light at the longer wavelength and transmit more at the shorter wavelength.

The detection comes as a relief for the theorists who had predicted[5–8] that water vapour should be a significant component of the atmospheres of hot Jupiters. But it contradicts previous studies of the same planet[9] and of another hot Jupiter[10], both of which found no evidence for water. The earlier study of HD 189733b involved looking for evidence of water absorption in the spectrum of light emitted by the hot dayside of the planet[9] (HD 189733b always presents the same face to its parent star).

So how can these findings[1] and the seemingly contradictory conclusions of the earlier work[9] be reconciled? A previous theoretical study[7] might hold the key: owing to the intense radiation from the star, the temperature of HD 189733b's atmosphere might remain constant over a range of altitudes (unlike Earth's atmosphere, which gets colder the higher you go). Absorption lines in a spectrum are created when radiation from a hot source (the interior of the planet in the earlier study) travels through a layer of cooler gas, where molecules selectively absorb light at a few frequencies. If the interior of the planet is the same temperature as the outer layers, this absorption doesn't occur, and the spectrum of light emitted from the dayside of the planet will be featureless.

This effect would wash out the signature of water in the dayside emission spectrum observed in the first study[9], even if a large amount of water were present. Tinetti *et al.*[1], however, measured light from the star that then passed through the outer layers of the planet's atmosphere. Because the star is always much hotter than the planet, the spectrum of this light will always have absorption lines, regardless of the temperature profile in the planet's atmosphere. The authors' measurement is also consistent with a previous claim[11] that water had been detected in the transmission spectrum of another hot Jupiter, HD 209458b. However, instrument effects in these data could have created the same signal, making this claim merely suggestive. The new data, by contrast, provide solid evidence.

But the data do contain a big surprise: the strength of the observed signal is almost four times larger than predicted by current models of such planets' atmospheres[1,12]. Tinetti and colleagues argue that, rather than requiring a significantly higher abundance of water in the planet's atmosphere, this strong absorption signal can be explained by including the full range of predicted absorption lines for water molecules at the high temperatures found in HD 189733b's atmosphere[2]. Previous models have used only those absorption lines measured in laboratory experiments, which were performed at significantly lower temperatures and therefore did not include some of the effects, such as interactions between water molecules, that are predicted to occur at these high temperatures.

Although this detection is a significant step forward, there is still much that we do not know about HD 189733b and similar hot gas-giant planets. The discovery of gas-giant planets so close to their parent stars was a great surprise to the astronomical community. Until then, it had been assumed that most planetary systems would look similar to our own, with smaller, rocky planets closer in and giant gaseous planets only farther out.

We still do not entirely understand how these massive planets migrate into such close orbits around their parent stars, or the effect that their extreme environment has on their structure. The discovery of water highlights one area of similarity between these unusual planets and the gas giants of our own Solar System. But the surprising strength of the detected signal is yet another demonstration that what we find is never quite what our models might lead us to predict. ■

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PLANT ECOLOGY

Family roots

Ragan M. Callaway and Bruce E. Mahall

Experiments in which related and unrelated plants were grown together reveal the ability of roots to recognize their kin. The ecological and evolutionary implications are tantalizing topics for future studies.

Knowing who are your relatives and who are not creates behavioural, ecological and evolutionary opportunities. Organisms capable of recognizing kin can adjust territories, avoid incestuous mating, decide to fight or not and, importantly, benefit evolutionarily from promoting the success of brothers, sisters and cousins — individuals that share their genes. Kin recognition is widespread in animals that recognize relatives by sight, hearing, smell and even taste. Dudley and File[1], writing in *Biology Letters*, now demonstrate that plants can also recognize their family members — through their roots.

Plants do not see, hear, smell or taste. But they communicate with each other in other ways, including chemical signalling among roots[2]; unknown mechanisms for pollen–stigma recognition; chemical signals between parasitic plants and their hosts[3]; volatile molecules emitted as warning signals by leaves damaged by attack[4]; gases in smoke from burning plants[5]; and neighbour-altered light-wavelength ratios[6]. Some of these communication techniques function to discriminate between self and non-self[7], and between members of the same population and those of a distant population[8]. However, unequivocally documenting self versus non-self recognition has proved difficult[9], and clear demonstrations of recognition of relatedness among plants are still rarer. If plants, like animals, can distinguish related non-self from unrelated non-self "and adjust their behaviour on the basis of kinship"[10], thereby enhancing the prosperity of close relatives, their genes might preferentially be passed on to future generations in a process known as kin selection.

But to do this, kin must first be distinguished from strangers. A plant called the Great Lakes sea rocket (*Cakile edentula*; Fig. 1, overleaf) seems to possess this ability. Dudley and File[1] found that, when individuals from the same mother were planted together in a pot, the total root mass produced was less than when individuals from different mothers were planted together. It is not clear whether kin-recognizing siblings reduced their own root growth, or whether unrelated individuals aggressively increased root growth to seize resources in a 'tragedy of the commons' scenario[11]. Either way, roots of the sea rocket responded differently to kin than to strangers. A possible result of lower root mass in the presence of kin is less root overlap, which could mean less competition for resources among kin than among strangers.

Root behaviour[8], overlap and competition were not directly measured by Dudley and File, however, leaving the ecological and evolutionary consequences in question. As Hans De Kroon remarked to one of us, for kin *recognition* to be interpreted as kin *selection*, one must demonstrate that recognizing kin results in increased progeny among the group of relatives — that is, in increased fitness. The plants in Dudley and File's experiment showed no such reproductive increase, but this may have been because they were grown in pots. Pots can be good for detecting root recognition but

NATURE

50 YEARS AGO

"Dr. Josephine Macalister Brew, C.B.E." — It is hard to believe that Dr. Macalister Brew is dead; for if any one adjective could have described her it would have been the hackneyed word 'vital'... [but it] was not surprising that she was worked to death. Government departments, charitable trusts, bodies as varied as the Marriage Guidance Council and the Educational Drama Association all made demands on her strength; and to none of them did she give half-measure.... there must be scores [of boys and girls] who remember this odd little figure who knew what they were thinking before they did and, more, could put it into intelligible words.

From *Nature* 13 July 1957.

100 YEARS AGO

The problem of determining the motion of the sun amongst the stars has undergone a great change in consequence of Prof. J. C. Kapteyn's investigations... These researches indicated that the stars surrounding us do not form a simple system, but a dual one. From a discussion of the motions of the stars of Bradley's catalogue, Prof. Kapteyn demonstrated the existence of two great streams of stars passing through one another, and found the directions of motions of these streams relative to the sun and to one another. The Bradley stars, numbering about 2600, are mainly stars visible to the naked eye; they cover nearly three-quarters of the celestial sphere, and throughout the whole of this area Prof. Kapteyn found the two streams prevailing, and it seemed probable that all the stars he examined belonged to one or other of the two streams... In conclusion, whilst Prof. Kapteyn's theory accounts in a simple manner for the very anomalous and unsymmetrical way in which the directions of motion of the stars are distributed, it is still awaiting the verdict of the spectroscopic determinations of line-of-sight velocities.

A. S. Eddington

From *Nature* 11 July 1907.

50 & 100 YEARS AGO

D. DITCHBURN

Figure 1 | The Great Lakes (or American) sea rocket, *Cakile edentula*. Dudley and File's experiments[1] on root growth show that kin recognition occurs in this species. Whether kin recognition translates into kin selection in sea rocket remains an open question.

they are lousy for assessing a plant's full growth potential. Avoidance of root overlap, as a consequence of recognition, requires space, and space is severely restricted in pots.

In a natural field setting, however, a plant detecting neighbouring kin at low densities could decrease root growth in the vicinity of neighbours and increase root growth away from them, thereby decreasing root overlap and competition for resources and increasing its performance. In support of this possibility, other research on sea rocket has shown that, in the field, groups of siblings have higher reproduction rates than groups of strangers[12]. By demonstrating kin recognition, Dudley and File have taken the critical first step; measuring the fitness consequences should be comparatively routine.

Kin recognition is sometimes linked to altruism, but reduction in root growth and overlap among sibling neighbours may not be purely altruistic. By detecting family members and sharing space with them, sea rockets may simply be ensuring that direct competition for resources does not suppress all members of the group. Competition among densely spaced individuals could result in a limiting resource being spread so evenly among relatives that no individual acquires enough to reproduce. This would be a disaster for an annual species such as sea rocket. On the other hand, kin recognition accompanied by inhibition[8] of neighbouring roots may constitute a formidable interference mechanism that would allow plants to form large enough territories[13] for the successful growth and reproduction of some family members at the expense of others. Kin recognition, therefore, may not directly benefit all members in a family. But it may increase the odds that at least a few members will successfully pass on the family genes to the next generation.

Without brains, how do plants recognize their relatives? No one knows. Possibilities include communication through chemical exudates, released volatile molecules, electrical signals, and enzymes functioning at cell surfaces[14]. Research on a desert shrub, *Ambrosia dumosa*, suggests that root interactions may involve at least two levels of recognition and interplay among physiological and genetic components. At the self versus non-self level, roots on the same individual shrub did not inhibit each other upon contact, whereas roots from genetically identical but physically separated individuals did[13]. At the population level, roots on different plants from the same population inhibited each other, whereas those from different populations did not[8]. In addition, recognition and response probably constitute two different mechanisms, because studies on other species have found, in contrast, that self-recognition can lead to inhibition[15].

Clearly, research on root behaviour is just beginning. But if neighbour identity commonly dictates root interactions, major overhauls of theories that assume that direct resource competition determines plant community organization will be necessary. And if kin recognition among roots can be unequivocally linked to evolutionary consequences, we will have to expand the pool of mechanisms known to drive plant evolution. ■

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NEUROPHYSIOLOGY

Channelling cold reception

Bernd Nilius and Thomas Voets

Perception of cold and hot is one of life's essentials. Three research teams find that, when a temperature-sensing receptor is deleted in mice, the animals lose their response to a range of cold temperatures.

In his description of the five senses, Aristotle described *visus* (sight) as the most supreme sense, yielding the highest pleasure, and *contactus* (touch and sensing temperature) as the most rudimentary sense, required for sheer survival[1]. Indeed, to maintain a healthy core body temperature of 37 °C, humans — like other animals that can retain a relatively constant internal body temperature — need to be able to 'feel' the ambient temperature and show a suitable physiological or behavioural response to drastic fluctuations in it.

Ambient temperatures are sensed by cells of the peripheral nervous system, which convey thermal information from the skin and peripheral tissues to the brain (for reviews see refs 2,3). Three papers[4-6], including one by Bautista *et al.* in this issue, now report the consequences of deleting the gene encoding a peripheral cold sensor called TRPM8. These researchers find that mice that do not have the TRPM8 cation channel — a member of the transient receptor potential (TRP) family — have severe deficiencies in sensing cold and in cold-induced behaviour.

It is not surprising that the deletion of the *TRPM8* gene leads to reduced cold sensitivity. Previous studies had shown that TRPM8 is a temperature-sensitive TRP channel that is activated by moderate cooling and by 'cool' substances such as menthol, eucalyptol and icilin[3]. It is expressed in the free nerve endings of a subset of small-diameter sensory neurons[7]; the nerve fibres of these neurons, which are not covered by the myelin sheath, carry sensory information from the skin to the brain (Fig. 1a). Consequently, TRPM8 had been proposed as the source of non-painful and painful reactions to cold[3] and as the molecular mediator of cold-induced pain relief[8].

The results of studies[4–6] on TRPM8-deficient mice mainly endorse these earlier views. At a cellular level, all three studies[4–6] showed that sensory neurons of these mice show a drastically blunted response to cold stimuli — for example, a drop in temperature from around 30 °C to below 20 °C — and to menthol. Behavioural studies[4–6] illustrate the consequences of such severe deficits in cold sensation. When given the freedom of choice, mice with their *TRPM8* gene intact prefer to reside in a warm (around 30 °C) rather than a cool (20 °C or lower) zone. By contrast, those without TRPM8 do not discriminate against cool temperatures, cheerfully walking into the cold. Moreover, these mice no longer exhibit the typical 'wet-dog-shake' response to injections of icilin, and show a reduced sensitivity to extreme and painful cold stimuli. Finally, Colburn *et al.*[4] find that TRPM8 might participate in hypersensitivity to cold, which is observed after inflammation or nerve injury[9].

So, do these studies fully elucidate the mechanism of cold sensing? Not really. First, all three papers[4–6] equivocally report the existence of a fraction of neurons in the TRPM8-deficient mice that still respond to cold. These neurons have a low temperature threshold for activation by cold (12 °C compared with around 22 °C for TRPM8-containing neurons)[6], and so they might be important for noxious cold sensing. The debate about whether the remaining cold sensitivity is mediated by another TRP channel, TRPA1 (ref. 3), is ongoing, and analysis of mice lacking both TRPM8 and TRPA1 should eventually settle this. Furthermore, another recent study[10] reports that a non-TRP channel — the voltage-dependent sodium channel $Na_v1.8$ — is a candidate sensor of very low temperatures.

These observations on TRPM8-deficient mice[4–6] also prompt a look back at neurophysiological results on the fundamental basis of temperature sensation published in the early 1950s. Hensel and Zotterman[11] reported the temperature dependence of cutaneous C and

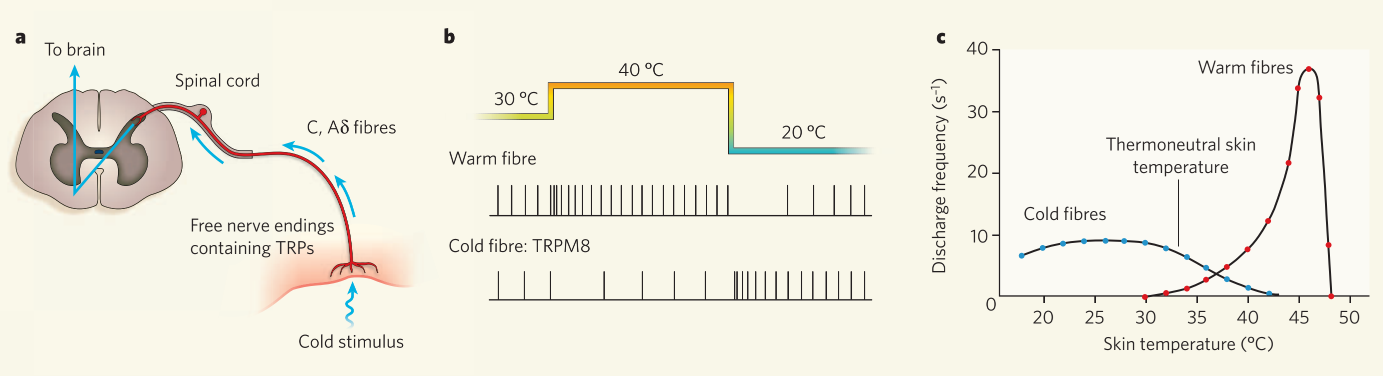

Figure 1 | Sensing cold. Three studies[4–6] implicate the TRPM8 cation channel in cold perception. **a,** Stimulation of TRPM8 in free nerve endings of C and Aδ fibres leads to the repetitive discharge of action potentials. These signals propagate into the dorsal root of the spinal cord, and stimulate neurons that transmit thermal information to the brain. **b,** Stepwise changes in temperature evoke mirror responses in warm and cold fibres. Warm fibres expressing heat-activated, temperature-sensitive TRPs respond to sudden heating with a transient increase in the discharge frequency of action potentials (on-response), whereas sudden cooling leads to a transient decrease in frequency (off-response). Cold fibres expressing the TRPM8 channel show an opposite reaction — an off-response to heating and an on-response to cooling. **c,** Steady-state discharge rates of cold and warm fibres. Note that the same steady-state discharge rate can occur at two different temperatures in a single fibre, raising the question of how the sensation of different temperatures is decoded.