The problem with plastics is not only one of waste management but also of production, an idea evoked in this installation by artist Benjamin von Wong.

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LETTERS

Edited by **Jennifer Sills**

Global plastic treaty should address chemicals

In March, the global community agreed to establish a legally binding treaty to end plastic pollution. To deliver on this goal, the treaty needs to cover all issues of plastics chemicals as an inseparable part of the problem.

Plastics are complex materials consisting of chemical mixtures, including polymers, additives, residual monomers and processing aids, and non-intentionally added substances. Such mixtures release across the plastics life cycle, from feedstock extraction, production, and use, to reuse, recycling, and disposal; they also recombine along complex, unplanned pathways (*1*). As a result, humans and environments are ubiquitously exposed to plastics chemicals, often with serious consequences.

Out of more than 10,000 known plastics chemicals, at least 2400 are classified as toxic, such as many phthalates and brominated flame retardants (*2*–*4*). Documented health effects span generations and include premature births, low birth weight, obesity, diabetes, cardiovascular disease, endometriosis, infertility, and cancers (*5*). In the United States alone, associated costs of endocrine-disrupting chemicals amount to USD$300 billion/year (*6*, *7*). The total burden on community, ecosystem health, and biodiversity is far greater (*8*, *9*).

Even with material recycling, plastics chemicals ultimately proliferate in the ecosystem, whether as emissions or by entering new products, exposing waste-laborers, consumers, and frontline communities to new chemical cocktails (*10*). An effective, fair, and safe circular economy can only be achieved by phasing out toxic chemicals from plastic production (*11*).

As negotiations for a global treaty begin, plastics chemicals need to be front and center. However, preparatory meeting documents focus on downstream plastic waste and work from a narrow definition of chemicals as hazardous additives (*12*). To enable the treaty to fully address plastics' ecological, health, and environmental justice problems, it is essential to redefine plastics as complex chemical mixtures and to integrate chemical issues across the life cycle within the scope and core obligations of the legal instrument.

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COMPETING INTERESTS
L.T. acknowledges scientific advisory board activities for Beautycounter, Ahimsa, and Footprint. R.A. is on the Board of Directors for the Science and Environmental Health Network. A.K. does journalistic reporting on plastics and hosts the podcast Plastisphere.

10.1126/science.adf5410

Assess and reduce toxic chemicals in bioplastics

To promote a circular economy and mitigate pollution, the bioplastics industry has begun to phase out polymers derived from petrochemicals (*1*–*3*). This action is a positive step, but it doesn't affect the many bioplastics on the market, which also contain potentially harmful additives. Given that bioplastics will likely replace polymers, it is crucial to determine which bioplastics cause the least harm.

Components of bioplastics can leak into the environment. After disposal, weathering and ultraviolet degradation lead to additional release of chemicals (*4*). When determining the safety of plastic materials, it is important to consider that such leakage could have adverse effects on ecosystems, wildlife, and humans (*5*–*8*).

Discarded plastics often end up in the ocean, where chemicals leaking into the aqueous environment are toxic to marine life. Additives such as phthalates from starch- and cellulose-based bioplastics can also leak into marine environments through wastewater and runoff from landfills. The chemicals affect bioluminescent bacteria and the development of sea urchin larvae (*5*–*7*). Bio-cups, bio-polyethylene bottles, and bioplastic supermarket bags are produced with polylactide (PLA), a polyester derived from renewable biomass. PLA contains chemicals of emerging concern (CECs), such as bisphenol A, that cause dose-dependent increases of malformed mussel larvae (*8*).

More information about the CECs in bioplastics is urgently needed. No protocols are available to characterize either the chemicals or the leachate of chemicals from conventional and bio-based plastics (*9*), making evidence-based, environmentally responsible management impossible. Manufacturers of plastic items and their consultants should be required to test for molecular, organismal, and population-level effects and make public the risks of each type of both conventional plastic and bioplastic (*10*). Integrated chemical and biological approaches should be used to assess the risks associated with low-level exposures to CECs released by bioplastics as well as their possible combined effects in mixtures. Assessing the toxicity of CECs that migrate from bioplastics into the surrounding environment could help determine how to prevent unexpected adverse health outcomes (*11*).

Instead of replacing one harmful material with another, the bioplastic industry and researchers should work together to identify the safest and most sustainable plastic alternatives (*6*). Creating and prioritizing the production of nontoxic materials with a low carbon footprint could lead to a reduced need for landfills and less ocean plastic waste.

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10.1126/science.ade9069

Rethink farm animal production: The 3Rs

Any scientist working with animals is familiar with the "3Rs"—replacement, reduction, and refinement (*1*). Replacement refers to using alternative methods instead of live animals. Reduction requires using the minimum number of animals. Refinement demands the optimization of experimental techniques, housing, and care to safeguard animal welfare. The 3Rs led to a paradigm shift in guiding the use of animals in research, through legislation or institutional review committees worldwide. The model could be similarly effective if applied to farm animal production.

Humans use animals predominantly to produce animal protein: 70 billion terrestrial animals (*2*) and between 59 and 129 billion aquatic animals (*3*) are used annually, compared with 192 million research animals (*4*). However, animal farming is not scrutinized through the lens of the 3Rs and instead remains focused on increasing production to feed the world. The justification for this ethical discrepancy is unclear.

The use of animals for food production should be reassessed according to each of the 3Rs. Replacement could be achieved by plant-based protein or in vitro meat (*5*), which would benefit the environment (*6*) and alleviate world hunger (*7*). Reduction could mean retaining only farm animals that exploit food sources that humans cannot use directly, such as ruminants on nonarable land. Massive reductions could also be attained by decreasing food waste (*8*) and overconsumption of meat and other animal products, which is typical for high-income countries and linked to diseases such as diabetes and cardiovascular disease (*9*). Refinement should not merely prevent animal suffering but guarantee husbandry conditions delivering animals a good life (*10*).

Most efforts to date, primarily through animal welfare science, have focused on refinement (*11*). Applying the 3Rs—especially replacement and reduction—to animal agriculture would reframe the focus on the sustainability of food production, limit its environmental and health impact, and support animal welfare.

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10.1126/science.adf3351

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Science, **378** (6622), .
DOI: 10.1126/science.adf5410