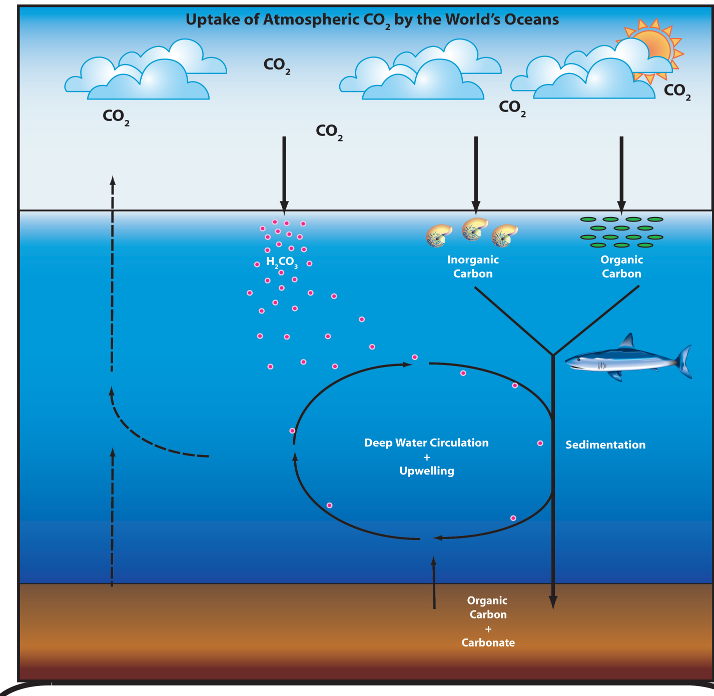
# Ocean Acidification

## Are the oceans turning acidic?

The short answer is no. Technically the changes forecast by scientists will result in a reduction of the oceans' pH, however, it is not expected that the pH will fall below the neutral "7", at least within the near future. Although the catchphrase "acidification" may seem slightly misleading, there is definitely a need for better understanding of the potential impacts of a low pH environment on the ocean ecosystem. The world's oceans absorb atmospheric carbon dioxide ($CO_2$) through two mechanisms; diffusion due to its solubility (product = carbonic acid, $H_2CO_3$); and biological processes, such as photosynthesis (products = inorganic carbonates, $CaCO_3$), or organic carbon (product = soft tissues of organisms). Due to light and nutrient limitations on the biological uptake of $CO_2$, diffusion plays the most important role in the absorption of $CO_2$ from the atmosphere. Since the start of the industrial revolution, humans have added such vast quantities of $CO_2$ that its concentration in the air today exceeds that inferred for at least the past 50 million years. This has greatly increased the amount of $CO_2$ being dissolved by the ocean, which has in turn, increased the production of $H_2CO_3$. This increase in production has already decreased the ocean's pH by 0.1 units (logarithmic scale), and is expected to decrease by a further 0.3 - 0.5 units by the year 2100[1,2,3]. This predicted drop in pH may appear insignificant, however, it significantly alters the carbonate chemistry of seawater because when $H_2CO_3$ is formed it "uses" carbonate ions. Currently, the surface oceans are supersaturated with respect to aragonite and calcite, the carbonate-based building blocks of all shell-building animals. An increase in $H_2CO_3$ will reduce the saturation levels of the oceans, reducing the ability of these organisms to produce shells and other skeletal structures.




Schematic diagram of the simplified fate of CO2 once absorbed by the ocean

## Has this happened before?

So far this question is still under investigation. By looking at marine archives, scientists have been able to show that at the onset of the industrial revolution, ocean pH and carbonate mineral saturation were already near the minimum values reached over the Pleistocene (1.8 Ma); hence the industrial revolution occurred at a time when the oceans were particularly susceptible to further reductions. Looking further back in time through the Cenozoic Period (65 Ma), there is no indication of either undersaturation of carbonate minerals or a decrease in ocean pH.

So current paleo research suggests that there is no past equivalent of the present-day CO2 emissions. However, projected future emissions may compare with the Paleocene-Eocene Thermal Maximum (PETM; 55 Ma) or the mass extinction events of the Cretaceous-Paleogene (K-Pg; 65 Ma) boundary, and this is now the focus of future paleo-research.

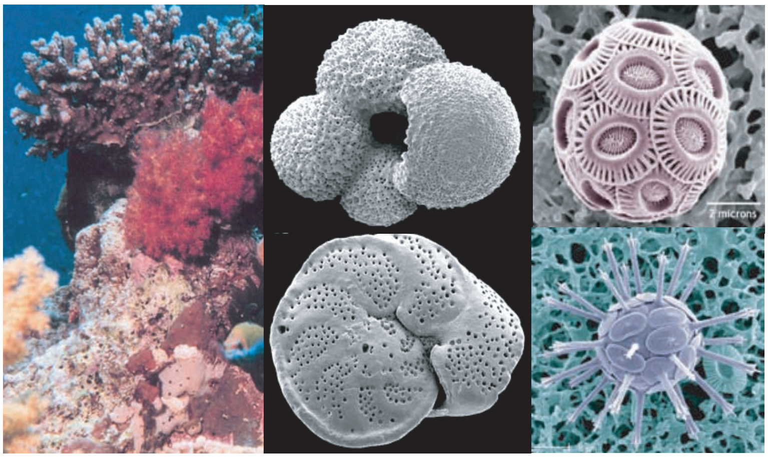
The current understanding is that the amount of carbon released into the environment during the PETM is comparable to what we could release over the next decades/centuries. Similarly, large-scale extinctions at the K-Pg boundary may have been caused by ocean acidification, although co-occurring factors may also have played a role.

# How will this effect the ocean ecosystem?

This is the BIG QUESTION when discussing ocean acidification, and currently we are unable to predict how marine organisms will respond. The most optimistic view is that for organisms with short generation times, micro-evolutionary adaptation could be rapid enough for adversely affected species to be replaced by a more $CO_2$ -tolerant strain, with minimal ecological impacts. Pessimistically, $Co_2$-sensitive groups (e.g., marine calcifiers) will be unable to compete ecologically, with profound ramifications up the food chain, including widespread extinctions.

Experimental reserach into specific organism responses shows that corals in particular have a linear relationship between calcification rate and the carbonate saturation of the oceans. The relationship is less clear for forams and coccolithophores, however, these experiments have involved only small numbers of individuals over short time periods and cannot be used to predict ecosystem responses on longer time scales.

For this information, we must once again turn to the paleorecord of ecosystem responses. Although paleorecords indicate no obvious parallel with today's situation, there have been times (e.g. the aforementioned PETM and K-Pg boundary) when carbon emissions were at the levels predicted in coming decades/centuries, if we do not reduce our emissions. These records indicate that during the PETM, disruptions to the marine fauna were confined to bottom dwellers, with no distinct impact on the pelagic groups. In comparison, the K-Pg saw large scale marine extinctions, with many of the planktonic calcifiers and corals becoming extinct. Paleorecords also indicate that it took millions of years for the ecosystem to recover, implying that the chemical and ecological effects of $CO_2$ levels that we are predicted to reach, are basically irreversible on societal timescales. A lot more research is required to clarify the full effects of ocean acidification on the marine ecosystem, as this situation will obviously have resounding implications when considering the stability of fisheries and industries important for the economy.




Examples of some calcifying organisms that may be adversely affected by future ocean acidification. Left to right; Corals, Foraminifera, Coccolithophores

# What can be done?

The most obvious answer to this question is to reduce $CO_2$ emissions to pre-industrial levels, however this is neither realistic nor feasible. The solution must come from a combination of both prevention and adaptation measures. This, however, requires governmental recognition of the problem, and this, in turn, requires a better understanding of the processes that are involved, and how they have effected ecosystems in the past. Research into this issue is not clear cut, as other large-scale and complex factors must be taken into account. For example, human-induced changes in ocean temperature and ocean circulation are two major issues that directly affect predictions of the effects of a low pH ocean on the modern-day ecosystem.

# Further Information

Many scientific publications exist on this topic. Listed below are just a few references to get you started,


1) Caldeira, K., and Wickett, M.E. (2003) Anthropogenic carbon and ocean pH. *Nature,* 425, 365-365

2) Orr, J. C. et al. (2005) Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. *Nature,* 437, 681-686

3) Raven, J. A. et al. (2005) *Ocean acidification due to increasing atmospheric carbon dioxide* Royal Society, London, UK

4) Kiefer, T. (2006) IGBP-SCOR Workshop: Ocean acidification- modern observations and past experiences, *PAGES News*, 14:3, 29-30