1 Natural and human-made structures

All physical bodies or objects have a structure. The purpose of a structure is to maintain the object's shape and not to break when a force acts on it. An elephant's skeleton or the walls of a building are examples of structures. Sometimes the structure is easily identified inside the body or object, such as the bones of vertebrates, the **frame**[1] of a boat or the **columns**[2] and **beams**[3] in a building. For other objects, the structures aren't easy to distinguish because the whole object forms the structure.

There are two types of structures:

- **Natural structures** are not made by humans. They're in or made by living things, or the result of geological processes. For example, the shell of a crab, a bird's nest or a cave.

- **Human-made structures** are made by people to satisfy a need. For example, the frame of a boat, the legs of a table, or a mobile phone case.

A structure prevents a body or object from breaking or **deforming**[4]. The larger something is, the more important its structure is. Large constructions, such as bridges or skyscrapers, have to **withstand**[5] huge forces so they have large structures, whereas a small object may have a structure which we can hardly see.

[1]**frame:** supporting structure of an object.

[2]**column:** vertical stone or piece of wood that supports a roof or arch.

[3]**beam:** horizontal straight piece of wood or stone to support a roof or floor.

[4]**deform:** change the natural shape.

[5]**withstand:** be strong enough not to be damaged by a force.

A **structure** is the set of elements in a body or object that resist the effects of the forces acting on it.

CLIL activities

1 In your notebook, draw and explain the purpose of these structures. Are they natural or human-made?

a. a skeleton
b. a plastic cup
c. a boat
d. a crab's shell
e. a bee's nest
f. a cave

2 Listen to the students talking about structures. What mistakes do they make?

3 Answer the questions. Then compare your answers with a classmate.

a. What's the purpose of a structure?
b. Why aren't some structures easy to distinguish?

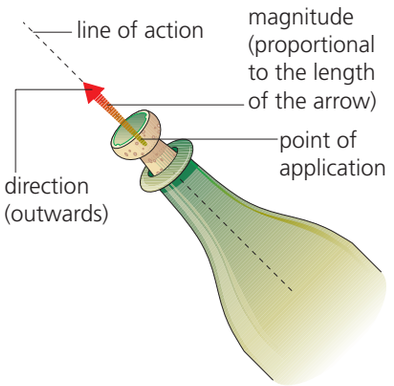
The purpose of a structure is to...

Some structures are not easy to distinguish because...

4 Look around you. What structures can you see? Discuss their purpose with a classmate.

2 Forces and loads

Physical bodies and objects need a structure to withstand the different forces that **act on**[1] them, such as gravity, which attracts objects to Earth and causes them to have weight; the wind that moves trees and buildings; or the pressure caused by a gas in a closed space. The force (or forces) acting on a structure is called the **load**.



Force

A **force** is anything that can deform a body (static effect) or make it move or stop (dynamic effect).

Static effect

Dynamic effect

[1]**act on:** have an effect on.

[2]**stress:** physical pressure on a body that can deform it.

[3]**vary:** be different or change state or condition.

Load

A **load** can be fixed or variable. Loads produce **stress**[2] on the structure of a body. The same load can cause different effects depending on the magnitude, the point of application, the direction and the line of the action of the load.

There are two main types of loads:

- **Fixed or permanent loads** are constant – they don't **vary**[3] over time. An example would be the weight of the structure of a bridge and its component parts (columns, road surface, etc.).
- **Variable loads** vary over time, for example, the traffic going across a bridge or the wind hitting it.

CLIL activities

5 **Work in pairs. Say if the force has a *static* or *dynamic* effect on these actions.**

a. Hitting a golf ball
b. Pushing a shopping trolley
c. Your heart pumping blood
d. Sitting down on a sofa
e. A picture hanging on a wall

The force in hitting a golf ball has a ... effect.

6 **Listen and answer the questions about the types of loads in your notebook. Check your answers with a classmate.**

7 **Finish these sentences in your notebook.**

a. Physical bodies and objects need a structure which...
b. The effects from force can be...
c. A force can...
d. A load can be...

3 Types of forces

[1]**deformation:** process or result of changing the shape of an object.

[2]**stretch:** make longer or wider by pulling.

[3]**crush:** press hard causing something to deform.

[4]**bend:** change something so it's no longer straight.

[5]**twist:** turn the ends of something in different directions.

We classify static and dynamic forces by the **deformation**[1] they produce: **tension**, **compression**, **bending**, **torsion** and **shearing** or **cutting**.

Tension

Tension is produced when forces try to **stretch**[2] the body they act on. These forces are opposing. This means, they go in the same line of action but in different directions – away from each other.

Compression

We see this when forces try to **crush**[3] or **compress** a body. These forces are opposing, in the same line of action but in opposite directions – inwards on the object.

Bending

This is when forces try to **bend**[4] the body they act on. They're not opposing, they go in the same direction.

Torsion

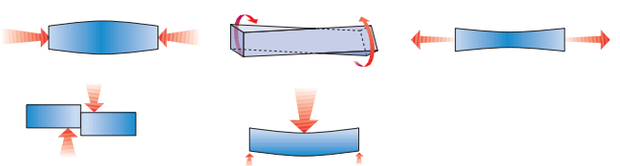
In this case, the forces try to **twist**[5] the body they act on. The forces act in different directions.

Shearing or cutting

When we apply this force, we're using forces that try to **divide** something. These forces act in opposite directions but aren't aligned – one goes up and the other goes down.

CLIL activities

8 Copy these diagrams into your notebook. Explain what force each one is.



9 Listen to the five different examples of forces and identify the type of force in each one.

10 Think of your own examples of each type of force on this page. Check your ideas with a classmate.

11 In pairs, look around you. Find an object. Test forces on it. Can you bend it? Can you twist it? Can you divide it? Write the results in your notebook.

4 Conditions of structures

When designing and building a structure, we have to consider three basic conditions for the structure to work well:

- **Stability**: the capacity of a structure to remain **upright**[1] and not fall over. A structure's **centre of gravity** must be centred over the structure's base and close to the ground to make it more stable. To give a structure stability we can:

[1]**upright:** in a vertical position.

[2]**bear:** support the weight of something.

[3]**joint:** place where two or more pieces are joined together.

- make the base wider

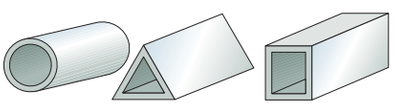
- bury the bottom section in the ground

- centre the weight at the bottom

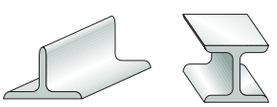
- fix the base to the ground.

- **Resistance**: the capacity of a structure to **bear**[2] the tensions acting on it without breaking. A structure's resistance depends on the material used to build it, the quantity of material and its shape. Examples of the strongest materials include steel, stone, cement, wood and plastic.
- **Rigidity**: all bodies deform slightly when a force is applied to them. This deformation, caused by **compression**, **traction** or **bending**, mustn't prevent the structure from performing its function. For structures to have **rigidity** and to avoid deformation, there are three basic aspects: shape, **joints**[3] and triangulation.

The type of force will determine the best structural shape. For example, we use thick, hollow elements to resist compression or I or T beams to resist bending. To create rigid joints, we can use rebar frameworks in concrete, for example. Triangular structures are one of the strongest and prevent deforming.



Hollow beams hold up well under compression.



T and I beams are best for resisting bending.

CLIL activities

12 **In your notebook, complete these questions and ask a classmate.**

a. What's the capacity of a _____ to remain _____ and not fall over?

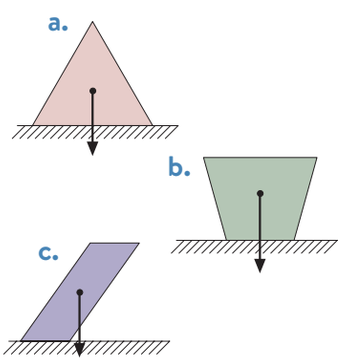
b. What's the _____ of a structure to bear _____?

c. What mustn't _____ the structure from _____ its function?

13 **Listen and choose the correct description of these terms. Compare your answers with a classmate.**

stability resistance rigidity

14 **Look at the pictures. Which structure do you think is more stable? Which one is less stable? Why? Write your answers in your notebook.**



Structure ... is the most stable because...

5 Structures in buildings

[1]**foundation:** layer of stone or concrete in the ground that forms the base for a building.

[2]**slab:** thick flat piece of stone.

The first human-made structures were cut out of rock or built by piling rocks or blocks on top of each other, such as in the Great Pyramids in Egypt. This left little or no space for passages and windows. Over time, vertical and horizontal elements, such as lintels and pillars were introduced to open up these spaces.

Egyptian pyramid

Stone lintel

Greek temple with pillars (Parthenon, Athens, Greece)

Columns, pillars and pilasters

Different types of **vertical elements** support the weight of the structure on top of them and transfer it to a lower level or to the **foundations**[1]. These elements resist compression stress. They are made of wood, stone or reinforced concrete or metal, depending on the historical period.

- **Pillars** are round or rectangular.
- **Columns** are cylindrical and usually have a decorative as well as structural function.
- **Pilasters** are columns or pillars which are part of the wall.

Beams, joists and lintels

These are **linear horizontal elements** that keep a space between two supports.

- **Beams** sit on pillars and transfer the weight of the floor **slabs**[2] or the roof.
- **Joists** are smaller beams within slabs that carry the load to the beams.
- **Lintels** are used to create open spaces between columns for openings, windows or doors in walls.

CLIL activities

15 **Copy the sentences into your notebook. Write true or false. Correct the false sentences.**

a. Columns are cylindrical and usually have a decorative as well as structural function.

b. Pilasters are used to create openings in walls for windows and doors.

c. Beams sit on pillars and transfer the weight of the walls.

d. Joists are smaller beams within slabs that carry the load to the beams.

16 **Listen and answer the questions about the structures in buildings. Check your answers with a classmate.**

17 **Write down what monuments you've seen that have pillars, columns, pilasters, beams, joists and lintels in their structures. If possible, find photos on the Internet or make drawings. Compare and discuss with a classmate.**

18 **Draw your own monument using all the vertical and horizontal elements you've seen on this page. Then, label the drawing.**

Arches and walls

With the invention of new building techniques, and in particular arches and vaults, builders were able to cover larger spaces and have bigger gaps in structures.

Arches are built using a temporary structure called a **centring**[1], which holds the pieces (the **arch stones**) that form the arch under construction. The final centre piece of the arch, called the **keystone**, ensures that the arch stays up on its own.

Vaults are built by using either a series of arches in a line (a barrel vault) or intersecting arches (a rib vault).

A semi-circular arch

A rib vault

[1]**centring:** temporary wooden frame used to construct arches.

[2]**reinforce:** make a structure stronger by adding extra material.

[3]**adobe:** mud that's dried in the sun, mixed with straw.

Buttresses and flying buttresses

A **buttress** can be part of a wall and is used to **reinforce**[2] the wall and transfer the loads from the vaults to the ground.

A **flying buttress** is an exterior arch which bears lateral loads from the vaults to the buttresses.

Load-bearing walls and retaining walls

Load-bearing walls bear vertical compression stress and can be built with materials like stone, bricks and **adobe**[3].

Retaining walls bear bending stress because of the lateral force that the earth puts on them. They must be built with reinforced concrete or with a large amount of material.

CLIL activities

19 **In your notebook, explain these terms and say what kind of stress they take.**

a. arch
b. vault
c. buttress
d. flying buttress
e. load-bearing wall
f. retaining wall

20 **Listen to the documentary about the structrure of a building and write the six missing words. Check your answers with a classmate.**

21 **Write the questions for these answers. Then compare your questions with a classmate.**

a. The arch stones
b. A flying buttress
c. Load-bearing walls

What's the name of... ?

[1]**laminates:** multiple layers

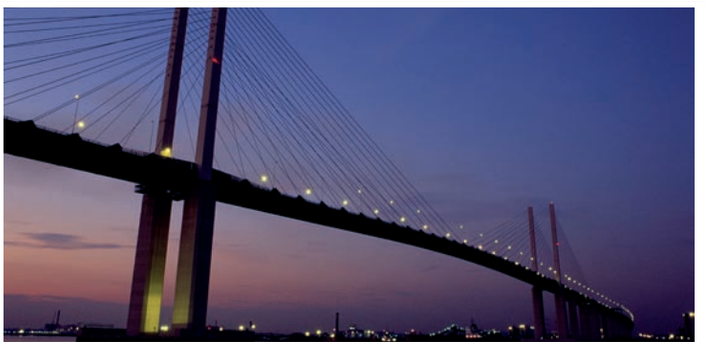
[2]**set up:** to put together, construct.

[3]**compress:** press together or into a smaller space.

Modern structures

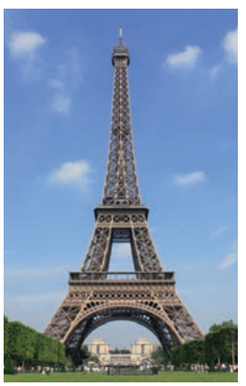
Suspended structures

This type of structure uses cables, called **suspenders**, which the structure hangs from.



Triangular structures

These structures are made from bars, normally metal or wooden. The use of triangular shapes means they are not easily deformed.

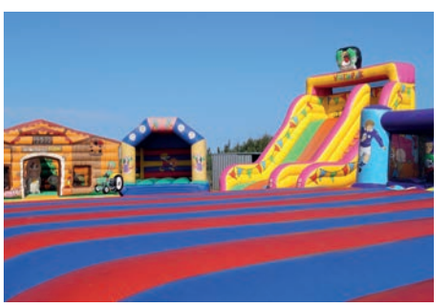


Laminated structures

These are formed by **laminates**[1] of metal, plastic or composite material, such as reinforced concrete. Their **curved shape** and **folds** give them their strength.

Pneumatic structures

Pneumatic structures are **light** and easy to transport, **set up**[2] and take down. These structures use **compressed**[3] air inside them.



Spatial and geodesic

These are three-dimensional structures of bars, which combine the properties of vaults with triangulated structures to create curved shapes and cover large spaces.

CLIL activities

22 In your notebook, write down what type of buildings use these structures.

a. suspended structure
b. triangular structure
c. laminated structure
d. pneumatic structure
e. spatial and geodesic

23 Listen to the man talking about structures and take notes. What examples does he give? Compare your notes with a classmate.

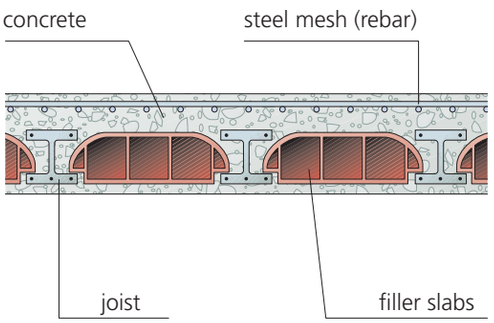
24 Work with a classmate. Say the names of some buildings you know. Your classmate has to guess what structure is used.

Reinforced concrete structures

Concrete led to major **advances**[1] in construction because it could be made into any shape. It's a very strong material used in all types of buildings.

Concrete slabs

These are flat, horizontal elements working in two directions. They transfer the loads that the rest of the structure bears and they resist bending stress. They're made up of:



Joists: carry the weight of the slabs to the beams.

Filler slabs: fill the space between the joists.

Reinforced concrete surface: makes the slabs even.

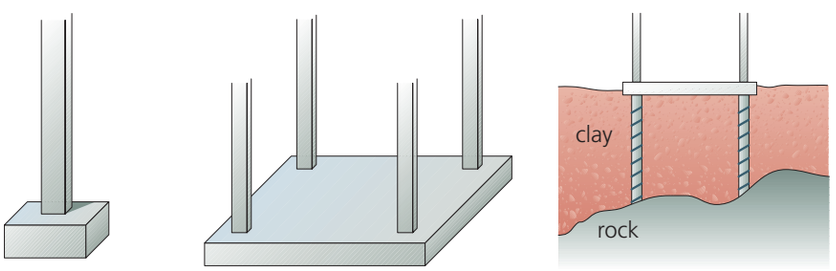
Footings, plinths, shallow foundations and piles

A **footing** is a type of **platform**[2] at the base of a structure that holds the weight of the rest of the structure.

Plinths are rectangular blocks of concrete under columns.

Shallow foundations are made of concrete and they sit on the ground and are used to distribute loads. They are usually used for soft ground.

Piles are columns pushed deep into unstable ground or **clay**[3], so that they rest in more solid soil.



footing | shallow foundations | piles

[1]**advance:** progress or improvement.

[2]**platform:** raised level surface.

[3]**clay:** heavy, sticky earth often used to make bricks.

CLIL activities

25 **In your notebook, answer these questions.**

a. What carries the weight of the slabs to the beams?

b. What makes the slabs even?

c. What fills the space between the joists?

26 **Listen to the architect and take notes. Answer these questions.**

a. Which part of the building is she talking about?

b. Which two elements do they use to save money?

27 TASK STEAM **Work with a classmate. Design a new, separate entrance for your school. Draw plans and decide on different structures and materials, and how you'll combine them to build the entrance, starting with the foundations.**