THE *CRISIS* AND CONVENIENCE OF SYNTHETIC PLASTICS

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"I just want to say one word to you. Just one word… plastics. There's a great future in plastics." Back in 1967, a movie titled *The Graduate* expressed this rather insightful sentiment. This quote very nearly predicted the future; indeed, in the modern world, plastics are practically ubiquitous. Most marketplaces bag groceries in plastic bags. Families store leftover food in plastic food wraps and containers. Transparent plastics have even replaced the glass of some windows and most bottles. In many ways, overstating the importance of plastics is difficult. However, this material, which seemed so revolutionary fifty years ago, has caused many problems that the quote from *The Graduate* could not have foreseen. Today, a quick Internet search reveals heartbreaking photos of animals caught and killed by the plastic waste that people carelessly leave around. That same plastic has also created the infamous island of trash floating around somewhere in the Pacific Ocean, an obvious problem with a less than obvious answer. While synthetic plastics have certainly had some positive impact on our society, their alluring convenience caused a new kind of crisis in waste production.

Calling this waste production a crisis is no understatement. Globally, the annual production of plastics exceeded 300 million tons in 2015. About 34 million tons of this plastic was turned to waste and over 90% of this waste (which is nearly one hundred times the weight of the Empire State Building) ended up in landfills or the ocean.[1] With the global population on the rise, the amount of generated plastic waste will likely continue to grow. With greater waste come greater problems—a crisis in the making, if not one already, due to the inherent toxicity associated with the chemistry of plastics.

Plastics are synthetic polymers—long chains of smaller molecules bonded into a macromolecule—often derived from petroleum. These polymers exhibit uniquely exploitable characteristics such as strength, flexibility, or a combination of both. The plastics used in packaging or consumer goods are special in part because they are considered safe and non-toxic.[2] Because consumer plastics are quite inert, people can use them for a variety of purposes and do not need to worry about, for example, their

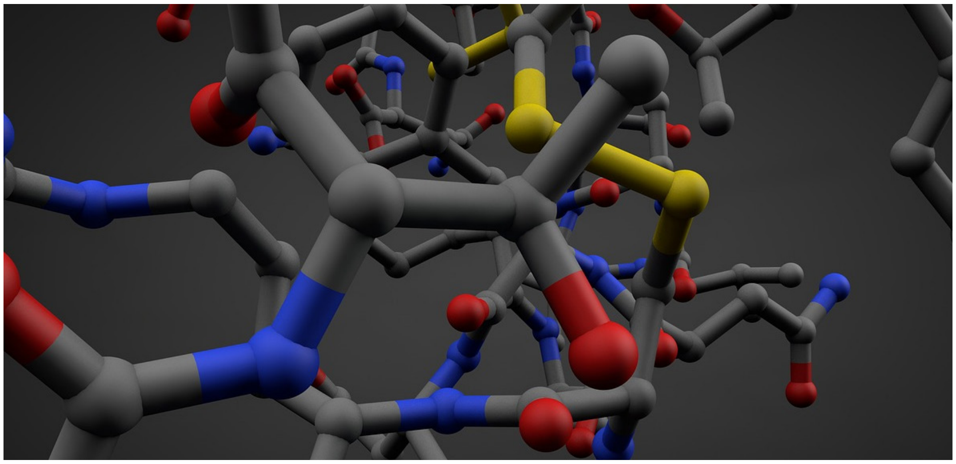

Figure 1: Polymer structure. Polymers are macromolecules—long chains of many atoms strung together to yield unique properties.

food wraps poisoning them. In this regard, most consumer plastics provide short-term convenience.

However, in the long term, nothing is perfect, and plastics are no exception. In fact, polymerization—the process of making plastics by stringing together monomers (individual small molecules) into a long chain—is rarely complete. Unreacted monomers and other additives, such as plasticisers or catalysts, sit in the material without being bonded to the polymeric chains.[2] These molecules are capable of seeping out of the material, especially when plastics are left in marine environments, which creates numerous public health hazards. For example, research reveals that vinyl chloride, the monomer of polyvinyl chloride (PVC), is carcinogenic, and benzyl butyl phthalate, a plasticiser used in PVC,

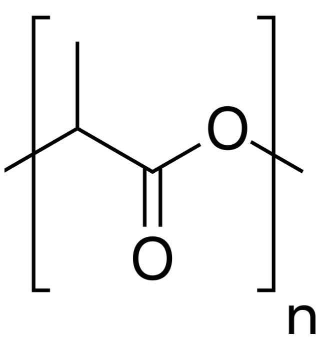

Figure 2: Chemical structure of polylactic acid (PLA). Synthesized from corn and sugars, PLA is a candidate for replacing synthetic plastics.

can cause reproductive harm.[2] PVC is the third-most widely produced plastic in the world.

The toxicity associated with plastics also causes negative ecological effects. Because plastics make up a large portion of marine waste, plastic debris are likely to degrade in water and break apart into smaller pieces. Most of this waste exists as microplastic—pieces of plastic smaller than 5 millimeters, which is about a quarter the size of a penny.[3] Animals can easily ingest microplastic, which acts as a carrier for a variety of toxic chemicals and builds up in tissues. This build-up can cause pathological stress and impede reproduction.[3]

To solve the problem of toxicity associated with plastics, scientists are investigating biodegradable and bio-based polymers, which are considered environmentally-friendly. Biodegradable polymers break down into carbon dioxide and water, while bio-based polymers are made of renewable resources.[4] At the forefront of this research is polylactic acid, a polymer that can be synthesized from only sugar and corn. Polylactic acid possesses a high transparency while remaining resistant to dissolving in water.[5] To replace most conventional plastics, the newly developed environmentally-friendly materials will need to possess both of these characteristics—transparency and dissolution resistance.[5] Other experiments have identified a natural polymer, poly-β-hydroxybutyrate (PHB), produced by bacteria.[6] Bacterial cells effectively function like "mini-factories" that produce this completely biodegradable material.[6] Both polylactic acid and PHB present apparently suitable replacements for conventional plastics.

Unfortunately, many biodegradable and bio-based polymers share faults that hamper their implementation by society. Perhaps the most pressing issue is the fact that these polymers do not display the same properties as their synthetic counterparts. Realistically, to be used effectively and achieve desirable properties, these environmentally-friendly polymers would require blending with conventional, synthetic polymers.[4] But while the addition of synthetic polymers mitigates issues surrounding the use of conventional plastics, it does not eliminate them.[4] Another issue is that environmentally-friendly polymers cannot yet be programmed to degrade at a specific time. For this reason, they cannot be used reliably for storage.

Nonetheless, polymer-decomposing microorganisms may provide an answer to the crisis of plastic waste. Researchers are considering natural enzymes as a solution to break down synthetic polymers.[7,8] Although this idea is feasible, it suffers from several limitations. The decomposition process initiated by enzymes takes place only under specific conditions. Furthermore, enzymes can only break bonds in the portion of the chain that has a specific molecular composition and a specific arrangement in space.[7] In other cases, enzymes act more readily on polymers that are already more liable to decompose in water.[9] In short, decomposition of current conventional polymers is possible but still impractical.[10,11]

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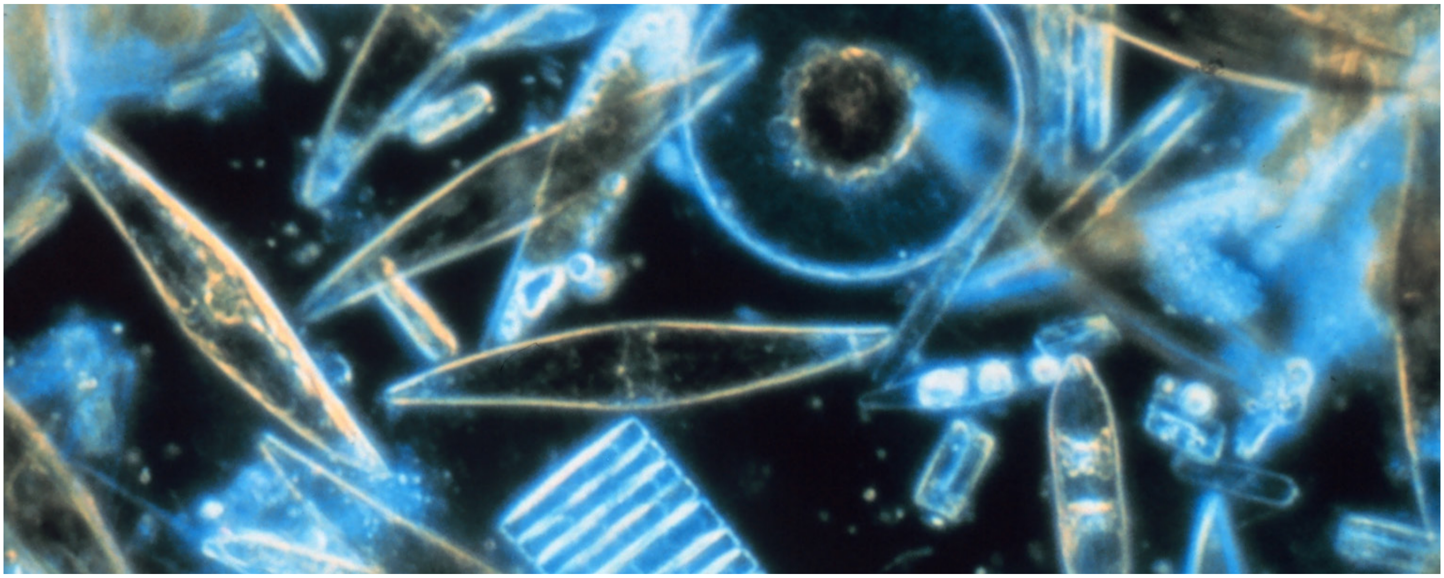

Figure 3: *Microorganisms. Scientists are currently considering using microorganisms and enzymes to break down polymeric waste.*

In many ways, plastics have lived up to their potential—to such an extent that solving their inherent problems introduces new ones. Until researchers find a solution with all of the benefits and none of the dangers, society will continue to face the dilemma of pitting plastic waste crisis against the comfort that comes with cheap convenience.

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