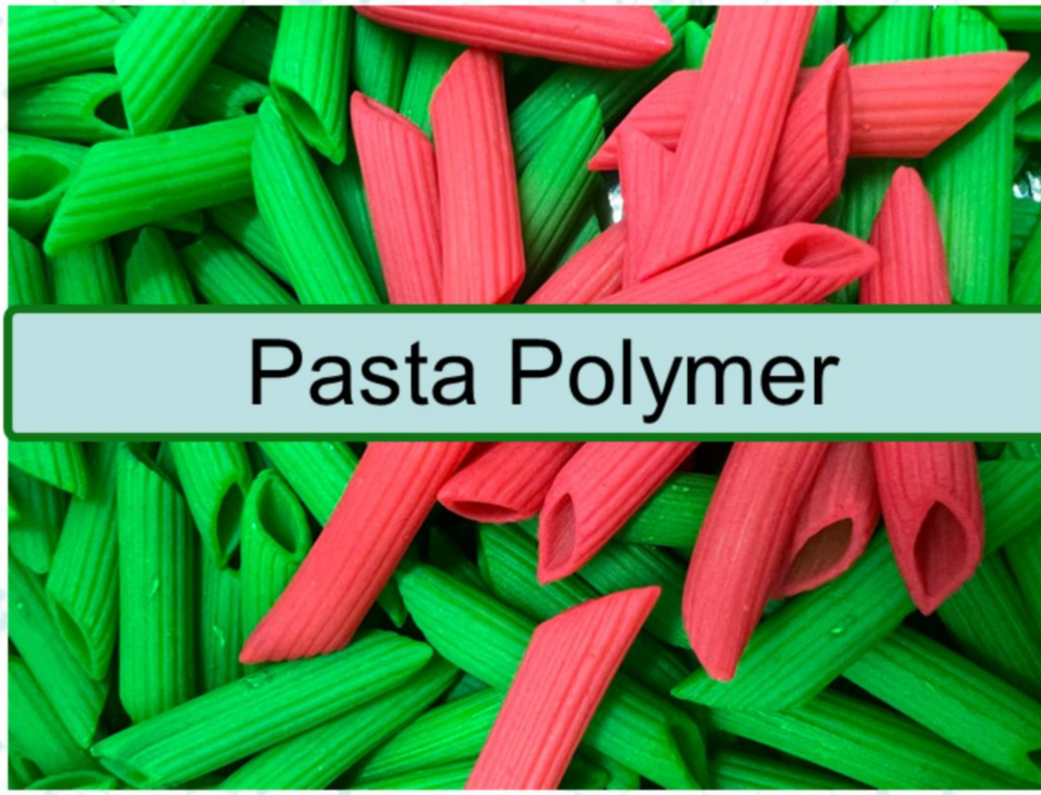
ARC TRAINING CENTRE FOR
GREEN CHEMISTRY
IN MANUFACTURING

Pasta Polymer



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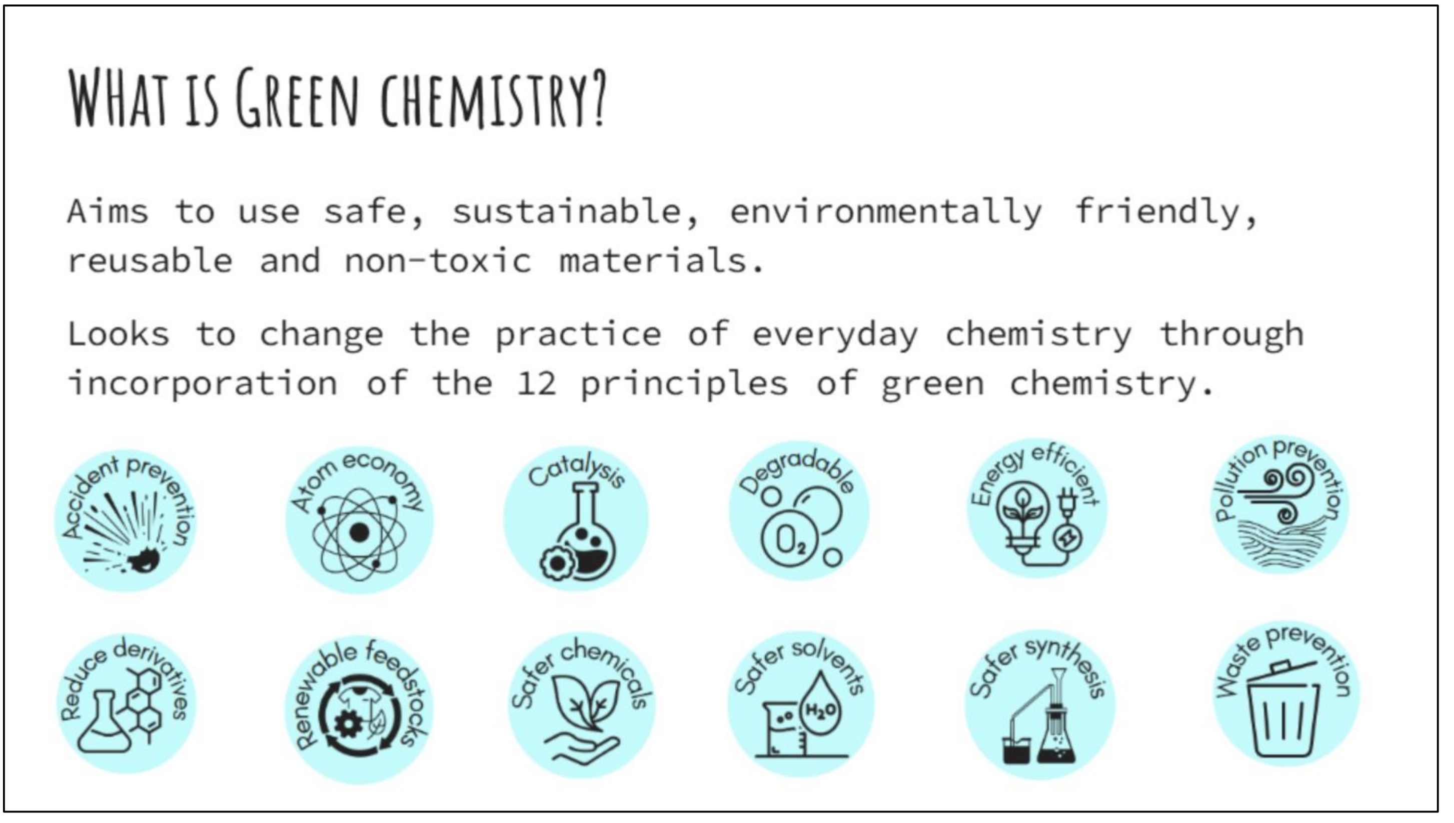

Green Chemistry aims to change the mindset and practices associated with everyday chemistry, to be safe, sustainable, environmentally friendly, re-used and non-toxic. The 12 principles of green chemistry were designed to help inform people about ways they can develop greener and safer chemical products or procedures. The 12 principles of green chemistry are shown on this slide - if there is time you can discuss with the students which principles they remember from the biodegradable water bottle experiment.

Plastics

Plastics are all around us!

Some of the materials used to make plastics are:

- ✗ **not** sustainable
- ✗ **not** environmentally friendly
- ✗ **not** reusable
- ✗ toxic!

They can take centuries to breakdown and as a result, pollute our environment.

Plastics are mainly made of non-biodegradable polymers.

Plastics are all around us. Conventional plastics are made from non-biodegradable materials that take centuries to break down in landfill and sometimes end up polluting our environment. Plastic in the ocean is one example of where conventional polymers have polluted our environment and don't breakdown completely. Most plastics are made up from polymers. Conventional polymers are typically made up of several monomers - which when reacted result in a sturdy impenetrable final product; however, this means that it may take centuries to breakdown.

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Plastics are mainly made of non-biodegradable polymers.

How can we make plastics more sustainable?

..first, we need to understand the science!

How can we make plastics more sustainable? If we understand the chemistry of polymers, we will have a better understanding on how we can develop greener, more biodegradable and environmentally friendly plastics. (like we did with the biodegradable water bottle practical experiment).

WHAT IS A POLYMER?

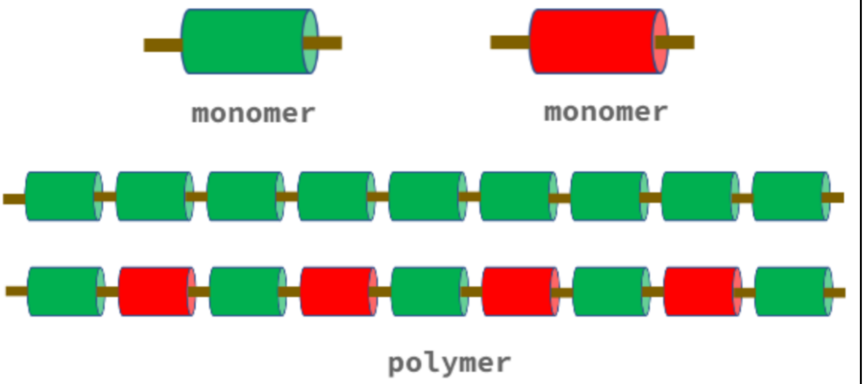
Polymers are large molecules made of connected monomers. Every monomer imparts specific properties to the polymer. (heat resistance, water resistance, antimicrobial properties)

Definitions:

‘mono’	one
‘poly’	many
‘mer’	unit

Monomer = one unit

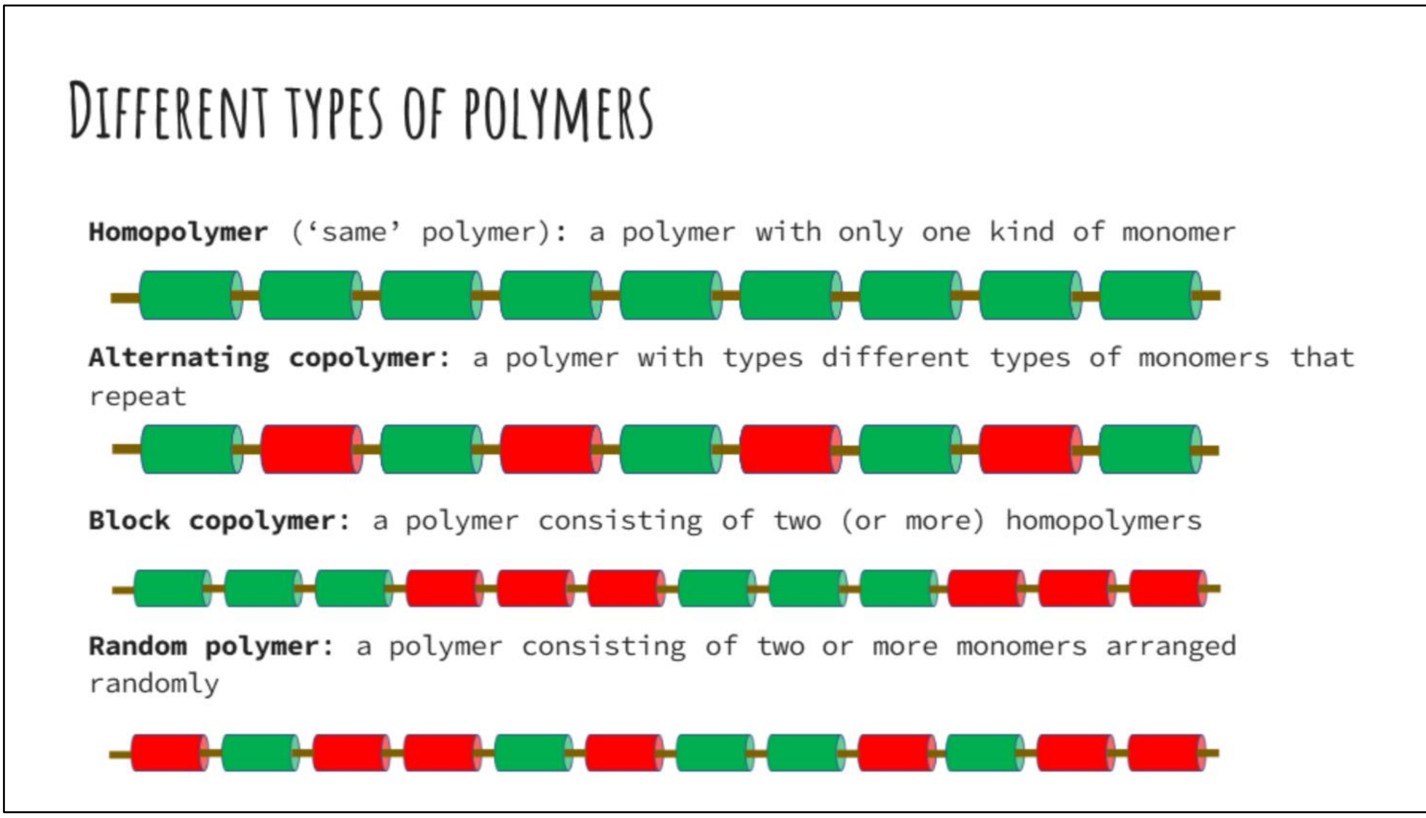
Polymer = many units



- A polymer is a large molecule composed of repeating structural units. These repeating units, known as monomers, are small molecules that link together to form long chains or networks. The process of joining monomers to create a polymer is called polymerization.
- Polymers can have a wide range of properties and are found in various natural and synthetic materials. They play a crucial role in our everyday lives and are used in countless applications, including plastics, rubber, fibers, adhesives, coatings, and more.
- There are two primary types of polymers:

1. Natural Polymers: These occur in nature and are often derived from biological sources. Examples of natural polymers include proteins, DNA, cellulose (found in plants), and natural rubber.
2. Synthetic Polymers: These are human-made polymers created through chemical processes. Some common examples of synthetic polymers include polyethylene (used in plastic bags), polypropylene (used in containers and textiles), polyvinyl chloride (PVC), and polyethylene terephthalate (PET, used in bottles and textiles).

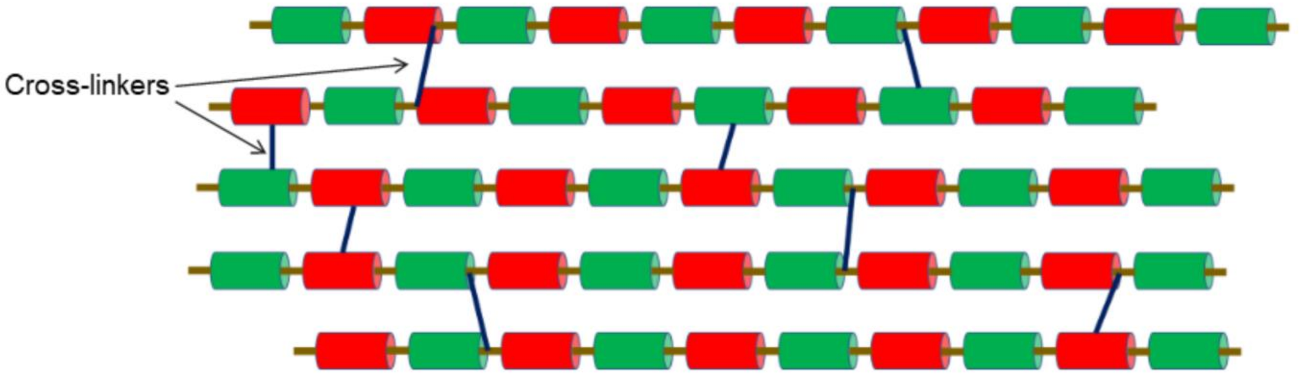
- Polymers can have varying structures and properties depending on the choice of monomers and the conditions of polymerization. This versatility makes them essential materials in many industries and applications.



Monomers can be arranged in different ways within the polymer chains. If you have multiple monomer types, you can create what is called an "alternating polymer", where each monomer alternates. Other polymers can be made by varying the monomers including block copolymers and random polymers. The arrangement of monomers will vary the physical properties of the final polymer. These four types of polymer chains will be made using the experiment kit.

Different types of polymers

We can join different polymers using cross-linkers to make them more stable, rigid and stronger.



Polymer chains are joined with cross-linkers to form polymers. Cross-linkers stop the chains sliding past each other and creates a structure like a net which is usually much more rigid. Varying the type of cross-linker will change the properties of the final polymer, making it more or less suitable for a particular application.

A cross-linker is a chemical compound that forms bonds between the polymer chains, creating a three-dimensional network within the material, leading to increased structural stability, strength, and durability. Cross-linking is a crucial technique used to modify the properties of polymers for various applications.

Here are some key points about cross-linkers and their effects on polymers:

- Improved Mechanical Properties: Cross-linking enhances the mechanical properties of polymers, making them more resistant to deformation, stretching, and breaking.
- Reduced Solubility: Cross-linked polymers are often less soluble in solvents including water than their non-cross-linked counterparts. This property can be advantageous in applications where chemical resistance is important.
- Thermal Stability: Cross-linking can improve the thermal stability of polymers, making them more resistant to heat and preventing them from softening or melting at elevated temperatures.
- Chemical Resistance: Cross-linked polymers are less susceptible to chemical degradation and can resist the effects of various chemicals and environmental factors.
- Applications: Cross-linked polymers find use in a wide range of applications, including the manufacture of rubber products (e.g., tires), dental materials,

adhesives, and coatings. For example, cross-linked polyethylene is commonly used in pipes for its improved strength and resistance to chemicals.

Let's make our own Pasta Polymers!

Aims:

- To make 4 different types of polymers and join them using cross-linkers

Materials:

- Part 1: Green and red penne pasta (2 different monomer units)
- Part 2: Paper clips (cross-linker 1)
- Part 2: Black twine (cross-linker 2)

Let's make our own Pasta Polymers!

Method - Part 1: Creating polymer chains from pasta

1. Collect all materials
2. Each person in the group should make one each of the following polymers.

    - Homopolymer (using green pasta)
    - Alternating copolymer (green and red pasta)
    - Block copolymer (green and red pasta)
    - Random polymer (green and red pasta)

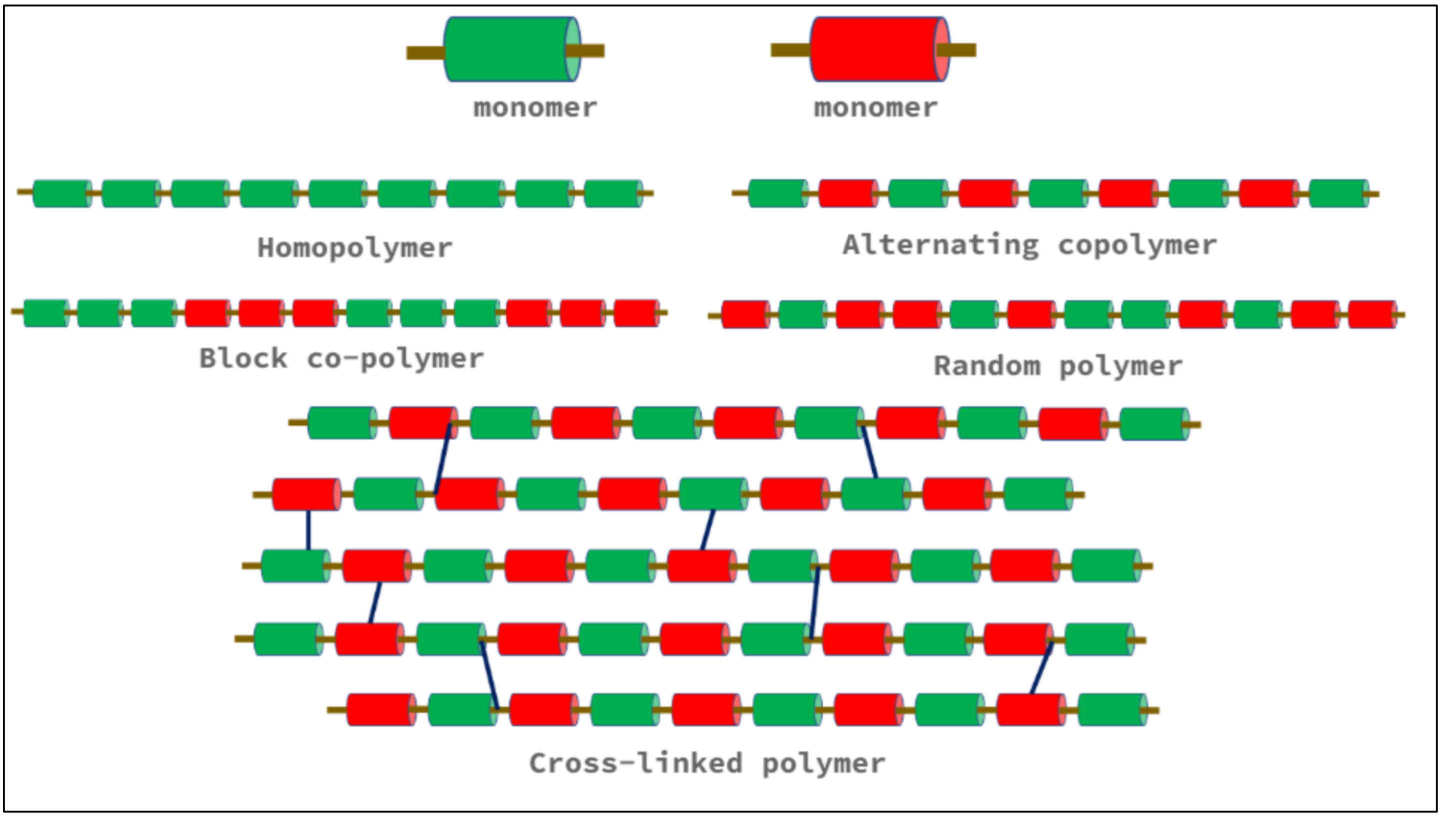
    Use 10-12 pasta (monomers) per polymer chain. Thread the pasta onto the twine to make the chain (tie a knot at each end of the twine).

Let's make our own PASTA Polymers!

Part 2: Cross-linking your polymers (groups of 4)

From part 1, you should have 4 polymer chains of each type of polymer.

1. As a group, cross-link your homopolymer chains using 8 cross-linker paperclips.
2. As a group, cross-link your copolymer chains using the black twine.
3. As a group, using up to 10 cross-linkers of any type, create a polymer that is flexible from your block copolymer.
4. As a group, using up to 10 cross-linkers of any type, create a polymer that is rigid from your block copolymer.


monomer
monomer
Homopolymer
Alternating copolymer
Block co-polymer
Random polymer
Cross-linked polymer

When are polymers biodegradable?

- When polymers can be broken down into individual monomer units and further break them down into natural elements in a short span of time, then they are biodegradable.
- Biodegradable polymers can be synthetic, natural or a combination of both.
- Natural biodegradable polymers - silk, keratin, cellulose, even our DNA!
- Synthetic biodegradable polymers- some types of polyester, poly(lactic acid).

What are green polymers?

- Green polymers are polymers made using sustainable methods.
- Green chemistry focusses on either replacing a synthetic polymer with a natural counterpart and if that is not possible, reducing the effect on the environment during synthesis.
- The green nature of polymers can be improved by using biodegradable cross-linkers that join the polymer strands.
- While all biodegradable polymers can be considered green polymers(if they are made in a sustainable way), not all green polymers may be biodegradable.