Table 1 Features of some horse-driven postal systems

Date	Mail system	Route	Distance covered Horse (km)	Rider (stations)	Average speed (km h^{-1})	Number of stations	Network extent (km)
540 BC	Cyrus the Great, Persian Empire	Sardis–Susa	24.3	–	15.3	111	2,757
AD 618	Tang Dinasty, China	Network in China	20.0	5–6	13.3	1,297	32,500
AD 1250	Kublai Khan, Mongol Empire	Network in Asia	18.0–25.0	–	15.0–20.4	1,400	60,000
AD 1260	Mamelouk Sultanate, Egypt, Syria*	Cairo–Damas	20.0–25.0	–	16.1	200	3,000
AD 1425	G. G. Visconti, Torre e Tasso, Italy	Network in Europe	16.1	–	14.8	–	–
AD 1477	Louis XI, France	Network in France	28.0 ± 1.2 s.d.	–	13.8–16.5	72	2,000
AD 1860	Overland Pony Express, USA	St Joseph–Sacramento	20.1	4–5	15.5	157	3,163

Although express postal systems date back to 1780 BC (Hammurabi), only those based on day-and-night express relay riding, for which reliable data and historical sources (ref. 2, and see supplementary information) are available, have been included. The Roman Cursus Publicus (AD 1), despite its huge extent, was not considered here because of its slowness[13].
*Both horses and camels (*Camelus dromedarius*) were used in this system.

may cause neuromuscular fatigue, musculoskeletal damage, altered kinematics of gallop, and lameness[12].

On this basis, it seems that relay postal systems selected the greatest speed and distance that were compatible with a low risk of damage to the horse (no spleen emptying, no anaerobic metabolism, adequate cooling; Fig. 1b, lower line), which was a valuable investment. The speed of 20–22 km h^{-1} used for delivery by the postal systems in daylight hours was slower than the speed of 35 km h^{-1} shown in Fig. 1 for élite, modern horses that have been subject to superior selection, training, feeding and resting regimes. Moreover, inclines and obstacles would have reduced the average speed of a postal horse.

It is remarkable how several civilizations in the history of postal systems, without any knowledge of equine physiology, independently worked out the same optimal parameters (maximum distance travelled and related speed) for reducing the risk of life-threatening conditions such as heat stress and lameness in their horses. The distance between the postal stations of the past finds a parallel in the distance between veterinary checkpoints in modern endurance races, in which cardiovascular, metabolic and locomotory status are monitored every 20–30 km. Only the rider who simultaneously proves to be the fastest and finishes the race with the horse in good condition is eligible as the winner.

Alberto E. Minetti
Institute for Biophysical and Clinical Research into Human Movement, Manchester Metropolitan University Cheshire, Alsager ST7 2HL, UK
e-mail: a.e.minetti@mmu.ac.uk

1. Xenophon *Cyropaedia* Book VIII, 6.17–18.
2. Gazagnadou, D. *La Poste á Relais* (Kimé, Paris, 1994).
3. Hoyt, D. F. & Taylor, C. R. *Nature* **292,** 239–240 (1981).
4. Minetti, A. E., Ardigò, L. P., Reinach, E. & Saibene, F. *J. Exp. Biol.* **202,** 2329–2338 (1999).
5. Hanak, J. *et al. Acta Vet. Brno* **70,** 133–139 (2001).
6. Potard, U. S., Leith, D. E. & Fedde, M. R. *J. Appl. Physiol.* **84,** 2052–2059 (1998).
7. Saltin, B. in *Limiting Factors of Physical Performance* (eds Keul, J. & Thieme, G.) 235–252 (Georg Thieme, Stuttgart, 1973).
8. Snow, D. H. *Res. Vet. Sci.* **27,** 372–378 (1979).
9. Woledge, R. C., Curtin, N. A. & Homsher, E. *Energetic Aspects of Muscle Contraction* (Academic, London, 1985).
10. Snow, D. H., Harris, R. C., MacDonald, I. A., Forster, C. D. & Marlin, D. J. *Equine Vet. J.* **24,** 462–467 (1992).
11. Rose, R. J. *Br. Vet. J.* **142,** 542–552 (1986).
12. Foreman, J. H. *Vet. Clin. North Am. Equine Pract.* **14,** 205–219 (1998).
13. Suetonius *The Twelve Caesars* Book I, 57.

Supplementary information accompanies this communication on *Nature*'s website.

Competing financial interests: declared none.

Structural colour

Opal analogue discovered in a weevil

Beetles in dimly lit tropical forests often display structural colours[1], but in direct sunlight only part of the insect can be seen from any direction — it appears as a spot of light because multilayer reflectors on its rounded surface act like mirrors[2,3]. Here we describe a beetle, *Pachyrhynchus argus*, found in forests in northeastern Queensland, Australia, that has a metallic coloration that is visible from any direction owing to a photonic crystal structure analogous to that of opal[4]. To our knowledge, this is the first recorded example of an opal-type structure in an animal.

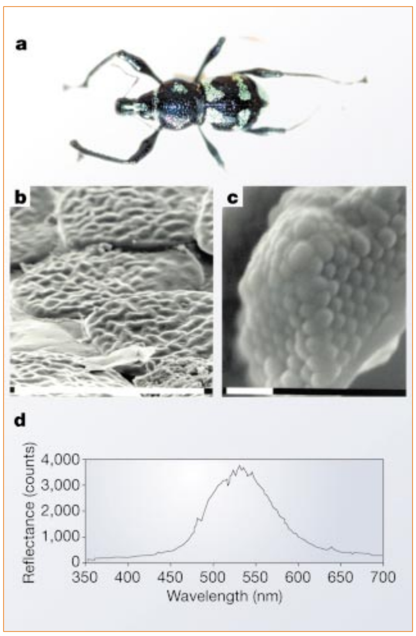

Figure 1 Structure and optical properties of the scales of the beetle *Pachyrhynchus argus.* **a,** Dorsal view. The beetle's metallic coloration is visible from every direction owing to the optical properties of its scales, which act as a photonic crystal and have a structure analogous to that of opal. **b,** Scanning electron micrograph (SEM) of several partially overlapping scales (green in **a**). **c,** SEM of a section through a single scale, showing the 'opal' structure fractured (as an artefact of sectioning) to form a pyramid shape. **d,** Spectrometric analysis. White light was incident at 20° to the normal of the scale surface, and the reflectance profile was measured at 20° to the other side of the normal. Scale bars: **b**, 100 μm; **c**, 1 μm.

The weevil *P. argus* has a relatively uniform, metallic colour (Fig. 1a), even though the light in its environment can be strongly directional. This colour derives from scales that are about 0.1 mm in diameter (Fig. 1b) and occur in patches on the top and sides of the beetle's roughly hemispherical body. Individually, the scales are flat, lying parallel with the body, and consist of two parts: an outer shell and an inner structure.

The inner structure is absent in some scales, causing the complete scale to appear transparent. Otherwise, in transmitted white light the scales appear as the negative of the reflected colour: yellow–green in reflected light and purple in transmitted light from most directions. When analysed using an ultraviolet–visible spectrometer (OceanOptics USB2000), with white light incident at 20° to the normal of the scale's surface, the peak reflectance occurs at a wavelength of 530 nm, at an angle of 20° to the other side of the normal (Fig. 1d).

We examined sectioned scales internally using scanning and transmission electron microscopes. The inner structure of the scales is a solid array of transparent spheres, each with a diameter, d, of 250 nm. They are arranged in flat layers and have a precise, hexagonal close-packing order (Fig. 1c). As the lattice constant of the crystal approaches half the wavelength of light, it acts as a three-dimensional diffraction grating[5], forming optical domains within a single scale. This is the most common nanostructure found in opal (although opal microspheres occasionally show face-centred cubic packing)[6,7], and allows for the reflection of a narrow range of wavelengths over a wide range of incident angles.

This opal-type structure is an example of a three-dimensional 'photonic crystal'. Using the formula $\lambda_{max} = 2d \times 0.816\sqrt{(n^2 - \sin^2\theta)}$ as an approximation (for details, see www.icmm.csic.es/cefe/Infiltration/R6G/R6G_infill.htm), the wavelength of maximum reflectance, λ_{max}, for an angle of incidence θ, was calculated as 573 nm at $\theta = 20°$. The constant $0.816 = 2/3^{1/2}$ accounts for the spacing between the close-packed planes in units of sphere diameter; n represents the average refractive index in the system where point scatterers are arranged in planes, calculated as $(n_s + n_m)/2$, where n_s is the refractive index of the microspheres and is taken as 1.56, and n_m is the refractive index of the matrix (1.33) — that is, the refractive index of the chitinous material and 'water' that make up the beetle's exoskeleton[7,8], respectively.

This is a good match with the measured λ_{max} and indicates that the cause of the optical effect is indeed similar to that of opal[7]. Variations in θ do, however, cause differences in λ_{max}; the range of θ values of 0–70° equates to a range of λ_{max} from 590 nm to 448 nm. The invariant colour (yellow–green) seen from the whole animal is a result of global averaging of the different domains within each scale and juxtaposed scales; the domain structure thus creates omnidirectional colour, removing the iridescent effect.

The first photonic crystal revealed as such in an animal (in this case a polychaete)[9] has a two-dimensional structure. By contrast, the three-dimensional properties described here allow for a relatively omnidirectional optical effect, which is important to the behaviour of this weevil because it appears to be strongly coloured from every direction *in situ*. This could be useful for interspecific colour or pattern recognition.

Opal is notoriously difficult to manufacture in solid form. However, transmission electron micrographs of the weevil's opal-like structure reveal repeating patterns of light and dark areas within each microsphere, providing a clue to their molecular structure (which may be revealed by X-ray diffraction analysis) and production. These microspheres must be constructed by molecular self-assembly, a process that could potentially be reproduced[10] by the synthetic-opal industry. After all, the self-assembly technique of the abalone has been successfully copied in the manufacture of a nanocomposite coating that is analogous to the nacre of its shell[11].

Andrew R. Parker, Victoria L. Welch, Dominique Driver, Natalia Martini

Department of Zoology, University of Oxford, Oxford OX1 3PS, UK

e-mail: andrew.parker@zoo.ox.ac.uk

1. Schultz, T. D. *Bull. Ent. Soc. Am.* **32,** 142–146 (1986).
2. Parker, A. R., McKenzie, D. R. & Large, M. C. J. *J. Exp. Biol.* **201,** 1307–1313 (1998).
3. Parker, A. R. *J. Opt. A* **2,** 15–28 (2000).
4. Sanders, J. V. *Nature* **204,** 1151–1153 (1964).
5. Ajgaonkar, M., Zhang, Y., Grebel, H. & Brown, R. A. *J. Opt. Soc. Am. B* **19,** 1391–1395 (2002).
6. Sanders, J. V. & Darragh, P .J. *Min. Rec.* **2,** 261–268 (1971).
7. Philipse, A. P. *J. Mat. Sci. Lett.* **8,** 1371–1373 (1989).
8. Land, M. F. *Progr. Biophys. Mol. Biol.* **24,** 75–106 (1972).
9. Parker, A. R., McPhedran, R. C., McKenzie, D. R., Botten, L. C. & Nicorovici, N.-A. P. *Nature* **409,** 36–37 (2001).
10. Nedelec, F. J., Surrey, T., Maggs, A. C. & Leibler, S. *Nature* **389,** 305–308 (1997).
11. Blackwell, J. & Weih, M. A. in *Chitin, Chitosan and Related Enzymes* (ed. Zikakis, J. P.) 257–272 (Academic, New York, 1984).

Competing financial interests: declared none.

COMMUNICATIONS ARISING

Plasma antioxidants

Health benefits of eating chocolate?

In assessing whether or not a compound or food acts as an antioxidant *in vivo*, a conventional approach is to monitor biological markers of oxidative damage in response to the intervention[1]. Another is to measure the change in total plasma antioxidant capacity, as investigated by Serafini *et al.*[2] in relation to the consumption of chocolate in the presence and absence of milk. The implications of the authors' finding that eating chocolate causes an increase in total plasma antioxidant capacity, and the mechanism by which this is achieved, must also be considered — however, it should not be assumed that the effect is necessarily beneficial.

I calculate that the maximum plasma epicatechin concentration in the study of Serafini *et al.* is about 1 μM. Epicatechin metabolites are likely to be present at lower concentrations and to have reduced antioxidant activity compared with that of epicatechin itself, because of blocking of radical-scavenging hydroxyl groups by conjugation[3]. However, the total plasma antioxidant capacity (TPAC) measured by Serafini *et al.*[2] rose by up to 18%. When measured by the ferric-reducing antioxidant-potential (FRAP) used by the authors, TPAC is usually 0.6–1.6 mM (ref. 4), of which 18% would be 108–288 μM. The rise in TPAC is therefore so large that it is unlikely to be due in significant part to the antioxidant action of epicatechin and its metabolites, or of other phenolics in chocolate.

The FRAP activity of human plasma is mainly attributable to ascorbate, α-tocopherol, bilirubin and urate[4]. Given normal plasma levels of these substances[5], an increase in urate concentration is most likely to account for the results of Serafini *et al.*, because urate is present in plasma at much higher levels than those of other antioxidants, and chocolate is unlikely to contain much ascorbate. Although α-tocopherol may be present in chocolate, even a high intake of this vitamin can increase its concentration in plasma by only a few micromolar at most[5].

The mechanism and consequences of increased plasma urate levels following consumption of chocolate would be interesting to investigate, but should not necessarily be regarded as beneficial. Hyperuricaemia has been associated with stroke, cardiovascular and renal morbidity, and gout[5–8].

Evidence is mounting regarding the potential importance of the overall redox network in disease prevention. It is crucial to our understanding to elucidate the mechanisms by which TPAC is modulated, and the effect of food on this important parameter.

Barry Halliwell

Department of Biochemistry, National University of Singapore, 8 Medical Drive, MD7 #03-08, 117597 Singapore

e-mail: bchbh@nus.edu.sg

1. Halliwell, B. *Nutr. Rev.* **57,** 104–111 (1999).
2. Serafini, M. *et al. Nature* **424,** 1013 (2003).
3. Rechner, A. R. *et al. Free Radic. Res.* **36,** 1229–1241 (2002).
4. Benzie, I. F. F. & Strain, J. J. *Anal. Biochem.* **239,** 70–76 (1996).
5. Halliwell, B. & Gutteridge, J. M. C. *Arch. Biochem. Biophys.* **280,** 1–8 (1990).
6. Weir, C. J. *et al. Stroke* **34,** 1951–1956 (2003).
7. Rott, K. T. *et al. J. Am. Med. Assoc.* **289,** 2857–2860 (2003).
8. Johnson, R. J. *et al. Hypertension* **41,** 1189–1190 (2003).

Nutrition

Milk and absorption of dietary flavanols

Flavanol compounds in wine, cocoa products and tea can exert a cardioprotective effect, for example by influencing endothelial-cell function[1], antithrombic mechanisms[2] and blood pressure[3,4]. Serafini *et al.*[5] claim that consuming dark chocolate, but not milk chocolate or dark chocolate together with milk, increases the antioxidant capacity of human plasma, and suggest that interaction between milk proteins and chocolate flavonoids inhibits the *in vivo* antioxidant activity of chocolate and the absorption of epicatechin into the bloodstream. This inference could have implications beyond chocolate consumption if dairy products do indeed counteract the putative health benefits of dietary flavanols.

The results of Serafini *et al.*[5] are open to a different interpretation if the biological availability and subsequent activity of any compound depends on the varying nutritional and biophysical properties of the matrix in which it is ingested (that is, caloric background, lipid/water content, viscosity, density, extent of mastication). To compare the absorption of epicatechin for chocolate ingested in the presence and absence of milk, it is necessary to control for the composition of the matrix in which the flavanols are delivered.

Compared with values obtained after consumption of dark chocolate alone (100 g, of which about 30 g is lipid), Serafini *et al.* find a lower plasma antioxidant capacity, as well as a reduction in the area under the curve of a plot of plasma antioxidant activity for epicatechin against time, in the case of milk chocolate (200 g, of which about 60 g is