Heroes and villains of the plant world?

Plants are vital sources of food and medicine. To us, some seem like heroes while others are villains – often because of our misuse of them.

Rice

Around 20 per cent of human energy intake worldwide comes from rice. Rice is often eaten boiled, but can also be used to make rice flour, sweets, rice wine or vinegar, and products such as cosmetics and medicines, as well as being used in crafts and for religious purposes.

There are currently over 40,000 types of rice in the world. It is thought to have originated in the Yangtze Valley in China, as far back as 6000–9000 BCE, but there is some debate about this.

Rice (*Oryza sativa*) is a type of grass which typically grows in wet paddy fields. It has inflorescence panicle flowers, which are flowers that grow in clusters arranged on stems attached to the main branch. It can grow taller than 1 m, or even 5 m when in deep water.

Nutrition

White rice is high in carbohydrate and low in fat, and has moderate amounts of protein. It has lower fibreand vitamin and mineral content than brown rice.

These differences are down to processing. A grain of white rice is a grain of brown rice minus the rice germ, the surrounding rice bran and the hull.

White rice is created by milling and processing the grain until all that's left is the endosperm. This process removes the nutritional benefits of the whole grain: the rice bran and germ provide fibre, protein, vitamins and minerals. But it makes the rice quicker to cook and easier to digest, so the energy from the grain can be used faster.

Rice has an additional benefit of being free of glutens, the proteins found in wheat. These proteins can affect the immune system of some people, particularly those with autoimmune diseases and allergies such as coeliac disease.

Fortification

Because rice is such a popular food, particularly in low- and middle-income countries, it is often fortified with minerals such as iron, zinc, folate, iodine and calcium, and vitamins such as A, B12 and D, to address malnutrition.

Early varieties of fortified rice were created by adding micronutrient powder that sticks to the grains. Unfortunately, even though instructions to not wash the grains appeared on packaging, typical preparation and cooking methods often rinsed away the enrichment.

Three more sophisticated techniques are now used, which take into account cultural and societal standards:

- **coating** involves spraying the surface of the grain with several layers of a vitamin and mineral wax or gum coat, which adheres to the grain better
- **hot extrusion** involves passing a dough of rice flour, vitamins, minerals and water through an extruder at temperatures of 70–110°C, which leaves partially pre-cooked grain-like pieces that resemble rice grains

- **cold extrusion** is similar to hot extrusion but uses a simple pasta press and works at lower temperatures

In both types of extrusion, a 'fake' rice is created which is blended with natural polished rice at a ratio of around 1:200 grains. It remains a technical challenge to create fortified rice that not only looks like actual rice but stands up well during cooking and preparation.

Research and development

Rice has the smallest genome of all cereals, with only 12 chromosomes. This makes it a prime candidate for genetic modification. In the 1960s, a GM rice was created which was more resilient and yielded up to three times greater produce. However, these GM crops require more artificial pesticides and fertilisers in order to flourish.

In China, new types of GM crops similar to rice and wheat, known as crop wild relatives, are being produced to thrive in extreme conditions, such as those that may result from climate change. Producing just 1 kg of rice takes up to 3,000 litres of water, so the rice on your plate has an impact on the environment. Researching this impact and finding solutions is vital for the planet's future.

Other research is looking at changing the structure of rice to reduce its calorific value, which could help to reduce obesity.

For instance, scientists in Sri Lanka are adding coconut oil to white rice while it boils and cooling it for 12 hours before oven-drying and then reheating it. This process lowers the GI (glycaemic index) of the rice so its sugars are absorbed more slowly by the body. Some of the starches in the rice are removed or converted into forms that are harder to digest, which results in less excess glucose in the body that would get stored as fat.

Soy

You can eat it. You can drink it. You can raise livestock with it, plant it to fertilise land, or process it to make varnishes, soaps, inks – even explosives. Eat processed food and you'll likely ingest it without even knowing. Yet live in the UK and you'll probably never see it grown.

What is it? Soy (*Glycine max*), the world's third most valuable crop – and arguably the most versatile.

Soy's success

G. max is an annual, self-fertilising legume that can grow up to two metres tall. It's valued for its resource-rich beans, which yield approximately 20 per cent oil and 40 per cent protein. The beans are principally sought after today because they're a very cheap source of protein.

Soybeans have proved popular for millennia due to their flexibility as a food. They also offer great nutritional value, containing no cholesterol, low amounts of saturated fat, and good levels of fibre, zinc, iron and calcium.

As soy is a good source of all of the essential amino acids (those that cannot be made by the body itself, such as tryptophan, phenylalanine and hystidine – see our amino acid images for more information), it's often a staple food for vegetarians (most people rely on meat as their source of essential amino acids).

However, G. max is actually classified as an oilseed. Its oil has dozens of culinary and industrial uses, and can even be used as a biofuel.

A further benefit is that, like many legumes, *G. max* fixes nitrogen, and so provides soils with nutrients.

The plant's roots

Cultivated for at least 3,000 years in China and Japan, the bean first spread across East Asia as a useful food that could be eaten fresh or dried, fermented into soy sauce, or powdered and mixed with water to make milk (and then curdled to make cheese-like tofu).

It wasn't until the mid-19th century that it really began to be noticed outside of Asia, and its modest early successes in the West weren't as a foodstuff. Unable to tolerate the harsh frosts of northern Europe, the bean grew well in the USA, where it was planted for livestock to forage and to replenish nitrogen in the soil of cotton fields.

But by the 20th century, agriculturalists had discovered the bean's high oil and protein yield, and so industrial use of soy oil accelerated (Henry Ford even made a car using soy-based plastics). Soy meal also started being used to bulk out food and make animal feed.

"Uncle Sam needs soybean oil to win the war"

It was World War II that really raised soy's popularity. In the early 1940s, the US government, needing to replace plant oils and edible fats that could no longer be imported from Asia, implored farmers to "grow more soybeans for victory".

Not only did the bean help feed wartime America and its allies, but its oils were used to glue US torpedo boats together and make foam for US Navy fire extinguishers. Soy became integral to America's war effort. Between 1940 and 1946, US production of the 'miracle bean' tripled.

Working after the war to put the rest of the world back on its feet – and to sustain its thriving soy industry – the USA then exported soy and its products to foreign markets across the globe. This launched the widespread use of soy that we see today.

A flowering modern industry

Global soy production increased nearly ten-fold between 1961 and 2009, and is double in 2016 what it was in the mid-1990s.

But, while it is a common ingredient in processed food the world over, direct consumption of soy only accounts for a small fraction of what we grow; it is the global rise in meat consumption that is responsible for the skyrocketing of soy production.

85 per cent of soybeans are crushed into oil and meal, with almost all of the meal – 98 per cent – then being processed into high-protein animal feed. And with the popularity of meat continuing to increase as global prosperity rises, demand for soy is likely to grow even more.

Cutting down the beanstalk?

This soaring demand has come at a cost. Valuable habitats have been transformed into soy farms, particularly across the Cerrado and Amazon regions of Brazil. As well as disrupting ecosystems, the creation of vast tracts of farmland causes soil erosion, displaces people, induces climate change and drains water reserves.

A further problem is genetically modified (GM) soy, which has become very popular as growers look to increase their yields. GM soy is resistant to the herbicide glyphosate, so farmers can spray this weedkiller directly onto their crops, wiping out the weeds while the soy plants thrive.

But, over time, the intense use of glyphosate has led to 'superweeds' developing resistance, meaning that more of it has to be used to have an effect. The weeds in turn develop even stronger resistance, while our exposure to the chemical increases (or, even worse, farmers are driven to use more toxic weedkillers instead).

In fact, glyphosate use is now so common that it shows up in human breast milk and urine. And, while it was originally thought to be safe, scientists are beginning to investigate whether it causes cancer.

So, though our reliance on soy is showing no signs of slowing, there are likely to be some tough decisions ahead – this once-heroic bean's popularity is already damaging the environment, and could also be damaging our health.

QUESTIONS FOR DISCUSSION

- What do you think is the best way to reduce our reliance on soy in the future?
- Compare the soybean's oil and protein content to other sources of protein. What do you notice?

Chrysanthemum

Concentrated within the head of a little white flower, *Chrysanthemum cinerariifolium*, are six chemical compounds (esters) known as pyrethrins. When they work together, they produce the substance pyrethrum, which can poison insects.

It has been used for centuries as an insecticide in the Middle East and is believed to have been brought to Europe in the early 19th century.

How does it work?

Pyrethrum is a broad-spectrum insecticide, meaning it affects a wide range of insects in gardens and farms, including leafhoppers, spider mites, harlequin bugs, ticks, pickleworms and more. It disrupts the central nervous systems of all types of flying and crawling insects, causing their nerve impulses to fail.

In high concentration, when entering an insect's body, the pyrethrins which make up pyrethrum attach themselves to the sodium channels lining the length of the nerve cells. As sodium is required for transmitting nerve impulses, the nerve cells stop functioning properly when the pyrethrins attach and the insect's nervous system shuts down, eventually leading to its death.

In a low concentration, the toxicity can affect an insect's behaviour by producing avoidance reactions, causing it to flee. For this reason, chrysanthemums are often used as companion plants to repel insects from nearby crops and ornamental plants.

As well as protecting crops and flowers, pyrethrum can induce abnormal behaviour in female mosquitoes, making them unable to bite normally – this could have wider implications for human health.

Properties of pyrethrum

- Since pyrethrins are extracted from chrysanthemum flowers, their supply is sustainable and environmentally friendly.
- High levels of UV break down the pyrethrins to a point where they are non-toxic in the environment.
- They are between 10 and 100 times less toxic than some of the synthetic pyrethroids.
- Pyrethrum exposure is relatively safe for humans and warm-blooded animals in low doses, though some symptoms can occur, such as itching, runny nose and sneezing.

Future trends

Pyrethrum looks set to continue to be in high demand as an insecticide. With threats of a global food crisis, an unsustainable population and climate change, pyrethrum is one of the most sought-after insecticides in the world thanks to its benefits in agriculture.

QUESTIONS FOR DISCUSSION

- What are the pros and cons of the use of insecticides?

Cinchona

In the early 1600s, Spanish colonists in Peru had perhaps the biggest stroke of luck in the history of medicine. They noticed that the indigenous Quechua people used the bark of the local cinchona tree, ground up and added to water, to relieve shivering.

Shivering is a major sign of the deadly recurring fever – then called ague and now known as malaria – that European doctors had long struggled to fight, so the Spaniards decided to try cinchona.

The Quechua's shivers were nothing to do with malaria, which wasn't native to the Americas. Knowing this, there would have been no reason to expect the bark to work against an unrelated infection. But it did. It could both cure and prevent malaria.

Saving lives is big business

Cinchona trees (there are at least 23 species in the *Cinchona* genus) are native to the slopes of the Andes. They're evergreen, have a red-pink blossom and can grow up to 30 metres tall. And they made a fortune for the Spanish Empire.

Once the Spaniards realised the bark's power, they built an industry around it. Massive logging of cinchona trees got underway, and fleets of ships carried the bark to Europe for sale. Doctors were sceptical at first, but ultimately they couldn't argue with the results: among the huge numbers of people saved from malaria were King Charles II of England and Louis XIV of France.

Cinchona bark didn't just defeat malaria in Europe. It also meant Europeans could survive in parts of Africa and Asia where malaria was rampant. The fruits of one empire enabled the spread of others.

The Spanish went to great lengths to keep their monopoly, but eventually, Dutch and British explorers managed to smuggle cinchona out of South America and started their own plantations.

Quinine: the drug inside the bark

What's in cinchona that makes it so effective? The answer came from two French chemists, Pierre Pelletier and Joseph Caventou, in 1820. They isolated several alkaloids (nitrogen-containing bases) from the bark, most notably quinine. This was the crucial antimalarial agent, and its discovery allowed treatment to become more efficient: irrelevant ingredients could be removed and doses could be standardised.

How, then, does quinine work against the Plasmodium parasites that cause malaria? We still don't quite know, although we do know what stage of the infection it disrupts.

When Plasmodium gets into human blood, it devours the protein haemoglobin, creating the iron-containing compound haeme as a by-product. Haeme, though, is toxic to *Plasmodium*, so the parasite converts it into an unreactive crystal form that doesn't pose any harm. What quinine seems to do – somehow – is prevent this crystallisation, so the *Plasmodium* parasites poison themselves as they eat and die before they can do serious harm.

There were other useful alkaloids in the bark too: quinidine, for instance, can treat heart irregularities (arrhythmia). Others have found uses in chemistry as catalysts.

Helping the medicine go down

Quinine tastes bitter. So, to make their doses more appealing, British colonials in India hit upon the idea of mixing their quinine water with gin and lemon. This healthy, restorative drink became known as the gin and tonic, and to this day tonic water is made with quinine. This is why on many of the 'soda guns' that bartenders use, the tonic button is marked with a Q.

You can't treat malaria with tonic water, though: it contains very little quinine. To get a single day's dose, you would need to drink 30 litres of Schweppes Indian Tonic Water – after which malaria would be the least of your problems.

Quinine in the 21st century

After 300 years as the world's leading malaria treatment, quinine has fallen from favour. During the 20th century, strains of Plasmodium evolved that could resist its effects. Luckily, in the 1970s, scientists in China isolated the drug artemisinin from the sweet wormwood plant – also long used in traditional medicine, and very effective against malaria.

Today, artemisinin is the World Health Organization's main recommended antimalarial drug. But for women in early pregnancy, its possible side-effects mean that quinine may still be preferred. It can also be used if artemisinin is unavailable.

Quinine isn't just an antimalarial, though. It's also a muscle relaxant (which may explain its value to the Quechua), and the NHS and other health systems still use it to treat cramps.

Figures on quinine production vary, but one 2009 estimate is that 700 tonnes of alkaloids are extracted from cinchona bark every year. Roughly half of this is used medically and the other half by the food and drink industry.

QUESTIONS FOR DISCUSSION

- What other medicines come from plants?
- What ethical issues are raised by the mass commercial use of traditional community medicines?
- Why might European doctors have been reluctant at first to accept this impressive new treatment?

Olive Tree

Olives are ancient. Archaeological evidence suggests that wild olives were being gathered from around 19,000 BCE.

The olive tree is a slow-growing evergreen characterised by a gnarled trunk from which grey fissured branches sprout white flowers and fleshy grey-green narrow leaves. Trees can reach over 15 metres in height and live for hundreds of years in the right conditions. The olive itself is a drupe or stone-fruit with a single, centrally located seed (pit) surrounded by edible pulp.

Where olives are grown

These squat, oval-shaped fruits that herald from the *Olea europaea* tree have long been synonymous with the Mediterranean, where they thrive in the muggy winters and arid summers.

Olive trees are grown in eight EU countries including Spain, Italy and Greece. They also grow in Syria, Iran and California. In 2010, it was estimated that olive groves covered an area of 5 million hectares in the EU.

How olives are grown

There are two main methods of growing olives: traditional and modern. Traditional processes involve unirrigated mountainous or hilly landscape. Modern methods involve irrigation and mechanisation. In traditional growing, labour represents half the production costs, so olive growing is often a significant feature of cultural heritage across the Mediterranean.

Olives will darken from yellow to a deep purple as they ripen; at what stage they will be harvested depends on whether they will be used for oil or eaten whole. Taken from the tree, olives are extremely bitter and almost inedible. So, before eating, they are typically cured, in water, brine or oil.

The hard wood of the tree is also highly valued by woodworkers, while the leaves are frequently used in medicinal teas.

Oil-rich fruit

Olive oil is arguably the most famous product of the tree, with its myriad of uses – from fuel for oil lamps to cosmetics to kitchen staple to anointing oil in certain religious ceremonies. For example, the Oil of Catechumens used in Roman Catholicism is traditionally made from very pure forms of olive oil.

Olive oil is often regarded as healthier oil owing to its high content of monosaturated fats and as such is a staple ingredient of the so-called Mediterranean diet. Olive oil is predominantly composed of triglycerides, lipids consisting of one glycerol molecule bonded to three fatty-acid molecules.

You have probably noticed on the supermarket shelf that there are a variety of grades for olive oil. When an olive oil is a 'virgin' blend, it simply means that the oil has been extracted from the olive by means (traditional or modern) that haven't led to changes in the oil. 'Extra virgin' is often seen as a premium oil judged by its taste, colour, smell and acidity, and contains no more than 0.8 grams of free oleic acid per 100 grams of product. Oleic acid is an abundant fatty acid that occurs naturally in animal and vegetable fats and is present in the tricyglerides – but it's the free oleic acid content that the oil is judged on.

Coffee

The story of the coffee plant, and the drink we make from it, is pretty remarkable, but no one is really sure when or where it was first discovered. The best-known rumour is about a goatherd called Kaldi.

Giddy goats

Legend has it that one day, many hundreds of years ago in the Ethiopian highlands, Kaldi's goats started eating some berries they found on a tree and became so energetic that they wouldn't go to sleep that night. Intrigued, Kaldi collected some of the berries and the following morning took them to his local monastery and explained the effect they had on his goats. The monks roasted the berries and mixed them with water, creating a delicious drink.

The coffee plant

We know that all of the world's coffee originated from plants in Ethiopia. Coffee plants are evergreen, meaning they have green leaves all year round. It takes three to five years for coffee plants to start flowering. The small white flowers then produce green berries, which take almost a year to ripen and turn red. These berries are home to two small pits, and these pits are what we know as coffee beans.

Whether from Kaldi's monastery or some other source, by the 15th century both coffee beans and excitement about their energising effects spread from Ethiopia to the Arabian Peninsula. The beverage initially met with controversy and was banned on religious grounds. But soon people realised that coffee would help them stay alert during long prayer and study sessions, and the bans were reversed.

The first known public coffee houses, which weren't that different to today's high-street coffee shops, were founded in Arabia. They were very popular and, as well as drinking coffee, customers would listen to music, watch performers and keep up to date on the news.

How coffee affects the body

Probably the main reason coffee became so popular was because of the buzz you get when you drink it. This effect is due to the caffeine in the coffee beans.

As our cells do work they produce a molecule called adenosine. Adenosine enters the bloodstream and travels around the body until it binds to brain cells. This sets off a series of reactions to tell the brain we are tired.

Caffeine binds to brain cells in the place of adenosine. This means that when we drink coffee, the brain doesn't get the message that we're tired. Instead the brain releases adrenaline, a hormone which makes our heart beat faster, dilates our pupils and releases sugar into our blood. This is what causes coffee's energising effect.

Coffee travels west

Thousands of people from Europe travelled to the holy city of Mecca on the Arabian Peninsula each year on religious pilgrimages, and in the 17th century some of them took coffee back home with them. Again the drink was met with suspicion and fear as priests called it the "bitter invention of Satan". Pope Clement VIII was asked to intervene, but when trying coffee for himself he found it so delicious he decided to baptise it, meaning Catholics were free to enjoy it.

Soon coffee houses sprung up across western Europe and became centres of social activity and conversation. A number of businesses grew out of coffee houses, including Lloyd's of London from Edward Lloyd's coffee house. The custom of tipping also emerged from the coffee houses of England. To make sure they were served quickly, customers would put coins in boxes labelled "To Insure Prompt Service", or TIPS for short.

A stolen seedling

In 1714, the Mayor of Amsterdam presented King Louis XIV of France with a young coffee plant as a gift, and Louis ordered it to be planted in the Royal Botanical Garden in Paris. Eleven years later a young naval officer, Gabriel de Clieu, stole a seedling from the King's plant and took it with him on a voyage to Martinique, in the Caribbean.

It was a terrible journey. A fellow crew member attacked Gabriel with a dagger and tried to destroy the small plant, but Gabriel was able to fight him off. Later, pirates attempted to take over the ship and the crew spent a whole day defending themselves. Then a terrible storm nearly sank the ship and almost all of the fresh water supplies were lost. Gabriel shared his water ration with the seedling for the rest of the journey.

After finally reaching Martinique, Gabriel grew the plant and within 50 years there were over 18 million coffee plants on the island. Incredibly, all of the coffee plants across the Caribbean – and South and Central America – originated from this seedling. The resulting coffee harvests were so profitable for the French that eventually Louis forgave Gabriel for his thievery and made him Governor of the Antilles.

The bunch of flowers

In 1727, the Brazilian government sent Colonel Francisco de Melo Palheta to French Guiana to get hold of some of the moneymaking beans. The French Governor was reluctant to give any away, but his wife was a little more generous. Rumour has it she had an affair with the Colonel, and when the time came for him to return to Brazil, she gave him a bunch of flowers, secretly sprinkled with fertile coffee seedlings. Brazil's coffee industry soon took off and it now is the globe's largest producer, growing around 30 per cent of the world's coffee.

Coffee plants can only thrive in tropical climates, because they can't survive winter frosts. There are two species of coffee plant that are used to produce all of the coffee drank today: *Arabica* and *Robusta*. *Arabica* plants produce the best-tasting drinks but can only be grown at altitudes higher than around 600 metres above sea level. *Robusta* plants can grow at lower altitudes, but the better taste of *Arabica* beans means that around 80 per cent of the world's coffee is produced from them.

Coffee beans are now the second most traded raw material worldwide, after crude oil, with sales of over £40 billion a year. With its widespread popularity as the world's second favourite drink, after water, and the special effect it has on the drinker, it seems likely coffee is here stay.

Pine trees (*Pinus sp.*)

Pines are conifer trees mostly native to the northern hemisphere. There are 115 types of pine, found in regions including Scandinavia, Canada, Alaska and as far south as northern Africa, Sumatra and China. Pines have been – and continue to be – used in many ways, from food to construction material.

Pine species can grow from 3 to 80 metres tall, with the majority averaging 15–45 m. They have four different types of leaf – seed leaves, juvenile leaves, scale leaves and needles, each representing a different age of the tree. Pines live a long life, typically reaching ages of 100 or even 1,000. The oldest known pine is a Great Basin bristlecone pine named Methuselah, which is around 4,600 years old. Methuselah is one of the world's oldest living organisms and can be found growing high in the White Mountains of Inyo County, eastern California.

Pines are a robust tree and this is reflected in their wide-ranging reproductive methods. Seeds from pines can be small with wings, dispersed by the wind, or they can be larger and dispersed by birds. When the tree reaches maturity, its cones open and release the seeds, although in some of the bird-dispersed species, the bird has to crack the cone open.

Other species (such as Canary Island pine and Bishop pine) have cones that are sealed shut by resin and can only be opened in particular (hot) conditions. This means that while forest fires can be devastating for ecology, in some cases they can actually help regenerate pines, melting the cones' resin and releasing the seeds to grow new trees.

Commercial products

Throughout history, all parts of the pine tree have been used by civilisations across the world in an array of ways.

Wood from pines is soft, light and malleable, which has made it popular for commercial timber, particularly for furniture and pulp wood used for paper. The bark, sap and resin can act as natural band-aids, while needles can be used to make baskets, trays and pots (they also serve as food for a variety of moths and butterflies).

Medicinal purposes

Around the Himalayas, pine forests are regarded as spiritual places and even host religious festivals. Here, pines are used to treat asthma through breathing in the forest air; seeds are used as a source of oil; and cones are used for decorations.

Native Americans used the tree bark as a food source. The white inner bark was consumed either in raw slices as a snack, or by grinding it up to a powder to use as flour or thickener for soups and stews. The inner bark is high in vitamins A and C, and thus has also been used for medicinal healing. Other medicinal properties of pine include being antiseptic, inflammatory and antioxidant, and often the needles are used to make tea to combat colds and flu.

Climate change

Recent scientific research has suggested that the smell of forest pine can limit climate change. Researchers found that the scented vapours coming off the trees turn into aerosols above the trees. The aerosol particles reflect sunlight back to space, helping clouds to form which promote cooling in the atmosphere. So, as well as keeping our rooms smelling fresh and cool, the aroma of pine could also help the whole world keep cooler.

Carnivorous plants

There are about 600 known species of carnivorous plants in the world. They attract and trap prey, which they then digest to absorb beneficial nutrients. But beyond those similarities, there are some striking differences. These 600 species come from more than a dozen genera in five orders. The different types evolved independently – they do not have a common ancestor.

Some plants are out-and-out carnivores, like the Venus flytrap and the common sundew *Drosera rotundifolia.* They have all three of the characteristics of a carnivorous plant: attracting prey, trapping it, digesting it for nutrients.

Some plants are ‘murderous’. Plants like blue plumbago (*Plumbago auriculata*) kill insects but don’t use their nutrients afterwards.

In practice, what makes a plant carnivorous isn’t always clear. The eastern purple bladderwort (*Utricularia purpurea*) can trap and kill prey, but it doesn’t do it often. Unlike other *Utricularia* species, it gets most of its nutrition from algae and zooplankton.

When plants fulfil only some of the criteria for a carnivorous plant, they’re sometimes called semi-carnivorous or para-carnivorous. Plants like birthwort (*Aristolochia*) temporarily trap insects in their flowers. The insects escape unharmed, but the trap makes pollination more effective.

Carrion flowers – plants that smell like rotting flesh – attract pollinators, which are sometimes trapped for pollination but never killed.

What they eat and how they catch it

Carnivorous plants ‘eat’ insects (especially flies, moths, wasps, butterflies, beetles and ants), spiders, crustaceans, and small vertebrates like frogs and mice.

The biggest carnivorous plant is Borneo’s rat-trapping pitcher plant (*Nepenthes rajah*). As its name suggests, it can trap rats and other small mammals.

Carnivorous plants have one of five types of trap:

1. Plants like the tropical pitcher plants (*Nepenthes*) use **pitfall traps, or pitcher traps**. The pits contain liquid, and they often have steep or slippery walls. Pitcher plants lure their prey in with nectar and bright colours.
2. **Flypaper traps, or sticky traps**, probably started out as a defence mechanism. Plants like sundews (*Drosera*) produce a glue-like substance called mucilage that traps their prey.
3. Two plants have **snap traps**: the Venus flytrap (*Dionaea muscipula*) and the waterwheel plant (*Aldrovanda vesiculosa*). These traps close around the prey when it touches one of the trigger hairs inside the trap.
4. **Bladder traps** are only seen in one genus. The bladderworts (*Utricularia*) have small underwater pouches, or bladders, with a partial vacuum inside. When the prey touches a trigger hair, a 'door' in the bladder opens – sucking in the prey and surrounding water.
5. The aquatic corkscrew plants (*Genlisea*) use **corkscrew traps**. So do terrestrial plants like the cobra lily (*Darlingtonia californica*). They are lined with hairs pointing one way, which make the traps easy to get into but hard to escape.

Like animals, carnivorous plants use enzymes for digestion. The enzymes dissolve soft tissue but can't completely dissolve skeletons or insects' exoskeletons.

Most carnivorous plants make their own digestive enzymes. Some, like cobra lilies, have a symbiotic relationship with bacteria that break down their food. Others, like corkscrew plants, use both approaches at once.

Where you'll find them

Non-carnivorous plants use light energy, carbon dioxide and water to produce glucose through photosynthesis and take nutrients from the soil. Carnivorous plants also produce glucose this way, but they get nutrients from their prey.

They do best in aquatic areas (such as rivers and peat bogs), coastlines and rainforests. They grow in places that have:

- waterlogged, acidic soil
- low levels of nitrogen and phosphorus in the soil
- lots of light.

Non-carnivorous plants struggle to survive in those places, but carnivorous plants have adapted to them. Taking nitrogen and other nutrients from prey is how they survive such extreme conditions.

But being carnivorous comes at a cost: traps can't photosynthesise as well as ordinary leaves can. That's why these plants need lots of sunlight and are outcompeted by other plants in less acidic soil.