KEY WORDS:
Nutrition, cereal, energy, calories, protein, carbohydrate, fat, growth

WHY DID THE VIKINGS INVADE?

POPULATION PRESSURES

In parts of Scandinavia it was difficult to grow enough food for everyone to stay healthy. This meant that many young men, especially younger sons, decided to find somewhere else to live.

Context: Leif's family were farmers, growing crops and raising livestock in the cold north of Norway. Lacking many options at home, and with food often in short supply for such a large family, Leif decided to leave and make his own fortune elsewhere.

Which is the best cereal?

Teachers' note: Ordinary people in Viking times got most of their daily calories from cereals used to make beer and porridge and, sometimes, bread. In Norway barley was mostly used for making beer, while rye was used to make bread. Where it would grow, rich people liked bread made from wheat, while oats were used to make a savoury porridge.

What can we ask? Which cereals contribute best towards a balanced diet? What are different cereals used for?

Equipment list: Cards showing key nutritional information for each cereal.

Activity instructions: Use the nutritional information provided to decide which cereal grains you would use to make bread, porridge or beer. Beer contains carbohydrates with lots of calories, so it was drunk for energy. Porridge contains carbohydrates and a little fat for energy, and protein to help you grow. Bread contains carbohydrates for energy.

Barley

NUTRITION FACTS	
Serving Size: 100 g or 3.5 oz	
AMOUNT PER SERVING	
Calories: 354	Calories from Fat: 19
	% Daily Value*
Total Fat: 2 g	4%
Total Carbohydrate: 73 g	24%
Dietary Fibre: 17 g	69%
Sugars: 1 g	
Protein: 12 g	
Vitamin A:	0%
Vitamin C:	0%
Calcium:	3%
Iron:	20%

*Percent Daily Values are based on a 2,000 calorie diet. Your Daily Values may be higher or lower depending on your calorie needs.

Nutritional data | SkipThePie.org

Wheat

NUTRITION FACTS	
Serving Size: 100 g or 3.5 oz	
AMOUNT PER SERVING	
Calories: 327	Calories from Fat: 13
	% Daily Value*
Total Fat: 2 g	2%
Total Carbohydrate: 71 g	24%
Dietary Fibre: 12 g	49%
Sugars: 0 g	
Protein: 13 g	
Vitamin A:	0%
Vitamin C:	0%
Calcium:	3%
Iron:	18%

*Percent Daily Values are based on a 2,000 calorie diet. Your Daily Values may be higher or lower depending on your calorie needs.

Nutritional data | SkipThePie.org

Oats

NUTRITION FACTS	
Serving Size: 100 g or 3.5 oz	
AMOUNT PER SERVING	
Calories: 389	Calories from Fat: 58
	% Daily Value*
Total Fat: 7 g	11%
Total Carbohydrate: 66 g	22%
Dietary Fibre: 11 g	42%
Sugars: 0 g	
Protein: 17 g	
Vitamin A:	0%
Vitamin C:	0%
Calcium:	5%
Iron:	26%

*Percent Daily Values are based on a 2,000 calorie diet. Your Daily Values may be higher or lower depending on your calorie needs.

Nutritional data | SkipThePie.org

Rye

NUTRITION FACTS	
Serving Size: 100 g or 3.5 oz	
AMOUNT PER SERVING	
Calories: 338	Calories from Fat: 14
	% Daily Value*
Total Fat: 2 g	3%
Total Carbohydrate: 76 g	25%
Dietary Fibre: 15 g	60%
Sugars: 1 g	
Protein: 10 g	
Vitamin A:	0%
Vitamin C:	0%
Calcium:	2%
Iron:	15%

*Percent Daily Values are based on a 2,000 calorie diet. Your Daily Values may be higher or lower depending on your calorie needs.

Nutritional data | SkipThePie.org

Related activities: Devise a healthy menu for a person living in Viking times using only seasonal plants and fruits, and what they could raise and grow.

Find out what other ingredients available in Viking times could be added to make a nutritious savoury porridge.

KEY WORDS:
Temperature, sunlight, growth, crops, seasons, photosynthesis

Growing cereal crops

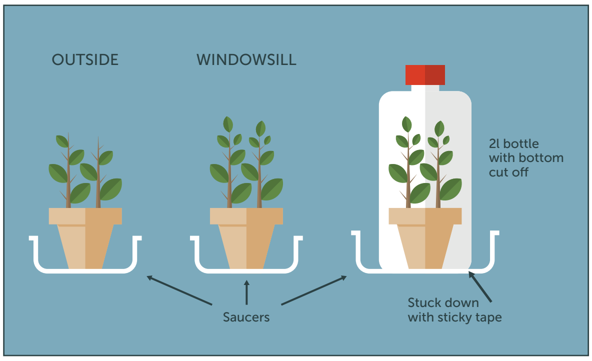
Context: After many years spent raiding, making a reputation for himself and accumulating wealth and men, Leif decided to settle in Cumberland. On the plains between the sea and the mountains the land was flat and fertile, unlike the icy lands in Norway that he used to call home. There he was able to raise many different crops, raise livestock and start a family. Life was much easier than in his old home.

Teachers' note: Parts of Norway have a much shorter growing season than Denmark or Britain because, being further north, the temperature is much lower. This means that some cereals don't grow well, with barley and rye the main cereal crops in the north, and rye, barley, oats and wheat in the south.

What can we ask? How does the temperature affect plant growth? Compare seeds from different crops. Do some crops grow better than others at a lower temperature?

Equipment list: Wheat seeds, plant pots, saucers, damp compost, ruler, empty 2-litre plastic bottle with lid, safety scissors, sticky tape

Activity instructions: Plant some wheat seeds in three pots (same number in each) and place the pots on saucers. Leave one pot outside in a place sheltered from wind, but in the light, and another pot on the windowsill indoors. With the third pot, cut the bottom from the 2-litre bottle and cover the pot, sealing the bottom to the saucer with sticky tape. This will keep the temperature slightly higher inside the bottle. Keep this on the windowsill, next to the other pot. Every day, once they have germinated, measure the height of the wheat plants.



Growing cereal crops

Explanation: The further north you go the shorter the growing season, due to lower temperatures. Photosynthesis is a chemical reaction, and chemical reactions run more slowly at lower temperatures, so plants have less time to grow at higher latitudes and elevations. The outdoor plant, during the winter, is less likely to germinate and will grow more slowly than the indoor plants. The plant in the bottle will have a slightly higher temperature, due to heat trapped within the bottle, so should grow slightly more than the plant without a bottle.

Related activities: How does the amount of light affect plant growth? Compare different cereals' growth at different temperatures.

KEY WORDS:
Acid, soil, growth, pH

What is the soil like in Scandinavia?

Context: When Leif remembered his homeland his main memories were of looking out over the fjords from the tops of the black, rocky hills and toiling in the thin, rocky soil. As a child one of his main jobs was removing the hard granite stones from the fields before ploughing. One time, he remembered, his father purchased some wheat seeds from a trader. Fewer than half of the seeds germinated, and those that did grew small and frail. They were all killed in the first frost, with nothing harvested. That was a bad year.

Teachers' note: Much of the bedrock in Scandinavia is igneous and metamorphic rock, plus lots of sandstone. This means the soil is often acidic, consisting of boggy land and heathland. This means that the area for growing cereal and other crops is limited, especially in Norway.

What can we ask? How does acid soil affect plant germination? Do some plants grow better than others in acidic soil?

Equipment list: Cress seeds, tissue paper, saucers, tap or distilled water, distilled vinegar

Activity instructions: Take two saucers and lay a few sheets of tissue paper on each. Count out and sprinkle the same number of cress seeds onto each piece of tissue paper. Pour 20 ml vinegar onto one set of seeds, and the same amount of water onto the other. Top up each day as necessary. After a few days count how many seeds have germinated on each saucer.

Explanation: Different plants prefer soils at different pH. Rye is more tolerant of acid soils than oats, wheat or barley, so was very widely grown in Norway. Soils can be made less acidic by treating with lime to raise the pH.

Health and safety: Wear eye protection when pouring vinegar. If vinegar does get in eyes, wash eyes under running water for at least 10 minutes and seek medical attention.

Related activities: Identify and classify rocks, test the hardness of rock samples, test the pH of soils from different areas. Does the concentration of vinegar affect plant germination?

Norway | Shutterstock

KEY WORDS:
Nutrients, soil testing, pH

Viking campsites

Context: When he was a young man Leif managed to persuade the local Jarl to let him join the crew on one of his longships. There, he learned how to sail and navigate, took his turn on the oars, and learned the best spots to stay when they pulled in to shore at night. Many of these spots were well known by people, with large black areas where the campfires were built. Every year the first visitors had to clear the weeds, or start a new fire site, as many different plants grew in these places, fed by the ash of the old campfires.

Teachers' note: When on a raiding or trading expedition, at night Vikings would often beach their ship, make a campsite and build a fire. Some places were well-known stopping points with fires built in the same place for years. Wood ash contains potassium, which is an essential nutrient for plants. Stinging nettles often mark the sites of ancient campfires, as they like potassium rich soils.

What can we ask? What nutrients do plants need to grow? Do all plants need the same nutrients?

Equipment list: Soil testing kit (available from garden centres), soil samples, beakers, distilled water. Optional: outdoor clothing, strong boots, trowels, sample bags

Activity instructions: Optional – Collect soil samples from different areas and place them in labelled bags to test later. Note the plants growing in each soil sample.

Use the appropriate soil testing kit to test pH, nitrogen, potassium (potash), phosphorus and other nutrients in soil samples. Follow the instructions for your particular soil testing kit.

Explanation: As well as sunlight, water and carbon dioxide from the atmosphere for photosynthesis, plants need nutrients from the soil to help convert the glucose from photosynthesis into proteins and lipids for growth and metabolism. The most important nutrients are nitrogen, potassium, phosphorus and magnesium, with other trace elements also being important.

Related activities: Research the different plants that grow on acid and alkaline soils. Soil is made from a mixture of rock fragments and organic matter. Add some water to the soil and watch the air bubbling out (important for the growth of micro-organisms). Leave for a few minutes to settle. The organic matter will float, the rock and sand particles will sink.

Leif camping | Terry Harvey-Chadwick

THE VIKING LONGSHIP

Vikings were great ship builders and navigators. Their great longships were a revolution in ship design, as they invented a brand-new kind of keel that enabled the longship to cross open ocean rather than just hug the coasts. They had quite flat bottoms, which meant they could navigate up rivers to inland towns that they thought were safe.

Context: Eventually, as he grew more skilled and gathered wealth, Leif bought a longship with 30 oars. The Jarl of Møre allowed him to select 40 men for a crew and finally, soon after his 18th birthday, Leif set sail from Giske in Norway. The ship was named Wave Strider, with a dragon head at the prow and a serpent at the stern. Sailing to the Orkney Islands to resupply his food and water, Leif then began to ravage the Western Isles of Scotland and even rowed inland up the rivers. However, Leif wasn't always a Viking. When his ship was full of goods he would sail to Dublin, removing the dragon head so it wouldn't scare away the friendly spirits of the land, and trade his plunder for silver and essential goods.

Leif and crew | Terry Harvey-Chadwick

KEY WORDS:
Viking longship, warship, ratio, data

What makes a longship long?

Teachers' note: A Viking warship was very long and thin, which made it able to skim across the top of the waves at sea. A common nickname for the Viking longship was the sea serpent. The longest Viking warship ever found is the Roskilde 6, which is 36 m long but just 3.7 m wide. Viking trading and fishing ships tended to be shorter and wider, for stability. Viking ships tend to have quite flat bottoms, which means they have a very shallow draught, ie they don't sink very much into the water.

What can we ask? What is the difference between a warship and a trading ship? What is a ratio?

Equipment list: Viking ship data table, calculators

Activity instructions: Viking ships were called longships. Some were used as warships and were very long and narrow. Others were used as trading and fishing ships and were shorter and wider. Use the data below to decide whether these old Viking longships were warships, or trading or fishing ships.

Calculate the width-to-length ratio by dividing the ship's length by its width. Any answer greater than 7 means it is probably a warship. Use the other data to help you decide and give additional reasons for your decision.

Ship name	Approx. date constructed	Length (m)	Width (m)	Draught (m)	Number of oars (Pairs)	Crew
The Ladby Ship	900	25.5	2.9		16	37–40
Haithabu Ship Burial	825	20	3.5			
Haithabu Harbour Ship	985	30.9	2.7		30	65–70
Puck 2	Early 10th C	20	2.2			
Roskilde 6	1025–30	36	3.7		39	80–90
Skuldelev 1	1030	15.84	4.8	1	1-2	6–8
Skuldelev 2	1042	29.28	3.76	1	30	65–70
Skuldelev 3	1040	14	3.3	0.9	2-3	5–8
Skuldelev 5	1024–40	17.3	2.5	0.6	13	30
Skuldelev 6	1030	11.2	2.5	0.5	7	5–15

Explanation: Viking warships were built to be long, manoeuvrable and fast. The narrow beam (width) meant that there was less drag through the water, so they were very fast. The shallow draught (depth in the water) meant they could beach and easily refloat the ship, and it could travel up rivers past points that were normally navigable by other large ships. However, this did make them quite unstable in the water unless they were travelling at speed, and they were prone to capsizing if hit beam-on by big waves. In a storm they could be blown far off course as they had to run with the wind to avoid being sunk. Trading ships had a much wider beam to hold more cargo, so were a lot more stable in the water.

Related activities: See floating and sinking activities.

KEY WORDS:
Keel, strake, hogging, sagging

The Viking longship

Teachers' note: The keel of the Viking longship was a simple, but revolutionary, design that made it the most sophisticated ship design for almost 600 years. Essentially, rather than a flat plank that made the ship prone to snap in half in rough weather, the Viking shipwrights used a T- or Y-shaped keel. This meant that the keel was much stronger and less prone to snap in rough seas. It also gave the ship flexibility in the hull, enabling it to flex as waves hit. A sailor in the prow or stern of the ship looking along the length would see the ship flexing and bending in the waves, thus the common nickname of sea serpent.

What can we ask? Why were Viking longships able to cross the ocean?

Equipment list: Metre ruler

Activity instructions: Demonstrate the strength and flexibility of the longship keel using a 1-m ruler. Hold it flat to show the old-style keel and how it can bend and snap in heavy seas (don't snap the ruler). This is known as hogging (bowed upwards) and sagging (bowed downwards). Try and flex it sideways and see how rigid it is. Old-fashioned ships needed very thick hulls to make them strong enough to withstand waves crashing against the side of the ship. Turn the ruler so its width is vertical. Try and bend it to show its strength in rough weather. Flex it sideways to demonstrate its flexibility, allowing the hull to absorb the energy of the waves crashing against the side of the hull. This flexibility made the hull very leaky, so there was always someone baling out water that leaked in between the planks.

KEY WORDS:
Friction, drag, pressure

Longship shape

Teachers' note: Viking longships were pointed at both ends to let them reverse easily after beaching the ship, or to avoid obstacles on a river. The pointed hull also allows the ship to cut through the water, reducing drag.

What can we ask? Why do pointed ships travel more easily through water?

Equipment list: Strong card about 6 cm × 12 cm, sink or bowl of water

Activity instructions: Put the card into the water vertically and push it through the water. Feel how hard this is. Now bend the card in half to an angle of about 60 degrees. It is much easier to push through the water.

Explanation: When you push the card vertically through the water the water has a large surface area to push back on, so it is hard to push through the water. When you angle the card you reduce the surface area the water can push on, so it is easier to push through the water. This force acting in the opposite direction to the movement through the water is known as drag.

Related activities: Investigate how drag varies with angle of point travelling through water.

KEY WORDS:
Float, sink, buoyancy, draught

Why do longships float?

Teachers' note: Viking longships tended to have flat bottoms. This made them very buoyant in the water as it had a larger surface area to push against. This meant that Viking longships had a very shallow draught, ie how far they sunk into the water, reducing drag, so they could travel very fast. It also meant that they could navigate relatively shallow rivers, as little as 1 m deep, allowing them to raid far inland away from the coast.

What can we ask? Why do things float? Why do Viking longships float so well?

Equipment list: Bowl or sink of water, plasticine, ruler

Activity instructions: Show that a lump of plasticine sinks in water. Make a solid boat shape and see if it floats. Make a hollow boat shape and see if it floats.

Explanation: An object will float if the amount of water it displaces weighs more than it does. A lump of plasticine displaces a relatively small volume of water, so it sinks. A hollow boat shape displaces a much larger volume of water that will weigh a lot more than it does, so it floats.

Related activities: Make different boat shapes to see which floats best: try flat bottomed or v-shaped hulls. Add stones, marbles, weights to see how much it can carry before it sinks.

KEY WORDS:
Sail, force, wind, pressure, shape

Which shape makes the best sail?

Teachers' note: The longship had square or rectangular sails made from wool or linen. These were mainly used when the wind was strong enough, and in the right direction, to travel longer distances. When there was no wind or not much room, like on a river, then oars were used for propulsion. Skilled captains were able to tack against or along the wind although, if the wind was in the wrong direction, most crews would use their oars.

What can we ask? Why do ships have sails? What shape sail is the best?

Equipment list: Flat wooden car with wheels, two sticks for mast and crossbeam, cotton thread, safety scissors, blu-tack, paper or other material for sails, fan or hairdryer, stopwatch

Activity instructions: Attach the mast to the car base with blu-tack. Make different shaped sails and attach them to the mast with the cotton and blu-tack, using the crossbeam if necessary. Use the fan or hairdryer to propel the car along a set length. Time how long it takes with each shape sail. Different shaped sails could include rectangular, square, triangular, circular, etc.

KEY WORDS:
Bernoulli principle, air pressure

Can Viking longships tack?

Teachers' note: Tacking is sailing across or against the direction of the wind. Square-sailed ships, like longships, cannot sail directly against the wind, but can sail across it. To tack against the wind you need lateen (triangular) sails. The main reason that tacking is possible is through the Bernoulli principle, which also helps aeroplanes fly. So, while Viking longships in the hands of a skilled captain can sail across the wind it is very difficult, and impossible to sail against the wind without the proper shaped sail.

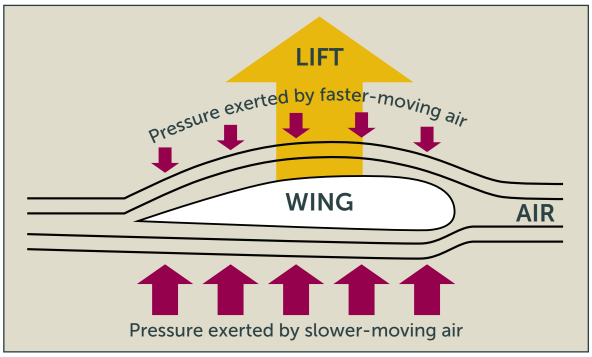
What can we ask? How can I blow up a big bag with just one puff?

Equipment list: Safety scissors, sticky tape, nappy disposal system refill or long narrow plastic bag

Activity instructions: Cut a 1–2 m length of the plastic sausage from a nappy disposal system and seal one end with sticky tape. Lay the sausage along a table. Hold the open end between 20 and 30 cm away from your face. Blow as hard as possible into the open end. See the sausage fill with air and quickly close the open end to prevent the air escaping.

Explanation: The Bernoulli principle (also called the Bernoulli effect) simply states that a fast-moving fluid, like air, has a lower pressure than slow-moving or still fluid. This is one of the effects acting upon an aircraft wing to produce lift.

If you try and fill the long sausage by blowing into it as you would a balloon, the only air going into it is from your lungs, so it would take several puffs to fill it with air. By holding it a few cm away and blowing into it you set up a stream of fast-moving air going into the bag. This, according to Bernoulli's principle, is at a lower pressure than the surrounding still air, so there is an area of low air pressure in the mouth of the bag. Pressure always moves from high to low, so the higher pressure still air in the room quickly moves into the bag, filling it up.



Bernoulli principle

In a tacking ship, as the wind hits the sail, filling it, it slows down. The air on the other side of the sail is moving faster, thus is at a lower air pressure. The resultant forces on the sail are perpendicular to the direction of the wind, thus enabling the ship to move against or across the direction of the wind.

KEY WORDS:
Navigation, Polaris, pole star

VIKING NAVIGATION

Vikings used to navigate using the stars and sun. When travelling long distances Vikings always navigated using latitude, ie how far north or south they were from their start or destination point. Sailors were unable to work out precise longitude until the 18th century as the time of day needs to be known very accurately. This means that they could not find their exact position but had to use experience and local knowledge of winds, tides, etc to navigate properly. The magnetic compass did not reach Europe until the 12th century.

Context: Leif got to know the waters of the Scottish Western Isles very well. He knew the currents, the effect of the tides, the direction of prevailing winds, the smell of the land, the taste of the water, the depth of the channels. When he went on longer journeys, to the Faroes, Norway or Iceland, he used the sun and stars to navigate. His navigation chest contained a sighting stick, a sun shadow board and a small sunstone.

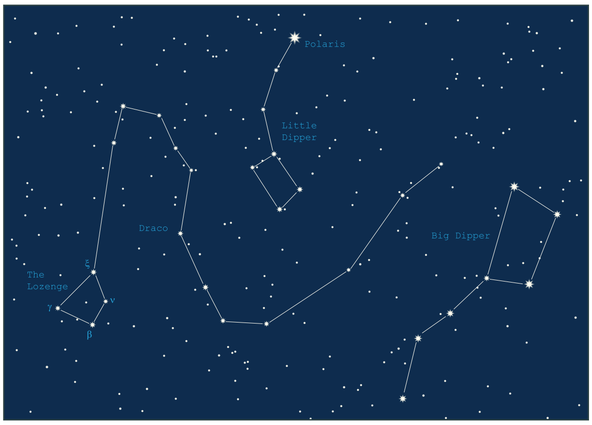
How to find Polaris, the Pole or North Star

Teachers' note: As long as the sky is clear it is very straightforward to find your latitude. To do this at night, first you need to find Polaris, the Pole Star or North Star.

What can we ask? How do we find Polaris, the Pole Star?

Equipment list: Map of the constellations in the night sky.

Activity instructions: Find the asterism known as the Plough, sometimes known as the Big Dipper. Draw a line upwards between the two stars furthest from the handle and continue on until you find Polaris, at the far end of Ursa Minor. This bright star is the Pole Star, used to find geographical north.



The Big Dipper | Shutterstock

KEY WORDS:
North, rotation, axis, star trails

Show photos of star arcs around Polaris

Teachers' note: The North Star is directly in line with the axis of the Earth's rotation. This means that it is a fixed point showing True North. All of the other stars in the sky appear to move around this point, producing star trails when photographed with a very long exposure.

What can we ask? What is a star trail?

Equipment list: Photographs of star trails or DSLR camera with a long exposure timer and a tripod.

Activity notes: On a clear night, if there is not much light pollution, set up a camera on a tripod, facing the North Star. Set a long exposure time to photograph star trails. Alternatively, show the photograph and explain, or allow the children to use the internet to find photographs of star trails.

Explanation: A pole star is a bright star that is directly overhead at one of the poles. Currently only the North Pole has a pole star, known as Polaris or the North Star. The North Star is almost directly in line with the rotation of the Earth's axis and sits at the north celestial pole. Because of this, as the Earth rotates during the night, all of the other stars appear to rotate about this fixed point. A long exposure on a camera makes star arcs because the stars appear to move around the celestial pole while the shutter is open, leaving a light trail on the CCD.

Star trails | Shutterstock

KEY WORDS:
Latitude, navigation

Use the Pole Star to navigate

Teachers' note: The elevation of the North Star can be used to navigate on a clear night by showing your current latitude compared to a fixed starting point.

What can we ask? How can you use the stars to find your way?

Equipment list: 1-m ruler, ping-pong ball or marble, graph paper, pencil

Activity instructions:

1. Work in pairs. One person, the navigator, uses a 1-m ruler as a sighting stick. The other person holds the ping-pong ball, which represents the North Star.
2. Mark the starting point in the middle of the right hand (east) edge of the graph paper. Mark the ending point (destination) on the opposite (west) side of the graph paper.
3. On the other side of the room the person with the "star" holds it up.
4. The person with the sighting stick holds it upright at arm's length.
5. Slide the stick through the hand until the top is level with the "star" when you look at it. Note the reading on the stick where it goes through the hand, next to the start mark.
6. Mark five squares along on the graph paper towards the left (west). This is the expected position, where you hope to be at the end of your day's journey.
7. The "star" is held up again. It can be higher or lower, or the same as before.
8. Take another reading with the sighting stick as before.
9. Mark your new position, where you actually are, on the graph paper. For every centimetre higher than the last reading mark your new position one small square above your expected position. For every centimetre lower than the last reading mark your new position one small square below your expected position.
10. Draw a line between your start point and your new position, and write your reading next to your new position.
11. If the new position is too high (too far north) the navigator must call "Bear south". If the new position is too low (too far south) the navigator must call "Bear north".
12. If the navigator calls "Bear south" the "star" must be held lower down for the next reading. If the navigator calls "Bear north" the "star" must be held higher up for the next reading.
13. Mark the next expected position another five squares along, level with the start position.
14. Take readings again, as before, to work out your new position.
15. Draw a line between your last position and your new position.
16. Repeat this procedure until you reach the other side of the graph paper.
17. See how close you are to your destination.

Explanation: Sailors during the Viking age used the stars to navigate at night, as long as the sky was clear enough. To journey north or south you would usually just follow the coastline in the right direction. But if your destination was to the east or west you could still navigate well just by knowing your latitude. Your latitude is your position north or south on the Earth's surface, given by your angle from the equator (0°) to the pole (90°). On a globe, these are the horizontal lines showing lines of equal latitude. You can, however, work out your latitude relative to your starting point by measuring the elevation of the North Star using a sighting stick. After you have taken your initial reading at your starting point, you can compare further readings as you journey to see if you are staying on the same latitude. If a reading is too high, ie the North Star is higher in the sky, you are too far north, and need to bear more southward as you journey. If the reading is too low, ie the North Star is lower in the sky, you are too far south and need to bear more northward as you journey. The course of your journey will, therefore, tend to zig-zag towards the east or west as you correct your bearing as you travel. It is easy to travel to a destination north-east or south-west, just by making sure you bear north or south as you journey. If, when you reach the opposite coastline, you have missed your destination, it is an easy matter to just travel north or south along the coastline until you reach your final destination.

Related activities: Try using this procedure to reach a destination further north or south from the starting point.

The North star | Shutterstock

KEY WORDS:
Sun, latitude, navigation, gnomon

Sun shadow board

Teachers' note: During Viking times sailors also used to navigate by the sun, when there were no clouds in the way. A reading could be taken at noon (not 12 pm, but when the sun is at its highest point in the sky) using a sun shadow board, which works in a very similar way to a sundial.

What can we ask? How can we use the sun to find our way?

Equipment list: Circle of polystyrene or card, short pencil or piece of dowel, bucket or bowl of water, bright torch or adjustable lamp, small ruler, graph paper

Activity instructions:

Option 1

1. Cut a circle from a piece of polystyrene or card big enough to comfortably fit in a bucket or bowl.
2. Draw a circle on the surface about halfway between the centre and the edge.
3. Fix a gnomon (pencil) in the centre.
4. Float in a bucket or bowl of water. Tip the bowl about to show how the board stays level (useful on the sea).
5. Use a torch or lamp to show the shadow of the gnomon touching the line.
6. Raise the torch to see the shadow shorten. This means you have gone too far south, because the sun is now higher in the sky.
7. Lower the torch to see the shadow lengthen. This means you have gone too far north, because the sun is now lower in the sky.

Sun shadow board

Option 2

1. Work in pairs. One person, the navigator, uses a sun shadow board, as detailed in option 1, and the ruler. The other person uses the torch to be the "sun at noon".
2. Mark the starting point in the middle of the right-hand (east) edge of the graph paper. Mark the ending point (destination) on the opposite (west) side of the graph paper.
3. The person with the "sun" shines it on the sun shadow board so that the shadow of the gnomon just touches the circle drawn on the board. This shows your starting latitude.
4. Mark five squares along on the graph paper towards the left (west). This is the expected position, where you hope to be at the end of your day's journey.
5. The "sun" is held up again. It can be higher or lower, or the same as before.
6. Measure the distance between the circle and the top of the gnomon's shadow with the ruler.
7. Mark your new position, where you actually are, on the graph paper. For every centimetre the tip of the shadow is past the circle mark your new position one small square below your expected position. For every centimetre the tip of the shadow is short of the circle mark your new position one small square above your expected position.
8. Draw a line between your start point and your new position, and write your reading next to your new position.

9. If the new position is too high (too far north) the navigator must call "Bear south". If the new position is too low (too far south) the navigator must call "Bear north".
10. If the navigator calls "Bear south" the "sun" must be held higher up for the next reading. If the navigator calls "Bear north" the "sun" must be held lower down for the next reading.
11. Mark the next expected position another five squares along, level with the start position.
12. Take readings again, as before, to work out your new position.
13. Draw a line between your last position and your new position.
14. Repeat this procedure until you reach the other side of the graph paper.
15. See how close you are to your destination.

Explanation: Sailors during the Viking age used the sun to navigate during the day, as long as the sky was clear enough. You can work out your latitude relative to your starting point by measuring the length of the shadow made by the sun at noon (when the sun is at its highest point in the sky). The sun shadow board is similar to a sundial. The gnomon casts a shadow across the circular board, which is usually floated in a bucket of water to keep it level on a ship. A circle drawn or carved into the board marks the tip of the shadow of the gnomon at the starting location. Every day, at noon, a reading is taken. If the shadow is too long, and goes past the circle, then you have drifted too far north, because the sun gets lower in the sky at noon the further north you go. If the shadow is too short, and doesn't reach the circle, then you have drifted too far south, because the sun gets higher in the sky at noon the further south you go. The course of your journey will, therefore, tend to zig-zag towards the east or west as you correct your bearing as you travel. It is easy to travel to a destination north-east or south-west, just by making sure you bear north or south as you journey. If, when you reach the opposite coastline, you have missed your destination, it is an easy matter to just travel north or south along the coastline until you reach your final destination.

Related activities: Make a sundial and use it to tell the time.

KEY WORDS:
Calcite, crystal, polarization, birefringent

Sunstone

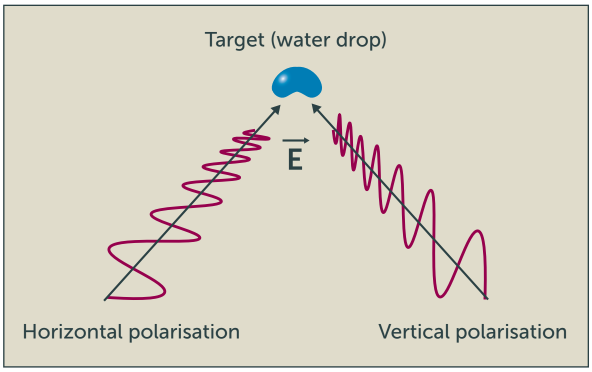
Teachers' note: Hrafns Saga mentions use of a crystal called the sunstone when the sky is overcast and the sun cannot be seen. Archaeologists and other scientists have debated whether the sunstone is real, but evidence is now starting to show that optical calcite, also known as Icelandic Spar, can be used to determine the azimuth (position on the horizon) of the sun in overcast conditions or when it is just below the horizon.

What can we ask? What happens to images when looked at through a crystal of optical calcite?

Equipment list: Optical calcite (Icelandic Spar) crystal (available on eBay), white paper, pencil, ruler

Activity instructions: Draw a straight line using a pencil and ruler. Put the calcite crystal on top of the line and look through it at the line. What do you see?

Explanation: Sunlight is polarized, which means some of the light waves in a ray of light vibrate in one direction and some light waves vibrate in a different direction.



Radar polarisation

Optical calcite ($CaCO_3$, the same chemical as chalk or limestone, but crystallised in a way that makes it transparent) is called a birefringent material. Its refractive index (how much it bends light that passes through it), depends on the polarization of the light passing through it. As this polarized light passes through the crystal some is refracted more than the rest depending on its polarization, so you see two images instead of just one when you look through it.

Birefringence of Icelandic spar | Terry Harvey-Chadwick

Sailors in Viking times could use this property in several ways to find the azimuth of the sun if it was overcast or even just below the horizon. This fix on the rough position of the sun can then be used to find north.