



**Figure 1 | Nitrification in the global nitrogen cycle.** Ammonia oxidation is the first step of nitrification, the process in which ammonia ( $\text{NH}_3$ , of organic origin) is oxidized to nitrate ions ( $\text{NO}_3^-$ ). Nitrification occurs on land and in the oceans and is essential for the global cycling of nitrogen. The process was long thought to be performed solely by bacteria, but certain archaea (Crenarchaeota) have recently been shown to be capable of ammonia oxidation, and to contain genes for ammonia monooxygenase (AMO, the key enzyme involved in ammonia oxidation). **a**, AMO converts ammonia into hydroxylamine ( $\text{NH}_2\text{OH}$ ). **b**, Hydroxylamine is converted by the same microorganisms into nitrite ions ( $\text{NO}_2^-$ ) — a protein that catalyses this process has not yet been found in archaea. **c**, Other specialized bacteria complete nitrification by converting nitrite ions to nitrate ions. **d**, The nitrate is then either assimilated into organic matter or denitrified by other microorganisms to produce nitrogen, which escapes into the atmosphere. **e**, ‘Anammox’ bacteria can also convert ammonia and nitrite ions into nitrogen. **f**, Nitrogen is fixed mostly by specialized bacteria, producing ammonia. This can be incorporated into organic matter, or oxidized as the cycle continues. Agogué *et al.*<sup>5</sup> show that ammonia-oxidizing archaea are abundant in the North Atlantic Ocean, but not in the deep sea of equatorial regions.

regions down to the Equator. They then quantified the ratio of the number of archaeal *amoA* genes in the samples to the total number of Crenarchaeota, the latter number being determined by measuring the abundance of an RNA gene that is ubiquitous in these organisms.

The results<sup>5</sup> indicate that the ratio decreases markedly from subtropical to equatorial regions, and also from subsurface waters to the deep ocean. Whereas the concentrations of *amoA* genes found at all depths in polar regions were high, they were 1,000 times lower than the concentration of total Crenarchaeota found in the bathypelagic waters (1,000–4,000 metres) of subtropical regions. The authors therefore conclude that most deep-sea Crenarchaeota in subtropical waters do not oxidize ammonia. Perhaps tellingly, the concentration of ammonia in subtropical deep waters is considerably lower than in the equivalent polar regions, where potential ammonia oxidizers are found in high numbers.

Agogué *et al.* also measured the ability of microorganisms taken from the locations described above to fix inorganic carbon. They found that the decreases in *amoA* abundance seen in their experiments<sup>5</sup> mirror the observed patterns of carbon fixation — as the ability of marine microorganisms to fix carbon declines, so does the number of *amoA* genes in the archaeal population. This in turn

suggests that deep-sea Crenarchaeota are not autotrophs.

Although these findings<sup>5</sup> significantly refine our perception of crenarchaeotal metabolisms in the ocean, some caveats remain. The authors’ gene-detection method assumes that archaeal *amoA* genes are similar to known *amoA* genes. But it is difficult to rule out the possibility that Agogué *et al.* simply missed specific variations of *amoA* genes that are typical of deep-water Crenarchaeota alone. Numerous cases exist in microbial ecology in which DNA-detection methods completely overlooked specific groups of genes, including *amoA* genes.

Similarly, Agogué and colleagues’ data do not conclusively prove that deep-sea Crenarchaeota are not autotrophic. But their conclusions are supported by evidence from a series of previous studies<sup>11–14</sup> that reported the incorporation of organic carbon sources into Crenarchaeota, thus indicating that at least some Crenarchaeota are heterotrophic — they take up organic carbon for growth.

It was not clear from the earlier studies<sup>11–14</sup> whether heterotrophic growth is a fallback option for otherwise autotrophic, ammonia-oxidizing archaea, or whether distinct populations of Crenarchaeota exist that are strictly either heterotrophic or autotrophic. Agogué and colleagues’ findings<sup>5</sup> suggest the existence of specific heterotrophic Crenarchaeota,



## 50 YEARS AGO

The first symposium on space medicine to be held in Great Britain was held at B.M.A. House, London, on October 16 and 17 ... The symposium was arranged to discuss the reactions of man to the conditions that will be encountered in space and on other planets, and of the equipment that will be required for survival in these hostile environments ... It is certain that man will travel into space within a few years. His first venture will probably be in orbit, close to the Earth, and lasting a few hours. His second venture will be to the Moon, and his third to one of the planets. Voyages beyond our own solar system are difficult to comprehend, but should not be dismissed too lightly. The reason for man travelling into space is a controversial subject. Some contend that he merely adds to the complexity of the space vehicle; others that he will earn his keep by taking decisions ... The fact remains, however, that he will go, and that he will be faced with many of the problems discussed at the symposium.

From *Nature* 13 December 1958.

## 100 YEARS AGO

From Prof. Haberlandt’s laboratory at Graz there has been issued another paper on the perception of light by plants ... The author, Dr. K. Gaulhofer, has studied the epidermal cells of the leaves of certain plants that take up a fixed light position, and suggests that an explanation may be found in the presence of pits or clefts in the cell walls acting as light distributors ... The rays of light impinging on the edges of the pits are deflected, and consequently, underneath the pits, shadows are produced. Good instances of such pits occur in *Aporrhiza paniculata* and *Banisteria splendens*, while *Hyperbaena laurifolia* and *Abuta concolor* show well-marked clefts. The combination of pits and curved cell wall in *Cocculus laurifolius* will repay examination.

From *Nature* 10 December 1908.

50 & 100 YEARS AGO