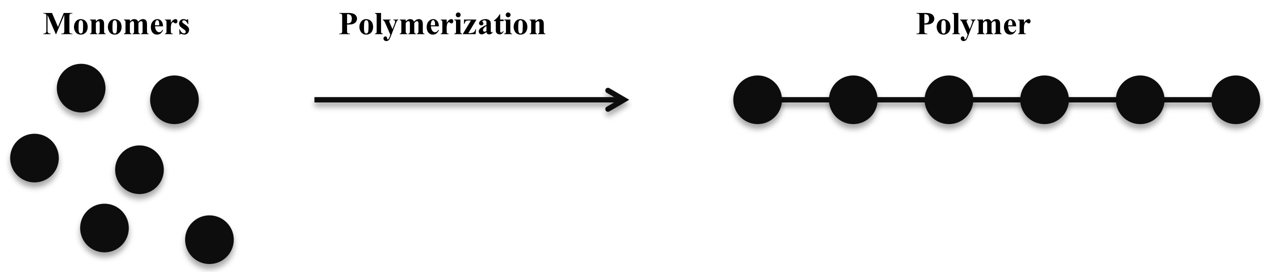
Lecture Notes for Chitin/Bioplastics Activity

Introduction to Plastics:

Plastics are an important class of materials that have become widely incorporated into our daily routines. For example, products such as beverage containers, dinnerware, bags, toys, furniture, packaging, building materials, appliance and automotive parts are made from plastics. Plastics are semi-malleable polymers composed of synthetic materials, natural materials, or a combination of these. Polymers are formed via chemical reactions whereby smaller molecules, called monomers, bond together to form chains of repeating subunits. In 2012, the United States produced 32 million tons of plastics. Such consumption leads to massive waste: less than 10 percent of the plastics generated could be recycled for reuse. The wasted plastics build up in landfills and oceans, leading to harmful health complications.

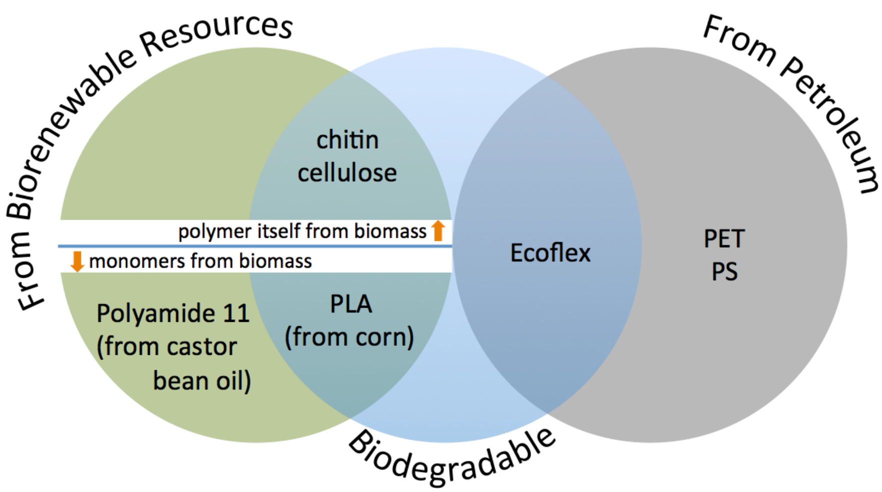


Common Plastics and Plastic Items:

Polyethylene terephalate (PET) – drink bottles, peanut butter jars
Polyethylene (PE) – grocery bags, drink bottles
High-density polyethylene (HDPE) – detergent bottles, milk bottles
Polyvinyl chloride (PVC) – plumbing pipes
Polyvinylidene chloride (PVDC) – Saran wrap
Poly propylene (PP) – bottle caps, straws
Polystyrene (PS) – take out containers, packing peanuts
Polycarbonate (PC) – CDs, reusable water bottles, eye glasses
Poly lactic acid (PLA) – compostable cups

Where Do Plastics Come From:

Many monomers are readily available from petrochemical feedstocks such as styrene, ethylene, and propylene, which means that the corresponding polymers (polystyrene, polyethylene, and polypropylene) are inexpensive and commonly available. Better yet, some monomers such as lactic acid are available from biorenewable feedstocks. Lactic acid, which we generate in our bodies as a result of anaerobic respiration (physical activity with a limited oxygen supply), is derived on a commercial scale from potatoes or corn. Monomers, sourced either from biorenewable feedstocks or depleting petrochemical feedstocks, are then linked together in a processing plant to form the polymer. Alternatively, accessing some polymers does not require industrial scale polymerization of monomers. Instead, some already polymerized biopolymers can be easily extracted from abundant biorenewable resources. Cellulose (derived from plants) and chitin (the major component of lobster shells and shrimp shells) are two very common biopolymers. Use of these biopolymers directly would represent an ideal scenario; The chemical complexity of the raw material is maintained, and it can be easily broken down by nature.



Where Do Plastics End Up:

Plastics from petroleum, such as polyethylene terephthalate (PET) and polystyrene (PS) generally do not biodegrade, because they do not contain the chemical linkages recognized by degrading enzymes. Essentially, living organisms do not know how to cut the polymer up into smaller pieces. On the other hand, many bioplastics, such as polylactic acid (PLA) and biopolymers (including chitin and cellulose, among others) are often biodegradable because they do contain chemical linkages recognized by degrading enzymes. However, exceptions exist to these guidelines for biodegradability. Rilsan, a bioplastic produced from vegetable oil is not biodegradable, while petroleum feedstock derived Ecoflex® rubbers are compostable. Plastics that do not break down collect in landfills and bodies of water. Accumulation of plastic trash in landfills of course is our deliberate attempt to ensure they don't end up in more ecologically sensitive environments, like the ocean, where accumulation of debris is arguably not deliberate. Marine debris has accumulated in the North Pacific Ocean, extending from the West Coast of North America to Japan. This ever-circulating debris creates a vortex termed the Great Pacific Garbage Patch, which is mostly composed of very small pieces of plastic, called microplastics. Because they do not biodegrade these plastics simply break into smaller and smaller pieces that are left floating in the garbage patches. Accumulation of marine debris in the Great Pacific Garbage Patch leads to many harmful outcomes such as disruption of marine food webs and chemical leaching, which leads to health implications throughout the food web. The outlook is not much better when plastics end up in landfills, just a change in venue. Americans discard 33.6 million tons of plastic per year, only about 15% of which is recycled. Rather than persisting in the ocean, these plastics persist in the terrestrial ecosystem, where they may take up to 1,000 years to break down.

In order for plastics to be considered biodegradable, they must fulfill three criteria set forth by the American Society for Testing and Materials. Biodegradable plastics must physically disintegrate to the point that they are indistinguishable from other compost. Additionally, microorganisms must consume such plastics at a rate comparable to that of other compostable material. Finally, biodegradable plastics cannot hinder the ability of the compost to sustain plant life. As mentioned previously, we aim to increase the production of biodegradable bioplastics. However, there are three obstacles that hinder this goal: cost, yield, and development of methods for proper biodegradation. Petroleum-based plastics are cheaper than bioplastics and current production methods allow for a much higher yield of these plastics as compared to the bioplastic equivalent. Finally, municipal governments must integrate compost centers into their current waste management facilities and procedures. Although these obstacles may slow the rate of turnover from petroleum-based plastics to biodegradable bioplastics, the growing need for these products is bringing suppliers, retailers and municipalities together in search of more sustainable options.

Chitin Extraction:

While lobster and shrimp shells are primarily composed of chitin, they also contain non-negligible amounts of minerals and protein. To extract the chitin in a usable form, the shells are typically crushed, deproteinized with aqueous NaOH, and demineralized with HCl at elevated temperatures for prolonged periods of time. Recently developed bioextraction techniques have enabled researchers and engineers to use microorganisms to do this extraction without NaOH, HCl or elevated temperatures.

Further reading:

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