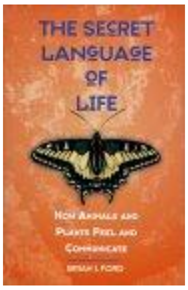
The Secret Language of Life



How Animals and Plants feel and communicate

Brian J. Ford

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"The awareness and responsiveness of plants lives in these pages and is highlighted in our chosen excerpts. The book teaches us more, that animals also have many of our senses, or much better, and we recommend it to you in full. Here is a taste of excerpts from Chapter 5, *Plants Have Sense*, pages 185 - 241.

Plants are bursting with movement. They are rich in sensation, and respond to the stimulation of the Surrounding world every moment of their active lives. They can send messages to one another about overcrowding or a threatened attack by a new pest. Within each plant there is ceaseless activity as purposive as that in an animal. Many of them share hormones that are remarkably similar to our own. Their senses are sophisticated: some can detect the lightest touch (better than the sensitivity of the human fingertips), and they all have a sense of vision.

Trees manage to grow in well-spaced patterns, as a walk through woodland will confirm. They employ mechanisms designed to prevent overcrowding, which would lead to competition for food, light, and water. Not only can plants communicate an attack by pests to other plants in the neighbourhood, but they can react to disease by chemical responses which parallel some of those seen in animals. Plants have great regenerative powers, and the way they heal themselves shows immense coordination of cellular growth. A tree from which a branch has been cut covers the site with wound tissue and makes good the damage. If you do not cut down a branch, then the tree may well do that for itself.

Trees have the ability to configure their outline during their lifetime. For example, they can shed their branches to maintain their equilibrium. An even more remarkable ability is reported by Bill Vinten in Suffolk, who reports that a tree which was partly dislodged by a gale has altered its branches to regain its balance. He observed that the tree had been left leaning down wind after the storm. Over the following years, no branches were lost from the tree, but those that remained have grown round to restore the tree's centre of gravity. We have no knowledge of how a tree does this, and the maintenance of the outline of a tree is clearly a result of its sensory awareness and is worthy of further study.

Plants have much in common with animals. The essential difference is that a green plant can capture sunlight and use its energy to power its life processes. The light from the sun is used by the plant cells to do something science cannot imitate: they take molecules of carbon dioxide and water, and fit them together to make carbohydrates. As long as plants are in the light, they will keep doing this. The simplest carbohydrate molecules are sugars, but; among the more complicated carbohydrates is cellulose. Cellulose does not dissolve in water, as sugars do, so it has to be laid down where it cannot harm living cells. As a rule, the cellulose is deposited around the outside of plant cells. This means that each plant cell is surrounded by a cellulose wall, and is trapped inside this insoluble box. Whereas typical animal cells can stretch and change shape, can expand and contract and can easily divide into two, mature plant cells are surrounded by a stiff capsule of cellulose and are far less mobile.

The growing tip of a plant is made of thin-walled cells which can still divide. The direction of growth is normally towards light (plants can, to that extent,'see') and upwards, away from the ground (they can sense gravity). As the cells mature they lay down their cell walls. Cellulose is the typical deposit in plant cell walls, though some plants produce other substances. Lignin, for instance, is widely found in woody tissues. Structures made of silica glass are found in some cell walls, which is why a blade of grass can cut the skin like a saw. It is the wall of a plant cell which prevents such plants from moving around. They are rooted to the spot, taking in water that evaporates from the leaves. This continuous current of water passing up along the stem carries nutriment through the body of the plant. The movement of water is called transpiration, and it is vital for a plant's growth.

The evaporation of water from a plant is regulated by pores (stomata) which can open and close as the plant dictates. They also control the passage of air and carbon dioxide through the network of cells within the leaf. Each stoma is controlled by two guard cells which can open and close the aperture between them. The chemistry is complex, but when the guard cells enlarge, so that the pore opens, potassium chloride migrates into the cells and starch breaks down. When the processes reverse, and potassium chloride is released from the cell as starch reforms, the guard cells lose volume and the pore closes. The guard cells do not simply control the pores, but sense what is going on around the plant. First, they react to the intensity and the quality of light. Second, the stomata can detect the chemical nature of the atmosphere, responding to levels of carbon dioxide and other gases. Third is their ability to respond to physical stimuli that affect the leaf, like vibrations and movement caused by wind, and their fourth sense is of substances produced by organisms on the leaf surface. As Terry Mansfield of the University of Lancaster has pointed out, these correspond to four of the classic senses: sight, smell, touch and taste.

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Although green plants have no nervous system, they can transmit messages through the length of the plant body. It has long been thought that the stomata open and close solely in response to what they sense, but we now know that they can also be controlled from as far away as the tips of the roots. During periods of drought, the water flow up a plant diminishes and the stomata close down to minimise water loss. It has long been believed that it was the closure of these pores in the leaf which reduced the water flow. In the 1980s it was discovered that the stomata start to close down the moment the roots detect dry soil, and long before there is any change in the water reaching the leaves. The plants are anticipating a threat before it arises. The mechanism seems to be some form of chemical signal which the plants can send to the leaves, and which leads to the closure of the stomata before the plant experiences water loss.

One of the simplest methods of demonstrating this effect is the split-root experiment. A plant is induced to share its root system between two pots, which can be independently supplied with water. If the soil in one of the pots dries out, the stomata over the whole plant tend to close. This occurs even if there is a plentiful supply of water to the second pot. The crucial role of the roots can be demonstrated by watering the dry soil, for the stomata immediately open. Confirmation is obtained by cutting off the roots to the dry pot. As soon as the roots are detached, the signalling system is severed and the stomata open. The control of the stomata by the roots may be by means of abscisic acid, a hormone which can cause stomata to close if present in very small amounts. One part of abscisic acid in a billion parts of water is enough to make them shut. Analysis of roots from split-root plant experiments substantiates the possibility, for there is always much more abscisic acid in the dry roots than in the moist ones.

Plants are subject to a great range of stimuli, and have fine tuned senses to optimise their behaviour. Inside a plant there is ceaseless activity. Microscopic particles within each cell are moving around to catch the light to the best advantage, and cytoplasm inside the cells is streaming from one place to another. Water is drawn up through the stem, and elaborated foodstuffs pass down like a nourishing blood supply. A plant in woodland may seem static to the casual observer, but inside it is a hive of activity.

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[The Venus Fly Trap] seems to be the closest to an animal, for it has jaws which snap shut in one-third of a second, and teeth which hold the prey. . . Each trap is composed of a leaf divided into two oval portions, which open like a butterfly's wings. On the glandular inner surface of each lobe are three fine spiny hairs, and around the far edge are interlocking teeth like those of a man-trap. A slight movement against one of the hairs triggers the trap into action: the two halves spring towards each other so fast that they prey cannot escape. . . Was the effect purely mechanical, or might there be a nervous response within the plant?

Sir John Burdon-Sanderson (1828 - 1905) hitched the leaves up to the apparatus that he was using to study how nerves send signals to muscles, and soon found an electrical signal in 1873. The electrical impulse was recorded immediately after the sensitive hairs were touched, and before any movement was detected. Here was a series of three events: stimulation of the hair, electrical impulse, and closure of the trap. This is very similar to the way an animal responds to a stimulus. . .

If the chemical change were produced by the stimulation of one of the trigger hairs on a fly-trap, we would expect it to be detectable as an electrical response. Just because we measure a peak of electrical activity does not necessarily mean that there is a nervous reaction; we could merely be measuring the results of a chemical change inside the cells. This objection was raised, at the time by Julius von Sachs, (1832 - 97) an eminent German botanist, who concluded that there was no true nervous activity in the fly-trap. He had two main reasons for drawing this conclusion. First, the speed of the impulse was too slow. Impulses can travel along animal nerves at thousands of centimetres per second, while the rate in the Venus fly-trap, was only 20 cm (8 in) per second. And second, there are no nerve cells in the fly-trap. Surely, von Sachs argued if there were nerve impulses, they must have nerves along which the impulses travel. This scepticism resulted in a lack of further interest in the study of plant movement and the subject lay dormant for a century. But in the 1960s, US scientists started to study how impulses are transmitted by cells, and similarities between plants and animals started to emerge.

Life on earth first developed in the salt water of the seas, and one of the fundamental mechanisms of any living cell is a way of controlling the level of salt - sodium chloride. Keeping the sodium ions from salt water at bay is done by restricting their movement in and out of a living cell. The cell is covered with a thin skin, the cell membrane, which is a fatty layer insulating the inside of the cell from the outside environment. Because of the ions inside the cell there is a negative electrical charge (about one-tenth of a volt). The central layer of fat in the cell membrane acts as an electrical insulator. Ions can pass this barrier only if tiny apertures open to allow them through, and these gates are used by the cell to regulate the passage of ions through the membrane.

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If an impulse passes along a nerve in an animal, an advancing wave of gates opens to allow sodium ions into the nerve and potassium ions out. Now that we can study plant cells, the same mechanism has been detected in them. The most interesting discovery of all was that plant cells, like animal nerves, can manifest a receptor potential before the action potential itself. The action potential is the electrical signal that induces a response in a living cell, the receptor potential is the signal created before that - when the stimulus itself is detected. The receptor potential results from the hair-cells in the fly-trap being touched. This stimulus is translated into an action potential only if it is strong enough.

So a small stimulus producing a modest receptor, potential, may be insufficient to cause the action potential to be triggered; in which case, the trap stays open. A strong: stimulus will create a receptor potential sufficient to generate an action potential, which closes the trap. But what happens with medium strength stimuli? If a stimulus is below the threshold, the trap remains open; but if several more small stimuli are received, the hair-cell will still generate an action potential. It is as if the cell is remembering the stimuli and adding them up, which suggests that there is a kind of memory within the plant-cell. This means that a tiny fly will not ordinarily be trapped, but a slowly moving insect, which produces only the slightest touch, will be trapped if it causes gentle movements of a hair cell. As a rule there needs to be a second stimulation within half a minute for the two to be associated. The sequence becomes complex:

1. Movement of a hair-cell, if slight, may be ignored; if sufficient, it causes a receptor potential to fire.

2. If this is small, it is ignored; if it is sufficiently strong, an action potential will fire and an electrical charge will pass across the open trap.

3. If the action potential is insufficient, the trap remains open; if it is strong enough, the trap will snap shut.

4. A later stimulation of a hair-cell may be too weak to generate a response. If a further stimulation within half a minute is enough to trigger a potential, the trap will close.

There are several stages of information processing in the Venus fly-trap. The timing of the responses, together with their nature, shows that they are based on mechanisms much like those in animals.

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Were the plants not confined by their stiff cell walls of cellulose, they might match animals for speed. The study of electrical activity in plants shows that they can sense touch, and respond to the stimulus, in a coordinated and appropriate manner. Clearly, they process data. They do no more than they need to, but what they do is well adapted to the demands of their daily lives.

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Mechanical Movement

Some of the movements in the plant kingdom result from harnessing the mechanical properties of matter. One of the earliest to appear in the literature of science was the awn of a grain of oats, a flexible spine at the end of each grain which twists and untwists according to the humidity of the air. Robert Hooke (1635 - 1703), the natural philosopher who is commemorated by Hooke's Law, used a wild oat awn to measure humidity and drew the apparatus in his pioneering book *Micrographia,* , first published in 1665. This marked the invention of the hygrometer. Some seeds harness the movement induced by changes in moisture to propel themselves into the ground. The storksbill *Erodium*, has spiral awns which coil and uncoil with changes in humidity. They propel the seeds across the surface of the earth until they encounter a crevice, and then the twisting movement helps to screw the seed deep into the earth where it can germinate in seclusion.

The drying out of fern sporangi is used to propel spores away from the plant like stones from a catapult. These sporangia are fringed by a layer of peculiar thickened cells, the annulus. Most textbooks explain its function incorrectly. They tell how the drying of the sporangium causes the cells of the annulus to contract suddenly, breaking open the capsule and scattering the spores far and wide. That is not what happens. In reality, the drying causes the capsule to break as the catapulting collar slowly bends backwards. As water evaporates from the cells they contract even further, until the whole structure is bent back upon itself. Suddenly, the partial vacuum inside each cell of the annulus is more than can be endured. The cell walls rupture, air rushes in, the shock-wave causes all the other cells to rupture in sequence, and the annulus springs back to its former position with a dramatic jerk. The effect is to launch the spores at high speed, all in the same direction, well away from the fern on which they formed. They travel far enough to reach currents of free air, and this completes their distribution.

Arceuthobium, has a more dramatic method. The fruits are filled with seeds lying in a liquid. The pressure builds up as the seeds mature, until the end of the fruit ruptures and the seeds are squirted out at speed up to 100 km/h (about 60 mph).

They can easily reach the next tree, and this form of parasitism has caused heavy losses to the timber trade.

Many flowers have a spring-loaded mechanism. The leguminous flowers (such as peas, beans and alfalfa) hold their stamens between paired petals which form a keel at the base of the flower. If small insects alight, nothing happens. It takes a bee of the right size to bear down on the keel. When that happens, the petals burst open and the stamens shoot upwards like an uncoiled spring, dusting the insect with pollen.

Flowers that remain unpollinated by insects (those grown in greenhouses, for example) sometimes spring their anthers without any outside interference. It is as though they have retained memory of what they are meant to do. There are aspects of plant behaviour that seem to suggest that a plant can store a memory of an earlier experience. Plants have been shown to remember earlier traumas - they can recall being wounded on one side, and compensate for the damage by later growth. If you have dandelions in a mown lawn you may observe that they flower almost prostrate on the ground, as though they have learned that a raised profile will lead to them being cut off in their prime. Equally interesting is the fact that plants can distinguish between one stimulus and another. If a sensitive plant is repeatedly stimulated by touch it will eventually fail to respond. If another form of stimulus is applied (an electrical stimulus, say) it will immediately respond to that. Plants clearly have the means to tell different types of signal apart. More research is needed into these phenomena, which suggest the plants are more alive to their surroundings than is widely believed.

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One plant, above all, is known as the sensitive plant. It closes its leaves in a second, and has long been known for this remarkable phenomenon . . . This is the *Mimosa pudica*, though there are several other species which are just as touchy . . . a train rattling along the track, can send sufficient stimulus to have the Mimosa plants closing up like umbrellas.

There are two remaining problems with *Mimosa pudica.*, One of these is where its sensitivity resides. There are no sensory hairs, and no specialised cells that seem to be specifically adapted to detecting pressure or touch. The cells of the leaf seem much the same as cells in any other plant. And, though there are several other sensitive species of Mimosa, others show no such movement at all, *Mimosa dealbata*looks very similar, for example, and shows similar cells under the microscope, but lacks any sensitive movement; The second major problem is the purpose that the collapse of the leaves might serve The rock-rose moves its anthers to protect its pollen, the fly-trap springs its leaves shut to capture prey. Without these mechanisms, the plants would find it hard to survive where they grow. This does not appear to be the case for *Mimosa pudica*. Many theories have been put forward -protection from the sun, avoiding being grazed by passing herbivores, and so forth - but they would apply equally to any other species. If those were the reasons, we would have leafy plants drooping and closing wherever we looked. We don't, of course. These mysteries remain.

The earliest research into the mechanism behind the sensitive plant showed that contact produced a collapse in the cells that ordinarily hold the leaves erect. As water passed rapidly out of these supporting cells, it was believed that they collapsed mechanically inwards and allowed the leaves to droop. A few years after the historical experiments by Burdon-Sanderson, who measured electrical responses in the Venus fly-trap, a German physiologist - Karl Kunkel of Heidelberg - described similar electrical impulses in *Mimosa pudica* as the leaves moved, This failed to trigger an upsurge in research, because it was concluded that the electrical activity was the consequence of the collapsing cells, and not the cause.

In recent years we have begun to find many other clues to the nature of the movement, and some of them point towards a distinctly animal-like series of mechanisms. There are long, thin cells inside the tissues which conduct sap, and some people have likened them to a kind of nerve fibre. Tannin was discovered within the cells, and tannin is a concentrated source of potassium ions, which is important for movement in animals. It has been discovered that, when the supporting cells collapse, there is a sudden surge of potassium through the cell membranes which causes them to lose water and collapse. Tiny vacuoles, fluid-filled spaces within each cell, have been found which have the ability to squirt water out of a cell at speed. More surprisingly, there are known to be fine fibrils inside the cells, which seem to be able to contract like muscle cells in animals. Why the sensitive species of Mimosa move so rapidly, while other very similar-looking species are unmoved by the sense of touch, is still unknown. Meanwhile, it is clear that these curious plants have mechanisms which are parallel to those we see in animals. They have a remarkable sense of touch, and respond much as animals would respond.

Refined senses

The sense of touch is highly influential in the life of many flowering plants. It is at its most highly developed in climbing plants, which have developed an extraordinary sense. Tendrils are highly adapted organs used by many plants to support them as they grow. Most tendrils are a few centimetres in length, but those of the grape vine *Vitis* can measure 50 cm (20 in). Normally, the tendrils move slowly round in an oval pathway as the plant grows up, as though searching for a point of contact. On a speeded-up time-lapse film the effect looks startlingly like a blind creature feeling its way. There is a sense of orientation to these searching movements. For example, the pea plant moves its tendrils in an ellipse so that the long axis of the ellipse is always at right angles to the sun. If an outstretched comes into contact with a solid support, it will slowly grow to enclose it and thus to support the plant. This response is called contract coiling.

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Pea plants are convenient for casual study, for their tendril can store the memory of a stimulus. If a pea tendril is stroked it will start to curl, though if the plant is chilled this responses does not occur. The memory remains, however, and if the plant is later allowed to warm up, the tendril then curls as if recalling or having stored the earlier stimulus. The tip of a pea tendril grows into a sharp little hook, helping to attach it to its support. If you stroke an outstretched pea tendril you will see it start to coil within a minute or so. Try it at night and nothing happens. The tendrils need to be in the light before they will respond to stroking. They can store the effect of the stimulus for more than an hour and, if brought into the light 90 minutes after the stimulus, they will start to coil as though they had just been touched . . .

In plants like the Virginia creeper *Parthenocissus* . . . [it is not clear, but it may be that Ford is referring to Parthenocissus here] . . . if even a single touch-cell is stimulated, the effect is transmitted to all other cells in the tendril, so coiling starts simultaneously all along its length. These cells can clearly communicate with their neighbours. The sense can be more highly developed that the sense of touch in humans. The touch of a single wisp of wool, less that you can detect on your skin, is enough to start some tendrils responding. The organs of touch in humans can detect a fine hair weighing 0.002 mg drawn across the skin. The sensitive hairs of *Drosera*, the sundew, can detect a stimulus of 0.0008 mg, while *Sicyos* tendrils respond to 0.00025 mg, which is eight times lighter than humans can detect. Not only have plants the ability to sense what's going on, bus some do it far better than we can.

The electrical nature of the stimulus has been demonstrated in several ways. There are action potentials which can be measured in a stimulated tendril, for one thing; and if an electrical signal is actually fed to a tendril, it can itself induce coiling. The pioneering experiments by the Italian physiologist Luigi Galvani (1737 - 98) at the University of Bologna in the late eighteenth century showed that electricity could stimulate frog muscle and make it twitch. Now we have a made similar observations in the tendrils of flowering plants.

There is a further comparison between plant and animal movement, namely that plants can be anaesthetised much like humans. It has been known for many decades that a dose of ether, chloroform, or morphine can render a plant senseless.

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. . . the most dramatic is the voodoo lily, *Sauromatum guttatum*. . . it emits the odour of rotting meat, the perfect lure for flies, and even heats up so that it perfectly imitates decomposing flesh. When it is approaching maturity, the flower becomes warm to the touch (some 15 degrees Celsius, 27 degrees Fahrenheit hotter than the rest of the plant) and burns energy at an astonishing rate. It is certainly comparable to the metabolic rates of a fast-moving mammal.

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In sunlight the leaves of the telegraph plant [*Desmodium gyrans*] stick out at right angles to the stem, but in the hours of darkness they hang straight down. . .

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Simple folding movements in response to a general stimulus (like light levels) rather than a specific stimulus (like touch) are known as nastic movements, or nasties. . . It's an odd term . . . and means 'folding'.

Thermonasties are the movements in plants caused by a change in temperature. The familiar rhododendron evolved in high mountains where low temperatures are common, and evolved a nasty to deal with the cold. Normally the plant has outstretched leaves like those of a laurel, but then the temperature falls below freezing they curl inwards and roll up; each leaf also droops towards the ground. In this way they can reduce the chance of frost damage. Not only do *Oxalis* leaves close when rain falls on them, but they respond to nightfall and remain closed during the hours of darkness. In direct sunlight the plants respond by closing their leaves, just as though it were raining. In this way they can see when it's too bright, and can take action to prevent damage to the leaves through overheating.

Although plants like light, and green plants need it to grow, too much light is often as great a hazard. One of the simplest but most dramatic examples is the compass plant *Silphium* which grows on the US prairies. As flat new leaves grow, they detect the direction of sunlight and develop in a north-south alignment. All the leaves of every plant are parallel to each other. This means that as the sun rises it shines directly onto one side of a leaf, giving it the full benefit of the solar energy. As the sun rises towards noon, it moves round so that it is shining edge-on to the leaves which are thus protected from the full- heat of the midday sun. During the afternoon, the sun moves round so that it starts to shine on the opposite side of the leaves, and they receive a second intake of solar energy. The leaves do not move, but their careful orientation means that they can extract the sun's energy throughout the morning and afternoon while avoiding the risk of over heating during the heat of noon. The compass plant manages to have a siesta through its curious design.

A sense of electricity

Plants have another sense of which we have little knowledge - the ability to detect an electrical field. There has long been a belief that a lawn become's greener before the torrential downpour of a thunderstorm. This belief is not new. Early in the twentieth century, experiments were carried out where high-tension cables were stretched across a field of growing crops. The results showed that the plant did indeed 'green up' in response to an electrical field. During the 1990s, research at Imperial College, London, located sensory cells within the plant which have the ability to sense electricity. It is true - plants really do "green up" in thundery weather before the rain starts.

The physiological purpose of this is complex. Before a dried-up plant can fully benefit from rainfall, a great cascade of enzymes leads to be set in train. The dried leaves need to return to an active state of metabolism, ready to receive the water when it comes. This takes time, and when rainfall is due, the sooner the process starts the better. Plants have adapted to this fact. When an electrical storm is approaching cells within the grass leaves begin to mobilise their metabolic processes, ready for the rainfall. The lawn really does turn green and, through the grass's extraordinary senses, it does so before the first drops of rain begin to fall.

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Solar input

Avoiding the sun may be important for some desert species, but plants in cooler latitudes need to collect sunlight whenever they can. In these species we find a regular daily movement as the plants track the sun across the sky, turning to keep facing it from dawn to dusk. Some plants are named for this legendary ability, like the sunflower and the heliotrope (*helios* is the Greek for 'sun'). The leaves: of cotton plants follow the sun, and *Malvastrum*, a plant of the deserts of California, also has leaves which it keeps facing the sun from dawn to dusk. These are tough species well used to the rigours of a hot climate. Lupins like *Lupinus arizonicus* follow the sun too, though they have more delicate leaves and manage to avoid over exposure by turning their leaves aside during the hours around noon.

Northern plants need sunlight more than any others, for it is in short supply, and the flowers of the Arctic tundra need all the light they can get. One garden plants which is found growing wild in northern and Western Europe, *Dyras octopetala*, shows how important it is to follow the sun. An experiment showed what happened if you fix the flowers to stop them turning through the day. In the plants whose flowers were free to follow the sun, the internal temperature rose 1 degree Centigrade (1.8 degrees Fahrenheit) higher than in those whose flowers were prevented from moving. This is an important difference, for it turns out that the size (and hence the viability) of the seeds is a function of the internal temperature of the flower. Thus, the ability to turn and face the sun can affect the chances of survival for plants.

In a few species, the behaviour depends on the conditions under which the plant lives. An Australian plant grown as, forage crop called siratro, *Macroptilium atropurpureum*, will orient its leaves so that they face the sun when the ground is rich in water. During conditions of drought, however, it changes its behaviour and holds the leaves edge-on to the light (like the compass plant). Clearly, this is meant to reduce the amount of evaporation from the leaves when ground-water is in relatively short supply. These mechanisms are present in a large number of plants. Even those which do not actually turn to follow the sun are able to sense the direction and strength of light, so that new leaves do not overshadow older ones more than necessary. The mosaic of leaves in trees, or on plants like ivy or Virginia creeper, is carefully contrived to give each leaf a fair share of the light. In that sense, all plants can see and can grow to optimise their benefits from sunlight. Before concluding that this is a simple physical mechanism, like a magnet attracting a pin, we need to understand that this turning mechanism sometimes suggests that plants have some form of active memory.

Plants become even more interesting when we consider not what they do during sunlight, but how they behave in the dark. Many of the species that follow the sun prepare themselves each night for the dawn. They turn to face the direction where the sun is due to appear. *Malvastrum* provides an intriguing example. The leaves are kept facing the heat of the sun all day long, finishing up at sunset facing west. After the sun goes down they resume; a normal posture with the leaves spread out conventionally and facing upwards. As dawn approaches the leaves turn again to face the east, ready for the time when the sun will appear. It is not unusual for sun-following plants to turn towards the direction of dawn during the hours of darkness. An interesting experiment would be to grow some plants in pots, and turn them through 180 degrees. That would show how quickly they could learn where the sun was due to rise, and it would demonstrate whether they were truly remembering the direction, or simply sensing a change in the light.

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How plants see

The sense of light detection exists even in seeds. Many plant seeds require sunlight to germinate. This explains the poppy fields of the battlegrounds of the First World War. Within weeks of terrifying ground attacks, the churned fields were cloaked in blood-red poppies. . . The disturbance of the soil brought to the surface many seeds which were stimulated to germination.

It was the sunlight which made the poppies grow. An old farming tale suggests that fields ploughed at night grow fewer weeds. Some recent research suggests that levels of weed growth can be cut by 80 per cent by ploughing at night. This does not make immediate sense to me - even if the seeds were exposed at night, they would surely be stimulated by sunlight the next day. However, the facts stand and more research will doubtless unearth the real answer to plants and their reactions to light.

Light is the green plant's primary source of energy, so it is natural that a plant should be able to detect light well enough to ensure that it derives maximum benefit from the sun. Some of the mechanisms of sense are simple. Plant growth hormones in stems are more concentrated in dark tissues than in those exposed to light. The effect of light on growth hormone seems to 'drive it away'. The plant-growth hormones, auxins, stimulate cells to grow. Imagine an upward-growing shoot, a simple rod of plant tissue. If light shines onto the left of the shoot, then this lighter side will continue to grow rather slower than before. The increase in size of the tissues on the darker (right) side will therefore tend to bend the shoot toward the light. Once illumination is evenly detected on all sides, the growth will continue in a straight line. In this way, a shoot will always grow towards the light.

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Plants and vision

There are light-sensitive chemicals in plants which do not take part in photosynthesis, but give the plant its sense of vision. Phytochrome, for instance, can sense the relationship between red and far-red light, enabling plants to sense the presence of their green neighbours. Another is riboflavin, which was proposed as a light receptor as a result of some simple experiments. If plant tissues are treated with potassium iodide, riboflavin (but not carotene) is inactivated. In that state, the plant fails to respond to light, which strongly supports the idea that riboflavin acts as a sensory compound. Another example is phytochrome. Although there has been much research into this potentially revealing area, it is hard to tell the relationship between a light sensitive pigment and the way a plant responds. This is where molecular biology could hold the key to unravelling the mechanisms hidden in the green plant's sense of sight. Riboflavin may have connections with human life. It was originally known as vitamin B2 and is essential for health. A lack of riboflavin in the human diet leads to problems with the eye. Cataracts can develop, the eye can become reddened, and a sense of itching or soreness develops. People deficient in riboflavin find bright light unbearable, and this photophobia can be so severe that they cannot endure even normal daylight. Such interesting coincidences between human sight and the photoreceptors of the plant kingdom remind us of the universality of the senses. The notion that perception is confined to humans, or even to the animal kingdom, can no longer be sustained. From pages: 239 - 241

Languages of plants

Plants have a vast vocabulary of signals and responses. They can detect the signs of a change in their environment and adjust their metabolism to anticipate its effects. They have finely tuned senses for signs of environmental stress which can compensate for its effects. Plants are able to detect the signals that herald a change in the leafy canopy above them, and alter their architecture in order to retain their fair share of light. Plants can detect changes in the total amount of light reaching them, and can also sense changes in the spectrum of the light. The most obvious method is for the plant to respond to the amount of light energy, sometimes even by twisting the leaf to avoid too much light, and the extent of photosynthesis within the leaf. However, we also believe that plants have specific light sensors which act as "yes'. They detect the nature and extent of the light, but consume very little of its energy.

This may be regarded as a sense of 'sight', quite distinct from a mere response to the effects of light energy on the rate of metabolism of the plant cell. Plants detect light in colour. They have sensors specifically for ultraviolet, blue, red and far-red radiation. These sensors provide them with a rich and detailed impression of their situation. Plants use the ratio of red to far-red radiation to control their rate of growth. By changing the speed at which stems elongate, a plant seems to be able to avoid future deleterious effects on its development. In particular, changes in light quality can forewarn the plant about future changes before any shading by neighbors has occurred, and we have seen that plants detect wind, too. Changes in calcium ions, Ca+2, trigger alterations in gene expression which modify the way the plant grows. The metabolism, the expression of genes and the rate of growth of the plant are an integrated response to all this sensory input.

Meanwhile, plant roots adjust to the availability of nutriment, and favour areas where nourishment is most abundant. Their sensing of the availability of food and water allows the plant to adjust its rate of nutriment uptake. Not only can they sense gradients of moisture in the soil, but they change their rate of growth in the presence of nearby roots. It seems that they are able to control their growth in order to avoid too much competition for scarce supplies of raw materials. There are mycorrhizal associations between plants and fungi, in which a fungus colonises the roots of a host plant (sometimes even penetrating inside the host plant cells, but causing no disease). These relationships bring a number of benefits. Not only do the fungi process wastes in the soil and recycle them as foodstuffs for the growing plant, but the interchange of compounds between fungus and plant provides many opportunities for communication and the transmission of warning signals. Plants have many of the senses possessed by humans. They have sight, as far as they need it; they have a sense of touch (sometimes to an extraordinary degree); can sense temperature, and - through gravity - they can tell 'up' from 'down', or 'left' from 'right'. Twiners can (usually) tell clockwise from anti clockwise. Plants can remember stimuli and tell one form of stimulus from another. They can communicate, and they cooperate to survive. If plants required more intelligence, they would have developed it. As it is, their senses and the limits of their sentience are exactly what they require. Some of the senses in the plant world are already more highly developed than ours (the sense of touch, for example). No longer should science regard a green plant as a simple organism which endures what it must, and adjusts like a chemical system. We owe plants respect, for on green plants we all rely for survival. They are not our subjects; plants are our cousins."

Secret Language scientific personality reports have proven to be over 90% accurate after 21 years in use by millions of people in a dozen languages worldwide. Our data comes from Gary Goldschneider's 40-year empirical study of the life stories of more than 20,000 people, analyzed by date of birth. Gary looked at 50 people born on your birthday and found the personality traits held in common by 45 of them. Then he created personality profiles from those traits for each day, week, month, season and year and I further combined those profile names into the ultimate distillation of your person