University of Sheffield

Materials -
a SUBJECT
that MATTERs

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Natural Materials.

Can spiders **save the world?**

What is Materials Science and Engineering (MSE)?

MSE is defined as an ‘interdisciplinary subject, bridging the physics and chemistry of matter towards engineering applications and industrial manufacturing processes.’ The programme content spans from foundations in physics and chemistry to the mechanical, electrical, magnetic, and optical properties of materials, and the design, manufacture and applications of metals, alloys, ceramics, polymers, composites, and biomaterials.

MSE continues to establish itself amongst engineering disciplines and is offered as a degree course across the UK at the Universities of Birmingham, Cambridge, Imperial College London, Leeds, Loughborough, Manchester, Oxford, Queen Mary, Sheffield and Swansea, as well as Materials Chemistry being offered at St Andrews and Glasgow.

Key Learning outcomes

- A silk is a structural protein that has evolved in animals such as silkworms and spiders. Silks are classed as high performance, biodegradable biopolymers.

- Animals produce these silks through ‘spinning’. The spinning process is very similar to our own industrial methods used to process polymers in engineering, however, in nature, the biopolymers are spun at room temperature and only produce water as a waste product. Therefore, the way that nature produces these biopolymers has a much better environmental impact than our current industrial polymer processing techniques.

- Materials scientists need to research the way in which silk is spun in order to understand the material and natural protein folding further. This will help to improve our own polymer processing routes, making them more energy efficient, and enabling us to design new materials.

GCSE Chemistry topics this episode could be taught alongside…

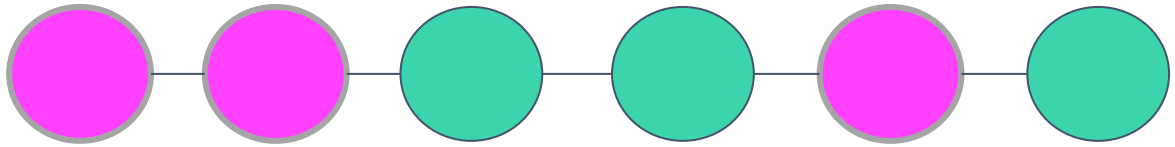
Bonds Structure and Properties of matter (Polymers)	Organic Chemistry (Synthetic and Natural Polymers)	Materials Properties

How does this episode go beyond the curriculum?

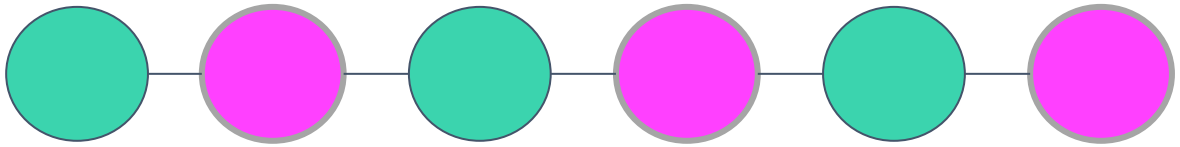
How is producing spider silk different to the chemical reactions taught for polymer production?

- Spider silk, although demonstrating similarities with polymer processing, is not produced through a process that can be replicated in the lab using the monomer reactions as taught at GCSE.
- Spider silk is tough protein fibre that is spun and stretched on demand by the spiders from a liquid silk precursor in special glands. The process is initiated by the silk being pulled away from the body. Spiders can use their legs or can simply fall and use their own weight to pull and stretch the fibre.
- Silk is a natural polypeptide, polymeric protein and is in the fibrous group which also includes collagen (in ligaments) and keratin (in nails and hair). The silk has a primary structure which is comprised of an amino acid sequence with repeated glycine and alanine blocks and so is essentially a block copolymer.

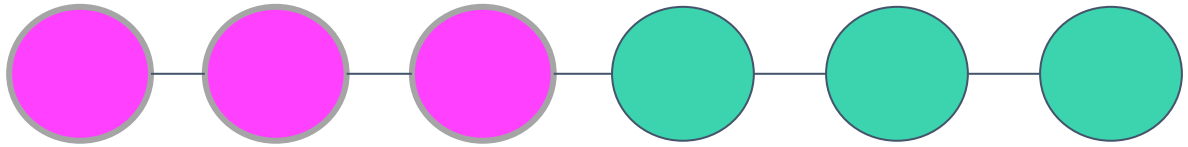
Random Copolymer



Alternate Copolymer



Block Copolymer



Alanine blocks are mostly crystalline, highly ordered microstructures.

Glycine blocks are the semi-amorphous, more flexible part of the fibre.

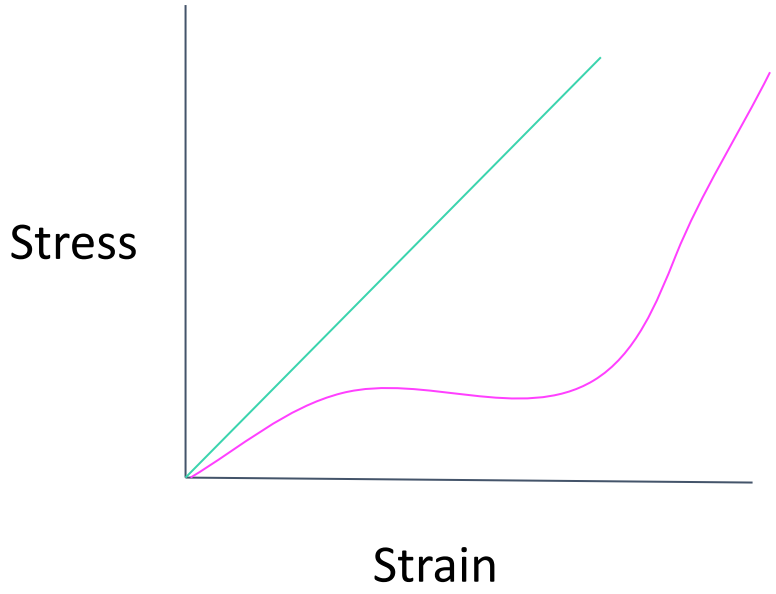
Materials Properties

We can teach students that spider silk also has a non-linear stress response.

This means that if you continue to pull a thread of spider silk, it is initially stiff, then stretchy, then stiff again.

This makes the material robust and so, if any damage is inflicted on the web, the damage is highly localized, meaning that the web can remain functional.

This is important when thinking about applications in the military, aerospace, and construction industries.



Key definitions

Polymer

A polymer is a large molecule made up of repeating subunits called ‘monomers’.

Monomers are small identical molecules covalently bonded to one another to form a long chain.

Protein

Proteins are large molecules made from lots of amino acids folded into the correct shape and joined together in a unique sequence to form chains.

They include enzymes, haemoglobin , collagen and keratin .

Co-polymer

A copolymer is a polymer that is made up of two or more monomers.

Copolymers are used in many important commercial applications.

Crystalline

A material that has a highly ordered microscopic structure.

The atoms, molecules or ions are arranged in a specific way, usually forming a crystal lattice that extends in all directions.

Amorphous

An amorphous structure is the opposite of a crystalline structure as it has no order.

The atomic structure is randomly arranged, resembling that of a liquid.

Amorphous materials are typically amorphous solids unless stated otherwise.

Semi-amorphous

Also known as ‘Semi-crystalline’ materials that have a highly ordered molecular structure with well defined melting points.

They remain solid until a certain temperature at which point they can then rapidly change into a low viscosity liquid.

Questions to think about…

What can we use spider silk for?

- Bulletproof armour
- Violin strings
- Medical bandages
- Optical fiber cables

What are the desirable properties of silk?

- Tensile Strength
- Elasticity
- Toughness
- Low economic cost

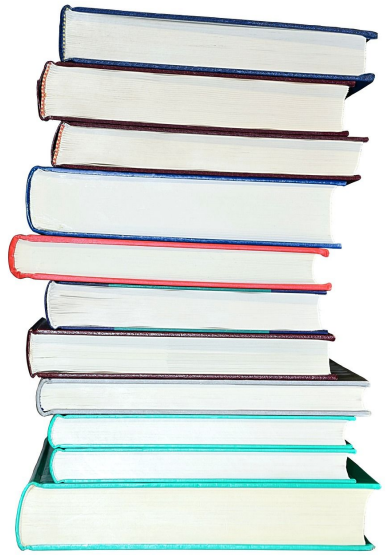
Discussion Topics…

- What materials in nature are like materials we use in industry?
- What materials in nature have interesting properties that we would want for certain applications?

"Weight for weight it stronger than steel, tougher than Kevlar used for bulletproof protection and can be more elastic than rubber… I don't think people would believe you if you told them, there's this creature that, if you scaled it up … to the size of the human, it could catch an aeroplane with the material that it makes itself out of itself. "

Fritz Vollrath, an evolutionary biologist at the University of Oxford who worked in the same group as Dr Chris Holland

Additional Resources



- **Flipt youtube video**
  https://www.youtube.com/watch?v=4KGllEGYYmc

- **Natural materials group webpage**
  https://natmatgrp.shef.ac.uk/

- **The conversation article- how scientists are making plant based foods taste and look like meat**
  https://theconversation.com/how-scientists-make-plant-based-foods-taste-and-look-more-like-meat-156839

- **Royal Society of chemistry Article**
  https://www.chemistryworld.com/features/spinning-out-spider-silk-research/3007091.article