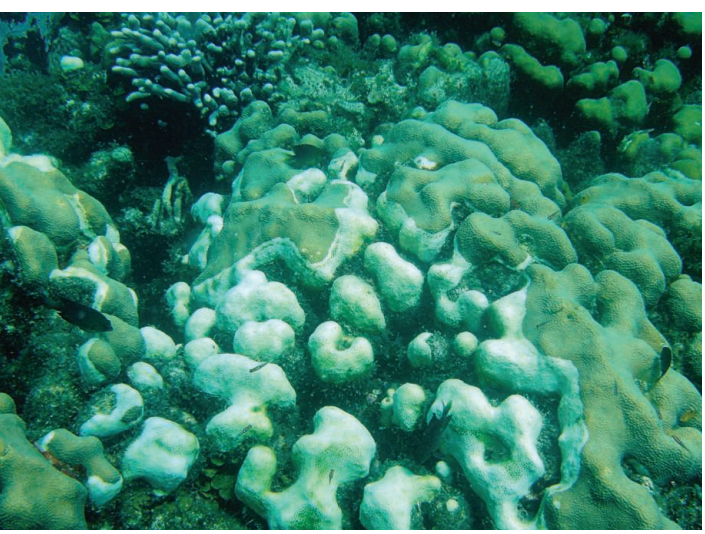
LETTERS

edited by Jennifer Sills

Coral Diseases Cause Reef Decline

THERE HAS BEEN A GREAT DEAL OF DISCUSSION ABOUT THE ROLE OF BLEACHING IN CORAL REEF degradation worldwide (*1–3*), but little focus on the numerous other coral diseases that are also causing substantial declines.

In the late 1970s and 1980s, disease caused extensive mortality in elkhorn coral (*Acropora palmata*) and staghorn coral (*A. cervicornis*), radically changing the shallow Caribbean seascape (*4*). The damage was so severe that these species became the only corals listed as threatened under the U.S. Endangered Species Act (*5*). More recently, almost all stony coral (*Scleractinia*) species in the Caribbean have been affected by one or more diseases. White plague and Caribbean yellow band have been particularly devastating in the Caribbean, causing declines in living coral cover of more than 50 to 60% (*6–8*). Diseases are becoming more widespread on Pacific reefs as well (*9*).



Diseased reef-building coral in the Caribbean.

Bleaching occurs with the disintegration and expulsion of symbiotic microalgae from corals, usually in association with higher seawater temperatures. Bleached corals are still alive, and bleaching is reversible if temperatures cool quickly enough. Bleaching differs from diseases that are associated with initial tissue loss.

Disease outbreaks are not as predictable as bleaching episodes; sometimes extensive reef areas become diseased without any preceding bleaching event or several months after bleaching (*8*). Diseases can kill individual corals in the absence of any major outbreaks, causing inconspicuous but damaging incremental losses. Even low levels of disease can have serious consequences if they are chronic.

With climate change, seawater temperatures are predicted to increase and bleaching episodes are expected to become more frequent. However, the relationships among increasing seawater temperatures, bleaching, and disease have not been well-established (*10*).

To prevent and treat diseases as well as bleaching, we must conduct further research on the links between human actions and coral reef condition, as well as on the potential for reef resilience. Reducing stressors such as excess nutrients from sewage or high levels of sedimentation could make corals less likely to bleach or become diseased, and/or more likely to recover (*11–14*).

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Reversing Excess Atmospheric CO_2

IN THEIR PERSPECTIVE "IRREVERSIBLE DOES not mean unavoidable" (26 April, p. 438, published online 28 March), H. D. Matthews and S. Solomon state that the effects of past anthropogenic CO_2 emissions are "irreversible on a time scale of at least 1000 years." Recent research suggests that this may not be true. A variety of carbon cycle interventions have been proposed, which in theory could substantially add to the natural, slow removal of atmospheric CO_2 [e.g., (*1–4*)] and/or increase the retention of carbon on land or in the ocean [e.g., (*5–8*)].

The natural fluxes of CO_2 into and out of the atmosphere, each more than 700 Gt/year, are exquisitely balanced, and individually dwarf the annual CO_2 input from human activity (*9*). Creating a relatively small decrease in this ratio of input to output CO_2

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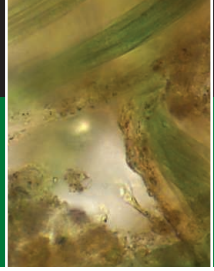

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by means of active management of natural fluxes [e.g., (*2*, *7*, *8*)], purely artificial strategies [e.g., (*1*, *3*)], or hybrid approaches [e.g., (*1*, *5*, *6*)] could therefore hasten the removal of CO_2 from the atmosphere. Indeed, the sensitivity of atmospheric CO_2 concentration to natural variations in this ratio is clearly evident in this concentration's seasonal rise and fall (*10*).

The cost-effectiveness, safety, capacity, and environmental and societal desirability of proactively reducing atmospheric CO_2 input/output (in addition to reducing anthropogenic CO_2 emissions) have yet to be fully evaluated. Until these strategies are better understood, it is premature to conclude that removal of existing, excess atmospheric CO_2 cannot be accelerated. Such methods may indeed prove essential given our ongoing failure to reduce our CO_2 emissions and, hence, to stabilize if not lower historically unprecedented atmospheric CO_2 concentrations (*10*) and associated effects on climate and ocean chemistry.

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Response

RAU AND LACKNER SUGGEST THAT WE SHOULD qualify our statements about the irreversibility of anthropogenic climate change with a caveat acknowledging the possibility of future technological interventions that can either actively remove CO_2 from the atmosphere or artificially cool the planet by reflecting solar radiation. We agree that it is important to discuss and debate the potential utility and effectiveness of carbon dioxide removal technologies as a future strategy to decrease atmospheric CO_2 concentrations. However, we do not feel these technologies will be relevant for the time scales we discussed in our Perspective.

Geoengineering interventions involving solar reflection do not constitute true reversibility of climate change. This type of intervention would only temporarily decouple global temperatures from rising atmospheric CO_2 concentrations (*1*), would lead to continuing ocean acidification (*2*), and could increase the risk of damaging changes in rainfall patterns (*3*, *4*).

Some carbon cycle geoengineering technologies may provide true reversibility by accelerating the removal of anthropogenic CO_2 from the atmosphere. If these technologies were combined with aggressive mitigation efforts, they could potentially meet long-term climate targets that would otherwise be inaccessible (*5*, *6*). However, although such technologies may be effective in principle, and some have been subjected to limited tests, at present most remain far from development or implementation (*7*). In addition, many such technological interventions in the climate system also carry the potential for environmental damage that may far exceed the climate benefit of sequestered CO_2 (*8*).

Finally, technologies that hold the largest promise with the least potential for harmful side effects [notably those in the area of direct air CO_2 capture (*9*, *10*)] are also thought to be very expensive and unlikely to be implemented on the time scale of the infrastructure commitments to carbon-intensive energy sources with which our article is concerned (*5*).

In a discussion of the potential for immediate or near-future action to slow the growth of atmospheric CO_2, we suggest that consideration of carbon dioxide removal (or other geoengineering) technologies would at best be not very relevant, and at worst could distract from the imperative of decreasing investment in energy technologies that lead to large CO_2 emissions.

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Good Grades for Dual Education

IN THE EUROPEAN UNION, 23.2% OF PEOple ages 15 to 24 (roughly 6 million people) are unemployed (*1*). Surprisingly, EU youth unemployment is higher in countries where more young people have university degrees. In France, Greece, and Spain, surveys show that 43, 42, and 39%, respectively, of people ages 25 to 35 have university degrees, compared with only 25% in Germany (*2*). However, the average youth unemployment has risen to 26.5% in France, 57.9% in Greece, and 55.9% in Spain, whereas in Germany is it only 7.6% (*1*).

One explanation for this discrepancy may be Germany's vocational education model. Referred to as dual education, this system combines classroom and business, theory and practice, and learning and working. It has been widely recognized as contributing to Germany's employment of young people (*3*, *4*). More than 50% of German high school students enroll in the dual-education system instead of traditional higher education (*5*). In contrast, few high school graduates in

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France choose vocational education (*3*, *6*). Rather than improving youth skill through vocational education, the French government has relied on ambitious job creation plans for young people since the mid-1990s (*4*, *7*). For example, the French government released a plan in 2009 to provide €1.3 billion ($1.7 billion) in tax breaks and cash incentives for employers who hired young people. However, the track record of targeted programs is dismal, and youth unemployment in France has continued to rise (*1*).

Youth unemployment in the European Union reminds us that there is a deepening mismatch between what the labor market needs and what the education system is producing. It is time to reform the current higher education system to prevent the most educated generation of young people from becoming a generation of the unemployed.

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Letters to the Editor

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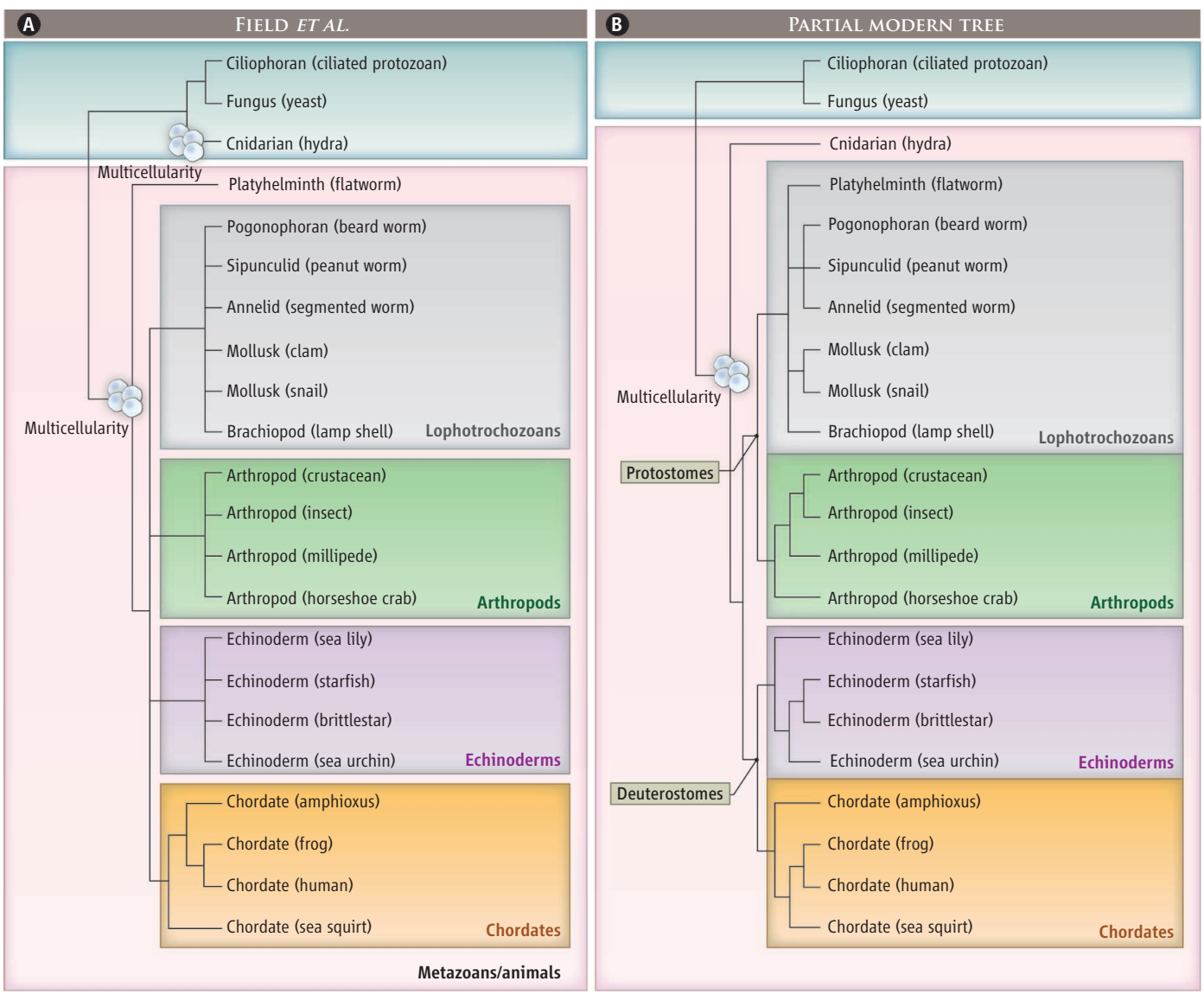
CORRECTIONS AND CLARIFICATIONS

Perspectives: "The animal tree of life" by M. J. Telford (15 February, p. 764). In the original figure, the symbol indicating multicellularity in the main group of animals was misplaced in both panels. The symbols have now been placed in the correct position. The revised figure is shown here. The figure has been corrected in the HTML and PDF versions online.



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