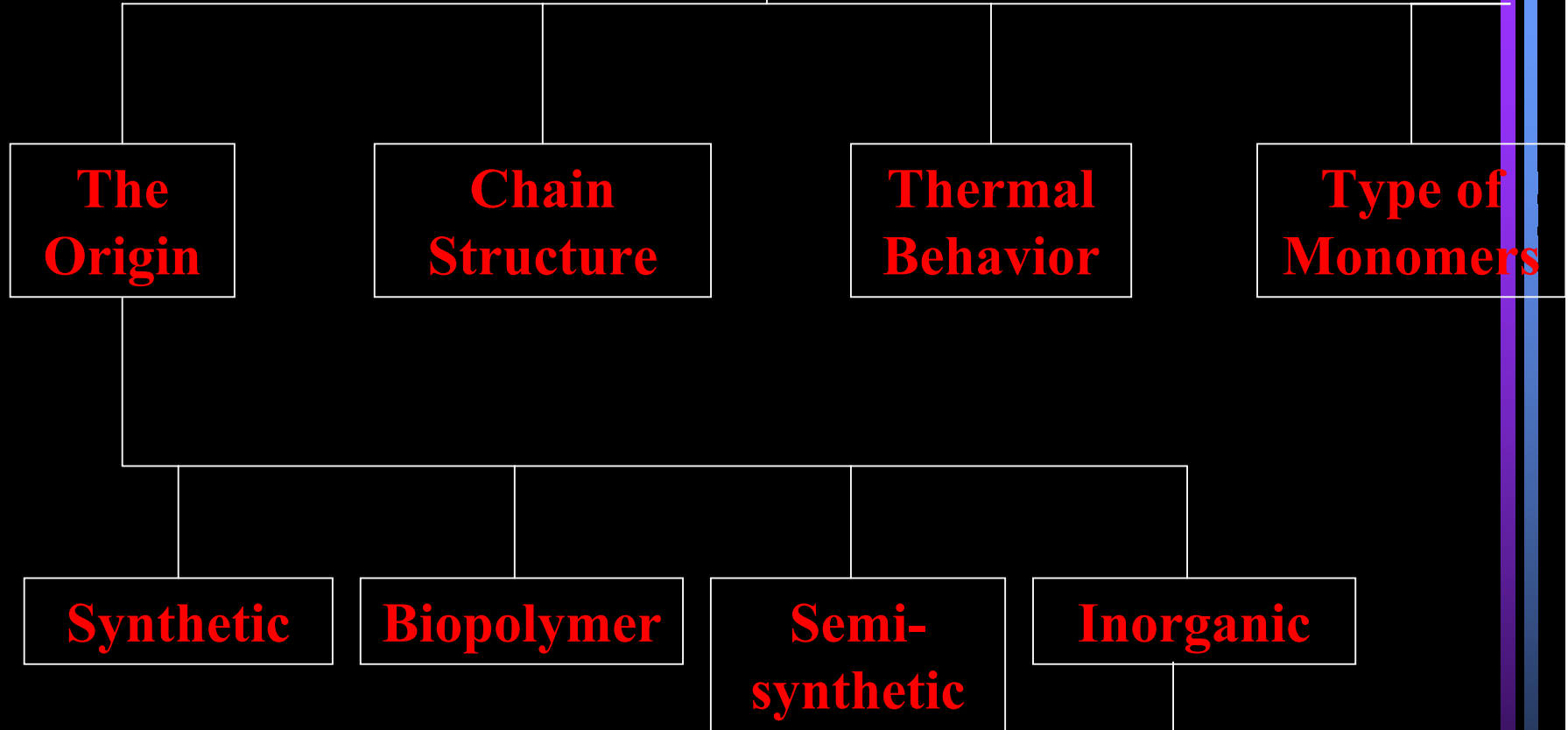


Polymers



```
graph TD; A[ ] --- B[Chain Contains Other Than carbon, Oxygen Or Nitrogen]; A --- C[Natural Silicates [Synthetic PolySiloxane]]
```

**Chain Contains
Other Than
carbon, Oxygen
Or Nitrogen**

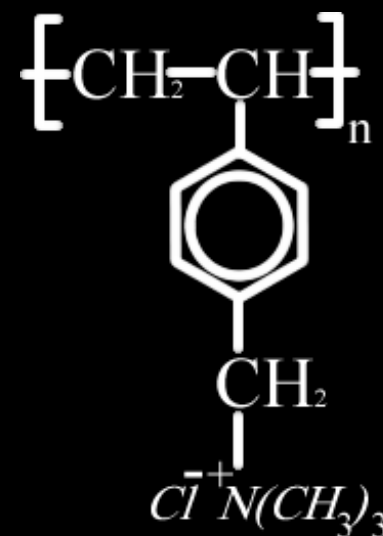
**Natural Silicates
[Synthetic
PolySiloxane]**

Inorganic polymers

The definition of inorganic polymers is still rather vague and contradictory. If we ground the definition on the main chain of the polymer inorganic when its main chain also contains atoms other than C, O and N, then it is obvious that a polyelectrolyte like cellulose sodium xanthate, The same holds for ion-exchange resins, which also contains inorganic functional units in the side groups like:

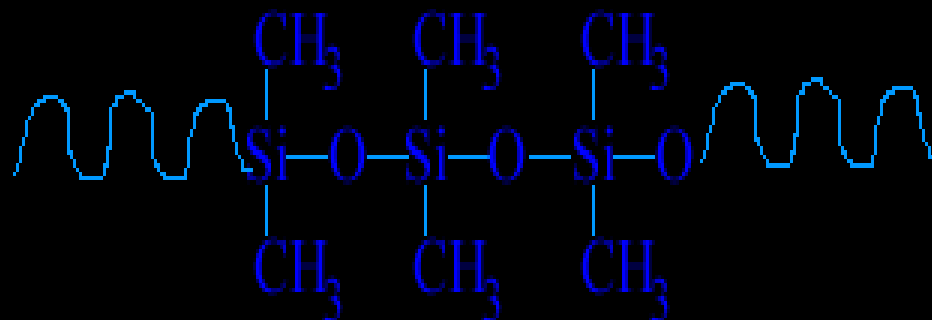


for cation exchange



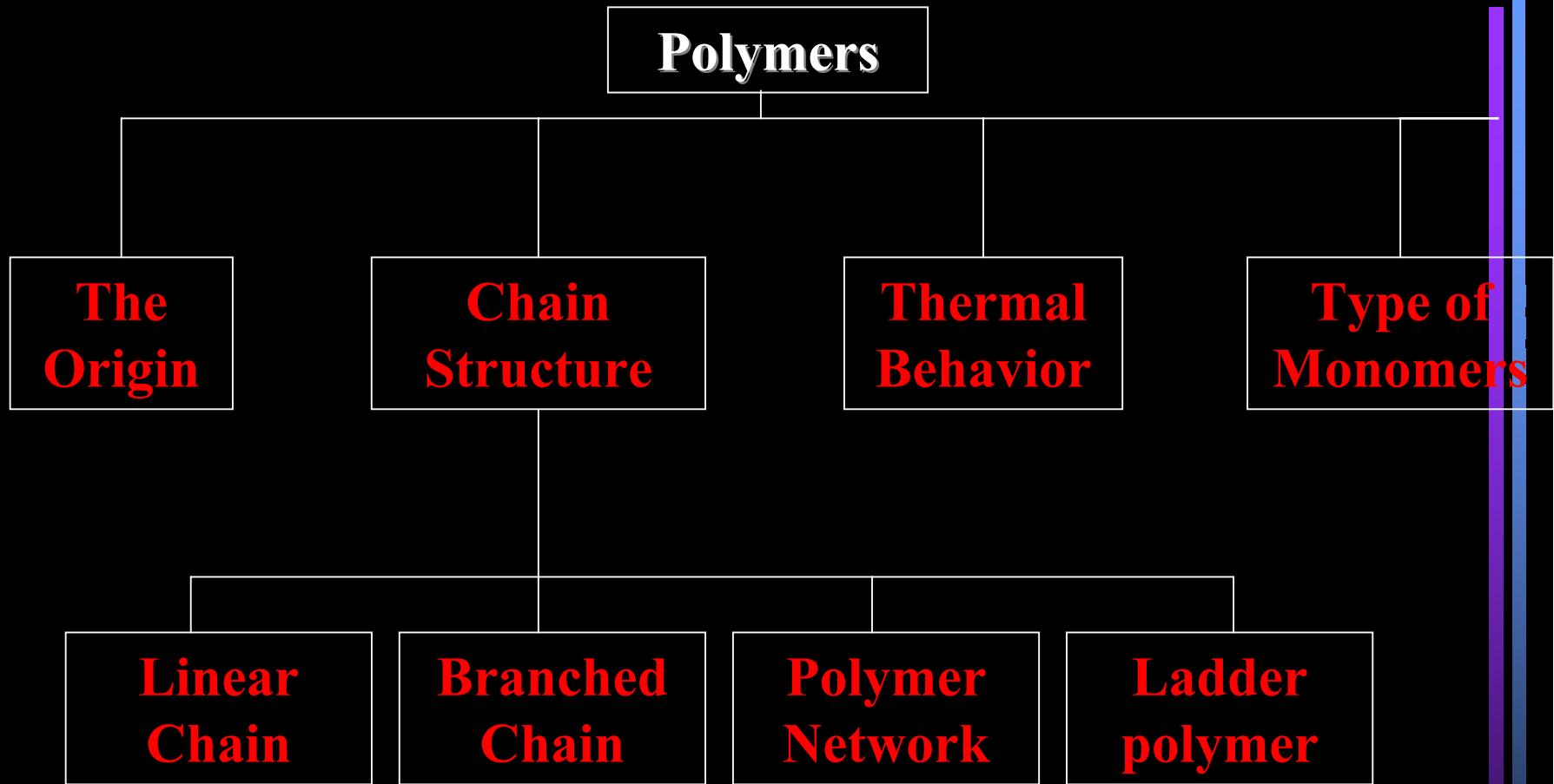
for anion exchange

Real inorganic polymers are some natural silicates and related synthetic polysiloxanes like:



Poly(DiMethylsiloxane)

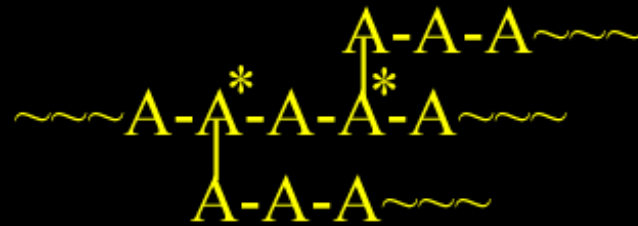
Although polymer science has developed along the lines of synthetic organic polymer chemistry, it is to be expected that inorganic and organometallic polymers will attract more attention in the future.



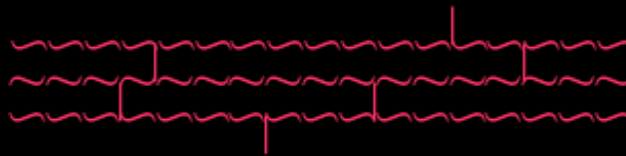
**Linear
Chain**



**Branched
Chain**

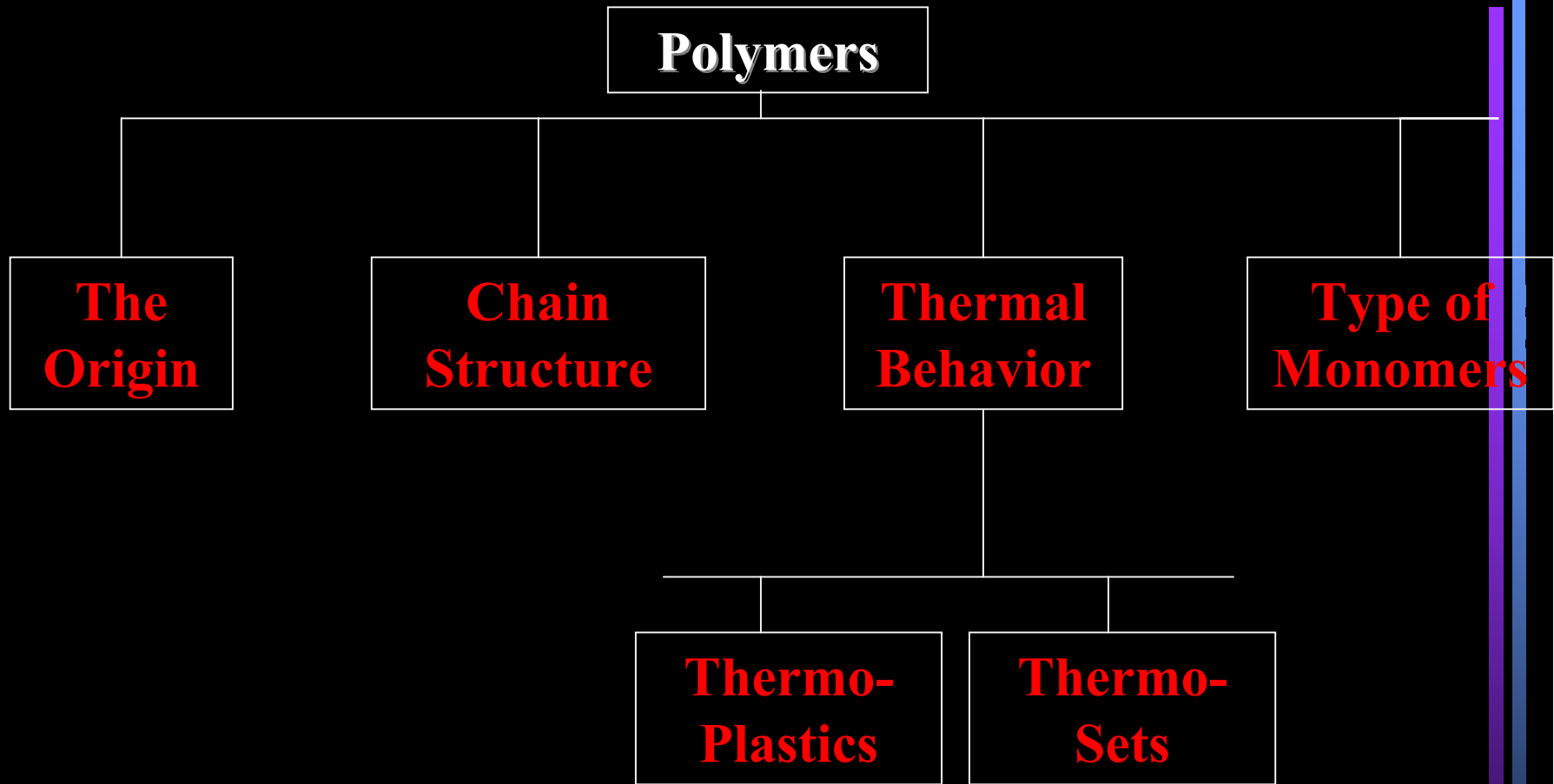


**Polymer
Network**



**Ladder
polymer**





Thermo-Plastics

I'm just guessing that everyone out there knows what plastic is. We call plastics *plastic* because they are pliable, that is, they can be shaped and molded easily. As plastics become easier to mold and shape when they're hot, and melt when they get hot enough, we call them *thermoplastics*. This name can help you tell them apart from [crosslinked materials](#) that don't melt, called [thermosets](#).

But like I said, everyone knows what plastic is, so why do we have a page here? Well, there are a few nuances and details of what makes a plastic a plastic that it might be useful to go over. For example, why do we call a material a plastic and not a rubber, or [elastomer](#)? The answer is in the bouncing. You can stretch an elastomer, and it bounces back. Plastics tend to either deform permanently, or just plain break, when you stretch them too hard.

But that's not bad. You see, although plastics don't behave as well as rubber when they're stretched, it takes a lot more energy to stretch them in the first place. The fancy way to say that is "plastics resist deformation better than elastomers do". This is good when we don't want our material to stretch.

But wait a minute! At the top of this page we said that plastics were called "plastic" because we could deform them, and mold them. That's just the point. It takes more energy to stretch the plastic, making it resistant to deformation. But at the same time, if you pull hard enough, you can not only stretch a plastic, but it will stay in the shape you stretched it into once you stop stretching it. Elastomers bounce back when you let go.

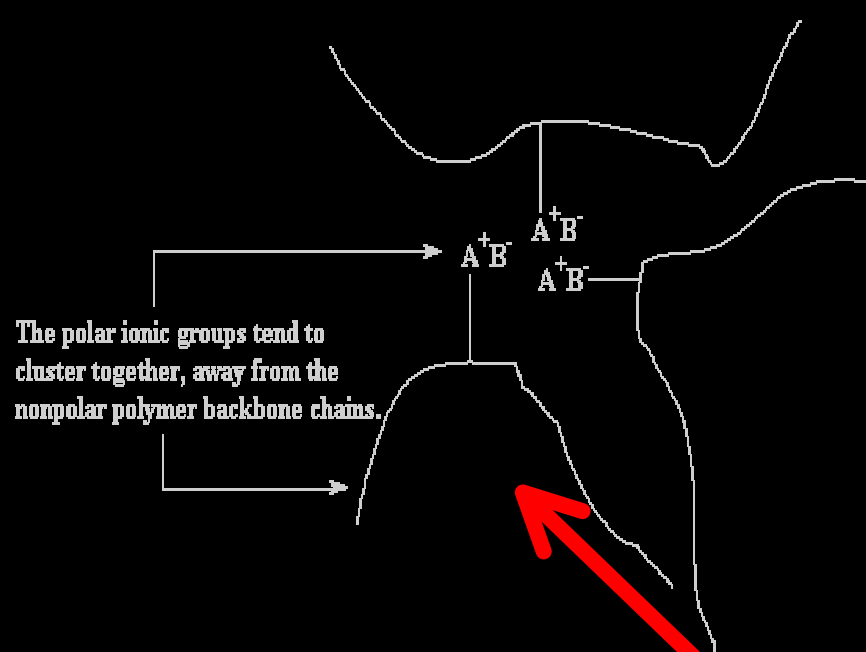
And plastics are also much more pliable than some other materials, like [fibers](#). Fibers stretch very little when you pull on them. This makes them good for things like rope.

Hard Plastic and Soft Plastic

Of course, we've all seen plastics that are hard, and some that are soft. The plastic keys on your keyboard are hard, while the plastic around the cables of the same computer is soft. This is because all plastics have a certain temperature above which they are soft and pliable, and below which they are hard and brittle.

This is called the [glass transition temperature](#), or T_g . The T_g is different for each plastic. At room temperature, some plastics are below their T_g , and so they are hard. Other plastics are above their T_g at room temperature, and these plastics are soft.

Sometimes additives are added to a plastic to make it softer and more pliable. These additives are called [plasticizers](#).



The polar ionic groups tend to cluster together, away from the nonpolar polymer backbone chains.

I'm just guessing that everyone out there knows what plastic is. We call them **elastomers**. We all know that **elastomers** are wonderful. **Crosslinking** makes this all possible. But crosslinked polymers can't be recycled very easily. So in the interests of keeping the earth from becoming a giant landfill, we've come up with a new approach, the thermoplastic elastomer. The idea behind thermoplastic elastomers is the notion of a *reversible crosslink*.

Normal crosslinked polymers cannot be recycled because they don't melt. They don't melt because the crosslinks tie all the polymer chains together, making it impossible for the material to flow.

This is where the reversible crosslink comes in. Normal crosslinks are covalent, chemically bonding the polymer chains together into one molecule. The reversible crosslink uses noncovalent, or secondary interactions between the polymer chains to bind them together. These interactions include hydrogen bonding and ionic bonding.

The beauty of using noncovalent interactions to form crosslinks is that when the material is heated, the crosslinks are broken. This allows the material to be processed, and most importantly, recycled. When it cools again, the crosslinks reform.

Two approaches have been tried, **ionomers** and **block copolymers**.

Ionomers

Ionomers are a kind of **copolymer**. They are copolymers in which a small portion of the repeat units have ionic pendant groups attached to them. Not a lot, now, just a few. Normally the polymer backbone chain will be nonpolar. We all remember the rule, like dissolves like. It works here, too. The nonpolar polymer backbone chains will go up together, and the polar ionic pendant groups will cluster together. Now as much as the cluster of ionic groups, snobbish as they are, would like to separate themselves completely from the nonpolar backbone chains, they can't. Remember, they're just sort of attached to the backbone chains. So what ends up happening is that these clusters of ionic groups serve to tie the backbone chains together, just like a normal crosslink would.

Except for one small difference. If we try, just for fun, to heat up these ionomers, something nifty and rather convenient happens. The ionic clusters will break up.

When molecules get hot, they move around more. To be sure, this motion of molecules is heat itself. Moving around like this at high temperatures makes it hard for the ionic groups to stay put in their little clusters. So they break up. Now the ionomer has lost its crosslinks, and can be processed and recycled just like an ordinary polymer. Cool it back down, and the ionic clusters form again, and it acts like a crosslinked polymer again. Nifty, huh?

ThermoPlastic

Elastomers

Block Copolymers

We can make a thermoplastic elastomer another way. That other way is called a **block copolymer**. A **block copolymer** is a polymer made from more than one kind of monomer, that is, made out of two or more **comonomers**. A block copolymer is a copolymer in which the comonomers are separated into long sections of the polymer backbone chain. Each of these sections, called **blocks**, looks sort of like a homopolymer.

A very common thermoplastic elastomer that is a block copolymer is **SBS rubber**. SBS stands for styrene-butadiene-styrene, because SBS is made up of a short chain of **polystyrene**, followed by a long chain of **polybutadiene**, followed by another short chain of polystyrene. If we could stretch out a chain of SBS, it would look like the picture below.

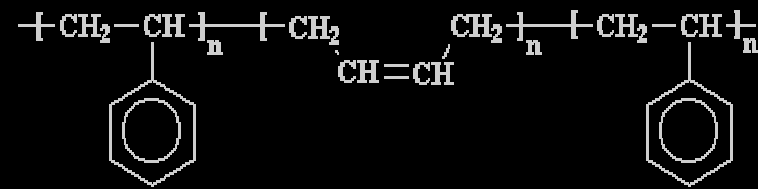
It's time we let you in on a little secret: different polymers don't mix very well. Remember the old "like dissolves like" rule? Well, polymers are even more snobbish than small molecules. It's very hard to mix two different polymers, even when they are very similar. This holds for the blocks of our SBS just as for any other polymers. So the polystyrene blocks tend to clump together and the polybutadiene blocks tend to clump together. The clusters formed by the polystyrene blocks tie the polybutadiene blocks together. Remember each polybutadiene block has a polystyrene block at each end, and the different polystyrene blocks of the same SBS molecule aren't necessarily in the same cluster. This means that the different polystyrene clusters will be tied together by the polybutadiene blocks.

So the polystyrene clusters act as crosslinks for the polybutadiene blocks. And just like the ionic clusters of the ionomers, the polystyrene clusters break up when the SBS is heated, so it can be processed and recycled like a non-crosslinked polymer.

Being green seems to be easier than certain frogs thought!

But you can also make a thermoplastic elastomer using a block copolymer made from only one kind of monomer! I know that makes no sense, a copolymer with only one kind of monomer, but it's true. You can make **polypropylene** in which there are blocks of different **tacticity**. One can make polypropylene with atactic blocks and isotactic blocks using **metallocene catalysts polymerization**, like this:

The blocks separate just as they do in SBS rubber. They separate because the isotactic blocks will form crystals, but the atactic blocks are amorphous. The result is something that looks like the picture you see on the right. It behaves as an elastomer for the same reasons as SBS rubber does.

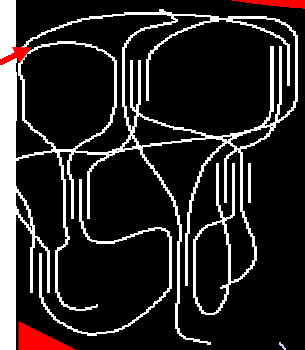


Poly(styrene-butadiene-styrene), otherwise known as SBS rubber

polystyrene
block

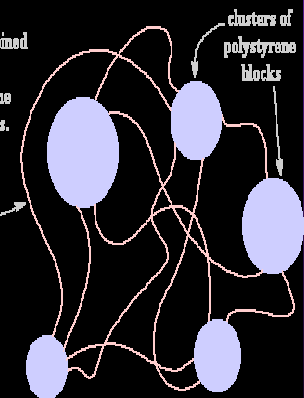
polystyrene
block

polybutadiene
block



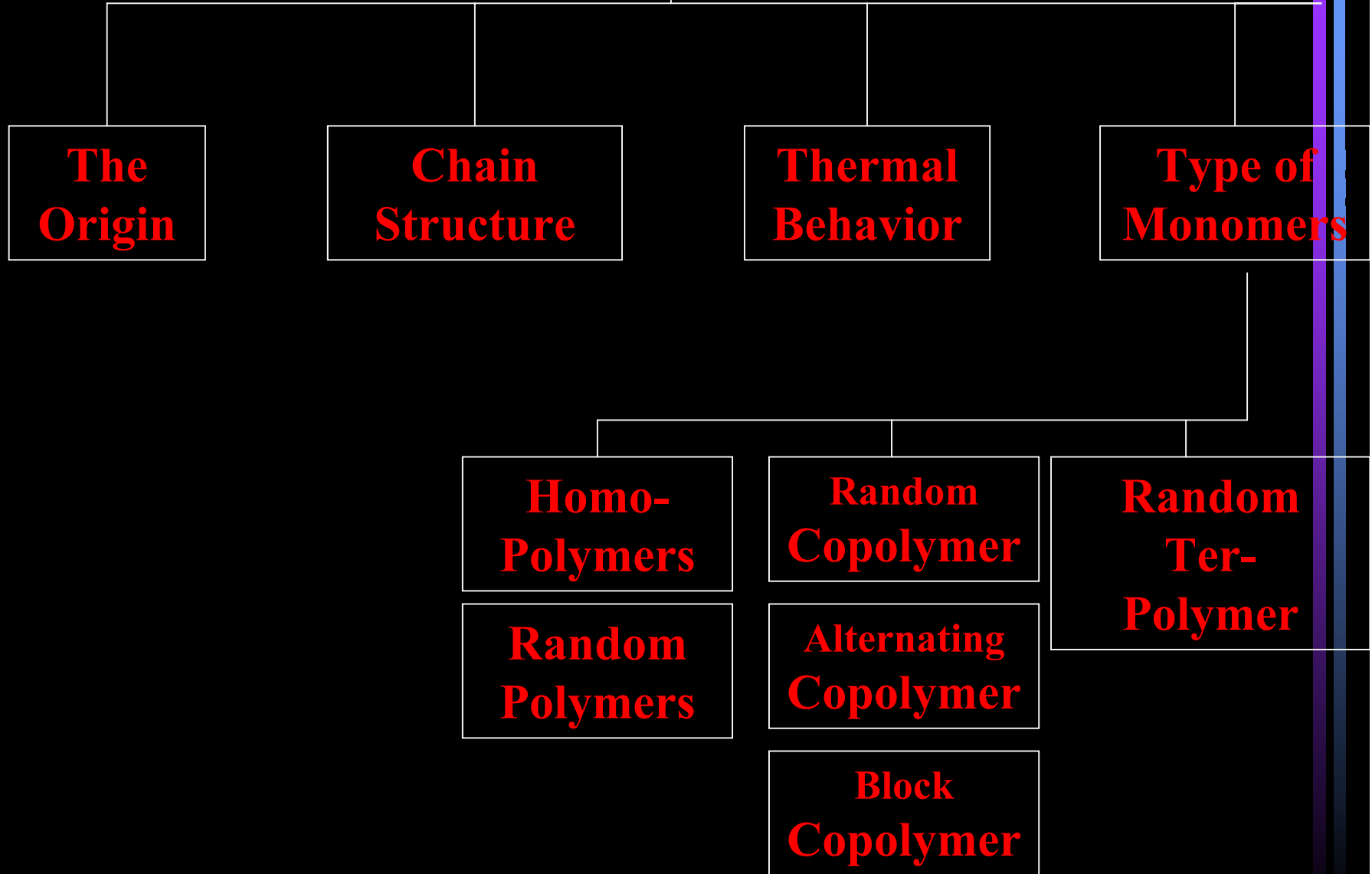
atactic block

Polybutadiene blocks, joined together by polystyrene clusters. The polystyrene clusters act as crosslinks.



clusters of polystyrene blocks

Polymers



**Homo-
Polymers**

**Random
Polymers**

**Random
Copolymer**

-AABABBABAAA-

**Alternating
Copolymer**

-ABABABABABA-

**Block
Copolymer**

-AAAABBBBAAAA-

**Graft
Copolymer**

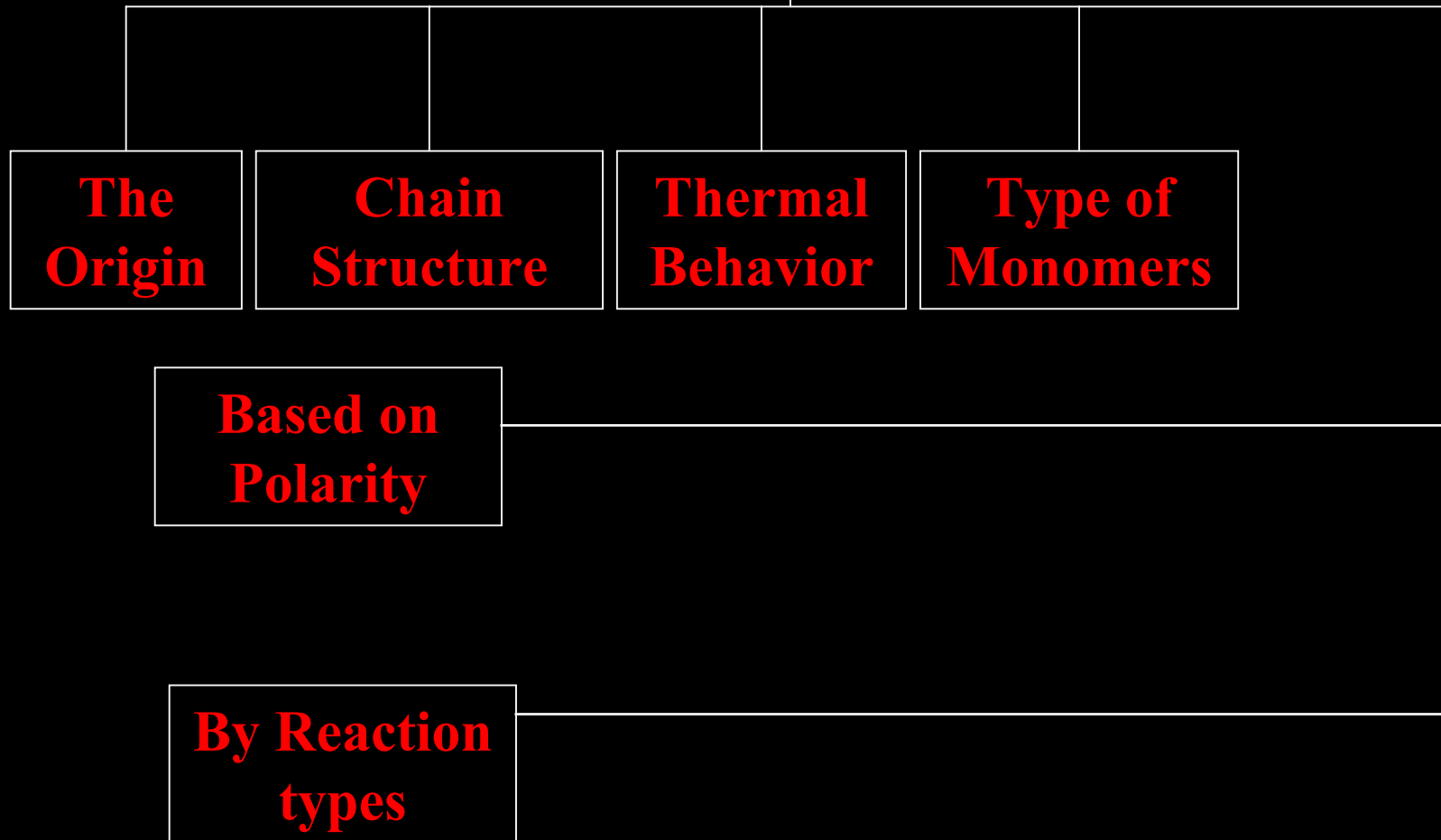
-A-A-A-A-A-A-A-

-B-B-B-B-B-B-B-

-B-B-B-B-B-B-B-

**Random
Terpolymer**

Polymers

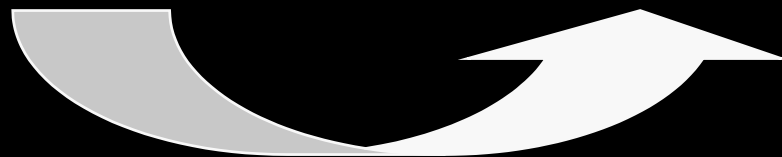


Based On Polarity

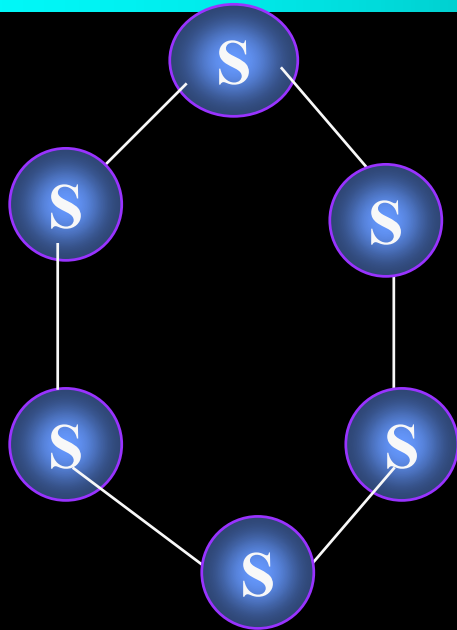


Homo Chain Polymers

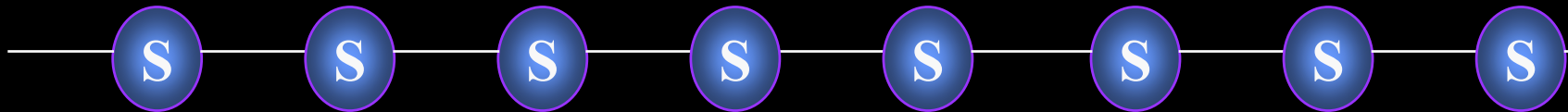
Hetero Chain Polymers



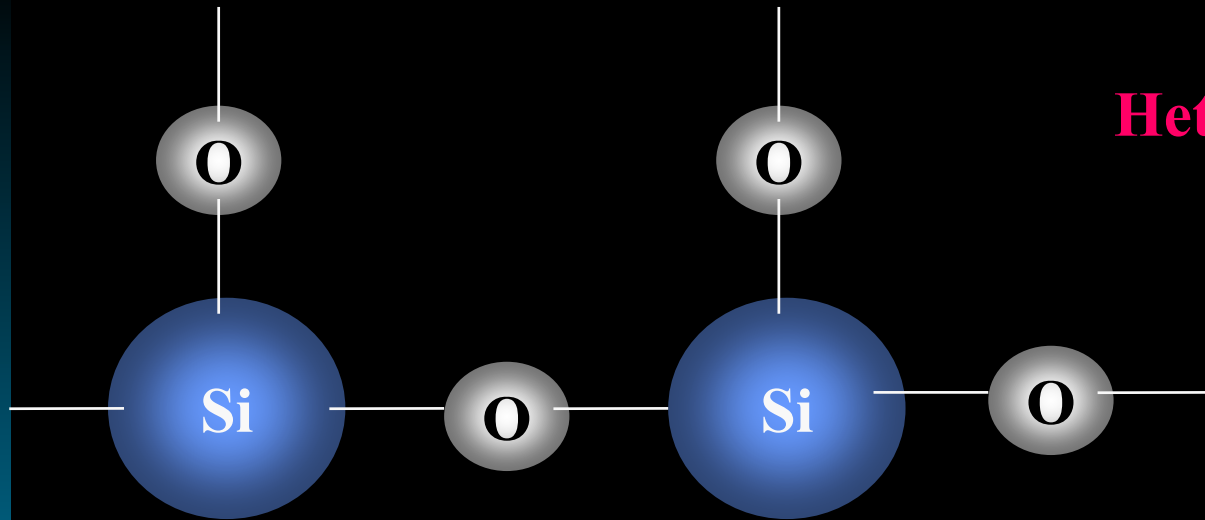
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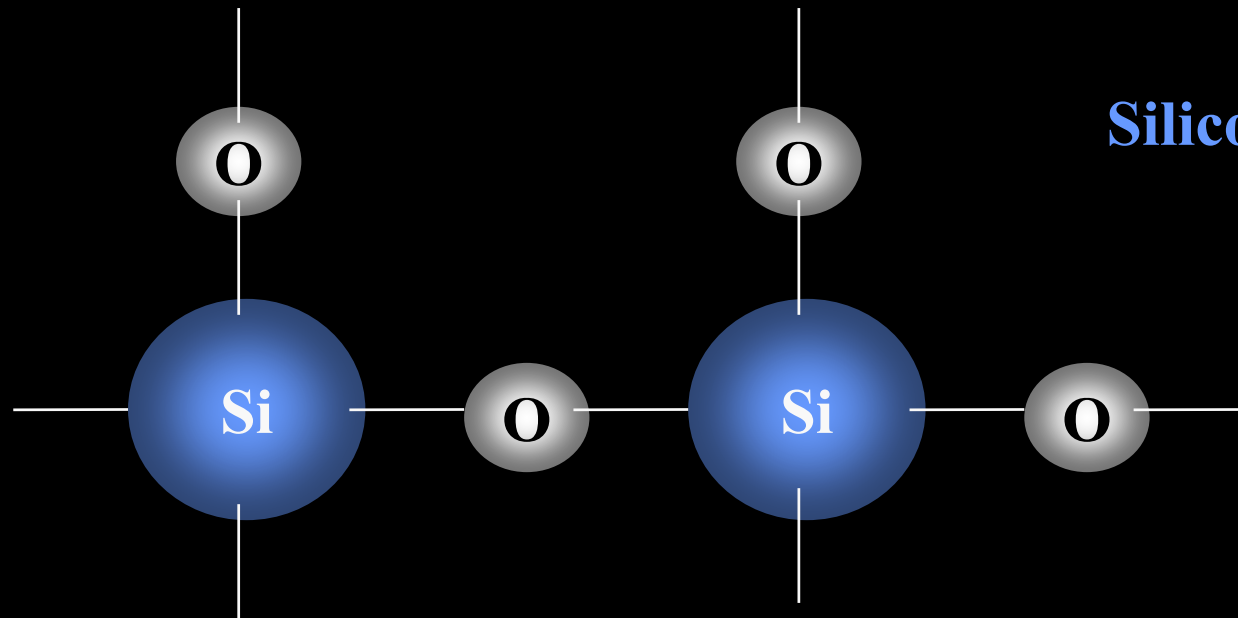
Homo Chain Polymers



Hetero Chain Polymers



Silicone Dioxide

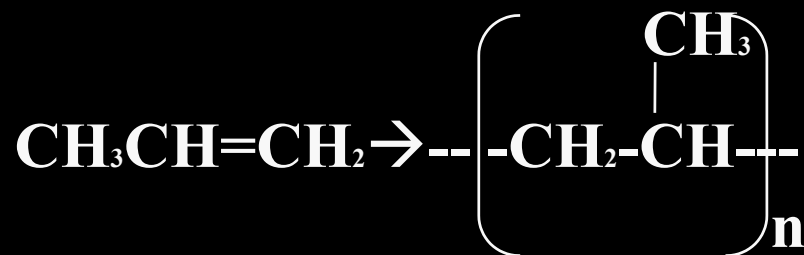


By Reaction Types

Oxidative Coupling
(open ring)

Addition polymerization
(chain polymerization)

Condensation
polymerization
(Step growth)



- (i) Ionic Polymerization*
- (ii) Coordination Polymerization*

Polymerization Techniques

- a.1. Bulk Polymerization
- a.2. Solution Polymerization
- a.3. Suspension Polymerization
- a.4. Emulsion Polymerization
- a.5. Solution Polycondensation
- a.6. Melt condensation
- a.7. Interfacial Condensation
- a.8. Solid and gas phase polymerization
- a.9. Gas phase polymerization of ethylene

THANKS

THE END

Murad AlDamen (M)

