

tracked clones of coronary arteries, veins and capillaries back to cells expressing the VE-cadherin protein. This result is the strongest argument yet against a PEO origin for coronary arteries, because the cells of this structure do not express VE-cadherin. Even more intriguingly, perhaps, this represents visual evidence of endothelial-cell reprogramming, which is further supported by Red-Horse and colleagues' description of a cell-autonomous switch from signatures of venous to arterial gene expression.

The significance of these observations<sup>1</sup> extends beyond the field of basic embryology. An understanding of both the origin of coronary vessels and the cell types that contribute to them during development is arguably an essential prerequisite for successfully stimulating the process of new vessel formation to treat coronary-artery disease in adult patients. Nonetheless, interesting questions remain for both developmental biologists and cardiologists.

For one, could it be that the PEO gives rise to a subpopulation (however minor) of endothelial cells and/or itself contributes progenitors to the sinus venosus? Indeed, both the PEO and sinus venosus might themselves arise from a common early progenitor-cell pool. Although Red-Horse *et al.* attempted to tackle

these questions, further embryological studies, which will benefit from the development of improved lineage-specific genetic markers, are required to obtain unequivocal answers.

From a more translational research standpoint, identifying the molecular cues that promote developmental reprogramming of vasculature as described here — vein-to-artery 'switch' — and targeting such signals towards an equivalent venous cell population in the adult organ could facilitate the formation of new coronary vessels for re-vascularization of a diseased heart. Thus, Red-Horse and colleagues' work may represent the first tentative step towards engineering a non-surgical, coronary-artery bypass as a vascular therapy to counter the main cause of death worldwide. ■ Paul Riley is in the Molecular Medicine Unit, UCL Institute of Child Health, London WC1N 1EH, UK. e-mail: p.riley@ich.ucl.ac.uk

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## CARBON CYCLE

# A warm response by soils

Pete Smith and Changming Fang

**The flux of carbon from soils to the atmosphere has apparently increased with climate warming. But does this reflect a net loss of carbon to the atmosphere that could exacerbate climate change?**

The world's soils contain twice as much carbon as the atmosphere<sup>1</sup>. As a result, small increases in organic carbon loss from soils could greatly enhance carbon dioxide concentrations in the atmosphere<sup>2</sup>, potentially creating a positive feedback on climate<sup>3</sup>. On page 579 of this issue<sup>4</sup>, Bond-Lamberty and Thomson add to our understanding of how soils might respond to climate change.

The climate is warming<sup>5</sup>, and it has long been assumed that, as soils warm, the rate of carbon flux to the atmosphere (through soil respiration;  $R_s$ ) will increase. However, this has been very difficult to confirm from measurements because  $R_s$  is highly spatially variable, it cannot be measured by large-scale remote sensing, and the soil medium is not easily accessible<sup>4</sup>. Bond-Lamberty and Thomson present an analysis of a five-decade record of global  $R_s$  chamber measurements, matched with high-resolution historical climate data and corrected for other factors, to show that, over the past 20 years,  $R_s$  has increased with climate warming. From the results of their meta-analysis, the authors also

estimate that  $R_s$  is much larger than previously reported.

But these findings do not necessarily mean that soils are losing a greater proportion of their large carbon stores to the atmosphere. Increases in  $R_s$  can also arise from the loss of fresh carbon inputs to the soil, driven by increased plant growth owing to climate change (at least in cooler regions; Fig. 1, overleaf). As Bond-Lamberty and Thomson point out<sup>4</sup>, their results may well represent an increase in the rate of carbon cycling, rather than a big shift between the global carbon pools in soils and the atmosphere.

Assessing the balance between increased soil carbon inputs through greater plant growth due to climate warming, and increased carbon losses through higher decomposition rates, should be a research priority. There are several methodological challenges to doing so.

One is accurately determining the carbon input to the soil, especially below-ground inputs from fine-root turnover and exudation. Another is to detect a small change in the



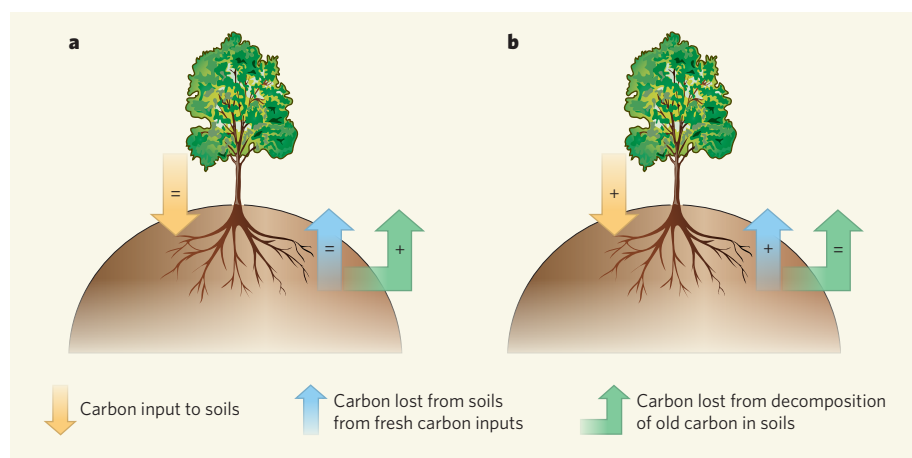
## 50 YEARS AGO

A recent report from British Glues and Chemicals, Ltd., reflects the increasing interest in leaf protein; the Chayen impulse process, introduced a few years ago by this firm for the disintegration and extraction of bones and animal fats, has now been applied to a variety of other materials, including oilseeds, such as groundnuts, and grasses. The principle of this method lies in the use of shock waves of sufficient intensity and frequency to burst the tissues and cells of biological materials; it is illustrated by the depth-charge technique used in anti-submarine warfare ... The report states that 100 tons of fresh grass ... treated by the Chayen method yields about 2¼ tons of edible protein. From *Nature* 26 March 1960.

## 100 YEARS AGO

*Music: its Laws and Evolution.* By Prof. Jules Combarieu — This important work could only have been written by a musician who was acquainted with the history of music, and also had a considerable knowledge of sciences connected with music, such as mathematics, physics in relation to acoustics, physiology, psychology, and aesthetics ... The fundamental thesis of the book is that music is the art of thinking in sounds ... Great as are the works of Bach, Handel, Verdi, and Wagner, each reflecting in a subtle way their individual genius, moulded by the circumstances in which they lived and the influences that conspired to make them great musicians, there may yet be in store for the human race even greater works, which, in their turn, will reflect the more complex conditions of civilisation, in even higher planes of non-conceptual thought, and in deeper knowledge and feeling. One may also suppose that in this further evolution the organs of music, the ear and the brain, will become more complicated. The evolutionary process has not ended. From *Nature* 24 March 1910.

50 & 100 YEARS AGO



**Figure 1 | Possible mechanisms driving increased soil respiration ( $R_s$ ) in a warming climate.** **a**, An increase in  $R_s$  could occur through a rise in the decomposition rate of old soil organic carbon, leading to a net loss from the global pool of soil carbon to the atmosphere. **b**, If carbon inputs to the soil increase, higher  $R_s$  could derive from enhanced release of fresh carbon. In this second case, there would be no net loss of carbon from the global soil pool. The findings of Bond-Lamberty and Thomson<sup>4</sup> leave open which of these processes — if not a combination of them — is likely to dominate.

content of soil organic carbon (its state) within a reasonable time period. A third is measuring the components of carbon output, particularly in distinguishing between output due to increased respiration from plant roots and the immediate root environment, and output due to respiration from free-living microbes in the bulk soil. These have often been referred to as autotrophic and heterotrophic respiration ( $R_A$  and  $R_H$ , respectively), but the distinction between them is blurred because of the close association of plants and soil organisms. Bond-Lamberty and Thomson's findings show that total  $R_s$  has increased, and suggest that both  $R_A$  and  $R_H$  have also risen. A barrier to reliably predicting the future of global fluxes of soil organic carbon to the atmosphere is the uncertainty associated with measuring all three components of soil carbon cycling (input–state–output).

Bond-Lamberty and Thomson's analysis<sup>4</sup>

also throws up a curiosity in northern soils. The authors fit a single global model to all of the  $R_s$  data from 1989 to 2008, which gives a positive global relationship between  $R_s$  and temperature. An unexpected result, however, is that the  $R_s$  data from the boreal and Arctic regions, when examined in isolation, show a significant negative relationship with temperature, which is unexpected from previous studies<sup>6–10</sup>.

This finding adds an intriguing aspect to the debate about how northern soils will respond to climate change, in which the following factors have to be taken into account. The boreal and Arctic regions are projected to experience greater than average climate warming<sup>1</sup>; they contain some of the largest soil carbon stocks on Earth<sup>11</sup>; the permafrost experiences seasonal temperatures either side of 0 °C such that small levels of warming could have profound effects on biological activity and carbon fluxes<sup>9</sup>; and

permafrost processes and highly organic soils such as peats are relatively poorly described in current coupled carbon-cycle–climate (C4) models<sup>12,13</sup>. For all these reasons, the response of northern soils to climate change is a fertile area for future research.

At the global level, however, Bond-Lamberty and Thomson's elegant analysis lends strong support to the hypothesis that soil carbon fluxes will increase in a warming climate. The outcomes of their meta-analysis should further drive efforts to develop methods to disaggregate the underlying processes contributing to  $R_s$ . Without understanding these processes, it will not be possible to accurately predict the net response of soil carbon stores to climate change — and that is a central question for determining the biospheric feedbacks between the carbon cycle and climate.

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## BIOGEOCHEMISTRY

# NO connection with methane

Ronald S. Oremland

**Microorganisms that grow by oxidizing methane come in two basic types, aerobic and anaerobic. Now we have something in between that generates its own supply of molecular oxygen by metabolizing nitric oxide.**

On page 543 of this issue, Ettwig *et al.*<sup>1</sup> report their discovery of a new type of methane-oxidizing (methanotrophic) bacterium, provisionally dubbed *Methyloirabilis oxyfera*. As its name suggests, this microbe does something quite unexpected: the process involved could provide another angle on our understanding of the biology and chemistry of the early Earth, and perhaps even extend to the possibility of

life on other methane-rich bodies in the Solar System.

*Methyloirabilis oxyfera* conducts what seems to be an anaerobic, nitrite-linked oxidation of methane ( $\text{CH}_4$ ) via a denitrification pathway to yield nitrogen and carbon dioxide. But Ettwig *et al.* show that this organism defies convention and, by means of a putative nitric oxide (NO) dismutase enzyme, reacts to

produce  $\text{N}_2$  and oxygen. The intracellular  $\text{O}_2$  produced is used to metabolize methane via the well-described pathway of aerobic methanotrophy initiated by the enzyme methane monooxygenase (Fig. 1a). NO dismutase is one of just a handful of enzymes that are known to evolve molecular oxygen. Hence, *M. oxyfera* can consume methane in anoxic environments that are rich in nitrogen oxides, such as the freshwater sloughs contaminated with nitrogenous fertilizer run-off investigated by Ettwig and colleagues. Nevertheless, the bacterium is at heart a cryptic aerobe, but rather than getting its  $\text{O}_2$  from the atmosphere, it generates its own from the ambient nitrite. Essentially, it contains its own little scuba tank that allows it to 'breathe' oxygen while immersed in methane-rich anoxic muck, thereby accessing the methane that conventional methanotrophs cannot reach.

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