The other carbon-dioxide problem

Acidification threatens the world's oceans, but quantifying the risks is hard

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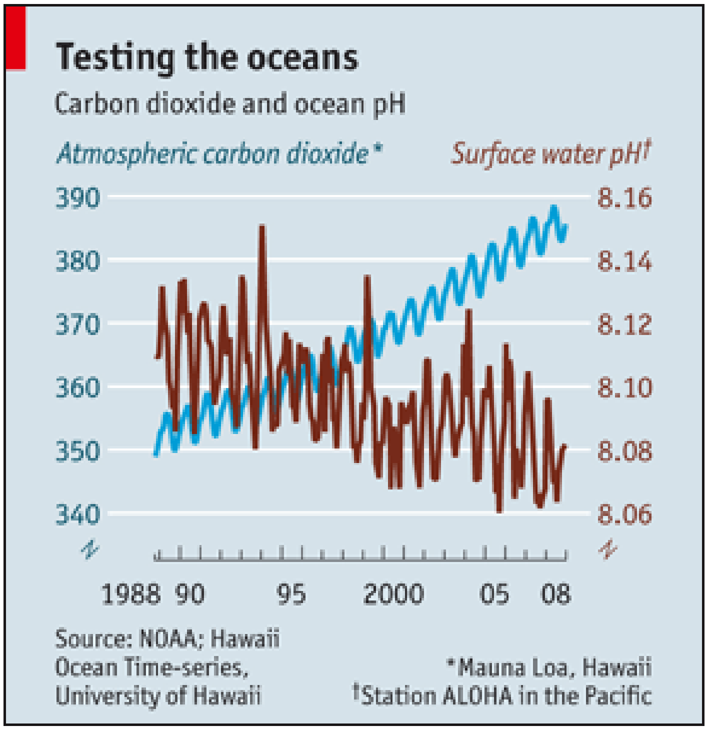
IN THE waters of Kongsfjord, an inlet on the coast of Spitsbergen, sit nine contraptions that bring nothing to mind as much as monster condoms. Each is a transparent sheath of plastic 17-metres long, mostly underwater, held in place by a floating collar. The seawater sealed within them is being mixed with different levels of carbon dioxide to see what will happen to the ecology of the Arctic waters.

As carbon dioxide levels go up, pH levels come down. Acidity depends on the presence of hydrogen ions (the H in pH) and more hydrogen ions mean, counterintuitively, a lower pH. Expose the surface of the ocean to an atmosphere with ever more carbon dioxide, and the gas and waters will produce carbonic acid, lowering pH on a planetary scale. The declining pH does not actually make the waters acidic (they started off mildly alkaline). But it makes them more acidic, just as turning up the light makes a dark room brighter.

Ocean acidification has further chemical implications: more hydrogen ions mean more bicarbonate ions, and fewer carbonate ions. Carbonate is what corals, the shells of shellfish and the outer layers of many photosynthesising plankton and other microbes are made of. If the level of carbonate ions falls too low the shells can dissolve or might never be made at all. There is evidence that the amount of carbonate in the shells of foraminifera, micro-plankton that are crucial to ocean ecology, has recently dropped by as much as a third.

Since becoming a topic of widespread worry about five years ago, the changing pH of the oceans has been added to the litany of environmental woes. Richard Feely, a researcher at the Pacific Marine Environmental Laboratory in Seattle, provided a gift to headline writers when he dubbed acidification “global warming’s evil twin”. Nowadays Dr Feely prefers to call it “the other carbon-dioxide problem”.

But for all this concern, how bad the change in pH will be for oceans is not yet clear. Indeed, such are the complexities of studying ocean life that the true risk may become apparent only in retrospect.



There is no doubt that a pH drop is under way. For example, as the atmospheric carbon-dioxide level in Hawaii goes up, the pH at a mid-ocean mooring about 450km to the north-west goes down (see chart). But the decline is a lot bumpier than the rise: the pH difference from one year to the next is frequently greater than the change in average pH levels over 20 years.

This is because the atmosphere does not have an iron grip on the carbon-dioxide level in surface waters. Increased photosynthesis will use up carbon dioxide; increased respiration produces more of it. Water coming up from below will often have a lower pH than the surface water, because at depth there is no photosynthesis but plenty of respiration. In many places, natural variations in pH will be larger than long-term changes in its mean.

This is not to say that such changes have no effect. If peak acidities rather than long-term averages are what matters most, natural variability could make things worse. But it does suggest that the effects will be far from uniform.

So, too, does research on how organisms respond to lower pH. Iris Hendriks of the Mediterranean Institute for Advanced Studies recently analysed data from a wide sample of research into how individual organisms respond to increased carbon dioxide in their seawater. She found that the range of responses was wide, with some seeming to prefer the lowered pH. She also found that the effects to be expected in the 21st century were on average comparatively modest.

Some researchers feel the way her study lumps things together plays down the more damaging effects. Even if that is so, there is a fair chance that the literature surveyed was biased the other way. Data showing a deleterious effect might well be more likely to be written up and published than data showing nothing much.

If some creatures can tolerate lower pHs and others cannot, you might expect things to average out: the tolerant and adaptable prosper, the more pernickety perish. For the "primary producers" in the ocean—the mostly single-celled creatures that photosynthesise—this will probably be the case. But changes in the relative prevalence of different photosynthesisers could still matter. The ecology of the oceans is all about who eats what, and small changes in the population of certain creatures near the bottom of the web could have large effects on larger ones that eat them. Some creatures may be double-whammied by having less of what they like to eat and by the pH itself, amplifying the disruption. And adaptation is not without costs: dealing with lower pH may divert a creature's resources from other ends.

This is where the condoms—or mesocosms, as their scientific caretakers would prefer it—come in. They are part of the European Project on Ocean Acidification (EPOCA), an initiative employing over 100 researchers, more than 30 currently in the Arctic. EPOCA is the most thorough investigation so far attempted of the effect of pH changes at the level of a whole ecology.

By looking at which creatures flourish in their mesocosms, Ulf Riebesell of the Leibniz Institute for Marine Studies in Kiel and his colleagues hope to see changes as they take place by keeping an eye on the water chemistry and nutrient levels. Dr Riebesell is particularly interested in the ecosystem role of pteropods, also called sea butterflies. These elegant micro-molluscs are a vital food for some fish. In the first year of their life, pink salmon eat more pteropods than anything else.

If reshaping food webs marginalises the pteropods, the salmon will have to adapt or die. But though the mesocosms may shed light on the fate of the pteropods, the outlook for the salmon will remain conjectural. Though EPOCA is ambitious, and expensive, the mesocosms are too small to contain fish, and the experiments far too short to show what sort of adaptation might be possible over many years, and what its costs might be.

This is one of the reasons why the fate of coral reefs may be more easily assessed than open-water ecosystems. The thing that provides structure in open-water ecosystems is the food-web, which is hard to observe and malleable. In reefs, the structure is big lumps of calcium carbonate on which things grow and around which they graze and hunt. Studies of Australia’s Great Barrier Reef show that levels of calcification are down, though it is not yet possible to say changes in chemistry are a reason for this. Current research comparing chemical data taken in the 1960s and 1970s with the situation today may clarify things.

But singling out the role of acidification will be hard. Ocean ecosystems are beset by changes in nutrient levels due to run off near the coasts and by overfishing, which plays havoc with food webs nearly everywhere. And the effects of global warming need to be included, too. Surface waters are expected to form more stable layers as the oceans warm, which will affect the availability of nutrients and, it is increasingly feared, of oxygen. Some, including Dr Riebesell, suspect that these physical and chemical effects of warming may prove a greater driver of productivity change in the ocean than altered pH. Wherever you look, there is always another other problem.

Disease and intelligence

Mens sana in corpore sano

Parasites and pathogens may explain why people in some parts of the world are cleverer than those in others

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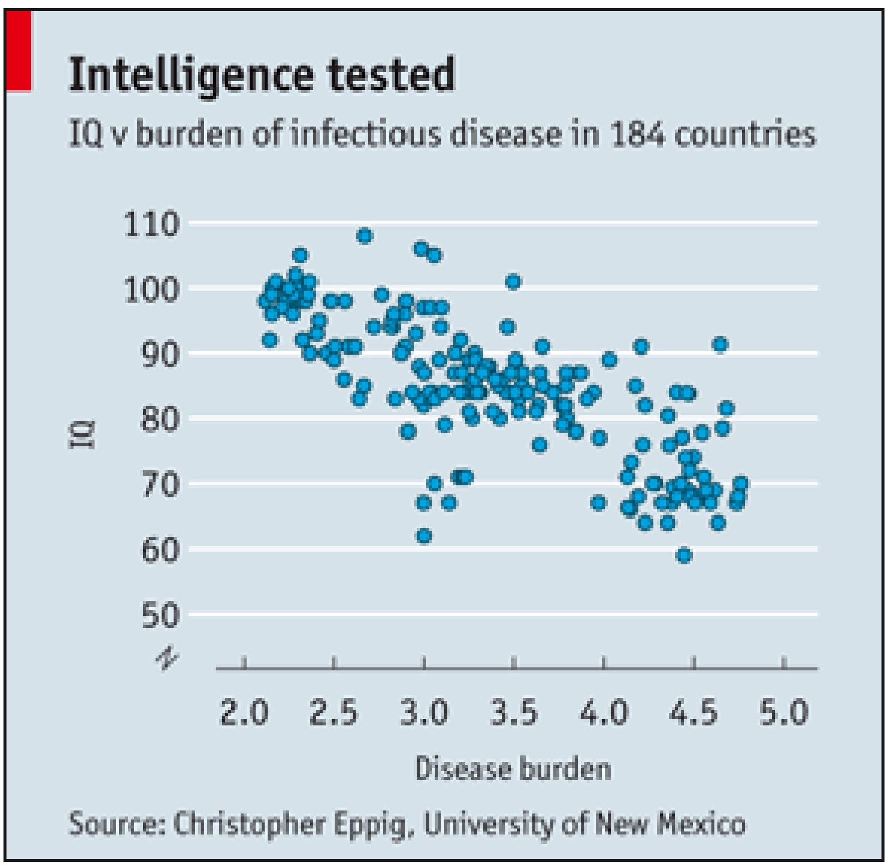
HUMAN intelligence is puzzling. It is higher, on average, in some places than in others. And it seems to have been rising in recent decades. Why these two things should be true is controversial. This week, though, a group of researchers at the University of New Mexico propose the same explanation for both: the effect of infectious disease. If they are right, it suggests that the control of such diseases is crucial to a country's development in a way that had not been appreciated before. Places that harbour a lot of parasites and pathogens not only suffer the debilitating effects of disease on their workforces, but also have their human capital eroded, child by child, from birth.

Christopher Eppig and his colleagues make their suggestion in the *Proceedings of the Royal Society*. They note that the brains of newly born children require 87% of those children's metabolic energy. In five-year-olds the figure is still 44% and even in adults the brain—a mere 2% of the body's weight—consumes about a quarter of the body's energy. Any competition for this energy is likely to damage the brain's development, and parasites and pathogens compete for it in several ways. Some feed on the host's tissue directly, or hijack its molecular machinery to reproduce. Some, particularly those that live in the gut, stop their host absorbing food. And all provoke the host's immune system into activity, which diverts resources from other things.



The inverse correlation that the group calculated between a country's disease burden and the average intelligence of its people is impressive. They estimated the disease burden from

World Health Organisation data on DALYs (disability-adjusted life years) lost caused by 28 infectious diseases. These data exist for 192 countries. The intelligence scores came from work carried out earlier this decade by Richard Lynn, a British psychologist, and Tatu Vanhanen, a Finnish political scientist, who analysed IQ studies from 113 countries, and from subsequent work by Jelte Wicherts, a Dutch psychologist.

At the bottom of the average-intelligence list is Equatorial Guinea, followed by St Lucia. Cameroon, Mozambique and Gabon tie at third from bottom. These countries also have among the highest burden of infectious diseases. At the top of the list of countries with the highest average intelligence is Singapore, followed by South Korea. China and Japan tie in third place. These countries all have relatively low levels of disease. America, Britain and a number of European countries, follow behind the leaders. A list of the countries included in the study can be found here.

The consequence of illness

The correlation is about 67%, and the chance that it might have come about at random is less than one in 10,000. But correlation is not causation, so Mr Eppig and his colleagues tried to eliminate other possible explanations. Previous work has offered income, education, low levels of agricultural labour (which is replaced by more mentally stimulating jobs), climate (the challenge of surviving cold weather might provoke the evolution of intelligence) and even distance from humanity's African homeland (novel environments could encourage greater intelligence) as explanations for national differences in IQ. However, all of these, except perhaps the last, are also likely to be linked to disease and, by careful statistical analysis, Mr Eppig and his colleagues show that all of them either disappear or are reduced to a small effect when the consequences of disease are taken into account.

There is, moreover, direct evidence that infections and parasites affect cognition. Intestinal worms have been shown to do so on many occasions. Malaria, too, is bad for the brain. A study of children in Kenya who survived the cerebral version of the disease suggests that an eighth of them suffer long-term cognitive damage. In the view of Mr Eppig and his colleagues, however, it is the various bugs that cause diarrhoea which are the biggest threat. Diarrhoea strikes children hard. It accounts for a sixth of infant deaths, and even in those it does not kill it prevents the absorption of food at a time when the brain is growing and developing rapidly.

The researchers predict that one type of health problem will increase with rising intelligence. Asthma and other allergies are thought by many experts to be rising in frequency because infantile immune systems, unchallenged by infection, are turning against the cells of the body they are supposed to protect. Some studies already suggest a correlation between a country's allergy levels and its average IQ. Mr Eppig and his colleagues predict that future work will confirm this relationship.

The other prediction, of course, is that as countries conquer disease, the intelligence of their citizens will rise. A rise in intelligence over the decades has already been noticed in rich countries. It is called the Flynn effect after James Flynn, who discovered it. Its cause, however, has been mysterious—until now. If Mr Eppig is right, the near-abolition of serious infections in these countries, by vaccination, clean water and proper sewerage, may explain much if not all of the Flynn effect.

When Dr Lynn and Dr Vanhanen originally published their IQ data, they used them to advance the theory that national differences in intelligence were the main reason for different levels of economic development. This study turns that reasoning on its head. It is lack of development, and the many health problems this brings, which explains the difference in levels of intelligence. No doubt, in a vicious circle, those differences help keep poor countries poor. But the new theory offers a way to break the circle. If further work by researchers supports the ideas of Mr Eppig and his colleagues, they will have done the world a good turn by providing policymakers with yet another reason why the elimination of disease should be one of the main aims of development, rather than a desirable afterthought.