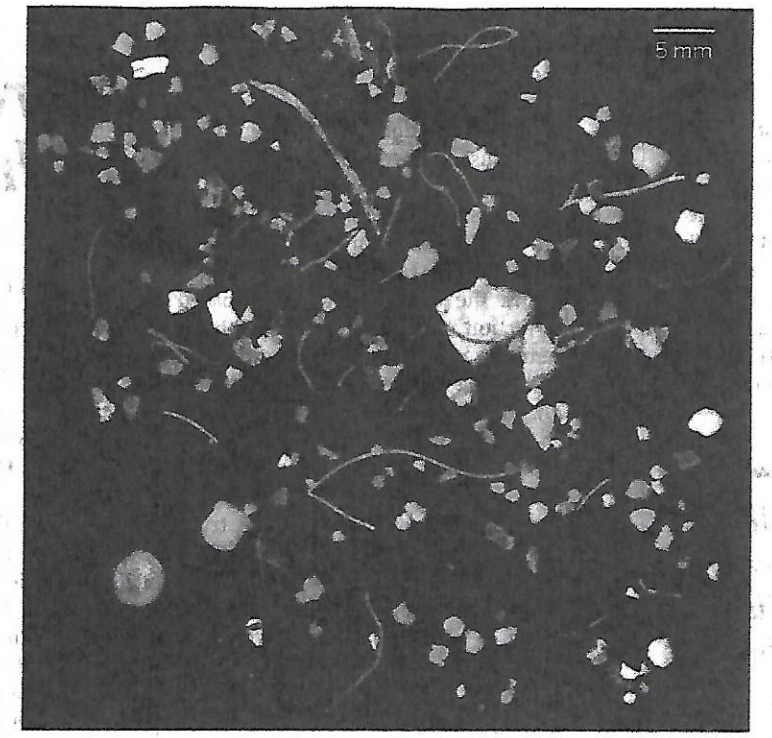
that pass through wastewater treatment into the environment. Although the sources are well known, knowledge of their relative contribution and geographic distribution is limited.

Once in the ocean, floating microplastics are transported passively by complex two- and three-dimensional physical flows, resulting in very large variability in surface concentrations that makes detection of long-term trends difficult even in the heavily sampled western North Atlantic (*2*) and eastern North Pacific Oceans (*3*). Oceanographic models [including (*4*)] and environmental observations find very high concentrations (up to 10^6 pieces km^{-2}) of floating microplastic in subtropical ocean gyres, far from land-based sources. In these gyres, converging surface currents trap and retain floating debris. Similarly high concentrations have been observed in enclosed basins such as the Mediterranean Sea (*5*).

In coastal sediments around the world, microplastics also appear to be ubiquitous, with quantities typically ranging from 2 to 30 particles per 250 ml of sediment (*6*). Arctic sea ice is the most recently identified reservoir of microplastics (*7*). With the exception of localized spills, the relationship between microplastic concentration and its sources is poorly understood because of complex transport mechanisms and unknown fragmentation rates.

Because of their size, microplastics may have different effects from larger items of debris. For example, floating microplastics in open ocean gyres provide habitats for diverse communities of microorganisms, with assemblages that differ from those in surrounding seawater and that vary with polymer type (*8*). Furthermore, microplastics may be ingested by many diverse organisms, and some animals such as mussels can retain particles after ingestion (*9*); ingestion of small quantities of microplastics can disrupt physiological processes in marine worms, compromising their ability to store energy (*10*).



Microplastics everywhere. Microplastics collected from seawater, shorelines, or marine sediments are typically defined as particles with a diameter of 5 mm or less. Sources include larger deteriorating plastic items, as well as microbeads used in the cosmetics industry. The microplastics in the photo were collected in the North Pacific subtropical gyre with a surface plankton net.

Plastic debris readily accumulates harmful chemicals such as dichlorodiphenyltrichloroethane (DDT), polychlorinated biphenyls (PCBs), and polybrominated diphenyl ethers (PBDEs) from seawater worldwide (*11*), increasing their concentration by orders of magnitude. This process is reversible, with microplastics releasing contaminants upon ingestion (*12*) and laboratory evidence of uptake in marine worms (*13*) and fish (*14*). Transfer depends on the polymer, contaminant, and conditions in the organism, particularly pH and temperature. These interactions are specific but not yet fully predictable (*15*). There is also concern that plastic debris might release monomers and potentially toxic additives such as plasticizers, flame retardants, and antimicrobial agents that are incorporated into plastics during manufacture.

This emerging evidence of harm comes primarily from laboratory studies. It is unclear whether microplastics in the environment transport chemicals to biota in concentrations high enough to cause substantial damage. The potential for harm from microplastics could increase with decreasing particle size, but size distributions and generation and degradation rates are essentially unknown, and the resulting effects on natural populations are difficult to ascertain. Nevertheless, ingestion of microplastics by mammals, fish, birds, and invertebrates is now well documented. Although quantities can be low, the widespread incidence in some natural populations together with evidence of potentially harmful effects is cause for concern.

Major questions remain about the risks from microplastics to marine organisms and ecosystems, as well as to food safety and public health. Research is urgently needed on the behavior of different polymers in the environment, including fragmentation, chemical release, degradation, transport, and accumulation; the rate at which organisms encounter microplastics, based on particle size and degradation time; and the physical, chemical, and interactive risks to organisms from these encounters, including possible magnification with increasing trophic level (biomagnification).

Given the concerns over microplastics, the temptation may be to "clean up the mess," but substantial removal of microplastic debris from the environment is not feasible. Identification and elimination of some of the major inputs of plastic waste is a more promising route, as is reduced consumption and the recognition of plastic waste as a resource. With the rapidly increasing human population, the need for greater resource efficiency could have a secondary benefit in reducing the quantities of debris entering the environment. ■

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PHOTO: JESSIGA DONOHUE/SEA EDUCATION ASSOCIATION

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10.1126/science.1254065