primates from the original data set, so altering the slope of the best-fit line for diurnal primates and strengthening the inference that *T. asiatica* was diurnal. Furthermore, no account was taken of the potential problem of 'phylogenetic inertia'[9]: closely related species may not be statistically independent, so estimates of probability may be open to doubt.

Biologically, one cannot assume that early primates (particularly if unusually small in size) showed the same functional patterns as modern primates — which themselves are very variable. Given that ancestral primates descended from ancestral mammals with smaller eyes, early primates presumably showed only moderate enlargement of their eyes, regardless of their habits. In early primates, the brain was less than half the size of the brains of their modern relatives[3]. So processing of visual inputs was probably more rudimentary, perhaps explaining why some Eocene lemuroids had far smaller orbits than modern diurnal lemurs.

Another source of information comes from a study by Kay and Kirk[8]. To increase visual sensitivity in dim light, nocturnal species show marked retinal summation of inputs from the photoreceptors, resulting in a narrower optic nerve. This is reflected by a narrower opening (foramen) for the optic nerve in the back of the orbit. For living primates, Kay and Kirk found a good match between activity pattern and relative size of the foramen. However, all Eocene primates have a small foramen, regardless of whether they have relatively small orbits (suggesting diurnal vision) or large orbits (indicating nocturnal habits). Thus, visual adaptations in early primates were clearly different from those in modern primates. Finally, a feature on the snout of *T. asiatica*, the infraorbital foramen, is markedly larger than in modern primates. The size of this foramen — large in primitive nocturnal mammals, typically reduced in diurnal mammals — indicates the degree of development of tactile whiskers for non-visual orientation.

I believe, then, that we remain in the dark with respect to the activity pattern of *T. asiatica*. Regardless of that, however, Ni and colleagues' discovery is notable not only for its implications for primate systematics but also from a biogeographical perspective. Until recently, it was widely held that direct migration of mammals between Asia and Europe around 55 million years ago was ruled out by a transcontinental marine barrier. The landmass of Eurasia was largely or completely split down the middle by a combination of the Western Siberian Obik Sea to the north and the Turgai Straits to the south. So it was suggested that the only possibility for interchange of mammals between Asia and Europe was indirect migration across the Bering Straits, through North America and across the Greenland landbridge, or vice versa. However, the presence of closely related *Teilhardina* species in China and Belgium (but not in America) in the early Eocene adds to evidence that migration between Asia and Europe did not necessarily involve such a roundabout route[10]. ■

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Oceanography

# The southern supplier

Joachim Ribbe

Physical processes in the Southern Ocean largely control nutrient distribution in the global marine environment, a finding that further highlights the influence of this oceanic region on Earth's climate.

To understand how climate change comes about, and what the future may hold, we need to untangle the linkages between ocean circulation and the productivity of phytoplankton. Productivity depends on nutrient availability in the ocean and, as phytoplankton are leading players in the global carbon cycle, they partly determine levels of the greenhouse gas carbon dioxide in the ocean and atmosphere.

On page 56 of this issue, Sarmiento *et al.*[1] argue that the Southern Ocean controls the distribution of nutrients in most of the upper ocean throughout the world. It does so through the formation of nutrient-rich water masses, which spread throughout the Southern Hemisphere and into the North Atlantic. A similar process occurs in the North Pacific, but makes a smaller contribution to nutrient availability.

The formation of water masses within defined geographical regions links the global

**100 YEARS AGO**

**Under the title of "The Case for Vaccination," Mr. C. E. A. Winslow gives an admirable survey of the statistical data in favour of the efficacy of vaccination (*Science*, July 24, p. 101). It points out that a single vaccination greatly reduces the probability of an attack of small-pox, postpones it to a later period of life, and renders it less dangerous if it does ensue. To ensure absolute protection revaccination is required. During the small-pox epidemic of 1871, of 734 nurses and attendants in the Metropolitan Asylums Board Hospitals 79 were survivors from small-pox attack, and escaped infection; 645 were revaccinated on entrance, and all escaped; 10 were not revaccinated, and all took small-pox. Mr. Winslow concludes, "if statistics ever proved anything, those quoted prove the protective influence of vaccination."**
**From *Nature* 31 December 1903.**

**50 YEARS AGO**

***Scientific centenaries in 1954.* The modern use of a surname is so well established that it is worth recalling that, as late as the fifteenth century, hereditary surnames were by no means general, it being the custom to add to the baptismal name the place of the owner's birth or residence, or his occupation or some peculiarity that would identify him. Thus we find that Hermann, an eleventh-century monk, was known as Hermann of Reichenau, after the abbey in Switzerland where he spent most of his life, or Hermann the Cripple, on account of the paralysis which had afflicted him from youth. Hermann, born in 1013, has been described as one of the most learned men of his age, and interests us particularly because he was devoted to the study of mathematics and astronomy… He died in 1054, at the castle of his father, Count Wolferad of Alshausen… The year 1954 marks the five hundredth centenary of the birth of the Italian astronomer Domenico Maria di Novara… Passing from Italy to Germany, we note the death in 1554 of Jerome Block, the herbalist… His great herbal, "New Kreütter Bůch", which appeared first in 1539, is remarkable because Bock was the first botanist to attempt descriptions, from direct observation, which would render illustrations unnecessary. To obtain his material he made long journeys on foot, dressed as a peasant, to avoid undue attention. Illness and misfortune clouded his later life, and he died when only fifty-six, predeceased by eight of his ten children.**
**From *Nature* 2 January 1954.**

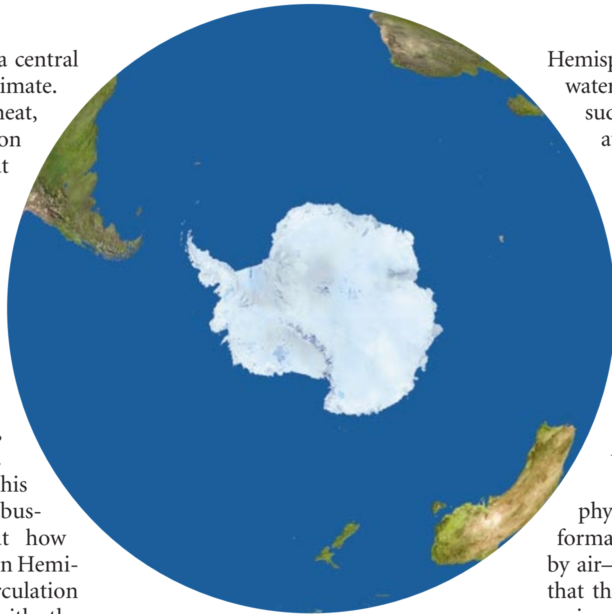
ocean and the atmosphere, and is a central mechanism of oceanic control of climate. They constitute a repository for heat, fresh water and gases such as carbon dioxide, all of which are exchanged at the ocean–atmosphere interface. On the largest scale, the water masses spread and fill the ocean basins. These huge bodies of water are also the engines of large-scale ocean circulation, one that is primarily driven by so-called North Atlantic Deep Water (NADW). As its name suggests, this is water that forms at high latitudes in the North Atlantic, sinks to depth and flows southwards.

Since the initial recognition of this circulation[2], oceanographers have busied themselves with finding out how NADW is resupplied to the Northern Hemisphere. A complex pattern of circulation pathways has become evident, with the Southern Ocean (Fig. 1) apparently having an important role in the production and interchange of water masses[3,4]. Subantarctic Mode Water (SAMW) is a large water mass created by exchange of heat and fresh water with the atmosphere over much of the Southern Ocean. It sinks below the ocean surface[5,6] and moves northwards at depths of about 200–600 m. These regions of the Southern Ocean can be thought of as windows to the deep ocean that allow water of particular heat, freshwater and nutrient content to enter the subsurface ocean.

The surface regions where SAMW is formed are characterized by low levels of silicic acid and high concentrations of nitrate. Sarmiento *et al.*[1] apply a newly designed 'conservative' tracer that captures this nutrient signature as a characteristic of SAMW. Their analysis of its distribution shows that SAMW reaches most of the world's upper ocean — that is, much of the global marine environment receives nutrients from the surface of the Southern Ocean. Another water mass, known as North Pacific Intermediate Water, has a subordinate role only: its nutrient delivery is limited to the upper ocean of the North Pacific.

Sarmiento *et al.*[1] also performed several computational experiments. They used a model of the global ocean that couples physical and biological processes, and came up with a reason why diatoms, a major component of the phytoplankton, do not reach their full productive potential in much of the global ocean. By varying the strength of the nutrient source in their models, Sarmiento *et al*. found that the ratio of silicic acid to nitrate in SAMW is less than ideal for diatom growth, and is therefore a primary cause of diatoms' widespread low productivity.

The conclusion that a physical process, and one operating in only a tiny part of the world's oceans, has such a huge influence on productivity is startling in itself. But there are more lessons to be learned from the new work[1].



WORLDSAT INT./SPL

Figure 1 **Well connected. The Southern Ocean surrounds Antarctica but has a global influence on marine productivity.**

First, use of the new tracer as a diagnostic tool allows further insight into the dynamics of present-day ocean circulation. In particular, it has revealed that Antarctic surface water, driven northwards by the winds, contributes to the characteristics of SAMW. This finding supports earlier studies of this water mass[6,7] and highlights the more general point that models of the climate system have to capture accurately the physical processes through which water masses form.

Second, the simulations identify a possible deficiency in representing mixing processes in the North Pacific. Models of the climate system may have to include the possible effect of tides on water-mass formation globally, which in turn has implications for the global influence exercised by the outflow characteristics of NADW.

Third, the SAMW pathway does more than provide nutrients for the upper branch of the ocean circulation. In the Southern Hemisphere it also supplies heat and fresh water to the thermocline — the layer of sudden temperature change that occurs at varying depth below the surface and effectively separates the upper, productive part of the ocean from the deeper waters. The authors do not stress this point, but it is highly topical, given its bearing on our understanding of climate variability in the tropics. At the moment there is vigorous debate over the question of oceanic 'teleconnection' of high and mid-latitudes with low latitudes, which may drive year-to-year climate variability in the tropics[8].

As to the climate connection, the physical processes that lead to water-mass formation in the Southern Ocean are driven by air–sea interactions. The indications are that the Southern Ocean is one of the few regions of the global ocean where the atmospheric consequences of climate change enter the ocean[9]. Any perturbation of the formation of SAMW, and subsequently of ocean circulation, is likely to have a dramatic impact on global marine productivity. That will affect the levels of carbon dioxide in the atmosphere, which in turn are linked to global temperature changes[10]. The overall conclusion is that the Southern Ocean has as powerful an influence on climate change as the North Atlantic. Difficult though it may be, it would pay to monitor conditions there. ■

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**Cell biology**

# Shape-shifting protein channel

Jordi Benach and John F. Hunt

**Newly made proteins are moved across cellular membranes through a protein channel. The crystal structure of this channel is now revealed and confirms expectations that it must change shape to allow proteins to pass.**

All cellular proteins are synthesized in the body of the cell, the cytosol. But many of them must then be transported through phospholipid membranes to reach their final destinations, which might be intracellular compartments or even, following secretion, outside the cell[1–5]. The molecular mechanism of this 'translocation' process has been the subject of elegant biochemical[1,4–9], genetic[3] and biophysical[10–12] studies. This body of work has shown that the main secretion pathway in all kingdoms of life involves a heterotrimeric protein complex, or translocase[4,5], which forms a