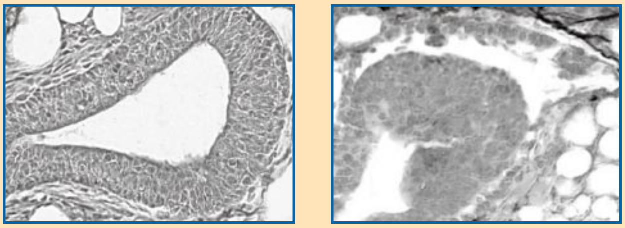
Developmental biology

Guidance molecule goes global



The guidance molecule netrin-1 is famous for its role in telling axons — the long extensions sent out by nerve cells — where they should and shouldn't go in the nervous system. Reporting in *Developmental Cell* (**4,** 371–382; 2003), Karpagam Srinivasan *et al.* extend the repertoire of netrin-1 activities to non-neuronal tissues, showing that it also acts to keep cells stuck together during the development of mammary glands.

It was already known that netrins are secreted by many cells outside the nervous system, but until now no one had really worked out what they were doing. Srinivasan *et al.* looked more closely at where netrin-1 occurs in the developing mammary glands of mice, and found that it surrounds the cap cells — the single layer of cells that caps the developing gland, or bud — in a pattern that is complementary to one of its receptors, neogenin.

Extrapolating from netrin-1's function in the nervous system, it might be predicted that it provides a positional cue to guide moving cells within the mammary gland. Surprisingly, the authors found that, instead, netrin-1 prevents cap-cell movement. Loss of either netrin-1 or neogenin disrupted adhesion between the cap-cell layer and adjacent cells, and resulted in cap cells moving into regions where they would not normally go, as seen in these images of normal (left) and netrin-deficient (right) buds. Furthermore, addition of netrin-1 to isolated neogenin-producing cells caused them to aggregate. So it seems that netrin-1 may be required in the developing mammary gland simply to make sure that cells stick together.

The authors are now investigating the long-term consequences of loss of netrin-1 for mammary-gland development, and in particular the possibility that these tissue disruptions increase susceptibility to cancer. At a more basic level, how does the binding of netrin-1 to neogenin immobilize cells? Studies of netrin-1 in the nervous system provide some hints, but there may be more surprises in store. **Alison Schuldt**

this small transit depth (Fig. 1) has been observed repeatedly[3,4]. The amplitude of the transit depth reported by Vidal-Madjar *et al.* thus corresponds to an extended atmosphere that has a radius 4.3 times that of Jupiter. At this distance, the gravity of the planet is no longer sufficient to retain the hydrogen atoms, and so some fraction trickles away. The calculated minimum escape rate for this process would reduce the planetary mass by only a negligible amount (0.1%) if held constant over its roughly 5-billion-year age. However, the data indicate a higher escape rate, enough to trim the planetary mass significantly.

Vidal-Madjar *et al.* conclude by pointing out that this planet lies exceptionally close to its parent star (completing a full orbit once every 3.5 days). The authors speculate that, at smaller orbital separations, the rate of mass loss is correspondingly higher, and planets that initially reside in such orbits evaporate. Eight extrasolar planets have similar orbital periods (between 3 and 4 days), and only recently has a planet been found[10] that has a shorter period (of 1.2 days). Seared to a temperature of 1,900 K, this new-found planet is in the hot seat — its existence provides an upper limit on the evaporation rate.

Reservations about Vidal-Madjar and colleagues' findings centre on possible contaminating sources of emission that vary with time at the wavelength concerned. Sunlight scattered by the outermost layers of the Earth's atmosphere is large and variable as viewed from the orbiting Hubble Space Telescope. And the emission of the parent star itself may vary in time or across the stellar surface. The authors present good evidence that these effects are excluded, but their conclusions will be all the stronger with confirmatory data.

Modelling the outer reaches of the planetary atmosphere in this high-energy environment, taking these new observations into account, should prove rewarding for both planetary scientists and astronomers, and there is always the promise of more data to come. The transiting configuration of HD209458b will ensure that it remains the centre of attention in the immediate future, and a keystone in our understanding of planets outside the Solar System. ■

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Behavioural science

Fair's fair

Truman Bewley

A basic theory of behaviour holds that people act only in their own best interests. But more complex motives are apparent in an experimental study that shows that generosity is diminished by the unfairness of others.

The rationality hypothesis brings order to much of the thinking in social sciences, and especially in economics. According to this hypothesis, people act solely to advance their own interests, interpreted in the most selfish way. But everyday experience indicates that this is not entirely true: people are willing to make sacrifices to reciprocate favours or to take revenge. People tip waiters even though they will never see them again, and insults can lead to dangerous fights. Experimental evidence that supports these common-sense observations is accumulating. On page 137 of this issue, Fehr and Rockenbach[1] describe experiments in which positive and negative forms of reciprocation — rewards and revenge — are potentially in conflict. They find that the threat of punishment for not rewarding a favour adequately can diminish the actual reward. Such insight into the motives that govern generosity, and our notions of fairness, is vital in the search for realistic principles that improve on the rationality hypothesis.

Applied to game theory, the rationality hypothesis gives rise to the concept of 'subgame perfection' — the assumption that people pursue their own interests from each point in a game onwards. In particular, players will not avenge or reward the actions of another player if doing so hurts their own interests at that time. People will never reciprocate kindness unless doing so brings further advantages to themselves. Nor will rational people avenge wrongs if the revenge will be costly to themselves. A great deal of evidence supports subgame perfection and the rationality hypothesis. For instance, in the workplace an employee's performance can be improved by offering financial incentives — or by disciplinary action.

But there is striking evidence against subgame perfection, in the form of experimental work on ultimatum games[2]. In these, one player (the leader) makes an offer to another (the follower) on how to split a sum of money. If the follower accepts, the split is made according to the leader's offer. But if the follower refuses the offer, neither player gets anything. According to the principle of subgame perfection, the leader should get almost the whole amount, because the follower gains nothing by refusing any offer that gives him something. In practice, however, small offers are almost always refused.

Fehr and Rockenbach's experiments[1] are more subtle. The subjects of their study (a sample of more than 200 students at the University of Bonn) played a game involving two players, an investor and a trustee, each of whom was given an equal sum of money. The investor decided on an amount of money to give to the trustee and specified the amount that he wanted the trustee to return. The experimenter tripled the amount offered by the investor and passed it on to the trustee. The trustee then chose how much to return to the investor. In a second version of the game, the investor, when making the gift to the trustee, could commit to imposing a fine of a fixed size on the trustee if he returned less than the amount requested. Each investor and trustee interacted only once (they were recruited for the experiment on the spot in the university canteen), so that no player could reward or punish a partner's behaviour in future rounds of play.

On average, trustees reciprocated investors' generosity by making payments that increased with the size of investors' transfers. Trustees were least generous when the fine was imposed, more generous when there was no possibility of a fine, and most generous when the investor could impose a fine but chose not to do so. Fehr and Rockenbach's close examination of their evidence indicates that perceptions of fairness influenced the trustees' negative reactions to imposition of the fine. The earnings of the trustee and investor are equalized if the trustee returns two-thirds of the investor's transfer. Trustees apparently made this calculation, for the imposition of a fine had less effect on what trustees returned when investors requested that the trustee return less than two-thirds of their transfer than when they requested that more than two-thirds be given back.

An explanation of the authors' findings is obvious — people are insulted and angered by threats that constrain their actions. Most of us want the freedom to choose. Nevertheless, the fairness that the authors emphasize may be crucial. Evidence from many sources indicates its importance[3]. People do seem to have in mind norms of behaviour for themselves and others, and try to enforce them. This vital topic of human motivation certainly deserves more experimental exploration. ■

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Planetary science

The core of planet formation

Bill Minarik

The rocky bodies from which the Earth formed may have already separated into a metal core and silicate shell. Innovative experiments exploring the behaviour of molten metal trapped between silicate grains suggest how.

Roughly speaking, the Earth is a metallic core surrounded by a silicate shell. Understanding the mechanisms that caused this separation, or differentiation, is one of the outstanding questions of Solar System science. Most of the Earth's volume is inaccessible to researchers, so information about its core must be gleaned indirectly. It comes from four main sources: remote sensing techniques using, for example, gravity and seismic waves; the study of core material from other Solar System bodies found on Earth as meteorites; inferences from the geochemistry of rocks formed from magmas that originated deep below the Earth's surface; and laboratory experiments at high pressures and temperatures, to simulate conditions approaching those at the core. This last is the approach taken by Takashi Yoshino and colleagues[1], who, on page 154 of this issue, present new constraints on the mechanism and timing of core formation.

Core formation probably occurred early in the history of the Solar System. Evidence for this comes, for example, from the decay of short-lived isotopes: decay of the hafnium isotope ^{182}Hf to tungsten (^{182}W) constrains the timing of core formation to the first 30 million years of the Solar System for all four bodies for which we have samples — Earth, the Moon, Mars and the asteroid Vesta[2,3]. Earth formed from a nebula of dust and gas, as material clumped together to form kilometre-sized planetesimals, which then rapidly accreted into larger bodies (Fig. 1), ranging up to thousands of kilometres in diameter. The end point of the accretion process involved energetic collisions of large planetesimals. The ejected material from one such collision re-accreted in the proto-Earth's orbit to form the Moon.

Chemical data require that both the proto-Earth and the object with which it collided had already formed metallic cores. But data from meteorites are less clear. Samples of undifferentiated materials (such as from the chondritic meteorites) suggest that some planetesimals reached sizes of tens to hundreds of kilometres without substantial melting (and hence without separation); but other samples (from iron meteorites)

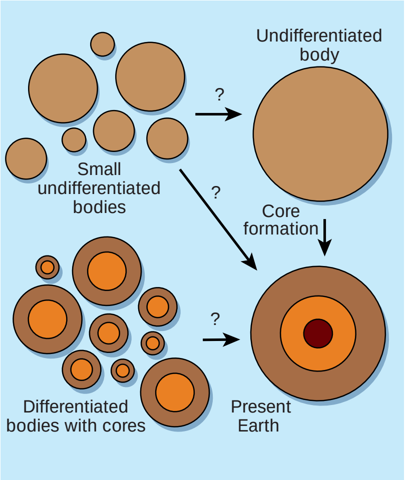

Figure 1 **Timing of core formation. The Earth formed through accretion, absorbing planetesimals (lumps of rock and ice) through collisions. Did the Earth accrete undifferentiated material that then separated into shell and core — in which case, did the planet reach its present mass before differentiating, or was it a more gradual process? Alternatively, core formation might have happened rapidly inside growing planetesimals, so that the Earth's core is a combination of these previously formed cores. Isotopic evidence supports the latter model, and now Yoshino *et al.*[1] demonstrate a mechanism for the physical process.**