GF Central Plastics Electrofusion Certification Program

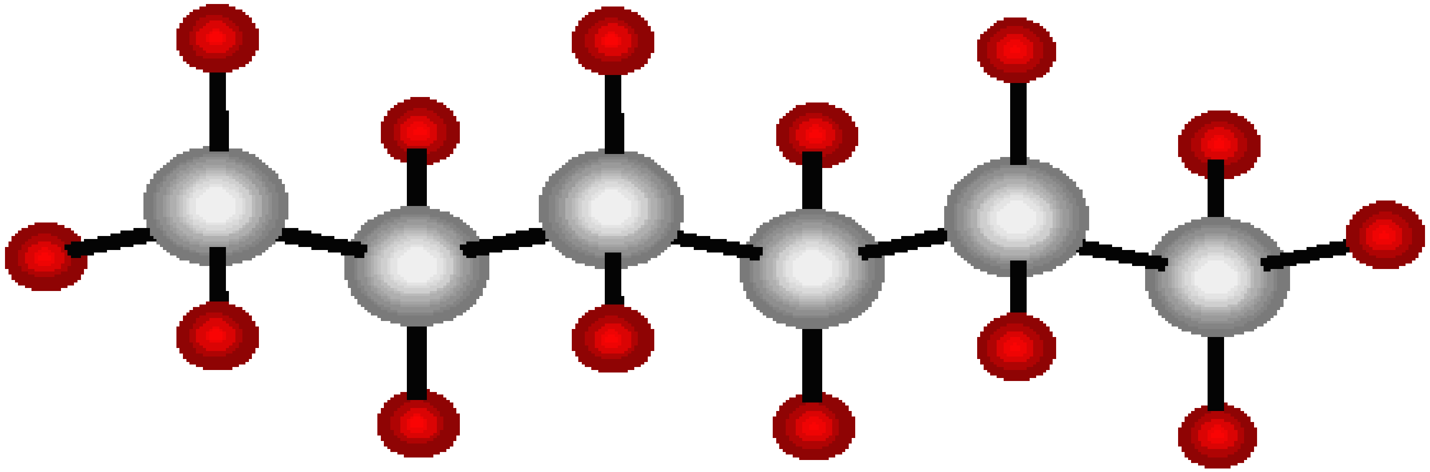
Polyethylene 101

Basics of PE and Heat Fusion

What is Polyethylene?

- Polyethylene is a plastic synthetic polymer derived from a hydrocarbon source.

- Like many other common classes of polymers that are composed of hydrocarbons; polyethylene is specifically made up of small molecular units that are bonded into long chains. Carbon makes up the backbone of the molecule and hydrogen atoms are bonded along the backbone.

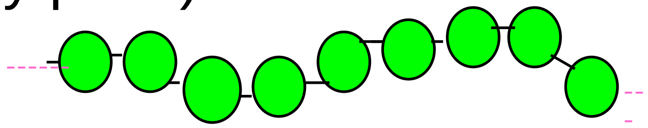


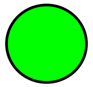
A little lesson in Greek?

- You'll often hear the words "polymer" and "monomer" when speaking of plastics.

- Poly – means *many* in Greek
- Mono – means *single* in Greek
- Meros – Means *parts* in Greek

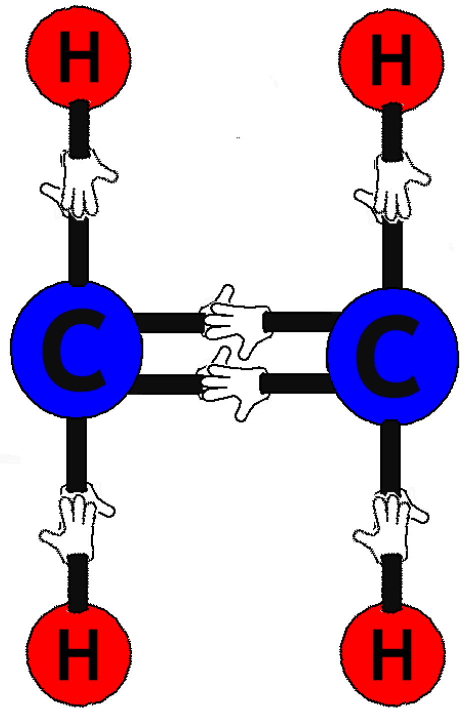
- Therefore we have:

- Polymer (many parts) – describes a chain of many molecules that makes up polyethylene: 

- Monomer (the building block) of polymers is a single molecule of ethylene. 

Structure of Polyethylene

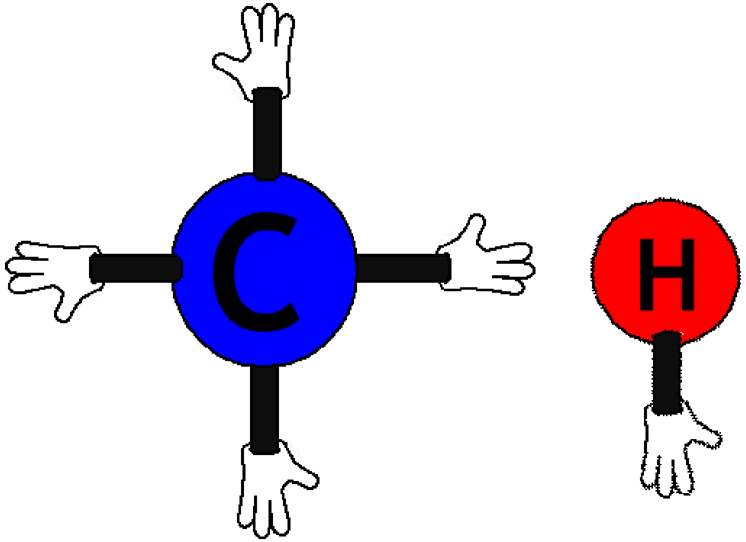
- **HDPE is created from one of the simplest molecules formed by Carbon and Hydrogen - The gas known as Ethylene.**



Ethylene is a gas that is extracted from a hydrocarbon source such as crude oil or natural gas and its basic molecular structure is formed by 2 Carbon atoms holding on to each other with two hands *(double bond)*, **and each of the remaining hands holding onto a Hydrogen atom** *(single bond).* **This is the basic building block (monomer) for many well known polymers we know as plastics.**

Structure of Polyethylene

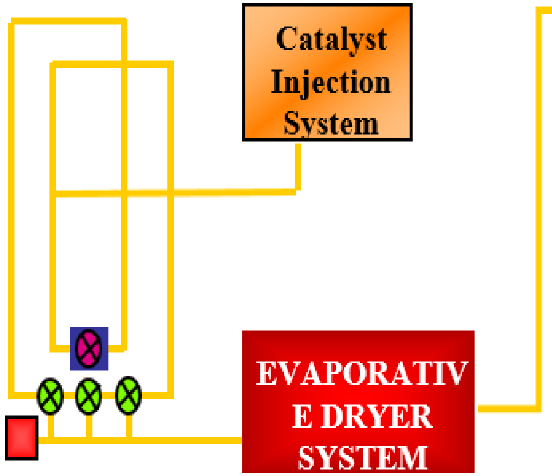
- **Polymers are very large molecules made up of repeating chains of mostly Carbon atoms** ***(symbolized by C)*** **and Hydrogen atoms** ***(symbolized by H).***



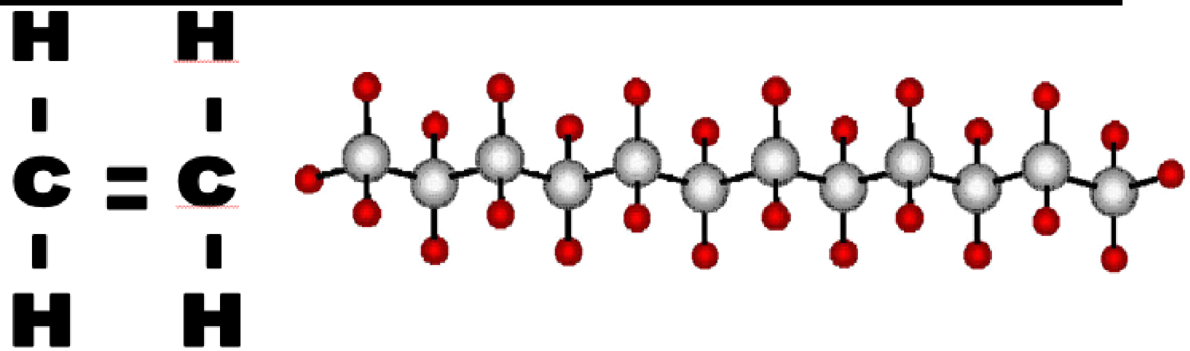
- ***By nature Carbon can join to 4 other atoms and Hydrogen can only join to 1***

Structure of Polyethylene

Polymerization



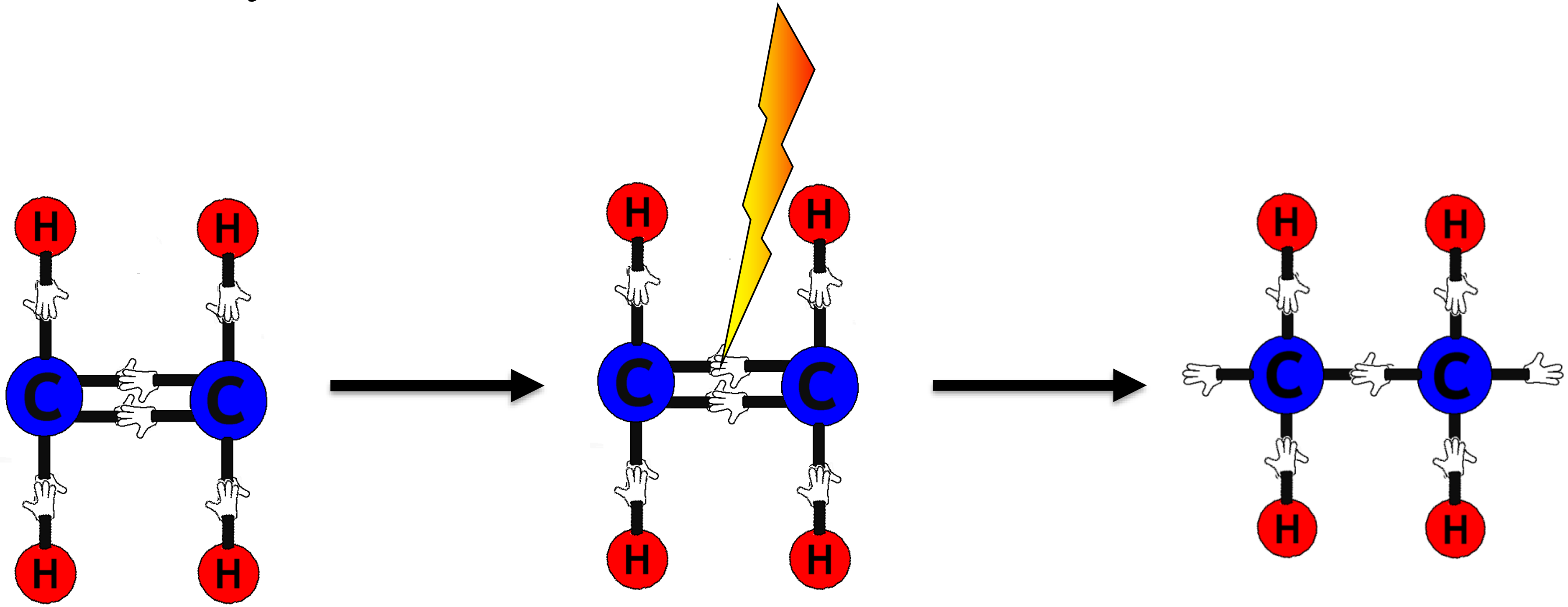
High Density Polyethylene (HDPE)



HDPE resin is derived from simple hydrocarbon polymer chains where the Ethylene molecules form a simple repeat structure (basically two carbon atoms and four hydrogen atoms repeated over and over again). From a molecular standpoint nothing is gained and nothing is lost.

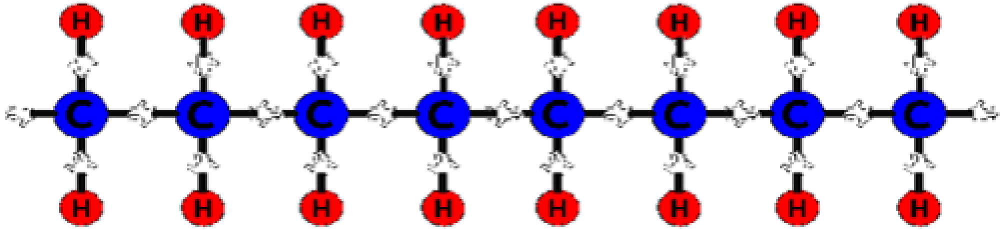
Structure of Polyethylene

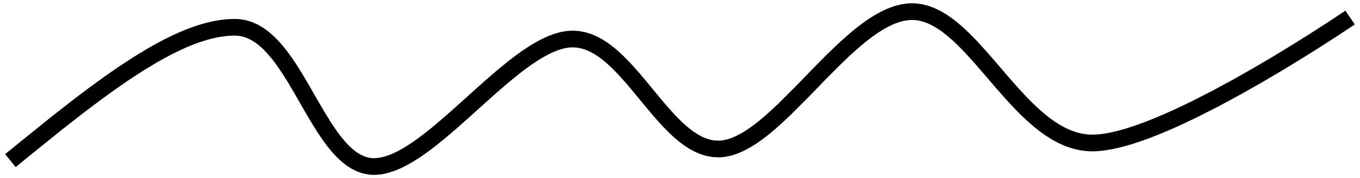
- To create HDPE the Ethylene building blocks (monomer) are fed into a reactor that is designed to break the Monomers double bond which in turn produces a slightly different form of Ethylene - called a radical.



Structure of Polyethylene

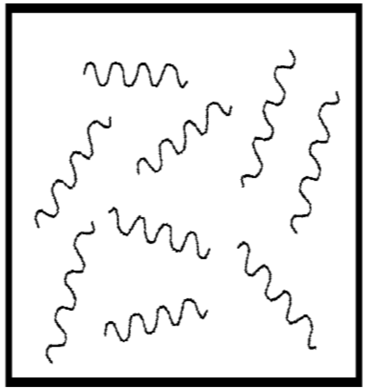
- Once this double bond is broken the ethylene radicals are left with two of their chemical hands empty. A state which neither of the molecules can naturally endure. Because of this, both of these new forms of Ethylene basically reach out and try to grab the first compatible hand they can find. Since no one else is around, the radicals grab the free hand of the next radical it can find. The process continues on and on forming the long chains known as polyethylene.



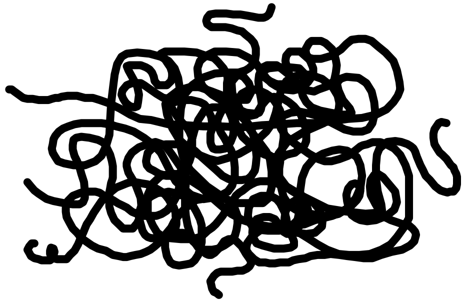


Structure of Polyethylene

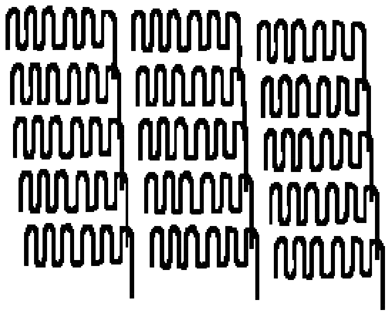
Eventually all the radicals in the reactor attach themselves into long chains and when the reaction process is terminated what is left is a “soup” full of long Polymer chains.



As this “soup” gradually begins to solidify, the polymer chains begin to organize themselves according to their chemical makeup and their molecular structure.

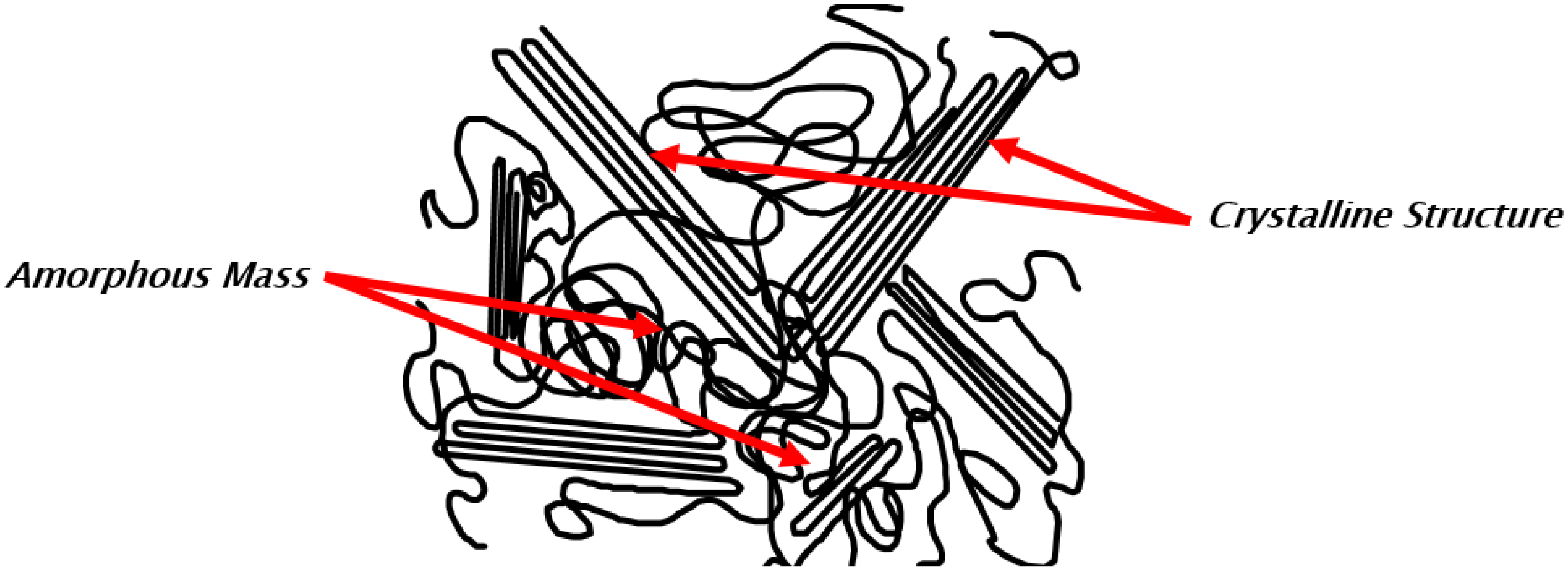


Polyethylene chains organize into both amorphous and semi-crystalline regions.



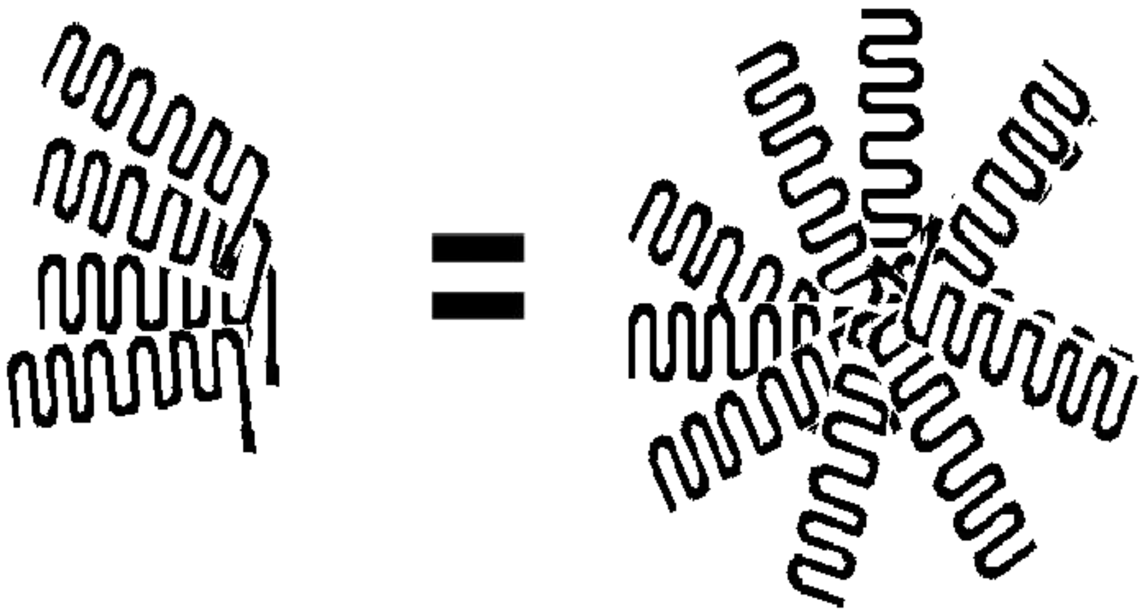
Structure of Polyethylene

Polyethylene consists of narrow and regular polymer chains clustered together in local axial alignment, forming "crystallites". It is known as a semi-crystalline plastic, which basically means that it will have regions of a crystalline-like structure throughout what would otherwise be known as an amorphous mass.



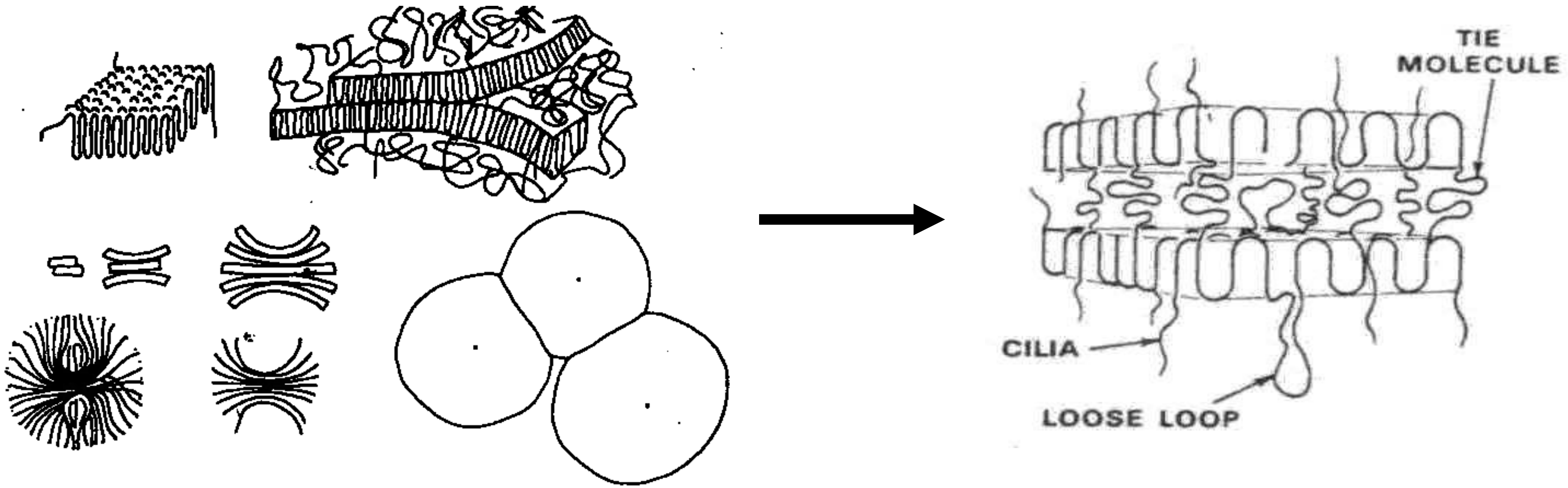
Structure of Polyethylene

- Crystalline structures will naturally form themselves into orderly arrangements. Since polyethylene is a semi-crystalline polymer, the polyethylene chains will naturally like to pack themselves into well organized groups called "spherulites".



Structure of Polyethylene

- In fact, as these long chains begin to arrange themselves, they begin to double back on themselves and pack into dense arrangements which are called a lamelae.
- As these lamelae begin to pack together they arrange themselves into spherulites. The spherulites pack together to form the solid. This is very similar to the regular crystal structure of other solids. Part of these long chain strands dangle from the lamelae and are called tie molecules.



Structure of Polyethylene

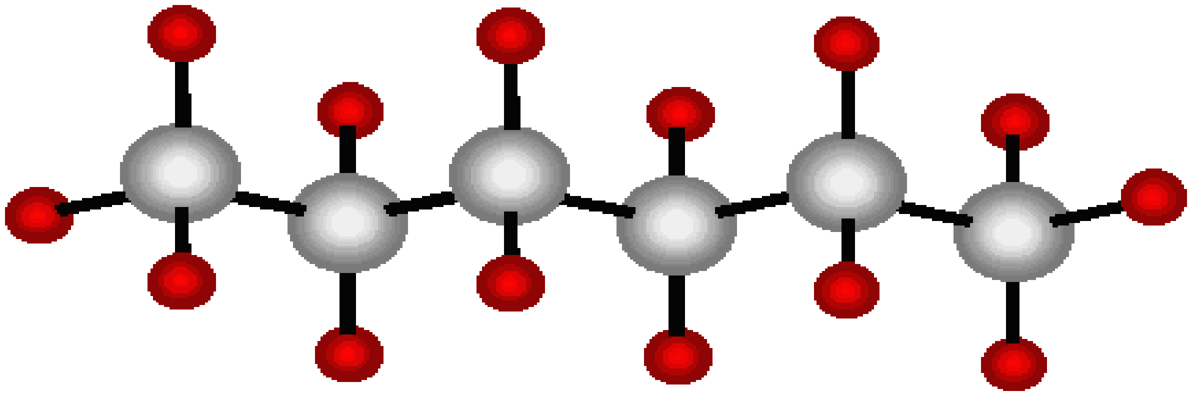
- What does all of this mean?
- As the HDPE crystallizes into spherulites, the molecular bonding that is taking place begins to put into place the unique material characteristics that make polyethylene a good material for piping, heat fusion and more.

- The crystalline lamellae provide the material with its;
  - Stiffness Characteristics
  - Tensile Strength Characteristics

- The amorphous regions provide the material with its;
  - Flexibility
  - Impact Resistance
  - Abrasion Resistance

Structure of Polyethylene

- **Most Importantly, polyethylene is *FUSIBLE***
- **Since Polyethylene is a semi-crystalline plastic it possess a sharp and predictable melting point and because it is a thermoplastic it can be heated, joined and cooled repeatedly with no damage to the material.**



Heat Fusion of Polyethylene

- Heat fusion is a welding process used to join two different pieces of a thermoplastic. This process involves heating both pieces simultaneously, allowing them to contact each other under pressure, thus allowing the melted materials to join together at the molecular level. The two pieces then cool together and form a single monolithic structure that is permanently bonded.

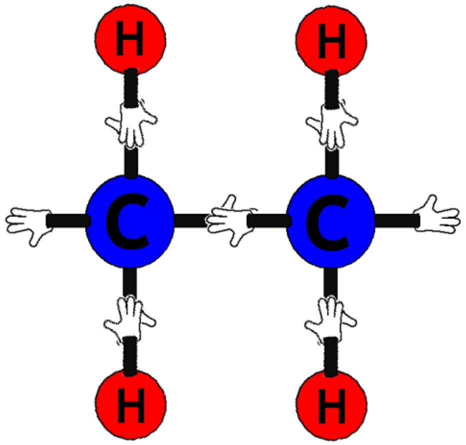
- The common methods are:
  - Butt fusion
  - Electrofusion
  - Socket fusion
  - Saddle or sidewall fusion

Heat Fusion of Polyethylene

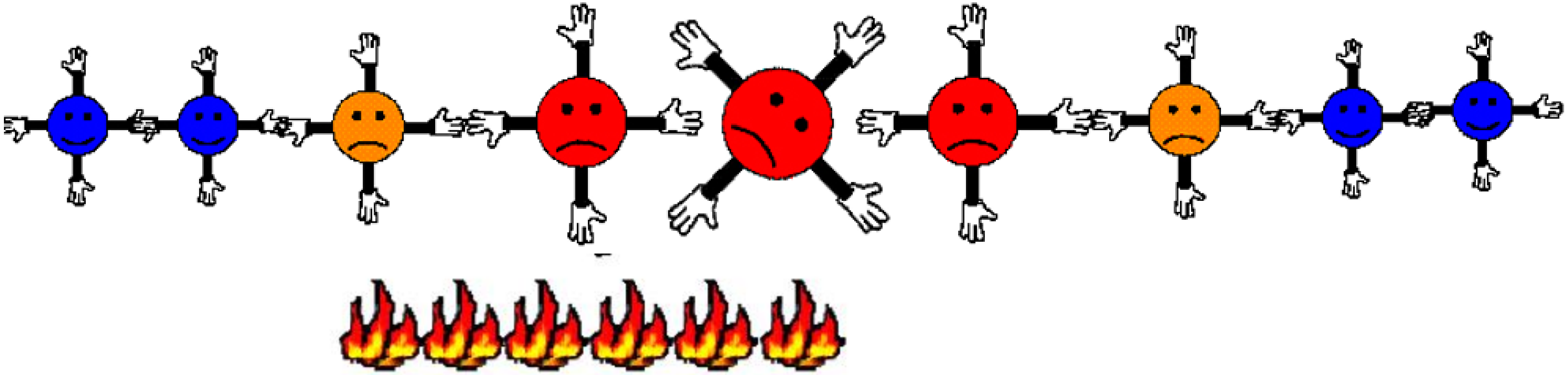
- All methods of heat fusion require:
  - Clean, contamination-free surfaces
  - Heating to a point above the co-crystallization temperature of the materials.
  - Contact interfacial pressure to achieve mingling of the melted surfaces.
  - Immobile contact to prevent stress of the softened material until the joint cools again to a point below the co-crystallization point.
  - Can be thought of as a combination of temperature, time, and pressure.

Heat Fusion of Polyethylene

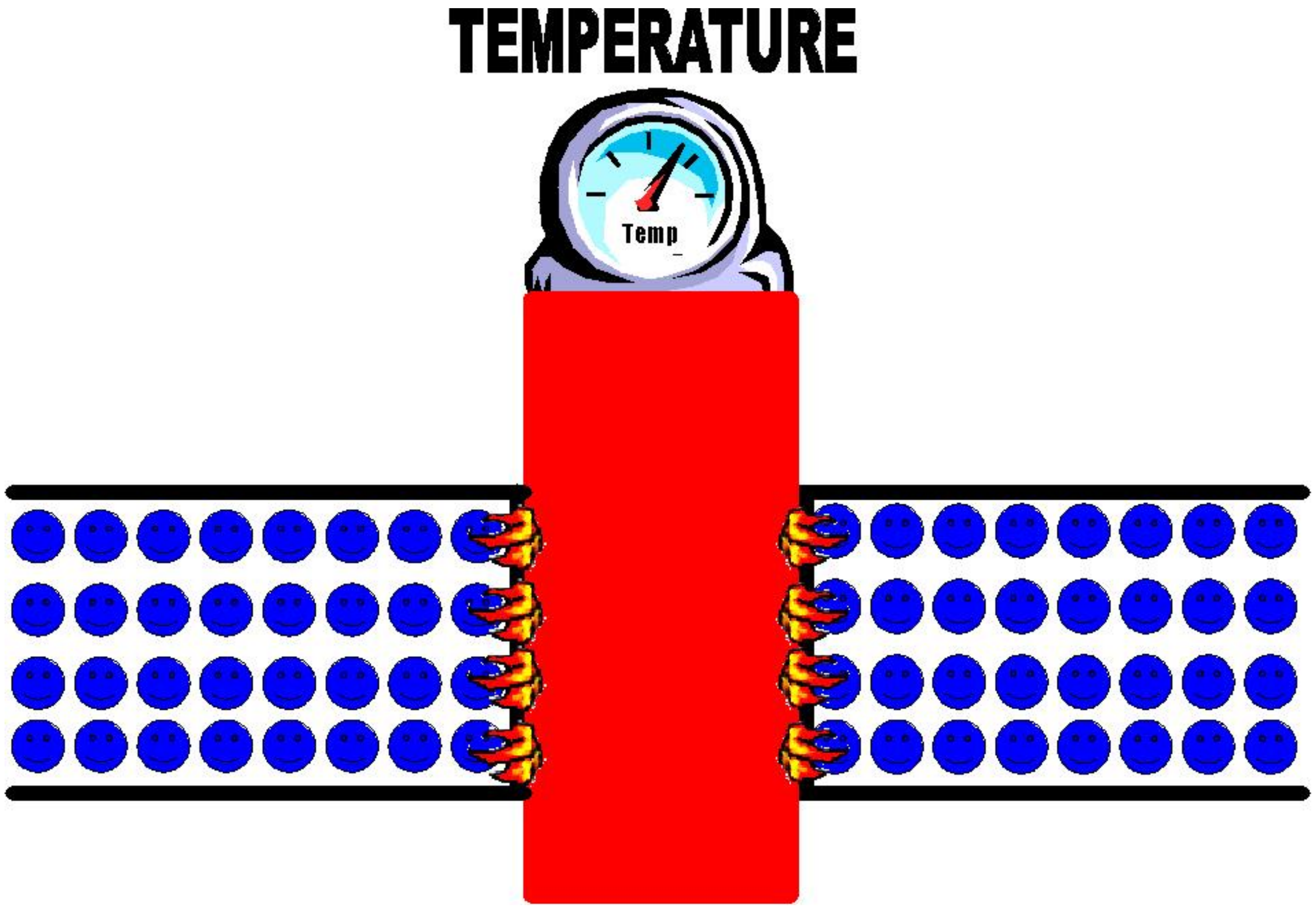
- Remember our 4-handed friends?



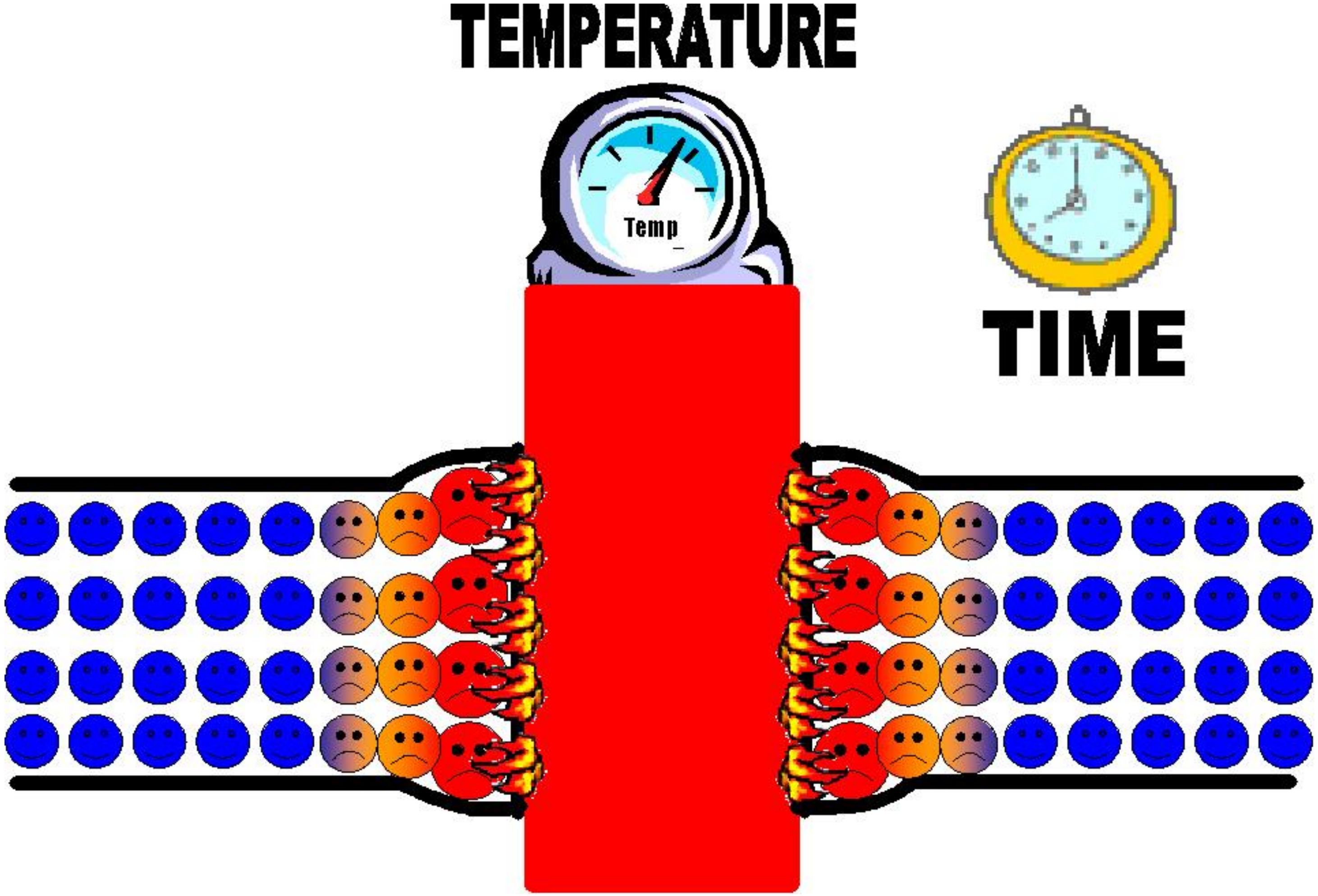
- Heat fusion processes free them to reach out and grab their neighbor:



Heat Fusion of Polyethylene



Heat Fusion of Polyethylene



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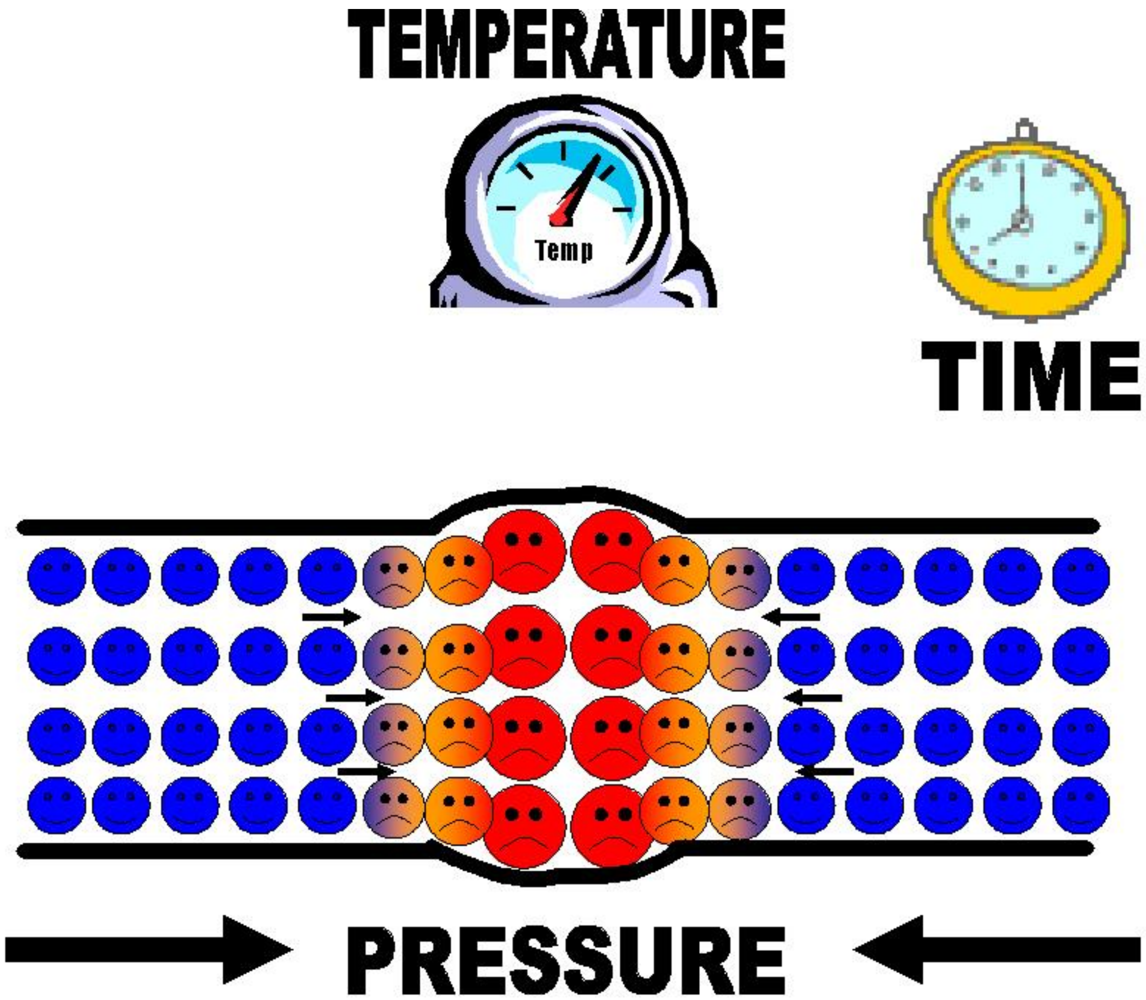

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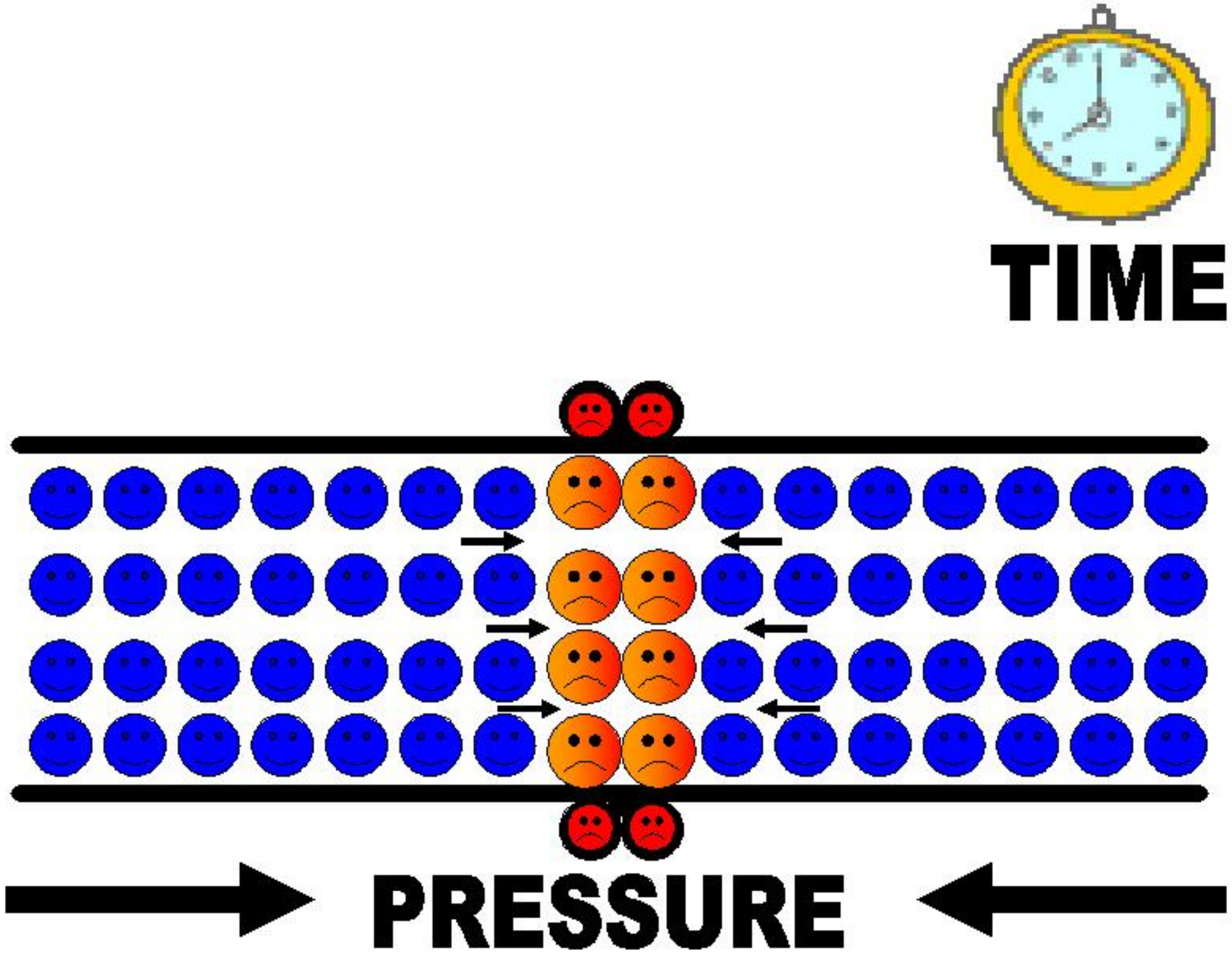
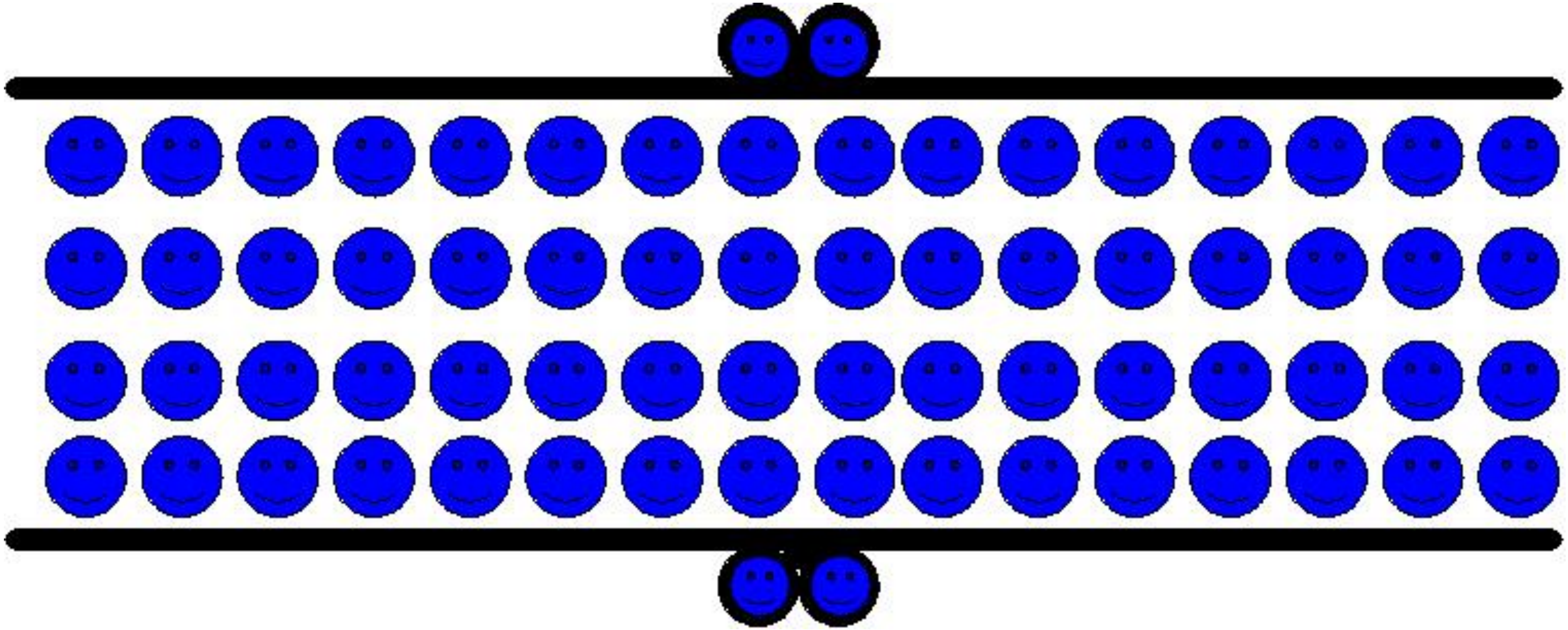


Heat Fusion of Polyethylene

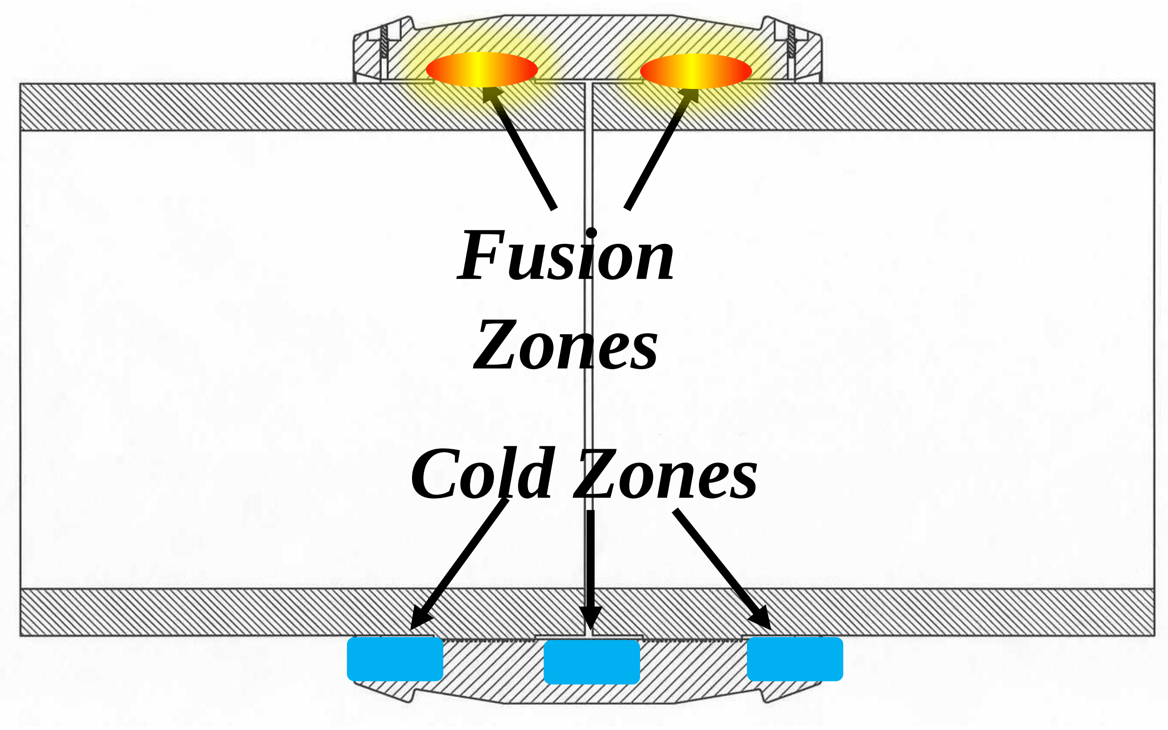


Electrofusion of Polyethylene

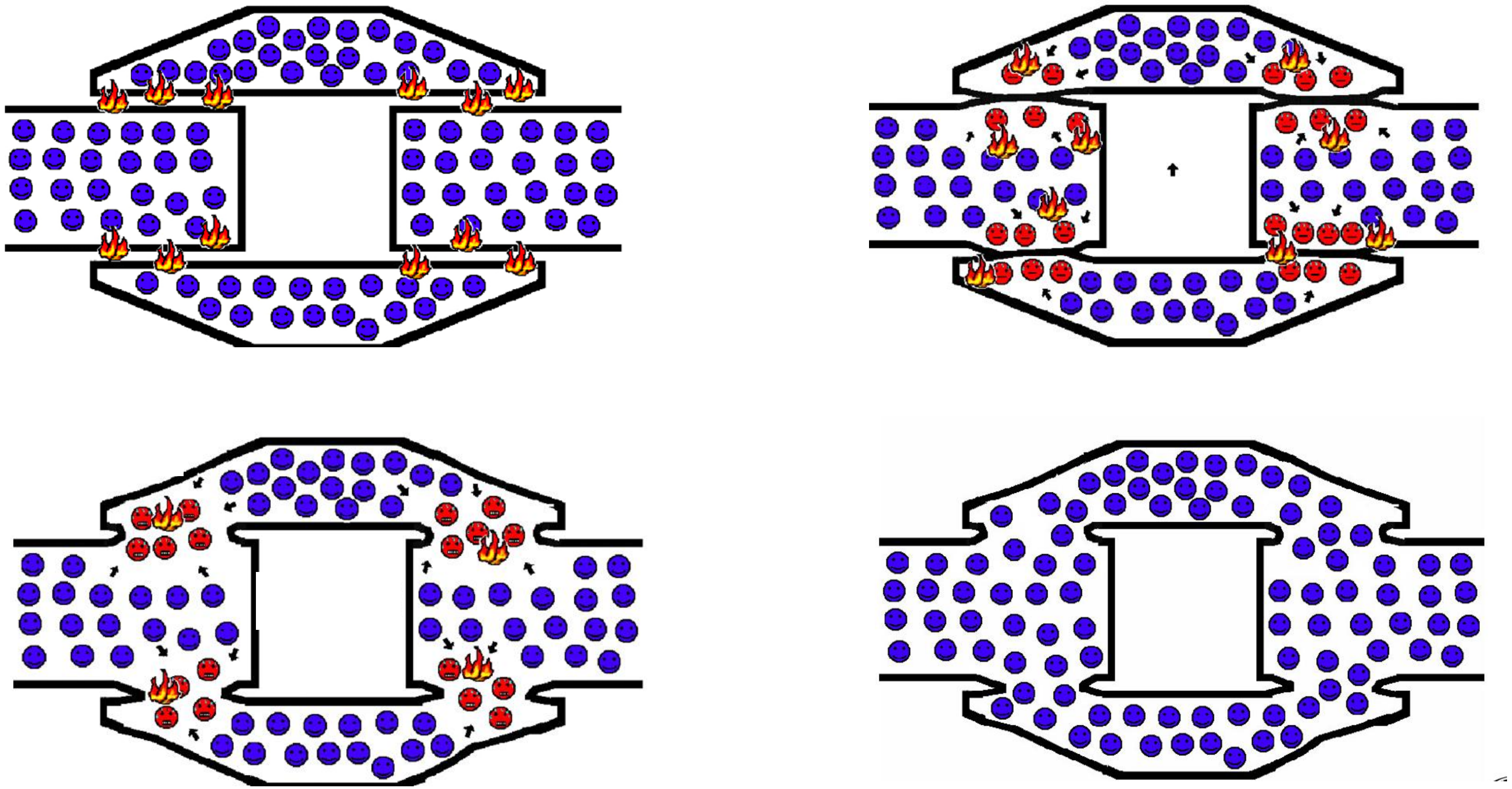
- Electrofusion is also method of heat fusion. The primary differences are:
  - The heat is generated internally by a conductive heating element.
  - The interfacial pressure is generated by melt expansion of the pipe and fitting
  - surfaces that is contained by cold zones that prevent the melt from escaping.
  - The fusion takes place on the outside surface of the pipe rather than the end.
  - The basic principles of time, temperature and pressure remain the same.

Heat Fusion of Polyethylene

- Heat is generated in the fusion zone
- Melt is contained within the fusion zone by the cold zones.



Electrofusion of Polyethylene



Electrofusion of Polyethylene