Catalyst

Secondary Science Review

Volume 25
Number 1
October 2014

Meadows in the sea

The value of seagrasses

SEP
Science Enhancement Programme

Catalyst

Volume 25 Number 1 October 2014

The cover image shows The cover image shows fish swimming through a Mediterranean seagrass meadow - see the article on pages 16-18 (Rich Carey/Bigstock).

Contents

Editorial team

David Sang	**Vicky Wong**	**Gary Skinner**
Physics	*Chemistry*	*Biology*
Brighton	*Didcot*	*Halifax*

Editorial contact:
01273 562139 or catalyst@sep.org.uk

Subscription information

CATALYST is published four times each academic year, in October, December, February and April. A free copy of each issue is available by request to individuals who are professionally involved in 14-19 science teaching in the UK and who are registered with the National STEM Centre. Teachers should visit www.nationalstemcentre.org.uk to find out how to register.

Individual annual subscriptions (4 issues) are available from Mindsets for £12.00. Bulk subscriptions are also available from Mindsets, ranging from £7.00 to £12.00 per subscription, depending on the number ordered.

Visit www.mindsetsonline.co.uk/catalyst for further details, or email catalyst@mindsetsonline.co.uk.

Exotic landing sites

In the last issue of CATALYST, Tom Lyons wrote about the Rosetta space mission. The Rosetta spacecraft is now in orbit around its target comet and the mission scientists are preparing to send the Philae lander down on to the comet's surface. On pages 21-22, Tom describes the decisions they must make in choosing a suitable landing site.

Can you imagine a 100 000-year-old plant? On pages 16-18, Stefania Hartley describes the biology of seagrasses. These are flowering plants that live in shallow seas. They spread rather slowly across the sea bed; DNA tests have shown that a large seagrass meadow may be a single clone. This means that every sample taken has the same DNA, implying that the meadow started from a single plant many years ago. This plant has gradually spread and, knowing the approximate rate of spreading, we can estimate its age. That is the power of vegetative reproduction.

Students: We have now created a website specially for you where you can browse hundreds of articles from past issues of CATALYST and find out how to subscribe.
www.catalyststudent.org.uk

Published by the Gatsby Science Enhancement Programme
Gatsby Technical Education Projects
The Peak
5 Wilton Road
London SW1V 1AP

ISSN 0958-3629 (print)
ISSN 2047-7430 (electronic)
Design and Artwork: Pluma Design

The Catalyst archive

Over 300 articles from past issues of CATALYST are freely available in pdf format from the National STEM Centre (www.nationalstemcentre.org.uk/catalyst).

Ella Goodall

Palaeontology goes hi-tech

A cast skeleton of Gorgosaurus *on display at the Manchester Museum (University of Manchester). It is remarkably complete, with over 80% of the original bones preserved. This is a cast of the original bones, held at the Indianapolis Children's Museum (USA).*

Key words

electromagnetic radiation

fossil

dinosaur

palaeontology

Meet *Gorgosaurus*, a close cousin of *Tyrannosaurus rex*. She, alongside many of her prehistoric friends, is now the subject of the application of 21st century science.

Palaeontology strives to discover evidence so that we might learn more about the fossil remains of life and understand how they lived, functioned and even died. Scientists at The University of Manchester have been using state-of-the-art imaging, chemical analyses and computer modelling techniques to study the remarkable fossils that litter Earth's history.

The electromagnetic spectrum has become the key to unlocking the dilute traces of evidence that are changing the way we view dinosaurs and the fossil remains of all life. From visible light to infrared and from X-rays to gamma, the evolution of life on Earth is a mere wavelength away!

Visible light

This is the most familiar part of the electromagnetic spectrum that almost all life on Earth can detect and it is visible light that begins the interrogation of any fossil.

Using visible light alone, the surface geometry and features that define the morphology of *Gorgosaurus* can be described, photographed and resolved. We can see how complete and well preserved the remains of this animal are. In this case over 80% of the original bones were found when it came out of the Two Medicine Formation (a late Cretaceous geological slice of time) in Montana, USA.

Figure 1 *Two of the pathologies of the* Gorgosaurus *currently on display at the Manchester Museum. The left scapula has abnormal bone growth shown by difference in size, texture and morphology to the surrounding bone. Evidence of infection can also be seen on the lower jaw, caused by bacterial infection.*

Part of what makes this fossil so interesting is the many injuries that she sustained when she lived over 72 million years ago. Figure 1 shows that some of these healed, showing that she survived the massive trauma that caused them. The catalogue of injury and disease would floor many living species, including us. A key muscle attachment site at the top of her femur (thigh bone) tore away. Her fibula juts painfully at a right angle to her leg, a result of a compound fracture where the broken bone literally pierced the skin envelope. Along with many broken ribs, fused tail-vertebrae (back bones) and bacterial infections that ate away at her lower jaw, she also had an abnormal growth on her left scapula (shoulder blade). All these pathologies can be seen by simply looking at the bones and evaluating the differences in shape, texture and size using visible light.

X-rays

Synchrotron-based X-ray fluorescence mapping can be used to image the chemical make-up of fossils. This can highlight specific elements in very small quantities that are crucial in living animals for bone healing and growth. Figure 2 shows an image produced using Synchrotron Rapid Scanning X-ray Fluorescence (SRS-XRF). This can show the distribution of elements and their coordination chemistry within the bone, helping us to decide if they were organic or inorganic in origin.

Was it there to begin with?

Endogenous chemical components are useful as they reflect the animal. However exogenous chemical components may also be present. SRF-XRF and XANES spectroscopy can be used to determine whether the chemical composition of the fossil is a fair reflection of the chemical composition of the animal that produced it.

Pathologies

We know that the broken bones were not the result of the fossilisation process or someone dropping the skeleton; they happened when she was alive. We know this because, like humans, this dinosaur's body started to heal itself by growing more bone or compensating for an injury by limping. We can see this on the scapula (Figure 1) where there is a difference between left and right in shape, surface texture and amount of bone growth.

Bone does not form scar tissue, like a skin injury. Instead, the body has to completely reform new bone in the same way that the skeleton grew in the first place. By detecting astoundingly dilute traces of certain chemicals, we can discover how the damaged bone healed. This means we can discover how dinosaur bone developed.

Of course, the chemical composition of a fossil may change as it lies in the ground. It is a fine line when deciding what was the original chemistry of *Gorgosaurus*. Scientists at Manchester were able to make such judgments through the precise measurements that can be made at facilities such as the Diamond Synchrotron Light source in the UK and the Stanford Synchrotron Light source in the USA. Previously, bone-healing was studied using thin sections of bone, viewed under a microscope. Newer techniques provide more information and are less damaging to the fossils.

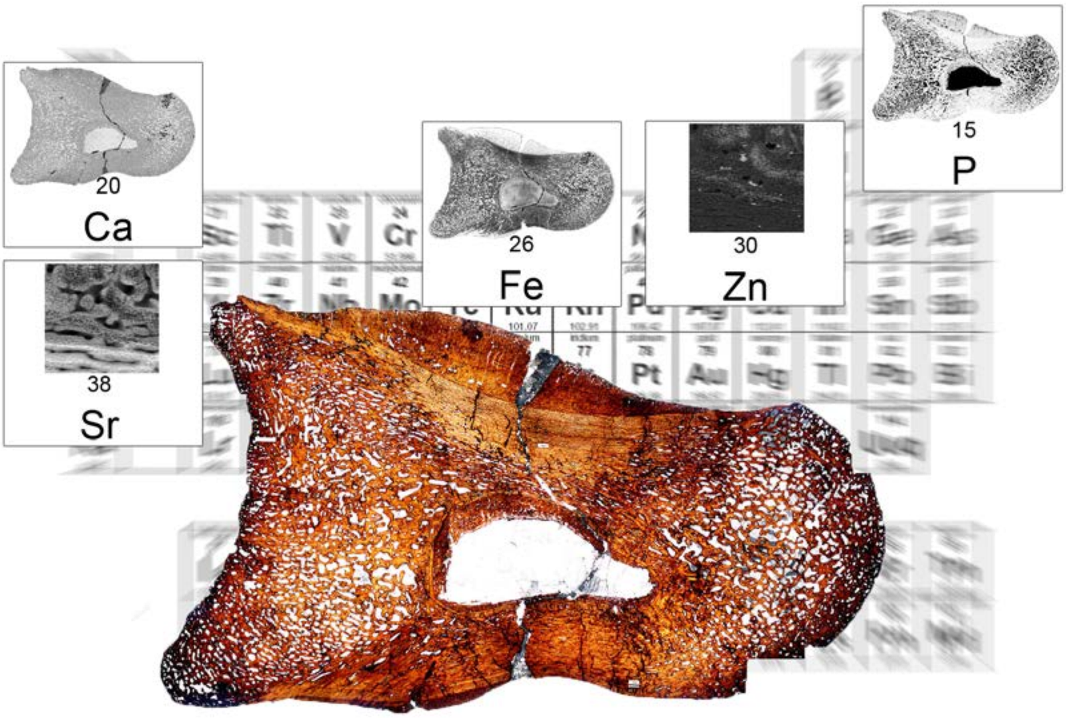


Figure 2 A thin section of a toe bone from Allosaurus fragilis*, approximately 6 cm long. This shows the variation in texture and elemental concentration of trace metals in normal bone and that which has formed a callus as a result of injury.*

Looking at pigments

SRS-XRF can also be used to determine the presence of specific biomarkers that represent pigments, such as melanin, in extinct animals. Melanin pigments can reflect differences in diet, sex and even the age of animals, both living today and in the past. Colour is also important in the behaviour of animals, for example in communication and protection in their environment by camouflage. Therefore to understand as much as possible about the fossilised remains of an animal, it is important to establish what they looked like.

Prof. Phil Manning, Uni. of Manch.

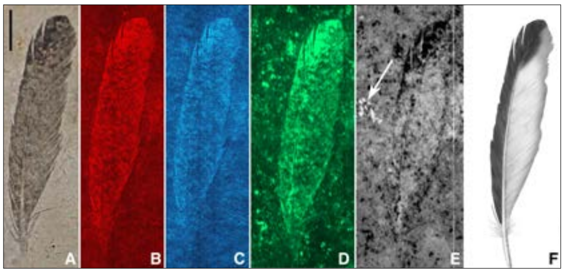


Figure 3 *A feather from* Archaeopteryx lithographica, *photographed in (A) visible light, together with SRS-XRF false colour images of concentration variations of trace metals and compounds, where the brightness indicates higher concentration: (B) copper, (C) nickel, (D) organic sulphur, (E) sulphate only and (F) an artist's restoration. The scale bar is 1cm (from Manning et al, 2013).*

Figure 3 shows the feather of *Archaeopteryx*. Visible light cannot show the presence or absence of pigment. However, SRS-XRF and Sulphur X-ray Absorption Near Edge Structure (XANES) spectroscopy have now been combined to show up both pigments and patterns in such feathers. It is remarkable that some of the original chemical composition of the feather tissues remains after 150 million years and can provide information on the type and position of pigments preserved in these Jurassic Age feathers. These techniques showed that the tip of at least some of the feathers from this early bird and also the outer edge were darker compared to the lighter, inner part.

It has been shown in earlier studies that pigments strengthen feathers, suggesting an early adaptation arose in *Archaeopteryx* that made its more exposed feathers less susceptible to wear through being pigmented. This is because the pigments act as a natural biocide, so that feathers survive better during their lifetime and long into deep time.

Infrared radiation

Broadly speaking there are two types of fossil: body fossils and trace fossils. Body fossils include the bones and shells of once living organisms. Trace fossils (such as footprints) record the behaviour of such creatures and are far less common than body fossils due to the unique settings they are created and preserved in. So how is it that we can understand the behaviour of animals that we cannot observe today?

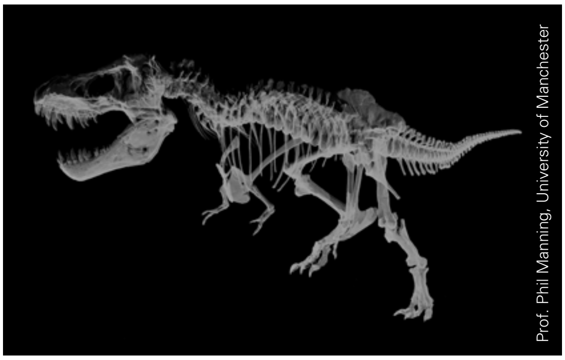


Figure 4 *A high resolution digital map of the skeleton of* T. rex, *made by scanning a mounted skeleton using a near-infrared laser scanner.*

A skeletal model, Figure 4, was produced from a laser scan of a mounted skeleton of *Tyrannosaurus rex*. Using data from living animals' muscle characteristics, a simulation was created that shows how this and other dinosaurs, including 40 m long giant sauropods, may have walked. This is a feat not possible without the use of computer simulations. Infrared provides the necessary imaging potential.

SRF-XRF

SRS-XRF is a technique that can produce a 2-D image of a scanned object. The image is a 'map' that shows the elemental composition of the object, in this case a fossil bird. Variations in elemental composition are highlighted and false-colour images can be produced showing these.

The potential for SRS-XRF is only beginning to be realised and is not limited to extinct animals but can be applied in archaeology, biology, forensics, etc. It is possible to chemically resolve lost words in ancient manuscripts that are invisible in visible light.

So which is best?

It is a multi-disciplinary approach that leads to the most conclusive and useful answers. By this I mean using several different technologies and directing them at one common aim. We can determine many things from the skeleton of a dinosaur, from its colouring to how it may have walked. The electromagnetic spectrum has more uses than ever and is greatly contributing to hi-tech palaeontology. See if you are able to spot the pathologies this *Gorgosaurus* has at the Manchester Museum, where she is now on display!

Ella Goodall is studying Geography and Geology at the University of Manchester and hopes to continue in her studies specialising in Palaeontology and museum preparation work of fossils.

Look here!

Find out more about the work of the Interdisciplinary Centre for Ancient Life at the University of Manchester: *www.ical.manchester.ac.uk*

Two previous Catalyst articles about the Diamond Light source:
www.catalyststudent.org.uk/cs/article/199
www.catalyststudent.org.uk/cs/article/267

A life in science

Stephanie Kwolek *Polymer chemist*

Stephanie Kwolek

Have you seen the nylon rope trick? It's a common school demonstration showing how a nylon fibre can be made from two liquids. But what is the connection with the bullet proof vests used by the United Nations peacekeeping forces?

The answer is that the same woman, Stephanie Kwolek, developed both the nylon demonstration and the material Kevlar which is the key lightweight polymer used in bullet proof vests. Born in the United States to parents who were Polish immigrants, she studied chemistry at university and hoped to become a doctor. In order to fund her studies she took a temporary job as a research chemist and enjoyed it so much that she stayed and never did study medicine.

A polymer is a long molecule made of lots of smaller molecules, called monomers, joined together.

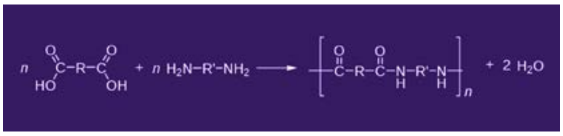
Stephanie Kwolek worked for the chemical company DuPont. DuPont were responsible for the invention of many different polymers during the twentieth century. These included neoprene used in wetsuits, Teflon used as a non-stick coating for saucepans, and Lycra used to make clothes stretchy and fit better. They also discovered and manufactured nylon, one of the first widely available polymers used in clothing.

Polymer names: Kevlar, Teflon and Lycra are trade names of polymers so are written with a capital letter.

A bullet proof vest, part of a United Nations peacekeeper's body armour

Making nylon

Nylon is a co-polymer, a polymer made from two different monomers joined together. As the monomers join, a small molecule is formed along with the polymer. This can sometimes be water so these are called condensation polymers.



This equation shows the formation of nylon. The n represents any number of the molecules; R represents a chain of carbon and hydrogen atoms joined together.

The first molecule has a carboxylic acid group, COOH, at each end and second has an amine group, NH_2, at each end. They react with each other producing a polymer which has the monomers in an ABABAB pattern.

The nylon rope trick

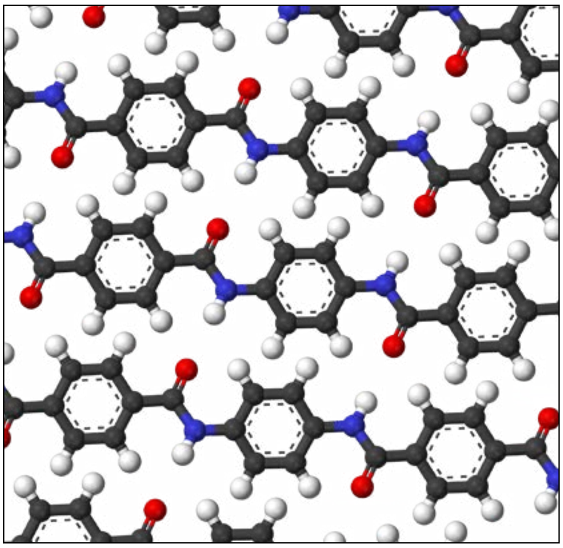
In the 1950s Stephanie Kwolek developed a method for demonstrating the production of nylon in the classroom which is still used today. The two monomers needed to make nylon are dissolved in two solvents which do not mix. The solutions are poured into a beaker where one floats on the other. You can see the two separate layers in the photo. They react at the interface where they meet, forming a film of nylon. This can be pulled upwards to form a fibre.

The nylon rope trick is used to demonstrate making nylon in the classroom

How Kevlar was found

In the 1960s, Stephanie Kwolek was working to produce an alternative material for making tyres. She was working with polymers and had produced a thin, cloudy solution which didn't look very promising. Usually it would be thrown away but Kwolek persuaded the technician who ran the 'spinneret', which tested if a polymer could be spun, to put her uninteresting solution through the machine. She and the other scientists were amazed to find that not only could it be spun, it didn't break. Further investigation showed that when it was spun, the polymer molecules all lined up in the same direction, making it incredibly strong. The new polymer was named 'Kevlar.'

Kevlar fibres – each fibre is about 10 micrometres thick.



When Kevlar is spun, the polymer chains line up. This gives the material its strength.

When interviewed in 2007 about her discovery, Stephanie Kwolek said, "The company management didn't fool around. They immediately assigned a whole group to work on different aspects ... It was very exciting, let me tell you."

Kevlar at work

Kevlar is very light and very strong. It is used for a wide range of applications including sporting equipment – canoes, sails, bicycle tyres, tennis rackets, sporting shoes. It is used for drum heads, ropes and brake discs. The most famous use for Kevlar, though, is in bullet proof vests.

Most police forces and military personnel now have body armour made of Kevlar as it is light and strong. There are thousands of people alive today because of the protection they got from Stephanie Kwolek's invention.

Stephanie Kwolek shows off work gloves with Kevlar pads.

Stephanie Kwolek died in June 2014, aged 90. The day before she died, DuPont announced that a million bullet-proof vests have been sold using the latest version of Kevlar.

In an interview a few years before she died, Kwolek was pleased with what she had achieved. She said: "At least I hope I'm saving lives. There are very few people in their careers that have the opportunity to do something to benefit mankind."

Vicky Wong is Chemistry editor of Catalyst.

Kevlar is used for sports equipment such as canoes

Vicky Wong

Chemistry and paint

Girl with a Pearl Earring by Vermeer

Like many other people, I thoroughly enjoyed Tracy Chevalier's book *Girl with a Pearl Earring*, later made into a film. It is an imagining of the story behind a seventeenth century painting by Johannes Vermeer. What fascinated me the most was the description of the artist and his assistants making the paint that he would use. I had never given much thought to what artists used in the days prior to paint being available in little tubes, but there is a lot of chemistry involved in paint-making, which dates back many millennia.

Key words

pigment

colour

transition metals

The oldest paintings in the Altamira cave in northern Spain are 35 600 years old, according to radioisotope dating. Early artists used easily available natural substances to make paint, such as iron oxides from the earth – whose colour they changed with fire, charcoal, berry juice, lard, blood, and plant sap.

Painting of a bison in the cave of Altamira, near Santander, Spain

This Egyptian painting, from 1360 BCE, shows the limited range of pigments available at the time.

It was the ancient Egyptians who really developed the use of what we know as paint and it was used for pictures on papyrus, on buildings and in tombs; some of their paintings have survived to this day and can be seen in museums including the British Museum.

What makes paint?

Paint consists of the pigment, which gives it colour, and a binder, which in ancient times was a resin or sap, which surrounds the pigment and holds it in place. These binders were often very thick so a thinner was added to make the paint spreadable.

The Egyptians developed earthy colours such as yellow, orange and red from pigments in the soil. The Romans developed purple, which they made from snails. Thousands of tiny snails had to be found, removed from their shells and left to soak before a liquid was extracted from one of their glands. Placed in sunlight, this changed through a series of colours to produce purple. The process could be stopped at different times to get a range of colours from bright crimson to dark purple.

Cochineal, which was widely used to produce both red and pink colours, was made from the cochineal beetle which was crushed to extract carmic acid. This was mixed with calcium or aluminium salts to produce cochineal or carmine. As the chemical industry developed synthetic pigments, the use of cochineal declined, but has increased again recently as consumers choose natural colours. Cochineal made from beetles is found in some foods and cosmetics.

Other natural pigments included yellow from concentrated cow's urine, green from blackthorn berries and sepia brown from dried squid ink.

Chemical pigments

Alongside the pigments from plants and animals, purely chemical ones were being developed and used by artists. The red colour vermillion comes from mercury sulfide. This compound can be found in nature, but gives a better colour if it is made directly from its elements. This process may have been developed in ancient China, but was certainly used from Roman times. Some artists bought the pigment from alchemists (the early chemists) or apothecaries (the early pharmacists) but others may have made their own. A handbook of art from the twelfth century includes instructions for making it.

To make the paint, the artist or assistants ground up the pigments and mixed them with the binders and thinners. As many of the pigments were very expensive this was a responsible job.

Making paint the traditional way – linseed oil is mixed with ground dried clay earth pigment. The paint takes about 2 days to dry.

From about the 1800s pigments began to be manufactured in larger quantities, making them cheaper and more widely available. One of the earliest pigments to be produced in a factory was lead white. Due to the lead content this was toxic, however, and made many of the factory workers ill. Zinc oxide was found to be a suitable alternative.

Extracting zinc was an important business in the early 1800s and by investigating some of the by-product of the smelting a new element was discovered, cadmium. Cadmium sulfide can give bright pigments in a range of reds, oranges and yellows. Cadmium red is still widely used today although it is toxic. In the nineteenth century a wide range of new pigments were discovered through the use of chemistry – bright greens from arsenic, many colours from chromium, and beautiful blues and purple from cobalt.

Many of these colours are based on the transition elements, those metals in the central block of the periodic table. Many of them can be used to produce a range of colours as they can have many different arrangements of electrons in their outer shells giving rise to different colours.

This new palette of colours meant that artists could paint in shades that previously weren't possible. The work of the impressionists in France was only possible because of the much larger range of pigments which were available.

Colours have changed with time: A Sunday Afternoon on the Island of La Grande Jatte by Georges Seurat.

Off-the-shelf

The use of new pigments was not without problems, however. Georges Seurat in creating his painting A Sunday Afternoon on the Island of La Grande Jatte used the new pigment zinc yellow, zinc chromate ($ZnCrO_4$), to create yellow highlights on the lawn and in mixtures with orange and blue pigments. This pigment darkened to brown, reducing the effect that the painter had in mind. This degradation of colour was not known about as the pigment was so new, but began even in the artist's lifetime. This shows one of the difficulties which can arise with the development of new pigments and materials – knowing how stable they will be over time. In spite of this, most paint continues to be made with synthetic pigments and blended in a factory.

Today, artists buy their paint ready-mixed and very few would even dream of making their own, but whether they realise it or not, painting is all about chemistry.

Vicky Wong is Chemistry editor of Catalyst.

Look here!

For a more detailed article about the relationship between chemistry and paint: *tinyurl.com/mk7qo4b*

Will Cottrell

Brighton goes solar

Key words
solar power
photovoltaic
alternating current
renewable energy

Brighton Energy Co-op recently installed Brighton's second-largest solar system on the roof of Shed 3a at Shoreham Port. Since May 2013, 800 panels have covered the two sides of this 3000 m^2 roof: half face east, the other half west.

The building itself is fairly simple: an industrial shed used by Shoreham Port to store imported timber. Yet compared to a typical domestic installation Shed 3a is huge, the equivalent of more than 100 average solar homes (typically 2 kW). This brings its own challenges.

The system is composed of 816 panels of 245 watts each, a total of 200 kilowatts. More than 5 km of cables connect the panels into the grid, and six inverters control the electrical flow.

Shoreham Port is a busy commercial harbour on the south coast of England, importing and exporting construction materials, timber and scrap metal.

Linking solar panels

Light from the Sun provides the energy needed to free electrons in the material of the photovoltaic panels. Once electrons start to flow in one of the panels, this current is combined with that of 20 other panels, and combined into a string. These strings then feed the electricity off the shed.

Solar electricity is direct current, DC, so it needs to be converted to the alternating current, AC, that we use every day. This is done via six inverters that are bolted to the side of the building at ground level.

The inverters direct the electricity to a distribution board which controls whether electricity is needed on site – mainly charging fork-lift trucks – or sent out into the national grid. A generation meter is also attached to this board to register the amount of electricity passing through it. Each night this meter texts data to our website so we can read daily output figures remotely.

If there's no usage in the shed then the distribution board sends the power through a 85 mm copper cable. This cable was a major sticking point: copper is expensive and the cable is 100 m long. Altogether it weighs just under 2 tonnes. Finding points to connect to the national grid can be a pricey business; if the connection point is a long way from the rooftop then not only do you have to buy the copper but you may also have to dig a trench to get it there, which is labour-intensive.

Metering the power

The last destination from our point of view is the electricity socket that plugs into the grid network – a metering point known as an MPAN. Every house and building with electric power in the UK has an MPAN where the electricity is metered as it enters; the network of MPANs around the country is the final destination for all the electricity producers. For renewable generation, however, we reverse the process and send electricity into MPANs.

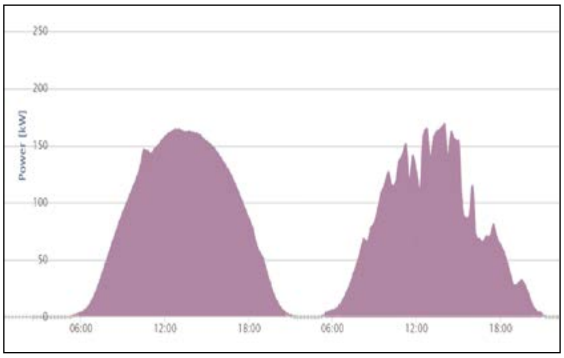
In Brighton, the local grid is run by a company called UK Power Networks. Before we could connect to the MPAN, they ran extensive tests to determine suitability before finally connecting our kit to their wider network. A second meter (an export meter) at the MPAN monitors the flow of electricity into the grid.

Daily output

Output varies with the weather. As the sun rises, voltage in the east-facing panels starts to increase, while the west-facing panels remain dormant until an hour or so later. The situation is reversed during sunset.

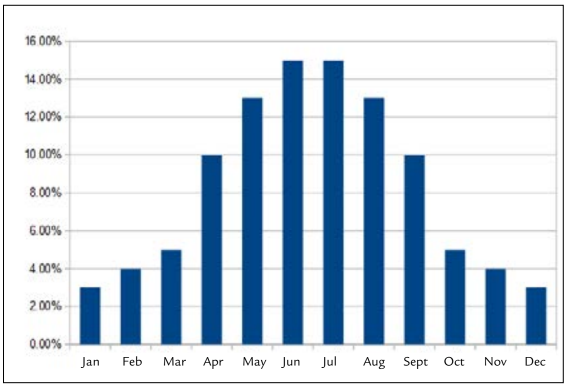
If it's a completely sunny day then output looks like a graceful bell curve: as the Sun approaches the horizon in the morning the output begin as to climb. As the sunlight strengthens output then climbs to a maximum around midday. For several hours output stays high as the sun passes through its zenith, then it drops rapidly, before gliding to zero as darkness covers the sky.

Other factors affect daily output. It dips significantly if a cloud goes across the sun, then picks up rapidly as the sun comes out. This makes output graphs look jagged and the passage of clouds across the sun can be clearly tracked by dips in the graph.



Electrical output from the solar panels varies through the day. (left) a sunny, cloudless day; (right) a day with intermittent cloud.

At peak times (midday) in July we can expect 160 kW output, some useful power. In winter, February produces barely 4% of annual output, with only around 30 kW around midday, barely anything at all.



We can expect the panels to produce 5 times as much power in June and July as in December and January.

Since weather varies from year to year it's difficult to predict exactly how much will be generated by the system over the course of one year. However, using weather data from the last 20 year we expect that the system will generate an average of 200 000 kWh a year.

The cost of solar

To pay for all this we raised £186 000 from the local community. Roughly half of that pays for the panels, the other half pays for inverters, cables, framing systems, labour, system design, transport and associated paperwork.

To raise the money we sold shares in our co-operative. We held various events, did public talks and lots of Facebook and Twitter work. Over a 6-month period more than 200 people joined Brighton Energy Co-op by buying shares. Some bought a few hundred pounds' worth, others £20 000, the maximum allowed for a co-op. Our members now range from students to retirees, some are professionals, some are just renewable energy enthusiasts. Our most distant member is a vicar in Northern Ireland. Members only have one vote irrespective of how much money they've invested.

As a co-operative we have the great advantage of being able to sell shares without government scrutiny. Regular companies must have a licence that can cost up to £50 000. Co-ops are exempt from this, so it's our organisational form that allows us to raise money in this way.

We are not a charity, however, and our members expect that they'll get their money back at some point in the future, plus interest. To pay for this, BEC earns money in three ways:

- Feed-In Tariffs, a government subsidy that pays renewable energy operators for each unit of electricity they generate.
- Selling electricity to our utility company Good Energy, who then supply home-owners and industry.
- Selling electricity to Shoreham Port, the owner of Shed 3a.

After covering our costs, we aim to pay 5% of a member's capital back each year, as well as 5% interest. This means they'll be completely reimbursed after 20 years – the lifetime of the FIT revenue stream. (The system itself will then be donated to Shoreham Port, and may continue long into the future.)

Will Cottrell on the roof of Shed 3a with Energy Minister Greg Barker and local MP Mike Weatherley.

Photovoltaic panels arrive at the site

Panels are lifted to the roof

Brighton Energy Co-op has installed 200 kW of solar panels on the roof of a storage shed at Shoreham Port in Sussex, UK.

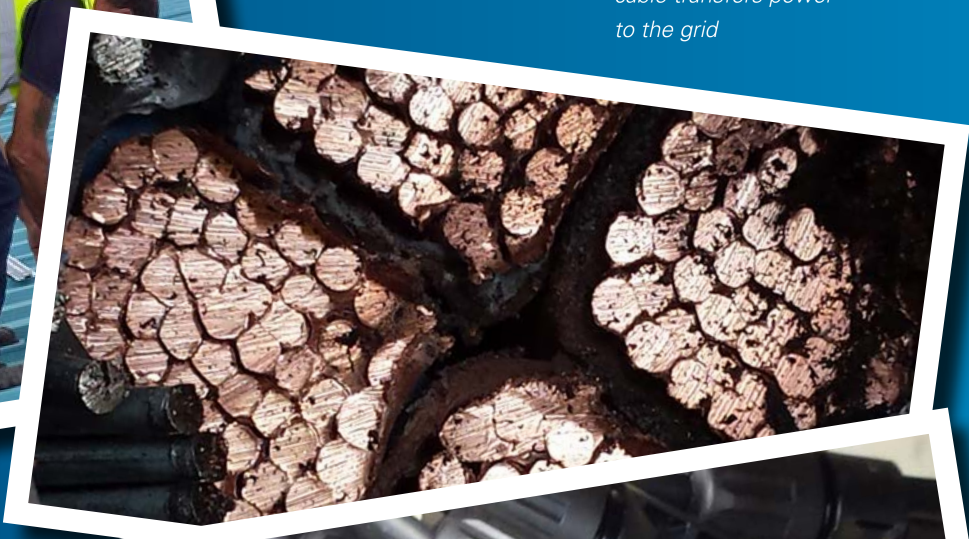
Panels cover most of the shed roof

Catalyst

www.catalyststudent.org.uk

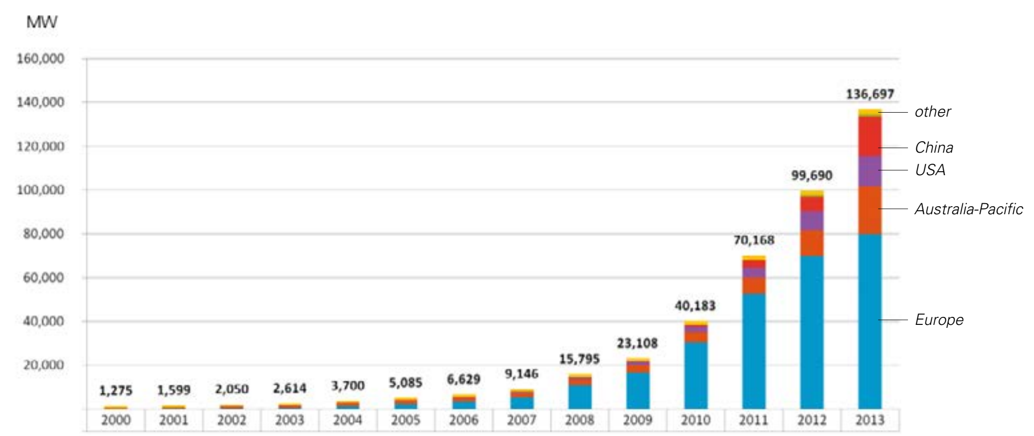
Preparing the roof fixings

An 85 mm copper cable transfers power to the grid



Connectors bring power from the panels

Inverters convert power from DC to AC



The installed capacity of solar power stations is increasing rapidly around the world. Source: EPIA

Why can this be done today but not ten years ago?

The UK solar marketplace was revolutionised four years ago by the introduction of Feed-In Tariffs (FITs). Previously, renewable projects were a very specialist subject. The technology was expensive and consequently so was the electricity they generated. So it remained the preserve of a few enthusiasts. FITs have revolutionised renewable energy because people can now make money from solar.

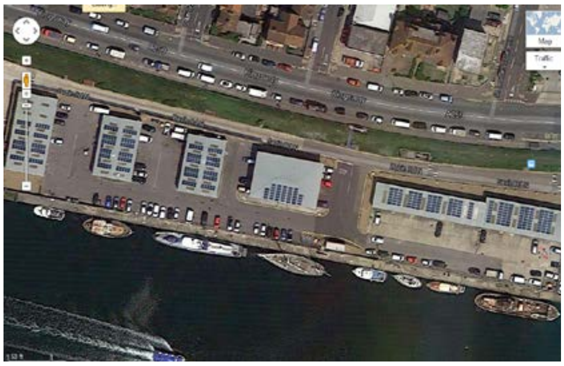
FITs are a subsidy that will disappear. As more projects get off the ground, so prices fall because there's more demand. The price of UK solar, for example, has fallen 70% in the last four years. Eventually the idea is that the technology becomes so cheap that no FIT subsidy is required.

Looking ahead

Brighton Energy Co-op will continue to develop new solar projects. We've several megawatts of new rooftop solar in development, and plenty of appetite from our community to invest in our schemes. We've also got some other new technologies under consideration, particularly anaerobic digestion.

In terms of the wider energy picture it's only going one way. The price of fossil-fuelled electricity will continue to rise as the costs of extraction go up because we've already drilled all the easy oil and gas. Meanwhile the price of renewables will continue to come down as the huge roll-out going on all over the world continues to reduce prices. Renewable energy is already big and it's going to be much bigger – and it's exciting to be in the centre of it.

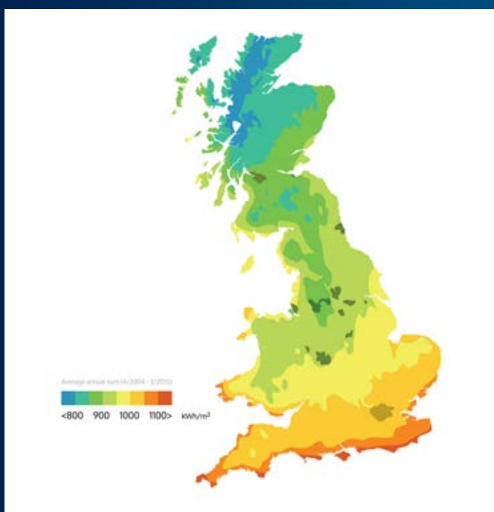
Will Cottrell is chairman and founder of Brighton Energy Co-op. www.brightonenergy.org.uk



Solar panels on the rooves of Hove Enterprise Centre, another Brighton Energy Co-op project.

UK Solar – where next?

The map shows how the available solar energy varies across the UK. Latitude and cloud cover are both important, so the south of England receives about 50% more energy per square metre than the north of Scotland. A 'solar farm' must cover a large area if it is to provide significant amounts of electricity.



Average annual energy per square metre of solar panel varies across the UK.

The map shows that Cornwall is one of the best counties for investing in solar power. Because the Wheal Jane solar farm is located on the site of an old tin mine, it does not use up valuable agricultural land.

David Carey

Gabriella Fabbri

The one-footed ape

Can we train elite football players to use both their feet?

We think we know a great deal about footedness in football. However, careful observations of what players do on the pitch reveals that our elite football heroes are much more one-footed than we think. ***David Carey*** *of Bangor University explains.*

Our sports pages are full of stories about football. Every year, one or two stories emerge which either bemoan the lack of 'two-footers' in the British game, or praise the incredible prowess of the left-footed player in a particular season. One of the best football players in the world right now is left-footer Lionel Messi of Barcelona. On the other hand, claims suggest that Cristiano Ronaldo can use both feet and is considered by some to be a better player than Messi.

The left-footed Lionel Messi

Key words

footedness

handedness

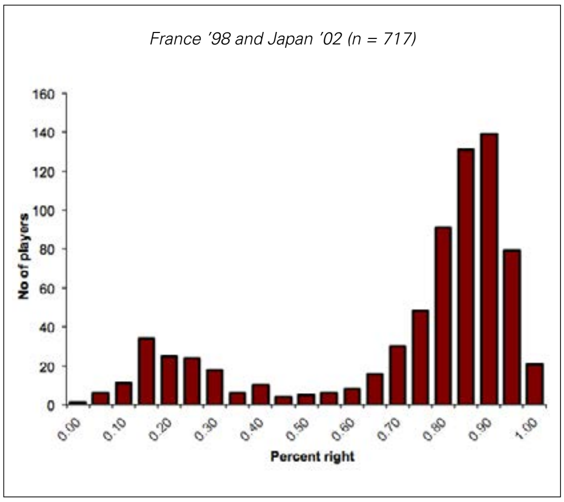
brain asymmetry

sport physiology

The two-footed Cristiano Ronaldo

In fact, we know remarkably little about how to make players more two-footed. Arguably, even the best coaching techniques in the world to date, are not particularly successful at doing so. We know this because research has shown that even the most elite players, as a group, are about as one-footed as the rest of us. Analysis of several matches from the World Cup in 1998 revealed that approximately 80-85% of 236 players use their right foot considerably more than their left, while the remaining players use their left foot considerably more than their right. What was amazing was the remarkable absence of two-footed players, even in this sample of some of the best trained and practised athletes in the world. Since that time, many more professional players have been analysed, and the story has not changed in the slightest.

The graph (Figure 1) shows the number of individual players against the degree of right footedness (measured by how often each individual player uses his left or right foot). This is what scientists call a bimodal distribution (it has two modes, one around 85% right footed and the other around 15% right footed).



The number of players as a function of how right-footed they were in terms of use. Very right-sided players are to the right of the graph; very left-sided players to the left.

The astute amongst you may realise that '15% right-footed' players are, of course, 85% left-footed players. You will also notice that the data are perfectly consistent with observations made by every football fan and pundit: left-footed players are rare, as are two-footed players, see the middle part of the graph.

Footballers and the rest of us

The proportions of left- and right-footers are surprisingly similar to those found in the general population. In this latter case, footedness is usually defined by responses to questionnaire items like "Which foot would you use to kick a ball?" or "Which foot do you lead with on a skateboard or a surfboard?" Taken together, these data suggest that all the efforts of players, coaches, academies and trainers to produce more two-footed players have not been particularly successful. Foot preference of this sort is probably something that people are born with.

That fact alone is surprising enough. Human beings are bipedal – unlike many other species, ***Homo sapiens*** gets around on two legs. From a motor control perspective, asymmetries in strength or coordination between our two legs would be unlikely – we need to make many fine postural and muscular adjustments with our feet and legs thousands of times each day. Therefore preferring one leg over the other for tasks like kicking, dribbling and tackling in the first place is rather peculiar.

One hypothesis to explain a foot bias is that, with practice and experience, tasks that have to be performed asymmetrically (like kicking a ball) are in some sense like handwriting or throwing – once a side is chosen, by using it repeatedly it becomes skilled and practiced. If that is the case, why aren't roughly 50% of all people right-footed and the remaining 50% left-footed? The asymmetry in the asymmetry (so to speak) is the real puzzle that scientists need to work out.

Our asymmetric brains

Some scientists believe that the most plausible explanation is that foot preference is related to brain asymmetry in the control of movement. The left cerebral hemisphere is very important for speech and language in most people, although it is moderated by handedness (and by implication here, footedness). In anyone, in spite of their particular hand or foot preference, each side of the body is largely controlled by the 'contralateral' hemisphere (the hemisphere on the opposite side of the limb). The idea here is that if one half of the brain, say the left, is good at controlling speech muscles, it will end up driving the right side of the body for more skilled actions, like kicking, throwing and writing.

Of course, this theory isn't perfect: some of us are 'crossed' in terms of our hand and foot preference (this must be the case, as roughly 90% of people are right handed while about 80% are right footed), so in some people either hand or foot, but not both, will be largely controlled by the side of the brain dominant for the control of speech.

A final suggestion that handedness and footedness are biologically predestined is related to a sex difference: men are more likely to be left-handed than women. A popular non-biological explanation for this phenomenon is that women are more receptive to 'anti-sinistral bias'; that is, parents and teachers may actively discourage youngsters from writing with their left hands, something that used to be quite common.

An experiment comes to mind here: are there similar biases against being left-footed? Probably not – if anything, these asymmetries are relatively unnoticed by most people or, if your mother or father is football daft, then the contrary may be true (left-footed players are rare, isn't it fantastic that you are left-footed!). On-going research at the universities of Bangor in Wales and Bergen in Norway suggests that fewer elite women players are left footed than their male counterparts. If this difference holds up, it really questions the idea that the hand difference between men and women is accounted for by anti-left sided bias – as you get the same differences where there isn't one.

Clearly much research remains to be done on how footedness relates to brain asymmetry – some of these experiments can be done in the lab. The tougher studies will need to look at players in the field, to help establish whether or not coaching and practice can make much of a difference to how often a player uses one foot or the other.

England Women's captain Casey Stoney is right-footed, while Brazil Women's captain Marta Vieira da Silva is left-footed.

Dr David Carey is reader in psychology at Bangor University, North Wales

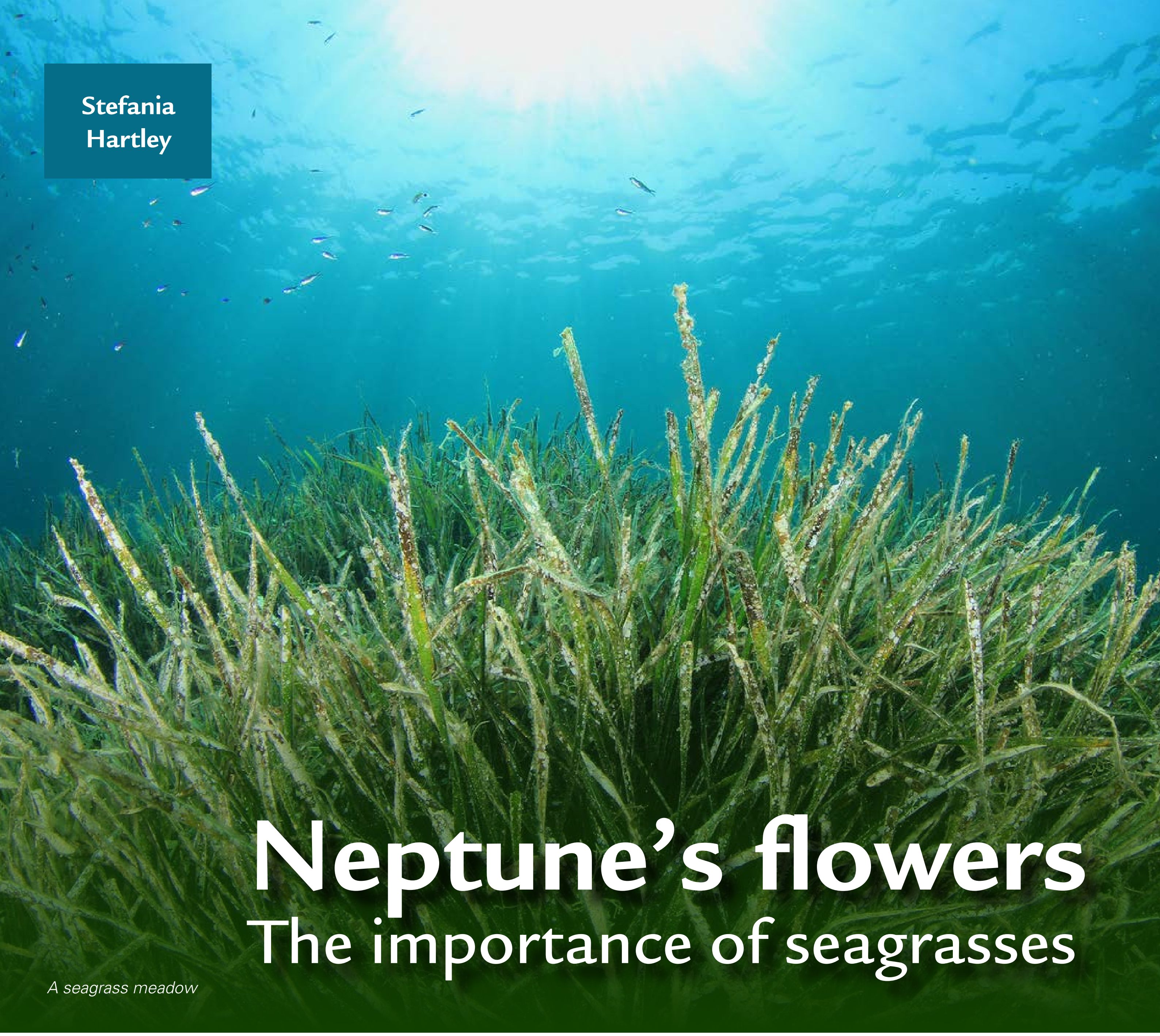
Look here!

David Carey and colleagues analysed footedness of players at the 1998 World Cup in France: *http://bit.ly/1umvFfD*

Find out how handedness and footedness compare:

http://www.footballtechnicallab.com/the-myth-of-the-two-footed-footballer-part-1/

Stefania Hartley



Neptune's flowers
The importance of seagrasses

A seagrass meadow

Key words
flowering plants
marine biology
seagrasses

Neptune, the Roman god of the sea, was not short of flowers for his valentines. I am not referring to the sea anemones that Disney's Little Mermaid uses to decorate her hair. I mean real flowers from flowering plants – angiosperms. Yes, there are angiosperms in the sea.

Still, these angiosperms do not do well in bouquets. No large and colourful petals, no beautiful scents. The flowers of marine angiosperms are water-pollinated and, much like terrestrial wind-pollinated plants, are not great at showing off.

Seagrasses

It is the simple look of these flowers, together with the narrow leaves, that has gained marine angiosperms the name of seagrasses, even though they are more closely related to lilies and gingers than to grasses.

Glossary

angiosperms: flowering plants

anoxic: free of oxygen

climax community: the final stage of an ecological succession

epiphytic: a plant growing on another plant without parasitizing it

eutrophic: describes a body of water excessively rich in nutrients and vegetation, whose decomposition causes oxygen depletion and death of aquatic animals

pericarp: the part of a fruit which has developed from the ovary wall

The flower and fruits of a seagrass (Posidonia oceanica)

The photos show the leaves and flower of a typical seagrass, one of 50-60 species of marine flowering plants. They descend from terrestrial flowering plants (Angiospermae) which colonised the sea during the Cretacean, around 120 million years ago. Their adaptations to sea life include:

- The leaves have a narrow blade shape to withstand the mechanical action of waves and currents.
- There are no stomata; instead a thin cuticle allows ions and CO_2 to be absorbed through the leaves.
- The flowers are water-pollinated.
- A system of air spaces allows internal gas flow (to allow oxygen to reach the roots and rhizomes which are buried in the anoxic sediment, and to remove carbon dioxide).

Relying on photosynthesis, seagrasses are confined to waters where light can penetrate. They form large meadows on muddy and sandy bottoms in shallow, coastal waters. These meadows are among the most productive ecosystems on the planet, with an average net production of about 400 g of carbon per square metre per year. Few marine animals graze on seagrass leaves, so the majority of the carbon fixed is locked in the sediment, making up 10-15% of the total marine carbon storage.

The value of seagrass meadows

Historically, seagrasses have been used as fertilisers, animal fodder, packing material, mattress filling and to weave objects (like rattan). But it is now apparent that the economic value of seagrass pastures goes well beyond these uses and they are estimated to be the third most valuable ecosystem on a global scale after estuaries and wetlands.

From an engineering point of view, seagrass meadows protect coastlines by taking the brunt of currents and waves. In tropical areas, the meadows are often associated with coral reefs. By slowing down the water currents, the meadow causes an increased rate of sedimentation, thus improving the transparency of the water to the greater benefit of the adjacent corals. Seagrass meadows are very diverse ecosystems, offering shelter and food to many species, and acting as fish nurseries for commercially valuable prawn and fish species.

A dugong feeds among seagrass rhizomes, accompanied by pilot jack fish.

Posidonia oceanica

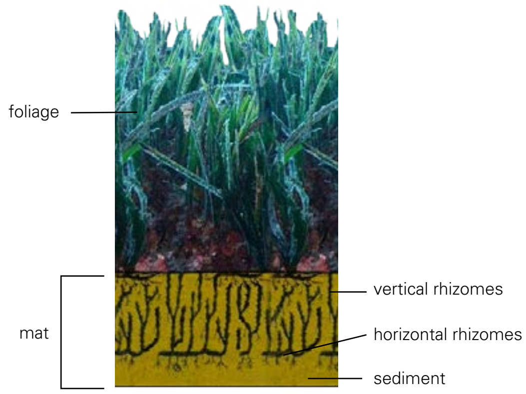
Named after the Greek God of the sea, *Posidonia oceanica* is endemic to the Mediterranean, where it covers about 3% of the area of the Mediterreanean basin (corresponding to about 38 000 km^2).

In autumn, just like terrestrial deciduous plants, *Posidonia* sheds its leaves. This is when seashores become covered in rotting *Posidonia* leaves, rhizomes and 'egagropili', balls made of fibres from the *Posidonia* leaves knotted together by the rolling of the waves.

Posidonia *egagropili on a Spanish beach*

Unpleasant to the sight and to the nose as it might be, beached *Posidonia* detritus brings good news: as well as protecting sandy beaches from erosion, it testifies to the quality of the water, as *Posidonia* cannot survive in turbid, eutrophic waters.

Posidonia oceanica is one of the largest, slowest growing and most long-lived plants. Each meadow is a clone of one plant, slowly growing vertically (1 m/century) through its vertical rhizomes, and horizontally (about 7 cm/year) via its horizontal rhizomes. One living specimen has been DNA-tested to show that it is a single clone, forming a patch over 15 km long off the coast of the Spanish island of Formentera. Given its slow rate of growth, its age is estimated at over 100 000 years.



A diagrammatic view of part of a Posidonia *mat*

Sexual reproduction also occurs, with male and female flowers in the same inflorescence. The flowers appear in September and October and the fruit reaches maturity after six months. Then it detaches itself from the plant and floats to the surface, thanks to the high oil content of its pericarp. The free-floating fruit resembles an olive and, in Italy, it is popularly called 'the olive of the sea'. When the pericarp decays, the seed is released and sinks to the sea floor. If it finds a bed with a high humus content, it will germinate. This means that new *Posidonia* meadows will only start in areas where organic detritus is present, making *Posidonia* meadows the climax community of the Mediterranean.

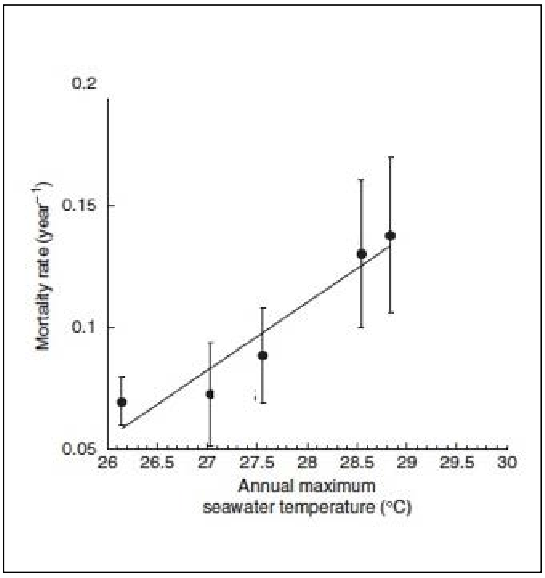
Human threats to underwater meadows

Human activity is the main threat to seagrasses. Maritime constructions, coastal water pollution, anchoring by boats, fishing by trawling and sea warming, are the main culprits.

Maritime construction, by increasing water turbidity, decreases the ability of the seagrass to photosynthesise. Eutrophication, as well as being directly toxic to seagrasses – which do not tolerate high levels of nitrates and phosphates – causes an increase in the growth of epiphytic and floating algae, which in turn affect the amount of light reaching the seagrass's photosynthetic organs and cause the seagrass to die. In a positive feedback mechanism, the increased decaying matter stimulates algal growth, further increasing water turbidity.

Seagrasses are also affected by the speed of sedimentation: too slow, and the rhizome will be exposed; too fast, and the plant will be suffocated.

But by far the most insidious threat to seagrass meadows is global warming. A recent study of *Posidonia* meadows in the western Mediterranean has shown a correlation between higher sea temperatures and increased mortality of *Posidonia* shoots, with the meadows particularly vulnerable in the growing season. This effect is visible even in relatively pristine areas, ruling out other stress factors. Only 60% of the shoots present at the beginning of the 2002-2007 period of study (which, significantly, included the heat waves of 2003 and 2006) were surviving at the end of the study.



A clear relationship between increased Posidonia *shoot mortality and warming – the mortality rate roughly doubles for a 2 degree temperature rise.*

A gradual sea warming by 4°C during this century could potentially cause losses of 20% of shoots per year, which is beyond the plant's regenerative abilities. The mechanism by which this damage occurs could be linked to the lower concentration of oxygen in warmer waters, which causes higher production of sulphides – to which Posidonia is particularly vulnerable – by the anaerobic bacteria living in the sediment.

Seagrasses worldwide are declining at a rate of 1-2% per year – higher than that of tropical forests (0.5%) – and *Posidonia*, with its slow rate of growth, is shrinking even faster (5-10%). The Mediterranean Sea has seen *Posidonia* being replaced by invasive exotic macroalgal species with inferior carbon sequestration abilities (i.e. *Caulerpa racemosa*).

Thankfully, awareness of the ecological importance of seagrasses has increased and the *Posidonia* meadows off the coasts of the Spanish islands of Ibiza and Formentera were declared UNESCO World Heritage sites in 1999.

Stefania Hartley is from Sicily, home to Mediterranean seagrass meadows.

Look here!

The Posidonia Project: *posidoniaproject.org/med/*

The 'Posidonia festival' (an International Festival of Art, Environment and Sustainable Development: *posidoniafestival.com/posidonia/*

Blue Carbon Initiative: *bluecarbonportal.org/*

Seagrass Recovery, a Florida-based company which can provide solutions for all your seagrass meadow's needs! *www.seagrassrecovery.com/*

Siri Spjelkavik

Try This

Water in the oceans

As you know, water in the oceans is salty. This may be obvious, but it has some consequences for how the ocean water mixes – or doesn't mix. There are distinct bodies of water in the oceans which mix only very slowly. These experiments will help to show you why this is.

Part 1 The density of salt water

You will need

- small pot, jar or glass
- bowl or plate
- salt
- teaspoon
- digital balance (optional)

You can add salt to a full glass of water without it overflowing.

What you do

Fill the small glass to the brim with water and stand it in the bowl, which should be dry. Carefully pour salt a teaspoon at a time into the glass and stop when it overflows. If you are very careful you should be able to get at least 3 or 4 teaspoons of salt into the already full glass. (If you start with the bowl and glass on the balance, you will be able to measure the mass of water and salt as you add them.)

What is going on?

Part of the answer is that water has high surface tension and will bulge slightly at the surface – but this isn't enough to account for 3 teaspoons of salt. Table salt is the ionic compound sodium chloride. As it dissolves, the sodium and chloride ions separate and act independently of each other. They fit into the spaces between the water molecules as shown in the diagram.

The volume of the water has not changed but the mass has. Each teaspoon of salt has a mass of about 5 g. You could find or estimate the mass of your water and salt. The water in the glass I used had a mass of 70 g and a volume of 70 cm^3 (pure water has a density of 1 g/cm^3). The density for the water before and after the salt is added can be calculated using density = mass/volume:

fresh water: density = 70/70 = 1.00 g/cm^3
salt water: density = 85/70 = 1.21 g/cm^3

The salt water has a higher density than the fresh water. This becomes important in the ocean when salt and fresh water meet, for example where a river meets the sea, although the density of seawater is lower than this.

When glaciers melt they pour fresh water into the salty oceans.

Part 2 Mixing fresh and salty water

You will need

- 2 jugs
- tall drinking glass (the narrower the better)
- salt
- spoon
- 2 colours of food colouring

Salt and fresh water form layers which are surprisingly stable – they will remain like this for hours.

What you do

Fill both jugs with water. To one add a handful of salt and stir until it dissolves. Keep adding salt until you can get no more to dissolve. Stir in some food colouring. Add some of the other food colouring to the other jug. Half fill the tall glass with the salt water. Tip it to one side and carefully pour the fresh water down the side of the glass. Stand the glass upright and you should see two distinct layers in the water.

What is going on?

The pure water is less dense than the salty water, so it floats on top. This is important in the oceans as it affects how different bodies of water mix. For example, water from melting glaciers is fresh so tends to sit above the saltier water of surrounding oceans. The Mediterranean Sea is very warm so water evaporates leaving it saltier than the surrounding oceans. As Mediterranean seawater pours into the Atlantic Ocean it sinks.

Part 3 Freezing salty water

You will need

- ice cube tray
- salt and fresh water with food colouring left over from Part 2
- access to a freezer or the ice compartment of a fridge

What you do

Fill about 4 sections of the ice cube tray with coloured fresh water and about 4 with coloured salty water. The colours help you to remember which is which. Place in the freezer for at least 2 hours.

You will find that the fresh water forms normal ice cubes but the salty water forms slush. This is because the salt is excluded as the water freezes so what you have is ice and salt water that is saltier than you started with. Salty water has a lower freezing point than fresh water and the freezing point goes down as the saltiness increases. Seawater is less concentrated than this and does freeze at about -2 °C, although the exact temperature depends on how salty it is.

This separation by freezing happens in the polar regions, especially near Antarctica. The salt is excluded when the first sea ice forms leaving sea water which is very cold and very salty. This sinks to the bottom of the ocean.

Sea ice forming in Antarctica leaves saltier water behind.

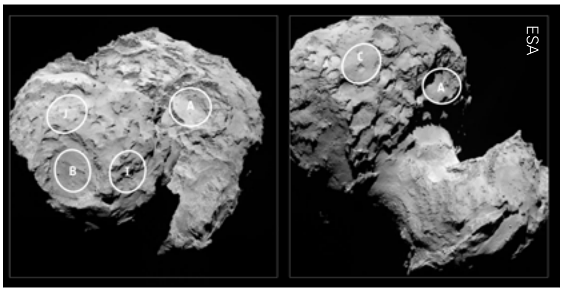
Vicky Wong is Chemistry editor of Catalyst.

Tom Lyons

Where will Philae land?

An impression of Philae touching down on Comet 67P

As the Rosetta spacecraft orbits Comet 67P, the project scientists must choose a landing site for Philae. Philae is a smaller spacecraft which will be dropped from Rosetta onto the surface of the comet. Five possible landing sites have been chosen. More detailed pictures will need to be taken to assess the terrain of these landing sites – large numbers of boulders or very steep slopes would not be good to land on. A final decision as to the landing site and date made in October 2014.



Site A Located on the large lobe but with a good view of the smaller lobe. Chosen because the region between the two lobes is the likely source of some 'outgassing'. As the comet approaches the Sun, heating will cause it to outgas more material, eventually producing the familiar coma of the comet (its tail). At present, two cups of water per second are evaporating from the comet. This will increase hundreds or thousands of times over the coming months.

Site B Located in the crater-like structure in the smaller lobe. Relatively safe for landing due to the flat terrain but the lack of sunlight on the solar panels may cause a problem for the power requirements of the lander.

Site C Located on the larger lobe, it has a range of features such as cliffs, smooth plains and depressions and it is well illuminated.

Sites I and J Both located on the smaller lobe in relatively flat areas with good illumination conditions.

Landing on a comet

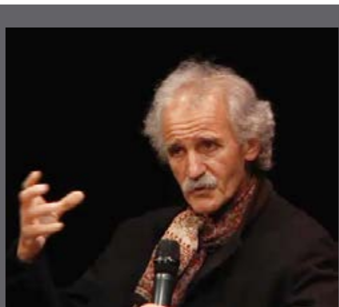
In mid-November, Philae will be pushed backwards behind Rosetta and fall towards the comet, touching down at around 1 m/s. Two harpoons will be fired to anchor to the surface. The energy of the impact will be transferred by a shock absorption system into electrical energy to help prevent an elastic rebound.

The drag from the gas in the coma of the comet means that it is difficult to predict exactly where Philae will touch down and the scientists must deal with an uncertainty of 1 square kilometre in their planning. The comet rotates on its axis once every 12 hours, further adding to the complexity of the landing.

Together Rosetta and Philae will measure the composition of the gaseous material leaving the comet, take samples at the surface and use radio waves to map the interior of the comet. Philae will also provide detailed information on the structure of the comet, never before obtained. It will hopefully give us insights into our early solar system and perhaps into the origin of life on Earth. All this on an object hurtling through space at around 55 000 km/hr, hundreds of millions of kilometres from the Sun.

Tom Lyons has worked as an engineer on space satellite systems. He is now based at the National STEM Centre in York.

See CATALYST Vol 24 Issue 4 (April 2014) for Tom Lyons' previous article about the Rosetta mission.



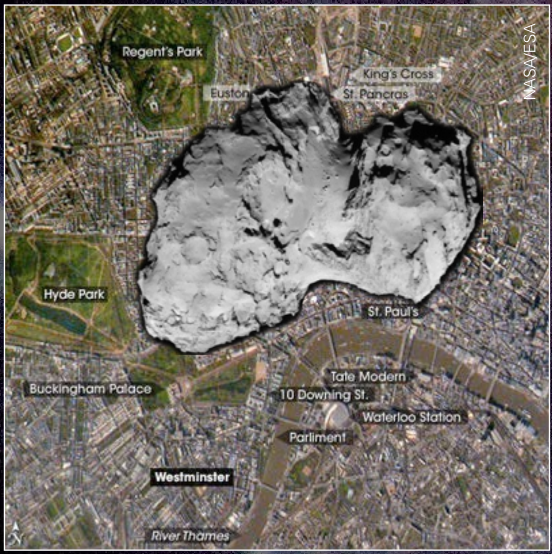
Jen Pierre Bibring is the French scientist in charge of the Philae lander.

"The comet is very different to anything we've seen before, and exhibits spectacular features still to be understood," says Jean-Pierre Bibring, a lead lander scientist and principal investigator of the CIVA instrument. "The five chosen sites offer us the best chance to land and study the composition, internal structure and activity of the comet with the ten lander experiments."

ROSETTA IN ORBIT

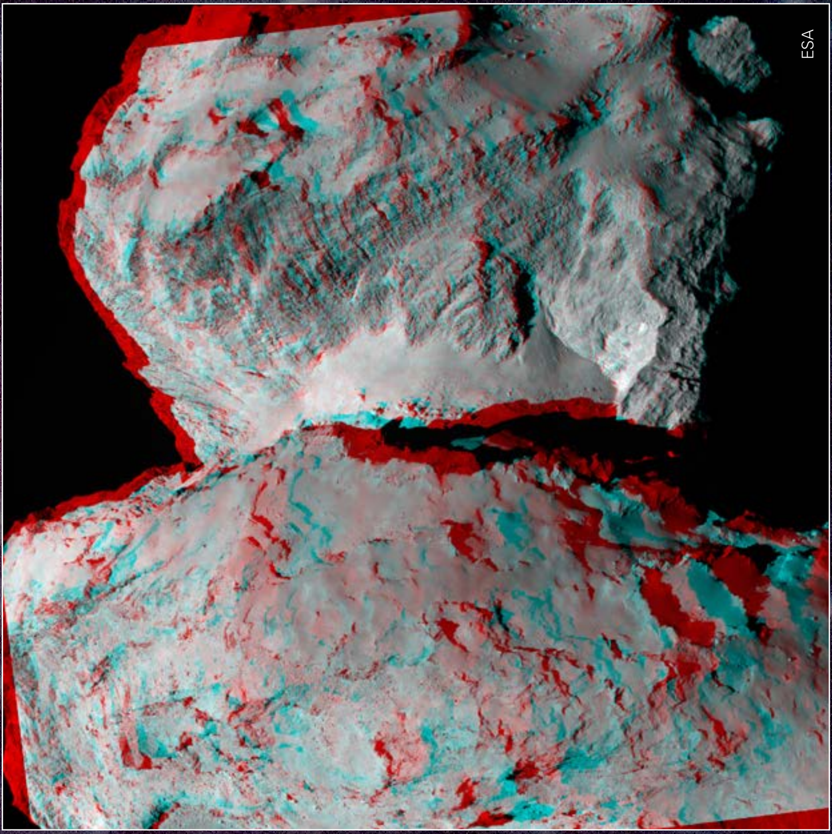
After a 10 year journey through space, the Rosetta spacecraft arrived at Comet 67P/Churymov-Gerasimenko on 6th August 2014. Rosetta's cameras show that the comet has two clearly defined lobes, one larger than the other – it may have formed when two bodies collided. Pictures of its surface also show that it is darker than might be expected for an icy body, suggesting the surface is covered in dark dusty material.

Rosetta's high resolution camera, OSIRIS, took this photo when the probe was 100 km from the comet. Some scientists are calling Comet 67P the 'rubber duck' because of its shape.

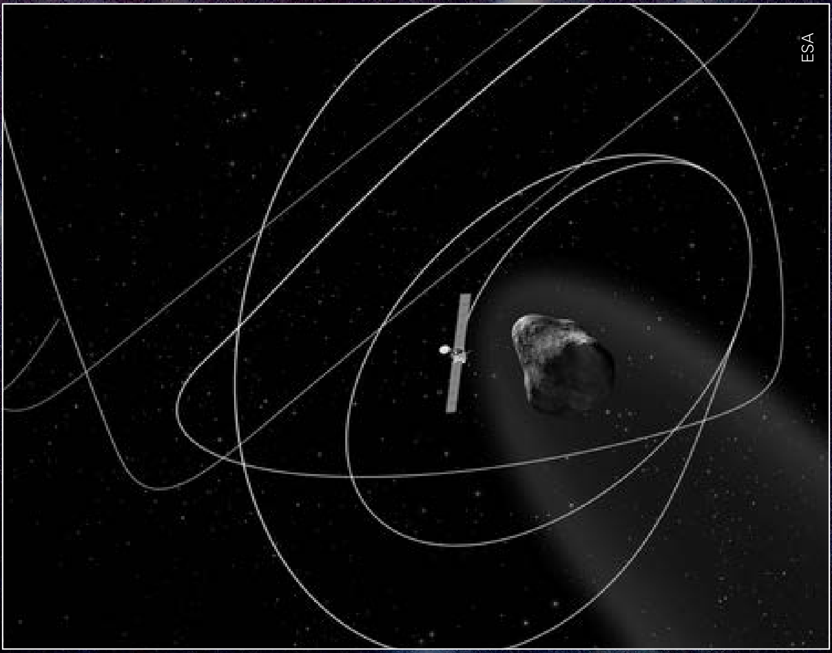


The nucleus of Comet 67P is around 4 km across. Here it is superimposed on a photo of London taken from the International Space Station.

It takes a team of engineers and scientists together with plenty of computing power to calculate and control the Rosetta mission to Comet 67P.



Use red/green stereo glasses to see Comet 67P in 3D.



As Rosetta approaches the comet, it has to do a set of complex manoeuvres to get closer. These require boosts from its rockets every few days. The curvature of the orbit between these boosts allows the scientists to determine a better estimate of the total mass of the comet – around 10 billion tonnes. The comet's density is approximately 300 kg/m^3 – less than one third the density of water.