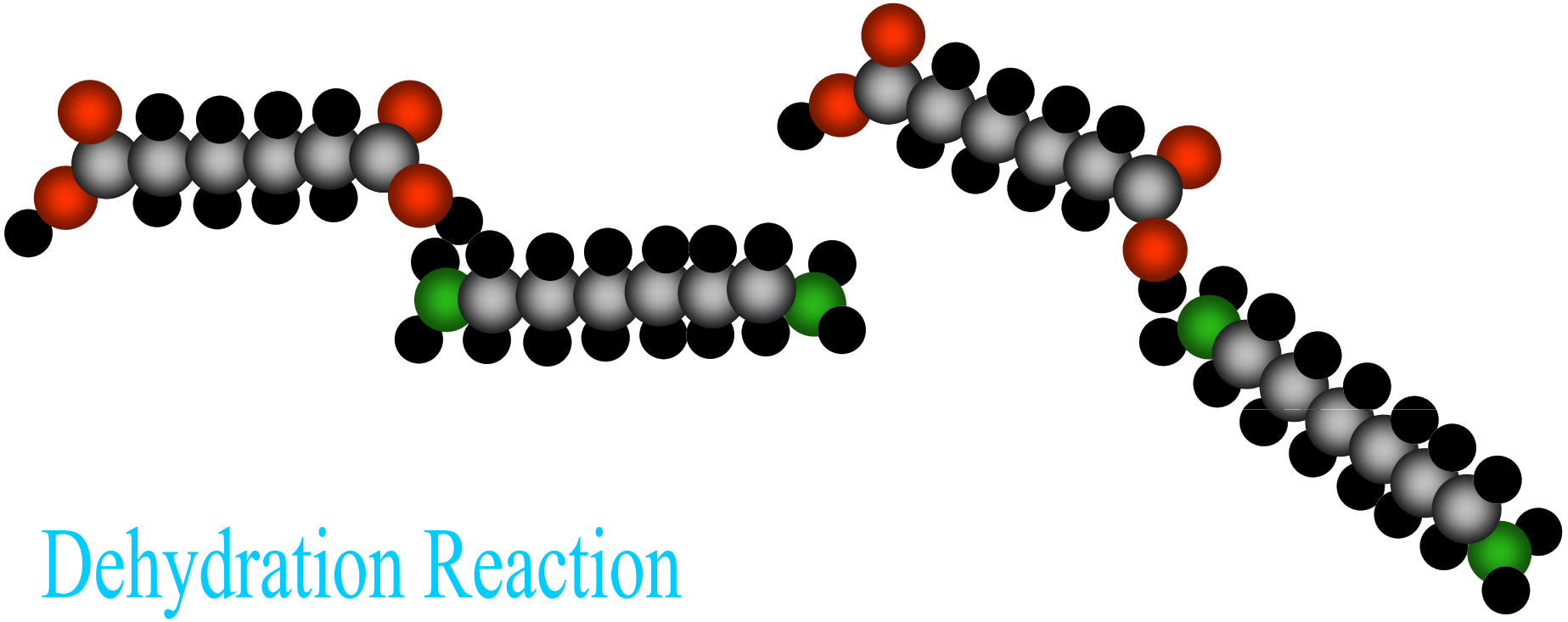
Hexamethylene diamine



methylene x 6 (hexa)

amine x 2 (di)

Nylon is actually a “copolymer” because is it made from two monomers. When these two monomers are in the same beaker, they combine and give off a molecule of water. This is called a “dehydration” reaction because we are taking away (*de*) water (*hydra*). (regarding odor: amines smell like fish or worse. Adipic acid is odorless)



Dehydration Reaction

Polyester is a another copolymer. It is made from equal amounts of two different monomers. Polyester is used to make bottles and fabrics.

terephthalic acid

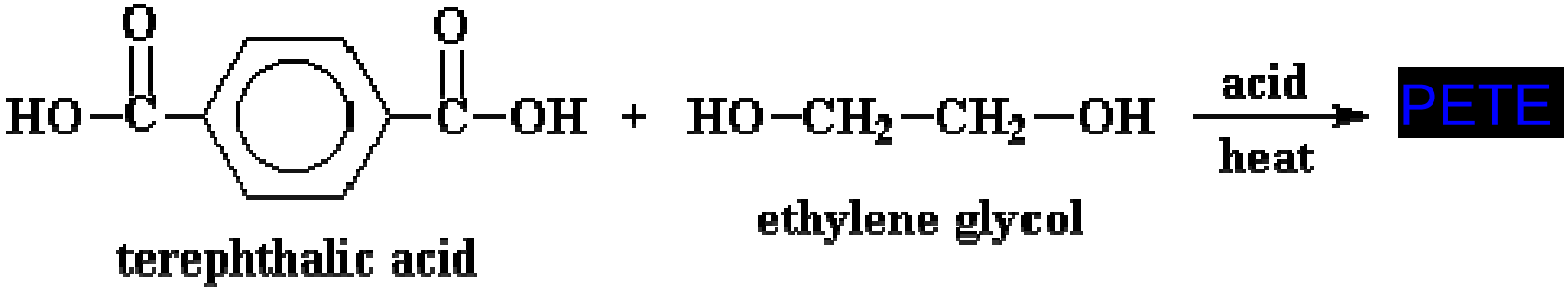
ethylene glycol

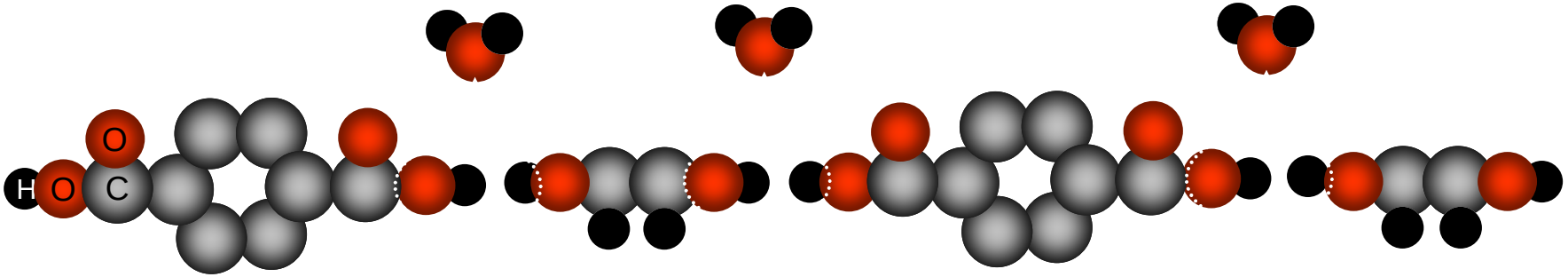
PETE

P e T e

dehydration

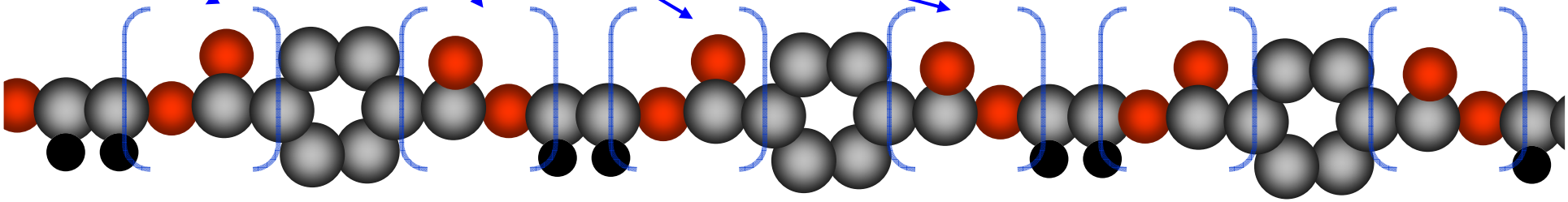
water





ESTER groups formed

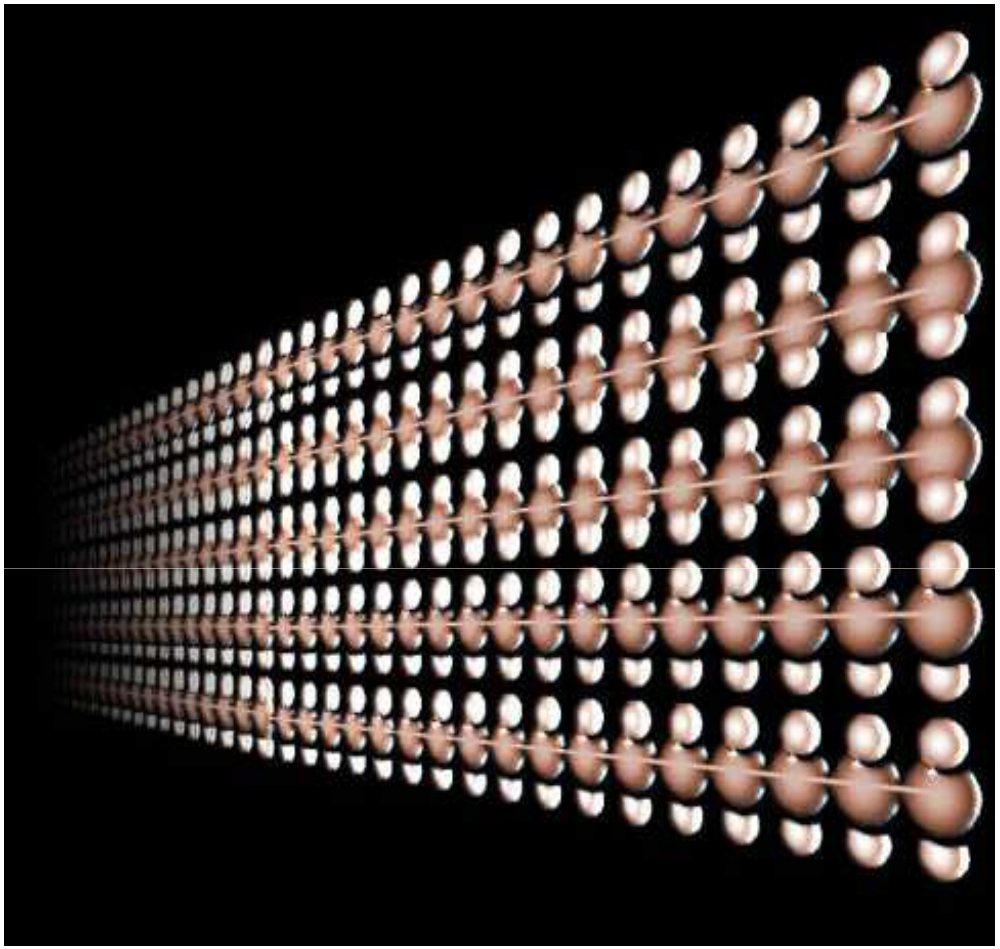
ESTER



A polymer made form just one monomer is polyethylene. It is the most common plastic you see.

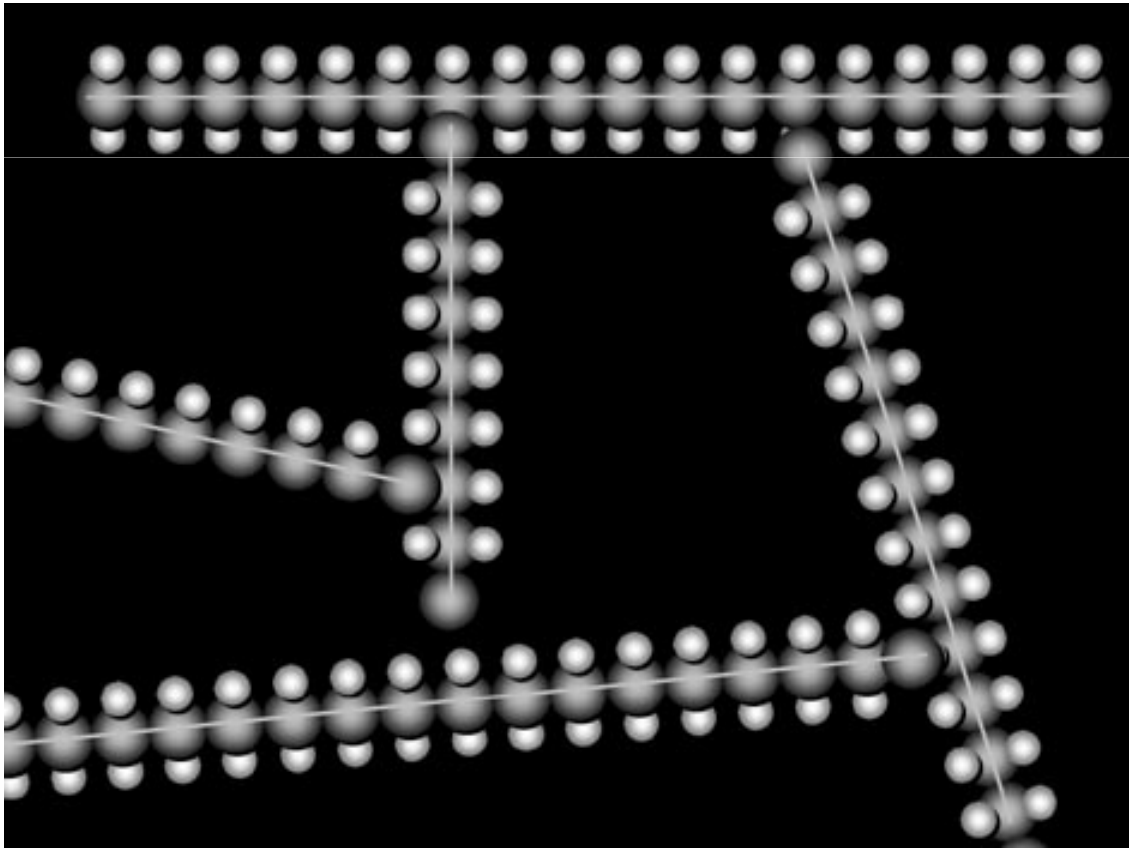
It is used for bottles, buckets, jugs, containers, toys, even synthetic lumber, and many other things.

There are two types of polyethylene polymers (plastics). One is when the polyethylene exists as long straight chains. The picture here shows the chains of one carbon with two hydrogen atoms repeating. The chain can be as long as 20,000 carbons to 35,000 carbons. This is called high density polyethylene (HDPE).



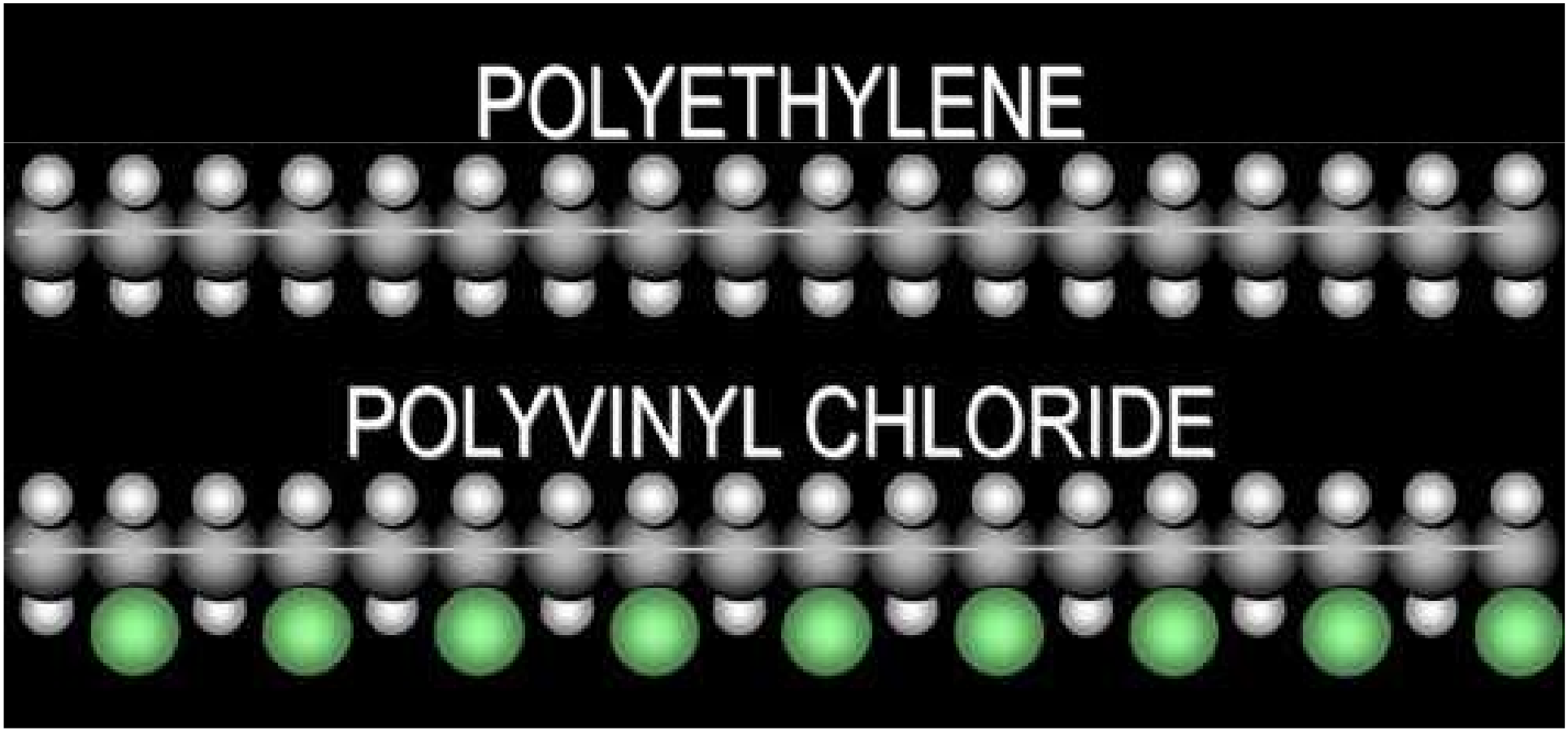
When the chains get up to 500,000 carbons long, they are tough enough for synthetic ice, replacement joints, and bullet-proof vests. Think about it. You start with ethylene gas molecules that can't stop a feather from passing through them. But after the double-bond of one ethylene molecule breaks, it causes a chain reaction that connects thousands to it. In less than a second, these long straight chains of carbon and hydrogen are strong enough to stop a bullet or play ice hockey on. Isn't chemistry wonderful.

We've mentioned high density polyethylene (HDPE); you probably were thinking, there must be low density polyethylene (LDPE). You are correct. It is made by causing the long chains of ethylene to branch. That way they cannot lie next each other, which reduces the density and strength of the polyethylene. This makes the plastic lighter and more flexible.



Low density polyethylene is used to make plastic bags, plastic wrap, and squeeze bottles, plus many other things.

Another polymer, which is almost the same as polyethylene, is **P**oly**V**inyl **C**hloride or PVC. The difference is that every other hydrogen is replaced with a chlorine atom (green sphere).



$(CH_2CHCl)_n + O_2 \rightarrow CO_2 + CO + HCl + H_2O$

PVC pipes are used in our homes and they are even handy for making a table or chair. PVC is also used as insulation around electric wires in the home and the automobile. PVC is quite safe until it burns. The chlorines in the PVC combine with the hydrogen atoms in the PVC to form hydrogen chloride gas (HCl). When this contacts water in lungs or mouth, it turns to hydrochloric acid ($HCl_{(aq)}$).

There are many types of plastics, but they all are based on tetravinyl

The favorite properties of plastics are that they are inert and won't react with what is stored in them. They also are durable and won't easily decay, dissolve, or break apart. These are great qualities for things you keep, but when you throw them away, they won't decompose.

Since they don't decompose, the answer is to recycle the plastics so they can be remade into something else. Here we see a bunch of CDs getting recycled.

1 Polyethylene Terephthalate (PETE)

2 High Density Polyethylene (HDPE)

3 Vinyl (V)

4 Low Density Polyethylene (LDPE)

5 Polypropylene (PP)

6 Polystyrene (PS)

Recycle or we will have a polymer planet.