

a millimetre in diameter, and are compartmentalized into two, four, eight or more bodies which are proposed to be blastomeres (cells in a cleavage embryo; see the stunning picture on the cover and those on page 556 of this issue). The constant size of the fossils, irrespective of the number of compartments, fits a pattern of developing early embryos with a constant cytoplasmic volume. This would not be expected in colonial algae or in objects formed by non-biological processes.

So what information can we get from these kinds of fossils? The two studies^{1,2}, although preliminary in nature, already yield some insights. The previously known oldest sponges were late Ediacaran hexactinellids (glass sponges)^{16,17}, but the spicule morphology and cell configuration of the Doushantuo sponges are very different from those of hexactinellids. The early-cleavage embryos have a tetrahedral blastomere configuration that is today known in some animals such as nematodes, flatworms and arthropods. One should be careful about drawing evolutionary conclusions from physically simple patterns like these, but the observation clearly shows the potential of such material. Only finds of later developmental stages will tell in which direction, and how far, these embryos developed.

The Doushantuo phosphorites cover an area of 57 km², and they undoubtedly contain further secrets. Phosphate is thus pay

dirt. But whereas digging up the basal roots of animals may have its particular appeal, let's not forget about the rest of animal history. Developmental and evolutionary biology are complementary but largely separate sciences, and the fossil record might help in bringing them together. Palaeoembryology may be a science of the past, but it could have a brilliant future. □

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Tracer studies using highly surface-active metal isotopes show that the marine colloidal phase is very dynamic, with high colloid aggregation rates being sustained even in nutrient-poor surface waters^{8,9}. These findings imply that colloid production rates must also be high, presumably through a combination of cell exudation and lysis, microbial degradation of particulate organic matter, and 'sloppy' feeding and excretion by zooplankton^{1,10}. Colloidal concentrates obtained by cross-flow ultrafiltration contain carbohydrates, proteins and lipids³, as well as significant quantities of the biologically essential metals iron, copper, zinc, nickel and cadmium⁵.

So what factors control colloid residence times in sea water? Most recently, interest has largely centred on the biodegradation removal pathway. Indeed, size-fractionation experiments suggest that colloidal organic matter supports the bulk of heterotrophic microbial production in sea water, rather than truly soluble substances¹¹. In this case, colloid 'removal' rates would be primarily a function of enzyme-specific reactions which, in turn, would be strongly influenced by the composition and steric accessibility of molecules within colloidal matrices.

However, the results of Chin *et al.*⁶ show the importance of nonspecific surface interactions in colloid cycling. They find that discrete natural polymers coalesce spontaneously to form large, sinking conglomerates (Fig. 1); from the results, it seems that the process has second-order kinetics, with aggregation reaching apparent equilibrium after about 80 hours under the authors' abiotic test conditions. This period is similar to estimates of colloid turnover times in surface waters from ²³⁴Th modelling^{8,9}. Ion-bridging between biopolymers seems to be the primary driving mechanism because the process is reversed by chelation of Ca²⁺ and Mg²⁺. As with colloidal concentrates, histological staining indicates that the aggregates are composed of carbohydrates, proteins and lipids — which is particularly interesting, because it suggests that the stability of a wide range of biocompounds within the dissolved-organic-matter component of sea water may depend less on their chemical composition than on their interfacial characteristics.

Chin *et al.* go on to show that these aggregates undergo reversible swelling and condensation as a function of hydration, a behaviour characteristic of gels formed by tangled networks of polymers. Although similar behaviour has been shown for terrestrial humic matter¹², this is the first report for marine aggregates. These changes were observed under chemical conditions very different from those characteristic of sea water, but Chin *et al.* suggest that similar transitions might occur over natural ranges of temperature and pressure or in chemically

Marine colloids

A neglected dimension

Mark L. Wells

Marine colloids are the most abundant particles in the oceans^{1,2}. They account for 30–50% of the 'dissolved' organic carbon in sea water^{3,4}, and they also contain biologically essential metals⁵. Although great strides have been made in assessing the bulk composition of the marine colloidal phase, there is little consensus about what processes regulate colloid cycling, or even what the ultimate fate of these substances is. The work of Chin *et al.* (page 568 of this issue⁶) adds a fresh perspective to these basic questions by invoking polymer gel theory to explain the behaviour of marine colloids. This insight is important because emerging evidence suggests that the marine colloidal phase is intrinsic to a variety of oceanographic processes, with potential ramifications running from the modulation of metal ion uptake by algae to global climate change.

Colloids lie at the boundary between soluble chemical species and sinking particles, and are defined as substances sized between about 1 and 1,000 nm in diameter. Particles in this range are large enough to acquire an

interface (that is, the interior is chemically distinct from the surrounding medium) but small enough for gravity not to be the dominant force acting upon them. So removal of colloidal substances from sea water depends upon either their degradation to soluble components or their aggregation to form sinking macroparticles.

It has long been recognized that colloids strongly affect the behaviour of carbon and metals in estuaries⁷. But their role in coastal and offshore sea waters had been largely overlooked, mainly because oceanographers have traditionally employed filters of 0.2–0.7 μm pore size to arbitrarily partition sea water into 'dissolved' and 'particulate' phases. Only recently have concerted efforts begun to discriminate colloidal from truly soluble components within the 'dissolved' phase. Given the early evidence that the marine colloidal phase may account for upwards of 250 gigatonnes of potentially bioreactive organic carbon, it is not surprising that new emphasis is being placed on understanding the sources, cycling and fate of these substances.

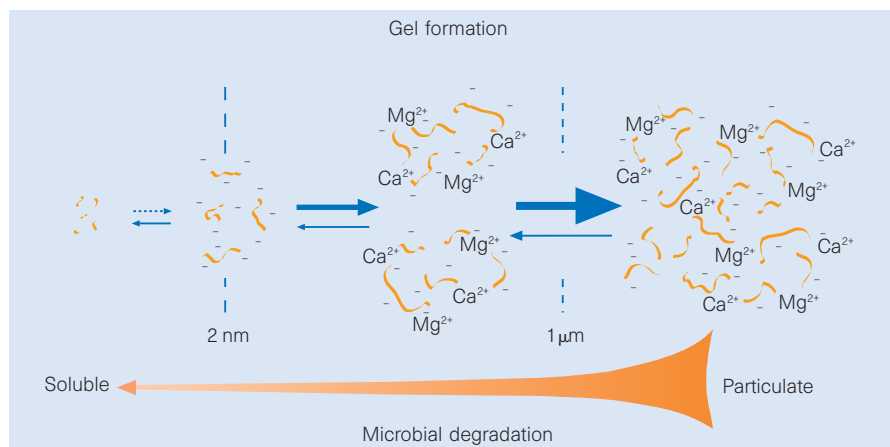


Figure 1 Representations of the dynamic interplay between marine gel formation and microbial degradation in sea water. The negative charges depict the anionic nature of marine organic matter, while cation bridging appears to drive polymer coalescence. Thickness of arrows indicates relative reaction rates. Previous tracer experiments in ocean surface waters had implied that colloidal-sized organic phases could aggregate quickly, but Chin *et al.*⁶ are the first to directly quantify colloid aggregation rates in sea water. They invoke polymer gel theory to explain the mechanism of aggregate formation as well as the physicochemical nature of the resultant macroparticulate phases.

distinct micro-environments. If so, gel condensation might encase biologically labile molecules within a tangled network cage that is sterically impervious to enzymatic attack. Given the swiftness of gel condensation, marine macrogels might be prominent precursors for the geopolymer condensates that are thought to help preserve organic matter in some marine sediments¹³.

Assuming basic polymer theory is well suited to the heterogeneous cornucopia of organic constituents in sea water, it could provide a pleasingly straightforward explanation for the old apparent ¹⁴C ages of oceanic dissolved organic carbon (2,500–5,900 years before present)¹⁴. Because the probability of polymer gels coalescing and becoming stable increases in proportion to the square of polymer length, the smallest organic constituents in sea water would be less likely to be incorporated into macropolymer assemblies than would colloidal constituents. Indeed, recent data indicate that colloidal organic carbon in the upper water column is only a few decades old, whereas the soluble dissolved organic carbon dates to 4,000 years or more¹⁵.

Perhaps the most startling aspect of Chin and colleagues' results is that particulate gels re-form from soluble and colloidal precursors after previous gels are removed by gentle filtration. The authors argue that the initial macrogels do not disintegrate upon filtration but that new macrogels form as a consequence of re-equilibration in the system. If confirmed, this finding has serious implications for oceanographers because it means 'dissolved' (that is, filtered) samples will, in time, come to contain particulates again. More strikingly, it raises the possibility that colloid aggregation in sea water may be strongly influenced by particulate removal rates.

The main component missing in these

experiments is biology, so we cannot assess the relative importance of competing processes of biodegradation and macrogel formation (Fig. 1). The balance of this tug-of-war will almost certainly vary for different substances and over time, because biodegradation may diminish the chance that residues will enter the aggregation cascade. Moreover, phytoplankton and microbial production are not coupled rigidly, so

Immunodeficiency viruses

1959 and all that

Simon Wain-Hobson

Origins continue to fascinate. When it comes to biology, Darwin set the stage and interpreted the play. Following the revolution in molecular biology, we know how to decode the digital information stored in DNA, and can look back in wonder at the phylogenetic trees of protein sequences such as cytochrome *c* or α -globin. Phylogenetic analysis was a fairly scholarly occupation until the polymerase chain reaction (PCR) discombobulated us all in the late 1980s. PCR allows billion-fold (and more) amplification of a precise segment of DNA — single DNA molecules can be analysed, and almost every living thing has had some part of its DNA amplified by now. Even Neanderthal bones in a museum drawer have harboured enough DNA to yield to PCR, so bringing new life to an old debate¹. And laboratory freezers the world over contain old serum samples, from Africa and elsewhere. Which brings us back once again to the human immunodeficiency virus, and to the paper by Zhu *et al.*² on page 594 of this issue.

Where did HIV come from? Both of the AIDS viruses, HIV-1 and HIV-2, originated

input of colloids may outpace degradation over short periods. One example may be the apparently spontaneous appearance of macropolymers responsible for the rapid aggregation of marine snow¹⁶. Although the debate over the dynamics and fate of colloidal matter in sea water continues, Chin *et al.* contribute a rich new framework for examining these basic questions. □

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in Africa, where the spread of AIDS preceded development of the disease elsewhere on the globe. How? As is often the case with microbes, a jump from one species to another is probably to blame. This conclusion comes from the observation of viruses with qualitatively identical genetic make-ups among chimpanzees (for HIV-1) and sooty mangabeys (for HIV-2), in geographically overlapping regions. Of the two viruses, HIV-1 is wreaking global havoc — although HIV-2 is capable of generating an AIDS epidemic, HIV-1 has a faster disease course and more efficient transmission.

When did the AIDS epidemic begin? There is the feeling that HIV first lingered in some people before going global. If so, then how long has it been around in humans? That's a more tricky question. To get some idea, researchers have turned to sera and tissue samples collected many years ago for other studies. Artefacts can crop up when using old sera in immunological tests. However, sera may also harbour viruses such as HIV. This is precisely what Zhu *et al.*² have found in a sample drawn back in 1959 in