thermal models to account for the data on the differentiated moons obtained from the Galileo spacecraft[4,5]. Later models have been more sophisticated[6], but have not considered the physical properties of the material being modelled.

Ruiz does so. He takes account of the fact that ice is highly anisotropic, and that its structure changes dramatically under extreme temperatures, pressures and stress conditions. There are over 12 known different crystallographic structures of ice, as well as two amorphous (non-crystal) types and of course the liquid form, and each is known to exist in the Solar System. Scientists have determined the viscosity (response to stress) of ice at temperatures, pressures and stresses relevant to the icy moons[7], and have shown that its viscosity varies drastically with pressure and temperature. But all previous models of ice on Callisto have taken the viscosity of ice to be that of water. Ruiz not only invokes the experimentally established viscosity of water ice found on the surface of Callisto, but also considers differing microstructural conditions, such as ice-grain mobility and sliding during convection.

Water seems simple, yet it is one of the most complicated molecules in the Solar System. By including the structural response of water and ice in models of the thermal evolution of a planetary body, Ruiz has made a leap in planetary modelling. His analysis brings into question our understanding of ice and water in the outer Solar System, and — just for starters — will force a re-evaluation of the thermal and structural models of the largest 14 or so moons of Jupiter.

If Ruiz is right, and there is a liquid-water ocean flowing and driving currents deep within Callisto, then we might be closer to solving the puzzle of why the sister moons Ganymede and Callisto are so similar in size and location, yet so opposite in nature. And of course, where there is any suggestion of water elsewhere in the Solar System other than Earth, there are suggestions of the possible existence of life. ■

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Population ecology

Birds in a buffer state

There is a happy history of long-term data collected by volunteer ornithologists being used to tackle ecological questions. The latest example is described elsewhere in this issue (*Nature* **412**, 436–438; 2001) by Jennifer Gill and colleagues. Their subject is the black-tailed godwit, *Limosa limosa* (pictured), a large migratory wader.

ROY HARVEY

Godwits that breed in western Europe, including Britain, mostly winter in Africa. But birds from an Icelandic population winter around the British coast, returning to Iceland each spring to breed. For reasons that are unclear, this Icelandic population has increased steadily for several decades, resulting in more winter migrants to Britain.

Combining census data and new surveys, Gill *et al.* find that British estuaries vary in quality as godwit habitats. Bird numbers at the best estuaries have remained relatively stable, and the overall population increase has been buffered by a disproportionate increase in birds using lower-quality sites. This cannot be explained by improved habitat quality, as prey availability does not seem to have changed. Gill *et al.* find that the food-intake rate of godwits at poorer sites is lower than on the traditionally favoured estuaries. Consequently, these birds have higher winter mortality; and those that do survive reach the Icelandic breeding grounds later, perhaps missing out on the best breeding territories.

Lower probability of survival or reproductive success could be a mechanism for population regulation. When the total population density is low, high-quality sites will be favoured. But as their numbers increase, some birds must use lower-quality habitats where they fare less well. Such density-dependent regulation could eventually check the current population increase. **Rory Howlett**

Daedalus

Deft definitions

All language depends on agreed definitions of its words. For public objects and actions this is easy; we can point to what a word refers to. But words for private sensations cause endless confusion. Defining them needs a subtler approach.

Daedalus has been inspired by a recent study in which volunteers claiming to be ‘in love’ were placed in a magnetic-resonance brain scanner, and shown photographs of their alleged beloved. Four specific brain regions immediately gained activity, and one lost it. Photographs of mere friends gave a different pattern.

The word ‘love’ must be responsible for more confusion and misery than any other in the language. How are we supposed to learn the difference between desiring, fancying, being infatuated with, falling in love with, being in love with, or loving, somebody? Do these states exhaust the emotional range? Are they the same for men and women? And what are the logical connections between them? (Daedalus reckons, for example, that falling in love leads to the state of infatuation, and that you can get to be in love with somebody without having fallen in love with him or her.) Romantic fiction merely confuses the issue. It generates innumerable emotional agonies in those who take it seriously.

So DREADCO’s psychologists are now launching a programme of emotional exploration. Volunteers from starry-eyed teenagers to ruthless Casanovas to long-married pensioners are being studied by all brain-scan technologies. At first the programme will be merely empirical. It will seek to correlate the brain maps of volunteers in various emotional states with what they claim to be feeling. In due course the team will discover the most consistent use of the existing words. New words, or new definitions, may have to be invented to fit the observed facts. The baffling private world of love will slowly gain an objective public map.

The programme will then switch into its educational phase. People confused by their emotional state will take a DREADCO brain scan. They will learn the right expression for their state of mind, and be taught how to recognize other states. The DREADCO standard vocabulary and definitions will spread through society, ending the anguished doubts and misunderstandings propagated by the current versions. The question ‘Do you love me?’ will at last have a true, demonstrable answer. David Jones