Week 6 Lesson 3

A new look at wood

Aim: To compare concrete and wood as construction materials and to look at a relatively new field of research, the molecular structure of plant cell walls.

Keywords: cellulose, durable, insulator, laminate, lignin, polymer, thermal energy,

Starter activity

1. A new look at wood

A quick starter activity to introduce the concept of different woods having different properties, see the PowerPoint 'A new look at wood'.

Main activities

1. Where does the hardness of timber come from?

Ask students to make suggestions based on their knowledge of the structure of plant and animal cells.

Demonstrate the effect of a cell wall on the rigidity of a cell by using a balloon and a shoe box.

The cell wall gets its strength from the world's most abundant organic polymer (polymers were discussed in WK 5 lesson 3) – cellulose. The cellulose polymer consists of 8 000 – 10 000 monomers.

A second polymer, lignin, is also important.

2. Comparing concrete and wood

Using the resource 'Comparing concrete and wood' students compare and contrast the properties of wood by placing statements into a Venn diagram. Discuss the advantages/disadvantages students have chosen. Highlight the differences in CO_2 emissions; wood is a much greener construction material.

3. Cellulose and other materials

A selection of short tasks to compare the strength of different building materials, see the resource ‘Cellulose and other materials.

Background information on current research

Scientists are only just beginning to look at how the cellulose and lignin molecules, which make up cell walls, are arranged. This is an unexplored area of research with huge potential.

Paul Dupree, a biochemist at the University of Cambridge has received a grant of £1.75 million to work with architects and polymer chemists. They will use a nuclear magnetic resonance machine to find out more about the atomic structure of cell walls.

If the complex arrangement of cellulose molecules could be mimicked this may lead to the design and production of stronger laminated materials or to genetically engineered trees, strong enough to be used in the construction of bigger buildings.

Assessment opportunity

Check students’ graph drawing skills, understanding of ratios, knowledge of prefixes and interpreting data.

Plenary activity

1. Biomimicry summary

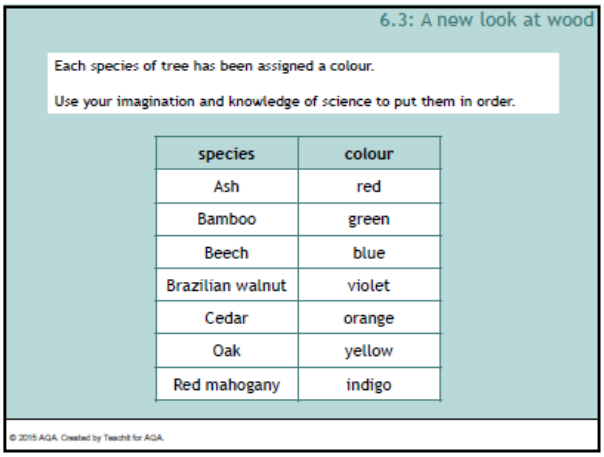
Students list as many examples of biomimicry as they can in 30 seconds.

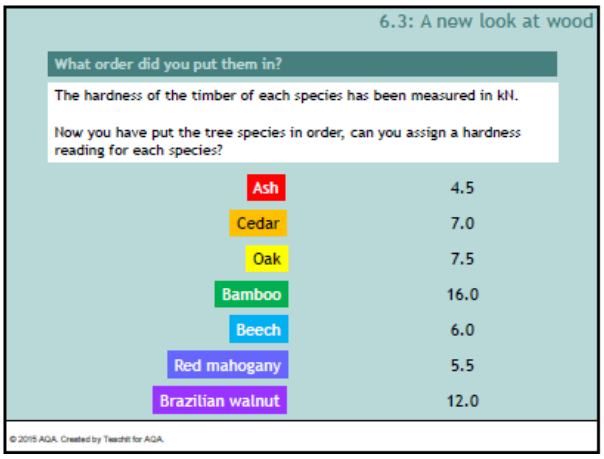
Students rank them in order of importance.

Which area of research/product development would they like to be involved in and why?

Starter 1

A new look at wood — PowerPoint





Main 2

Comparing concrete and wood — Answers

Material	Property
Concrete	Strong enough to support very tall buildings
	Can be poured into moulds
	Will solidify under water
	Durable
	Fire resistant
	Poor thermal insulator
	Can store and release a lot of thermal energy
	Requires a lot of energy to manufacture and transport
	Responsible for 5% of greenhouse gases*
	When liquid may cause burns to skin and eyes
Wood	May swell when wet
	Good thermal insulator
	Higher strength to weight ratio than structural steel
	Safe; non toxic
	Plentiful
	Lightweight
	Oldest building material
	Some species are very durable
	Removes CO_2 from atmosphere
	Waste and off cuts can be recycled
Both	Composite material
	Low maintenance

* produced by human activity.

Comparing concrete and wood

Look at the statements in the table.

- Which ones apply to wood?
- Which apply to concrete?
- Which are shared by both?

Draw a suitable Venn diagram to sort the statements.

Discuss each statement with your partner before adding them to the Venn diagram.

Property	
strong enough to support very tall buildings	good thermal insulator
safe; non toxic	removes CO_2 from atmosphere
will solidify under water	can be poured into moulds
waste and off cuts can be recycled	fire resistant
plentiful	lightweight
low maintenance	can last for hundreds of years
some species are very durable	can store and release a lot of thermal energy
requires a lot of energy to manufacture and transport	higher strength to weight ratio than structural steel
responsible for 5% of greenhouse gases*	durable
when liquid may cause burns to skin and eyes	composite material
may swell when wet	poor thermal insulator

* produced by human activity

Q. What do you think are the main advantages and disadvantages of concrete and wood as building materials?

Main 3

Cellulose and other materials — Answers

Task 1

1. **What will be the length of four fibres laid end to end?**

100 µm

2. **How many fibres would there be in 750 µm?**

30 fibres

3. **How many fibres would be in 1 mm?**

1000 µm = 1 mm

1000 µm ÷ 25 µm = 40

Task 2

1. **What is Pa short for?**

Pascal

2. **What does the unit Pa measure?**

Pressure

3. **What does MPa mean?**

Mega Pascal 10^6 Pascal

Task 4

Material	Tensile strength (GPa)	Stiffness (GPa)	Ratio tensile strength :stiffness	Working	Unitary ratio
Cellulose nanocrystals	7.5	150	7.5 :150	150 ÷ 7.5 = 20	1 : 20
Glass fibre	5	85	5 : 85	85 ÷ 5 = 17	1 : 17
Steel wire	4	208	4 : 208	208 ÷ 4 = 52	1 : 52
Kevlar	3.8	152	3.8 : 152	152 ÷ 3.8 = 40	1 : 40
Graphite whiskers	21	420	21 : 420	420 ÷ 20 = 21	1 : 21
Carbon nanotubes	11 73	275 876	11 : 275 73 : 876	275 ÷ 11 = 25 876 ÷ 73 = 12	1 : 25 1 : 12

2. **Which material shows the greatest proportional difference between its tensile strength and stiffness?**

   Steel wire has the greatest difference between tensile strength and stiffness.

3. **Describe how cellulose compares to other materials used as reinforcement.**

   Cellulose is very similar to graphite whiskers, glass fibre and carbon nanotubes.

4. **Do you have access to the internet? If so, can you find out why carbon nanotubes have a range of measurements for strength and stiffness?**

   You may remember from Week 1, lesson 2 nanotechnology that; the properties of carbon nanotubes including strength, depend on how the sheet of carbon atoms is rolled up.

5. **What does GPa mean?**

   Giga Pascal 10^9 Pascal

Cellulose and other materials

Task 1 - cellulose

Cellulose fibres are on average 25 µm long.

1. What will be the length of four fibres laid end to end?
2. How many fibres would there be in 750 µm?
3. How many fibres would be in 1 mm?

Task 2 – comparing strength of different materials

Material	Strength when compressed (MPa)
Bone	170
Cast iron	170
Cellulose fibres	80
Concrete	40
Douglas fir (wood)	50
Marble	15
Pine tree (wood)	40
Polystyrene	30
Structural steel	400
Tooth enamel	83

Table 1: Showing the compressive strength of a range of materials.

Draw a bar chart of the information in Table 1.

1. What is Pa short for?
2. What does the unit Pa measure?
3. What does MPa mean?

Task 3 – making models of cellulose and cell walls

What do you notice about the strength of wood and concrete? What about when you compare cellulose and wood?

Wood is not is not as strong as cellulose because it contains vessels and water. Also, most of the cells are orientated in one direction – vertically.

In cell walls, cellulose fibres are tightly packed and arranged in layers. In each layer the fibres have a different orientation and are 'glued' together by a substance known as pectin. (This is what makes jam set).

Modelling cell walls and cellulose

Use this information to make simple models of the arrangement of cells in wood and the arrangement of cellulose fibres in cell walls.

Apparatus

- strips of stiff cardboard 1 cm wide, 20 – 25 cm long
- glue sticks

Task 4 – working out ratios

Material	Tensile strength (GPa)	Stiffness (GPa)	Ratio tensile strength :stiffness	Working	Unitary ratio
Cellulose nanocrystals	7.5	150	7.5 :150	150 ÷ 7.5 = 20	1:20
Glass fibre	5	85			
Steel wire	4	208			
Kevlar	3.8	152			
Graphite whiskers	21	420			
Carbon nanotubes	11 73	275 876			

Table 2: Showing the tensile strength and stiffness of materials used for reinforcement.

1. Complete the table.
2. Which material shows the greatest proportional difference between its tensile strength and stiffness?
3. Describe how cellulose compares to other materials used as reinforcement.
4. Do you have access to the internet? If so, can you find out why carbon nanotubes have a range of measurements for strength and stiffness?
5. What does GPa mean?