1 Introduction

Whether tools, weapons, clothing, shelter, jewelry, or even toys, humans have always made things. One might even argue that the meaning of the word human is *to make*.

The materials used to make things have changed throughout history, from found to extracted to synthesized. In the process, knowledge about how to use these materials has been passed along from generation to generation, from culture to culture, from continent to continent. This knowledge comes in a variety of forms, ranging from common sense, to tribal knowledge, to sage wisdom, to trade secrets and intellectual property.

Today, many of the things that humans make are made from plastics. We use plastics to protect our children, to preserve our food, to entertain us, and to communicate and connect with other people. Our health and happiness in our day-to-day lives—and, one might even argue, the very future of our species—depends on our effective use of these materials.

Plastics are unique materials, with unusual properties and performance characteristics. They range from simple compounds similar to beeswax, to highly engineered, specialty materials like Teflon®, whose properties seem to defy the laws of physics. After all, if Teflon is such a resilient, repellant, and nonstick material—how does it stick to the pan?

There are many books about plastics technology, including some that try to help users select an appropriate plastic material for a given application. Sadly, most of these books are written from the perspective of a polymer chemist, and they fail to provide the user with any guidance on how to evaluate plastic materials in a practical, hands-on manner.

This book is meant to be a guide in the process of plastics material selection. It is based on the simple premise that we all make things, and that we have a fundamental understanding of how to use materials—based on our heritage as human beings.

Let us begin our journey into the world of plastics by taking a quick look at human history. You may find that you know more about materials—and about plastics—than you think.

1.1 The Stone Age

Paleoanthropology—the study of ancient hominid fossils—has shown that humans have always made things. The oldest stone tools, found in

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Ethiopia, date back to about 3.4 million years ago, and could have been used by any of the several varieties of hominid, perhaps even by the ancestors of our species, *Homo sapiens* [1]. Less than a million years ago, Neanderthals, a not-so-distant cousin (and perhaps a subspecies of *H. sapiens*), left behind musical instruments made out of bones, along with stone tools and flint blades. They used these blades to make wooden spears, hand-axes, and to skin animal hides for clothing and shelter. Historical records of our species, *H. sapiens*, date back to about 200,000 years ago. It is now known that *H. sapiens* interacted with Neanderthals, resulting in some genetic exchange, and probably some material culture sharing, too [2–4] (Figure 1.1).

Regardless of the species, all of the earliest hominids used naturally occurring materials, such as plants, bones, feathers, skins, and tendons. Humans found and modified shells, antlers, and horns for functional and decorative purposes. Shells coated in red ochre clay and used as beads for jewelry, found in what is now eastern Morocco, date back to 82,000 years ago. Excavations in the Sibudu Cave alongside the Tongati River in South Africa reveal shells that were used as containers—not just for water or other goods, but for paint (see Ref. [5]). Layers of sediment preserving

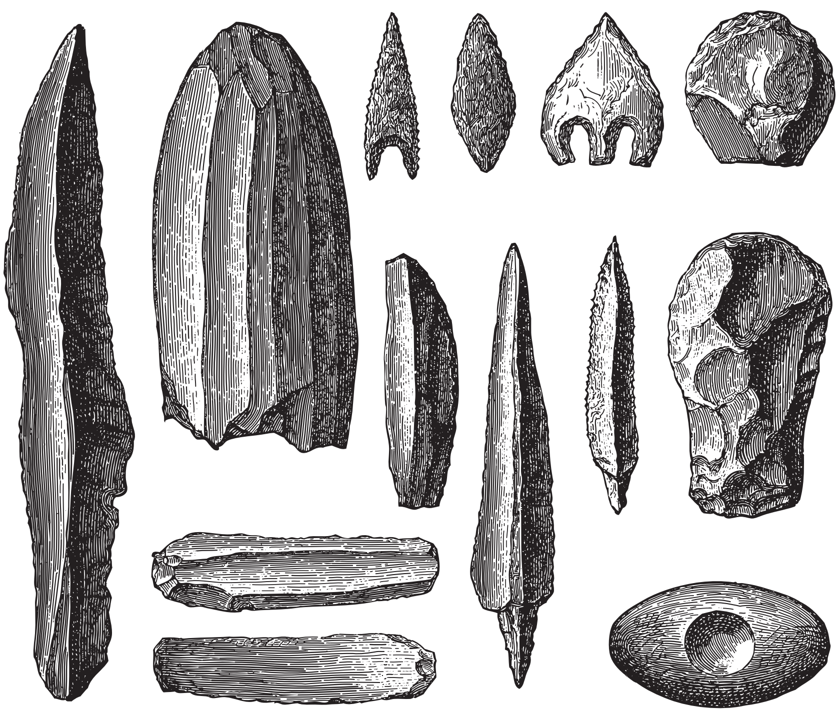

Figure 1.1 A sample of early stone tools. HeinNouwens/Shutterstock.com.

years of occupation dating from 50,000 to 80,000 years ago contain needles, animal traps, bone arrowheads, some stone tools, and a type of binder or glue made of ochre clay [6]. Much later, stone was used to make massive buildings and, around the time the wheel was invented, the first roads.

The materials these early humans left behind have enabled anthropologists to learn about each civilization's technological and cultural development. The things they made and how they made them—their material culture—can tell us a lot about how they lived, what was important to them, and what motivated them to build and invent new things. Much of the knowledge about materials came from the exchange of ideas and material culture between peoples, as well as apprenticeship, the passing on of knowledge through generations. As it turns out, there was a "materials science" long before the term was ever coined and institutionalized in universities.

As humans developed, so did their use of materials. Many of the materials used in ancient times are still in use today, including stone and animal shells. These materials still have the same qualities that they did back then, including appearance and feel. But the development of metals led to a whole new way of life, made possible by the unique qualities of these materials. While it was once thought that the practice of metallurgy began in one place and diffused around the globe through trade, the latest archaeological evidence indicates that it was more complicated than that. In many cases, people discovered how to use metal independently of one another. This led to a diversity of techniques in metallurgy, some of which led to smelting, as well as the synthesis of new alloys.

1.2 The Age of Metals

Beginning about 8700 BCE, copper with its lustrous sheen and flexible properties attracted the human eye in Mesopotamia, Asia and other sites around the world. People learned how to extract raw metal from ores, and began to use found metals like copper, silver, and gold. Europeans and Asians first used copper to make pigments and jewelry [7]. Smelted copper appeared around 5500 BCE in southeastern Europe—what is now Serbia [8]. The Sumerians and Egyptians also loved copper, crafting religious iconography, jewelry (of course), and even pipes for use in plumbing [9,10]. Copper was used in North and South America, too. Some of the oldest copper artifacts date back to about 6000 BCE in North America. Indigenous Americans did not smelt copper, but hammered it into shapes. Living near the Great Lakes, they had access to a great deal of pure copper, and made knives, awls, spearpoints, and jewelry [11,12] (Figure 1.2).

Figure 1.2 A sample of copper ore. RussellShively/Shutterstock.com.

With the advent of smelting, metals could not only be extracted and purified, but also intentionally combined with other materials while in a molten state. The resulting metal alloy would then be poured into a cast, usually made of clay, and cooled until hardened in the desired shape. Bronze, the first alloy, was primarily made of copper combined with smaller amounts of arsenic or tin. It first appeared as a copper and tin mixture in the Near East, Egypt, and Mesopotamia. The oldest known artifacts were produced by the relatively peaceful Vinča farming culture in what is now Serbia, and included figurines and ornaments [13]. Around the world, bronze became the primary metal for use in toolmaking, as it was much stronger than copper. In China, bronze remained the preferred metal for vessels, art, and utilitarian objects even after iron came into use (Figure 1.3).

Iron developed in a more haphazard way around the world due to the difficulty involved in mining and shaping iron and, in some cases, a cultural preference for the look and feel afforded by bronze. Ancient peoples first used meteoric iron (an alloy containing nickel), hammering it into the desired shape. This alloy is naturally found in meteors, and did not need to be smelted for use, and some people used it without ever having discovered bronze. However, while iron ore is found throughout the world, iron is rarely found in nature in a pure state. Extracting pure iron from iron ore requires smelting. It is during the smelting process that carbon can be introduced to iron, resulting in steel, a harder and stronger material. Since steel was lighter

Figure 1.3 Ancient bronze helmet. Planner/Shutterstock.com.

and cheaper than bronze, and in many cases stronger, it became the preferred metal for weapons, armor, containers, and other objects in many parts of the world. Artisans began to depart from the casting methods that were commonly used for bronze, and began utilizing forging and tempering, developing the blacksmith tradition. More advanced metallurgy and smelting at higher temperatures led to the crafting of new kinds of steel, using different amounts of carbon and nickel and other alloying elements. The swords and weaponry of the middle ages were the result of the materials science developed during this period (Figure 1.4).

Ulfberht, the famous Viking sword featured on the PBS NOVA program [14], is the first known example of fine steelmaking. In fact, it predated similar technologies by nearly a thousand years. While most medieval weapons were made from common wrought iron, the Ulfberht swords—so named because the brand was marked in the blade itself—were made from something called crucible steel. At the time, Vikings would most likely have acquired the technology from trade or conquest activities in Central Asia. Fired at a much higher temperature and made

Figure 1.4 A sample of iron ore. Kletr/Shutterstock.com*.*

Figure 1.5 Ulfberht swords, forged of crucible steel, were superior in performance to all other swords made during this period. *Photo by Torana, shared on Creative Commons.*

liquid, crucible steel absorbed a much larger amount of carbon, while impurities—such as slag and other particulates—were dissolved. Crucible steel was therefore much stronger and more flexible, and made a much finer (and more deadly) edge. It was able to pierce through most armor (Figure 1.5).

With all of the historical and archaeological emphasis on stone and metal it can be easy to forget about other materials. But metal blades do not cut most efficiently and effectively all by themselves. A handle—usually made of wood or another relatively light, sturdy material—provides grip and leverage, and supports the blade for greater accuracy. The blade must be bound to the handle in such a way that heavy use will not dislodge it. For as long as humans have been using raw materials, we have also been inventing and improving fasteners, fillers, binders, and accessories that, put together, turn a man-made item into a functional thing. While often overlooked, this kind of practical, hands-on experience is an important part of materials science; sometimes it is even more important than the technological advances in the processing of raw materials.

1.3 Other Materials

Wood has been, and continues to be, a basic building block of human architecture and machinery. The Ancient Egyptians built statues and other detailed works of art out of wood. The Chinese timber frame is considered one of the most important contributions to architecture worldwide (Yingzao Fashi). African artisans developed unique carving techniques as they used wood for architectural embellishments. People all over the world made masks, jewelry, and ceremonial items out of wood. Traders harvested and sold unique varieties, like ebony and mahogany, from various parts of the world—many of which are still some of the most valuable materials today. Nearly every seafaring society built ships out of wood, often coating it in pitch or other water resistant sealants to prevent waterlogging. The oldest simple machines—including medieval weapons such as the trebuchet—were made from wood, as were the first wheeled vehicles. The Mississippian culture of North America built enormous pyramid-like religious and residential structures out of river clay and sand, topped with buildings entirely from wood from 600 AD to the 1400s. South Americans used a great deal of wood in their famous architecture as well. It has been, perhaps, the most ubiquitous building material, though it does not preserve well in the archaeological record compared with nonorganic substances. Yet there is no “wood age,” perhaps because people have always used wood and will continue to do so. It is a functional, versatile, and beautiful resource, and when used properly, a renewable one as well.

In China, artisans learned how to craft bamboo—an exceedingly light, hollow wood—in ways that are still poorly understood in most of the world. Mass production of paper made from bamboo fibers enabled the development of paper currency and, of course, accessible and cheaply made tablets for writing. The Chinese also invented paper kites, then around 600 AD combined flexible bamboo with silk for the fabric and twine, and sometimes equipped these kites with strings and whistles for musical quality. Kites and other flyers were not just for entertainment, but became useful for military communication, and provided the basis for the science of aerodynamics [15]. Much later, wood was even used to build the first airplane.

Then there are ceramics, fired clays, and glass. Around the same time Americans were crafting wood and clay, artisans in China were developing porcelain, a ceramic material made from processing a specific type of clay. The first artifacts made from these materials include pottery: containers used to carry water and food. Over time ceramics have become more specialized, with new firing techniques and glazing giving rise to a wider variety of materials. The properties of ceramic make it an ideal material for a number of surprising functions. For example, ceramics are used in the auto industry for a wide range of applications including engine parts and brake disks, due to the material's resilience at high temperatures. Ceramics are also sometimes used in the medical field, as synthetic bones or for orthopedics.

Chemistry played an important role in the use and development of new materials. As a study of the composition, properties, structure, and change of matter and energy, chemistry is an ancient field first known as alchemy, which also encompassed metaphysical concerns. Though alchemy had long been practiced around the world, Grecians are credited with coming up with the first basic theory of chemistry [16]. Chinese artisans also developed chemical solutions, devising the explosive potassium nitrate from sulfur, charcoal, and saltpeter (later used in the Chinese cannon). Chemistry was canonized as an empirical academic discipline by Sir Francis Bacon, Robert Boyle, and their colleagues in sixteenth-century Britain.

Another aspect in the use of new materials is fuel sources, which arguably drove the development of metallurgy and, ultimately, the Industrial Revolution. Fuel has always been necessary in the production of ceramics and glazes, metals, and certain stonework. It was the discovery of coal—which replaced wood because it burned hotter and was easier to find—that enabled the Industrial Revolution.

1.4 The Industrial Revolution

Beginning in the late 1700s and lasting into the 1800s, new manufacturing processes, the use of coal as fuel, the development of steam technology, new agricultural methods, and new machines all contributed to the boom in production and innovation known as the Industrial Revolution. Along with machine production came a new concept: the factory. Up until now the makers-of-things were part of the village, or the tribe. They might be a carpenter or a blacksmith or a tailor or even a mad-hatter. They had their workshops, and sometimes there were clusters of artisans—the first cottage industry as it were. But then the concept of the factory developed. The factory enabled not only mass production, but also specialization. Each machine designed a different part: one machine would pour the glass into a mold while another pressed the caps, while yet another applied the caps to the jar. At first, factories still required a lot of human labor too. Mass migration from rural areas to the cities provided that, and people worked alongside machines in factories (Figure 1.6).

Wheeled vehicles—carts, wagons, trains, and later trucks and automobiles—and ships, of course, made relatively fast work of transporting materials from the mine to the factory, and then to the consumer. Aside from enabling a massive increase in metal production—particularly lead, iron and steel—the Industrial Revolution also saw innovations in chemistry, gas utilities and lighting, cement, glass, paper, transportation infrastructure (such as railways), and mining.

The advance of the machine did not result in a betterment or worsening of goods overall. Rather, where once there had been bad artisans and good ones, now there were dysfunctional machines and excellent ones. Depending on the company, the materials used, and quality of the human labor (often related to how well the laborers were treated), factories produced a wide range of products from shoddy to quality-made. Overall, consumers benefitted because there was better access to a wide variety of products including clothing, household goods, transportation, and fun things like toys and entertainment, and advances in packaging and distribution allowed for low cost access to quality food and medicine.

Most things being made by machines had another effect: the resulting objects looked and behaved the same. It became popular for people to buy what was fashionable. Consumers wanted to emulate celebrities—and each other. Having a brand name became a mark of social status. Originality

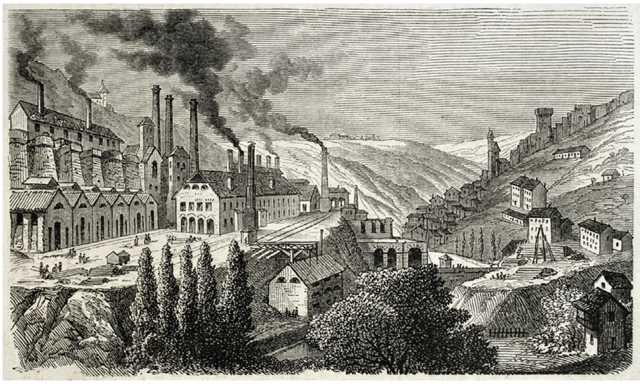

Figure 1.6 Antique illustration of Aubin forging mills, France. *Original, from drawing of Forest, published on L'Illustration, Journal Universel, Paris, 1860.*

now took extra effort and had to be customized, and so it became the mark of the ultrawealthy and the eccentric. This changed the way things fit into people's lives. People had a new relationship with objects, and by extension, a new relationship with the artisan or manufacturer. The Age of Mass Production had arrived.

1.5 Mass Production

As factories became more and more specialized, the machines used in the factory began to take center stage. Humans designed the machines, turned them on, maintained and cleaned them. The saying "Never buy a car that was made on a Monday"—insinuating that the workers might have had a little too much fun over the weekend—became less relevant. Now machines could do things that could not be done by hand. They could make and move bigger and heavier parts, like ship propellers. All made the same way, products became more reliable. They were all the same size and could fit in the same spaces. For example, doors made out of the same materials and all the same way would fit into the same size doorways, resulting in standardization of building practices and, therefore, cheaper prices all around. More complicated devices could be put together in an assembly line, allowing for replaceable parts to be used.

It was Henry Ford who sponsored and championed the assembly line, promoting an industry standard known as "Fordism," which prioritized high wages for employees and cheap, accessible products for consumers. Ford also implemented the first vertically integrated factory, with steel and glass developed in-house. Thus Ford developed the first affordable automobile, the Model T, which was introduced in 1908. As part of the standardization process, Ford later had the Model T painted only in black because that was the cheapest color to use. He famously said: "Any customer can have a car painted any color that he wants so long as it is black" (Figure 1.7).

In *The Work of Art in the Age of Mechanical Reproduction*, the philosopher Walter Benjamin discussed what happens to the originality of a work, and its social impact, once it can be easily reproduced. If we take liberties in paraphrasing Benjamin, we can say that the author of a work lost face once that work could be reproduced en masse. Extending the analysis beyond works of art, we can say that the machine entered the realm of production as a primary interlocutor, and the value of all things based on their reproducibility became one of the driving forces behind their initial design.

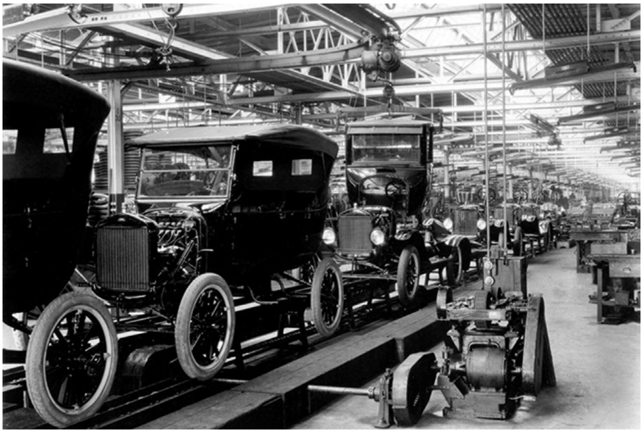

Figure 1.7 Ford Model T factory.

But as it turns out, the role of the artisan or designer—the person who makes a thing—is still every bit as important in the age of mass production. One of the reasons for this has to with materials science.

1.6 Materials Science

One of the most important things about designing a product is choosing the right material for its manufacture. In the human history of making things, we have managed to come up with hundreds—if not thousands—of different raw materials to choose from, as well as a number of varieties of each material having to do with where it came from, the specific physical and chemical properties of that particular source, and its method of manufacture or processing.

In the old days, if an artisan made a clay bowl that broke, the user would be unhappy. If it happened again, the user would not buy any more bowls from that artisan. The same with a blacksmith: one did not become a respected blacksmith by making shattering swords. But when a manufacturer produces a part that breaks, the consumer (and often the company too) shrugs it off as a manufacturing defect, or simply as a bad design. Rarely do they consider the very real possibility that they are simply using the wrong material.

Choosing proper materials has always been an important part of the creative process, one that requires learning from those who are not only knowledgeable, but who are also experimenting, and building on existing theory and practice. In the era of mass production, proper material selection takes on a whole new level of importance because of the degree of specialization required. However, it was not until 1955 that the study of the properties of materials became formalized when faculty at Northwestern University in Illinois founded the first Materials Science Department [17]. As materials science has developed and become formalized, professional societies have formed to help guide practitioners in their respective fields. These include the following:

The American Society for Materials

The Aluminum Society

The Association for Iron and Steel Technology

The Pulp and Paper Association

The Concrete Institute

Professionalization has become necessary because the process of material selection has changed from a task based on conversation and familiarity, to one of mathematical analysis. And often, one needs an advanced degree just to understand the math.

Plastics entered the scene during and after the professionalization of materials science, so unlike older materials—like stone, steel, and the ever ubiquitous wood—it lacks that history of apprenticeship. There is no oral tradition where knowledge and insights and sage wisdom about plastics is passed from generation to generation. However, a person who works with plastics needs to have an appreciation for their history, their variety, and the attributes that make them so functional, versatile, and yes—even beautiful.

1.7 The Plastics Age

Plastics are organic materials, that is, they are composed of chemical compounds containing carbon. These compounds are linked together to form molecules known as polymers. While we may think of polymers as being new and high tech, the reality is that they have been around forever. They exist in nature in many forms. Latex rubber, made from the sap of the rubber tree, is the most obvious example. Rubber tapping is an age-old tradition practiced around the world and usually passed down through generations. Even today, families and communities still keep groves of rubber trees, carefully tapping them for the viscous sap, plugging up the holes, and working their way up the tree as each spot heals over.

Rubber is not the only naturally occurring polymer; all plants contain cellulose in their cell walls. Cellulose is a polymer based on carbohydrate compounds. Egg and blood proteins—long used to make paint, glue, and textiles—are also naturally occurring polymers. Naturally occurring polymers have always been used as fillers, additives, adhesives, and colorants. Some of these polymers are still in use today, and are resurfacing in today's plastics industry as a viable material for use in bioplastics, and the sustainable rubber trade is still going strong.

Today, much of what we think of as plastics are synthetic materials, which came about as a result of chemical synthesis. The first synthetic, laboratory-born polymer came about as a replacement for ivory. In the 1800s elephants and other ivory-bearing animals were dying out because of the prolific use of ivory, for everything from the boning in corsets, to combs, to piano keys, to billiard balls. Inventor John Wesley Hyatt made celluloid, meaning *like cellulose*, by experimenting with cotton. Similar to naturally occurring polymers, it was more versatile, although it had the drawback of being extremely volatile and explosive. It did not quite make good billiard balls—not yet—because celluloid balls were too loud when they hit each other, and factory production was extremely hazardous. But celluloid replaced ivory for other products, most notably film. The success of celluloid led to development of other materials, such as Bakelite (whose rather daunting chemical name is polyoxybenzylmethylenglycolanhydride) and other phenolics. Bakelite was the first thermoset plastic ever made, and was invented to replace shellac, a polymer derived from insect excretions. This phenol–formaldehyde solution had the advantage of being more versatile, and much less volatile, than celluloid [18,19].

Further advances in polymer development were led by the DuPont company. Nylon (polyamide), invented in 1935, was fabricated as a silk replacement, and was introduced at the World's Fair as a textile in 1939. The material, a thermoplastic, was lightweight and cheap to produce. It was also resistant to heat, mold, mildew, and abrasion. Since it was also very strong, it replaced metal in the manufacture of many mechanical parts and tools. One of the most versatile materials ever made, it was used to make everything including parachutes, stockings, tents, musical strings, sausage casings, and tires. Quite literally, nylon changed the world. It was nylon production that led to the development of more specialized polymers, like Saran Wrap (polyvinylidene chloride), whose impermeability makes it ideal for food storage. By the 1950s, synthetic polymers had become a staple of everyday life (Figure 1.8).

Today, the body of knowledge about plastic materials and their use is vast. There are hundreds of thousands of people who work in the plastics industry.

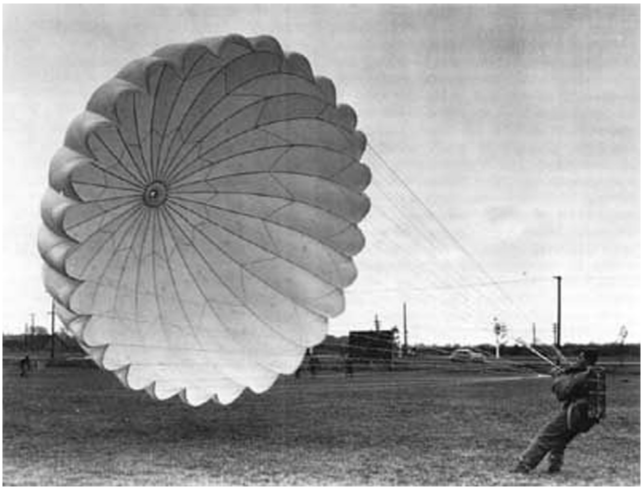

Figure 1.8 Nylon parachute.

In the United States, plastics represents the third largest manufacturing sector. There are hundreds of universities around the world offering degrees in Polymer Chemistry and Plastics Engineering. There are dozens of professional societies dedicated to various areas of plastics technology. There are thousands of technical books, and hundreds of thousands of technical papers on plastics processing, plastics design, and plastics engineering. Yet, on a societal level, even a personal level, most people are ignorant about plastic materials—and even think about them negatively because they are synthetic. But plastic is not the first ubiquitous, and indispensable, synthetic material.

1.8 Plastics—The Other Synthetic Material

Many people think of plastics and other synthetic materials in a negative light. In common language, plastic has sometimes become a derogatory term people use when they want to imply that something is cheap, superficial, or artificial. This attitude is linked with fear of chemicals, or "chemophobia" [20–22].

To better understand this mentality, let us take a look at the etymology of the word "synthetic." Originally, it comes from the Greek *synthetikos*, which means "skilled at putting together, constructive." It is generally understood to be something that is not found in nature, meaning that one has to put together elements of other things to make it. Steel is often idealized as "the real thing," but it is man-made, too. It is a metal alloy, composed of manipulated iron and other elements. The reality is that steel is a synthetic, man-made material.

Plastic is also a synthetic, man-made material, and is often considered the antithesis of natural. But is natural always better? There are lots of natural materials that are toxic—lead, arsenic, mercury, asbestos, hemlock.

Both plastics and steel are man-made, but that does not make them unnatural. They are made from elements found in nature, by people who as carbon-based life forms are not only part of nature, but have been working with natural elements and modifying those elements since early hominids walked the earth. Just as a metals expert constructs and alters metals, so does a polymer chemist synthesize compounds from organic elements. In reality, chemicals and synthetics are a result of a creative process—or, in other words, people making stuff.

So whatever you think about plastic, it is definitely not artificial or fake. Artificial implies that something acts as a substitute for “the real thing”—like artificial flavors. While plastic is sometimes a substitute for another material, plastics are unique materials with unique properties that make them ideal for a wide variety of uses.

Now, let us look more specifically at the word plastic itself. Before the word *plastic* (from the Greek *plastikos*) was used to name the material we know today, it was used to describe anything that could be easily molded or shaped. We still use it as an adjective: clay has plastic qualities, for example. The substance we call plastic was so named for its very physical characteristics—plastic materials can be easily molded or shaped.

While there are concerns around the environmental implications of plastics use, some legitimate and some not, a quick look at the history of the material reveals another side to the matter. Plastics were originally invented to replace ivory, that extremely “natural” substance whose use today is responsible for several present-day extinctions of large mammals, such as recently, the Black Rhinoceros. Like most materials, plastics can be more responsibly and aptly used when better understood. The reality is that plastics are all around us, and will continue to be important to our daily lives. Proper understanding of these materials will lead to innovative and sustainable use and development.

1.9 Plastics Material Selection

As discussed earlier, proper material selection is a critical component of any manufactured product. This is especially true with plastics. Traditionally, engineers and manufacturers have used a combination of methods for selecting plastics materials, including a comparison of published property data, recommendations from material suppliers, and good old trial and error. The process can be difficult, time-consuming, expensive, and often frustrating.

What is often lacking in this process is a fundamental understanding of plastics as a raw material—a substance used to make things; one that requires creativity and consideration. For example, the blacksmith had to acquire a lot of detailed knowledge about materials to make a good sword, which is really a very advanced product. Many people who work with plastics think it is enough to use "SKP"—just *some kind of plastic*. This results in a bad quality product, just like a blacksmith making a brittle sword containing too many impurities. How can you make something out of plastic if you do not understand the material? This book is designed to fill that gap, by describing the characteristics of these unique materials and providing a guide for effective plastics material selection.

1.10 How This Book Can Help You

This book is for a diverse audience: engineer, manufacturer, industrial designer, supply chain professional, architect, scientist, student, physician, teacher, student, politician, policymaker, artist. Students and educators can use it both as a resource for information and a guide in the classroom. Psychologists, historians, and anthropologists, who look at the way in which each individual, and the species, grows through creative interactions with objects and materials in everyday life, will find interesting lessons in the story of plastic. Astrophysicists, physicists, and chemists will gain insight toward the application of the material by knowing more about its origins, properties, and potential. Medical professionals may want to make products for patients that are more marketable, usable—and even fun. Policymakers—people who legislate, regulate, and make policies and procedures—may become better informed to make good decisions.

Last, but far from least, creative technical specialists—people who are in the business of making things—can use this book to guide their work. Designers, engineers and other specialists need to know how to choose the right material for their products. While the right material may or may not be plastic, learning about the advantages of plastics and how to choose them will open your horizons and give you more flexibility in your field. This is, of course, also useful information for supply chain professionals: those in the trenches of the manufacturing world, getting the job done everyday and forming the backbone of the industry.

While an ambitious project, it is a necessary one. Even though we are in the midst of The Plastic Age, the plastics industry is transforming, undergoing some critical self-evaluation, and feeling more than a few growing pains. Plastics are not going away; if anything they are becoming more prevalent. The industry is growing and becoming more innovative. 3D printing has introduced a new level of efficiency to the market. New material technologies, such as bioplastics, are garnering more attention due to a depletion of natural resources and a sense of urgency about the effects of global warming. Professionals in all industries need to become familiar enough with plastic materials to understand their traditional use and manufacture, their history as a material, their untapped potential, and their role in the future.

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