
NANYANG
GIRLS' HIGH

Chemistry of the Built Environment

Part One

Introduction – What is the Built Environment?

- Video duration = 2 minutes

Click here to watch the video on YouTube


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The Built Environment

The Natural Environment

- Link to Biology


The Built Environment
The Natural Environment
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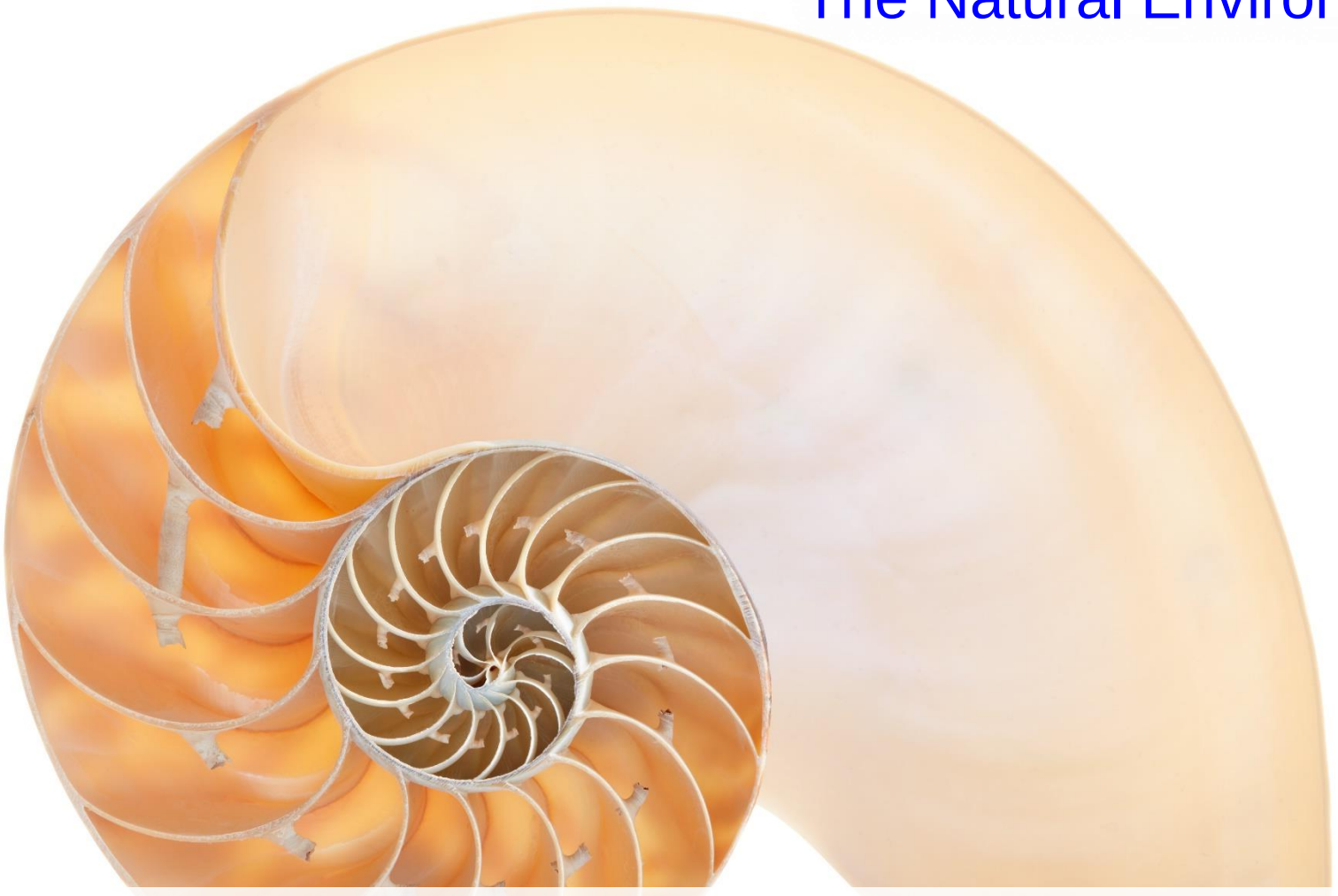
- The boney elements of a tortoise shell are composed of *hydroxyapatite*, $Ca_5(PO_4)_3(OH)$.

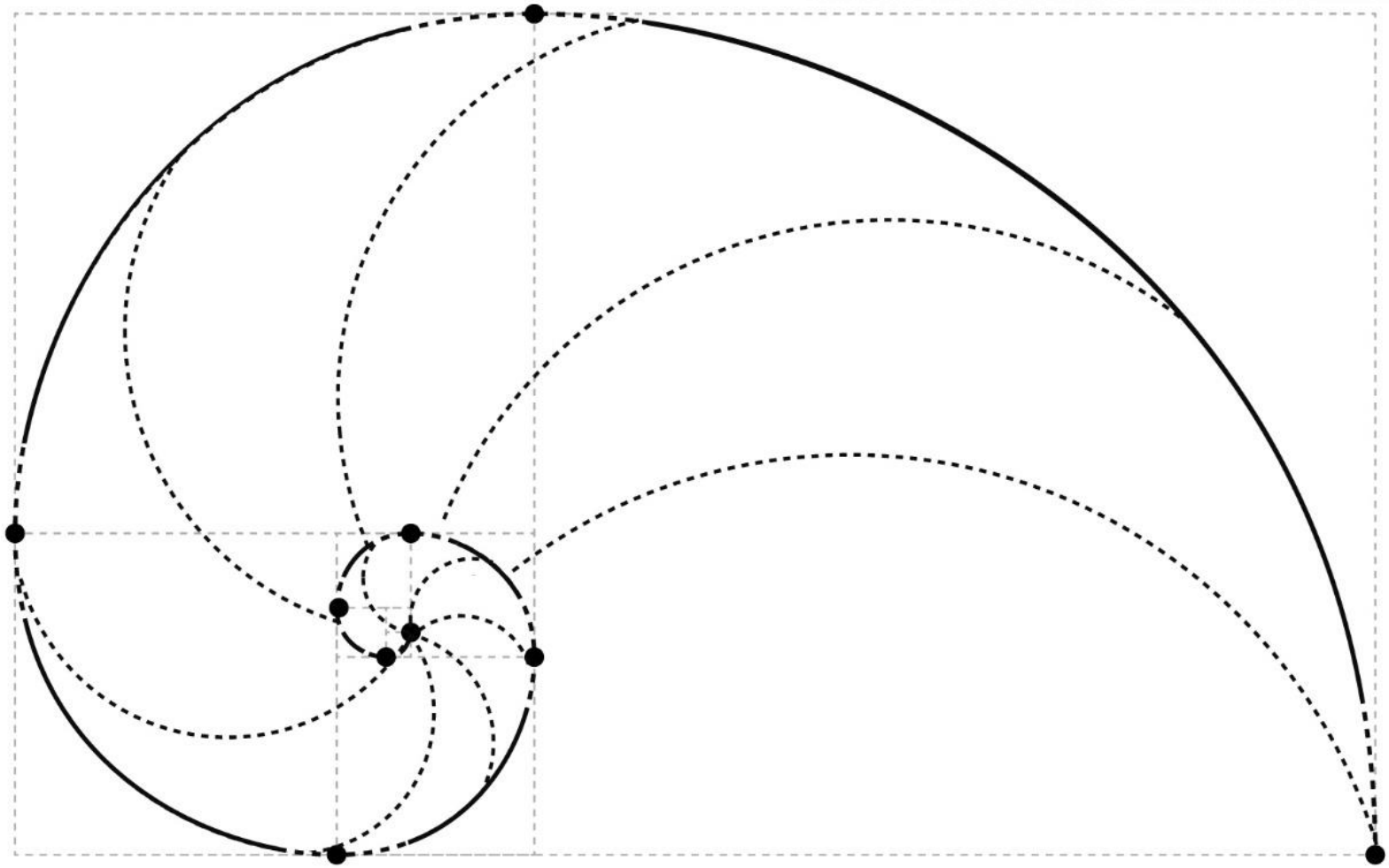
The Built Environment
The Natural Environment

- The natural built environment surrounds us.
- For thousands of years, civilisations relied on the natural built environment to provide basic human needs such as food and shelter – humanity had little impact on nature.
- More recently, humanity has started to shape the natural built environment to further meet its essential needs – but nature also shapes humanity.

- A snail shell is composed mostly of *calcium carbonate*, formula $CaCO_3$.



- A Nautilus shell is composed mostly of *calcium carbonate*, formula $CaCO_3$.



- Fibonacci Sequence

…0 + 1 = **1**, 1 + 1 = **2**, 1 + 2 = **3**, 2 + 3 = **5**…

The Built Environment
The Natural Environment

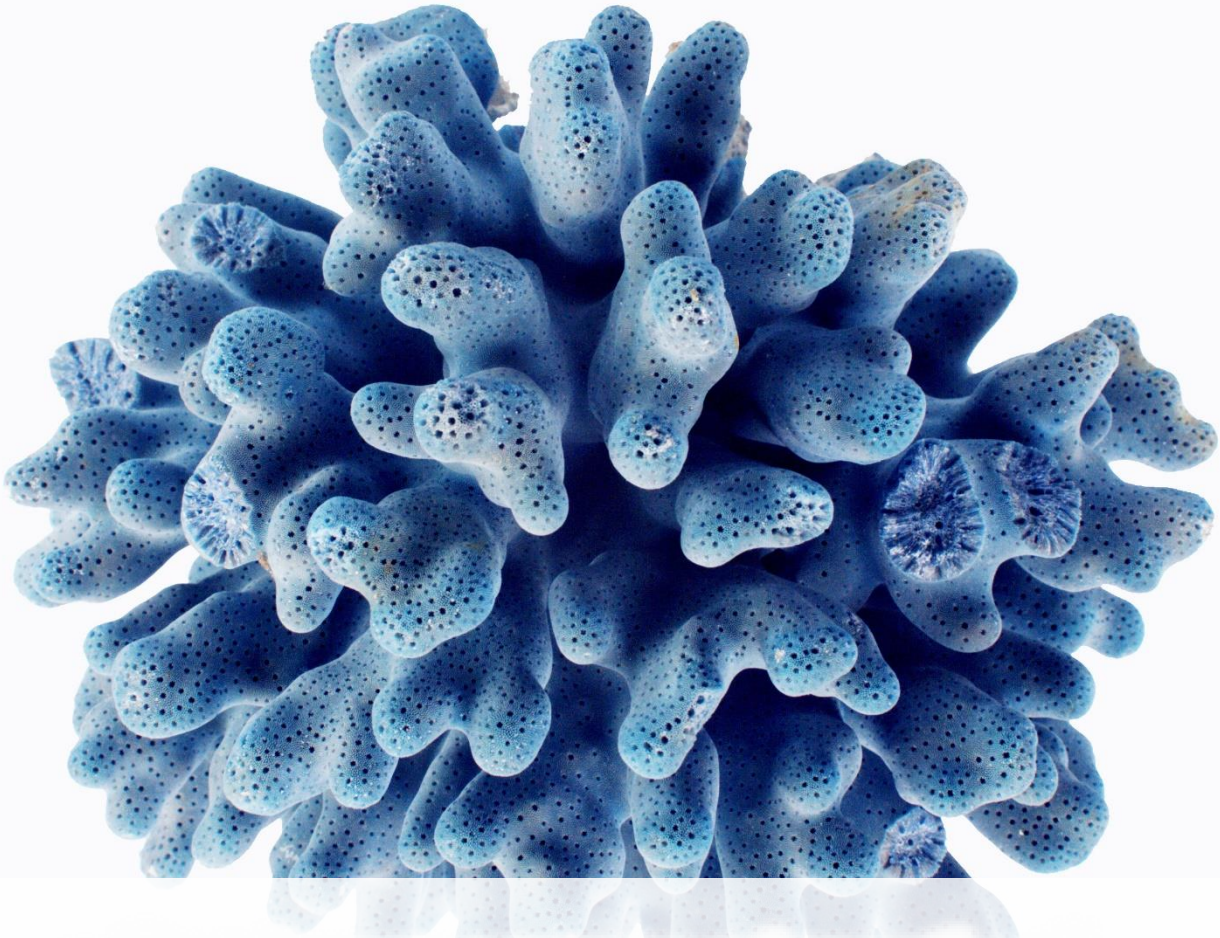
- Architects draw inspiration from the patterns and shapes that they see in nature to design their buildings.

- Chemists study the structure a bonding in naturally occurring materials, such as silk, spiders' webs and diamond, in order to develop new materials.

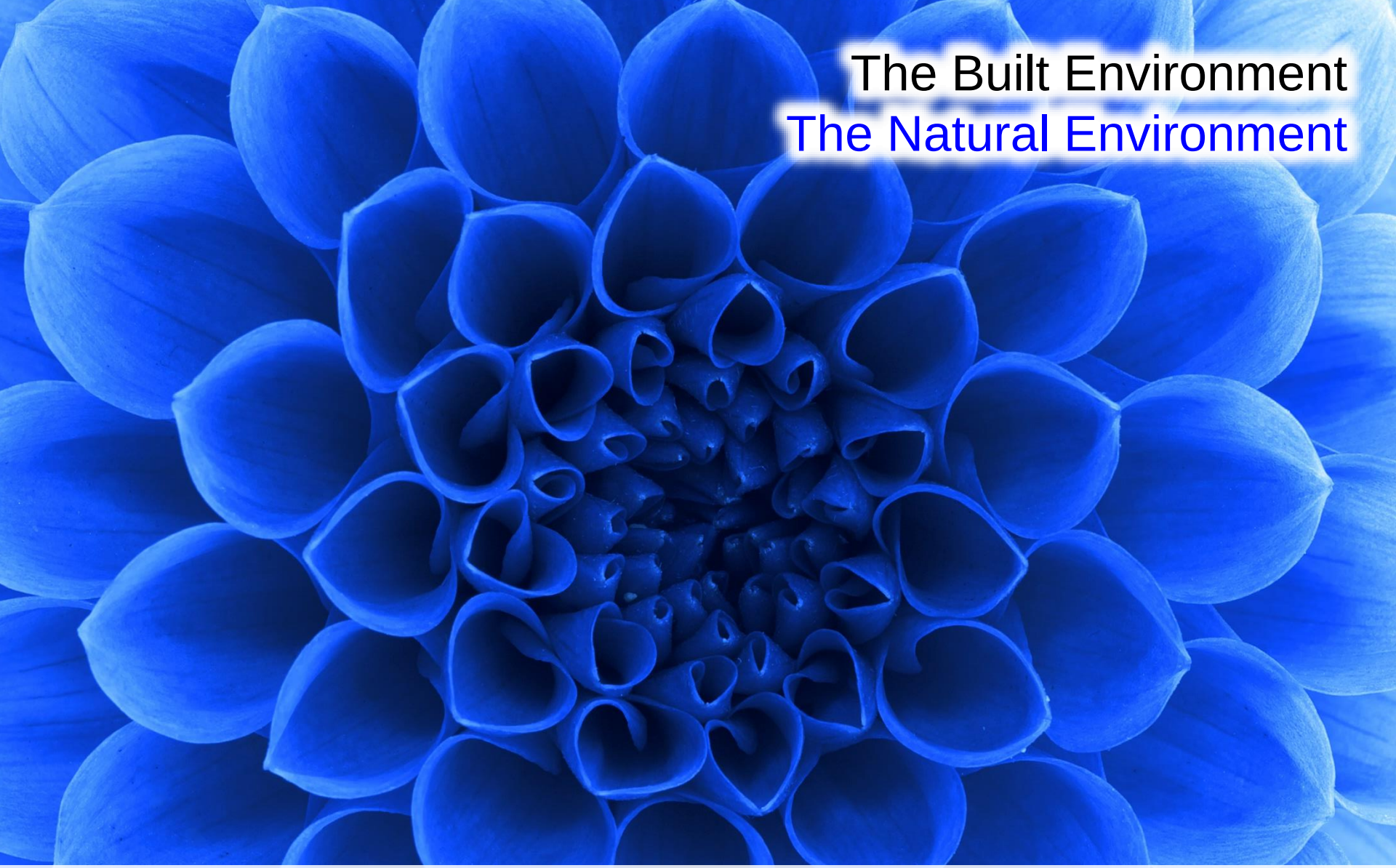
- Mathematicians and Physicists explain and predict nature using mathematical and physical models.

- Engineers replicate natural structures in both small-scale and large scale designs.

- Sea shells are composed mostly of *calcum carbonate*, formula $CaCO_3$.

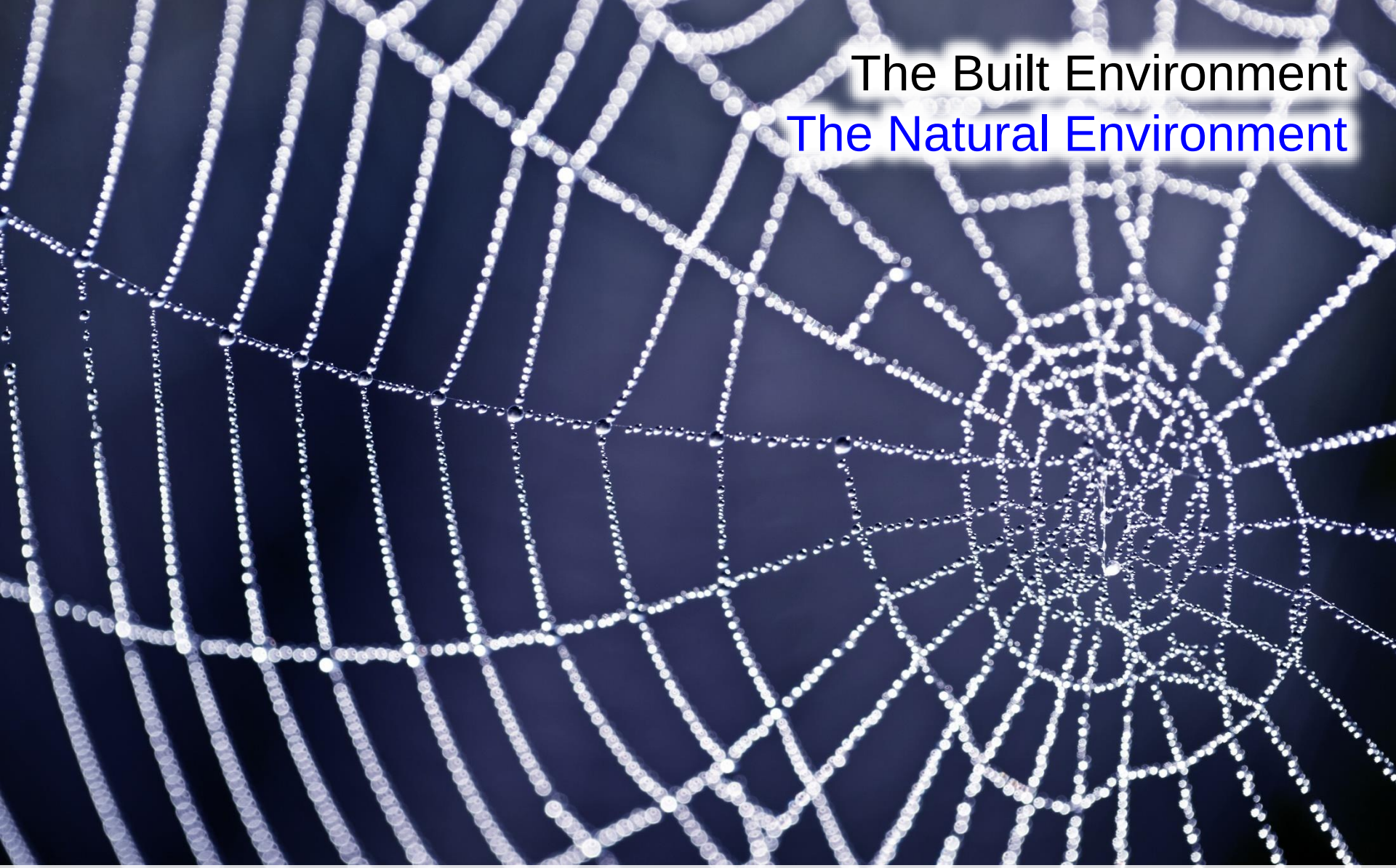


- Corals are composed mostly of *calcium carbonate*, formula $CaCO_3$.



The Built Environment
The Natural Environment

- In addition to artists, architects and engineers draw inspiration from nature in their designs.



The Built Environment
The Natural Environment

- Spider web is a *protein* composed of carbon, hydrogen, nitrogen and oxygen bonded together.

The Built Environment
The Natural Environment

- Silk is a *protein* composed of carbon, hydrogen, nitrogen and oxygen bonded together.

The Built Environment
The Natural Environment

- Wood is a very strong natural material that is used throughout the construction industry.

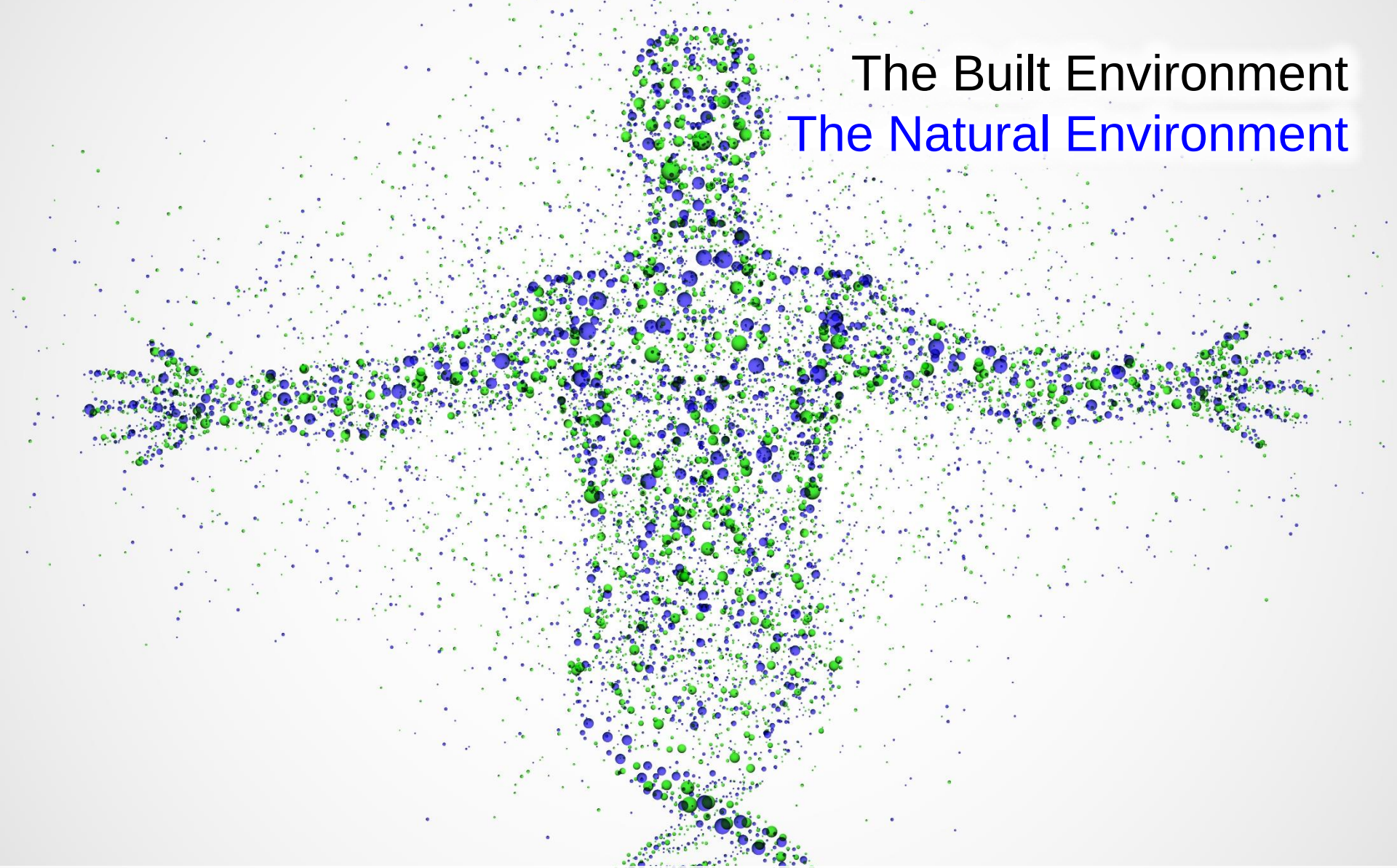
The Built Environment

The Natural Environment

- In addition to humans, other animals are able to purposefully construct things.

The Built Environment
The Natural Environment

- The genetic material *dexoyribonucleic acid* (DNA) is composed of carbon, hydrogen, nitrogen, oxygen and phosphorus.



The Built Environment

The Natural Environment

- The information contained within our DNA determines how we are *built*.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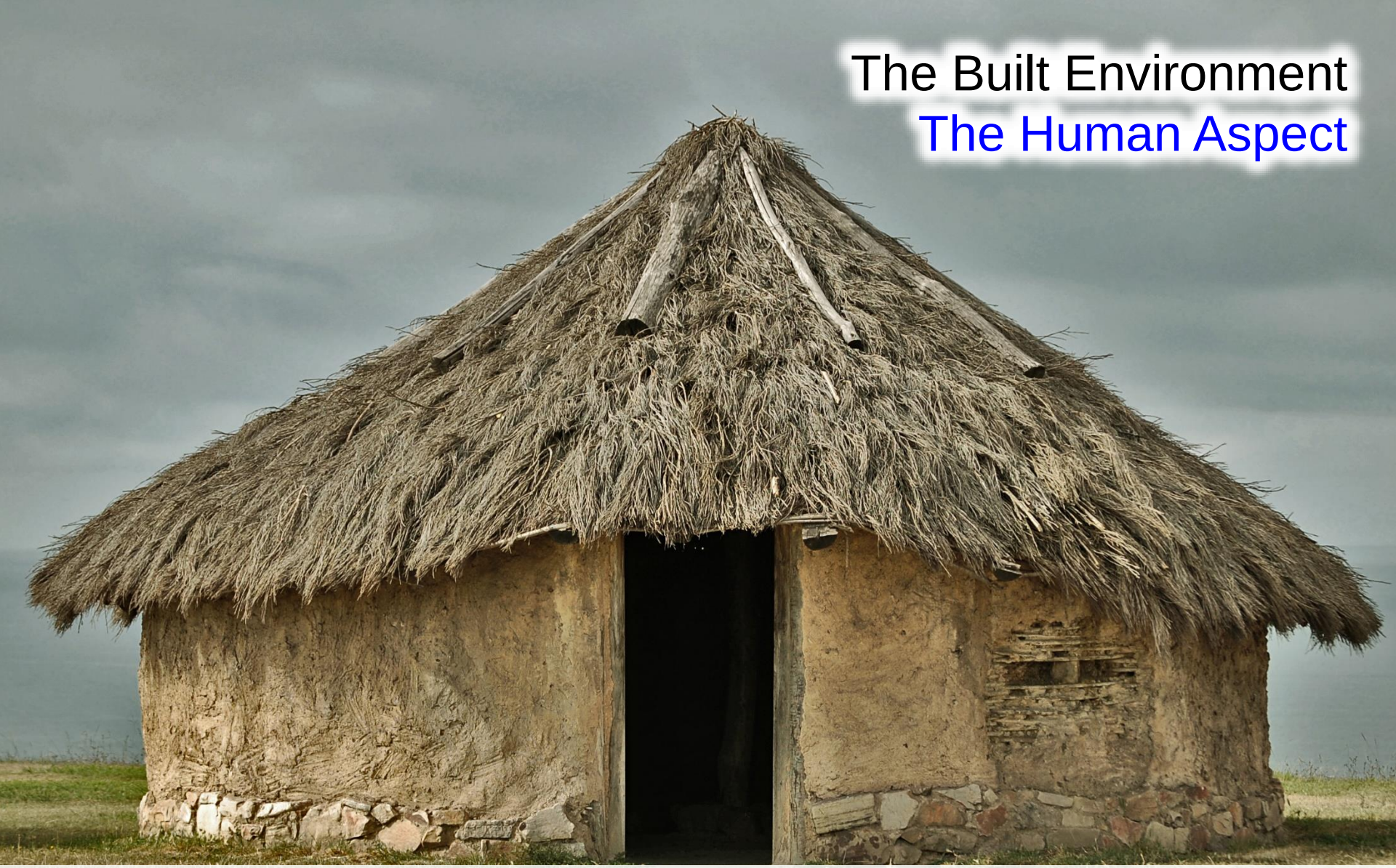
The Built Environment

The Human Aspect

- Link to Geography

The Built Environment
The Human Aspect



- Village hut, Thar Desert, India.

Composed of clay, stone, straw and wood.

The Built Environment

The Human Aspect

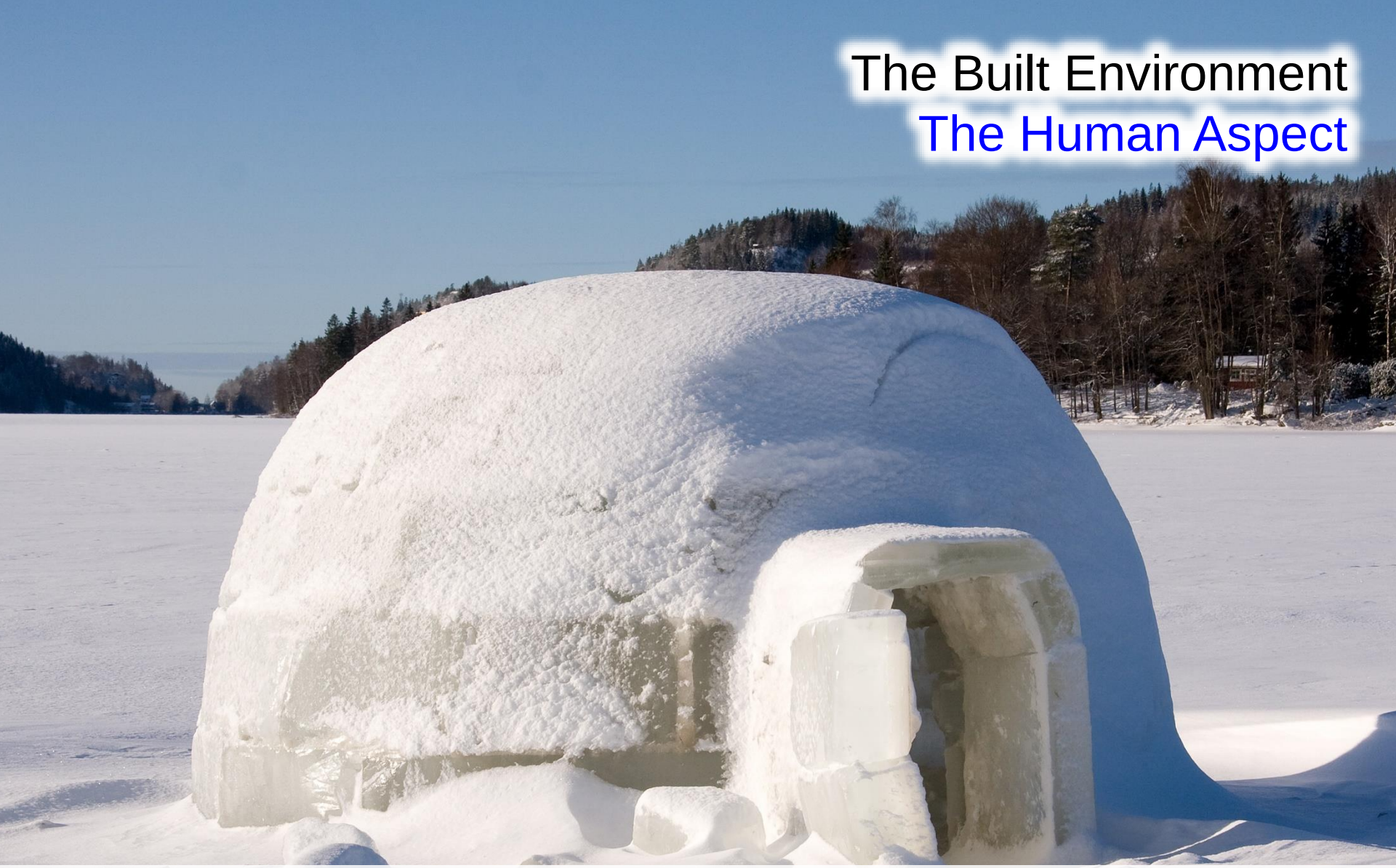
- Native huts, Lake Turkana, Kenya.

Crops can provide both food and shelter.

The Built Environment
The Human Aspect

- Indian tipis, New Mexico. Traditional tipis are made of animal skins hung over wooden poles.

The Built Environment
The Human Aspect



- An Inuit (Eskimo) igloo, Alaska, constructed of blocks carved out of ice.

The Built Environment
The Human Aspect

- Indigenous tribes build shelters using materials that are readily available to them.
- Studying their shelters gives us a deep insight into their habitat and natural surroundings.
- Although these shelters from around the world vary in shape, building materials and complexity, they all serve the same essential purpose, *protection from the elements*.
- As a culture becomes more advanced through science and engineering, this is reflected in the size and complexity of their built environment.

The Built Environment
The Human Aspect

- Homes on stilts in the floating village of Kampong Phluk, Cambodia. Standing on wooden poles, the houses are made out of straw and corrugated metal.

The Built Environment
The Human Aspect

- Traditional house found in parts of Cambodia and Malaysia. The house is made out of wood, with a corrugated metal roof.

The Built Environment

The Human Aspect

- Typical red-brick house with tiled roof.
  Found throughout England.

The Built Environment
The Human Aspect

- Suburban low-rise accommodation in North America. Brick, concrete and wood.


NOW
RENTING
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The Built Environment

Contemporary and Iconic

- Link to Aesthetics

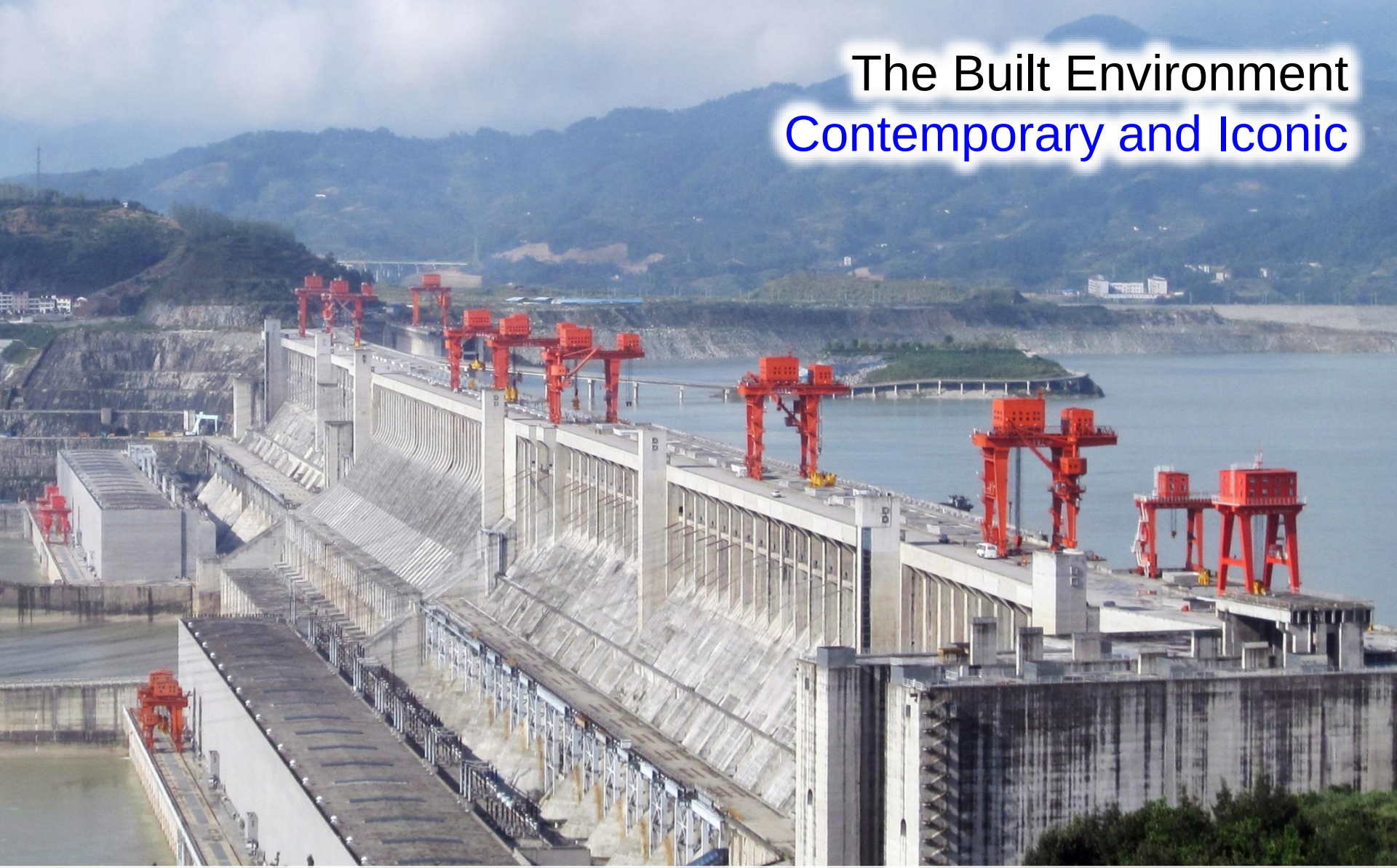
The Built Environment
Contemporary and Iconic

- The Empire State Building, New York (1931) – 381 m (h).

The Built Environment
Contemporary and Iconic

- Iconic buildings are captivating due to their unique innovative design and because they push the boundaries of engineering.
- Architecture is used by countries to demonstrate their social and economic power in the world.
- Architecture can be used demonstrate how advanced a country is in terms of science, technology and engineering.
- Architecture can be used to *inspire*.
- Architecture can be used to demonstrate humanity's progress and dominance over nature.

The Built Environment
Contemporary and Iconic

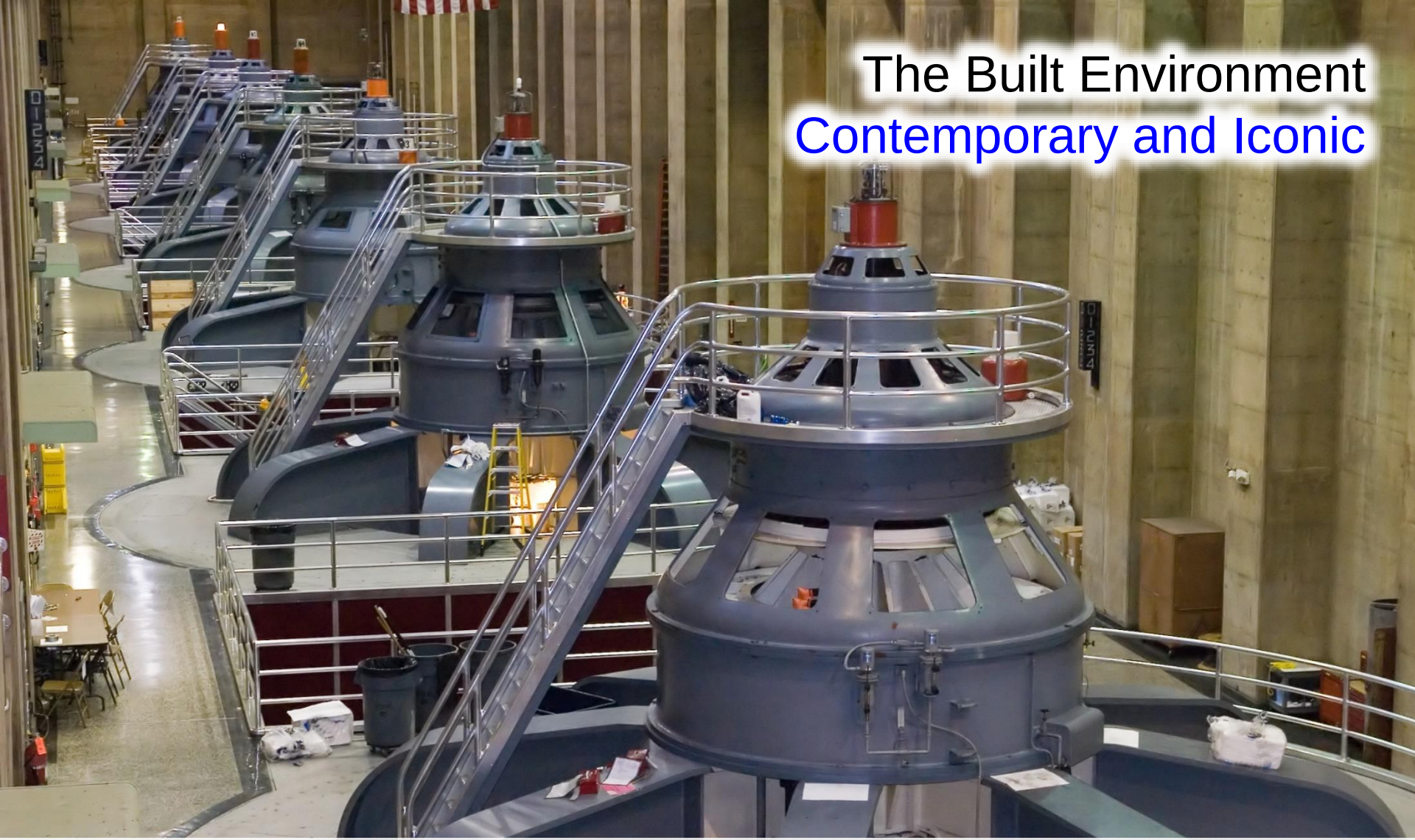


- Three Gorges Dam (2003) – 181 m (h).
  Mass of concrete = 65 300 000 tonnes.

The Built Environment
Contemporary and Iconic

- Three Gorges Dam (2003) – 2335 m (l).
  Mass of steel = 463 000 tonnes.

The Built Environment
Contemporary and Iconic



- Turbines within the Three Gorges Dam convert the kinetic energy of the water into electrical energy.

The Built Environment
Contemporary and Iconic

- The Eiffel Tower (1889) – 324 m (h).

Constructed from 7 300 tons of wrought iron.

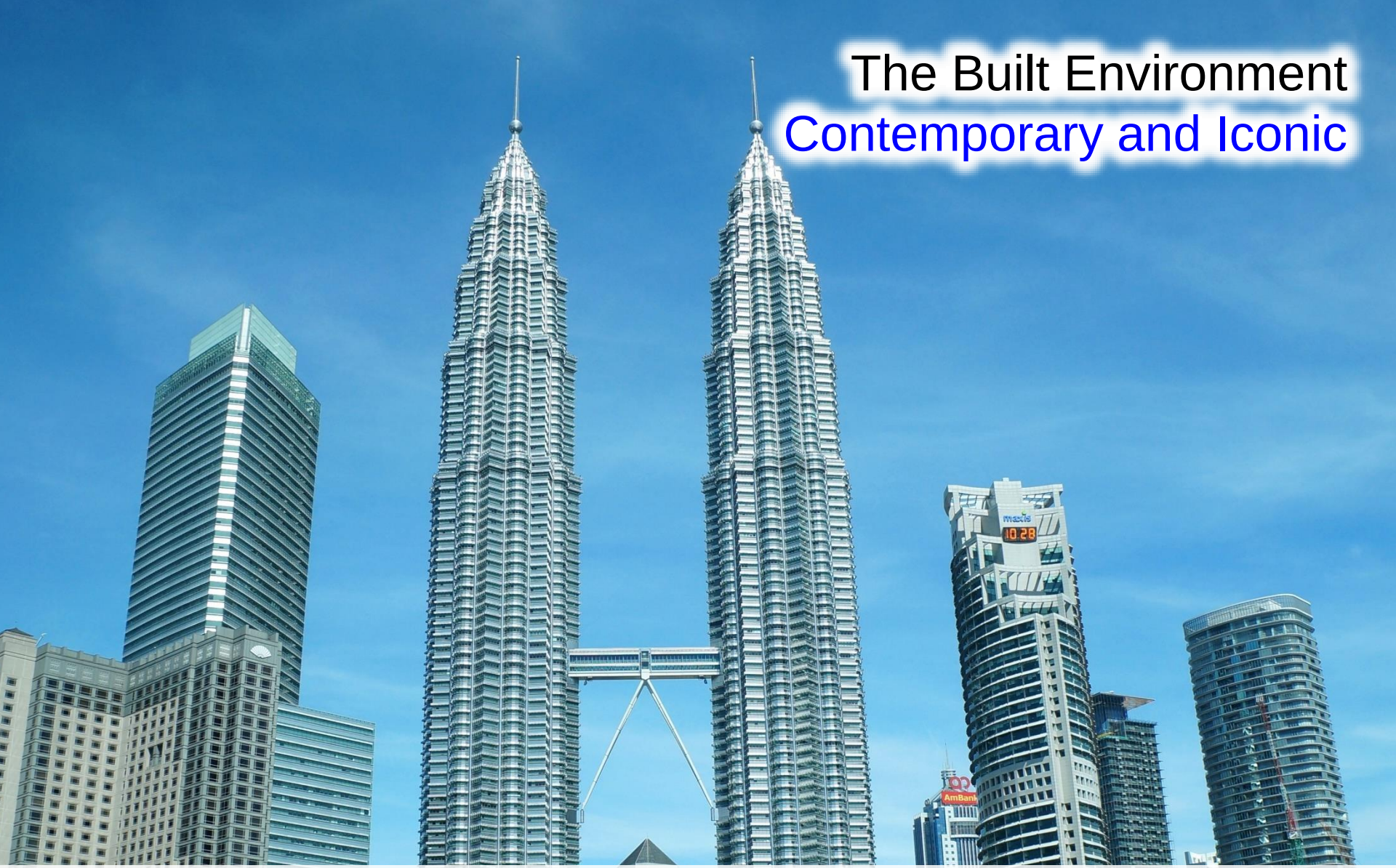
The tallest building in the world for 41 years.

On hot days its height increases by 18 cm.

The Built Environment
Contemporary and Iconic

- Sydney Harbour Bridge (1932) – 134 m (h).
- Sydney Opera House (1973) – 65 m (h).

The Built Environment
Contemporary and Iconic



- Petronas Twin Towers, Kuala Lumpur (1998) – 452 m (h).

The Built Environment
Contemporary and Iconic

- Taipei 101 (2004) – 509 m (h).

The Built Environment
Contemporary and Iconic

- One World Trade Centre, New York (2013) – 546 m (h).

The Built Environment
Contemporary and Iconic

- Burj Khalifa, Dubai (2010) – 828 m (h).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The Built Environment

Building Materials

- Link to Materials Science

The Built Environment
Building Materials

- There are many different building materials.

It is extremely important for a building material to *fulfil its structural requirements*.

The Built Environment
Building Materials

- The choice of building material will depend upon many factors.

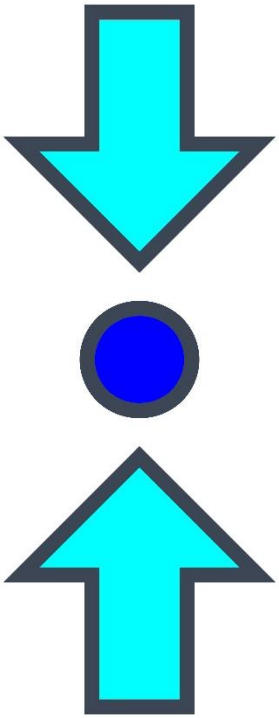
- The most significant is for the material to *fulfil its structural requirements*, making properties such as strength, stiffness, toughness and durability important.

- A number of other factors are critical, including the following…

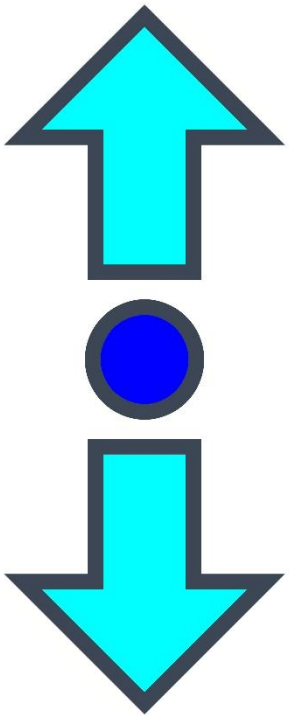
The Built Environment
Building Materials

- Cost – both initial and during the lifetime of the structure.
- Availability – often linked to cost.
- Fabrication – either on-site or, increasingly, off-site for rapid assembly on-site.
- Energy – required to produce the structure and consumed during its lifetime.
- Maintenance – required to ensure that the structure remains fit-for-purpose.
- End-of-life Properties – particularly re-use and recycling.

Forces Commonly Encountered in Construction



Compression
(push together)



Tension or Tensile
(stretching)

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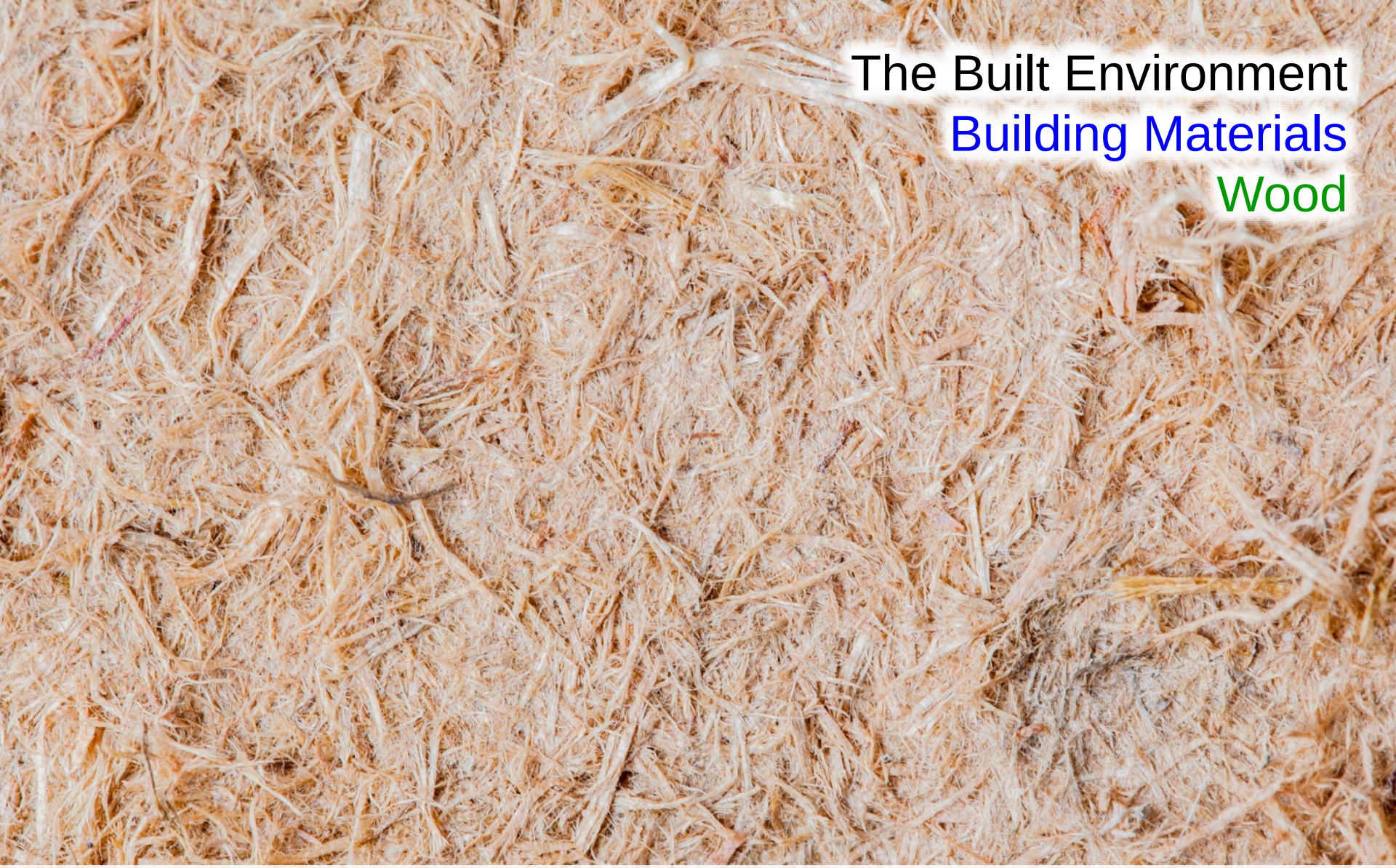
Building Materials

Wood

- Wood has been used as a construction material for thousands of years.



The Built Environment

Building Materials

Wood

- Wood is a fibrous material composed of *cellulose* and *lignin*.

The Built Environment
Building Materials
Wood

- Wood is an organic compound composed mostly of the chemical elements carbon, hydrogen nitrogen and oxygen, with traces of sulfur and phosphorus.

- These chemical elements are bonded together to form the compounds *cellulose* and *lignin*.

- The cellulose fibres are strong in *tension* (resists stretching), while the lignin is strong in *compression* (resists being pushed together), which makes wood an ideal material from which to construct low-rise buildings.

The Built Environment
Building Materials
Wood

- Wood is *renewable*. During their growth, trees remove carbon dioxide (CO_2) from the atmosphere, and release oxygen (O_2) through the process of photosynthesis:

carbon dioxide + water $\rightarrow$ glucose + oxygen

$$6CO_2(g) + 6H_2O(g) \rightarrow C_6H_{12}O_6(aq) + 6O_2(g)$$

- Wood is a *sustainable* building material whose use is construction can be beneficial to the environment, as long as its production and use are correctly monitored and regulated.

The Built Environment
Building Materials
Concrete

- Concrete is the most widely used manufactured material, with nearly 2 tonnes produced annually for each living person. The oldest concrete known to exist is in Israel, and dates from 7000 BC.

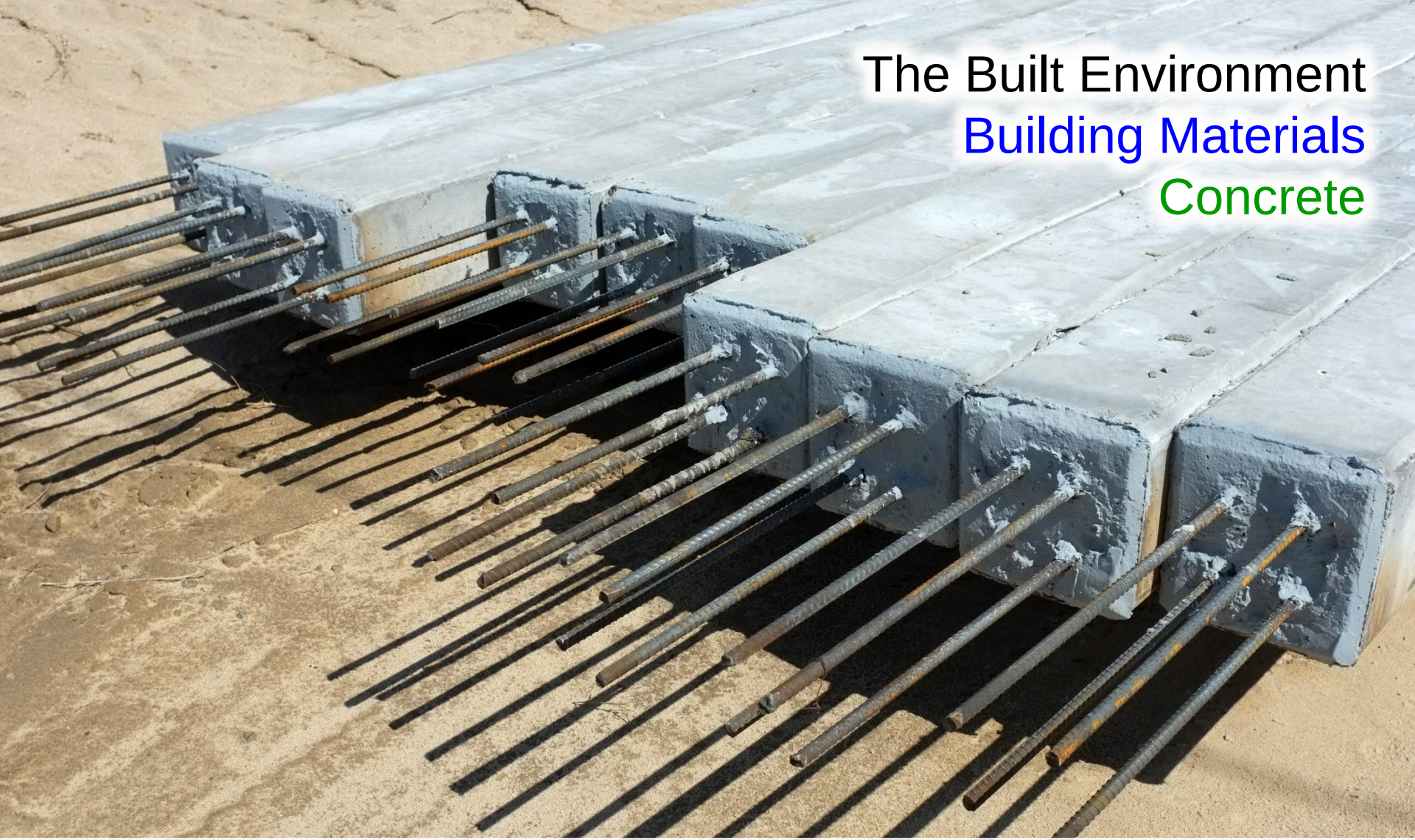
The Built Environment
Building Materials
Concrete

- Concrete is a ubiquitous building material. Its versatility and ready availability have ensured that it has been, and will continue to be, of great and increasing importance for all types of construction throughout the world.

- Concrete can be found *above* ground, in housing, commercial buildings, industrial buildings and bridges. Concrete can be found *on* the ground in roads and airport runways. Concrete can be found *below* the ground in foundations, tunnels, and drainage systems.

The Built Environment
Building Materials
Concrete

- Concrete has a low tensile strength, but a high compressive strength.
- To overcome its weak tensile strength, concrete is often *reinforced* with steel bars.



The Built Environment

Building Materials

Concrete

- Concrete reinforced with steel rods.

Reinforced concrete has a good combination of compressive strength and tensile strength.

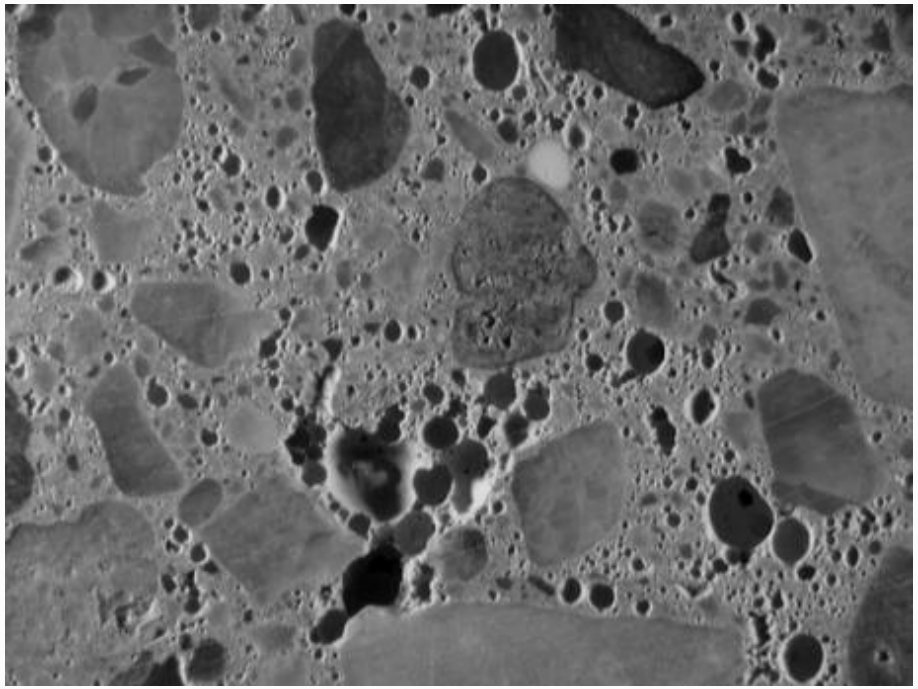
- Upon the addition of water, tricalcium silicate rapidly reacts to form calcium silicate hydrate, calcium hydroxide and a large amount of heat.

tricalcium silicate + water $\rightarrow$ calcium silicate hydrate + calcium hydroxide

$$2Ca_3SiO_5 + 7H_2O \rightarrow 3CaO{\cdot}2SiO_2{\cdot}4H_2O + 3Ca(OH)_2$$

- Calcium silicate hydrate and calcium hydroxide *crystallise*, binding sand, small stones and other aggregate together.

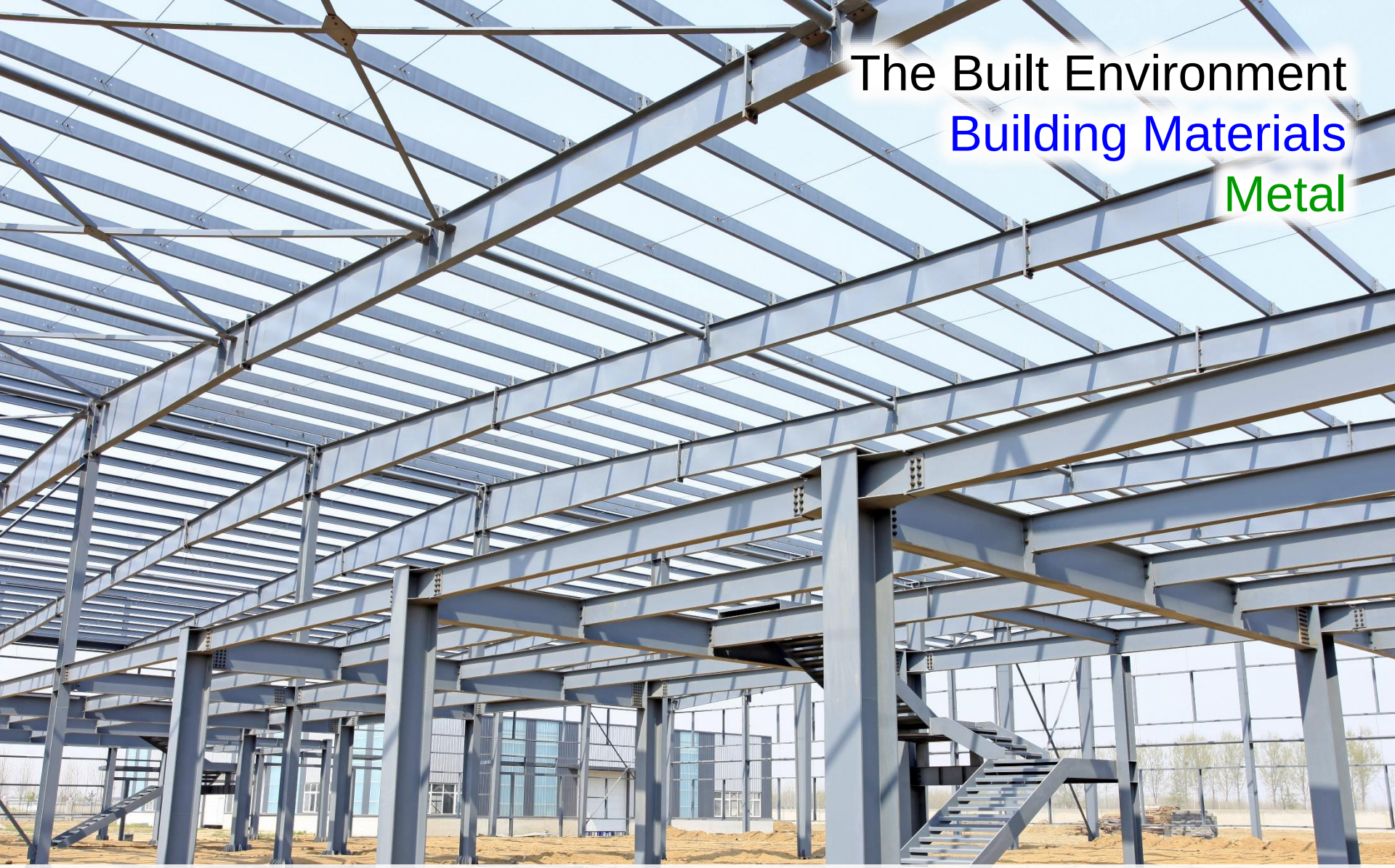
The Built Environment
Building Materials
Concrete



- This magnified view of concrete show the cement crystallising around small stones.

The Built Environment
Building Materials
Concrete

- Structures made out of concrete can be *prefabricated* away from the construction site, and then quickly assembled on-site.



The Built Environment

Building Materials

Metal

- Steel (an *alloy* of iron and carbon) is widely used in modern construction.

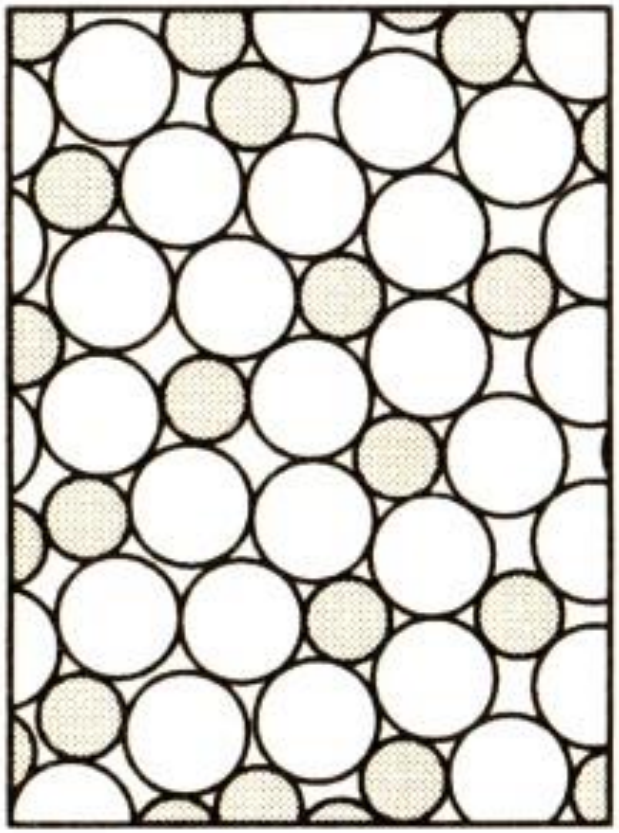
The Built Environment
Building Materials
Metal

- Useful metals have been known to humanity for a long time. When metals became available, they offered many advantages over stone and timber. In addition to being hard and strong, metals are also *malleable* and *ductile*, meaning that their shapes can be changed without breaking.
- Steel can be used on its own in construction, forming the framework of the building to which other materials will be added.
- Steel bars can be incorporated into concrete blocks, forming *reinforced concrete*.

The Built Environment

Building Materials

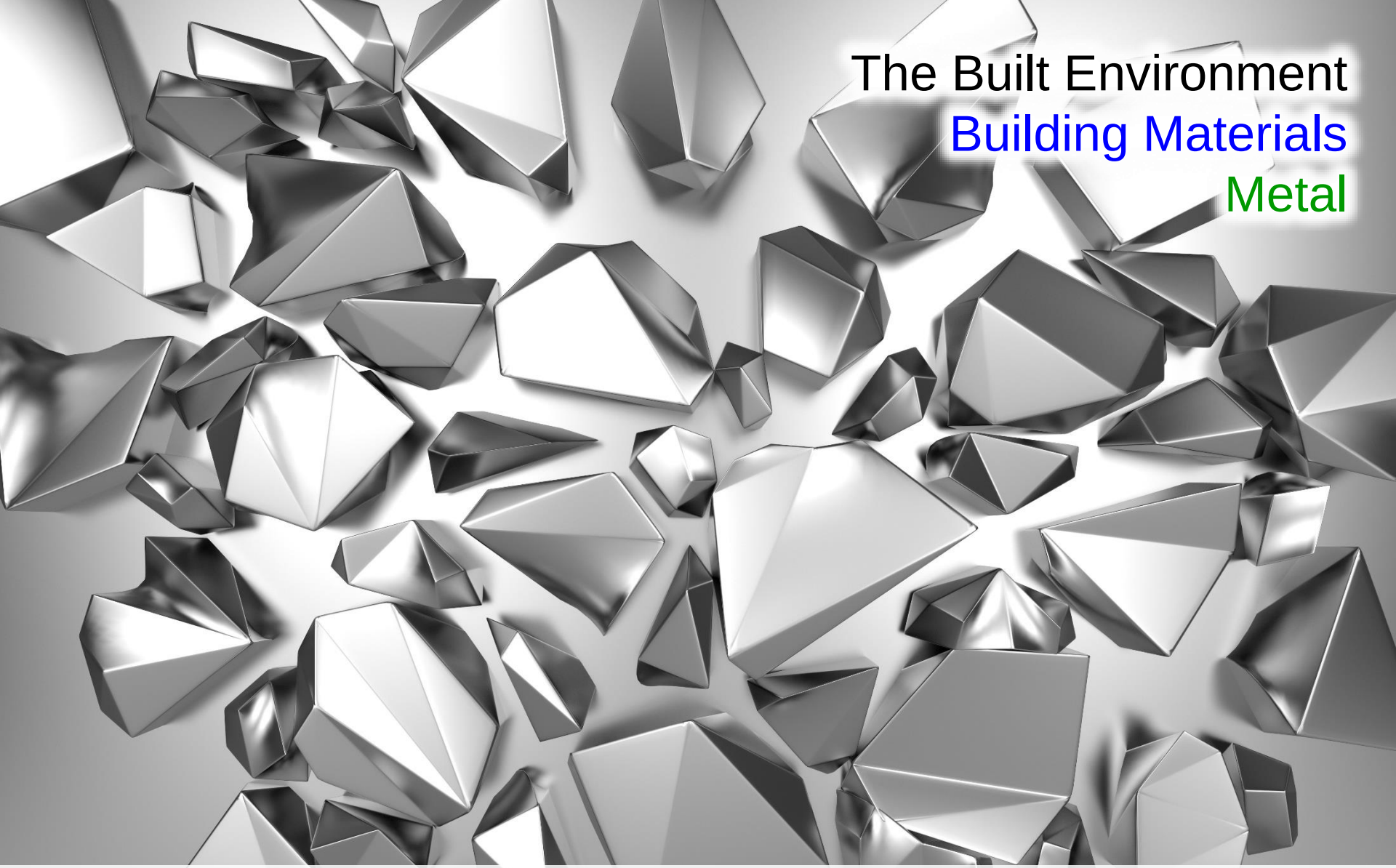
Metal



- An *alloy* is a mixture of a metal with at least one other chemical element.

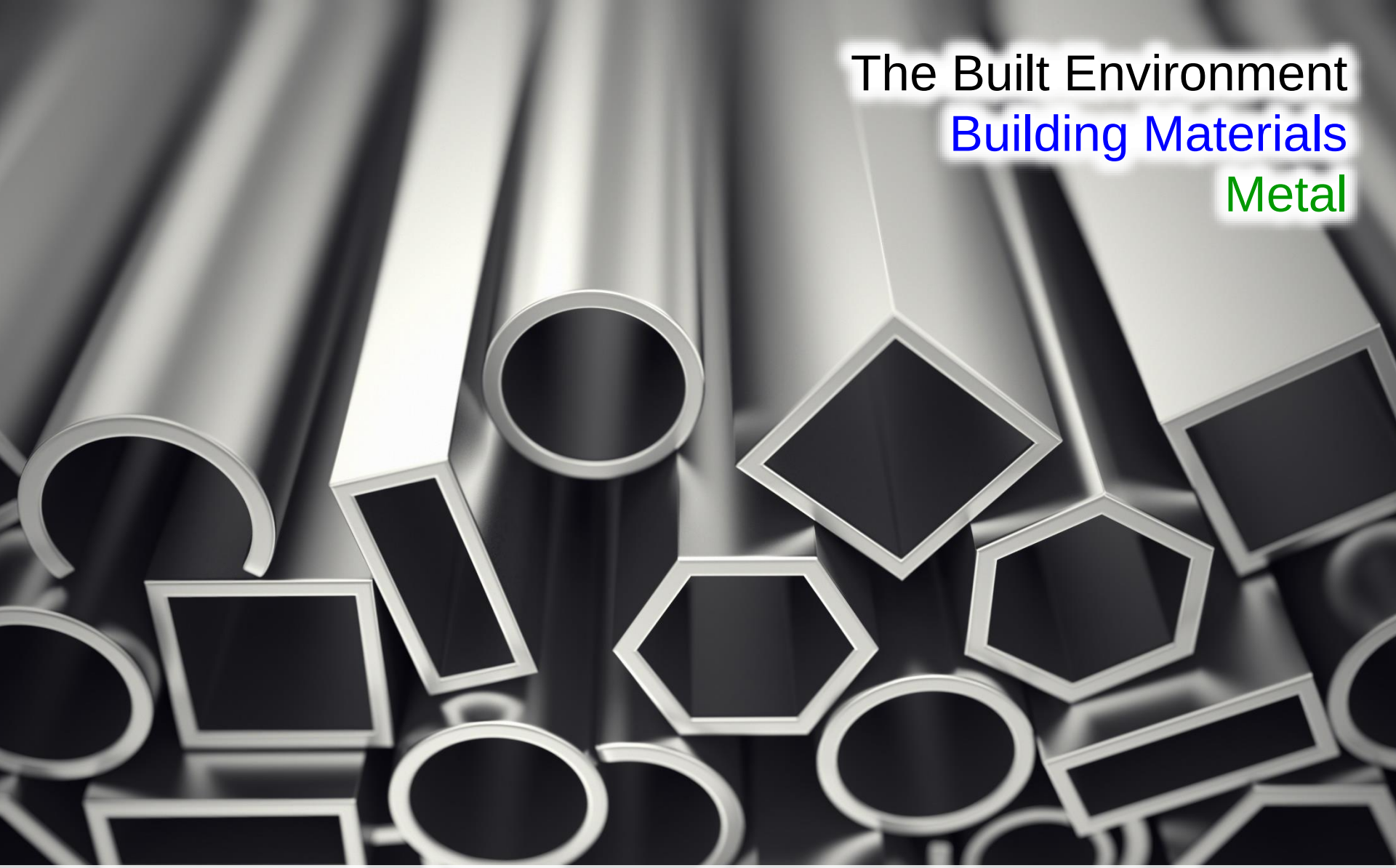
- Because the particles that make-up an alloy are of *different sizes*, they do not pack together in a very orderly / regular manner.

- This means that the particles *cannot slide* over each other very easily, making the alloy *harder* then the pure metal.



The Built Environment
Building Materials
Metal

- Metals have a regular, ordered, crystalline structure.



The Built Environment
Building Materials
Metal

- Many different metals are used in the construction industry, *e.g.* *iron* and *aluminium*.

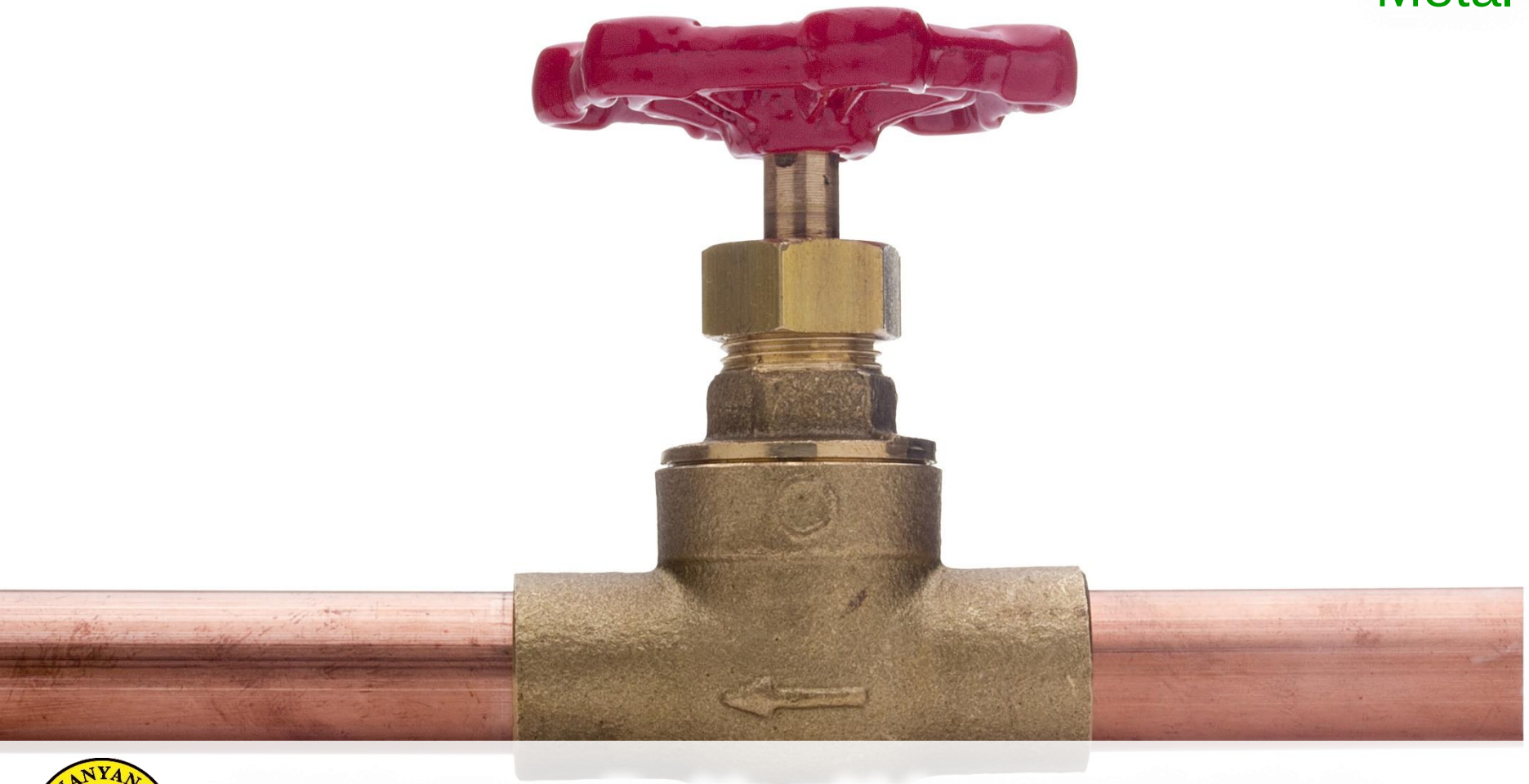
The Built Environment
Building Materials
Metal

- Some metals *corrode* (a process called *oxidation*) when they come into contact with oxygen and water over a long period of time.

The Built Environment

Building Materials

Metal

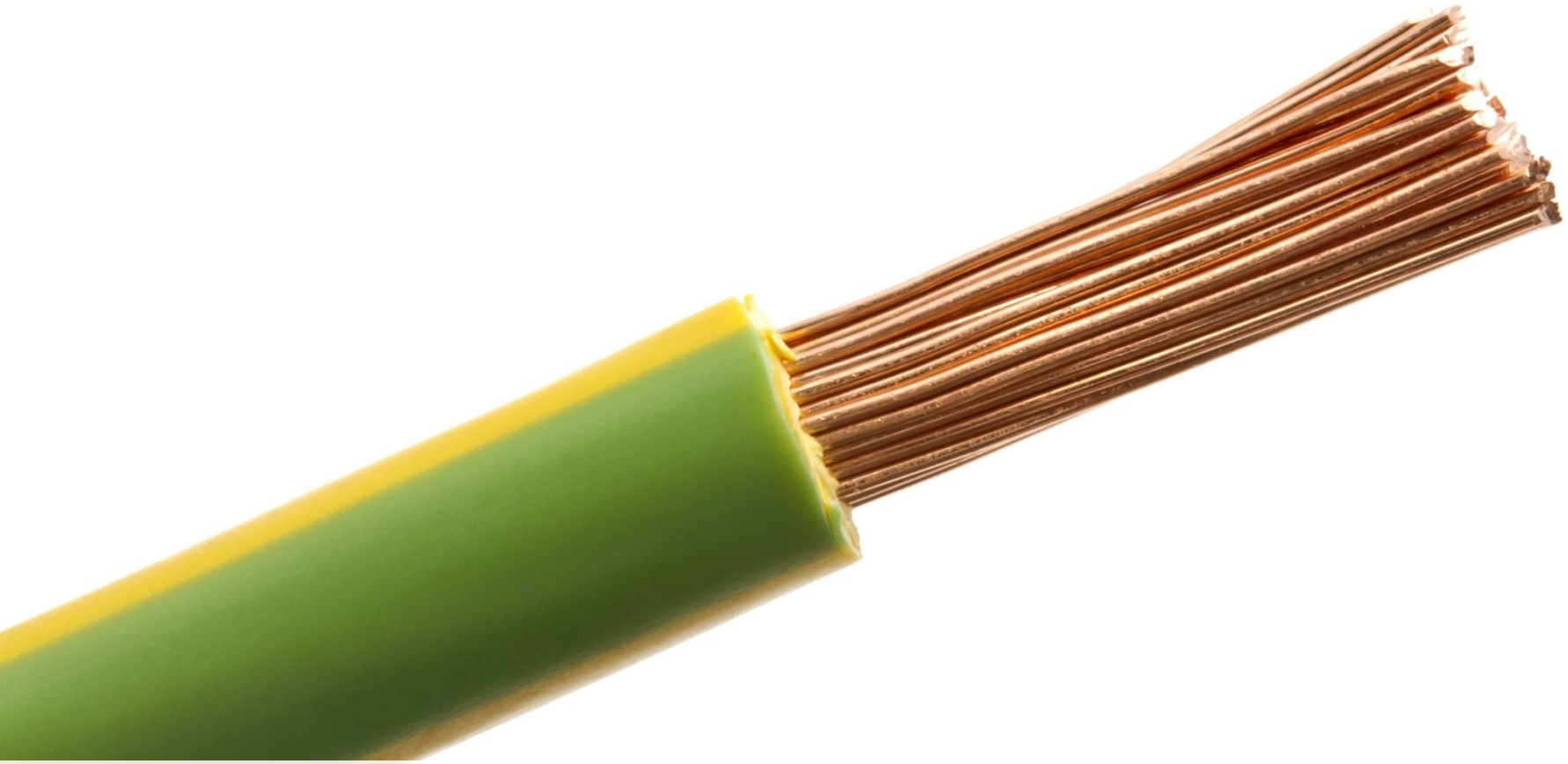


- Metals are *malleable*, which means that their shape can be changed without breaking.

The Built Environment

Building Materials

Metal

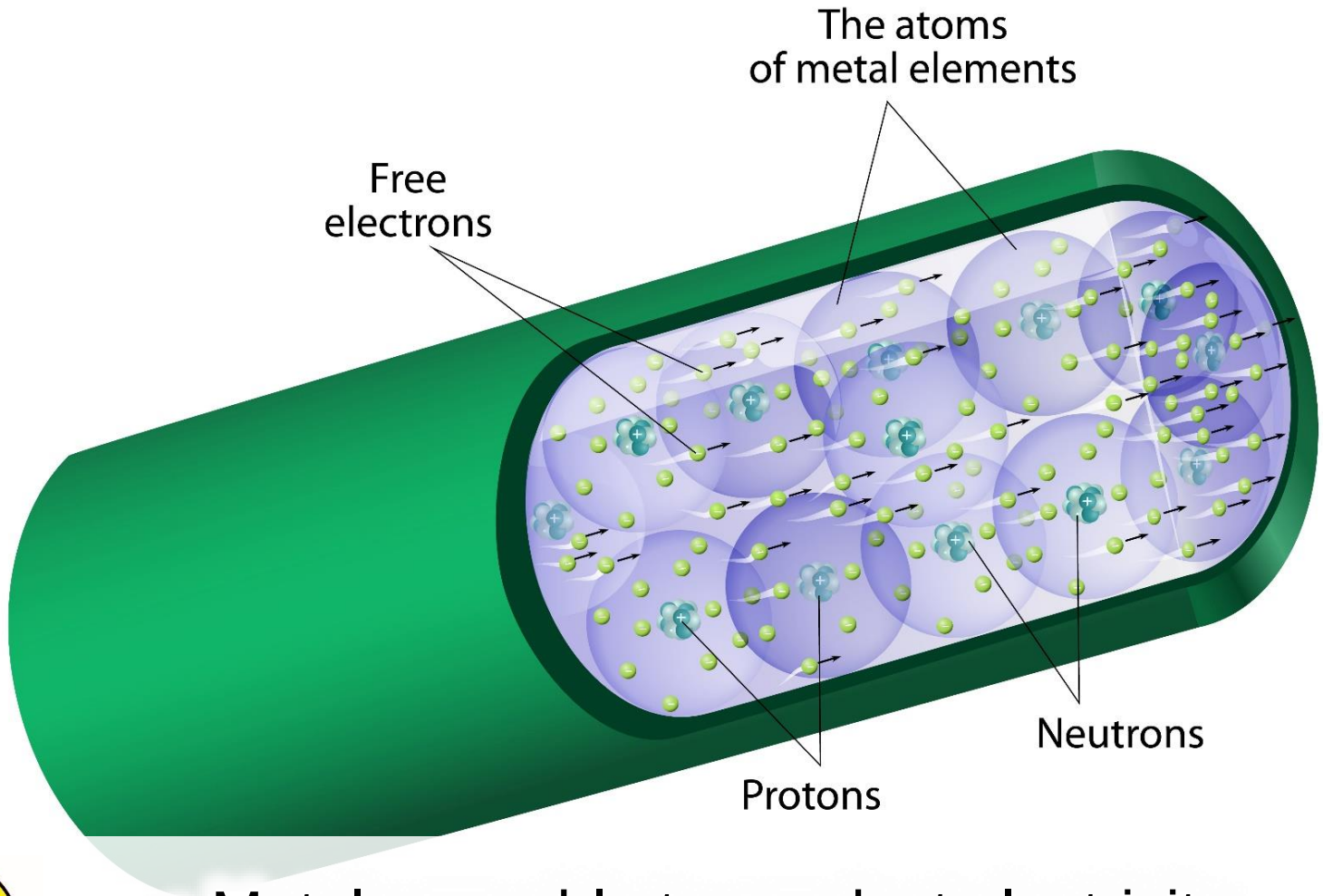


- Metals are *ductile* (can be drawn out into wires) and are *good conductors of electricity*.

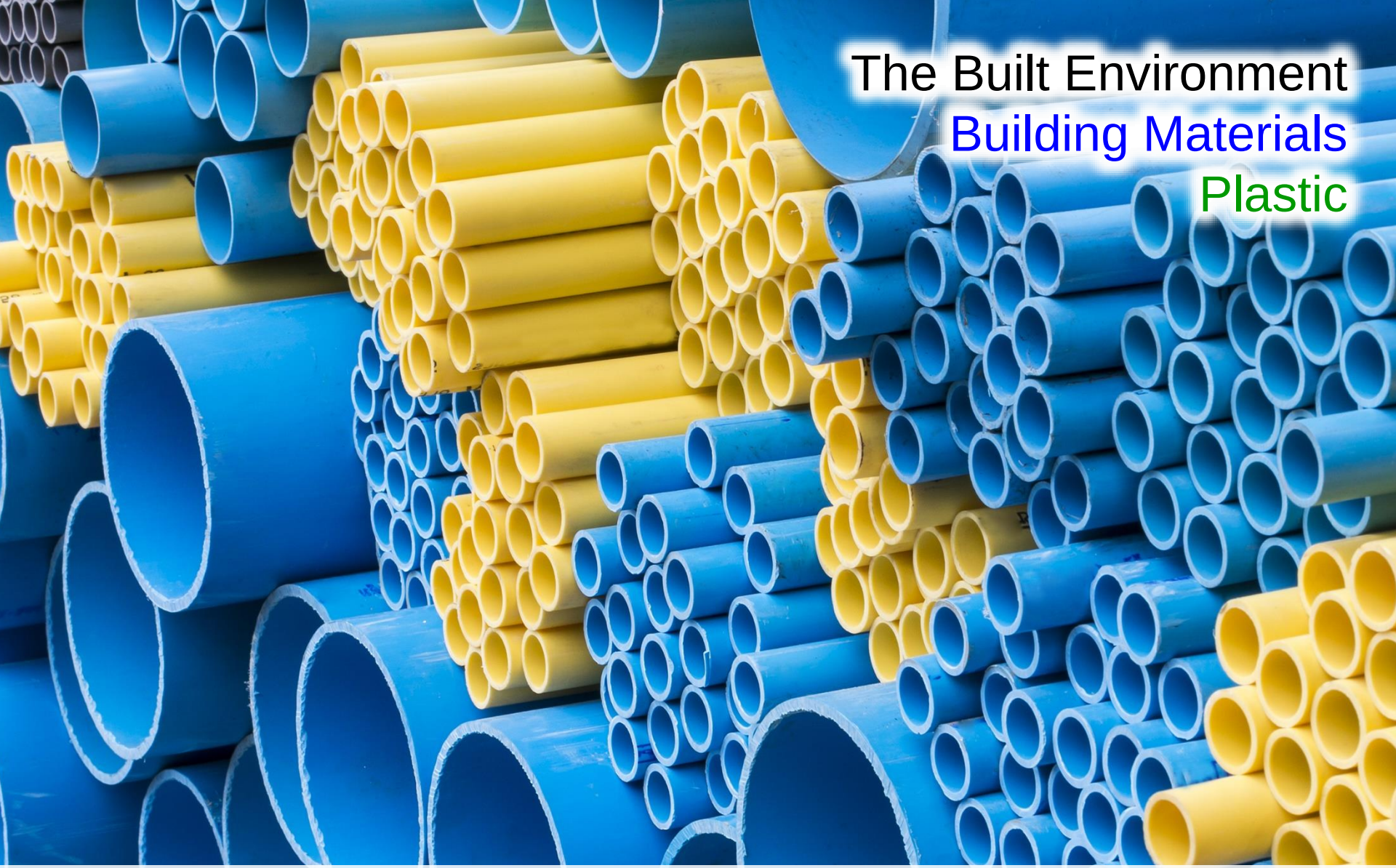
The Built Environment

Building Materials

Metal



- Metals are able to conduct electricity because they contain free, *mobile electrons*.



The Built Environment
Building Materials
Plastic

- Plastic pipes in different sizes and colours.

The Built Environment
Building Materials
Plastic

- Polymers contain long chain-like molecules of very high molecular weight. They occur naturally in plants and animals, or can be synthesised by a process called *polymerisation*.

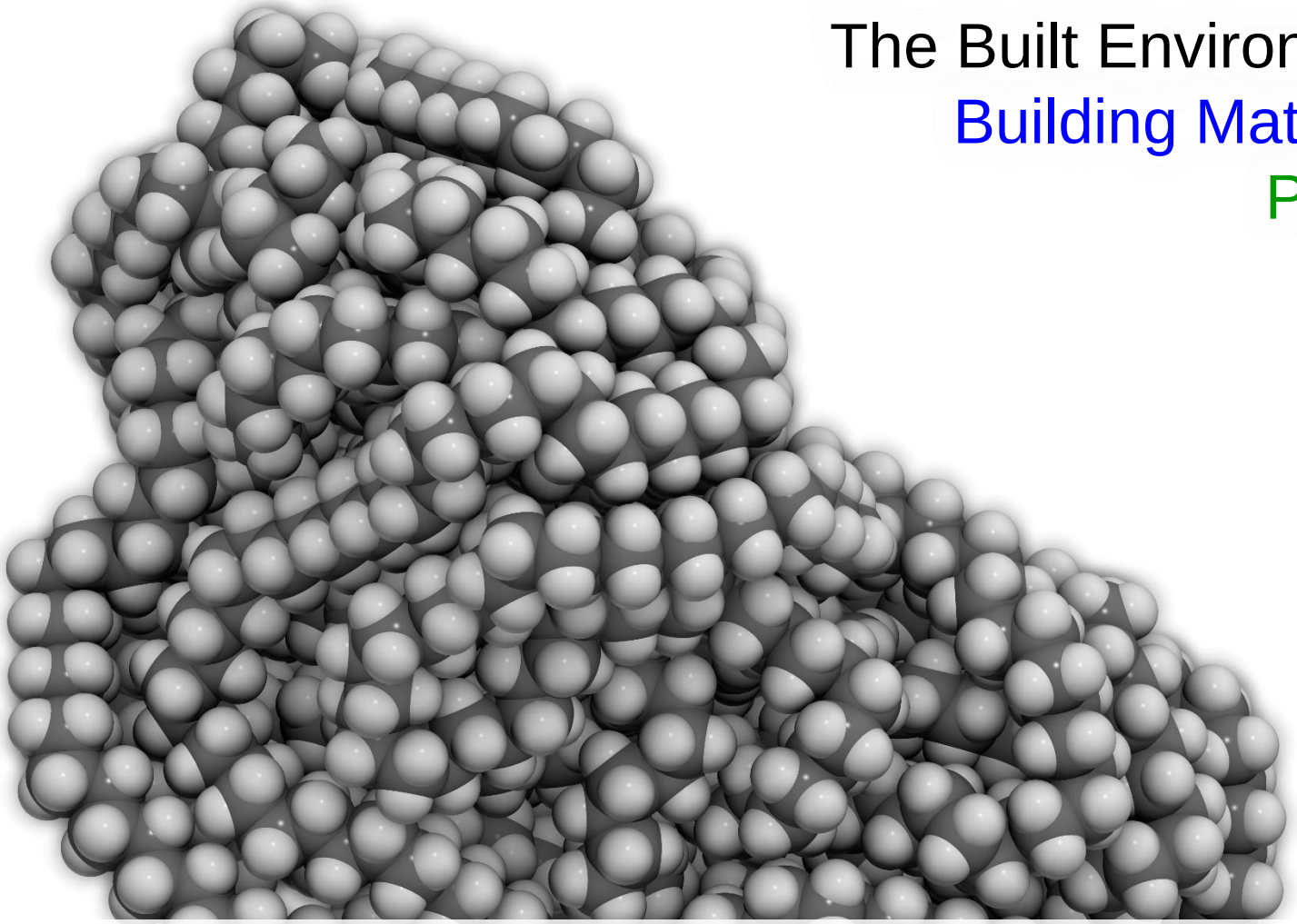
- During polymerisation, many thousands of small molecules (called *monomers*) bond together to form one large molecule (called a *polymer*).

- For many centuries, rubber and wood have been the most widely used natural polymers, but synthetic polymers – such as *plastics* – are of increasing importance.

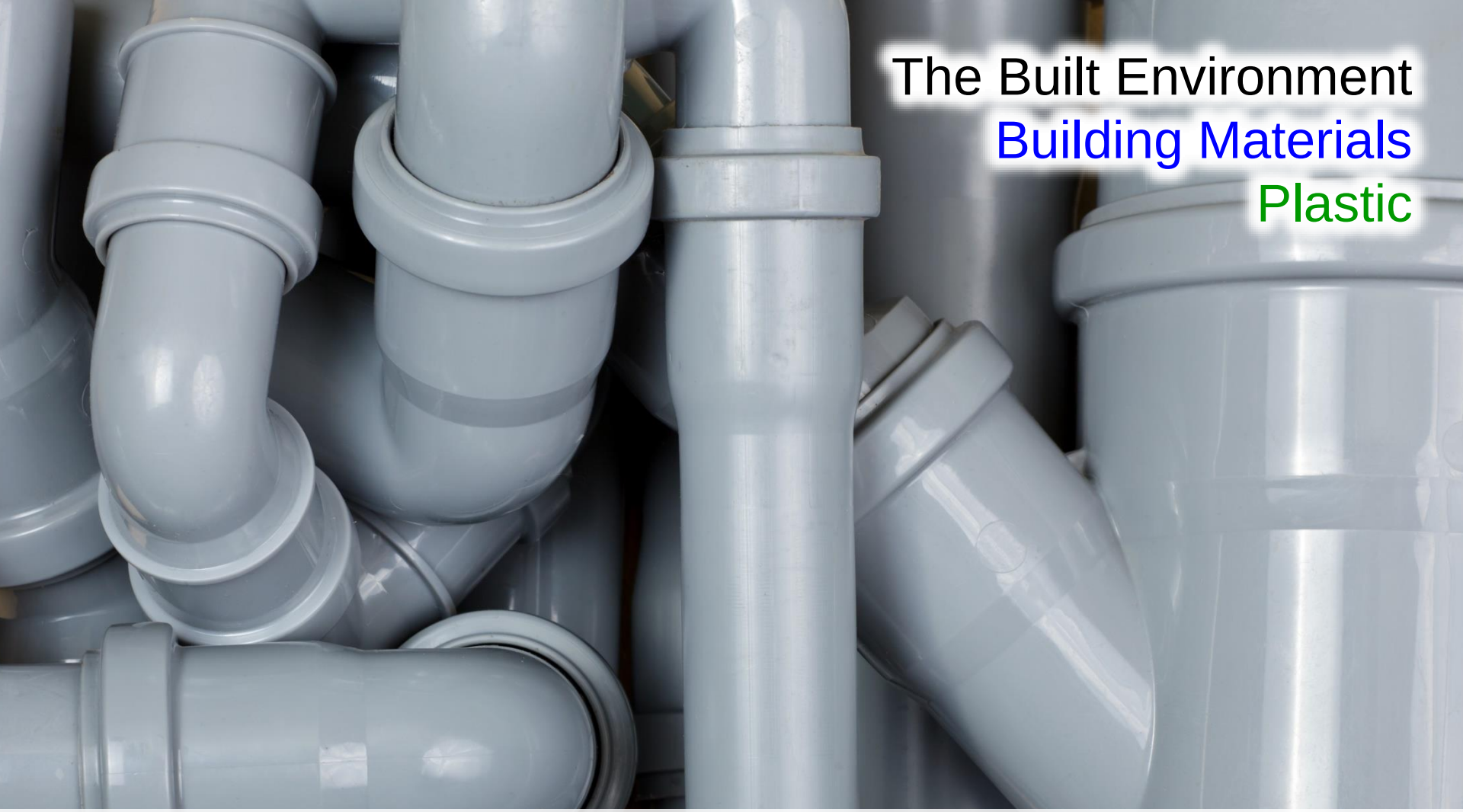
The Built Environment

Building Materials

Plastic



- The structure of a plastic, such as polythene. It is a single long chain of *carbon atoms*, with *hydrogen atoms* bonded along the side.
  - = atom of carbon. = atom of hydrogen.



The Built Environment

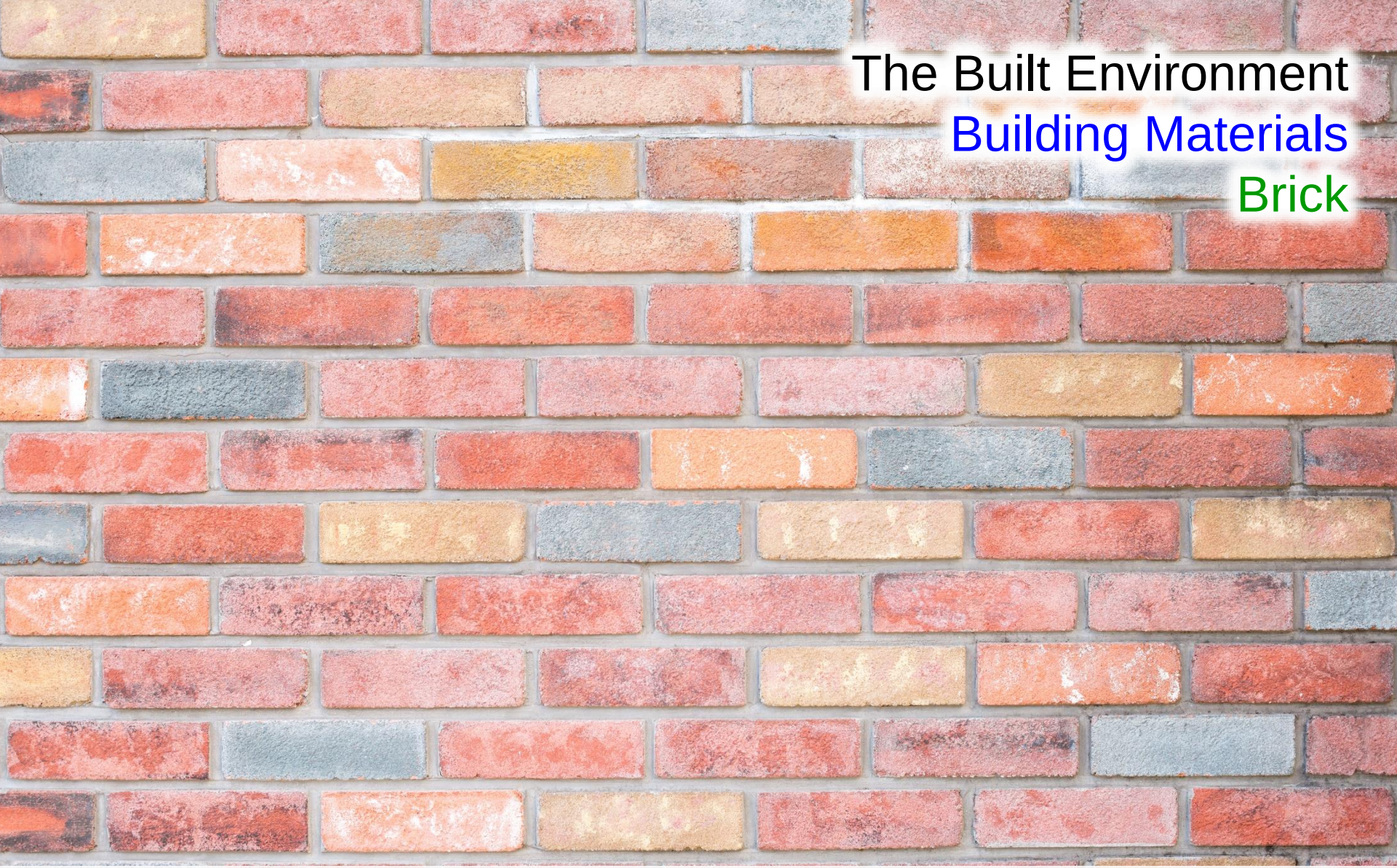
Building Materials

Plastic

- Plastics are relatively *cheap* to manufacture. They are *durable* and can be *moulded* into many different shapes. Plastics are *insoluble* in water and are *electrical insulators*.

The Built Environment
Building Materials
Plastic

- Plastics are *non-biodegradable*. They are not broken-down naturally by bacteria and therefore accumulate in the environment.



The Built Environment

Building Materials

Brick

- Interlocking stacks of bricks held together by mortar.

The Built Environment

Building Materials

Brick

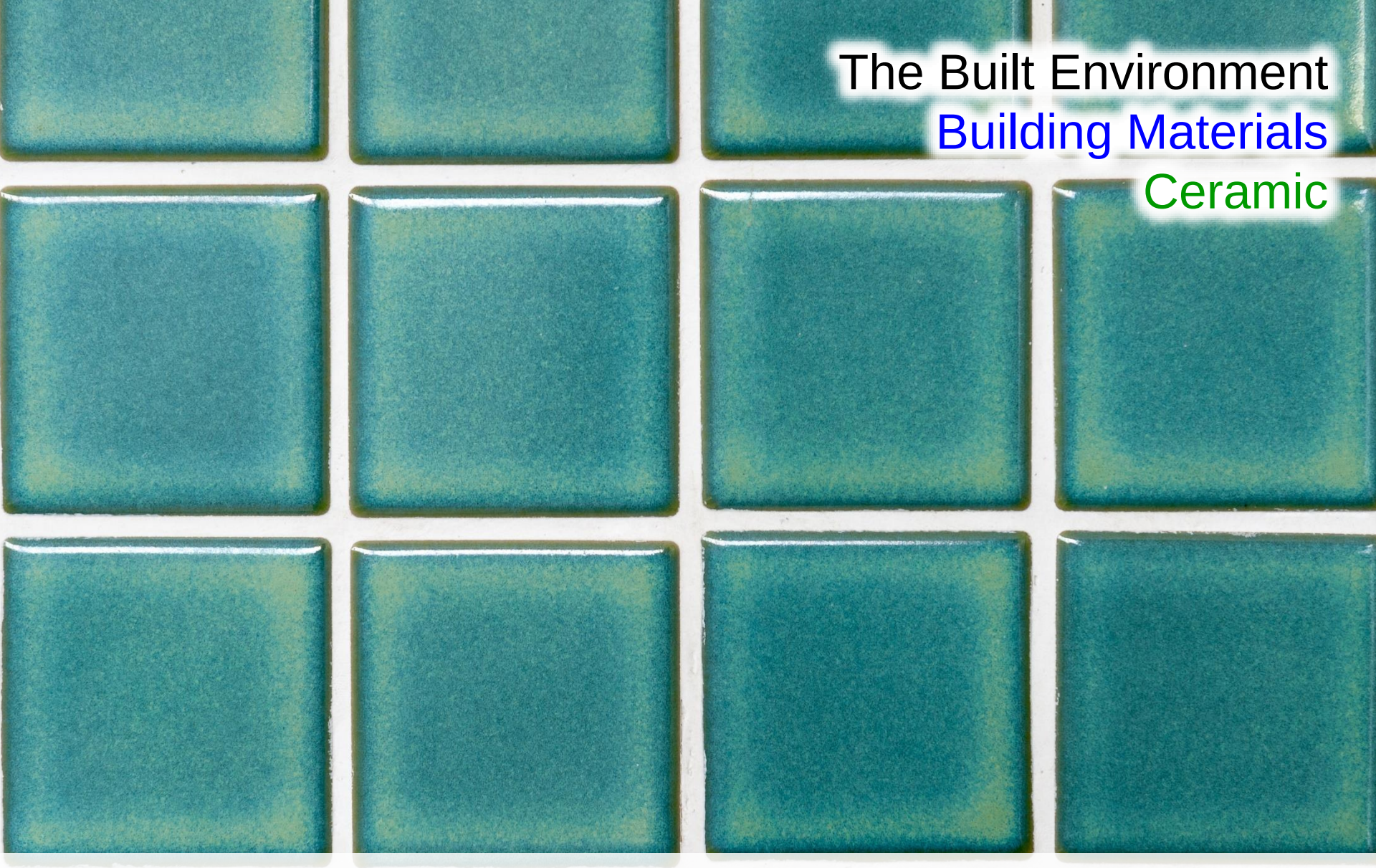
- Second to wood, masonry (bricks) is probably the oldest building material used by humanity. It dates from the ancient civilisations of the Middle East and was used widely by the Greeks and Romans.

- Early cultures used bricks made of mud, but little of their work has survived. Stone structures, such as the Egyptian pyramids and Greek temples, and structures made from fired clay bricks have survived for thousands of years.

The Built Environment
Building Materials
Brick

- The idea of masonry is to build stable interlocking stacks of hand-laid pieces, usually bonded together by another material, *e.g.* mortar. The pieces are usually chosen or manufactured to be of a size and weight that one person can place by hand.

- The weight of the masonry makes it resistant to natural forces, such as wind and water.



The Built Environment

Building Materials

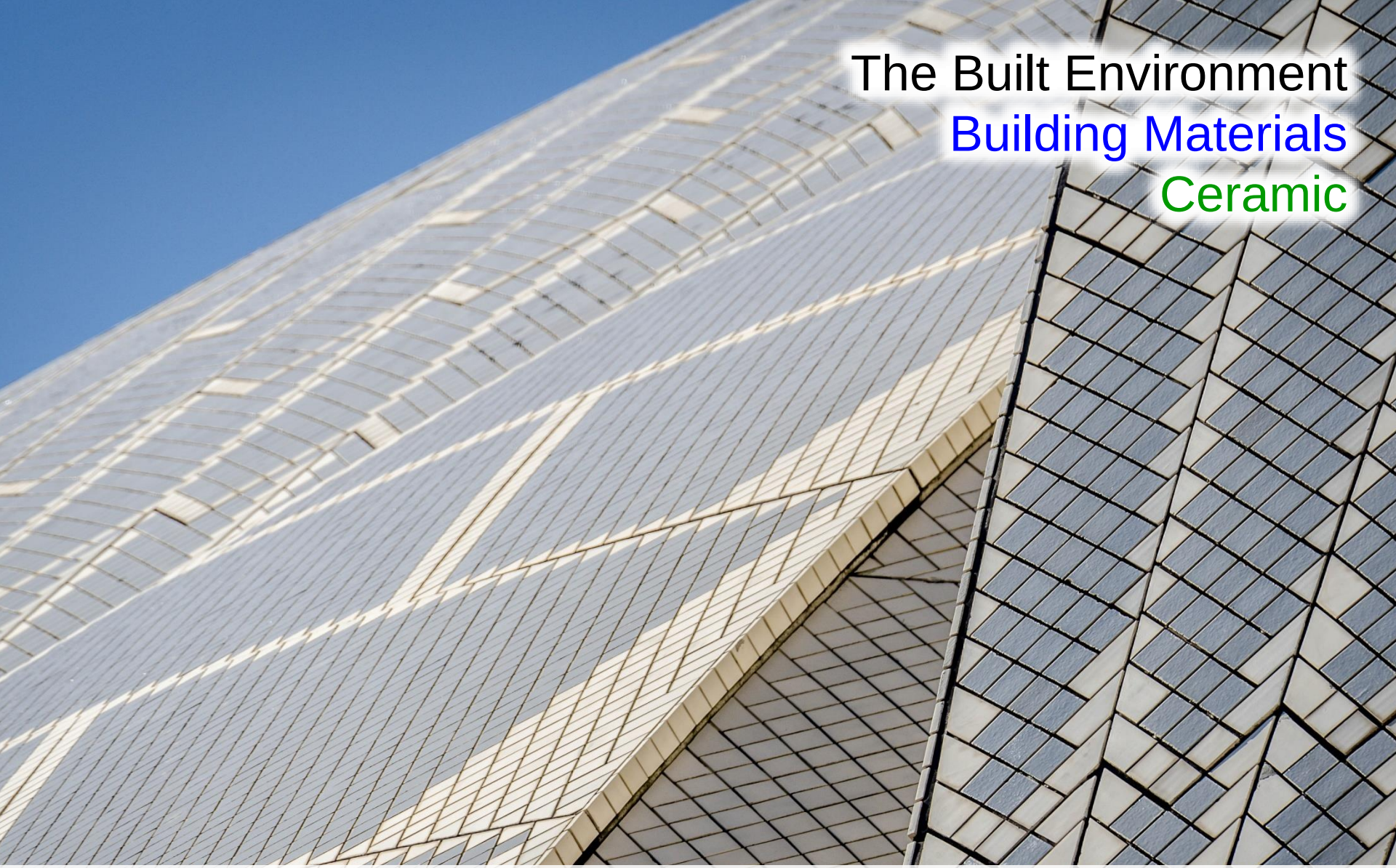
Ceramic

- Ceramic tiles. Ceramics are decorative, heat resistant, easy to clean, but *brittle*.

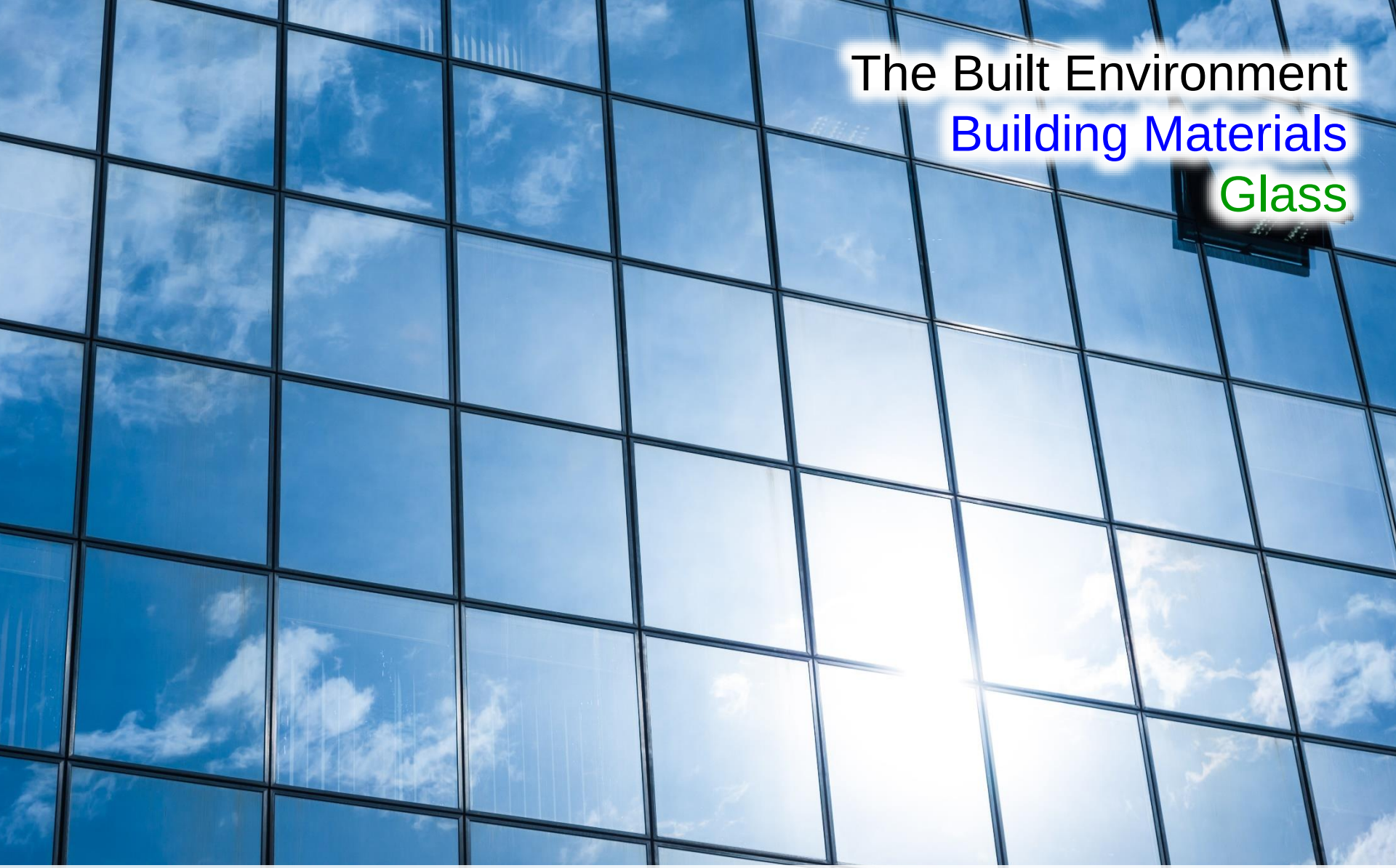
- Most ceramics are composed of metallic and non-metallic elements, *e.g.* silica, which is silicon oxide, SiO_2, or alumina, which is aluminium oxide, Al_2O_3.

- The bonding between the particles that make-up ceramics ranges from *ionic bonding* to *covalent bonding*, and many ceramics have a combination of the two.

The Built Environment
Building Materials
Ceramic



- Ceramic tiles on the roof of Sydney Opera House.



The Built Environment

Building Materials

Glass

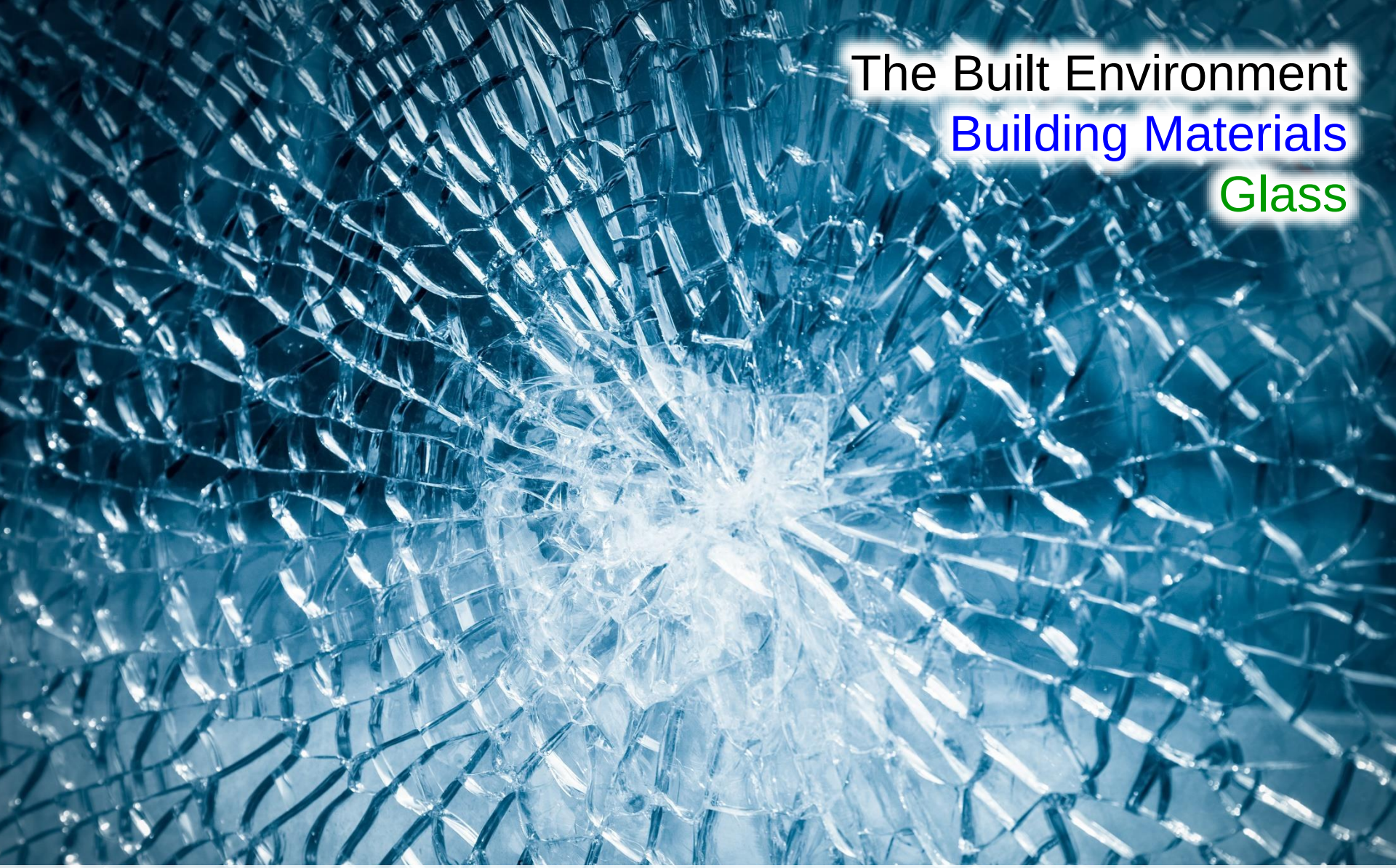
- Glass is transparent, chemically unreactive, easy to clean, but very brittle.

The Built Environment
Building Materials
Glass

- Glass is a prominent material in the modern construction industry.

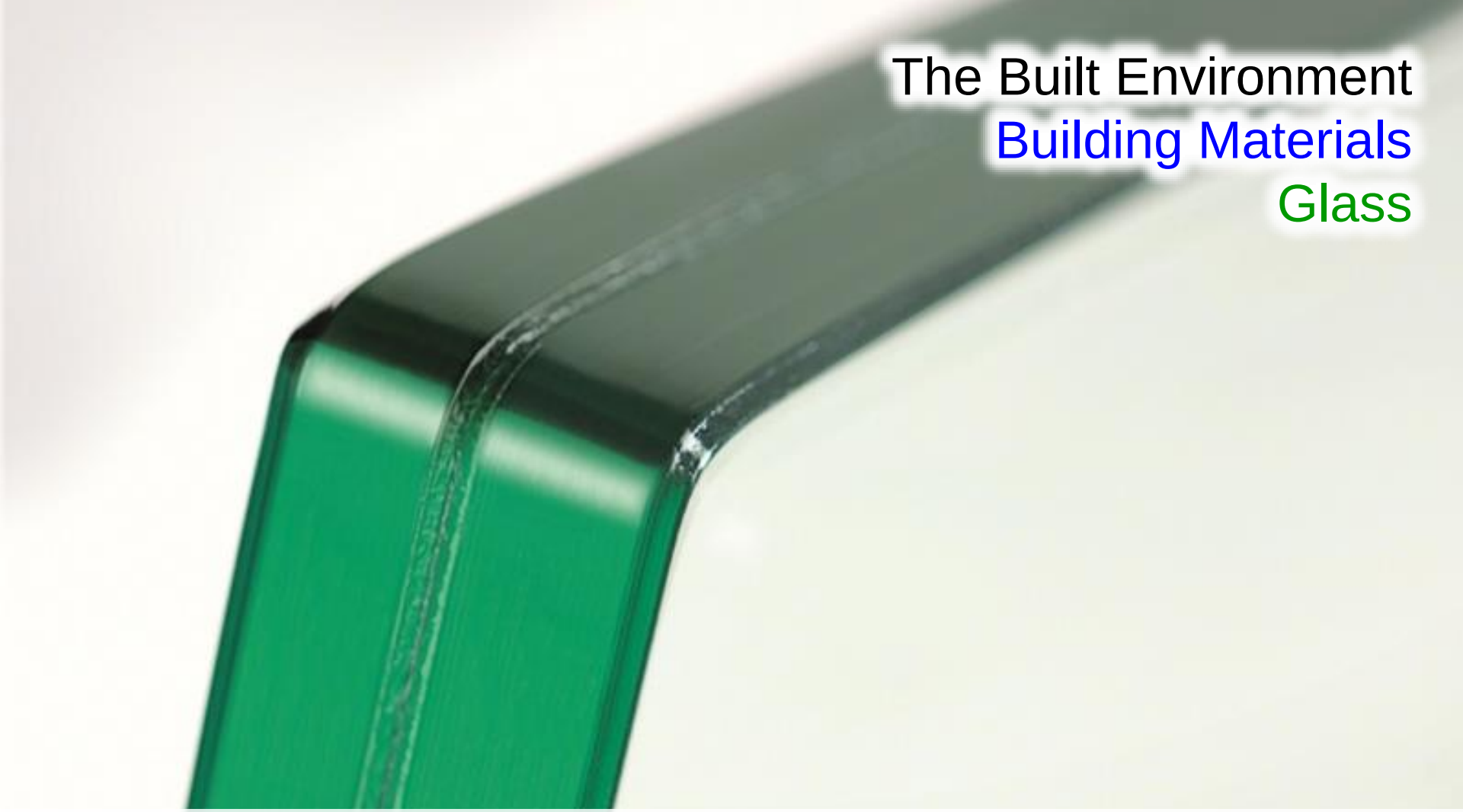
- One advantage of glass over other construction materials is the fact that it is *transparent*. It can be mixed with traces of transition metal compounds in order to tint or colour it.

- One disadvantage of glass is the unforgiving nature of its *brittleness*, although it can be toughened by *laminating* it with plastics.



The Built Environment
Building Materials
Glass

- Due to its brittle nature, glass shatters easily, but broken glass can be *recycled*.



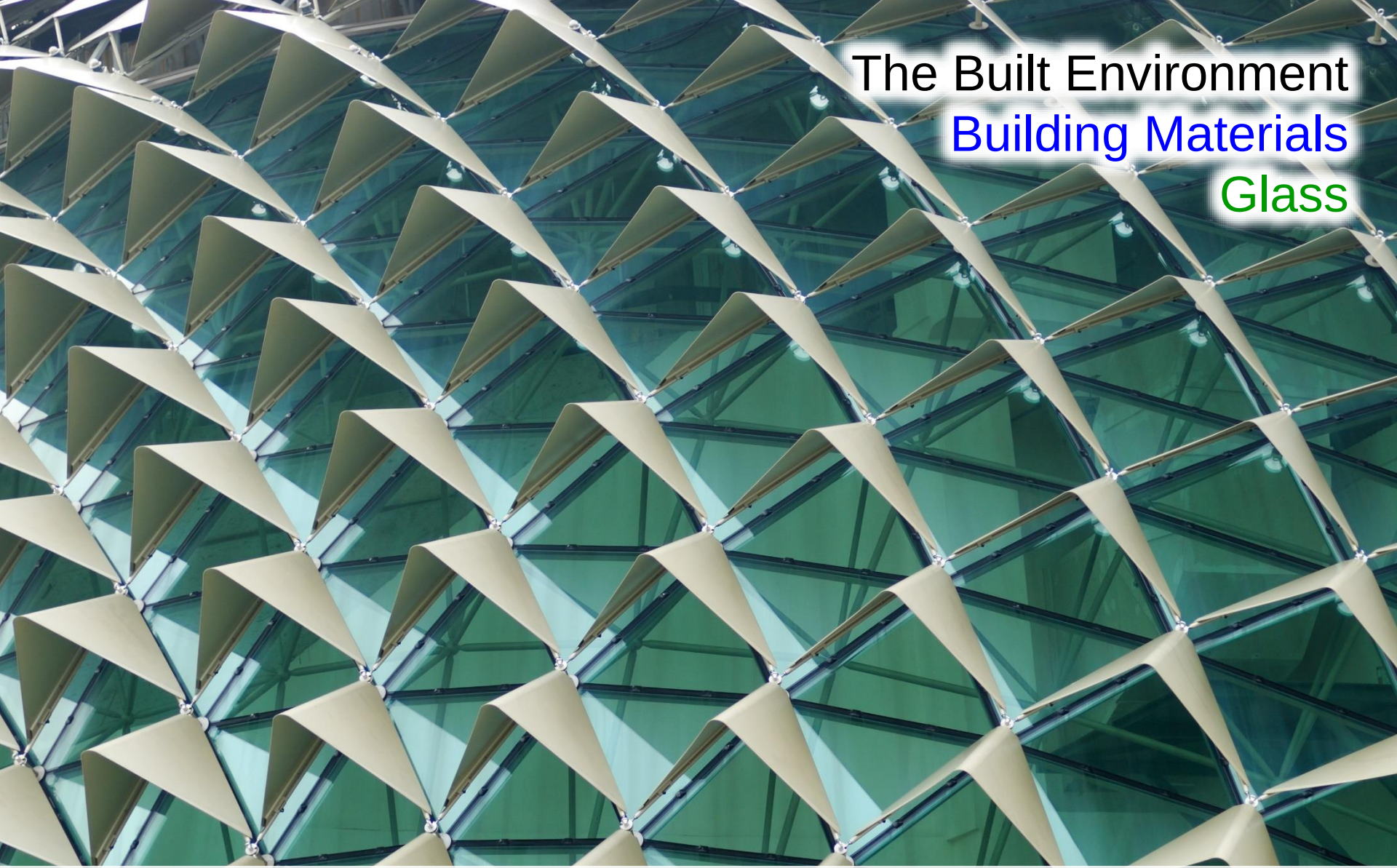
The Built Environment

Building Materials

Glass

- The strength, durability and safety of glass can be improved by *laminating* it. Laminated glass is made of two sheets of glass with a plastic interlayer.

The Built Environment
Building Materials
Glass

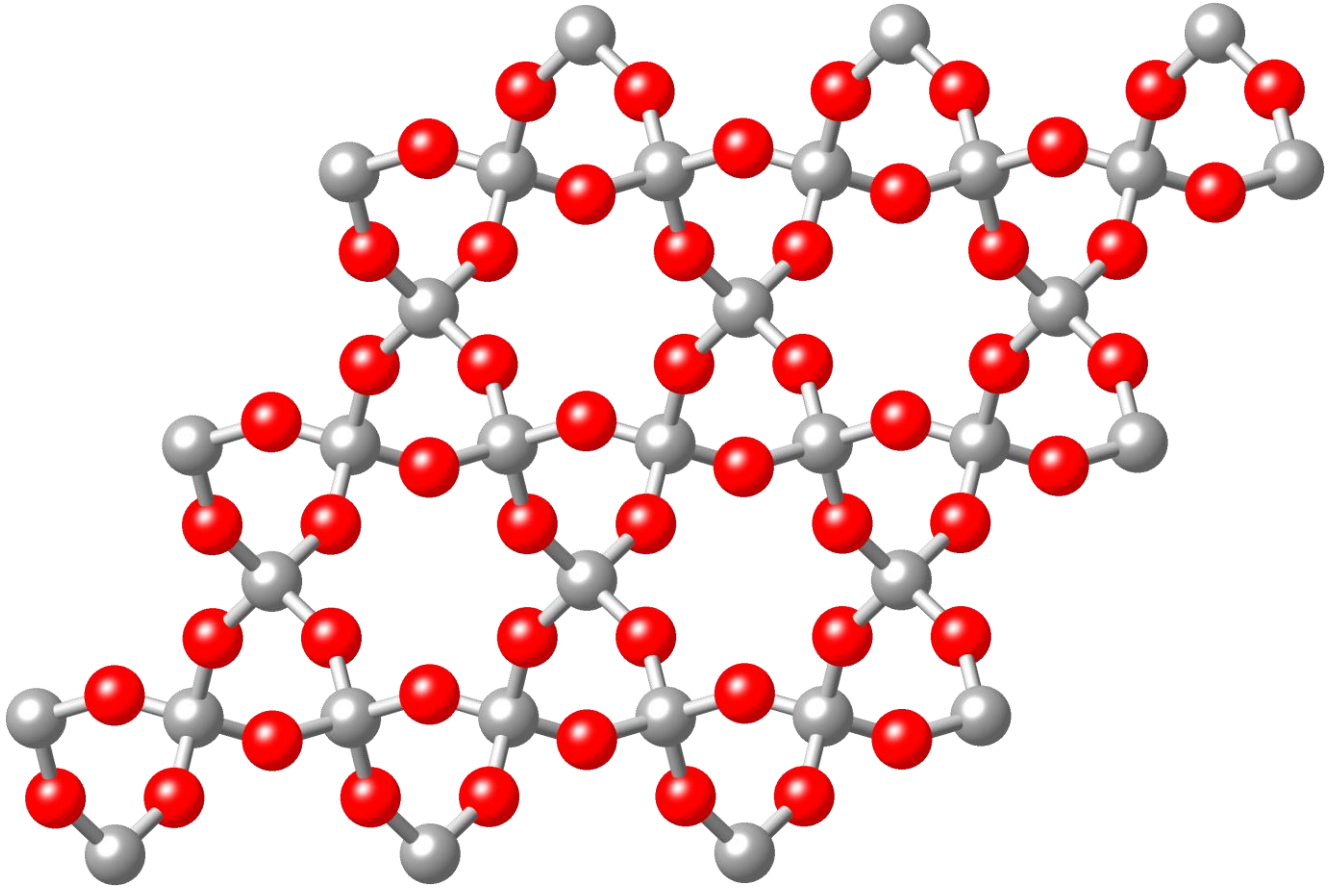


- Tinted glass panels and metal shades at the Esplanade Theatre, Singapore.

The Built Environment

Building Materials

Glass



- The structure of silicon dioxide, SiO_2, the main component of glass.

● = atom of silicon. ● = atom of oxygen.

Presentation on
Chemistry of the Built Environment

by Dr. Chris Slatter
christopher_john_slatter@nygh.edu.sg

Nanyang Girls' High School
2 Linden Drive
Singapore
288683

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