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Plastics and Sustainability

A Possibility Contingent on Science and Policy

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Illustrated by Josie Brane-Wright

Polymers are everywhere. They are large chain molecules composed of smaller, repeating units called monomers. Plastics are a class of synthetic polymers that are ubiquitous in modern society. From your morning cup of coffee to innovative silicon heart valves, synthetic polymers are pervasive in our lives. The durability and low cost of many synthetic polymers make them attractive and omnipresent materials for a myriad of applications, and they have become a practically indispensable tool in modern society. However, this also leads to significant disadvantages; effective polymer recycling is an unsolved problem. Most plastics eventually make their way into the environment or landfill, breaking down over the course of centuries. Plastics can break down into smaller units called microplastics, where they are tiny enough to be ingested by organisms and accumulate. Further, nearly all conventional plastics are made from hydrocarbons derived from fossil fuels, thus contributing to climate change. Because plastics are necessary for modern society but highly detrimental to the environment, the development of new classes of sustainable polymers is of paramount importance.

The answer to the issues of conventional polymers is sustainable polymers such as polylactic acid (PLA). For the purposes of this essay, a sustainable polymer is a plastic material that addresses the needs of consumers without damaging the environment, human health, or the economy. An ideal sustainable polymer will require less water and consume less non-renewable energy during production. Two areas of research are biodegradable polymers and bio-based polymers. Biodegradable polymers can be derived from fossil fuels or biological sources, but have the ability to fully break down into the environmentally-friendly components of water, carbon dioxide, and biomass relatively quickly — a solution to the issue of litter and microplastics. Bio-based polymers are plastics fully or partially produced from biological sources, rather than traditional fossil fuels. The end goal is to produce plastic replacements that biodegrade, produce less greenhouse gas emissions and waste during production, and have an overall smaller carbon footprint.

From your morning cup of coffee to innovative silicon heart valves, synthetic polymers are pervasive in our lives.

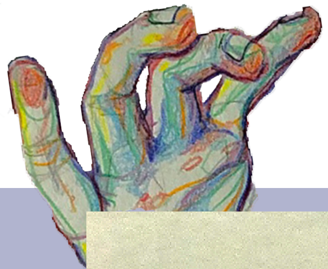
Sustainable polymers, including PLA, comprise a growing sector in the enormous market for plastics. Polylactide, a plastic derived from corn, is used to make plastic cutlery, food containers, fibers for clothing, and cell phone cases. Modified soybean oil is used to manufacture polyurethane foam for products such as seating cushions and memory foam pillows. PLA is used for medical implants (such as plates, pins, and rods) because it degrades to lactic acid, which naturally occurs in the body. The application of, and demand for, sustainable polymers will grow as more research is done and more polymers are developed.

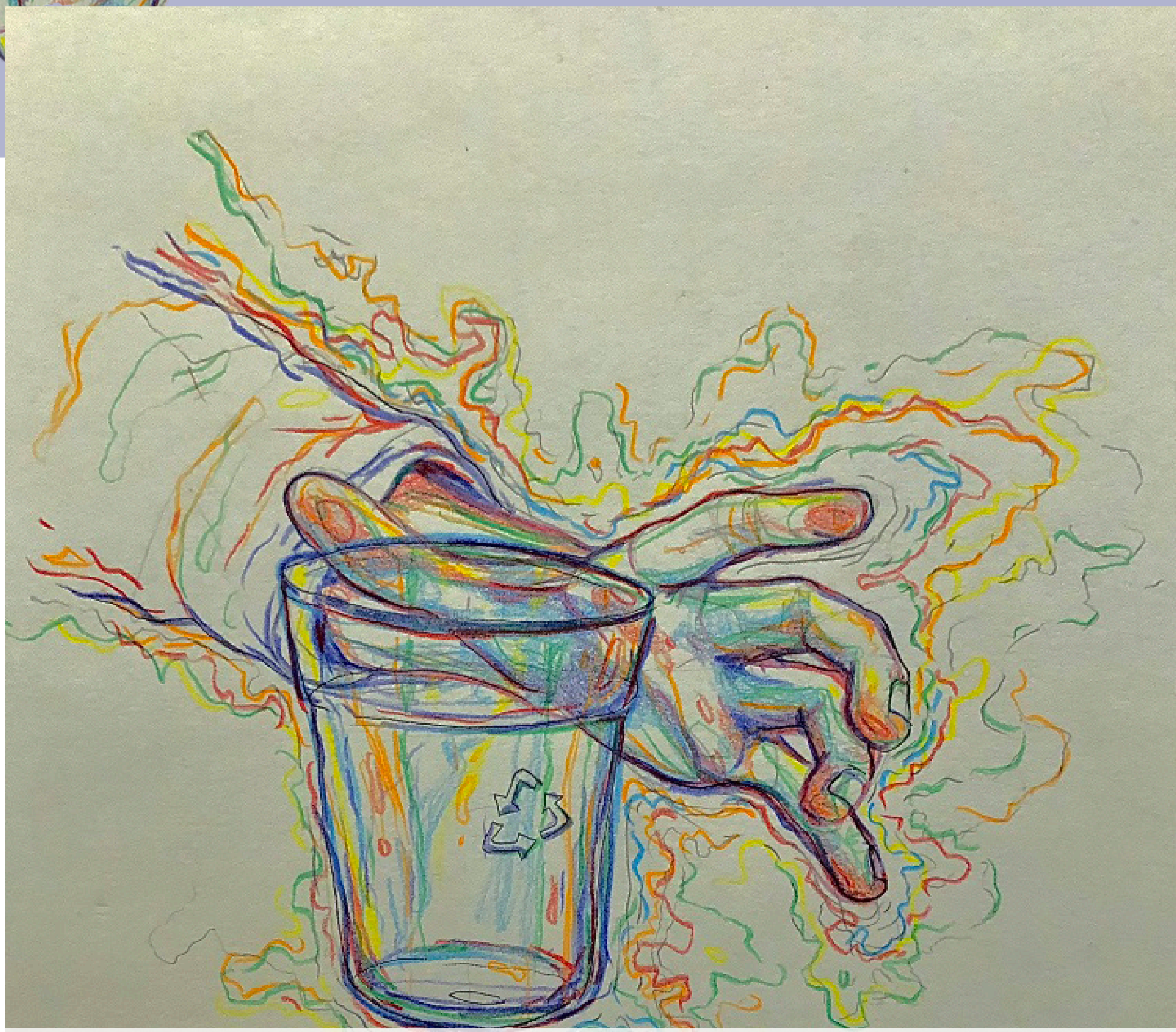
PLA is derived from renewable sources such as corn starch, tapioca roots, or sugarcane. It is produced through two main processes: condensation and ring-opening polymerization. Ring-opening polymerization uses metal catalysts and lactide to create PLA molecules. Condensation is similar to ring-opening polymerization, with the main difference being the temperature needed for production and the byproducts of production. PLA is also easier to degrade than its traditional counterpart. Given sufficient oxygen and temperature, it decomposes quickly. PLA can biodegrade, but only in industrial composts — it will not readily degrade in any natural environments, such as in the ocean, landfill, or soil. PLA production is more sustainable than low-density polyethylene (LDPE) production because it is derived from renewable sources rather than non-renewable sources and is easier to decompose.

Low-density polyethylene (LDPE), a traditional polymer, is produced by modifying natural gas (such as methane or ethane). The modified natural gas is then sent from the refinery to a separate polymerization plant. The double bond of the ethene monomer is then reacted to link the monomer to other ethene monomers. However, LDPE decomposes very slowly, tends to break down into harmful microplastics in the environment, and cannot be recycled effectively. A majority of manufacturers would rather produce entirely new LDPE rather than undergo the expensive and time-consuming process of recycling it.

However, biobased and biodegradable polymers also face challenges that conventional polymers do not. Some do not have the same physical properties (such as toughness, melting point, and elasticity) that their conventional counterparts do, limiting their application and versatility. Further, most sustainable polymers are more expensive to produce than traditional plastics, making it difficult for them to be competitive replacements. Because of these issues, a single type of sustainable polymer is not going to be the sole solution to our plastics issue. However, a collection of different polymers, with specific applications based on their physical properties, could be enough to make a big difference. Biobased and biodegradable plastics would be particularly impactful if they were substituted for traditional plastics in products that have a short lifespan and often end up in the environment, like plastic bags, straws, or water bottles.

One of the most important aspects of sustainability is how a product interacts with the environment. It is of utmost importance





that sustainable polymers be recyclable, biodegradable, and biobased. The most commercially available sustainable polymer currently is PLA. A recycling technology called near-infrared (NIR) has been shown to effectively sort PLA from a stream of mixed plastics in a recycling plant. NIR exploits the distinct light spectrum of polymers to accurately identify different plastics, making it the preferred sorting technology. This sorting step is essential for recycling to be viable for a polymer.

A product's interaction with consumers is also immensely important to its sustainability. It is very difficult for the average consumer to compost sustainable polymers effectively. Polymers marked with a seal from the United States Composting Council (USCC) can be composted in industrial compost facilities. The USCC advances compost processing and utilization to benefit individuals, society, and the environment. Backyard compost heaps do not get hot enough or produce adequate oxygen for these plastics to decompose. PLA requires a temperature of 176 to 212 degrees Fahrenheit (80 to 100 degrees Celcius) to break down. Some cities (such as San Francisco, California, and Denver, Colorado) have made effective composting accessible to their residents through citywide curbside compost pickup, but most cities have not taken the time to develop such systems. To fully utilize the properties of compostable polymers, industrial composting must be made available to consumers through large curbside compost pickup initiatives. Making sustainable polymers widely available will require more research to develop further the plastics and the widespread implementation of sustainable systems.

The successful production and implementation of sustainable polymers will require extensive public support, research, and political support. While there has been notable progress in developing sustainable polymers, there is still much work to be done before this class of materials is accessible to the public and a strong competitor to traditional plastics. Having significant public and political support will allow for the implementation of sustainable polymers on a large scale. Ultimately, progress toward improved sustainable polymers can only result from the combination of scientific research, technological innovation, and public and political support. • • •