combination with geochemical studies of erupted picrites and komatiites, would provide more solid information on conditions in the melting region. ■

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1. Morgan, W. J. in *The Sea* (ed. Emiliani, C.) 443–487 (Wiley, New York, 1981).
2. Richards, M. A., Duncan, R. A. & Courtillot, V. E. *Science* **246,** 103–107 (1989).
3. Thompson, R. N. & Gibson, S. A. *Nature* **407,** 502–506 (2000).
4. White, R. & McKenzie, D. *J. Geophys. Res.* **94,** 7685–7729 (1989).
5. Campbell, I. H. & Griffiths, R. W. *Earth Planet. Sci. Lett.* **99,** 79–93 (1990).
6. Wolfe, C. J., Bjarnason, I. T., VanDecar, J. C. & Solomon, S. C. *Nature* **385,** 245–247 (1997).
7. Echeverria, L. M. *Contrib. Mineral. Petrol.* **73,** 253–266 (1980).
8. Echeverria, L. M. & Aitken, B. *Contrib. Mineral. Petrol.* **92,** 428–436 (1986).
9. Larsen, L. M. & Pedersen, A. K. *J. Petrol.* **41,** 1071–1098 (2000).
10. Thompson, P. F. & Tackley, P. J. *Geophys. Res. Lett.* **25,** 1999–2002 (1998).
11. Brunet, D. & Yuen, D. A. *Earth Planet Sci. Lett.* **178,** 13–27 (2000).

Molecular physiology

Globins in the brain

Luc Moens and Sylvia Dewilde

The globins are proteins famed for their oxygen-carrying capacity. Two types are known in vertebrates: haemoglobin, found in the blood, and myoglobin, located in muscle. Now a third has been identified, as described by Burmester *et al.* on page 520 of this issue[1]. It is found in the nervous system, mainly the brain, so the authors have called it 'neuroglobin'.

Haemoglobin is the protein responsible for the red colour of blood, and belongs to one of the best-studied protein families. The basic molecule, the globin chain, is a small globular protein with a relative molecular mass of ~17,000, carrying a porphyrin ring with a central iron atom. Haemoglobin-like molecules occur widely, in organisms ranging from bacteria to man. They transport and store oxygen, which is essential for the oxidative (aerobic) generation of energy by a cell's mitochondria; other functions include oxygen scavenging, transporting and detoxifying nitric oxide, and enzymatic activities[2]. The other well-known globin, myoglobin, is involved in oxygen storage and facilitating oxygen diffusion to the mitochondria in muscle cells[3].

Burmester *et al.* found neuroglobin, in both mice and humans, through database mining of genome-sequencing data. It is expressed at small but differential levels throughout the brain, and the authors suggest that it increases the oxygen availability to the tissue; this is the most likely explanation. The human neuroglobin gene maps to chromosome 14, and a comparative analysis of its protein product implies that members of the globin family diverged early in the evolution of multicellular animals.

The discovery of human neuroglobin is not completely surprising as neuroglobin-like proteins are known from the nervous systems of several invertebrate groups[4]. Their occurrence is not a general characteristic of these groups, however. These other neural globins probably occur because of special needs created by the environmental conditions in which an organism lives. In such species, the functioning of the nervous tissue depends greatly on the oxygenation state of the associated globin. In *Aplysia,* a gastropod mollusc, for example, the firing activity of the neural ganglia (which effectively constitute the animal's central nervous system) is proportional to the degree of oxygenation of the neural globin[5]. And when *Tellina*, a bivalve mollusc, is kept in anaerobic conditions, neural excitability is sustained as long as oxygen can be delivered by the neural globin[6].

Nerve tissue has a high energy demand: although the brain constitutes only about 2% of human body mass, it consumes about 20% of the available oxygen. The resulting energy is produced mainly by the aerobic combustion of glucose. It is used both to maintain ion gradients across cell membranes, which are essential for generating the action potentials necessary for nerve firing; and to power the motor proteins needed to transport materials throughout the nerve cell. A temporary, localized lack of oxygen (ischaemia) in brain tissue, as occurs in stroke, results in cell death and partial loss of nerve function. The oxygen stored by neuroglobin might help to maintain nerve function under these conditions, as it does in the invertebrate species. In this sense, neuroglobin might function in a similar way to myoglobin in cardiac muscle cells; as was confirmed last year in 'knock-out' mice lacking myoglobin[7], myoglobin helps oxygen to diffuse to the mitochondria.

The data of Burmester and colleagues[1] suggest that neuroglobin expression in different regions of the human brain is inversely related to the sensitivity of these regions to ischaemic injury[8]. For example, the average duration of ischaemia producing half-maximal damage is 19.1 minutes in the cortex and 12.7 minutes in the hippocampus; expression of neuroglobin in the hippocampus is four times less than in the cortex[9]. One might speculate about a further clinical connection in diseases leading to neuronal degeneration. Lower resistance to ischaemia because of lower expression of neuroglobin, and thus reduced oxygen availability, could be a secondary factor in increasing cell death[10]. For

Conservation biology

Ducks and drakes

FRANK LANE/E. & D. HOSKING

In Europe, the ruddy duck (*Oxyura jamaicensis*, right) was once seen as a welcome North American addition to wildfowl collections. But the species escaped, became widespread and has threatened the existence of the native white-headed duck, *O. leucocephalus*, by mating with the females. In Britain, the reluctant decision was taken to control ruddy ducks by shooting them.

But why should the bigger female white-headed ducks prefer the smaller ruddy-duck drakes rather than males of their own species? A clue comes from a paper by K. G. McCracken in *Auk* (**117,** 820–825; 2000). Studies of the related Argentine lake duck *O. vittata* reveal that the male has an especially large penis — 20 cm, when erect, which is about half of its owner's length. McCracken includes observations of drake ruddy ducks displaying their penises, apparently to impress the females; similar displays, where the males compete in groups for the favours of the females, occur in all the six other species of the *Oxyura* genus.

Whether penis size is an explanation for why female white-headed ducks preferentially mate with male ruddies remains a matter of speculation, however. Further anatomical and behavioural studies — a Kinsey report for ducks, as it were — are needed to resolve the question.

On the conservation front, the spread of ruddy ducks to Spain and Turkey is threatening the white-headed populations there. In Spain, the interloper and any hybrids (which are fertile) are shot in an attempt to allow pure-breeding of *O. leucocephalus*. An encouraging report comes from one site near Alicante, on the Mediterranean coast. The estimated population in August this year was over 4,000, compared with 22 in the 1970s. **Chris Mead**

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example, it is striking that in Alzheimer's disease the hippocampal region — which has the lowest expression of neuroglobin — is frequently affected by neurofibrillary tangles and senile plaques, which are the morphological hallmarks of the disease characterized by neuronal degeneration[11].

The discovery of neuroglobin in mice and humans, and the sporadic occurrence of neural globins in invertebrates, suggests that these molecules probably evolved with the evolutionary development of the nervous system itself, and that they will be found in all taxonomic groups. Beyond that, neuroglobin's likely involvement in supplying oxygen to nerve cells may lead to the possibility of improving neuron function and survival in both health and disease. ■

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1. Burmester, T., Weich, B., Reinhardt, S. & Hankeln, T. *Nature* **407,** 520–523 (2000).
2. Minning, D. M. *et al. Nature* **401,** 497–502 (1999).
3. Wittenberg, B. A. & Wittenberg, J. B. *Proc. Natl Acad. Sci. USA* **84,** 7503–7507 (1987).
4. Vandergon, T. L. *et al. J. Biol. Chem.* **273,** 16998–17011 (1998).
5. Chalazonitis, N. *et al. C. R. Seances Soc. Biol. Fil.* **159,** 240–244 (1965).
6. Kraus, D. W. & Colacino, J. M. *Science* **232,** 90–92 (1986).
7. Gödecke, A. *et al. Proc. Natl Acad. Sci. USA* **96,** 10495–10500 (1999).
8. Adams, J. H., Corsellis, J. A. N. & Duchen, L. W. *Greenfield's Neuropathology* (Butler & Tanner, London, 1984).
9. Zivin, J. A. *Neurology* **50,** 599–603 (1998).
10. de la Torre, J. C. *Ann. NY Acad. Sci.* **826,** 75–91 (1997).
11. Hendrick, L. & Van Broeckhoven, C. *Eur. J. Biochem.* **237,** 6–15 (1996).

Optical astronomy

The resolution revolution

Tyler Nordgren

Astronomers are fond of 'standard candles' — objects, such as supernovae or Cepheid variable stars, whose brightness is related in a predictable way to their true distance from us. On page 485 of this issue, Lane *et al.*[1] report the first unambiguous detection of the pulsating diameter of a Cepheid variable star. The observations were made using the Palomar Testbed Interferometer and exploit the continuing revolution in telescope resolution to attempt to answer one of the hottest questions in extragalactic astronomy: how big is the Universe?

Stars make up the vast majority of objects visible to the naked eye yet the average star looks the same to the casual star gazer as it does through the largest telescopes on Earth. Even NASA's Hubble Space Telescope sees all but the largest star in the sky, Betelgeuse, as unresolved points of light[2] (Fig. 1a). As the diameter of a telescope's mirror increases, so does the angular resolution (the ability to discern fine detail). But the blurring effect of the Earth's atmosphere means that the finest resolution available to ground-based optical telescopes is only about 0.8 arcseconds (1 arcsecond is 1/3,600 of a degree). The giant star Betelgeuse is only 50 milliarcseconds in diameter, whereas most stars visible to the naked eye are ten to a hundred times smaller. With recent advances in adaptive optics this blurring effect can be largely removed from ground-based telescopes, yet engineering and cost constraints still limit the size of a single mirror and thus the maximum possible angular resolution.

An interferometer combines the light from two or more widely spaced mirrors, resulting in an array with the same resolution as a single large telescope of the same diameter as the separation between the mirrors. So radio astronomers using the Very Long Baseline Array are able to simulate a single radio telescope the size of North America. Unfortunately, most stars emit radiation at optical rather than radio wavelengths, and technical obstacles have prevented optical telescopes being built on this scale. The Palomar Testbed Interferometer (PTI), located on Palomar Mountain in California, has the resolving capability of a single 110-metre infrared telescope — much larger than any single telescope built so far, and good enough to resolve stars as small as a few milliarcseconds in diameter[3].

Optical interferometers are now operating or under construction in Britain, continental Europe, Australia, Hawaii and North and South America. In the past decade, interferometers have successfully measured stellar angular diameters smaller than two milliarcseconds with precision greater than 10% (ref. 4). With the increase in size and resolution of these instruments has come an increase in the number of fields in which contributions and discoveries can be made. One such area is the size and age of the Universe.

Cepheid variables are supergiant stars that regularly change in size and brightness. Numerous Cepheids have been found in our own and other galaxies including the Large Magellanic Cloud (LMC), a satellite galaxy of the Milky Way. Observations of the Cepheids in the LMC, all of which are about the same distance away, reveal a direct relation between pulsation period and intrinsic brightness (luminosity). Measure the period of a Cepheid's pulse cycle, and the derived luminosity combined with its apparent brightness yield its distance. Identify Cepheids in a nearby galaxy and one immediately knows that galaxy's distance (a key project of the Hubble Space Telescope). These distances are used to help derive the Hubble constant — a measure of the expansion rate of the Universe — which is the most direct indicator of the size and age of the Universe[5].

For this method to work, we also need an independent measure of the distance to the Cepheids that allowed us to derive the period–luminosity relation in the first place. With the size and age of the Universe at stake, the distance to the LMC is one of the most hotly debated values in astronomy[6]. Finding a simple way to measure distances to enough Cepheids in the LMC would allow one to calibrate their overall period–luminosity

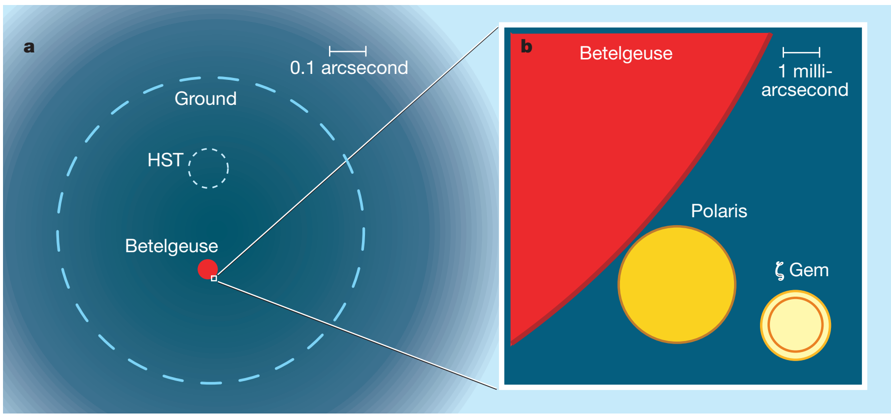

Figure 1 **Getting up close and personal to a star.** a, **The relative sizes of the average resolution available to a ground-based telescope because of atmospheric interference and the diffraction-limited resolution of the Hubble Space Telescope (blue dashed circles). The scale bar represents 0.1 arcseconds, where 1 arcsecond is 1/3,600 of a degree. The angular size of the largest star in the sky, the red supergiant Betelgeuse, is shown for comparison.** b, **An enlargement of a box 10 milliarcseconds in size, showing part of Betelgeuse and, for comparison, the warmer supergiant Polaris, the North Star. The minimum angular diameter (red contour) of the pulsating Cepheid variable ζ Gem is only 10% smaller than its maximum angular size. For comparison, a person standing on the Moon is only 1 milliarcsecond in height as seen from the Earth.**