ABSTRACT

HEDLUND, JOHN ANDERSON. The Development of Plastics in the United States: A Political Economic, Historical, and Socioecological Analysis. (Under the direction of Drs. Stefano B. Longo and Michael Schulman).

The purpose of this dissertation is to conduct an historical analysis of plastics as a raw material of production from the mid-19th century to the post-World War II period. This is done in light of two Marxian theoretical frameworks that deal with the political economy and socioecology of capitalism: the former being monopoly capitalism-imperialism, while the latter is the theory of social metabolism. This analysis is also conducted through a consideration of what I call the nature/society problematic: debate over how, or whether, to demarcate between social and natural phenomena. This debate is currently concentrated in the milieu of social metabolic scholarship and thought.

Beginning in the 19th century, I trace the development of plastics of natural origin to synthetic plastics. Specifically, I analyze natural plastics such as rubber, gutta percha, and shellac; celluloid, the first semi-synthetic plastic material; Bakelite, the first fully synthetic plastic, and a thermoset plastic; and the class of synthetic thermoplastics that first emerged between the two world wars and proliferated in the post-War period. In doing so, I consider the relationship between these materials and some critical technoeconomic developments, particularly in the ICT (information and communication technology), military, and transportation sectors, among others. Relatedly, I also consider the relationship between the larger political-economic context and the ecological implications of plastics in its various phases of development.

Finally, I conjoin the historical development and current state of plastics with the nature/society problematic. Analyzing the debate between metabolic rift and hybridist

approaches to metabolism and use of the dialectical method, I conclude that while society is embedded and rooted in nature, the instance of plastics provides further insights into the ways in which social forms of organization demand distinction between social and non-social, or natural, phenomena.

I conclude by suggesting directions for future research on plastics, the society/nature problematic, and the theoretical frameworks I employ. Plastics in its global, and contemporary, iteration requires further critical analysis in the social sciences, where the subject has largely been ignored. The society/nature problematic can be examined through other cases beyond plastic, to further concretize the questions it raises. Further analysis of the ways in which the theoretical frameworks of monopoly capitalism and social metabolism, and the political-economic as well as the socioecological, interface and intersect is also called for.

The Development of Plastics in the United States: A Political Economic, Historical, and Socioecological Analysis

by
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DEDICATION

This dissertation is dedicated to the people of Gaza. Their struggle is our struggle: Never again means never again for *anyone*.

BIOGRAPHY

John Anderson Hedlund was born in Chapel Hill, NC in 1986, and grew up in nearby Durham. Raised by two professors, he initially had little interest in academia. An introduction to the world of social ideas came through involvement in the anti-war movement. John spent two semesters at UNC Greensboro before dropping out to pursue political activism more fully. A few years later, he returned to school at the City College of New York (CUNY), where he fell in love with sociology and finished his bachelor's degree. John returned home to central North Carolina in the mid-2010s, and applied to graduate schools. He happily ended up at North Carolina State University, pursuing a PhD in sociology, in the food and environmental sociology concentration.

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Thank you to Stefano Longo, for believing in me and this project from the very beginning. I couldn’t have done it without you. Michael Schulman, thank you for taking on the role of co-chair, and providing much-needed support and clarity throughout. To the rest of my committee members—Sarah Bowen, Tom Shriver, and Andrew Davis—thank you for your helpful comments, commitment, and support. To Anna: I love you dearly. Thank you for loving and believing in me. To my family: Thank you for showing me the meaning of unconditional love. And to all those fighting for a radically different and far better world: Thank you for forging the path forward.

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CHAPTER 1: PLASTICS, HISTORY, AND NATURE: AN INTRODUCTION

Introduction

Few things have entered our world as quickly, and in such abundance, as plastics. Virtually nonexistent a little over a hundred years ago, plastics have become ubiquitous in our social world and daily lives. From the clothes we wear, to the structures in which we reside, to the packaging of our food, they make up much of the material foundation of our built environment. As writer Susan Freinkel, author of *Plastic: A Toxic Love Story* discovered through keeping a journal of every plastic item she touched, this material is virtually impossible to avoid. Everywhere we turn—in our homes, offices, cars, cityscapes, and shopping malls—we are confronted with it, in both overt and covert forms.

But this human-engineered class of material used to manufacture everything from building lumber and spaceships to artificial heart implants does not remain confined to our socially constructed world. Plastic waste and pollution have become one of the defining, paradigmatic environmental problems of our age. From the darkest depths of the ocean floor to the frozen Arctic landscape, to the surface waters of the Antarctic; plastic can now be found in nearly every ecosystem, and every region, of the planet (McCallum 2018). It has even managed to enter our very bodies, as recent studies confirming the presence of plastics in our bloodstream show (Carrington 2022).

Stories about plastics—what to do about their seemingly insurmountable, daily accelerating accumulation in the oceans and its long-term impacts on marine systems; their effects on the health of humans and other species; and how to avoid using them in our daily lives—are becoming as omnipresent as the material itself. From international conventions dealing with global plastic pollution; to nationwide bans on the import of plastic waste and the use of plastic bags; to the viral photograph of a dead albatross, its decaying intestinal remains filled to the brim with the colorful synthetic material; plastics have become firmly entrenched in both our social consciousness and individual consciences.

But where did this material come from, and why? What role does it play, economically and socially? How did it go from being a negligible to a pervasive part of our world? How does its existence and proliferation relate to larger political and economic events, factors and processes; and to the economic system that generated it? And what does the presence, on such a monumental scale, of this human-made synthetic material say about humanity's relationship with the natural world?

Outline

In this dissertation, I look at the rise of plastics as both a raw material of capitalist production, and, more broadly, as a material force in the modern world. My analysis starts in the mid-19th century, when plastics of natural origin—such as rubber and gutta percha—began to be incorporated into the circuits of capitalist production, as raw material for the assembly of saleable commodities. Over the course of more than a century, what started as a marginal product became an epoch-shaping material force. This process coincided with major changes in the political-economic underpinnings of the United States, and indeed the world as a whole. Among them are the increased centralization and concentration of capital, the heightened global integration of the economy, the emergence of more capital- (rather than labor-) intensive methods of production, and more. Much of these changes can be umbrellaed under the theoretical framework of monopoly capitalism-imperialism, one of the two main theories used to unfold my analysis, and which I explain in some detail in the subsequent chapter.

Also central to the historical development of plastics is the rise of synthetic productive materials, and consequently of synthetics as a material force in society, which coincided with, spurred forth, and resulted from the emergence and development of plastics as a material. The progression of organic chemistry and founding of chemical engineering, the scientific-technical revolution, the widespread adoption of fossil fuels and their byproducts, and the rise of the petrochemical industry, among other occurrences, all conspired to set in motion a new material and energetic substratum upon which world society developed.

Marx's theory of metabolic rift, and the theoretical framework of social metabolism that flows from it, helps make sense of capital's inner compulsion to alienate the social world from the natural world within which it is embedded. This is the second main theoretical framework I apply, and which I unfold in detail in the subsequent chapter. The rise of what Foster (1999/1994) called "The Synthetic Age" during the second half of the twentieth century is a specific expression, and logical extension, of the alienation of society from the natural world that Marx spoke of 150 years ago. The story of plastics, its traversal from the mid-19th century to the present day, represents an intensification of this chasm, and by analyzing this material's biography an understanding of the larger phenomenon of the Synthetic Age can be gleaned.

The history of plastics is also heuristically useful in grasping the interrelations, and distinctions between, what can be considered social phenomena on the one hand, and natural (non-social) phenomena on the other. Within the social metabolic school of thought, how to deal with what I call the "society/nature problematic"—whether it is analytically useful to draw distinctions between social and natural phenomena, and if so, how to appropriately manage such distinctions—is a contentious question. Reconsidering this problematic through the lens of plastics, and particularly in light of this material's historical development, and transition from its natural origins to its synthetic present, injects novel insights into this contention.

Overview

This dissertation will proceed as follows. First, after a brief introduction to the subject and an explanation of this project's methodology, I will begin with a basic outline of the theoretical framing that guides the remainder of the paper. This chapter will consist of three parts. First, a brief overview of a Marxist theory of the relationship between technological development and social change. This is followed by an exposition of the two dominant theoretical frameworks applied throughout this paper: the theory of monopoly capitalism-imperialism and the theory of social metabolism. In unfolding the latter theoretical framework, I consider two differing approaches of social metabolism—a hybridist approach and the theory of metabolic rift—and how they relate to the society/nature problematic.

In the subsequent chapter, I begin to develop the “prehistory” of plastics by starting with plastics of natural origin in the 19th century. I first consider the earliest incorporation of forms of plastic mass into the productive apparatus of capitalism: plastics derived directly from natural resources, such as rubber, gutta percha, and shellac. Then I examine the emergence of the first attempt at a synthetic plastic material: celluloid. This "semi-synthetic" nitrocellulose substance was a kind of stopgap between natural and synthetic, petrochemical plastics. Its story is instructive because of the substance's limitations as an easily moldable, cheaply produced, inert, and inherently plastic raw material contributed to the search for a more fully "plastic" one. But also, due in large part to its success in transcending some of the shortcomings of other raw materials, celluloid also played a small but important role in some crucial political-economic and technological developments of the late 19th and early 20th centuries. All this will be analyzed, as will the tension inherent in this first primitive attempt at creating a material liberated from the contingencies and limitations of nature.

In the following chapter, I continue to trace the historical development of plastics as a raw material of production. Here, I begin with the first truly synthetic plastic material, called Bakelite, which was invented at the beginning of the 20th century. I end with the post-World War II explosion of a new type of synthetic plastic base materials, which continue to dominate much of the contemporary raw materials market.

This chapter accomplishes three main things. One, it develops an understanding of the intimate relationship between the further rise and consolidation of monopoly capitalism, particularly in the United States, and synthetic plastics. Two, it examines the centrality of the Second World War both as a harbinger of the postwar synthetic plastics proliferation, and it further elaborates the significance of this war, and world wars generally, in the configuration of the political-economic order under globalized monopoly capitalism. And finally, it begins to explore the monumental alteration in humanity's relationship with the natural world through the introduction of synthetic materials. This notion of a synthetic social metabolic order, and what it means for society's place in and relation to the earth system, is expounded upon in a beginning way here.

In the final substantive chapter, I take up the question of social metabolism and how different iterations of this framework view the society/nature problematic. I consider two differing approaches of social metabolism—a hybridist approach and the theory of metabolic rift—and how they relate to the society/nature problematic. Here I conjoin this scholarly debate with the historical development and contemporary experience of plastics, and the synthetic/natural dialectic. In doing so, I use plastics as an instance and example of why analytic distinction between social and natural phenomena is both theoretically relevant and practically important in navigating this historical moment and understanding how to transcend it. Central to the nature/society problem, the historiography of plastics, and the social metabolic school of thought, is the question of dialectics and the dialectical method. Thus, in analyzing the question of the social metabolism of society/nature as it relates to plastics, I will briefly outline the materialist dialectical method, and how its application deals with analysis and abstraction, as well as synthesis and unification.

In conclusion, I will briefly review my findings, context my contributions to the literature, and present some suggested directions for future research.

Methodology

This dissertation seeks to understand and make sense of the rise of plastics as a central component of our modern world. I approach this question historically, through the lens and methodology of historical sociology (Calhoun 2003; Delanty and Isin 2003; Duncan 2003; Skocpol 1984). I thus draw on and analyze historical data. I mainly rely on secondary sources: scholarly accounts of the development of plastics, from the first half of the 19th century to the post-World War II era, up to the present. I also utilize statistical data as well as primary sources: accounts written by some key actors involved in the production, development, and dissemination of plastics. I follow the tradition of eminent sociologists, social historians, and political economists, and their historical analyses, such as E.P. Thompson (1966), Craig Calhoun (2012), Karl Polanyi (1944), Sven Beckert (2014) and Andreas Malm (2016), among others.

Historical sociology can be seen as both a subdiscipline of sociology and an interdisciplinary field. As Delanty and Isin (2003) put it, "historical sociology occupies an ambiguous space between history and sociology," in which a primary focus is "a concern with the formation and transformation of modernity" (p. 1). Thus, historical sociology draws from both disciplines, attempting to overcome the sometimes ahistorical and "presentist" shortcomings of contemporary sociology, and the occasionally atheoretical nature of history to forge a higher synthesis.

But historical sociology is also eminently sociological. As historical sociologist Craig Calhoun puts it, "The most compelling reason for the existence of historical sociology is embarrassingly obvious . . . This is the importance of studying social change" (2003:383). Since social change is a (if not *the*) foundational concern of sociology, the need for taking an historical approach to social research is clear. In fact, much of the work of the canonical sociologists was explicitly historical, both in its methodology and in its subject matter. Karl Marx and Max Weber, for example, "saw no clear distinction between historical and sociological analysis" (Duncan 2003:11). This is not simply because the disciplinary boundaries between the two had yet to be clearly demarcated. It is also a question of method and approach: we can understand the social world of the present only by excavating and reconstructing the past.

Similarly, Abrams (1982) points out that at the heart of Marx, Durkheim, and Weber's work was their devotion to the basic question: "to what extent does the world have to be the way it is? It was," Abrams continues, "the decision to seek an historical answer to that question," rather than a philosophical one, "that made each of these men sociologists" (p. 5). Thus, to treat contemporary social formations as reified phenomena, taken for granted as simply "how it is," misses the point of sociological inquiry.

This leads us to the second reason Calhoun gives for the importance of historical sociology: it "is a way of dispelling the illusions of false necessity. . . of demonstrating that what happens to be is not what must be" (2003:384). Not only are the current forms of social organization and edifices of social structure temporal and mortal, but they were also not destined to be as such. This dissipation of "false necessity" liberates thought about both why the world is the way it is, and how it could be different, even radically so. It challenges non-sociological notions about the "permanent necessity" of contemporary conditions and opens vistas to a potentially different and far better future (Avakian 2010). It is a key feature of the sociological eye—the ability to look beneath the surface of the social world and grasp the inner workings and deeper dynamics at play.

The third reason for the importance of historical sociology given by Calhoun is as follows: "the need to grasp analytic categories in the historical contexts of their production and application" (2003:384). In the analysis that follows, I use many such categories and concepts: social metabolism, the productive forces, monopoly capitalism, commodity production, etc. Such abstractions only come alive in their application to historical analysis, and it is through this application that their meanings are constructed. This is not to denigrate the importance of generalized, abstract categories of thought such as these; it is merely to highlight the importance of their application to the motion (and messiness) of real historical processes. Theory and history are in this way intimately connected, and mutually reciprocal. In the following dissertation, I attempt to bring such theoretical abstractions alive through applying them to the historical context from which they emerged.

What does it mean to *do* historical sociology, as a methodology? Is historical sociology a method, a subfield of the discipline, or is it both? Calhoun (1998) argues that historical sociology over time became, misleadingly, presented as a method or "style of research," as part of legitimizing it as a respectable field within the discipline (p. 850). Coinciding with a larger shift away from recognition of the importance of social theory toward an almost exclusively empirical focus, this "rebranding" of historical sociology as a scientifically rigorous approach to data collection and testing tended to divorce the discipline from its theoretical agenda. But at its core, historical sociology has always been theoretically centered and driven (Calhoun 1996). The centrality of theory is what sets historical sociology apart from the discipline of history. As Calhoun (1998) puts it:

> Whatever theory historians use to organize their narrative explanations . . . is commonly left implicit. Historical sociologists have related to history partly by making such theory more explicit, subjecting it to logical scrutiny, and challenging it substantively. Conversely, they have also related to theory by challenging its historical presuppositions. (pp. 855-56).

In other words, historians and historical sociologists both make use of theories and historical data in their research and analysis. The latter, however, tend to make the connection between the two more explicit, bringing into the foreground both the reciprocal relationship between theory and history as well as the often-obscured theoretical underpinnings of any historical narrative.

This is a critical insight. What Calhoun is arguing is not that historical sociology is *not* a methodology: rather, it is that historical sociology is *not reducible to* an approach to social research. Further, historical sociology is not simply a means of theory testing, through the generation and analysis of historical data; it is also a site of theory construction and elaboration. "What exists between theory and research practice," Calhoun contends, "is not a relationship of simple testing but one of sustained mutual engagement" (1998:863). Historical sociology is thus theory-driven and theory-generating.

In the analysis that follows, I use both historical data and theoretical framing in order to narrate the rise of plastics as a raw material of commodity production. In keeping with the method and approach of historical sociology, my aim is not merely to empirically test, or validate, the theoretical premises that guide my analysis. Instead, the relationship between the theoretical framing and historical narrative is interactive, mutually reinforcing, and reciprocal. I argue that the trajectory of plastics, and its relationship to many of the monumental political-economic occurrences that coincided with its rise and consolidation, can be best understood through the lens of the theoretical frameworks I employ. This is because these frameworks help explain the larger context within which plastics emerged, as well as both the direct catalysts for their emergence, and (more importantly) the underlying mechanisms at play which created the need (from the perspective of capital) for them. But at the same time, I use the historical experience of plastics to critically interrogate, challenge, and elaborate upon those frameworks.

For instance, I use the example of plastics in its role in the continued expansion and development of capitalism, and as part of a larger shift toward synthetics, as a means of interrogating contrasting precepts of the hybridist and metabolic rift approaches to social metabolism. Not only does the theoretical framework of social metabolism guide how I analyze the shift from natural to synthetic plastics, but my analysis of the shift from natural to synthetics, I contend, contributes to the further development of this framework.

With the theory of monopoly capitalism/imperialism, excavating and unfolding the history of plastics within the context of larger political-economic changes challenges aspects of economic determinism. This is particularly true of the iteration of this framework espoused by Baran and Sweezy (1966), including their tendency to reduce the question of imperialism and inter-imperialist war to being mainly an avenue for surplus absorption. Further, it strengthens some of the claims made by other iterations of this framework, namely that which is presented by Raymond Lotta (1984), about the ongoing existence, and intensification, of competition under monopoly capitalism, operationalized particularly as inter-imperialist rivalries. Theory and history here are not simply sequential: they are interpenetrating and mutually determining.

Research Questions

Before beginning, I want to present some of the questions I explore in this dissertation, as well as some comments on my key takeaways and findings. The next chapter, as discussed above, is where I flesh out the theoretical underpinnings of the subsequent analysis. In the third chapter, I trace the development of plastics in its earliest phase, starting in the 19th century and continuing through the early 20th century. Here I set out to make sense of how and why plastics of natural origin and early semi-synthetic plastics became incorporated into the circuits of productive capital as raw materials of commodity production, the relationship between this process and larger political economic developments of the time, and what drove the transition from natural to synthetic plastics. I analyze such larger political economic shifts through the theoretical framework of monopoly capitalism-imperialism, as well as Marxist theory more generally. I look at the transition from natural to synthetic plastics through the framework of social metabolism. As mentioned in the section above, the relationship between these theoretical frameworks and the history I construct is non-sequential and reciprocal: I attempt to use the historical data to guide theory as much as the theory guides my analysis of these data.

What I discover in the process is that not only do these early natural, and semi-synthetic, plastics fulfill important roles in the process of capital accumulation in the mid-19th century — and are closely aligned with scientific, technical, and cultural shifts and advancements of the time — but that through an analysis of these particular materials a larger understanding of the political-economic motion and development of this era can be developed. For example, the experience of rubber's incorporation into the capitalist economy details how technological and scientific developments, such as that of rubber vulcanization, interact with economic imperatives to catalyze new directions of socioeconomic and political development. Further, the production of the machinery used to process rubber into salable commodities, the historic transition from its extraction from wild rubber plants in the Amazon to the cultivation of rubber plantations in Southeast Asia, and the structural limitations of rubber as a moldable material, encapsulate much of the momentum and direction of the capital accumulation and the related sociopolitical developments of the time.

In this chapter, I also probe the following question: Why did these early "proto plastics" largely die out, and become replaced with a series of synthetic plastics? What social, political, and economic processes drove this shift from natural to synthetic plastic materials? What I discovered is that these early plastics simultaneously presented vistas for a whole new material underpinning of commodity production, while also failing to fulfill that role itself. This contradictory tension inherent in these materials—of both revealing the possibilities of plastics while lacking many of the characteristics that made the material so valuable—relates to the relative distinction between natural and synthetic. This is a matter I begin to explore here, through both engagement with the history of plastics and the theoretical insights of social metabolic theory and will return to later.

In chapter four, I begin to analyze the history of synthetic plastics proper, at the turn of the 20th century, and its relationship to some of the key technological, political-economic, and military events of the time. In doing so, I pose the following questions: What spurred the development of the first synthetic plastic mass, Bakelite? And why did this material itself become largely superseded by a new class of synthetics? What role did the Second World War play in the emergence of synthetic plastics? In what way was this shift to and proliferation of synthetic plastics part of a larger phenomenon, in which synthetics came to predominate the material and energetic underpinnings of society? And what drove this process? In doing so, I aim to historicize and contextualize the rise of synthetic plastics as a whole, as well as the crucial, if often overlooked, shift from thermoset synthetic plastics like Bakelite to the post-World War II class of synthetic thermoplastics.

One thing I discovered here is that, like its semisynthetic and natural predecessors, Bakelite both played an important role in some of the key economic and technological developments of the early 20th century and ran into its own material limitations. Bakelite—an essential ingredient in the automobile, radio, and telephony industries, among others—was the first synthetic raw material that could seriously compete with its natural counterparts. Like celluloid and natural plastics such as rubber, it presaged radically new possibilities regarding the material foundations of the economy and society. And it set the groundwork for the post-World War II explosion of new synthetics. But it differs structurally from what came to be the dominant plastic material of the post-war era, up to today. While Bakelite, and other phenol-based plastics, was ideal for industrial, electrical, and mechanical use, these very properties simultaneously limited its applicability to the larger world of consumer goods and beyond. The new class of synthetic plastics—an array of thermoplastics derived from petrochemicals and reliant upon the oil and gas industry, new advances in technology and science, and the rise of the United States as the new global imperial hegemon—coincided with a larger phenomenon, the birth of the

Synthetic Age, which fundamentally altered humanity's relationship to the rest of nature. The historical methodology I use in this chapter is the same as that of the preceding chapter.

In the process of historical research and analysis, some important theoretical questions surfaced. In chapter six, I take up the society/nature problematic and the relationship of plastics to it. Here, I consider the following questions: What can we learn from the historical development of plastics about this society/nature problematic? Does the emergence of synthetic plastics mark a subsumption of nature by society, and a dismantling of the society/nature distinction? Or does it instead highlight the importance of maintaining some analytic distinction between human-made, social phenomena and non-social, natural phenomena?

Analyzing the contemporary state of plastics—their post-World War II proliferation, and the relationship between plastics and both the Great Acceleration period and coinciding Anthropocene epoch—in the context of their centuries-long development from plastics of natural origin, provides valuable insights regarding the society/nature question. In doing so, I find that it is the very distinctness of synthetic plastics—composed of molecular arrangements not found in nature, and that could only be put together through human agency—that make them both so economically valuable and ecologically calamitous. Rather than eschewing the need for distinctions between society and nature, the emergence of synthetics in fact strengthens it. Without such distinctions—for example, the difference between the laws, motion and development of the capitalist mode of production on the one hand, and the laws and imperatives of ecology on the other—it becomes quite difficult to understand both aspects, the economic value and ecological peril, of plastics.

Conclusion

Plastics are now being widely discussed and deliberated over in media, governmental, and scientific forums. Yet despite both its political-economic and socioecological relevance, sociologists and other social scientists have largely ignored it. In analyzing plastics sociologically, from a historical perspective, and in relation to contemporary theoretical debates in the field of environmental sociology, I attempt to introduce this critical issue to the discipline.

While my focus is on its historical development, ecological impacts, and political-economic relevance, there are a number of additional areas of sociological inquiry ripe for analysis of plastics. For example, the role plastics played in promoting and facilitating mass consumption and "throwaway culture" (Hine 1995); or in changes in the time spent on "social reproduction" labor such as cooking and cleaning (Clarke 1999); or as a cultural artifact that transformed how we think about art, design, and temporality (Meikle 1994); are all sociologically relevant, plastics-related queries. There is also a near endless array of ecological concerns, only some of which I will be able to briefly touch on, regarding plastics to which environmental sociologists could contribute much needed thinking. It is my hope that the following dissertation contributes to elevating plastics specifically, and socioecological analysis generally, within sociology and the social sciences.

CHAPTER 2: MARXISM, MONOPOLY CAPITALISM, AND SOCIAL METABOLISM. A THEORETICAL FRAMEWORK

Introduction

In this chapter, I will outline the basic theoretical framework which will guide the subsequent analysis. This will consist of three main parts: an opening section on the Marxist theory of the relationship between technological/productive force development and social change; a section on the theory of monopoly capitalism-imperialism; and, finally, a section on the theory of social metabolism and metabolic rift. Each of these theoretical frameworks will inform my overview of the historical development of plastics in the following pair of substantive chapters. The latter framework will be the focus of the third substantive chapter, which analyzes different approaches to social metabolism in relation to the society/nature problematic.

Technology and Society

To understand the historic rise of plastics, in all its manifold forms and uses, a theory of the relationship between technological development, political-economic structures, and society is required. At a basic level, and as a necessary foundation, such a theory is found within Marx and Engels's elucidation of the historical materialist method they developed, and of their application of this method to understanding the development of capitalism. Therefore, I will begin with an outline of the Marxist theory of the relationship between technology (or the "productive forces" more broadly) on the one hand, and society (including the political-economic structures of society) on the other. Here I will rely on both Marx and Engels's original work, as well as contributions from later Marxist theorists and thinkers, among others.

As alluded to above, a Marxist theory of the relationship between technological development and society is fundamental to the historical-materialist method developed by Marx and Engels. This is because their starting point was the practical activity of humans as they collectively produce and reproduce the material necessities of life. This being the first fact of human social existence, that people "must be in a position to live in order to be able to 'make history,'" Marx and Engels developed an historical understanding of how societies transformed over time from the starting point of "[t]he first historical act . . . the production of the means to satisfy [human] needs, the production of material life itself" (1978a:155-56). Thus, the basis for understanding human history—an investigation of the ways in and means through which people come together to appropriate and produce the necessities of their own reproduction—centers on the forces that are used to produce that history, i.e., the *productive forces*. As Marx and Engels put it in *The German Ideology*:

> The premises from which we begin are . . . real individuals, their activity and the material conditions under which they live, both those which they find already existing and those produced by their activity. . . . The first premise of all human history is, of course, the existence of living human individuals. Thus the first fact to be established is the physical organisation of these individuals and their consequent relation to the rest of nature. . . . The way in which men produce their means of subsistence depends first of all on the nature of the actual means of subsistence they find in existence and have to reproduce. This mode of production . . . is a definite form of activity of these individuals, a definite form of expressing their life, a definite *mode of life* on their part. As individuals express their life, so they are. What they are, therefore, coincides with their production, both with *what* they produce and with *how* they produce. The nature of individuals thus depends on the material conditions determining their production (1978a:149-50, emphasis in original).

The "material conditions," the nature of which determine the nature of social production, broadly speaking, are the productive forces.[1]

It is thus the level of the development of the productive forces—which include land, natural resources, raw materials, technology, machinery, science and scientific knowledge, as well as people with their skills, accumulated knowledge and abilities—that most fundamentally shape the character and nature of the relations people enter into in order to produce the material basis for that society (Avakian 2006, 2019; Marx and Engels 1978a). And these production relations are what constitute the foundation and tenor of that society; not in an overly-determinative, reductionist way, but as the basic scaffolding upon which other layers of that society develop and unfold, while also interpenetrating with and affecting that scaffolding in turn. To put it simply, the productive forces are the foundation upon which people organize themselves in order to produce and reproduce their social necessities. These forms of intercourse, or relations of production (and reproduction) are then the basis upon which there develops forms of political organization, cultural phenomena, and corresponding ways of thinking (Avakian 2006).

The above analysis means that productive forces play a decisive role in shaping the nature of not only the economic structure of society, but of other aspects of the social world as well. This fundamental insight of Marx's, however, need not provide cover for a vulgar, economic determinist and crude materialist understanding of the relationship between technology and raw materials, or the productive forces more generally, and society overall (Avakian 2006).

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[1] Along with the *material conditions of production*, which include the indirect forces that contribute to and facilitate production, such as social and natural infrastructure.

In addressing sociologists' fear of various forms of reductionism, particularly biological reductionism, as a barrier to considering the relationship between the social and the larger biophysical realms, Carolan (2005) draws on the concepts of *rootedness* and *emergence*. Extrapolating from his analysis of the social/biophysical dialectic, we can here argue that the productive relations are fundamentally *rooted* in the naturally and historically available forces of production, meaning the latter could not exist without, and derives its basic identity from the former. At the same time, the economic (or productive) relations have an *emergent* reality, or relative autonomy, from those productive forces. The same basic analysis can then be applied to the relationship between the production relations, on the one hand, and the political sphere of society, with the political sphere being both rooted in, and emergent from, the production relations of a given social configuration.

Relatedly, Carolan (2005) notes that, between the different ("higher" and "lower" order) levels of reality,

> causality is not unidirectional, but rather has the potential to flow in both directions—both upward and downward (and, as is often the case, synergistically). . . Thus the need for the “higher” level social sciences; for ultimately, the “higher” level [social] phenomena that they study cannot be explained away with references to particle physics or genetic sequencing alone (p. 3).

Not only are higher order phenomena irreducible to the levels of reality within which they are ultimately rooted, but the former can and do react upon, affect, and transform the former.

With this understanding of the centrality of the material underpinnings of social reality, and of the dynamic, multifaceted nature of the relationship between these material underpinnings and the emergent levels of society—the cultural, political, non-economic social, ideological, etc.—the importance of understanding the historic rise of plastics, and of the concomitant technological and political-economic transformations becomes clear. The emergence of synthetic plastics represented an epochal shift in the nature of the material underpinnings of society, and of the ways in which things are produced, distributed, and consumed. Plastics—highly amenable to mass production—coincided with the epochal (yet still ongoing) shift from craft and simple manufacture forms of production to large-scale, mechanized industrial production (Braverman 1974; Marx 1976). This is what Marx (1976) referred to as the real, as opposed to the formal, subsumption of labor under capital. Because capitalism emerged from the remnants of feudalism, it initially adopted much of the small-scale, handicraft, individualized productive apparatus as it was. In its early stages, capital, in order to extract more surplus value from the labor process, primarily relies on the prolongation of the working day, which Marx (1976) terms the formal subsumption of labor under capital.[2]

But this can only go so far—not only are there objective constraints, but political limits on the length of the working day, such as concessions won in part by the workers themselves, emerge as well. Both factors helped to ignite what would become one of the main drivers of economic growth and social change over the last two centuries: the continuous revolutionization of the labor process itself through increasing the division of labor, collectivizing production, and introducing new productive forces in the form of technology, new materials, etc., among other things (Braverman 1974; Lotta 1984; Marx 1976; Marx and Engels 1978a). This is what Marx (1976) referred to as the production of relative surplus value from the real subsumption of labor:

> the production of relative surplus-value completely revolutionizes the technical process of labour and the groupings into which society is divided. . . . It therefore requires a specifically capitalist mode of production, a mode of production which, along with its methods, means and conditions,

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[2] This was also called the production of absolute surplus value by Marx (1976).

> arises and develops spontaneously on the basis of the formal subsumption of labour under capital. This formal subsumption is then replaced by a real subsumption (p. 645).

Thus, the relationship between social and technological development, while quite complex in its various manifestations, has as its very definite foundation the drive under capitalism to accelerate capital accumulation through both reducing the value of labor and by replacing living labor with dead labor, or variable with constant capital through increasing labor productivity, i.e., increasing the organic composition of capital. For labor productivity to increase, there must be:

> an alteration in [the worker's] tools or in his mode of working, or both. Hence the conditions of production of his labour, i.e. his mode of production, and the labour process itself, must be revolutionized. By an increase in the productivity of labour, we mean an alteration in the labour process of such a kind as to shorten the labour-time socially necessary for the production of a commodity, and to endow a given quantity of labour with the power of producing a greater quantity of use-value (Marx 1976:431).

As mentioned above, and will be gone into further depth later, plastics were an important factor in this process, starting as a very marginal productive material at the end of the 19th century, increasing in importance in the interwar period, emerging in earnest during World War II, and ballooning into one of the dominant ingredients of the material world at the end of the 20th century.

With this basic understanding of the role of the productive forces, technological development, and the relationship between the foundation (or "base") of society and its other manifold manifestations, we can examine the next key theoretical framework: the theory of monopoly capitalism-imperialism.

Monopoly Capitalism-Imperialism

Key to understanding the social landscape of the late nineteenth and twentieth centuries is the political economic framework of monopoly capitalism/imperialism[3]. This theoretical framework explains the nature of the economy and polity in advanced capitalist countries, how these countries relate to one another, and how they relate to the rest of the world. It contextualizes the technological transformations, geographic configurations, composition of labor, and even our society's changing relationship to the environment over the last century and a half. With it, we can situate the rise of plastics and identify the role this material has played in shaping our world. First developed at the turn of the twentieth century, this Marxist theoretical framework was introduced by Vladimir Lenin. Further elaborations of this perspective followed, particularly after the Second World War, and later with the rise of financialization in the 1970s. Below I will outline the basic premises of monopoly capitalism-imperialism and demonstrate its salience to understanding the rise of plastics.

The basic contours of monopoly capitalism were introduced at the turn of the twentieth century by Marxist theorists such as Rudolf Hilferding and Vladimir Lenin, who identified the changing nature of capitalism from its competitive to monopolistic phase. Lenin (1917), influenced by Hilferding (1981), noted this shift as being characterized by an increasing concentration and centralization of capital, the rise of both vertical integration and conglomerization (along with more traditional monopolization in the form of horizontal integration), the development of finance capital as a fusion of banking and industrial capital, and

[3] Throughout the course of this dissertation, I will use the terms "monopoly capitalism," "capitalism-imperialism," and various iterations thereof interchangeably.

the heightened global scope of capital accumulation. He saw monopoly capitalism as a transitory phase between the era of so-called "competitive" capitalism[4] and socialism, as monopoly capital increased the concentration, globalization, and socialization of production, yet with appropriation remaining privatized, leading to an intensification of capitalism's fundamental contradictions, injecting into the system a greater degree of instability and tendency toward crisis. Several other theorists, including Thorstein Veblen, further fleshed out a theorization of this transition in the following decades. However, it was Baran and Sweezy who in 1966 presented what some think to be one of the most thoroughgoing elucidations of monopoly capital in their essay of the same name.

Baran and Sweezy, following Lenin's insights, argue that in the last quarter of the nineteenth century some important changes began to occur in the basic structure of the capitalist economy. While the main driving forces and mechanisms of profit accumulation, exploitation, geographic expansion, and economic growth remain, the way that blocs of capital are organized, relate to one another, and operate in accordance with these goals have changed. Instead of being characterized by intense competition between small blocs of capital—each confined to a single industry and accounting for a very small share of the market—this new era is characterized instead by rivalry between large monopolistic blocs of capital. These enterprises, which Baran and Sweezy (1966) call "giant corporations," are extremely profitable, relatively stable (as compared to their smaller, competitive predecessors), control large portions of the market, can

[4] Here I put "competitive" in quotations because, while I refer to the pre-imperialist phase of capitalism as competitive for lack of a better term, doing so can also present monopoly capitalism-imperialism as *non-competitive*. However, as will be explained below, while competition is recast and operationalized in some different ways, it in fact intensifies overall under the latter epoch of capitalism (see Lotta 1984).

largely set their own prices, and are often conglomerated; meaning they operate in multiple industries, and are vertically integrated; meaning they control each aspect of the production process for a given set of commodities. While rarely monopolies proper, the basic unit of capital under monopoly capitalism shares many characteristics with monopolies and has certain monopolistic powers, including being "price makers" rather than "price takers," meaning they have more autonomy in setting prices for their wares. Giant corporations also tend to be financially autonomous, or less reliant on outside sources of funds such as investment banks (although this ended up being short-lived—more on this later). The corporation itself rather than an "interest group"—a group of companies under the control of a single investment or commercial bank—is the key unit of economic power. Another key change is "the replacement of the individual capitalist by the corporate capitalist" (Baran and Sweezy 1966:44), the latter being a "company man" who is tethered to the corporation itself unlike the individual tycoon of the past. The giant corporation "is [also] better equipped to pursue a policy of profit maximization" than its smaller, competitive predecessor, because it "has a longer time horizon" and more rational management structure (relatively speaking), allowing it to make more calculated business decisions (Baran and Sweezy 1966:28, 47).

The rise of the giant corporation represents a further concentration—increase in size and scope of each bloc of capital— and centralization—through mergers, acquisitions, buyouts, and smaller competitors being driven from business—of capital, a tendency built into the very process of capital accumulation itself (Braverman 1974; Foster 2014/1986; Lotta 1984; Magdoff 1969; Marx 1976). The change in the composition of capital—the modification of the hosts of capital from many small, anonymous capitalists competing for tiny shares of the market to large corporations that dominate large shares of the market—thus does not represent a fundamental departure from the nature of capitalism, or of Marx's analysis thereof. Rather, as Foster (2014/1986) puts it:

> [T]he notion of monopoly capital develops quite naturally out of Marx's theory of accumulation. Capital, by its very nature, is self-expanding value. The individual capitalist experiences the compulsion to enlarge "his" capital as both an objective and a subjective necessity. . . Capital accumulation presupposes both a growth in the size of individual capitals (concentration) and the fusion together of many capitals . . . (centralization) (p. 60).

Lenin (1917) also noted that the concentration of both capital and of production is a basic feature of capitalism's trajectory of limitless growth, expansion, and accumulation, thus the rise of monopoly capital is not anomalous, but a logical outcome of capital’s maturity.

It is also important to note that competition does not cease under monopoly capitalism, and in many ways it intensifies. As Raymond Lotta argued in an important treatise on the political economy of capitalism-imperialism, *America in Decline*:

> Competition . . . is not a function of how many individual capitals may exist. . . Fundamentally, competition involves struggle over the expansion and appropriation of surplus value and it grows more, not less, intense in the imperialist epoch (1984:42).

However, as the number of capitalists competing within a given market decreases, and the amount of capital each bloc controls increases, the way that each bloc relates to one another changes, including in how corporations compete for market shares. Monopoly capitalists tend not to engage in price competition—the lowering of the price of their wares to undercut their competitor—which was the dominant form of competition under competitive capitalism, as all out price wars are harmful to all involved and are thus exceedingly rare. Instead of price wars, modern corporations compete in two primary realms: in cutting costs of production and in what Baran and Sweezy call "the sales effort." Below, I will discuss each of these forms of competition in some detail, before turning to what Baran and Sweezy (1966) identify as being the main problematic of monopoly capital: the inadequate absorption of economic surplus.

With price wars effectively banned under monopoly capitalism, how do various units of capital compete with one another for market shares, profits, and customers for their wares? One way is through cutting the costs of production. If one capitalist can produce their goods for less cost than their rivals, their profits will increase. There are two ways to do this: to reduce labor costs (variable capital) or reduce the costs of the materials of production (constant capital), which takes two forms: either the machinery and other forms of capital that are reused in the process of production (fixed capital), or of the raw and auxiliary materials that directly enter into, and/or are used up during the production process (circulating capital) (Marx 1978a). While these two forms of productive cost-cutting are of course related, I will focus on each in turn, starting with the latter form: reducing the costs of constant capital. As Baran and Sweezy (1966) put it:

> [T]he firm with lower costs and higher profits enjoys a variety of advantages over higher-cost rivals in the struggle for market shares. . . The firm with the lowest costs holds the whip hand; it can afford to be aggressive even to the point of threatening, and in the limiting case precipitating, a price war. It can get away with tactics (special discounts, favorable credit terms, etc.) which if adopted by a weak firm would provoke retaliation. It can afford the advertising, research, development of new product varieties, extra services, and so on, which are the usual means of fighting for market shares and which tend to yield results in proportion to the amounts spent on them. . . The lower-cost, higher-profit company acquires a special reputation which enables it to attract and hold customers, bid promising executive personnel away from rival firms, and recruit the ablest graduates of engineering and business schools. For all of these reasons, there is a strong positive incentive for the large corporation in an oligopolistic industry not only to seek continuously to cut its costs but to do so faster than its rivals (p. 69).

In other words, companies who produce consumer goods—Department II in Marx's formulation of the two basic Departments of Production, with Department I being producers of the means of production (Custers 2007; Marx 1978a)—struggle to keep their costs of production low, and are consistently cutting these costs, are well-positioned to maintain their spot as a large, highly profitable oligopolistic corporation. It gives giant corporations the flexibility to spend large amounts on various aspects of the sale effort (which will be discussed below), an essential component of business in monopoly capitalism. And it positions corporations to attract top business, engineering, and marketing talent. This drives corporations to, for example, relentlessly seek out cheap raw materials of production, a drive that contributes to the rising of profits and economic surplus under monopoly capitalism.

Reducing the costs of labor (variable capital) is another way for capitalists to reduce their costs of production. This is done by cheapening the cost of each unit of abstract labor power, and by increasing the productivity of each unit of labor. Cheapening the cost of each unit of abstract labor power primarily occurs through dividing the labor up, and making each constituent task as simple as possible, devoid of both skill and special knowledge. As Braverman (1974) puts it, "in a society based upon the purchase and sale of labor power, dividing the craft cheapens its individual parts" (p. 80). As this quote implies, the process of labor deskilling, of cheapening the cost of labor by dividing craft labor up into abstract labor (detail work), of separating mental from manual labor, is endemic to capitalism as a system. Marx argued in *Wage Labor and Capital*, well before the emergence of monopoly capitalism, that:

> the *division of labor* increases [under capitalism], labour is *simplified*. The special skill of the worker becomes worthless. He becomes transformed into a simple, monotonous productive force that does not have to use intense bodily or intellectual faculties. His labour becomes a labour that anyone can perform" (Marx 1978b:214, emphases in original).

However, the deskilling of labor for purposes of simplifying, controlling, and cheapening labor power intensifies under monopoly capitalism, with the rise of scientific management and the scientific-technical revolution, which coincide with the emergence of monopoly capitalism (Braverman 1974).

The increase of the productivity of labor is also a means by which the capitalist reduces the cost of their variable capital. Again, this drive to increase labor productivity is endemic to the entire epoch of capitalism and precedes the rise of monopoly capitalism. Marx spoke of its importance in his discussion of absolute vs. relative surplus-value in the first volume of *Capital*, with the latter being "the curtailment of the necessary labour-time," or an increase in labor's productivity (Marx 1976:432). Yet the importance of increasing labor productivity is also qualitatively heightened under monopoly capitalism, while the means of doing so on a level unimaginable in earlier eras of capitalism is facilitated by the scientific-technical revolution. The scientific-technical revolution, which emerged at the end of the nineteenth century, unleashed the powers of science in the service of capitalism. It was in large part propelled "by the drive for greater productivity . . . the effort to find ways to incorporate ever smaller quantities of labor time into ever greater quantities of product. This leads to faster and more efficient methods and machinery" (Braverman 1974:170). Thus, the cheapening of labor as a part of production costs increases under monopoly capitalism, as it becomes one of the main ways capitalists compete for greater profits.

There is another factor, other than competition between the producers of consumer goods (Department II) for market shares and profits, which drives the "tendency for costs of production to fall [in the] entire monopoly capitalist economy" (Baran and Sweezy 1966:70). This has to do with the first department in Marx's (1978a) Department of Production schema: Department I, production of the means of production (MP). These are the raw materials and machinery that enter into the production process (constant capital). The sellers of producer goods have as their customer the sellers of consumer goods—the former sells their products to the latter, who in turn use their purchase to produce commodities sold on the consumer market. Like the sellers of consumer goods, the sellers of producer goods face "the exigencies of non-price competition," and must find other ways to compete for shares of the producer goods market (Baran and Sweezy 1966:70). The buyers of producer goods, however, are different from the buyers of consumer goods. The former are "sophisticated buyers whose concern is to increase profits. . . If the manufacturer can convince his customers that his new instrument or material or machine will save them money, the sale will follow almost automatically" (Baran and Sweezy 1966:70).

Thus, the drive among producers of producer goods to compete for a greater share of the market by introducing new techniques, materials, production methods, or technology that will reduce the cost of production for the producers of consumer goods is a crucial determinant of the tendency for costs of production to decline under monopoly capitalism. This competition among producers of producer goods, which is "as important as it is neglected," is a crucial driving force in much of "the extraordinarily rapid advance of technology and labor productivity which characterizes the developed monopoly capitalist economy" (Baran and Sweezy 1966:70, 71). In other words, this competition between blocs of capital in Department I helps to explain much about the character of technological and social development under monopoly capitalism. It is an exceptional driving economic force, as it is an important part of the rise of plastics and the convergence of monopoly capital and social metabolic theory.

Giant corporations under monopoly capitalism also compete with their counterparts through their sales efforts. What Baran and Sweezy called "the sales effort" incorporates a number of both productive and non-productive aspects of the monopoly capitalist economy. As they put it, "Price competition has largely receded as a means of attracting the public's custom and has yielded to new ways of sales promotion: advertising, variation of the products' appearance and packaging, 'planned obsolescence,' model changes, credit schemes, and the like"

(Baran and Sweezy 1966:115). The sales effort represents massive outlays in the form of production—changes in product appearance that serve no purpose other than to entice customers, or to differentiate the product from a competitor's, or unnecessary yearly model updates, etc. This is called the "interpenetration effect": the interpenetration of sales into the production process itself, to the point where it is impossible to distinguish between what part of the product is composed of necessary labor and what part consists of unnecessary, or sales-specific labor (Foster 2013a). The sales effort, of course, also generates an entire realm of unproductive labor as well—marketers, salespersons, researchers, designers, and so on—that, while present in pre-monopoly capitalism, increases exponentially in both scale and import under monopoly capitalism (Baran and Sweezy 1966; Foster 2013a, 2014/1986). The sales effort serves a dual purpose in the epoch of monopoly capital: (1) as one of the main forms of competition between rival corporations, replacing price competition; and (2) as an essential absorbent of economic surplus. It is to the latter—the issue of rising economic surplus, and the problematic of its absorption—that we will now turn.

Because of many of the factors explored above—the tendency for prices to rise not fall, companies in Department II driven to cut costs of production, along with companies in Department I driven to provide their customers (companies in Department II) with cost-saving production methods, the concentration and centralization of capital—monopoly capitalism appears to be an epoch of rising profits. This means that, according to Baran and Sweezy, "the 'classical Marxian law of the falling rate of profit' must give way, in a highly developed monopoly capitalist system, to the 'law of the rising surplus' and the problem of surplus absorption" (Foster 2014/1986:19). Thus, the problem of too much surplus, or of insufficient sources of profitable investment for this surplus, becomes a central socio-political problem under monopoly capitalism, which Baran and Sweezy refer to as the problem of surplus absorption. They devote the bulk of their essay to this problem.

First, Baran and Sweezy demonstrate that while capitalists' consumption increases absolutely, it "decline[s] as a proportion of surplus and even more as a proportion of total income. . . [Thus] it is clear that no solution of the problem of surplus absorption can be expected from this quarter" (1966:81). The same is true in regard to the portion of surplus invested by the capitalist class: while it may rise absolutely, it declines as a share of the overall rising surplus. Three sources of investment—what Baran and Sweezy (1966) call "exogenous," as opposed to "endogenous investment," meaning "investment which takes place independently of the demand factors generated by the normal workings of the system," are considered for their surplus-absorbing potential (p. 89). These are: investments to meet the demands of a rising population, investment in new production methods and products, and investment in foreign markets. Generally speaking, and with a few exceptions, none of these investment outlets are sufficient to absorb the ever-rising surplus generated by monopoly capital, and in the latter case, foreign investment, largely has the opposite effect of generating further surplus (or productive capacity) rather than absorbing it, making the problem worse. Baran and Sweezy (1966) therefore conclude that "the *normal* state of the monopoly capitalist economy is stagnation" (p. 108, emphasis in original). How, then, do monopoly capitalist economies prevent wholesale economic recession?

Monopoly capitalism's "self-contradictory character," the inability for it to generate sufficient outlets to absorb all of the surplus it is capable of producing, leads to a "chronic under-utilization of available human and material resources" (Baran and Sweezy 1966:108). It also gives rise to a host of processes meant to counteract the system's stagnation tendencies, all of which, according to Baran and Sweezy, can only partially, and temporarily, counter its tendency toward stagnation. The three most important sources of the absorption of monopoly capital's surplus highlighted are the sales effort, military spending, and epoch-making inventions.

As mentioned above, the sales effort plays a dual role under monopoly capitalism: as both a form of competition between blocs of capital and as an absorber of surplus. These roles are interrelated, and both ultimately serve the same purpose: to facilitate and increase capital accumulation under the unique conditions of monopoly capitalism. The sales effort acts as a surplus absorbent in a couple of different ways. First, it stimulates overall demand for goods and services. Advertising, marketing, the release of new annual product models (like, for example, car or cell phone models), is all meant to offset "insufficient demand," which is inherent to monopoly capitalism , and to increase overall consumption (Baran and Sweezy 1966:124). In this way, the sales effort is predicated on the constant introduction of "new" products. There are two ways to do this. The first is what Baran and Sweezy call "fraudulent newness," or the use of marketing to present a product as having some unique characteristic that is in fact generic. A contemporary example of this would be a company marketing their food product as being "gluten free" when in fact all such similar products are already gluten free by definition. This is a purely marketing phenomenon, meant to increase demand for the product and differentiate it from commodities of identical or near-identical character (Baran and Sweezy 1966:129).

The second form of product "newness" that becomes essential to the sales effort, which is also the second way in which the sales effort acts as an absorbent of surplus, is the incorporation of the sales effort into the production process itself, or "the interpenetration effect." This "penetration into the productive process of sales efforts" is as vast as it is convoluted and circuitous (Foster 2014/1986:43). It consists of all sorts of product modifications that serve no practical purpose but are meant to stimulate consumption. Some manifestations of the interpenetration effect include built-in obsolescence, which intentionally reduces the utility of the product, requiring it to be replaced prematurely; and regular style changes as well as model updates, both of which "increase the rate of discarding." These both "are inextricably linked together" (Baran and Sweezy 1966:133). Thus, the sales effort both stimulates overall consumer demand for already-existing commodities by increasing commodity turnover and generates production of all sorts of "new" commodities through the incorporation of advertising into production itself, leading to an array of new product models, design variations, and stylistic changes that serve no purpose other than as an outlet for monopoly capital's ever-rising surplus.

Another important form of surplus absorption is state spending, and in particular military spending. Foster (2014/1986) notes that "although it was reasonable to assume under conditions of competitive capitalism—when full capacity utilization could generally be taken for granted—that the state was essentially a drag on the private economy, consuming surplus that would otherwise be used for private accumulation, this was not equally true in modern times" (p. 132). Under monopoly capitalism the state becomes a key source of surplus absorption in areas where it does not compete with private enterprise. For example, the state is able to decrease idle capacity (of both constant and variable capital), putting people and machinery to work and increasing purchasing power of the citizenry by creating effective demand through "direct government purchases of goods and services, or of 'transfer payments' [i.e.,] (subsidies to businessmen and farmers, doles to the unemployed, pensions to the aged, and so on)" (Baran and Sweezy 1966:143). Baran and Sweezy break down government spending into three components: transfer payments, defense spending, and non-defense spending. It is mainly the first two—transfer payments and military expenditures—that contributes to surplus absorption.

Military expenditures in particular are essential to the normal functioning of monopoly capital. This is because "the building up of a gigantic military establishment neither creates nor involves competition with private enterprise. . . [and because] the military plays the role of an ideal customer for private business, spending billions of dollars annually on terms that are most favorable to the sellers" (Baran and Sweezy 1966:207). While defense spending is a consistent counterforce to stagnation, this is especially true in times of war. Baran and Sweezy divide the effect of wars on surplus absorption into two phases: the combat and post-war phases. In the combat phase there is a massive re-shifting of production and resources to military needs, employment shoots up, and civilian demand is reduced, often through state control. "Existing plants are converted to war production, and most new investment is similarly channeled." In the aftermath phase, there is a massive backlog of civilian demand that must be met, much of which cannot be met "by converting war factories to civilian use," and instead those war facilities largely "must be scrapped" and new ones constructed (Baran and Sweezy 1966:224). Thus, while connected, the "during" and "aftermath" phases of war have unique features, each phase of which significantly offsets monopoly capital's stagnation tendencies through the generation of enormous surplus and utilization of productive capacity (both of constant and variable capital).

During times of relative peace, the defense industry acts as a consistent, yet by itself insufficient, absorbent of surplus. This is so for two reasons: one economic and one military. The former is "that the new technology of warfare has reduced the power of arms spending to stimulate the economy," in that advances in military technology have reduced the amount of expenditures devoted to the "mass-produced military hardware" that is so effective in sopping up economic surplus (Baran and Sweezy 1966:213-14). The second is that it is illogical from a military perspective to keep accumulating weapons of mass destruction ad infinitum. Eventually, this process becomes militarily self-defeating. Therefore, defense spending, like the sales effort, can only provide a partial fix at best to monopoly capitalism's chronic stagnationist tendencies.

Finally, Baran and Sweezy focus on the role of what they call epoch-making inventions in absorbing monopoly capital's ever-expanding economic surplus. Epoch-making inventions differ from normal inventions and innovations, which are an insufficient counterforce to stagnation, in that they "radically [alter] the economic geography of the entire system, thus creating enormous new outlets for surplus absorption" (Foster 2014/1986:102). Baran and Sweezy (1966) argue that only three inventions fit the description of "epoch-making": the steam engine, the railroads, and the automobile. What each of these have in common, in their overall economic impact, is that they both directly and indirectly absorbed vast amounts of economic surplus. Of the three, the railroad "occupies a unique place" and may well be the quintessential epoch-making invention (Baran and Sweezy 1966:220). The importance of railroads was also identified by Lenin (1917) at the beginning of the twentieth century, as he noted that "[r]ailways are a summation of the basic capitalist industries: coal, iron and steel; a summation and the most striking indices of the development of world trade and bourgeois-democratic civilization" (pp. 10-11).

Each of these inventions triggered monumental investment in a number of industries: from production of raw materials like glass, plastic, and metal in the case of the automobile, as well as the manufacture of the cars themselves and the construction of highways and roads; to a whole spatial rearrangement of society, leading to the expansion of communities and commerce into regions heretofore largely outside the orbit of capital, as well as the construction of the continent-spanning rail tracks themselves with the case of the railroads, and later of interstate roads; to the impetus for industrialization and the Industrial Revolution itself (which preceded the era of monopoly capital); while also facilitating the invention of the railroads, in the case of the steam engine. These epoch-making inventions, as the name implies, characterize entire epochs of capitalist development and expansion: the Industrial Revolution for the steam engine; the first phase of monopoly capitalism, from the last half of the nineteenth century until the beginning of the twentieth for the railroads; and both the post-World War I and post-World War II eras for the automobile.

It is important to note that there are some substantial problems with the economic surplus framework presented by Baran and Sweezy, and some of the conclusions they drew from their overall analysis presented above. To start, the notion that a vast economic surplus can exist without the clearly related tendency of the rate of profit to fall is dubious. In particular, there is an attempt to divorce the question of economic surplus from the problem of the rising organic composition of capital and the related tendency of falling profits.[5] As Baran and Sweezy (1966) point out, the lowering of the costs of production eases some of this downward pressure, and there are other transformations under monopoly capitalism which counteract the tendency for the rate of profit to fall, each of which are factors that increase the rate of surplus value. But ultimately these counteracting factors, including the cheapening of the elements of constant capital, as Marx (1981) pointed out in the third volume of *Capital*, are in fact temporary, half-measured, and partial (see also Lotta 1984:58-61).

[5] The problem of the rising organic composition of capital is that, as labor becomes more productive, this increases the ratio of constant-variable capital. An inherent and irresolvable contradiction of capital, the rising organic composition of capital tends to lead to falling profits, as constant capital accumulates relative to the value-creating portion of capital, variable capital (Lotta 1984; Marx 1976).

This error is related to Baran and Sweezy's overestimation of the stability of the dominant economic actor of the monopoly capitalist era: the giant, oligopolistic corporation. It appears that they overestimated the permanence of the relative post-WWII U.S. economic stability, spurred by unprecedented rates of growth of both industrial output and capacity (Lotta 1984; Sweezy 1991). The assumptions about the freedom from competition these corporations enjoyed, and their financial independence, was thus belied by a wave of hostile takeovers, mergers, and buyouts of the decades that followed the publication of *Monopoly Capital*, as Sweezy (1991) himself later noted. Notions of "corporate rivalry" replacing competition, and of more rational planning and longer time horizons replacing the anarchy and myopia of the earlier capitalist epoch were also overinflated and misguided. While the rise of secular financialization, and what some call the new era of monopoly-finance capital (Foster and Magdoff 2009; Foster and McChesney 2012), may partially explain these errors, the source of this confusion is in fact more fundamental to the basic analysis of *Monopoly Capital*. These central flaws include the downplaying of the ongoing role of competition as the beating heart and driving engine of capital, including competition between rival imperialist nation-states, and an underappreciation of the centrality of the globalization of the productive circuit of capital as a foundational component of the epoch of monopoly capital (Lotta 1984; Smith 2016).

These errors aside, the basic framework of the theory of monopoly capitalism-imperialism, as developed not only by Baran and Sweezy but also by a host of other theorists—such as Vladimir Lenin (1917), Rudolf Hilferding (1981), Thorstein Veblen (1923), Harry Magdoff (1969), John Bellamy Foster (2013a, 2014/1986), John Smith (2016) Raymond Lotta (1984, 2021), and Bob Avakian (1981, 2019), among others—is essential for understanding the political-economic landscape of the late 19th century up to the present. Monopoly capitalism-imperialism represents both a continuation and an intensification of the basic driving mechanisms of capital: the consolidation of an economic order around the law of value, and the anarchic nature of production and exchange that this generates; the unceasing quest for capital accumulation, with the dictate of "profit in command" guiding economic decision-making; and the generation of surplus value through the exploitation of labor-power. At the same time, the very unfolding of this system has led to the global expansion of this system, and concentration as well as centralization of capital, consolidating into a new phase of capital accumulation. The ramifications of these changes for the overall social, political, and economic landscape are manifold. As it relates to the rise of plastics as a material throughput, monopoly capitalism is intimately bound up with this, as will be discussed in the following chapters. But first I will turn to another seminal Marxist theoretical framework, this one with particular relevance for the ecological contradictions of capitalism: the theory of metabolic rift.

Theory of Metabolic Rift

As Fischer-Kowalski (2002) puts it, "It was Marx and Engels who first applied the term 'metabolism' to society" (p. 18). While Karl Marx's use of the term was referenced by later Marxist scholars, it was primarily John Bellamy Foster who first excavated Marx's theory of metabolic rift in order to demonstrate that Marx had in fact seriously taken nature into consideration in his analysis of capitalism. In particular, Foster revealed that classical sociological thought was not devoid of ecological awareness, or solely social reductionist, by revealing Marx's ecological thought (Foster 1999). Foster (2000) also returned to the theory of metabolic rift to refute arguments waged by, along with more mainstream critics, ecological economists and first-wave ecosocialists, that Marx's historical materialism did not appropriately account for the role of nature in contributing to social wealth, nor of the widespread ecological consequences of the capitalist mode of production. These thinkers argued that at his core Marx was an anti-ecological, Promethean thinker who, at best, peripherally considered the extra-social environment and ecological consequences of social production. Marx's critics also argued that this Prometheanism bled into his writings on communism—that his formulations for a post-capitalist, communist society were marred by a blind adherence to limitless industrial growth, without concern for its ecological effects. In response, Foster, among others, contended that not only did Marx take into consideration ecological conditions and the natural, extra-human world in both his analysis of capitalism and his musings on a future, post-capitalist society, but that these considerations were in fact central to Marx's overall materialist conception of history, his body of work, and his comprehensive theoretical framework (Burkett 2014/1999; Foster 1999, 2000, 2002; Foster, Clark and York 2010; Foster and Clark 2020; Saito 2017).

Foster (1999) revealed that the origins of Marx's theory of metabolic rift was the second agricultural revolution of 1830-1870, during which the nutritional depletion of the soil was one of the biggest environmental concerns of the time. Two factors of the second agricultural revolution are key here. First is the rise of intensive capitalist agriculture, with its increased mechanization, the reduction of the rural population, and a less localized agricultural economy, leading to an increased number of agricultural products being exported, and to widespread soil depletion. Second is the advances in the science of soil chemistry—an understanding of the soil's necessary chemical nutrients, such as nitrogen and phosphorus, and the process of nutrient cycling, whereby plant growth contributes to nutrient depletion and the need for the continued recycling of fertilizers back to the soil for the continued maintenance of the soil's fertility—

generated an understanding of what caused this soil depletion and what was required to prevent it.

Marx was greatly influenced by both of these factors and was deeply informed by the work of German agricultural scientist Justus von Liebig, whose breakthroughs in the study of soil chemistry helped spur the advances in soil science. Liebig's understanding of soil chemistry and in particular the law of compensation—that nutrients taken from the soil in the form of food and fiber needed to be returned to the soil in the form of organic fertilizer—led him to be highly critical of capitalist agricultural methods, which systematically violated this law (Foster and Clark 2020). The injection of the capitalist law of value into the process of agricultural production, combined with the separation of the population from the land (part of the town-country rift that is intrinsic to capitalism), led to the disruption of the law of compensation. Agricultural production became driven by the time cycles of capitalism, which demanded cheap, quickly produced raw materials in the form of food for workers as well as circulating capital, a form of constant capital composed of materials required for production. This overburdened the soil (along with the workers of the soil), asking for more from it than was returned to it, a process Marx referred to as the robbery of the soil (Foster and Clark 2020). With the town-country divide, which while it predates capitalism, becomes under capitalism the key form of socio-spatial organization, the requisite return to the soil of processed agricultural goods, including in the form of human waste, is instead squandered as pollution and sewage in the towns, which are far removed from where the food and fiber was grown.

Marx's theory of metabolic rift can be summarized by explicating three interrelated concepts: social metabolism, metabolic rift, and the universal metabolism of nature (Foster and Clark 2020). Social metabolism constitutes the interaction between humans and the rest of nature; the exchange of energy and matter between society and the Earth system—with the former being an emergent property of the latter (Foster 2000; Malm 2018). Every social system forms a particular social metabolism—that is, a particular energetic and material relationship with the rest of nature. Capitalism is therefore but one form of social metabolism. However, capitalism as a form of "social metabolic control" is utterly unique compared to all previous forms of social metabolic reproduction in several ways (Mészáros 1995). One, the social metabolism of capitalism is ultimately uncontrollable in its outward, global expansionist aims—it is driven by its internal contradictions to fully consolidate itself on a global scale. Two, it is an internally antagonistic, volatile form of social metabolic control in three principal respects: (a) It severs production from consumption which, among other things, leads to an overaccumulation of use-values in certain parts of the world, and an under-accumulation of use-values in other parts of the world, irrespective of these regions' contributions of labor-power and natural wealth to the system of global production; (b) It severs the process of production from the control of production, or it detaches the producers themselves from the decision-making processes of its production, which leads to the phenomenon of alienated labor[6]; (c) It separates production from the circulation of the produced use-values, or, the circulation of goods in the capitalist social metabolism must by definition be a global enterprise, while capitalism is organized into separate

[6] This contradiction—between production and control—goes beyond divorcing the producers themselves from the decision-making processes to also include alienation from the owners of capital themselves, the subjective embodiment of capital, the capitalists. Capitalism is ultimately driven by the demands of capital accumulation and growth irrespective of the subjective wishes of even the capitalists themselves. Thus, capital's order of social metabolic reproduction is ultimately subject to "*subjectless control* in which the controller is actually controlled by the fetishistic requirements of the capital system . . . because of the radical separation of *production and control*" (Mészáros 1995:66, emphasis in original).

nation-states—this is another way of describing the contradiction between capitalism as a system that is on the one hand a global economic system, and on the other hand is politically configured into individual nation-states (Mészáros 1995). And three, it is unique compared to all previous forms of social metabolic reproduction in how it does away with production based on use-value. Under capitalism, "the dominance of use-value characteristic of self-sufficient reproductive systems is historically left behind" (Mészáros 1995:51), establishing production for exchange value, or abstract value, in its place. As Burkett (2014/1999) puts it, drawing from both Marx's early writings on the subject as well as the *Grundrisse*:

> In a pre-capitalist economy, the scope for regulation of production by exchange values is limited by the social ties between the producers and the natural conditions of production—ties that tend to create a situation in which "production is determined by need." Specifically, the pre-capitalist sphere of exchange value is limited by "the content outside the act of exchange" . . . This content "can only be: (1) The natural particularity of the commodity being exchanged; (2) The particular natural need of the exchangers, or, both together, the different use values of the commodities being exchanged" (p. 63).

This last feature of the capitalist social metabolism, the contradiction between use-value and (exchange-)value as embodied in the commodity (Marx 1976), is in fact a particular expression of the primary general contradiction of capitalism—between socialized production and private ownership—and is the ultimate source of both its social and ecological ills (Longo, Clausen and Clark 2015).

Based on these unique characteristics, the capitalist social metabolism is one that generates an irreparable rift between itself and the universal metabolism of nature. This latter concept—of which the social metabolism is an emergent property—refers to the physical and biological laws governing the cycling of energy and matter within the earthly biosphere. As Foster (2013b) explains,

> To account for the wider natural realm within which human society had emerged, and within which it necessarily existed, Marx employed the concept of "the universal metabolism of nature." Production mediated between human existence and this "universal metabolism." At the same time, human society and production remained *internal to* and *dependent on* this larger earthly metabolism, which preceded the appearance of human life itself" (p. 8, emphasis in original).

Marx argued that human society was both embedded within, and dependent upon, yet also transformed (or "breathed new life into") this universal metabolism of nature, and that what humanity collectively created—society—was a kind of "second nature" (Foster 2013b.:8). This second nature, under the social metabolic order of capital, is, however, an alienated form of social metabolism. Thus, capitalism as a form of social metabolic production and reproduction is, in many crucial respects, at odds with the imperatives of the universal metabolism of nature (Foster 2013b).

When the form of social metabolism violates the requirements of the universal metabolism of nature, of which the social metabolism is an emergent component, a metabolic rift develops between them. Capitalism is a form of social metabolic reproduction that, due to its internal characteristics and driving tendencies discussed above, is an alienated form of social metabolism. As Foster (2000) explains, "Marx employed the concept of a 'rift' in the metabolic relation between human beings and the earth to capture the material estrangement of human beings within capitalist society from the natural conditions which formed the basis for their existence" (p. 163). The key manifestation of this rift in the metabolic interaction between society and its natural conditions of existence is the further development of the town-country divide. Marx (1976) notes, in the first volume of Capital that:

> Capitalist production collects the population together in great centres, and causes the urban population to achieve an ever-growing preponderance. This has two results. On the one hand, it concentrates the historical motive power of society; on the other hand, it disturbs the metabolic interaction between man and the earth, i.e. it prevents the return to the soil of its constituent

> elements consumed by man in the form of food and clothing; hence it hinders the operation of the eternal natural condition for the lasting fertility of the soil (p. 637).

The rift within the social metabolism, or the metabolic rift between the social metabolism and the universal metabolism of nature results from the violation of the energetic-material exchange of equivalents (Foster and Clark 2020). This is first expressed specifically in the robbery of the soil inherent to capitalist agricultural production. It also manifests more generally in capitalism as a mode production that abstracts from the particularly of the use-values of things via the flattening, homogenizing, quantifying process of production based on exchange-value, where the particular characteristics of differing components of nature are represented as interchangeable quantities of labor power as value (Foster and Clark 2020).

A metabolic rift emerges when the mode of social metabolic reproduction, which is humanity's relationship with extra-human nature, comes into antagonistic conflict with the universal metabolism of nature. Another way of putting this is that the social metabolism shifts from one of appropriation, which is inherent in all forms of social metabolism, to one of expropriation, or appropriation without exchange (Foster and Clark 2020). Marx argued that "appropriation of nature was a universal phenomenon of social life, of the social metabolism of humanity and nature" (Foster and Clark 2020:38). The social metabolism of capitalism, however, goes above and beyond the mere appropriation of nature, and creates conditions for the expropriation of nature and the alienation of social systems from the natural systems within which they are embedded. Capitalism treats nature as a set of separate material conditions required for the production of use-values (which are only embedded with value through the application of labor-power), thus setting up a system that devalues nature, treats the qualitative distinctions between different use-values as inherently interchangeable, quantitative representations of material throughput for production, and downgrades nature "to the status of mere conditions of money-making" (Burkett 2014/1999:62). It is this devaluing of extra-human nature, its treatment as a "free gift" to capital, because of capitalism's historically unique value system in which human labor-power alone generates value, which embodies and encapsulates capitalism's rift within its social metabolic mode of reproduction.

It is important to grasp that Marx's theory of metabolic rift, rather than being peripheral, was in fact (as mentioned above) central to his overall analysis of historical capitalism. Before moving on, I will demonstrate the veracity of this claim with a few examples, first by considering further the town-country contradiction, and then the role of labor in both Marx’s theory of metabolic rift and his overall historical materialist approach to capitalism.

The town-country divide is the determining spatial contradiction of the capitalist mode of production, as well as the emergence of the metabolic rift between the social organizations of capital and the universal metabolism of nature (Burkett 2014/1999; Foster 1999, 2000, 2013b.; Marx 1976; Moore 2000; Saito 2017). This is because the antagonistic relationship, which unfolded historically, between the urban centers and rural countryside is connected to the essential ingredient of capital: a surplus of propertyless (potential) workers, who have been separated from the means to produce the essential necessities for their own reproduction. In other words, the process of separating the mass of people from the land, a process Marx (1976) referred to as “primary accumulation,” provided capital with a surplus of people who were reliant on a wage in order to feed, clothe, and shelter themselves and their families. The spatial manifestation of this process was the town-country divide. The result of the town-country divide was the rift between (or within) the social metabolism of capitalism and the universal metabolism of nature.

The alienation of the population from the means of their own reproduction, and their concentration in urban centers where industrial production was located, is a process both central to the functioning of the social metabolism of capitalism, and an ongoing one, unfolding on an increasingly global scale. This process is so central to Marx's analysis of historical capitalism, that he describes it as

> the "eternal natural laws" of the capitalist mode of production . . . the process of separation between the workers and the conditions of their labour, to transform, at one pole, the social means of production and subsistence into capital, and at the opposite pole, the mass of the population into wage-labourers, into the free "labouring poor," that artificial product of modern history (Marx 1976:925).

This process of "so-called primitive accumulation" is driven by "[t]he expropriation of the agricultural producer, [the] peasant, from the soil" (Marx 1976:876), producing the proletariat. The proletariat, the propertyless class of industrial workers (and of potential surplus workers, who constitute the reserve army of labor, and thus keep the price of labor-power down and serves as a safety valve for capital), along with the bourgeoisie, is one of the "two great classes" that emerge and "directly fac[e]" one another in the social metabolic order of capitalism (Marx and Engels 1978b:474). The antagonistic relationship between these two poles is the definitive social relationship of capitalism; in fact, inasmuch as capital itself is "*a social relationship* between capitalist [bourgeois] and proletarian" (Wolff 1983:105, emphasis in original), this historic process of "so-called primitive accumulation," which is captured by the ongoing (and intensifying) chasm between town and country, is the precondition for the emergence of the social metabolic order of capital itself. Thus, Marx's theory of metabolic rift, in that it describes both the process and consequences of the town-country antagonism, is not ancillary to his overall analysis of capitalism, but in fact occupies a central position in his historical materialist approach to capitalism's development.

The centrality' of the theory of metabolic rift to Marx's overall analysis of historical capitalism is also gleaned through an examination of the concept of labor in Marx's thought. Labor is fundamental not only to Marx's analysis of capitalism, but to his overall philosophical orientation of historical materialism as well. For Marx, labor plays a transhistorical, or universal role, in that it is operative in all periods of human history, in defining humanity's relationship both to its collective self and to external nature. Labor, or humanity's cooperative, conscious, creative interface with the forces of nature, is key to Marx's materialist, as opposed to idealist, philosophical orientation. In his and Engels' polemic against Hegelian idealism *The German Ideology* they argue that

> the first premise of all human existence and, therefore, of all history, [is] the premise, namely, that men must be in a position to live in order to be able to "make history.". . The first historical act is thus the production of the means to satisfy these needs, the production of material life itself. And in this is an historical act, a fundamental condition of all history, which today, as thousands of years ago, must daily and hourly be fulfilled merely in order to sustain human life (Marx and Engels 1978a:155-56).

While the above quote may be reasonably applied to the requirements of sustaining all life, they also argue that humans "begin to distinguish themselves from [other] animals as soon as they begin to *produce* their means of subsistence" (Marx and Engels 1978a:150, emphasis in original). The act of producing and appropriating one's means of subsistence, creatively, consciously, and collectively, is the act of human labor. Humanity's ability to consciously produce things, both for survival and for pleasure, beyond our mere material needs is what makes homo sapiens as a species unique.

Labor is central to Marx's materialist, rather than idealist, conception of history because of the former's emphasis on the practical activity of humans, as opposed to the latter's "subsum[ption] of material reality/existence under thought" (Foster 2000:5). This is a practical materialism, or a praxis-orientated approach to understanding reality, with a focus on the sensuous activity of humans, collectively, in shaping historical society and nature (Bhaskar 1997; Foster 2000).

Human labor, defined as "conscious life-activity" (Marx 1978c:76), is in fact essential to human nature, according to Marx's materialist conception of history. Engels, in his essay "The Part played by Labour in the Transition from Ape to Man," argues that not only is labor "the prime basic condition for all human existence," but that "in a sense, we have to say that labour created man himself" through the historical process of evolutionary transformation from apes to hominids (Engels 1940:279).

Marx's view on labor stemmed in large part from the early Greek materialists like Epicurus, who recognized the centrality of "work as the embodiment of the organic, dialectical relations between nature and society" (Foster and Clark 2020:177). The Marxian critique of labor was therefore not a critique of work in general, but of the alienated labor that occurs under capitalist relations of production. Having demonstrated the importance of labor to Marx's philosophical orientation of historical (and dialectical) materialism, I will now elucidate the centrality of labor to the theory of metabolic rift, connecting this theory to Marx's overall analysis of historical capitalism, which constituted his life's work.

The key hinge that links any form of social metabolic reproduction, capitalist or otherwise, to (and ultimately within) the universal metabolism of nature, is human labor. The labor process was described by Marx (1976) as

> purposeful activity aimed at the production of use-values. It is an appropriation of what exists in nature for the requirements of man. It is the universal condition of the metabolic interaction [Stoffwechsel] between man and nature, the everlasting nature-imposed condition of human existence, and it is therefore independent of every form of that existence, or rather it is common to all forms of society in which human beings live (p. 290).

Marx described labor as the subjective element in the metabolic interaction between humanity and extra-human nature. Human production is, in Marx's analysis, both social and material, as well as the defining element of humanity's relationship with its organic body, the natural world (Burkett 2014/1999; Saito 2017).[7] Thus, "Labor is, first of all, a process between man and nature, a process by which man, through his own actions, mediates, regulates and controls the metabolism between himself and nature," and is "an external natural necessity which mediates the metabolism between man and nature, and therefore human life itself" (Marx 1976:283,133). Thus, Marx's theory of metabolic rift hinges on labor because it is through labor that societies establish a metabolic relation with their natural conditions (Saito 2017). Labor in a real sense *is* the society-nature dialectic; it is the interface between them, through which humanity asserts and recreates its embeddedness within the biosphere.

When the mode of production—which ultimately determines the social relations within which things are produced and labor is performed—is governed by capital accumulation, and the general quantitative expansion of value predominates over the qualitative distinctiveness, or specific use-values of things, the character of this social metabolic order is that of chasm between the economic imperatives of capital and the ecological imperatives of the universal metabolism of nature. In this way, the alienation of society from nature and the alienation of people under capitalism are linked. "In Marx's analysis," as Foster and Clark (2020) put it, "the dual alienation of land and labor took the form of 'a dissolution of the relation to the earth' for the majority of the population. . . It was this alienation that came to define the entire human

[7] Of course, in the final analysis the social is itself an emergent form of the material.

metabolism with nature through production" (p. 44). In fact, capital has similar effects on both labor and nature, the two universal sources of wealth. Foster (2000) notes this connection between capital's exploitation of labor and its appropriation as well as despoliation of nature in Marx's thinking, which constitutes a "twofold alienation": alienated labor and alienated nature (p. 9). Marx (1976) explicitly draws connections between the two by noting that the developing capitalist town-country antagonism "destroys at the same time the physical health of the urban worker, and the intellectual life of the rural worker" (p. 637). Further, he notes:

> In agriculture, as in manufacture, the capitalist transformation of the process of production also appears as a martyrology for the producer; the instrument of labour appears as a means of enslaving, exploiting and impoverishing the worker; the social combination of labour processes appears as an organized suppression of his individual vitality, freedom and autonomy. . . Moreover, all progress in capitalist agriculture is a progress in the art, not only of robbing the worker, but of robbing the soil . . . Capitalist production, therefore, only develops the techniques and the degree of combination of the social process of production by simultaneously undermining the original sources of all wealth—the soil and the worker (p. 638).

Thus, it is clear that the concept of labor is central to Marx's theory of metabolic rift, his overall analysis of capital, and the philosophical underpinnings that frame his entire analytic approach.

Before concluding, there is one more component of the theory that deserves highlighting. As already mentioned, Marx's original discussion of metabolic rift occurred at a time when the degradation of the soil through intensive agricultural practices constituted "the overriding environmental concern of capitalist society in both Europe and North America," comparable only to concerns about overpopulation and its effect on resource depletion, as well as the issues of both urban pollution and deforestation (Foster 1999:375). The second agricultural revolution in Europe and the Americas was the context that conditioned Marx's thinking. His theory of metabolic rift focuses specifically on this environmental problem—as well as its connection to the problem of urban sanitation. But is it confined to this context, in terms of its analytic scope and explanatory power? Drawing from the work of contemporary metabolic rift scholars I argue that not only has the original theory been elaborated to include the wide-ranging, global scope of contemporary environmental problems, but that the seeds for this expanded scope reside in Marx's original formulation.

While Marx first analyzed this metabolic rift in terms of the town-country divide, capitalist agriculture, and the rupture in the circulation of matter and energy from agricultural production to consumption and its requisite return in the form of fertilizing nutrients, the concept of metabolic rift has broader applications as well.[8] Schneider and McMichael (2010), for example, argue that metabolic rift "refers to a double separation: of agriculture from its biological foundations, and of humans from nature" more generally (p. 461). This greatly expands the concept's purview, beyond soil chemistry and agriculture—an expansion the germ of which can be found in Marx's original formulation of the concept. In fact, just as Marx's ecological critique, embodied in the metabolic rift concept, was fundamental to his overall analysis of capitalism (Burkett and Foster 2006; Clark and Foster 2010), it also speaks to the more fundamental chasm between the social system of capitalism and the life-sustaining requirements of the earth's natural systems, beyond the particular rift generated by industrial agricultural production (Foster 1999). Clark and Foster (2010) point out that there is a larger "ecological context" of Marx's historical materialist method, demonstrating that "Marx . . . established a materialist conception of both nature and history, in which each was dialectically

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[8] However, this is not to deny that the town-country antagonism is the principal moment in the historical unfolding of capitalism—in other words, the town-country divide is not merely one of a number of (equally important) rifts, but instead is a spatial expression of capitalism's primary historical development (see Burkett 2014/1999; Foster 2000; Moore 2000).

bound to each other" (pp. 143-44). Beyond his focus on agriculture and soil nutrition, Marx applied the concept of metabolism broadly. For example, he recognized that all "natural systems . . . had [their own] particular metabolism," and that, likewise, every social configuration had its own "social metabolism" which interacted with a variety of these natural metabolic systems (Clark and Foster 2010:144). The concept of metabolic rift extended to a general ecological critique of the capitalist mode of production, and in Marx's material conception of history, a recognition of society's fundamental dependence upon and embeddedness in the natural world. Below are a few examples of applying this framework to contemporary environmental problems.

Clark and York (2005) use the theory of metabolic rift to analyze the carbon cycle, and anthropogenic CO2 emissions. They demonstrate the utility of metabolic rift theory in explaining how the capitalist metabolic order has disrupted the carbon cycle by rapidly releasing CO2 emissions into the atmosphere via fossil fuel combustion, while simultaneously depleting natural carbon sinks such as forests. They also demonstrate the role of capitalism's insatiable quest for profit expansion as the driver for continued CO2 combustion and destruction of carbon sinks via land-use change (Clark and York 2005).

Clausen and Clark (2005) and Longo (2012) apply the theory of metabolic rift to marine systems and fisheries, connecting capitalist fishing methods to oceanic crises. Clausen and Clark (2005) argue that "[m]arine ecosystems are experiencing the same exploitative disconnect recognized between soil ecology and capitalist agriculture" (p. 427). They demonstrate how technological advancement in the fishing industry, driven by the demands of the social metabolism of capitalism, have created rifts in marine ecosystems, leading to fisheries collapse and the destruction of life-sustaining coral reefs, among other rifts. Longo (2012) compares the contemporary capitalist fishing industry with the traditional tonnara system of Atlantic bluefin tuna (ABFT) capture. He argues that under the profit-driven imperatives of capital, “the modern system of ABFT production and consumption creates conditions that are ecologically and socially unsustainable” (Longo 2012:430). He contrasts this with the traditional tonnara system, which operates according to the long-term sustainability needs of the ABFT and the larger ecosystem in which it is embedded.

Since Marx's day, the harmful environmental effects of capital have expanded in both its breadth, incorporating the entire globe, as well as its depth, impacting virtually every ecosystemic level and metabolic interaction of the earth system. The reasoning for this expansion resides in both the inner workings and dynamics of the capitalist system itself, as well as the shift in that system from its competitive to its monopolistic phase.

The very nature of capital—its raison d'être—is its self-expansion. Capital cannot sit still. The process of M-C-M', as elucidated by Marx (1976), of self-expanding value, is theoretically infinite; there are no built-in limitations to capital's programmed drive toward greater and greater accumulation. As Foster et al. (2010) explain, the dominance of exchange-value over use-value in capitalism's order of social metabolic reproduction causes "capital [to] constantly [metamorphosize] into more capital, which includes surplus value, or profits, the generation of which is 'the absolute law of this mode of production'" (p. 39). Thus, capitalism as a mode of production and social metabolic order is driven—short of its revolutionary abolition and transcendence by the oppressed of the world taking history into their own hands and overthrowing it—to expand beyond its original purview, which was originally limited to parts of Europe and the Americas[9].

The shift from capitalism in its industrial phase to capitalism in its imperialist phase further exacerbated the system's internal dynamics, leading to a qualitative intensification of its social metabolic order. Capitalism-imperialism, emerging in the last quarter of the nineteenth century, is characterized by not only the further global expansion of capital and the division of the world between competing imperialist powers, on the one hand, and nations of the oppressed global South on the other; but also by chronic economic stagnation, or capital overaccumulation, meaning a lack of sufficient investment outlets for capital. It is the global character of monopoly capital, the rivalry between imperial powers, which heightens both capitalism's expansionist inclinations and its penchant for running roughshod over ecological boundaries as well as overloading the planet's natural regenerative and absorptive capacities. "Under monopoly capitalism," as Foster (2013b) explains:

> The system increasingly demands, simply to keep going under conditions of chronic overaccumulation, the production of *negative* use-values and the *non-fulfillment* of human needs. This entails the absolute alienation of the labor process, i.e., of the metabolic relation between human beings and nature, turning it predominantly into a form of waste (p. 15, emphasis in original).

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[9] Of course, it can be argued that capitalism as a system was in a sense *always* global, or near-global, in that it incorporated large swaths of the world through interdependent processes such as the slave trade, colonialism, and resource appropriation, i.e., primary accumulation (Marx 1976)—from Africa, Oceania, and Asia to the entire Western hemisphere. However, what is being argued here is that capitalism as the dominant social metabolic order did not become *the* global system of production and reproduction until later in capitalism's development—into the late nineteenth and early twentieth centuries, with the rise of monopoly capital. Further, what marked imperialism as unique, and as an epoch of qualitatively greater globalization and global integration, was the globalization of the circuit of productive capital—as often manifested in the export of capital, and later in the globalization of the production relation itself (see Lotta 1984:78-79; Smith 2016).

In other words, there is inherent difficulty in making a profit under monopoly capitalism due to market saturation, extremely high levels of labor productivity and concomitant rise in the organic composition of capital, and a lack of investment outlets with high returns, among other reasons. Thus, to be able to make "monopolistic profit margins under these conditions it has mutated into an economy of built-in waste: both economic and ecological" (Foster and Clark 2020:249). Along with financialization, this represents one of the main ways in which capitalists under monopoly capitalism attempt to further accelerate capital accumulation.

Another way of characterizing the changing nature of the social metabolism under monopoly capitalism is by highlighting the development of *specifically capitalist use values*. Largely a novelty of monopoly capitalism, they include use-values that serve no real purpose other than profit for one or another set of capitalists. Such wasteful and destructive products—including military hardware (e.g., nuclear weaponry), excessive packaging, unnecessary new model updates on products—are detached from human need, in any meaningful sense (Custers 2007; Dowd 1989; Foster 2002, 2013a). Thus, there is a material basis upon which the contemporary capitalist system generates ever-increasing harmful environmental effects, accelerates the amount of material and energetic throughput into production, and escalates the inundation of environmental waste sinks, all on an increasingly global scale.

Relatedly, the nature of the materials that circulate through the social metabolism have changed under monopoly capitalism. In other words, monopoly capital not only quantitatively increases the generation of waste (among other increases in the scale of environmental harm that occurs), but also ushers in a shift in the quality of those materials. The material foundation of the social metabolic reproductive order becomes increasingly toxic and human-made, with an array of synthetics, fossil fuels, and petrochemical products circulating through the social metabolism of monopoly capital (Foster 1999/1994, 2002). Such a shift represents the emergence of a "Synthetic Age" of the social metabolic order of capital, which coincides with the Anthropocene Epoch and “Great Acceleration” following the Second World War, marked by the production of petrochemical plastics and use of nuclear weapons (Commoner 1971; Foster 1999/1994, 2022).

There are concrete, material reasons for this as well: "energy intensive and thermodynamically inefficient" forms of production are incentivized under monopoly capitalism (Foster 2013a:8), and where competition between the producers of producer goods (raw materials of production—Department I) takes on heightened importance. Producer goods that are more labor-intensive—which generally includes those that use traditional, natural raw materials—are substituted for producer goods (like synthetic plastics) that instead have a higher energy-to-labor value ratio, making them economically cheaper but more environmentally deleterious (Baran and Sweezy 1966; Commoner 1971; Foster 1999/1994, 2013a.; Foster and Clark 2020).

As a result of the heightened environmental impact of the capitalist mode of production, which was both presupposed by capital's inner contradictions yet also the result of the system's transition from its industrial to its monopolistic phase, contemporary scholars have expanded Marx's theory of metabolic rift into a global ecological rift, pitting the system of capitalism against the entire planet. Foster et al. (2010), for example, note that "[e]cologically," the system of capitalism "draws ever more destructively on the limited resources and absorptive capacity of nature, as the economy continually grows in scale in relation to the planetary system. The result is emerging and expanding ecological rifts that are turning into planetary chasms" (p. 29). The original metabolic rift of the soil, reflected in the spatial rift between town and country, has grown into a global abyss, transgressing dire planetary boundaries, including the nitrogen cycle, the biodiversity loss threshold, and the carbon cycle, among others (Foster et al. 2010). The ecological rift has expanded to the point where it now constitutes one of the key contradictions of capital, at least equal to (and in concert with) capital's exploitation and oppression of people. As Foster and Clark (2020) argue,

> it is no longer realistic to treat—even by way of abstraction—the crucial political-economic struggles of our day as if they were confined primarily to the exploitation of labor within production. Instead, social conflicts are increasingly being fought over capitalism's exploitation and spoliation of its wider social and natural environment (p. 35).

In this way, the second contradiction of capitalism, "the absolute general law of environmental degradation," has caught up with the first law, "the absolute general law of capitalist accumulation" (Foster et al. 2010:207).

Conclusion

Each of the preceding theoretical frameworks — the Marxist theory of the relationship between technological development and social change, the theory of monopoly capitalism-imperialism, and the theory of metabolic rift — will animate the following study of the historical emergence of plastics as a raw material of capital, and dialectical analysis of differing approaches to social metabolism and the nature/society distinction. The theory of the relationship between the productive forces, or technology broadly speaking, and social development will serve as the basic theoretical scaffolding for the two chapters on the political economy of plastics development.

Plastics, as a material of production, is both a type of technology and key component of larger social-technological developments of the epoch of monopoly capitalism, an era of capitalism the characteristics of which help explain their emergence and later proliferation. It also represents a shift in the social metabolic order of capital — the rise, during the post-World War II "Great Acceleration" and emergence of the Anthropocene, accentuated further in the 21st century, of a synthetic social metabolic order. The history of plastics also raises questions regarding the distinctions between what is social, or human-made, and what constitutes natural, or extra-social, phenomena.

The theory of metabolic rift offers important insights into how the distinction, and unity, between social and natural (or "non-social") phenomena can be handled, as to allow for analysis of different spheres of reality without severing their fundamental integrality. This has important ramifications in terms of understanding synthetic plastics, and the historical development of plastics, as a uniquely social phenomenon that comes into direct conflict with the metabolic exigencies of nature. It is to the historic emergence of plastics in their nascent form, and the relation between this and other technological, political, and economic changes, from the latter half of the 19th century and into the early 20th, that we will now turn.

CHAPTER 3: THE ERA OF NATURAL PLASTICS AND THE SHIFT TO SYNTHETICS

Introduction

In this chapter, I will begin to periodize the development of plastics as an industry and raw material of production in its earliest phase, starting in the 19th century and continuing through the early 20th century. I will address key moments of this historical process as they relate to: (1) the political-economic development of the United States during the era of what is called by Marxist scholars monopoly capitalism and imperialism (Avakian 1981, 2019; Baran and Sweezy 1966; Braverman 1974; Foster 2014/1986; Lenin 1917; Lotta 1984, 2021; Magdoff 1969); (2) the shift from plastics of natural origin to synthetic plastics. These two points are interrelated: certain changes in the mode of production—in how things were produced, the volume and scope of production, the scale of production, the productive relations, etc.—coincided and correlated with shifts in the nature of the productive materials. The need for raw materials with certain characteristics—rapid production time, mouldability, compatible with a high capital-to-labor ratio, widely accessible, durable, inert, lightweight, etc.—was intimately connected to the new freedom, and new necessity, which arose with the further development of capitalism.

This is not to say that the development of synthetic raw materials is reducible to the advancement of the productive forces, as if the latter are imbued with a force and life of their own, or inevitably progressing forward on their own accord—a technological determinist rendering of the relationship between technology and society soundly rebuked a half-century ago by Raymond Williams (1974). Instead, the engine of this process is found in the very nature of capitalism as a system, its laws of motion, as refracted through their application to the real material world. How these laws are operationalized can only be gleaned through concrete historical analysis.

In what follows, I will begin by tracing the development of plastics of natural origin – particularly rubber and gutta percha. While many of these materials have been used for thousands of years, here I will be focusing on their incorporation into the modern capitalist economic system, as raw materials to produce commodities (capital), specifically beginning in the 19th century. This history is important because these materials played an important role in the capital accumulation process of this time. Gutta percha, for example, was essential to the nascent telegraph industry, which was a breakthrough telecommunications technology, leading to the further consolidation and expansion of capitalism as a global system. However, these materials' shortcomings also help reveal why the shift from natural to synthetic materials was necessary from the standpoint of further capital accumulation.

Next, I will trace the emergence of a new, semi-synthetic plastic material called celluloid as a kind of stopgap between natural and synthetic plastics. Celluloid's history, along with that of plastics of natural origin, is similarly instructive both for its role in commodity production, and because of its material shortcomings. Celluloid represented the first primitive attempt to develop a raw material that was severed from the exigencies of nature. And it portended the rise of fully synthetic plastics, which will be explored in the next chapter.

Natural Plastics

The history of the plastics industry can be divided into two different axes. The first is the natural/synthetic axis, the second is the thermoset/thermoplastic axis. Starting with the first historical arc, we see a clear progression from plastics of natural origins—which include rubber, gutta percha, and shellac—to the widespread use of synthetics (DuBois 1972; Friedel 1983; Meikle 1995; Moore and Phillips 2011). Depending on one's definition of plastic, some would include material such as glue, ivory, tortoiseshell, horn, and bone in the natural plastics category. Each of these forms of plastic are derived from naturally occurring, or non-synthetic, materials. DuBois (1972), who includes the latter class of materials in his definition of plastic, argues that plastics can be defined as any material that, whether by its nature or after being treated with either heat or solvents, can be molded into many different shapes or forms. In fact, according to this definition, he argues that the first commercial use of plastic material in the United States was keratin, which was made from horse and cow hooves, tortoiseshell, and animal horn (DuBois 1972:3). This material can be "plasticized," or made moldable, by boiling it in water or soaking it in an alkaline solution.

Friedel (1983), on the other hand, excludes materials such as ivory, horn, and tortoiseshell, noting that a definition of plastic broad enough to include these materials must also include materials that are universally excluded from the plastics category, such as glass or metal. The broadest definition of plastic, he argues, is that "a material is plastic if at some time between its initial composition and its final state, it passes through a stage in which it can be molded . . . [which] includes almost every manufactured solid." Thus, while noting that materials such as ivory and bone have a "kinship" to plastics, "Because they are used largely in their unaltered natural form" (Friedel 1983:24), he includes within the class of natural plastics only those materials that are sufficiently formless and can take on a wide array of shapes and forms through the molding process.

Rubber

Perhaps the best known and most widely used plastic of natural origin is rubber. Originating from the sap of heava trees, rubber in some form or another has been used for millennia. However, it was not until the early 19th century that the rubber was converted into capital via technological developments which allowed it to be used for commercial purposes and incorporated into capitalist production as a raw material (Bunker 1984; DuBois 1972; Friedel 1983; Tully 2011). Early uses included rubber in fluid form for waterproofing fabric and cloth. Its commercial potential was limited until 1839, when Charles Goodyear introduced the process of vulcanization. Through the combination of raw rubber with sulfur and heat, vulcanization transformed rubber into a moldable material able to withstand temperature changes in non-tropical climates (Bunker 1984; Fenichell 1996; Friedel 1983; Meikle 1995; Tully 2011; Williamson 1994). In the nineteenth and early twentieth century, rubber was used to make bicycle and automobile tires, denture plates, jewelry, buttons, combs, electrical insulation, surgical products, and much more (Bunker 1984; DuBois 1972; Friedel 1983; Williamson 1994). By 1900, rubber consumption in the United States was around 15,000 tons (Friedel 1983), and two-thirds of Amazonian wild rubber was consumed in the United States (Tully 2011:69). Much of the machinery and labor processes used in the manufacture of vulcanized rubber goods (also known as "hard rubber") were later used in the synthetic plastics industry (DuBois 1972).

Rubber was initially extracted from wild rubber trees that grew in South America, through an intensive, and notoriously exploitative and cruel, labor regime (Bunker 1984). As demand for the raw material soared, particularly during the early rise of monopoly capitalism, the naturally occurring rubber supply could not keep up. It thus began to be cultivated in Southeast Asia via large rubber plantations, a method of extraction that was cheaper and more efficient, if no less brutal and exploitative for the workers, while also less reliant on the exigencies of nature (Bunker 1984; Tully 2011). In 1913, the year when plantation rubber exceeded wild rubber production by 25%, "the average production cost of Asian rubber was one shilling and ten pence a pound whereas Amazon rubber cost two shillings and four pence per pound to produce" (Tully 2011:72). "Wild rubber producers," Tully continues, "could not compete with an industry based on cheap regimented labor and systematic cultivation under the supervision of scientific experts" (2011:190). “As soon as Asian rubber came on the market in sufficient quantity the high costs of the Amazonian extractive system priced its rubber off the market,” according to Bunker. “Within less than a decade, Amazonian rubber fell from supplying nearly 100% of the world market to supplying only 20%" (Bunker 1984:1031-32).

This transition from wild to plantation rubber coincided with the early rise of multinational, vertically integrated blocs of capital. These firms operated globally, exported capital from their home countries to the global periphery, and often controlled their own supply chains. They also relied on "scientifically managed" forms of production and the scientific-technical revolution more generally, in both its environmental and labor aspects, as part of the systemic shift to the epoch of monopoly capitalism (Baran and Sweezy 1966; Braverman 1974; Lenin 1917; Lotta 1984). Such operating procedures were a manifestation of the imperative of capital to control nature in the name of rationalizing production, standardizing the extraction of raw materials, increasing yields, and cheapening costs. These two phenomena are connected: as blocs of capital expand in size, both the freedom and necessity to tighten their control over raw materials supplies expands as well (Magdoff 1969).

The freedom lies in the fact that highly concentrated, centralized capitals have more accumulated wealth at their disposal. Thus, their ability to invest in more capital-intensive (and thus less labor-intensive) production operations such as rubber plantations, rather than relying on the more labor-intensive wild rubber extraction operations. Capital export, operationalized as the globalization of the circuit of productive capital—a hallmark feature of the monopoly capitalist epoch, distinguishing it from early eras of capital in which only money and commodity capital are global in scope—led to increased profits in the rubber industry, and shifted production to the more profitable plantation operations in East Asia (Lenin 1917; Lotta 1984; Tully 2011).

The necessity lies in the requisite increase in the scale of production—also a hallmark of the monopoly capitalist era—in order to maintain monopoly profits and counteract capital's tendency of the declining rate of profit, due to the rising organic composition of capital. The drive to control nature, to remake it in the image of capital through imposing rationalized and human-controlled reproduction processes of rubber trees via plantation rubber, is thus not only embedded into the very functioning of capitalism. This tendency becomes heightened during the era of imperialism, because of the very ways in which imperialism intensifies the latent contradictions of capital: including heightened need for efficiency and control of the production process; the increasing importance of access to raw materials; and the greater stakes involved in competition between blocs of capital, as well imperialist nation-states, who have accumulated substantially greater wealth and power.

Gutta Percha

Another natural plastic, gutta percha, also originates from the sap of a tree found in the tropics and had been used domestically for millennia. It is similar in its properties to rubber, except that it naturally contains oxygen. Because of its kinship to rubber, gutta percha was initially seen as a potential rubber replacement or supplement. However, it cannot be vulcanized, and thus is significantly more limited than rubber in its uses. Gutta percha, unlike rubber, is dielectric—it can transmit electricity without conduction—and is therefore perfectly suited for underwater electrical wire insulation, and greatly superior to rubber for this purpose (DuBois 1972; Fenichell 1996; Friedel 1983; Tully 2009; Williamson 1994). Starting in the 1850s, it was widely used specifically for submarine electrical telegraph cable wiring insulation, because of its ability to withstand saltwater corrosion (Fenichell 1996). In fact, it is safe to say that the ability to communicate through telegraphy across long distances—starting in the mid-19th century, which was crucial to the administration of the global British empire, and ushering in a new era of long-distance telecommunication—including the transatlantic communication between Europe and North America, would have been difficult if not impossible without gutta percha (DuBois 1972; Fenichell 1996; Tully 2009, 2011; Williams 1974). It remained the primary material for insulating submarine electrical cables until the 1920s and 30s, when suitable synthetic replacements were discovered (Friedel 1983).

The history of gutta percha encapsulates and concentrates much of the early history of natural plastics: the rapidity of technological and industrial development under capitalism generating a host of new material needs, the demand for raw materials for industrial production quickly outstripping their supply, and primitive methods of extraction coupled with increasingly advanced means of industrial production and organization (Tully 2011). Gutta percha, as a raw material used in industrial production, served an essential and pivotal role in the further development and expansion of capitalism, to which it was uniquely suited.

Telegraphy—the primary information and communication technology of the mid-19th century, an era that preceded telephony, television, radio, or wireless communication methods—was "called forth" by the exigencies of empire, as was a material which could effectively insulate a massive network of underground and underwater electrical cables connecting much of the world. As Tully (2009) explains,

> the administration and economic exploitation of such sprawling domains begged the creation of new communications technology to bind them efficiently together. It could take over six months by ship for messages to reach the imperial capital from the colonies. The problem was solved by the invention of the electric telegraph. . . The key to the success of the new system was a natural plastic, gutta-percha . . . which proved indispensable as insulation for the submarine cables. However . . . the 'gum' was obtained by profligate, inefficient, and ultimately unsustainable methods of extraction, which killed the trees in the process. . . So great was the demand for the gum that the wild trees that provided it were almost extinct by the late nineteenth century, causing a flutter of panic in an industry that had taken it for granted (p. 560).

Gutta percha played an important, if largely overlooked, role in the global consolidation of capitalism during the era of industrialization, British empire-building, and colonialism—directly preceding the era of imperialism and monopoly capitalism, and in fact helping to facilitate its rise by laying the groundwork for a more globally integrated capitalism. Its brief, yet pivotal, story also highlights the shortcomings of natural plastics as capital in raw material form, and the impetus to develop synthetic alternatives that transcended these shortcomings.

Natural Plastics and a Basic, Generalized Plastic Mass

There are a number of additional natural plastic or plastic-adjacent materials that played a role in the historical evolution from natural to synthetics—including papier-mâché; materials such as ivory, tortoiseshell, and bone mentioned earlier; as well as shellac. Shellac is derived from the secretions of the female lac beetle, found deposited on the bark of trees in India and other parts of East Asia (Moore and Phillips 2011; Parry 1935). Like most natural polymers, it had been used for millennia by local populations, and was introduced to Europeans and North Americans in the mid-19th century. Shellac is probably most well-known for its use in phonograph records. It was first used for this purpose in the 1890s (Friedel 1983) and continued until synthetic vinyl replaced it (DuBois 1972). It was also widely used to produce electrical equipment, insulation, and as a lacquer (DuBois 1972; Fenichell 1996; Friedel 1983). Similar to rubber and gutta percha, shellac production relied upon low-technology, labor- and environmentally intensive forms of processing and extraction (Parry 1935).

These natural plastics, or sometimes called proto-plastics, each have two things in common. One: with the exception of hard rubber, they were largely replaced by synthetics in the twentieth century; and even rubber, while it continues to be used, was supplemented by a synthetic substitute—today, roughly half the world's rubber supply is synthetic (Tully 2011:21). And two, the adoption of each of these substances portended the desire for a sufficiently pliable, moldable, lightweight, inert—in a word, plastic—raw material that could be applied to the production of the ever-increasing number of industrial and consumer goods demanded by the dictates of ever-expanding capital accumulation.

A *basic, generalized plastic mass material* would be able to replace the labor-intensive, craft production methods that required great skill, time, and dexterity — demanding relatively high variable capital costs, even considering the greatly reduced wages paid to workers in the colonized world. Also, the experiences of natural plastic use and production signaled the need for a raw material less dependent on the vagaries of ecological processes, geographic specificity, and natural limitations of supply; as well as a material better able to withstand temperature changes, moisture, and the inevitable wear and tear that comes with transport, use, and time.

In this sense, plastic would serve as the apotheosis, and ideal reflection in raw material form, of capitalist production: embodying the contradiction between use-value and (exchange-) value, and between the imperative of continuous, exponential, infinitely quantitative capital accumulation within a qualitatively distinct, quantifiably limited, finite world. Perfectly moldable, plastic could be transformed into virtually any form or shape imaginable. Versatile, plastic was able to replace an incredibly diverse array of materials—from wood to metal, paper, cotton and silk, ivory, glass, and ceramic, ad infinitum. Seemingly derived from magic, plastic production appeared to resolve the inherent problem of material supply shortages, particularly from distant, foreign sources. Synthetic plastics made from fossil fuels — or plastic qua plastic — were derived directly from the dominant sources of energy used to globalize and expand the reach of the capitalist system. The United States, with its large domestic coal supply and, even more importantly for later iterations of plastic, oil and natural gas fields, was also well positioned for greater self-reliance on synthetic plastic production. As central as coal and petroleum have been to the emergence of first industrial capitalism, and then monopoly/imperialist capitalism, synthetic plastics were developed from byproducts of these sources of energy. Being coupled with and inextricably integrated within the fossil economy and fossil capital, so central to the consolidation and expansion of that system (Malm 2016), gave synthetic plastics a built-in competitive advantage, as growth in the fossil economy incentivized and directly facilitated the production of more fossil fuel-based plastics.

Celluloid: Natural or Synthetic?

The first reasonably successful attempt at making a (partially) synthetic base plastic material, for generalized use, was celluloid. The original iteration of this material, which is considered to be the "first [hu]man-made plastic" (Fenichell 1996:18), was first created in 1862 by British inventor Alexander Parkes (DuBois 1972; Friedel 1983; Mossman 1994). Dubbed "Parkesine," its namesake aimed to create the first "plastic mass": a widely used plastic raw material that could be industrially molded, shaped, and mass-produced for a vast variety of commercial and industrial uses. "This matter of molding went straight to the heart of the Industrial Revolution, because a moldable material is ideally suited to mass manufacturing," and can be produced "without having to resort to skilled artisans hand-tooling each article," notes Fenichell (1996:33-34).

As mentioned above, central to the goal of developing a general plastic mass was the cheapening of labor costs involved in the production of manufactured goods (both consumer and/or producer goods), and of raw materials for production (producer goods). The deskilling of labor through dividing the tasks of production as comprehensively as possible serves this purpose in two principal ways. First, it tends to reduce the amount of socially necessary labor time—meaning less quanta of labor power, and thus less cost, is embodied in each good (Braverman 1974; Marx 1976). And two, it reduces the quality of the labor to its most basic level—what Marx (1976) calls "simple labor power" (p. 135). This decreases the cost of this labor to its minimum because labor power's "value, like that of all other commodities, is determined by the labour-time necessary to produce it" (Marx 1976:340).

Deskilled, simple labor power requires less socially necessary labor-time to (re)produce it, as its value is reduced to the cost of the bare necessities for human survival. Thus, as Braverman (1974) demonstrates, "in a society based upon the purchase and sale of labor power, dividing the craft cheapens its individual parts" (p. 80). Parkes wanted to produce a material more cheaply, and from more easily accessible raw materials, which could compete with natural materials like tortoiseshell, ivory, gutta percha and rubber, including in the waterproofing, jewelry, consumer items, and electrical wiring insulation markets (DuBois 1972; Fenichell 1996; Friedel 1983). His attempts to do so were fraught and riddled with holes—particularly in regard to material quality, production costs, and the maker's uncertainty about his own product.

As noted, there were a number of problems with Parkesine, which caused the company Parkes formed in 1866 to make the material—Parkesine Company, Limited—to fold two years later (Mossman 1994). One was that the quality of Parkesine was poor, largely because of Parkes's obsession with making it a cheaper raw material than its competitors, such as rubber, ivory, and gutta percha (Friedel 1983). Parkesine, like celluloid that would succeed it, was a pyroxylin plastic, made from nitrocellulose. The nitrocellulose was produced from paper, linen, and the byproducts of cotton production. Because of his determination to make it as cheaply as possible, Parkes "used special devices to recover the solvents of the pyroxylin and adopted cheaper solvents, such as wood naphtha. The result of these efforts was a considerably cheapened product—one that turned out to be almost worthless in manufacturing" (Friedel 1983:10).

Another reason for Parkesine's failure was that Parkes was unsure how to market it. This stemmed in part from Parkes's general uncertainty about what constituted the best use of his product. Parkes, like many other inventors in the mid-nineteenth century, was searching for a new material that combined the properties of the natural plastics, plastic-like materials such as ivory and tortoiseshell, and other raw materials such as wood and metal, into a singular base material which could largely replace all of the former and be used to cheaply mass-produce consumer and producer goods (Fenichell 1996; Friedel 1983; Meikle 1995). An 1862 Exhibition that presented Parkesine stated that the material was "a substance hard as shorn, but as flexible as leather, capable of being cast or stamped, painted, dyed or carved and which above all can be produced in any quantity at a lower price than gutta percha" (quoted in Mossman 1994:12). This is in fact an apt description of contemporary, post-World War II thermoplastics, but not an accurate depiction of Parkesine itself, nor of the plastics that immediately followed it.

This leads us to the final shortcoming of Parkesine: many of Parkes's efforts were premature from a world-historical perspective, in regard to the level of development of the productive forces and the corresponding production relations at the time. As hinted in the quote above, Parkes was attempting to develop a plastic material akin to the plethora of synthetic plastics on the market today, but without the necessary conditions to do so. Organic chemistry was still in its infancy, particularly concerning synthetics. Production methods were not developed to the point where the economy of scale required to keep costs low and output high was practical in the making of Parkesine and Parkesine goods. And much of the organization of labor, and relations of production, were still dependent upon craft forms of production. The "scientific-technical revolution," along with scientific management, had yet to emerge in earnest (Braverman 1974). This meant that the technical and scientific knowhow required for breakthroughs in the development of plastic production, and both the production methods and machinery it required were either completely unknown or in their infancy. Thus, while perhaps visionary from a capitalist’s perspective, Parkes's ambitions for Parkesine were premature and out of step with the concomitant level of productive, technological, and scientific development.

As mentioned, Parkes's discovery was part of a broad cultural zeitgeist driven by the imperatives of capital accumulation and industrial demand for a generalized plastic material: a raw material seemingly, but not actually, divorced from the exigencies of ecological processes, timescales, skilled craft labor, geographical dispersion, geopolitical competition, and withering materials supply. But the conditions for such a material had not yet emerged—they simply did not exist at that time. Because of Parkes's ambition, he presented Parkesine as capable of fulfilling a plethora of industrial, commercial, and artistic roles, leaving both the public, potential investors, and manufacturers (potential buyers of the material to use for production) unclear of its purpose or best uses. His emphasis on undercutting the cost of the materials Parkes was attempting to replace—gutta percha, rubber, ivory, pearl, etc.—compromised the quality of Parkesine, and caused the company to fail.

Besides xylonite—another pyroxylin plastic developed by Daniel Spill, who had worked closely with Parkes, after the Parkesine Company went under, and was never really commercially successful—the next chapter in the development of a synthetic plastic starts with John Wesley Hyatt. Hyatt was inspired to find a substitute for ivory-made billiard balls, a highly popular mid-century game in the United States (Fenichell 1996; Friedel 1983; Meikle 1995). Inventors had long searched for a sufficient substitute for ivory, which was primarily made from elephant tusks. By the 1860s, there was much panic about the decline in ivory's availability, and one of the top billiard companies put out an ad offering $10,000 to the developer of a replacement material. While the validity of the existence of a widespread ivory shortage in the 1860s is questionable (see Friedel 1983:29-34; Meikle 1995:17), the belief that ivory stocks were drying up among the producers of ivory goods in the United States was very real, as was the quest for a good quality, cheap, dependable ivory substitute. In reality, panic concerning the depletion of ivory in the West may have reflected underlying concerns regarding reliance on "foreign" material stocks, particularly those sourced from the colonized global South, or not indigenous to Western Europe or the United States. Interestingly, it is worth noting that celluloid production itself was dependent on camphor, which could not be produced or sourced domestically in either the US or Europe. Instead, it was sourced from the camphor laurel tree, which was only found in East Asia (Meikle 1995:20).

Hyatt's key contribution to the chemical development of pyroxylin plastics was his successful application of camphor as a solvent to the nitrocellulose base (Friedel 1983; Meikle

1995; Mossman 1994). While largely built off the work done by Parkes and Spill, he was the first to develop a commercially successful plastic that was at least partially synthetic in nature. Called celluloid, Hyatt's new material, developed with the intent of replacing ivory, particularly for billiard balls, was actually first used as a replacement for hard rubber and shellac in denture plates, and for costume jewelry. In fact, celluloid was not a successful substitute for ivory in billiard balls (Fenichell 1996; Friedel 1983; Meikle 1995). Celluloid did compete with ivory in the manufacture of other goods, such as piano keys, as well with a host of other natural plastics and parallel raw materials similar to ivory, such tortoiseshell, pearl, ebony, and horn (DuBois 1972; Fenichell 1996; Meikle 1995). In competing with the latter class of materials, celluloid was heralded for both its substitutive and imitative qualities. Many of these materials produced luxury goods and commanded a high price. Celluloid could successfully imitate these materials in the form of jewelry, combs, buttons, and mirrors.

Celluloid's role as both imitator and substitute made it a relatively successful material in a variety of niche markets (Meikle 1995). However, especially early on, celluloid was limited in a number of ways. It was limited by its fairly high productive costs and labor-intensive production processes, which, while still cheaper than the luxurious ivory or mother-of-pearl, made it more expensive than natural plastics such as shellac and rubber, and not as cheap as future, fully synthetic plastics, of which it acted as a precursor. Celluloid, as Friedel (1983) argued, was "an intermediate substance" between the progression from natural to synthetic plastics, "never as cheap as rubber and a few other materials, but definitely cheaper than the natural materials [such as tortoiseshell or ivory] it imitated so well" (p. 66). In other words, celluloid was only partially successful in its substitutive role. Celluloid was also highly flammable, making its production dangerous and risky (Fenichell 1996; Friedel 1983; Meikle 1995; Mossman 1994). Although celluloid's flammability was mainly limited to its manufacture, stories about factory fires gave the material somewhat of an undesirable, dangerous reputation among consumers (Friedel 1983). Nonetheless, it was quite successful, as alluded to in the quote above, as an imitator of other, more expensive luxury materials. Thus, celluloid's shortcomings in this department have more to do with the inherent limitations of a largely imitative material than with any unique deficiency regarding celluloid's imitative capabilities. More fundamentally, celluloid was not able to successfully realize the qualities of a basic, generalized plastic mass material, which embodied the exigencies of capital, and imbued with sufficient plasticity—strength, tensility, pliancy, moldability, innate formlessness—cheapness, with reduced labor time and cost; widely accessible source materials; and mass demand for its products.

The limitations of imitation are twofold: the difficulties of an imitative material to generate its own novel markets, and the association between imitation and inauthenticity, or cheapness. Friedel (1983), commenting on celluloid's limitations, noted that, with a few notable exceptions, the material "did not change markets; it adapted itself to them" (p. 64). Meikle (1995), referring to the connection between imitation and inauthenticity, argues that "disdain for imitation as dishonest and immoral had its roots in nineteenth-century British critics of industrialization who promoted a romantic aesthetic of craftsmanship" (p. 13). Beyond moral concerns, imitation is also closely linked with cheapness, inauthenticity, and low quality. In celluloid's early days, and to some extent throughout its life, the material was largely limited to only the first two of what Meikle (1995) calls "the three distinct motives for using plastic": substitution, imitation, and innovation (p. 11). Celluloid was partially successful in its role as a substitute for other raw materials, quite successful in its role as an imitator, but, withstanding a few important exceptions, largely lacked an innovative character. While plastic's role as an innovative material, or a material capable of generating novel products and uses, did not come to full fruition until the arrival of fully synthetic plastics, celluloid did shed its imitative character in one particular use. This is worth discussing briefly, as it portended plastic's later role as an innovative material that generated its own markets and products, stimulated mass consumption, and spearheaded technological development, including in the important realm of media and communications technology.

Celluloid and Photography

Celluloid's greatest impact was arguably in photography. DuBois (1972:49) notes that "[p]lastics and photography [grew] up together," while Fenichell (1996) states that "celluloid film succeeded in raising the first plastic's cultural profile from a medium of mere mimicry into a priceless repository of human memory" (p. 63). Friedel (1983) argues that "[t]he large scale adoption of celluloid in photography revolutionized that medium . . . and gave celluloid its most significant breakaway from imitation" (p. 90). Meikle (1995) also claimed that photographic film was "Celluloid's most innovative application" (p. 28). Celluloid replaced glass plates, as the material upon which the photographic images were cast. But its impact on photography went far beyond mere substitution. Celluloid film helped change the very nature of photography itself.

The relationship between celluloid and photography begins with collodion, a solution of nitrocellulose and solvents. Collodion was used in early photography starting in the 1850s "as a support for the light-sensitive emulsions used in photography" to coat the glass plates, also known as the "Wet Plate Collodion Process" (Fenichell 1996:32). Collodion, a nitrocellulose solution, was a precursor to celluloid. However, celluloid's injection into the photography industry did not come until a few decades after its introduction to the market, and its revolutionary role in photography was largely discovered by actors outside of the celluloid industry proper. It was George Eastman, founder of the Eastman Kodak Company, who is generally credited with this discovery. Prior to roll film, photography required large, bulky equipment. Wet plate photography demanded near-complete darkness to quickly capture images on the plate before the liquid collodion began to dry. Thus, outdoor photographers were forced to haul with them a collapsible "dark tent" within which to develop the images (Fenichell 1996). While Eastman was not the first to use "dry plates," which were coated with gelatin to slow the evaporation process, he was the first to develop an "amateur camera" that required no technical knowledge or skill to operate.

The Kodak camera, introduced by Eastman in 1888, was small, relatively inexpensive, and required little more than the push of a button to capture images (Fenichell 1996; Friedel 1983). Once pictures were taken, the amateur photographer would send the camera to an Eastman factory where the film would be developed, reloaded with fresh film, and sent back. At this time, paper roll film had already been introduced in place of glass plates. Called stripping film, this gelatin- or collodion-soaked paper film was not well-suited for the Kodak, and by 1889 Eastman Kodak was selling cameras with celluloid film (Friedel 1983). As film, celluloid had found a niche market in which it provided neither imitation nor substitution, but instead was uniquely suited, acting as an innovative, market-generating material for the first time (Meikle 1995). Celluloid's novel "combination of transparency, flexibility, toughness, and uniformity" (Friedel 1983:94), which, as Eastman advertised, "'combine[d] the lightness and convenience of paper with the transparency of glass,'" was not shared by any other known material at the time (quoted in Fenichell 1996:58). Importantly, photography's continued evolution toward the self-developing film would have likely been impossible without celluloid. Photography and celluloid mutually shaped, propelled, and co-determined one another.

The relationship between photography and celluloid plastic film is important for two main reasons. One, as a photographic base, celluloid—and therefore synthetic plastics more generally—had found its calling card as a raw material imbued with unique qualities not shared with any found in nature. Its combination of lightness, strength, durability, moldability, and consistency would make it the preferred material for a host of products—both new and old. This would propel plastics in the second half of the twentieth century into the role of dominant raw material of producer and consumer goods. Also, celluloid film helped the camera to become a mass-produced consumer item, accessible to the public due to both its low cost and user-friendly mechanics. These developments—of plastic as a novel raw material that combined characteristics uniquely suited to industrial mass-production under capitalism—made celluloid the prototype for the synthetic plastics that would later supersede it, and a harbinger of the future Plastic Age of the late twentieth century (Fenichell 1996; Friedel 1983).

There were a few other markets in which celluloid played a key role. While initially playing a largely imitative or substitutive capacity—in comb making, as well as detachable collars and cuffs—the unique properties of celluloid, which portended the novelty of the synthetic plastics that would proceed it, ended up changing the nature of these products. Finally, in cinema, an industry closely linked to photography and in which celluloid also played a unique, innovative part. Before moving on to the next chapter in the history of plastics, I will briefly discuss each of these celluloid products in turn, as they each highlight some important economic, technological, and cultural changes that celluloid helped induce and codetermine.

Celluloid, Comb-making and the Technological-Labor Shift in Its Production

Combs provided one of the largest markets for celluloid. As an imitative material, celluloid was easily able to mimic and replace many of the traditional combmaking materials, such as bone, ivory, wood, and shell. Celluloid fit perfectly for comb manufacturing: It could be colored and decorated in ways that natural materials could not, was quite convincing in its imitation of natural materials, and could be uniformly molded and produced with machinery. The material was flexible and could be used to make either harder or softer combs. But even more impactful was the role of celluloid in changing the configuration of the comb-making labor process, and thus the entire industry. In this way, celluloid reflected and spurred the ongoing transition from craft to industrial and then to scientific-technical production, which was a key shift in the capitalist mode of production (Braverman 1974). Comb-making had long been considered a skilled handcraft. The shift from feudalism to capitalism heralded a subsequent shift from handicraft to factory forms of production, as part of cheapening labor costs, scaling up and socializing production, and intensifying the division of the labor process (Braverman 1974; Marx 1976). However, the traditional materials used for comb-making limited this transition—as these materials required skilled, labor-intensive production to shape the material into combs, restricting the role of capital-intensive, labor-simplified, and machinery-based production methods.

Friedel (1983) states that while the nineteenth century saw the introduction of machinery intended to replace the human labor required for comb-making, "the problems arising from the variability and limitations of a natural material could not be dealt with by mechanization" (p. 73). *A new material for production was thus required*. This new material upended and transformed the existing productive relations. The shift to celluloid in comb-making started around 1890, and caused profound changes in both the industry as well as the communities in which comb-making was the dominant craft. Towns in which comb-making had been the main industry became dominated by plastic goods manufacturing generally, as the introduction of the machinery to produce celluloid combs made the production of other celluloid items fairly easy. In these comb-making towns, the introduction of celluloid destroyed craft production, and made the material (celluloid plastic), rather than the product (combs), the locus of economic activity (Friedel 1983).

Celluloid, Collars and Cuffs

The detachable collars and cuffs market was another where celluloid made noteworthy inroads. The material which celluloid competed with for market shares in this industry was linen. As with combs, celluloid's ability to enter into this market was highly dependent on its imitative properties of a traditional material, in this case linen. However, celluloid collars and cuffs were sold at about twice the cost of linen ones (Friedel 1983:78). Thus, it had to be presented as more than a mere imitation of, and sufficient substitute for, linen.

Here, celluloid's novel properties were its calling card—celluloid collars and cuffs did not need to be laundered, but merely wiped down with a wet cloth, thus purportedly saving money and time on professional laundering. Further, celluloid's resistance to moisture, and its durability, were highlighted in marketing the product, making it superior to linen. Collars-and-cuffs were considered an important market for celluloid producers (Fenichell 1996; Friedel 1983; Meikle 1995). While it never seriously threatened linen—Friedel estimates that celluloid could never have represented more than a small sliver of the collars-and-cuffs market (1983:84)—detachable collars-and-cuffs represented a notable moment in the development of the plastics industry. It reflected an awareness of plastic's simultaneous ability to emulate traditional materials while offering wholly unique characteristics rarely found in non-synthetic, natural materials.

Celluloid and Cinema

The final example of celluloid's impact is in the motion picture industry. Here, celluloid's role was similar to photography, with one key distinction: while photography originally emerged independently of celluloid, in the case of motion pictures, the material was key to cinema's emergence. From its earliest days, the motion picture "depended on celluloid film" (Fenichell 1996:74), and likely would have never evolved past its nascent "magic lantern" phase without it. Celluloid in fact became literally synonymous with cinema.

Like with photography, celluloid played an innovative, rather than imitative, role in cinematography. Celluloid film made cinematography "technically feasible for the first time," and along with photography "gave celluloid its most significant breakaway from imitation" (Friedel 1983:90). Like photography, the first attempts at motion picture used glass film, although in cinematography the use of glass as the medium was severely limiting to the point of making the task nearly impossible (Friedel 1983). The next film material adopted was paper. While paper film was less fragile, it failed to provide the necessary transparency, like glass, to project a clean image. By the mid-1890s celluloid had been adopted as the preferred medium, and quickly became synonymous with cinematography and the burgeoning motion picture industry (Fenichell 1996; Friedel 1983).

Celluloid and Monopoly Capital

Celluloid came onto the scene in the latter quarter of the 19th century, coinciding with some of the earliest shifts monopoly capitalism. This was a time in which production was becoming increasingly concentrated, centralized, globalized, and scaled up (Lenin 1917; Lotta 1984). Along with this, production methods and relations were changing, through the further implementation of industrial methods of manufacturing and the undermining of craftsmanship labor methods (Braverman 1974; Marx 1976). Celluloid, while never a major raw material of production in the economy, nonetheless reflected these changes in the ways and means of capitalist production and its corresponding socioeconomic relations. Its promise as a raw material that was highly amenable to capital-intensive, rather than labor-intensive, production methods—in which machine labor replaced human labor, the work was deskilled and divided into its individual parts, thus cheapening it, and reducing production time—was only partially fulfilled, but portended the emergence of fully synthetic plastics.

Celluloid production was also highly centralized, a reflection of the increasingly monopolized character of capital. While celluloid was never a major industry, on the level of steel, railroad, or coal, its manufacture and ownership were similarly dominated by a handful of relatively large corporations. By the 1890s, there were two main blocs of celluloid capital: the Celluloid Company, which formed after the Celluloid Manufacturing Company bought out and absorbed most of its competitors; and the Arlington Company, which became its main competitor, after absorbing a number of similar enterprises itself (Friedel 1983). These two companies dominated the American market and engaged in "price-signaling" and other forms of duopolistic behavior common within monopolized sectors of the economy (Baran and Sweezy

1966; Friedel 1983; Lenin 1917; Lotta 1984). For example, a letter sent from the office of the Arlington to the office of the Celluloid Company included the following:

> Would it not be well for arrangements to be made for a representative from your Company to meet one from ours with a view to adjusting the prices and terms for the sale of waterproof collars and cuffs for the year 1893. There are, as you are aware, only you and ourselves making and controlling these goods and it seems to us unnecessary to sell at the low prices now being obtained (Quoted in Friedel 1983:70).

This is a textbook example of the “price-making,” rather than price-taking, character of monopoly capital, and of the centrality of price signaling (and even, at times, price fixing) to monopoly capitalism discussed by Baran and Sweezy (1966:53-65, 115; see also Lenin 1917).

Celluloid, as the first partially synthetic plastic material, both generated greater interest in a synthetic plastic base material that was more widely and generally applicable for use, while simultaneously running up against its own limitations in this regard (Bijker 1995). There are a number of reasons why celluloid both presupposed such a generalized plastic material while being unable to fulfill this role itself. Celluloid was in part developed out of a desire for raw materials for mass production that were not contingent on the vagaries of natural processes—of reliance on resources that were both in places far away from and out of reach to the centers of capital, geographically and/or politically. Celluloid, however, largely failed in this regard. As mentioned above, the reliance on camphor, which was sourced from East Asia, made celluloid susceptible to many of the same problems as natural plastics and other raw materials. Many celluloid producers attempted to develop a synthetic substitute for camphor that could be produced domestically, to little avail (Bijker 1995).

Celluloid was also developed in part with the aim of overcoming the constitutional limitations of natural materials—their inherent tendency to decay, degrade, and, with time, lose their structural integrity. While the partial synthetic transformation that occurred in producing celluloid made it less susceptible to these processes—akin to the rubber vulcanization process's effects on the structural integrity of rubber—it was nonetheless still limited in this regard. As mentioned earlier, celluloid was widely perceived as having a flammability problem. While this was primarily confined to the production process, it was not immune to catching fire in its finished form. Further, celluloid did not handle high temperatures particularly well (Friedel 1983). Bijker (1995) notes that "At a temperature of 100° [Fahrenheit], celluloid softened considerably and showed slight swelling" (p. 119). As the temperature continued to rise, it began emitting camphor fumes, swelled further, and showed other clear signs of temperature instability. These limitations further highlight celluloid's role as an "intermediate material" (Bijker 1995:112), an important yet incomplete stopgap between the pre-synthetic (natural) and synthetic ages of capitalist production methods. Sometimes classified as a synthetic plastic, sometimes a natural one, it is in fact demonstrative of the temporal, partial, and blurred distinctions that separate the world of the purely human-made and that of the natural elements. The next step, the development of the first fully synthetic plastic material, represented a qualitative leap beyond the precursors that came before it, into the realm of human-made materials and products that did not, and could not, exist in nature prior to their development in industrial laboratories.

Conclusion

The story of natural plastics, and the first attempt at a synthetic plastic, serves as the prehistory to the proliferation of plastics after the Second World War; the coronation of the Synthetic Age (Foster 1999/1994). This culmination of the Synthetic Age–where plastics, among other synthetics, have come to dominate the material and energetic substratum of our society–

represented a fundamental shift in the social metabolic order of capital and has intensified the rift between the social metabolism and the rest of nature.

The analysis here makes clear that the development of natural plastics and protosynthetics happened within a specific political-economic and social context. The need for raw materials with particular characteristics, the shift to new methods and arrangements of production, and the expanding global reach of capital all contributed to its development. And the development of these materials in turn reacted back upon and opened new vistas for the further expansion and consolidation of the political-economic system of monopoly capitalism.

Early natural plastics, such as gutta percha and rubber, were both harbingers of the plastic proliferation to come and played critical if often overlooked roles in the development of pivotal industries such as telegraphy, electricity, and pneumatic tires. The expansion of global empires was facilitated by these raw materials, and the industries they generated were early, archetypal examples of capital concentration, centralization, the rationalization of production, and global supply chains. Celluloid, a so-called “semi-synthetic” plastic, was an important transit in the trial-and-error process of discovering a basic, generalized plastic mass.

But if synthetic plastic production did not commence in earnest until the interwar period (between the two world wars)—and was only more fully consolidated after the Second World War, reaching its peak (thus far) in the twenty-first century—why pay such close attention to its prehistory? Examining the early history of plastics—of first attempts to develop such a "generalized plastic mass material"—is instructive from the perspective of understanding the constraints and limitations of these early attempts, which helps to define the qualities being sought out for such a material. Natural plastics formed the scaffolding upon which the Synthetic, or Plastic Age, was constructed. In many cases, synthetics were developed explicitly as substitutes for natural plastics. The first attempt at creating such a synthetic material—celluloid—that was (partially) free of these limitations and constraints, can be recognized in hindsight as a sort of stopgap, or liaison, between natural and synthetic plastics, and of the ongoing limitations inherent in a material that was not truly a synthetic plastic. It is to the emergence of synthetic plastics proper that I will now turn.

CHAPTER 4: THE EMERGENCE OF SYNTHETICS

Introduction

To detail the rise of synthetic raw materials, the ways in which this contributed to the transformation of the social metabolism of capital, the relationship between these changes and the imperatives of monopoly capitalism, and how this relates to scholarship on the nature/society question, I will, following the methodological approach of the prior chapter, historically trace the development of these materials. Starting with the first synthetic plastic, Bakelite, I will explain the important role it played in some of the key technological and industrial developments of the early twentieth century, while also focusing on the limitations and shortcomings of this material. These shortcomings, like those of its natural and semi-synthetic plastic antecedents, among several other factors, portended the emergence of a new class of synthetic plastics during the interwar period. These new plastics were synthetic thermoplastics, which ushered in a proliferation of both overall plastic production, as well as variety in the types of plastics, methods of production, and uses. I will also explore the role of the Second World War in both shifting the entire global political-economic order, as well as in reconfiguring the material foundation of the U.S. economy, as a key nodal point in the consolidation of an increasingly synthetic social metabolic order.

Synthetic plastics not only coincided with and helped spur forward the further consolidation and growth of monopoly capitalism, but it changed, on a fundamental level, humanity's relationship with the natural world. The historical example of plastics—its development, in tandem with fundamental political-economic and technological changes, and its circuitous trajectory from plastics of natural origin to synthetics—is particularly salient in relation to understanding questions about the distinction between social and natural phenomena. This will be the subject of the following chapter. However, in a beginning way, these questions will be probed in this chapter, as in the previous chapter—particularly as it relates to both the physical characteristics of synthetic plastics that make them so amenable to their wholesale incorporation into the metabolic order of capital.

The emergence of Bakelite represented an epochal leap into the realm of synthetic materials proper. Bakelite—and other analog plastics—as will be explained below, consisted of novel, human-made molecular configurations not found anywhere else in nature. This expressed not merely the rise of a new class of raw materials, but of a fundamental shift in the social metabolic order. As detailed in the theory chapter above, every society has a metabolic order, which is ultimately determined by the economic foundation of that society, and which is an expression of the material and energetic relationship this society has with the rest of nature. The introduction of synthetics broadly—including synthetic dyes, detergents, agrochemicals, paints and adhesives, fibers, fuel and, for our purposes here, of synthetic raw materials of production—fundamentally altered that relationship, and further alienated the metabolic order from the universal metabolism of nature.

Synthetic Plastics: Thermosets

The second classification method for categorizing plastics, after the natural-synthetic axis, is by whether the material is thermosetting or thermoplastic. The first thermoset plastic—which means that it "sets" and takes form when heated and cannot be melted down and refurbished—was called Bakelite. Conversely, thermoplastics—which include celluloid, as well as most of the synthetic plastics developed in the interwar period and widely introduced to consumer markets after the Second World War—can be melted down and refurbished (Freinkel 2011; Meikle 1995). This made Bakelite and other thermosets ideal for industrial and electrical uses, as it forms a durable, rigid material once cured, yet could be molded into a plethora of shapes and forms before being heated, to meet an array of hardware needs (DuBois 1972; Moore and Phillips 2011). It also made Bakelite quite different from celluloid—in fact, most celluloid engineers did not understand how to work with it at first (Bijker 1995; DuBois 1972). This is because Bakelite was not just a new material, but also a new industrial process for producing raw materials and consumer goods—an important distinction between what Bijker calls "product" versus "process" inventions (1995:12). Bakelite represented an innovation of not just materials, but of ways to produce those materials, and of qualitative leaps in the field of organic chemistry as well as the scientific methods of production and manufacture.

Developed by the Belgian-American chemist Leo Baekeland in 1907 and named Bakelite after its namesake, it was also the first plastic that relied on fossil fuel production, namely coal, for its material feedstocks. Bakelite was discovered via the first successful chemical synthesis of phenol and formaldehyde, an enigma that had long stumped chemists (Bijker 1995; DuBois 1972; Fenichell 1996; Meikle 1995). Phenol was a byproduct sourced from coal tar, while formaldehyde was derived from wood alcohol (Meikle 1995). Baekeland was initially less interested in developing a celluloid substitute and was instead more motivated to discover a synthetic replacement for the natural plastics of shellac and hard rubber, particularly for use as an electrical insulator, as well as for other industrial-electrical uses (Bijker 1995; DuBois 1972; Fenichell 1996; Freinkel 2011; Meikle 1995). In fact, the electrical insulation market was where Bakelite first found success, for which it was vastly superior to natural plastics (Bijker 1995; Fenichell 1996). While celluloid helped generate new markets and new ideas for plastic materials, its shortcomings prevented it from expanding in ways that it presaged. Baekeland, an independent entrepreneurial inventor, "was more concerned with industrial applications," as well as "[p]roducing raw materials for industry," than he was concerned "with finding a substitute for luxury plastics." This was explicitly in contrast to celluloid, as "celluloid chemists focused primarily on consumer goods" (Bijker 1995:148).

Bakelite fit many of the turn-of-the-century needs of capital accumulation by providing a crucial, if often overlooked, material throughput for the expansion of the electricity, telegraphy, telephony, phonography, radio, and automobile industries—key industries to the emergence and consolidation of monopoly capitalism-imperialism. Regarding its use as electrical insulation, the precipitous explosion in demand for electricity, fueled by the discovery of the electrolytic cell at the end of the 1800s, generated a need for both a technically superior, as well as more readily available, raw material than shellac and gutta percha (Geiser 2001). Here, the story parallels that of John Wesley Hyatt's quest for an ivory substitute in billiard ball production.

Shellac, as discussed above, was sourced from the secretions of the lac beetle, native to Southeast Asia (Parry 1935). Similar concerns about the stock of this natural resource, sourced from the far-away East, dwindling in supply, and reliant on both a labor-intensive extraction process as well as the natural metabolic life activity of the insects and the trees upon which they secreted, motivated Baekeland to find a synthetic substitute (Bijker 1995; Fenichell 1996; Meikle 1995; Parry 1935). Fenichell notes that "[j]ust as the precipitous decline in the elephant population had sent billiard-ball ivory out of reach of the average citizen, the rapid expansion of the electrical industry had caused the price of shellac . . . to soar above a dollar a pound" (1996:87). Not only was Baekeland able to replace shellac with a synthetic substitute seemingly divorced from reliance on nature's metabolic cycles and labor-intensive processes, but he also produced one that was "vastly superior" as an electrical insulator "to any natural material on the market" (Fenichell 1996:91). Comparing it to non-synthetic raw materials for use as electrical insulation, Fenichell (1996) states:

> [Bakelite] was more electrically resistant than porcelain or mica; more chemically stable than rubber; more heat resistant than shellac; less liable to shatter than glass or ceramic; it would neither crack, fade, crease, nor discolor under the influence of sunlight, dampness, or salt air; it was impervious to ozone, contained no sulfur to cause the 'greenling' (degradation over time) suffered by hard rubber, and could not be weakened by hydrochloric acid or blemished by alcohol. Contact with oil- or grease-stained fingers would not warp, mar, or disfigure it; it was virtually impervious to natural or human attack (p. 91).

This is how the "fourth kingdom" (Bijker 1995)—synthetic, human-made materials not found in nature; neither animal, vegetable, nor mineral—was founded.

Bakelite's first major use being for electrical insulation, and its being a superior alternative to the natural plastics it replaced, is in fact acutely metaphorical. Its superior insulative qualities listed above betrayed the very characteristics that made it so valuable as a form of productive capital. The ability of human-made, synthetic plastic material to resist the natural metabolic processes of aging, weathering, state changes of matter, and certain chemical alterations appeared to insulate it from nature itself. This reflected, in material form, the partial realization of a more generalized tendency of the social metabolism of capital: liberation from the exigencies of the metabolic cycles of the natural world. This drive—to "insulate" itself from the imperatives and effects of the disruptive processes of nature—while baked into the very nature of capitalism, took a qualitative leap in the era of monopoly capital. This is in large part due to the further globalized nature of monopoly capitalism—along with the coincident need to communicate, travel, and ship goods over longer distances, more frequently, and with greater urgency. The development of more mechanically complex, sophisticated technology—which was central to the further development of capitalism and the shift to its monopolistic phase—

often foreshadowed the necessity for more structurally durable, reliable, and inert materials available in large amounts and produced cheaply. This further heightened the importance of control by both nation states and blocs of capital over access to crucial material inputs, such as fossil fuels, during the era of monopoly capitalism-imperialism (Magdoff 1969).

As mentioned, Bakelite both provided a spur for and was an important component in the further expansion and consolidation of the dominant information and communication technologies of the late 19th and early 20th centuries, as well as transportation technologies, both so crucial to the consolidation of globalized monopoly capitalism. The export of capital, an essential feature of imperialist monopoly capitalism, required greater and more efficient means of global transportation of machinery, production equipment, goods and other material and energetic throughput (Lenin 1917; Lotta 1984; Magdoff 1969; Smith 2016). The substantial leaps in the rise of global finance at the turn of the century, with the United States in a favorable position after the First World War to dominate as the world's leading creditor nation, also gave rise to new global communication needs (Lotta 1984). New forms of transportation, namely the automobile—one of the most central developments of the monopoly capitalist economy (Baran and Sweezy 1966)—required a host of raw materials amenable to both the mass production methods of Fordian manufacturing, as well as a range of industrial-electrical parts, gears, gadgets, and insulation material. With intensified global trade came the need for faster, more reliable forms of both transportation, as well as communication and information technology.

A major obstacle to the development of these industries "was that natural raw materials could not always provide the properties and consistency of quality" required for them (Reboul 1994:26). Specifically, when it came to electrical insulation, and more particularly underwater transatlantic telegraph cables, the near depletion of gutta percha stocks by the turn of the twentieth century, and the ongoing expansion of intercontinental telegraphy presented pressing material needs (Tully 2009, 2011). In 1902, the President of the Institution of Electrical Engineers argued that it was precisely the problem of cable insulation that was impeding further expansion of the distance of these cables (Reboul 1994). Thus, it is not merely that Bakelite was a better substitute for the natural materials that it replaced. Bakelite also opened vistas for the expansion of telegraphy, electricity, telephony, automobilization, and a host of other industries that were essential to the expansion and intensification of the social metabolism of monopoly capitalism and ongoing capital accumulation. Below I will explore Bakelite's role in some other key industries, highlighting its innovative role in generating new markets, expanding existing ones, and overcoming the limitations of naturally sourced materials.

One new market that generated demand for Bakelite was the burgeoning radio industry. Bakelite's contribution to radio production resulted from what made it useful in electrical industries generally—its application "for small, precision-molded components" that held up better to heat and wear than any other raw material on the market (Bijker 1995:175). Beyond electrical parts, Bakelite was also essential to the design of radio. By the 1930s radio cabinets themselves eventually came to be composed of thermoset plastic (DuBois 1972), and "the plastic radio cabinet . . . physically embodied a revolution in communication similar in scope to that effected by the automobile in transportation" (Meikle 1994:45). Initially, most radios were self-constructed by home enthusiasts, with the home radio amateur boom of 1920 to 1924, the exact year which Meike (1995) notes "the meaning of Bakelite had come to a focus and was merging with a general definition of plastic as an embodiment of twentieth-century modernity" (p. 46). From 1922-1924, the Bakelite Corporation's—a company which represented a merger between the three dominant phenol plastic companies at the time: Bakelite, Condensite and Redmanol

(Fielding 1947)—sales almost doubled, with much of the increase accredited to the radio market (Meikle 1995).

Bakelite also helped lower the price of radio cabinets for consumers, as the increased use of plastic in radio production cheapened production costs, making radios more accessible to a wider portion of American consumers (Meikle 2001). Like celluloid and film, Bakelite and radio became interchangeable. Not only for amateur radio enthusiasts, but eventually the general public, Bakelite "became a household word," as it "surfed the crest of the radio wave" (Bijker 1995:176; see also Meikle 1995:57). It was the radio, perhaps more than any other item, which helped transform Bakelite from a purely industrial material into a key raw material of consumer goods (Meikle 1995, 2001).

Another key market for Bakelite that emerged alongside Bakelite was the automobile industry. Bakelite was important for automobile production, as it provided the raw material for several key parts—including the automotive ignition, gear shift knobs, timing knobs, radiator caps, magneto couplings, distributor caps, steering wheels, gasoline tank covers, and door handles (Bijker 1995; DuBois 1972; Fielding 1947). As in radio and electrical insulation, phenolic plastic's qualities of chemical inertness, temperature durability, and amenability to mass production all made Bakelite superior to other raw materials, natural plastic or otherwise.

Like radio, Bakelite and the automobile came of age together, with the further development of each spurring the other forward. Bakelite helped transform cars from the realm of "luxury to necessity" (DuBois 1972:155), as its properties of "dielectric strength, the immunity to adverse affects from temperatures, acids, oils, and moisture" made the automobile "a reliable means of transportation" (DuBois 1972:167). It did so in part with phenolic sealing solutions, which were used to insulate cast aluminum for motor parts. Like the use of phenol laminate to better insulate electrical wiring, phenol sealant could treat metal materials in car parts, as untreated parts proved too porous. DuBois points out how the process of treating metal car parts with phenolic sealing solution "proved to be extremely economical," as it allowed leaky parts to be salvaged "which might otherwise have to be rejected" (1972:173). The ability of Bakelite, and by extension all synthetic plastics, to form a near-impenetrable fortress between whatever it protected and the natural elements—whether liquid, solid or gaseous—was key to its successful supersession of materials that came before it. This property of plastic appeared to give it an edge over all sorts of natural processes—aging, decay, reaction, and degradation—while providing certain benefits to industrial production, contributing to the further alienation of the social metabolism of capitalism from the universal metabolism of nature.

Finally, Bakelite was essential to the expansion and development of telephony. Bakelite, of course, was used as insulation in telephone cables. However, it was also a key ingredient in the manufacture of telephone receivers themselves. Here, as in its many other uses, Bakelite was considered superior to other raw materials for purposes of telephony. "Plastics offered many obvious advantages over metal for the manufacture of telephones," argued Fielding. "Their light weight, ease of production, the ability to mould connecting leads and wiring generally as an integral part of the handset, their electrical insulation properties, appearance, etc.," all made phenolic plastics the ideal material for telephone manufacture (Fielding 1947:58). Bakelite thus came to replace shellac and hard rubber as the raw material for telephone receivers and mouthpieces (DuBois 1972).

Bakelite was central to the design of the prototypical rotary-dial receiver phone, which combined the speaker and headset into a single unit. First designed in the late 1920s and introduced by Bell Telephone, this Bakelite model "was to define 'phone' for decades to come, until the advent of the digital era" of telephone technology (Fenichell 1996:99). In both the device itself and in its necessary electrical components, Bakelite provided a key raw material for the advancement and expansion of telephone technology in the early 20th century.

Bakelite, the first fully synthetic plastic and the first non-natural plastic that could seriously compete with traditional raw materials on a mass scale, was what set the terms for the pending post-World War II plastics explosion. But there were significant differences between it and the array of new synthetics that emerged in the interwar years, and later expanded into consumer markets en masse after 1945. As mentioned above, the latter class of plastics were thermoplastics, rather than thermosets like Bakelite. Not only did the class of plastics—thermoplastics as opposed to thermosets—change, but the variety of different types of plastics exploded. The era of phenol plastics shifted into the era of plastics of a plethora of varieties.

Also, the terrain of plastics expanded from mainly industrial and electrical uses to mass-produced consumer goods—a return of sorts to the celluloid era on a much larger scale. Increasingly, plastics expanded from the hidden abode of mechanical parts, electrical insulation, and radio tubes to the indiscreet realm of consumer packaging, single-use items, textiles, and commodity goods, as well as other key sectors of the economy, such as construction and agriculture.

Another important factor in the shift from the Bakelite era to the thermoplastic era was technological changes in the production of plastics, namely from compression to injection molding, which further streamlined and cheapened plastic's production. Finally, the primary feedstock of synthetics shifted from coal to mainly petroleum and, increasingly, natural gas. Before expanding upon each of these points in turn, I will briefly discuss some of the characteristics of Bakelite that limited its further expansion, as well as some of the Bakelite-era developments in synthetic plastics that attempted to address these limitations, including urea formaldehyde and cellulose acetate.

The Great Thermosetting Era and the Transition to Thermoplastics

DuBois characterizes the forty-year generation of 1910-1950 as the "Great Thermosetting Era." Thermoset plastics played a pivotal role in the industrial development of the first half of the twentieth century—fueling the electrical industry and the mass production of cars, radio, television, telephones, refrigerators, and airplane travel—setting the terms for future plastic development, and popularizing plastic in the public consciousness (1972:155). However, many of the thermosetting plastics' characteristics that made it the ideal material for industrial hardware uses—extreme temperature stability, inertness, inability to remelt and remold—also limited its further market expansion (Meikle 1995). What also limited Bakelite's further expansion, particularly in the world of consumer goods, was its narrow range of colors. Bakelite could only be colored black or dark brown. This may have been fine for industrial purposes, but it constrained its use for consumer goods, where bright, appealing colors and color variation were important (DuBois 1972; Meikle 1994, 1995).

One early attempt to remedy Bakelite's color problem was the development of urea plastics, and urea formaldehyde in particular, which was introduced in 1921. A thermoset plastic like Bakelite, urea formaldehyde (as opposed to phenol formaldehyde which is Bakelite), or Beetle, as it was called commercially, was able to be dyed all sorts of colors, including bright and commercial-friendly yellows, blues, and reds (Meikle 1994, 1995). Unlike Bakelite, Beetle was not reliant on coal-tar byproducts for its production, as urea could instead be synthesized from ammonia and carbon dioxide. Beetle plastic was used for several household items, including dishware, lampshades, cups, flatware handles, and consumer packaging (DuBois 1972; Meikle 1994, 1995).

Another intermediary plastic that emerged between the thermoset and thermoplastic eras was cellulose acetate. Initially created as a non-flammable substitute for celluloid (cellulose nitrate), cellulose acetate eschewed camphor, and thus negated celluloid's flammability issues (Friedel 1983; Meikle 1995). Cellulose acetate was also made from cellulose, rather than coal tar byproducts. It also addressed some of Bakelite's limitations, including its relatively intensive production methods, and acted as a harbinger for the new wave of petroleum-based, World War II-era thermoplastics.

Bakelite products were manufactured primarily via compression molding technology, which involved the application of heat and pressure to a mold, setting the plastic into its final shape, which was then cooled (Meikle 1995). Cellulose acetate, on the other hand, was manufactured by injection molding, a cheaper, less labor-intensive, and significantly streamlined process more amenable to mass production that would come to be the main method of plastic production in the thermoplastic era. Thus, this cellulose plastic helped shape the transition away from thermosets to thermoplastics primarily through the introduction of new methods of plastic production, injection molding, and the corresponding machinery and other productive forces.

Both urea formaldehyde and cellulose acetate functioned as stopgaps between the era of thermosets and thermoplastics, in a manner akin to celluloid's role as a bridge between the natural and synthetic plastic epochs. Both attempted to address some of the shortcomings of Bakelite—particularly its limited color range and its slower, more labor-intensive production methods. And both highlighted many of the characteristics sought after in the synthetic thermoplastic boom. But neither fully broke through to become the principal form of plastic for the new, post-World War II era of capitalist production. Below I will discuss this new class of plastics that first emerged during the period between the two world wars, and that came to dominate markets after the second war. While this new class of plastics represented an explosion of variability in form and function, there are certain throughlines that connect them. As mentioned above, these commonalities include their main chemical feedstocks being from petroleum and natural gas, rather than cellulose or coal tar; the nature of their composition, being thermo- rather than thermoset plastics; and their method of production being primarily derived from injection, rather than compression, molding. Finally, these new plastics greatly expanded their domain outward, into the world of consumer goods and packaging, as well as other sectors of the economy like agriculture and construction.

The New Thermoplastics

The chemical basis for these new thermoplastics began to be established in the 1920s, through the scientific discovery that polymers were in fact massive molecules, containing hundreds of thousands of atoms and with massive molecular weights (Spitz 1988). This recognition, as well as the discovery of long-chain theory—that the atoms in the large polymer molecules are connected by long chains, rather than networks or block formations—provided polymer chemistry with the foundational knowledge needed to produce this new class of plastics. From here, organic chemists could distinguish between thermosetting and thermoplastics based on their atomic structures, as well as distinguishing between different types of polymerization, and different ways to produce polymerization (Spitz 1988).

The development of plastics such as Bakelite and celluloid were mainly driven by efforts to substitute raw materials that were either expensive, finite, rare, imported, or some combination thereof. The impetus behind the development of this new class of thermoplastics, however, was more complicated. Another way of putting it is that the plastic developers of the late 19th and early 20th centuries set out to produce a new plastic mass to meet a particular material need. In contrast, the development of new thermoplastics was more multilayered and multifaceted. At times, this process started with a chemical monomer of which there was an abundance, and then the petroleum and/or chemical company sought to find a way to monetize this monomer through transforming it into a polymer, via a process of polymerization. This was in part a question of supply (of chemical byproducts produced from the processing of fossil fuels) rather than demand (for new materials) and stemmed from the rise of the petroleum and natural gas industries, industrial chemistry, and the marriage of the two which culminated in the petrochemical industry (Meikle 1995; Spitz 1988). Yet demand for raw materials played a crucial role as well, particularly during the war, as access to many staple raw materials was restricted, spurring demand for domestically produced, synthetic replacement materials.

With the further consolidation of more monopolized capitalism in imperialist nations such as the U.S., the centrality of control over raw materials comes to the fore in ways that diverge from pre-monopoly capitalism, heightening the importance of control over raw materials stock and supply (Lenin 1917; Lotta 1984; Magdoff 1969, 1978). Here, material discovery also played a pivotal role—with the revelation of vast oil fields throughout North America and the Middle East, among other regions—as well as technical innovation, enabling petroleum to replace agricultural goods and coal as the main synthetic feedstock. Similarly, the importance of the sales effort to monopoly capitalism played an important role here too—both in convincing producers of producer and consumer goods, as well as consumers themselves, of the desirability of plastics (Baran and Sweezy 1966; Lotta 1984). This two-pronged sales effort—aimed at both producers and consumers of goods, albeit in different ways and using different methods of persuasion—on the part of the plastics industry generated demand for new products and for the replacement of traditional raw materials with plastics. This required persuading the general public of a number of things, ushering in disposable consumption on a mass scale, along with increased consumption generally, and massive public relations campaigns promoting the safety and superiority of plastics for a variety of uses, directed toward a range of audiences (Meikle 1995; Moore and Phillips 2011).

Synthetic, petrol-based thermoplastics were completely dependent upon the rising oil industry: its infrastructure, industrial processes, high demand, and the emerging science of petrochemistry. Thus, thermoplastics were part of an "integrated materials production system," in which oil and natural gas refining provide the raw materials for plastic production (Geiser 2001). Plastics as a competitive, abundant, relatively cheap raw material owes much to the fact that they are produced from fossil fuel byproducts. "The history of integrated production systems is often a history of by-product management," argues Geiser (2001), "because the profitable utilization of waste materials is a frequent determinant of a successful process" (p. 75). The stories of oil and plastics, from the interwar period up to today, are thus intimately and inextricably linked.

While Germany was the unrivaled global leader of organic chemistry during the late 19th and early 20th centuries, the birthplace of the modern petrochemical industry is the United States. The U.S., unlike Germany, had vast oil and natural gas reserves, and thus U.S. companies were on the cutting edge of the use of petroleum and natural gas byproducts and feedstocks for chemical production (Geiser 2001; Spitz 1988). German chemistry was primarily reliant on coal byproducts and used synthetic gasoline liquified from coal before it could be used to make organic chemicals (Spitz 1988). Using coal as the feedstock for organic chemistry thus required an additional step of coal liquefaction.

Organic chemistry originated with the production of synthetic dyes, particularly in England and Germany in the second half of the 1800s, using coal tar and coke oven gasses as feedstocks. There was a high demand for cheap, synthetic dyes because of the great importance of the textile industry to the Industrial Revolution. In Britain, the epicenter of this revolution, most natural dyes were imported (Fenichell 1996; Geiser 2001; Spitz 1988). Until the Second World War, Germany had the most powerful, advanced organic chemical industry in the world (Spitz 1988). Synthetic dyes were in fact the first large-scale replacement of a synthetic material for a natural material (Geiser 2001).

In the United States, petrochemical production began modestly in the late 1920s. It was long known that petroleum and natural gas would provide better feedstock for organic chemistry, because it was already in liquid or gaseous form, while, as mentioned above, coal had to be converted from its solid state. However,

> The problem with using crude oil-derived feedstocks had been that paraffins—the main constituents of crude oil—are relatively nonreactive. Until the development of various petroleum cracking processes, the more reactive hydrocarbons [olefins] had not been available in refinery streams (Spitz 1988:64).

The invention of the Burton thermal cracker changed this, which became more widely available by the mid-1920s, facilitating the use of petroleum and natural gas as chemical feedstocks (Geiser 2001).

Four giant U.S. companies—two chemical, two petroleum—were the primary players in the rise of the U.S. petrochemical industry: Union Carbide (the company that acquired Bakelite in 1939) and Dow Chemical on the chemical side, with Shell and Standard Oil of New Jersey (one of the independent regional companies formed after Standard Oil's court-mandated break up, which later became Exxon, and then ExxonMobil) on the petroleum side (Spitz 1988). These four companies were ahead of the curve, as most of their chemical and petroleum peers in the U.S. remained loyal to coal feedstocks and were not interested in transitioning over to petroleum and natural gas, a shift that was not consummated until World War II.

The oil companies provided the feedstocks for chemical companies. The question, however, was whether oil companies would capitalize on this themselves or cede control to chemical companies. What ended up happening was a combination of both, with chemical and oil companies coming together to form a new monopolistic mega-industry, based on the chemical know-how of the former and the materials of the latter (Spitz 1988). The petrochemical industry formed the foundation for the new thermoplastics, and for the precipitous rise in plastic production, consumption, and raw material market domination in the second half of the twentieth century and twenty-first century. It also played an essential role in the consolidation of U.S. imperialism, and its domination of the global monopoly capitalist system following World War II.

The Second World War was the harbinger of this new class of synthetic thermoplastics. While many of these new plastics first started to emerge in the period between the two world wars, they were initially of limited use. The war directed massive government funds to their further development. In the United States, access to foreign raw materials like natural rubber and silk were cut off, spurring demand for domestically produced materials to serve the war effort. Also, with large amounts of petroleum being used as fuel for military purposes, there was incentive to use the chemical byproducts produced in the extraction and refining processes. Here, the case of rubber in particular serves as a brief illustrative example of the role of petrochemical-based plastics in producing war materials, the competition between Allied and Axis powers to develop them, and the ultimate rise of the United States as the global imperial hegemon within the framework of monopoly capitalism, vis-à-vis the traditional imperialist powers of England and France, and competitor powers like Japan and Nazi Germany.

World War II, Synthetic Rubber and Thermoplastics

Synthetic rubber was one of the first synthetic polymers produced in large quantities from petroleum feedstocks and was critical to the emergence of the U.S. petrochemical industry (Spitz 1988). Yet it was initially Germany that developed a working synthetic rubber: first because they had lost their colonies, and thus their supply of rubber, as the result of World War I; and later, as part of Hitler's plan for German autarky, or economic self-sufficiency; as well as Germany's advanced coal industry (Spitz 1988; Tully 2011). In 1934, German companies BASF and Bayer produced Buna-S rubber, a copolymer made from the monomers butadiene and styrene, produced from coal-tar derivatives (Fenichell 1996). The United States, the world's biggest user of natural rubber, accounted for half of the world's total consumption by 1937 (Morris 1994). By 1941, the U.S. was consuming closer to two-thirds of the world's rubber, largely because the U.S. also contained 80% of the world's cars, along with their pneumatic rubber tires (Fenichell 1996). The overwhelming majority of that rubber was imported from Southeast Asia, mainly Malaysia and the Dutch East Indies (Tully 2011).

After hostilities commenced between the U.S. and Japan, the Japanese closed off U.S. access to these sources of rubber (Fenichell 1996; Morris 1994; Spitz 1988). The government started a reclamation project for rubber tires, but it did not bring in enough rubber to tide them over for the war. This forced the United States to jumpstart their incipient synthetic rubber program, which it had already begun in anticipation of this exact scenario.

The Rubber Reserve Company, a creation of the Reconstruction Finance Corporation (RFC), the agency in charge of the U.S.'s rubber stockpile, “had in 1941, requested the four largest rubber companies, Goodyear, Goodrich, Firestone, and U.S. Rubber (later Uniroyal) to each build a 10,000-ton Buna-S plant. Shortly after the war broke out, this was raised to 30,000-ton plants for each company" (Spitz 1988:143). The United States government—led by petrochemical and rubber capital—developed its own version of Buna-S, which proved to be superior to Germany's version. The styrene required for this American synthetic rubber, produced from the chemical benzene, was primarily sourced from coal tar, with some of it being produced from petroleum. The butadiene was derived from two sources: grain-based alcohol and petrochemical feedstocks. While alcohol initially produced the lion's share of butadiene, the alcohol-petrochemical ratio shifted, and by 1945 over half of the butadiene was made with petrochemical feedstocks (Spitz 1988). U.S. access to large oilfields and their petroleum stocks was an essential advantage over Germany. U.S. synthetic rubber consumption grew from almost nothing in 1941 to comprising 85% of total U.S. rubber consumption by 1945, accounting for over 900,000 tons (Spitz 1988). Its production reached 900,000 tons in 1943, "which meant that within two years the United States had 'duplicated the capacity of the entire world's natural rubber plantations'" synthetically and domestically (Tully 2011:326).

While synthetic rubber represented the pinnacle of World War II-era polymer production, it was far from the only plastic that played a critical role in the war economy. Wartime production of plastics increased overall production, spearheaded the shift from coal and cellulose to petrochemical feedstocks, innovated the application of plastics in their use, and increased the concentration—spurring both vertical and horizontal integration—of the plastic industry while simultaneously reducing the power of small-scale plastics molders and fabricators (Meikle 1995; Spitz 1988). As the supply of more traditional raw materials was severely compromised, both well-known plastics like Bakelite, as well as a host of new thermoplastics, came to replace them, oftentimes proving to be superior in cost, weight, and performance.

Polyethylene came to supplant both natural plastics as well as Bakelite as insulation "for coating the new high-frequency, multichannel coaxial cable" which was essential for the "new era of high-speed, multiplex telecommunications" (Fenichell 1996:202). Polyethylene enabled the Allied forces to reduce the weight of their radar stations, allowing airborne radar detection of German air bombers by 1940. Germany was unable to develop polyethylene during the war, which meant that, "For the remainder of the conflict, their airplanes and ships were at a distinct disadvantage in tracking enemy attackers at sea and in the air" (Fenichell 1996:203).

Synthetic plastics replaced brass in the production of military bugles and steel in helmet linings. Nylon, the synthetic fiber produced by DuPont, was used as a substitute for natural and semi-synthetic fibers, including silk, the supply of which was cut off because of Japanese control during the war, in the making of parachutes and rope. Polymethyl methacrylate, a type of acrylic thermoplastic that includes Plexiglas, was used for the covers of airplane cockpits and gunner enclosures, as a replacement for glass. Vinyl was used in place of natural rubber for its waterproofing and flameproofing qualities, including for military-issued raincoats and boat upholstery. Saran, made from vinyl, was used for insect-proofing mesh tent equipment; while Teflon, or polytetrafluoroethylene (PTFE), was used in weapons-making, including for the Manhattan Project (Fenichell 1996; Meikle 1995; Tilley 1994). The development of new plastics, and the scaling up of previously marginal plastic production, was pivotal in U.S.'s success in the war effort.

World Wars and Monopoly Capital

World War II was perhaps the pivotal moment in the history of the plastics industry, with plastic production in the United States, directed to serve the war effort, nearly tripling between the years of 1940 and 1945 (Meikle 1995:1; see also Hine 1995). After the war, production skyrocketed further, as domestic markets began absorbing plastic production previously directed to the war machine. Here it is necessary to step back and consider this process of the emergence of plastics during the war in light of larger political economic considerations, both theoretical as well as practical. The rise of synthetic thermoplastics and the "changing of the guard" of world hegemon from the U.K. to the U.S., in the context of an inter-imperialist world war, in tandem with a "changing of the guard" of raw materials from naturals to synthetics, all within the context of (but not reducible to) ongoing global capital accumulation, are interrelated and interdependent processes. Here I will explore the role of world wars in the historical development of monopoly capitalism, and the experience of World War II in particular, as it relates to this history of synthetic plastics.

Global military conflicts, of the scale and scope of World Wars I and II, have played a decisive role in the overall geostrategic order. Because the epoch of monopoly capitalism is one in which the global contest over "spheres of influence"—access not only to labor and commodity markets as well as, crucially, raw materials sources, but also to destinations for capital export—inter-imperialist rivalry is an ongoing feature, with the potential for either proxy or direct wars omnipresent. Of course, whether such wars occur is a matter of both causality and contingency—

there is nothing predetermined about them, as the absence of a "hot" world war between the U.S. and U.S.S.R. in the post-World War II period demonstrates (Revolutionary Communist Party, USA 1999). The important point is that there is an underlying drive and tendency toward such conflicts, inherent in the intensified competition between both blocs of capital on a world scale, and between the rival nation-states that anchor these blocs while having their own, larger strategic interests.

These conflicts have tended to demarcate different epochs within the contemporary period (Lotta 1984). When such contests do break out, they impact and shape the entire configuration of the world capitalist system: economically, politically, socioculturally. Economically, all-out global war efforts bring a level of state command and control to capitalist economies that would be considered heretical to free market orthodoxy in times of peace. For example, the sudden, rapid production of synthetic rubber in the United States during WWII discussed above was not primarily driven by the anarchy (or "invisible hand") of the market and its underlying law of value. It was directed by the Roosevelt Administration who, after auditing the nation's rubber supplies, determined that the U.S. rubber stockpile—including reclaimed rubber scrap—would only last about six months. In 1943, synthetic rubber production facilities were created to meet the president's goal of producing one million tons of synthetic rubber, and this was coupled with spartan rationing of the domestic use of national rubber supplies (Spitz 1988:141-43; Tully 2011:324-26). This precipitated the fall in natural rubber use in the U.S. from 99% of total rubber used in 1941 to only 11% by the end of the war (Tully 2011:320).

Other synthetic plastics—which already existed in nascent form during the interwar period—were brought online en masse in similar fashion. The combination of several factors—shortages of foreign raw materials through denial of access to supply stocks, the outsized role of petroleum fuel for the war effort, an explosion in demand for materials to produce a plethora of wartime commodities, decisions made by state leaders to use petrochemicals rather than agricultural products as the raw materials for plastic production, in the face of intensive pressure and lobbying from the agricultural industry, etc.—led to the incorporation of synthetics into production on a scale well beyond what existed prior. Like the war itself, the injection of new, fossil fuel-based synthetics into the economy to serve the war effort was not inevitable; nor was it predetermined by the inexorable march of History, development of the productive forces, or technological progress. But the very properties of synthetic plastics made them favorable for such selection.

The historical example of plastics and World War II demonstrates not only how state intervention in the economy occurs during wartime with unprecedented scale and scope, but also how these wars shake up and reconfigure the whole national production apparatus. New (or previously marginal) production methods, technologies, labor regimes, and materials are generated and expanded. As Raymond Lotta argues,

> War production in general elicits expansion and facilitates economics of scale, while raw materials must be husbanded and waste reduced, and labor discipline must be exacted more ruthlessly. At the level of productive technique, new or previously unprofitable technologies are tapped and pressed into service, even spawning new industries. For example . . . various synthetic materials and the modern electronics industry were basically products of the Second World War. The 'eating up' of less efficient capital by more efficient capital and the rechanneling of resources as part of war-related investment spur high levels of productivity. Although such measures are temporary, their effects are long-term. And on the heels of war, an initial stimulus to production comes from the reconversion needs associated with pent-up demand and reconstruction (1984:155-56).

The conjunctural nature of these crises, and their ability to shake up, bend the rules of, and intensify normal economic functioning—through spurring demand; redirecting large volumes of capital from one sector to another; bringing online new raw materials, fuels, technologies, and production methods; and through injecting vast sums of capital from the state into private enterprise, with state direction and planning—gives wars of this magnitude a pivotal role in the functioning of monopoly capitalism.

As Baran and Sweezy argue, the two world wars were “epoch-making” events in that “not only [did] total production rise to the limits set by available resources but the whole pattern of economic life [was] drastically altered” (1966:224). The political economic impact of these wars extended beyond wartime itself and can in fact be divided into two distinct yet interrelated phases: the combat and aftermath phase (Baran and Sweezy 1966). The combat phase, as can be seen with the example of synthetic plastics, gives impetus to all manner of new production methods, ways of organizing social production, and use of novel (or previously marginal) forms of constant capital such as machinery or materials. This occurs within the overall framework of redirecting and increasing production to serve the war effort, and the changed conditions brought on by the war (such as restricted supplies of previously accessible markets and materials). In the postwar, aftermath phase there is a massive backlog of civilian demand that must be met, much of which cannot be produced simply “by converting war factories to civilian use” and instead those war facilities largely "must be scrapped," and new ones constructed (Baran and Sweezy 1966:224). Yet not only the new materials, technologies, and production methods but also the entire reshuffling of the global political order triggered by these wars set the framework for this new phase of postwar development.

Wars and the military apparatus more generally have always played a lead role in spurring changes and developments in the entire structure of society (Baran and Sweezy 1966). However, the political-economic importance, and effects, of wars increased precipitously during the era of monopolized capital. Baran and Sweezy go as far as to argue that the economic history of the nineteenth century, post-Napoleonic Wars, would have likely been unchanged if that era's wars had not happened (1966:222-23). This claim, however, is difficult to square without engaging in vulgar economic reductionism, as if the economic history can be so easily severed from the larger nexus of social phenomena within which it is embedded. It is hard to imagine, for example, how the dramatic social, political, and economic transformations would have occurred in the United States without the American Civil War. Nonetheless, it is important to consider that the *global* nature of the two major twentieth century wars coincided with the emergence of a more thoroughly globalized epoch of capitalism. Nor is it mere coincidence that these wars, with their scale and scope, transformed the economic and political landscape in qualitatively more significant ways than wars of earlier eras.

That interimperialist world wars induce such epochal economic alterations is not to say that these conflicts are merely in the service of such economic restructuring. Rebuking such economic reductionism, Lotta argues:

> The imperialists do not consciously go to war to restructure capital; they wage war because they must defeat global rivals and redivide the world. Interimperialist rivalry culminating in the violent collision of imperialist national capitals is not, therefore, the same as economic competition or simply a response to economic pressures; interimperialist rivalry and war have their own internal logic. (1984:150.)

The two—the political-geostrategic and the economic—are in fact deeply intermingled and in dialectical unity (through contradiction). As the historical narrative above demonstrates, it is impossible to separate the origin of the Plastic Age, and the synthetic plastic breakthrough of the Second World War, from the rise of the U.S. as the top global imperialist hegemon.

It is also important to note that the shift from the combat to aftermath phases of the Second World War as it relates to the plastics industry, which culminated in an explosion of new markets, uses, production methods, and types of synthetics, did not automatically follow from the combat phase. In other words, the mere fact that new synthetic thermoplastics were vital to the wartime effort, and thus their production expanded greatly during the conflict did not guarantee their continued use, and in fact proliferation, after the war. There was a massive struggle waged on the part of the plastics and petrochemical industries, targeting both consumers and the producers of various material commodities, to ensure that plastics filled the role of the new material foundation of the post-war epoch.

This changing of the guard, or injection of synthetic plastics into the scaffolding of the economic structure of society also represented more than a change in the type of material used in production. It in fact expressed a qualitative alteration in the very nature of our socio-material world, and of our relationship with the rest of the environment. This changeover in society's material and energetic interaction with the environment, or a development in the social metabolic order and intensification of the rift between the metabolism of society and metabolic cycles of biosphere as it relates to synthetics, is relevant in regard to the ontological/epistemic relation between society and nature. Before expounding on these points in the subsequent chapter, I will first properly introduce the host of new thermoplastics that emerged after the Second World War as conquerors of domestic, peacetime markets, focusing on those polymers that became key cogs in the post-war U.S. economy.

The Post-War Thermoplastic Boom: Types and Production Methods

While it was the post-war era that saw the eruption and proliferation of new thermoplastics, as mentioned above, many of these new materials were first produced in the interwar period. Polyethylene, the most widely used plastic, was first discovered in 1933, and developed from the monomer ethylene, which is derived from fossil fuel refinement and production. Polystyrene, the puffed-up version of which is known commercially as Styrofoam, was first produced in 1930 (Andrady 2003b). Polyvinyl chloride (PVC) was first successfully produced commercially in 1927 (DuBois 1972). These plastics had their coming out party during World War II. Others, like polypropylene, currently the second most widely used plastic, and different variations of polyethylene like high density polyethylene (HDPE) were first produced after the war, in the 1950s (Andrady 2003b; Buffington 2019).

There are six main thermoplastics, along with hundreds of additional ones that are used less frequently. These correspond to the "base polymer" categorization of numbers, often found lurking on the bottom or side of plastic consumer products inside a triangle or arrows (which people erroneously assume means said product is therefore recyclable). This system is called "plastic resin codes," or resin identification system (RIS). Within this system, Plastic #1 is polyethylene terephthalate (PET). PET is a form of polyester, used as fiber, and is most commonly used for beverage bottles, and is made from the monomer ethylene terephthalate. PET was not patented until 1973 (Buffington 2019; Zalasiewicz et al. 2016). Although less commonly used than polyethylene and polypropylene, it is a key thermoplastic, the most easily recycled of plastics, and constitutes about seven percent of the world plastic market (Buffington 2019). PET's primary use is blow-molded soda bottles, as it provides a good carbon dioxide barrier (Andrady 2003b).

The two main forms of PE are plastic #2, high density polyethylene (HDEP), which constitutes about fifteen percent of the world's plastic production; and plastic #4, low density polyethylene (LDEP), which makes up seventeen percent (Buffington 2019). They are both produced from the monomer ethylene. Plastic #3 is polyvinyl chloride (PVC), which is highly toxic and almost impossible to recycle. Making up about sixteen percent of the world plastic market, it is based on the monomer vinyl chloride (Buffington 2019; Geiser 2001). Plastic #5 is polypropylene (PP), made from the monomer propylene and constituting about twenty-three percent of the world market (Buffington 2019). Finally, there's the polymerized styrene, or polystyrene (PS), plastic #6, making up about seven percent of the world market, and is also almost impossible to recycle (Buffington 2019). Plastic #7 is a catchall for the plethora of other plastic materials, both thermoplastic and thermoset, of which polycarbonate (PC) is perhaps the most widely used (Buffington 2019).

Here it is important to step back and analyze what these thermoplastics actually are, in order to get a better sense of what is contemporarily meant by the term "plastics." While some of this can be applied to synthetic plastics more generally (such as thermosets), there are some particularities to consider concerning thermoplastics. Thus, pausing now to review this will help us gain greater insight as to the nature of the post-war rise of the plastics industry.

The contemporary thermoplastics industry is predicated on the petrochemical industry—an amalgamated industry of both chemistry and petroleum, rooted in the science of organic chemistry and the wide variety of chemical feedstocks generated in the petroleum and gas production process. For a number of reasons—including the Second World War, the rise of the U.S. as the dominant capitalist-imperialist nation-state, and its large petroleum and natural gas reserves—the modern petrochemical industry was born in the United States (Geiser 2001; Lotta 1984; Spitz 1988). A combination of the increased use and centrality of petroleum, technological advances, and the restructuring of the wartime economy brought the petroleum and chemical industries together and created the raw materials for mass plastic production (Spitz 1988).

In understanding the postwar synthetic plastic boom, and how it differed from pre-war plastic production, it is necessary to briefly discuss the differences between compression vs.

injection molding. As mentioned above, thermoset plastics like Bakelite were primarily produced via compression molding, although thermosets can also be injection molded (DuBois 1972). Injection molding is the production process that is most associated with thermoplastics. Injection molding was originally used with cellulose acetate, one of the intermediary plastics, but became widely used during World War II. Injection molding is a faster, less labor-intensive production process, requiring less skilled labor and amenable to the mass production of plastic goods during the war. And as Meikle observed, "injection molding liberated plastic from Bakelite's industrial phase and made it the material of choice for inexpensive toys and gadgets," among other mass-produced consumer goods (1995:64).

Before concluding, I will quickly discuss how synthetic thermoplastics are made. As mentioned above, the process starts with the monomers, feedstocks derived primarily from petroleum and natural gas production. These raw materials of plastic production became available with the invention of cracking, which separates them from the crude oil in the refining process (Andrady 2003b; Spitz 1988). The monomers are then turned into polymers through complex chemical reactions that create long, chainlike macromolecular structures not found in nature (Andrady 2003b; Moore and Phillips 2011). The plastic resin pellets are then "compounded." Compounding involves mixing the raw pellets with additives. Next, the compounded resin is re-pelletized and "processed," or "convert[ed] . . . into a useful plastic product" (Andrady 2003b:107). Processing involves melting down the compounded resin pellets, molding it into a given shape, and then re-cooling the material. Some minor retooling and preparation may still be required, but at this stage the plastic is a ready-made productive material.

This makes plastic a raw material of production. It is a form of constant, as opposed to variable capital (Marx 1976). Specifically, it is a circulating and not fixed form of constant capital (and even more precisely, plastic is a raw material, and not an ancillary, form of circulating capital), as it gets used up during the production process and becomes embodied in the product itself (Marx 1978). It is a means of production: a producer good, rather than a consumer good, and thus belongs in Marx's first department of social production: the means of production (Department I (MP)) (Marx 1978). While many consumer goods are indeed made of plastic, consumers do not buy plastic itself—they buy products made of, or packaged in, plastic. It is also still used in many industrial capacities as well, making it a means of production for both producer goods and consumer goods.

Conclusion

Here I have cataloged the history of a groundbreaking development: the creation of a material that has no natural analog. Emerging due to a confluence of events—world wars, advances in organic chemistry and the use of fossil fuels, serendipitous discovery, as well as new material and technological needs, among others—these materials were central to the project of twentieth century capital accumulation in several ways. From replacing raw material stocks that were limited for various reasons, to providing key material parts for some of the pivotal technological developments of the century, to facilitating mass production methods, synthetic plastics helped spur forward the concentration, centralization, and internationalization of capitalism. This new epoch of capitalism both brought forward the basis for synthetic plastics to emerge, with the coincident scientific-technical revolution and increased the desirability of the material (Braverman 1974; Foster 1999/1994).

But more than its role as a facilitator of and key component in the epochal shift from industrial to imperialist capitalism, plastics, as part of a larger synthetic emergence, signaled a reconfiguration of the entire way humanity interfaces with and interacts through nature. This reconfiguration, which has taken a quantum leap in the last few decades—and of which I have only traced the prehistory and opening moments—raises important questions about the very relationship between society and the biosphere within which its embedded. How is it that we have managed to create a fourth kingdom—neither animal, vegetable, nor mineral—for which nature has no answer, a whole set of material and energetic throughputs that appear to have broken the universal metabolic cycle, and the basic laws of ecology, such as "Everything is connected," and "Everything must go somewhere"? (Commoner 1971; Foster 1999/1994). And what questions does it raise about the political-economic system of capitalism-imperialism that facilitated its emergence? Does the existence, and astronomical proliferation, of these materials in fact challenge the very demarcation between nature and society, blurring them together both materially and conceptually? Has humanity entered a new epoch in which society has subsumed nature? Or does the historical development of synthetics rather reiterate the importance of these analytical distinctions? These questions will be taken up in the following chapter.

CHAPTER 5: PLASTICS, METABOLISM AND THE SOCIETY/NATURE DIALECTIC

Introduction

In this chapter, I raise the question of different iterations of social metabolism and how they consider the "society/nature problematic.” That is, how, or whether, to demarcate between these two spheres. Generally, there have been two overarching uses of metabolism within contemporary socioecological thought: one as mediator of the social within its larger ecological context, and one that removes the demarcations between the two. The former, best represented by the theory of metabolic rift, wields metabolism as a concept to describe society's interface with the ecological systems within which it is embedded. The latter, I categorize under the umbrella of a hybridized approach to metabolism, uses metabolism to remove any demarcation between society and the rest of nature.

In what follows, I first present these two schools of metabolic thought. I have already outlined the theory of metabolic rift in the theory chapter. Here I begin by presenting two hybridist approaches to social metabolism—urban political ecology and world ecology/singular metabolism. I then focus on how these different theoretical frameworks view the relationship between social and non-social (natural) phenomena through application of the dialectical method.

In doing so, I consider each framework’s use of the concept metabolism in managing (or dissolving) this relationship. Then I will analyze the society/nature problematic through the lens of plastics, making use of the historical data on the development of synthetic plastics and the current moment of widespread plastics production and proliferation within the proposed Anthropocene Epoch, conjoining this with the theoretical debate over the society/nature problematic. I will consider the following: What does the historical development and legacy of synthetic plastics as outlined in the preceding chapters tell us about the society/nature problematic? Does the emergence of synthetics represent a subsumption of nature by society, and a disintegration of the society/nature distinction? Or does it rather buttress the importance of (relative) analytic distinction between human-made, social phenomena and things produced solely by non-human, natural processes? I will then conjoin this question with further exposition of the dialectical method, and how its application deals with analysis and abstraction, as well as synthesis and unification.

Hybridity and Metabolism: World Ecology and Urban Political Ecology

Urban Political Ecology and Urban Metabolism

Urban metabolism as a distinct iteration of Marx's concept of socioecological metabolism can be traced to Erik Swyngedouw's efforts to urbanize the field of political ecology[10]. In his seminal article "The City as a Hybrid," Swyngedouw (1996:67), in aiming to help bridge the gap "between ecological thinking, political economy, urban studies and critical social and cultural theory," starts from Marx's materialist approach to analyzing the dialectic between society and the rest of nature. He notes, "Marx insisted on the 'natural' foundations of social development," and that "[s]ocial relations operate in and through metabolizing the 'natural' environment through which both society and nature are transformed, changed, or

[10] Portions of this chapter are derived from the following article: Hedlund, John, Stefano B. Longo, and Timothy P. Clark. 2022. "The Role of Distinction in Dialectical Analyses of Socioecology: Metabolic Rift, World Ecology, and Urban Political Ecology." *World Review of Political Economy 13*(4):449-475.

altered and new socio-natural forms are produced" (p. 68). However, the approach developed then goes on to critique Marx's bifurcation of society and nature in a dualist fashion, thus banishing nature to a separate realm from society, particularly because of his primary focus on the human labor process.

This work argues that scholars such as Henri Lefebvre, Neil Smith, Bruno Latour, and Donna Haraway, among others, provide a necessary corrective to Marx's dualism and exclusion of nature from its central role in social practice. Proceeding from a position of fidelity to a materialist dialectics, the conceptual tools provided by postmodernist and poststructuralist thinkers are incorporated as a means "to transcend the binary formations of 'nature' and 'society' and to develop a new 'language' which maintains the dialectical unity of the process of change as embodied in the thing itself" (Swyngedouw 1996:70). Thus, from this view, while Marx was correct in positing that humanity and the social realm rest upon a natural foundation, he erred in differentiating too absolutely between the two, ironically mirroring the bourgeois philosophy and political economy that he criticized.

According to urban political ecology (UPE) scholars, the contribution of poststructuralist thought serves as an essential supplement to our understanding of socioecological metabolism, with its emphasis on hybrids, and the dissolution of boundaries and binaries. Wachsmuth, in his overview of the history of social metabolic thought, argues that urban metabolism

> borrows heavily from Marx's original formulation of social metabolism . . . But to avoid the traps of the society-nature and material-discursive binaries . . . insist[s] upon the ubiquity of nature in social realms . . . while denying that nature can ever be independent of the social (Wachsmuth 2012:516).

The result is a conception of "socio-nature," a result of modernity's absolute entanglement of the two (Wachsmuth 2012).

Urban political ecologists employ "metabolism" differently than metabolic rift scholars. In addition to "the material production of socio-nature," in which metabolism is the mediation of biogeochemical phenomena and social practices, there is an equally real and important "representational production of socio-nature," in which metabolism mediates "the discursive production of socio-nature," resulting in hybrid constructions which cannot be analyzed or distilled into their respective parts (Swyngedouw 1996:71–72). Borrowing from cultural theorist Donna Haraway, cities are formulated as "a cyborg world, part natural/part social, part technical/part cultural, but with no clear boundaries, centres, or margins" (Heynen, Kaika, and Swyngedouw 2006:12). The "material substratum," especially in an era of global capital accumulation and extensive commodification, "was more and more a product of social production" (Smith 1984:32). In other words, phenomena that we consider social or human, such as urban landscapes, are in fact entangled socio-natural phenomena, in ways that make the demarcating of the two aspects impossible.

This concept of hybrids is, thus, central to UPE: drawn from Latour, hybrids consist of the products of socio-natural admixtures such as cities which both no longer have identifiably "social" or "natural" components and are equally the result of material and discursive/cultural practices. Here metabolism represents this process of hybridization, the act of blurring binaries like nature and society, city and country, human and non-human. As Swyngedouw (2006a:113) puts it: "When mobilizing the twin vehicles of 'metabolism' and 'circulation' from a historical materialist epistemological perspective, the binary construction of 'nature' and 'society' that characterized much of the modern scientific and cultural tradition radically disappear." Thus, metabolism is the process of combining and intermingling what are often seen as mutually exclusive opposites. It is the obscuring of distinctions and their recasting as irreversibly blended conglomerates. This hybridized conception, or blurring of distinction, contrasts with the metabolic rift school's tendency to situate capitalist production as alienated from, and antagonistic to, the natural world.

The UPE approach also incorporates the notion of the agency of non-human forces into its concept of metabolism, as a particular manifestation of socio-natural hybrids. Also derived from Latour—in this case, his notion of actor–network theory (ANT) and of diffused agency —non-human agency functions as part of an ensemble of agency, dispersed within socio-natural hybrids, or assemblages (Zimmer 2010). Take, as an example, a hydroelectric power plant: here would be an assemblage of human and extra-human actors, which would include the engineers who designed the plant, the capitalists of the corporation who owned and directed the construction of the plant, the geological conditions within which it was constructed, the water itself, and the wildlife within it. Each is entangled within one another, each imbued with agency, à la an organic machine, to borrow White's (1996) framework for understanding the hybrid metabolism of the Columbia River.

Like metabolic rift scholars, urban political ecologists politicize these socionatural arrangements, and argue against their naturalization (Zimmer 2010). Significantly, this politicization is posited by some UPE scholars as distinguishing it from a Marxian approach. As Zimmer (2010:348; emphasis added) notes, "Based on Marx, metabolism in Urban Political Ecology is taken as a material or energetic exchange, *but* this exchange is seen as a historical product," allowing greater room for human intention and agency in this process of metabolism. Thus, there are clear distinctions between the UPE approach to social metabolism and that of the metabolic rift school, including how to operationalize the relationship of society to extra-social nature, the role of hybrids as key units of analysis and reflections of reality, as well as the question of agency.

World Ecology and the Singular Metabolism

In an approach that often parallels and expands upon UPE's iteration of urban metabolism, a school of thought led by Jason W. Moore has criticized the metabolic rift approach, proposing an alternative rendering of social metabolism. This approach characterizes the theory of metabolic rift as a dualistic theorization of the relation between the social metabolism and a universal metabolism of nature.

Moore (2017) proposes instead the framework of a single metabolism, or a "world ecology," as the means to unify the conceptually disparate but internally, intrinsically linked phenomena of class, nature, political economy, and history. Like UPE and the critique of Marxist ecological thought, the world ecology approach argues that the philosophical underpinnings of the theory of metabolic rift are ideologically rooted in the very processes it claims to critique. "The notion that social relations (humans without nature) can be analyzed separately from ecological relations (nature without humans) is the ontological counterpoint to the real and concrete separation of the direct producers from the means of production" (Moore 2015:19). Despite the metabolic rift scholars' claims to the contrary, the world ecology analysis posits that the theory's method of abstracting the social from the ecological, and the human from "extra-human natures," are not mere abstractions, for analytical purposes, or mere social constructions. Instead,

> They are, rather, abstractions at once violent and real. They are *violent*, in the sense that they abstract too much reality in the interests of conceptual clarity. And they are *real*, in the sense that Society and Nature are in fact operative forces (Moore 2015:27; emphasis original).

The attempts of social scientists who study the environment to ontologically abstract humanity from nature and then subsequently analyze relations between the two are regarded as engaging in a sort of “Green Arithmetic,” which mechanically adds together the two “violent abstractions” of nature and society. This approach, while purporting to be a dialectical one that focuses on the internal relations among and struggle between unified opposites, is rebuked as ultimately a metaphysical orientation, one of isolated “things,” rather than internal relations (Moore 2011, 2015).

There is, in this view, a disconnect between the ontological recognition that nature and society are dialectically linked in “an internal relation within a single totality” (Foster et al. 2010:229), and a theoretical orientation that, when employed, treats them as separate properties, with one acting upon the other. Thus, while metabolic rift theorists recognize in principle, as famously stated by Hegel, that “the truth is the whole” regarding the relations between social and nonsocial systems, there is a theoretical disconnect in terms of how these scholars approach theory and historical analysis. It is an example of the fallacy of a “double yes”: answering in the affirmative to both the question “Are humans a part of nature?” and “Can we analyze human organizations as if they are independent of nature?” (Moore 2017:292).

In opposition to the alleged dualism of social metabolism, the world ecology approach presents an ontological orientation of the “*oikeios*” (Moore 2011). This conceptualization is developed with the intention of transforming “objects” into “relations.” Interaction, it is argued, implies separate objects that encounter one another. Dialectics, instead, implies undetachable, non-abstractable relations. “From the perspective of the *oikeios*, civilizations (another shorthand) do not ‘interact’ with nature as resource (or garbage can); they develop *through* nature-as-matrix” (Moore 2015:36; emphasis original). The *oikeios* originates from Greek philosopher

Theophrastus, who used it to describe the relationship between a plant and its environment and is thus indicative of the integral whole this relationship represents. The *oikeios* conveys the "messy bundle of relations" that have been improperly, violently abstracted and divided into the dichotomized objects of nature and society (Moore 2011:5).

Relatedly, the *oikeios* conceptualization challenges the causal flow of humans as actors and nature as acted-upon. Like UPE, borrowing from both the new materialism and actor–network theory scholars like Bruno Latour and Donna Haraway, world ecology emphasizes the agency of inanimate nature. The *oikeios* thus allows "the relations of specific civilizations, food, water, and oil [to] become real historical actors" (Moore 2015:36). However, "The issue is emphatically not one of the agency of Nature *and* the agency of Humans" (Moore 2015:37; emphasis original). Rather, from a world ecology perspective there is no such thing as *distinctly human* agency, but only agency as expressed through historically specific human and extra-human bundles of social aggregates, non-human species, and inanimate features such as geological formations, weather patterns, or bodies of water.

Central to the world-ecological approach is the dissolution of the boundaries between what traditionally constitute "social" and "natural" historical developments. For example, the "social" phenomenon of "financialization," is reconceptualized as "a *bundle* of human and extra-human natures," as "[i]ts claims on future wealth involve claims on future capacities of human *and extra-human* work, and its transmutation into capital" (Moore 2017:289; emphasis original). An example of this is demonstrated by how a supposedly purely "natural" phenomenon—the geological limits that determine how much crude oil objectively exists underground, or the amount of greenhouse gasses released into the atmosphere that would trigger certain environmental tipping points—is in fact codetermined by these bundles of human and extra-human nature. Thus, the notion of “peak oil” is a co-produced phenomenon, determined not only by objective biospheric limits of oil reserves and atmospheric carbon sinks, but by the dialectical interplay between these limits, broadly speaking, and how “social” institutions like markets react upon (and within) them.

> Financialization not only exerts upward pressure on oil prices and encourages market volatility. To the extent that financial activities are more profitable than investing in exploration and extraction, it renders the latter insufficiently profitable, an effect homologous to (and reinforcing) the rising costs of production stemming from depletion (Moore 2015:148–149).

In other words, social–environmental scholars need not fetishize the notion of “natural limits” to capital’s excursions—the formula is not as simple as “nature” providing a quantitatively determined number of resources that humanity has to extract, or a finite area of space within which societies can deposit their waste. This example is an expression of what is essential to the world-ecological framework: the recasting of environmental and social phenomena as intrinsically intertwined, so that any attempt to untangle these bundles is an act of excision that does irreparable damage to the whole, despoiling any subsequent analysis of its parts.

Dialectics, Metabolism, and the Society–Nature Problematic

Dialectics and Metabolism

A central point of discord between metabolic rift and hybridist approaches lies in their conceptualization and application of dialectics. Here, I provide a brief overview of dialectical analysis, and then detail how each approach utilizes dialectics in unpacking the society–nature question. Dialectics, which has its origins in Greek philosophy, was most famously advanced within an idealist framework by Georg W. F. Hegel, before being transformed and synthesized on a materialist foundation by Marx and Engels (Ollman 1993). Dialectics deals with “[t]he identity of opposites . . . the recognition (discovery) of the contradictory, *mutually exclusive*, opposite tendencies in *all* phenomena and processes of nature" (Lenin 1975:648; emphasis original). It is a methodological approach to understanding reality as matter in motion, in which all phenomena consist of internal struggle between opposing (and uneven) aspects, privileging change over stability, and emergence and transformation over stasis. Dialectics was integral to Marx's entire theoretical and methodological framework (Ollman 1993), and has been further developed by subsequent Marxist theorists, among others.

Each approach to social metabolism discussed makes use of, or references, the dialectical method. Important in this analysis, each of the two frameworks of socioecological metabolism—metabolic rift and hybrid approaches—develops a distinct set of arguments on the correct orientation toward social and extra-social (or "natural") phenomena. Metabolic rift theorists argue that a key point of delineation between the theory of metabolic rift, and that of its critics, is the former's comprehension and assimilation of the dialectical method. Urban political ecologists contend that the society–nature binary is undialectical, and that, to maintain a dialectical approach of internal contradiction and unity of opposites, we must forge a new way of speaking about and understanding socio-nature. Similarly, world ecologists argue that the concept of *oikeios*, or singular metabolism, is "a concept that moves from the *interaction* of independent units—Nature and Society—to the dialectics of humans in the web of life" (Moore 2015:35; emphasis original). So how do dialectics, and a dialectical method, help us comprehend the relationship between qualitatively distinct, yet unified, phenomena? How can the method deal with both aspects of this: distinction and unity? Next, I will characterize how each of these approaches makes use of it in relation to the question of nature and society, or socio-nature.

Metabolic Rift

Metabolic rift scholars, drawing on Marx as well as other Marxist theorists, view society as an emergent property of nature, one that is both united with (and ultimately a subordinated part of) the “whole” of universal nature, yet also consisting of specific properties and characteristics that are irreducible to the totality (Foster 2013b, 2016b, 2020; Foster and Burkett 2000; Foster and Clark 2016, 2020; Malm 2018, 2019). In relation to this, it is important to re-clarify the concept of emergence: What does it mean to say that society is an emergent property of nature? First, it means that society and the natural world from which it emerges are both composed of the same substance—matter in motion—and are therefore not ontologically distinct. This position is called substance monism (Malm 2018, 2019). Thus, on the most fundamental of levels, society and the rest of nature constitute a whole, and societies constitute parts within the whole of the planetary ecosystem, or the whole of nature. Carolan, drawing on the critical realist philosophical approach of Roy Bhaskar (2008), explains the concepts of both emergence and rootedness as follows:

> “higher” level phenomena are rooted in, and emergent from, more “basic” phenomena . . . Thus, the need for the “higher” level social sciences; for ultimately, the “higher” level phenomena that they study cannot be explained away with references to particle physics or genetic sequencing alone (Carolan 2005: 2–3).

Metabolic rift scholars are strongly influenced by Bhaskar’s critical realist (often dubbed critical materialist) ontology (Foster et al. 2010; Foster and Clark 2016; York and Clark 2010; York and Mancus 2009). Here, the notion of “higher” phenomena refers to things that have “emerged” from more “basic” phenomena, the former being social forms of reality, and the latter being the forms of reality from which these social forms emerge and are still rooted. This includes everything from the basic particles that constitute all matter, to the specific biochemical processes from which all living things are constituted, to the entire Earth system. This dialectic—of the social metabolic order being both rooted in yet also distinct from, and thus composed of properties not found anywhere else in, the universal metabolism of nature—is at the essence of the metabolic rift theory, and a form of what is called *substance monism, property dualism* (Malm 2018, 2019).

Further, because societies emerge from and are rooted in the natural world, societies at their core *are* natural, and not only are of the same substance—matter in motion, elementary particles—but share some of the same properties. This includes, for example, materials and resources drawn from and then embedded within social configurations; and, in the process, are transformed through human labor. This is because the boundaries between societies and the planetary ecosystems from which they emerge and within which they are rooted are relative—like all boundaries and borders. That is, they are relative, but real (Avakian 2009). Drawing from Engels, Foster argues that "[s]uch a conception meant that nature and humanity had to be conceived in historical terms, that is, in their making, with humanity to be viewed in large part in terms of its self-making." As integrated levels of reality, nature and history are understood in an "ontologically emergent" manner (Foster 2020:222).

Hybridist Metabolic Approaches

Urban political ecologists and world ecologists also emphasize dialectics as essential to their analytical orientation. Urban political ecologists argue that metabolism, along with circulation, are "the central metaphors" of a historical materialist approach, "With its emphasis on movement, change, and process . . ." Metabolism and circulation "embody what modernity has been, and will always be about: change, transformation, flux, movement, creative destruction" (Swyngedouw 2006b:22). Yet it is also posited that Marx's method of distinguishing between society and nature was undialectical, as it externalized and reified a relationship that is, in fact, internal and porous.

> If we, however, maintain a view of dialectics as internal relations, we must insist on the need to transcend the binary formations of "nature" and "society" and to develop a new "language" and understanding which maintains the dialectical unity of the process of change as embodied in the thing itself. The things are hybrids or quasi-objects (subjects and objects, material and discursive, natural and social) from the very beginning (Swyngedouw 1996:69–70).

Here, drawing distinctions between things is seen as inherently undialectical. The solution is to treat all phenomena as hybrids, which converge subject and object, internal and external, material and discursive, natural and social, and so on.

This understanding of dialectics coincides with that of world ecology. However, instead of critiquing Marx, world ecologists focus on the metabolic rift theory for its Cartesian dualism, in opposition to a dialectical approach, and in contrast to Marx. In place of what is seen as a process of bifurcating society on the one hand and nature on the other, the *oikeios*, or singular metabolism, is presented as "a radical elaboration of the dialectical logic immanent in Marx's concept of metabolism," as it "moves from the *interaction* of independent units—Nature and Society," found in metabolic rift scholarship, "to the dialectics of humans in the web of life" (Moore 2015:45, 35; emphasis original). Here the claim is that the very notion of interaction implies separation—for two things to interact, they must be severed from one another, and thus not in dialectical unity. Further, it is argued that a dialectical unity of opposites requires asymmetry—the relations between aspects of a contradiction are uneven (unevenness being the basis for its transformation). Finally, a dialectical approach requires resolution, or change, rather than reified and static categories. Thus, it is argued that "[Metabolic] Rift analyses have resisted the tendency of dialectical praxis to dissolve its analytical objects, and to create new categories suitable to comprehending the historically successive interpenetrations of humans with the rest of nature" (Moore 2017:295–96). If the ideological concepts do not transform, interpenetrate, and dissolve into hybrids, in a process of analysis and synthesis, these abstractions become ossified and mechanical, rather than dialectical and fluid.

Rift or Hybrid? Some Key Points of Demarcation

The application of the dialectical method is one of the central differences between the metabolic rift approach, on the one hand, and hybrid approach, on the other. Specifically, the analytically appropriate way, or whether, to handle the distinction between society and the rest of nature lies at the heart of the differences. The primary questions here are: Does analytic demarcation between social and extra-social systems and phenomena contribute to or hinder our understanding of socioecological questions? How do the different approaches alter the application of social metabolism? And how does the historical development, existence, and proliferation of synthetics, and synthetic plastics particularly, contribute to our understanding of the society/nature problematic, and the role of social metabolism in apprehending it?

As mentioned, hybrid metabolic approaches—both UPE and world ecology scholars—ultimately answer these questions along similar lines: that such distinctions hinder or obscure our understanding of the world. A world ecology approach argues that the nature–society divide is a product of Cartesian dualism, and that this binary is in significant part culpable for many of the horrors of modernity, within which the logic of capital accumulation is embedded (Moore 2015). UPE scholars contend that "we do not need . . . specific conceptual or methodological tools for investigating the place of nature in the society . . . *All* the features of modern urbanization are socio-natural" (Wachsmuth 2012:516; emphasis original), and that "[t]he urban world is a cyborg world, part natural/part social, part technical/part cultural, but with no clear boundaries, centres, or margins" (Heynen, Kaika, and Swyngedouw 2006:12).

Metabolic rift theorists attest that recognizing the "metabolic rift in the relation between human society and the larger natural world of which it was an emergent part" is essential to understanding our current ecological crisis, and the underlying dynamics which have given rise to and continuously regenerate such crises (Foster and Burkett 2018:2). These latter scholars suggest that to do so, we must be able to analytically distinguish between social and non-social phenomena (Foster and Clark 2016, 2020; Malm 2018).

Plastics and the Anthropocene

Synthetic Plastics Today

With the motion and development of early synthetic plastics unearthed and historically traced, focusing on key conjectures in this movement—from natural plastics to celluloid as the first partially synthetic plastic mass, Bakelite as the first plastic created from fossil fuels and without natural analog, World War II as the coronation of a new era of numerous synthetic thermoplastics infiltrating every sphere of the economy—we now turn to the moment in which we currently find ourselves. Synthetic plastics, having emerged as a true material force during the Second World War and in the post-war period, made leap after quantum leap in the years since.

Compared to the level of production and use today, mid-century, post-war plastic production barely registers on a graph. In 1950, when thermoplastic synthetics were increasingly but still nascently becoming a raw material for not only industrial and electrical, but consumer goods, largely confined to the industrialized nations, global plastic production reached roughly

1.5 million metric tons (Mt). In 2021, this ballooned to over 390 Mt (Statista Research Department 2023), a 25900% increase over 71 years, with a compound annual growth rate of over 8%, outpacing that of virtually any other material (Buffington 2019; UNEP 2018). Much of this growth has come in the last few decades.

> Global production of resins and fibers increased from [about] 2 Mt in 1950 to 380 Mt in 2015, a compound annual growth rate (CAGR) of 8.4%, roughly 2.5 times the CAGR of the global gross domestic product during that period. The total amount of resins and fibers manufactured from 1950 through 2015 is 7800 Mt. Half of this—3900 Mt—was produced in just the past 13 years (Geyer, Jambeck and Law 2017:1).

Thus, while the preceding historical analysis of the early development of plastics is essential to understanding how this material became what it is today, the growth and prolific diffusion of synthetic plastics has sharply accelerated within the last few decades. Indeed, according to one estimate, "More plastic was produced in the first decade of the twenty-first century than in the entirety of the last" (Taffel 2016:360).

The increase in plastics production directly correlates with the growth in global solid waste generation. Cumulative plastic waste disposal and generation, at negligible levels in 1950, reached about 5000 Mt in 2010 (Geyer et al. 2017). As Humes (2012) argues, the two complementary trends that have led to the growth in solid waste generation are the concomitant rise in plastics and of disposable products largely made of and/or packaged in plastics. Today, the largest outlet for plastic production is packaging, which accounts for about 42% of non-fibrous plastic production. Packaging is also the sector that has the shortest product lifespan, an average of less than a year, meaning it is used and then quickly disposed of (Geyer et al. 2017).

Because synthetic plastics are non-decomposable, they end up contaminating terrestrial, marine, freshwater, and atmospheric ecosystems, depending on their method of disposal. Geyer et al. (2017) estimate that "[b]etween 1950 and 2015, cumulative waste generation of primary and secondary (recycled) plastic waste amounted to 6300 Mt" (p. 2). The majority, 4900 Mt, was discarded as waste, ending up either in landfills, or as refuse in the environment. A significant portion ends up, because of its durability, lightness, and inability to decompose, eventually accumulating in marine ecosystems, often by way of riverine systems (Moore and Phillips 2011). Synthetic plastic, rather than biodegrading, breaks down into smaller and smaller pieces, creating micro- (smaller than 5 millimeters) and even nanoparticles (smaller than 0.0001 millimeters) (Sutton et al. 2019). This has created a kind of "plastic soup" within marine ecosystems, particularly in ocean gyres which, because of ocean and wind currents, are sites of matter accumulation. Plastics travel hundreds and thousands of miles to one of the five ocean gyres, slowly breaking up into smaller particles along the way (Buffington 2019; Moore and Phillips 2011). Recent estimates put the total number of plastic particles in the world's oceans at 5.25 trillion, with a combined weight of 270,000 tons (Eriksen et al. 2014). It has been estimated, and widely reported, that by 2050 plastic mass in the oceans will outweigh fish (Taffel 2016).

The plastic not discarded as waste is either still in use, recycled, or incinerated. Incineration is not a safe method of disposal, as it generates microplastics and other secondary pollutants such as heavy metals (Shein et al. 2021). An estimated nine percent of cumulative plastic waste has been recycled. While rates of plastic waste diverted from municipal solid waste (MSW) and refuse to recycling plants is increasing, the reality is that:

> Recycling delays, rather than avoids, final disposal. It reduces future plastic waste generation only if it displaces primary plastic production; however, because of its counterfactual nature, this displacement is extremely difficult to establish. Furthermore, contamination and the mixing of polymer types generate secondary plastics of limited or low technical and economic value (Geyer et al. 2017:2).

The plastic recycling that does occur is mainly downcycling, meaning the repurposed plastic is turned into a new product that itself is nonrecyclable, thus merely delaying its inevitable disposal, as the quote above states. Further, the environmental and human health costs of plastic recycling itself are high. Plastic recycling is energy- and resource-intensive and often outsourced to the global South, where environmental and labor regulations are scarce. Much of the plastic waste exported from the global North to the global South is not, in fact, in a recyclable state, and ends up accumulating or being burned as a cheap source of fuel, with disastrous environmental and human health effects (Minter 2015).

The human and environmental impacts of profligate plastic production, consumption, and waste are manifold, while much is still unknown. Plastics are ingested by fauna up and down the food chain, from blue whales to zooplankton, disrupting digestive and other metabolic systems, causing suffocation, death, and other potential health effects. Since plastic cannot be metabolized, it concentrates in organisms over time through bioaccumulation. Through biomagnification, larger organisms accumulate large volumes of plastic through consumption of smaller organisms. Plastic production itself is energy intensive and toxic, and intimately intertwined with “fossil capital”: fossil fuel production, refinement, and use (Malm 2016). Discarded plastic acts as a kind of "toxic sponge," which absorbs persistent organic pollutants, making them even more dangerous to consume (Freinkel 2011; Meikle 1995; Moore and Phillips 2011). Plastics, and the host of additives they contain, have been found to be mutagenic, carcinogenic, and teratogenic (Foster 2022).

The scale and scope of the contemporary plastic crisis is so concerning, so without precedent, and so rapidly advancing, that it raises some fundamental questions about the politico-economic system that has spurred and facilitated its emergence and proliferation, as well as the changing character of humanity's relationship to the environment. As detailed in the preceding chapters, the birthplace of modern synthetic plastics was principally the United States. Its long, circuitous gestation period occurred over many decades during the first half of the 20th century, with the rise and consolidation of monopoly capitalism-imperialism. Its violent and bloody birth, the Second World War, was marked by a pivotal change in the global political-economic structure, order, and character. Two of the central changes that occurred were the rise of the United States as the dominant capitalist-imperialist world hegemon, and, relatedly, the transformation of the material (and energetic) underpinnings—the nature of production, and of the materials of production—of society.

The emergence of the so-called "Plastic Age" (Fenichell 1996; Moore and Phillips 2011) is thus one of the central factors in the advent of a new (proposed) geological epoch: the Anthropocene. This proposition is based on the argument that humans have become a dominant driving force of Earth System change. There are differences of opinion regarding the periodization of the Anthropocene Epoch, with some contending that it emerged with the beginnings of the Industrial Revolution in the late 18th century—roughly coinciding with James Watt's invention of the steam engine, the beginning of accelerated anthropogenic CO2 emissions, and the origins of fossil capital (Crutzen 2002; Malm 2016). However, there is now an emerging consensus that the Anthropocene's origins can be properly traced to the post-World War II "Great Acceleration" period (Foster 2022; McNeill and Engelke 2014; Steffen et al. 2015; Zalasiewicz et al. 2016). The Great Acceleration, beginning around 1950, is marked by a precipitous rise in CO2 emissions, resource and energy use, deforestation, urbanization, population growth, globalization, as well as synthetics production and consumption (Foster 2022; McNeill and Engelke 2014; Steffen et al. 2015; Waters et al. 2016; Zalasiewicz et al. 2016).

Importantly, the argument for using the Great Acceleration rather than the Industrial Revolution as the start of the Anthropocene is based on more than just a general understanding of a change in the nature of the relationship between humanity and the planet: it is based on this periodization's potential for verifiable stratigraphic markers (Foster 2022). The two current leading candidates for these "golden spikes" that signal the shift from one epoch, the Holocene, to the other, the Anthropocene, are radionuclides from nuclear weapons testing and use, and synthetic plastics (Foster 2022; Zalasiewicz et al. 2016). Zalasiewicz et al. (2016) make the case for using plastics as a stratigraphic indicator of the emergence of the Anthropocene Epoch via the Great Acceleration, as plastics are easily identifiable as sedimentary deposits; are durable; are historically novel, thus distinguishing this period from all others; and because their widespread production and diffusion in the environment generally correlate with the trajectory of the Great Acceleration period.

The Synthetic Age: Plastics, and Natural/Human-Made Distinctions

Plastic proliferation, the post-World War II Great Acceleration period, and global environmental crises were interpenetrating phenomena, each closely linked with a larger shift to what Foster (1999/1994) calls the Synthetic Age. The Synthetic Age represented a "qualitative transformation" in the composition of economic goods produced and consumed; a "replacement of the products of nature with synthetics" (Foster 1999/1994:113). The synthetic shift went beyond plastics: a panoply of fuels, fibers, paints, adhesives, elastomers, pesticides, fertilizers, and detergents derived primarily from petrochemicals, themselves the product of breakthroughs in organic chemistry and the scientific-technical revolution, began to displace their natural counterparts.

While the Second World War spearheaded this synthetic displacement, the profitability of synthetics solidified their domination (Commoner 1971; Foster 1999/1994; Geiser 2001; Lotta 1984; Magdoff 1969). Synthetics, and the technologies that develop and produce them, generally increase economic productivity per unit of output, as they reduce the quantity of labor required for production (Commoner 1971; Foster 2013b). Synthetics are simultaneously a boon for capital accumulation, growth and profitability *and* are more environmentally deleterious. This is true for two basic reasons. First, because the widespread introduction of synthetics into the economy is predicated upon and generates further reliance on more energy- and resource-intensive, instead of time- and labor-intensive, methods of production. Second, both these methods of production as well as many of the products themselves are highly toxic, and relatively little is known about the effects of their diffusion into the environment (including into human bodies). It is exactly an example of the phenomenon identified by Commoner (1971), in which "[t]he very system of enhancing profit in [a given] industry is precisely the cause of its intense, detrimental impact on the environment" (p. 250).

With both the history and current moment considered, what does the emergence of the Synthetic Age, synthetic plastics particularly, the Anthropocene, and the Great Acceleration tell us about the preceding discussion of metabolism and the society/nature problematic? First, it is worth returning to and reconsidering what makes synthetic plastics unique. All "natural" raw materials—glass, metals, rubber, wood, etc.—are originally derived from nature, either from unearthed minerals or vegetation. Most are then transformed through human labor and technology in some way, sometimes significantly so; often they are chemically altered to better suit their material purpose. For example, rubber—a natural plastic discussed earlier—is derived from the sap of heava trees. Transformed via the chemical process of vulcanization, it becomes hard rubber, a raw material that can be used for a plethora of industrial and commercial purposes (Tully 2011). But as mentioned earlier, hard rubber is still a (chemically altered) natural plastic, a natural and thus not technically a synthetic raw material. What distinguishes synthetics from non-synthetic materials is that the former is composed, at a molecular level, of configurations which *not only* cannot be found anywhere else in nature, but which are *fundamentally at odds* with the basic universal metabolism of nature.

Synthetic plastics are polymers, which are abundant in nature. Their unique, long chain-like, polymeric, macromolecular composition developed through the trial-and-error process of evolution, and which include bone, wood, hair, shell, starches, and proteins (Andrady 2003a; Geiser 2001; Moore and Phillips 2011). Natural polymers, particularly in the flora kingdom, "predominate as the structural component of organisms" (Williamson 1994:5). Yet, "for every polymer produced in nature by living things, there exist enzymes that have the specific capability of degrading that polymer" (Commoner 1971:153). Organic chemistry enabled humans to bypass the arduous, millennia-spanning evolutionary development and instead combine various molecules into amalgamations not found anywhere on Earth, *without* a corresponding enzymatic counterpart. Such composites are definitively human made from the inside out, in ways that make them categorically distinct from even chemically modified natural materials. It is precisely this material novelty that makes synthetic plastics so valuable, so without historical antecedent or analog, so uniquely suited to fulfilling its sector-spanning economic functions, yet so fraught in its ecological assimilation and material configuration. This dual nature of plastics—as apparent conqueror yet simultaneous despoiler of nature, as material that is analogous to yet radically disparate from organic polymers—flows from the very nature of the synthetic/non-synthetic distinction.

But if polymers are omnipresent in the natural world, and synthetic plastics are polymers that “socially evolved,” in a sense, from natural polymeric plastics, what makes this synthetic/natural distinction meaningful? What analytic role does this distinction play in understanding not only plastics as a material, but the larger political-economic context within which it arose, as well as the contemporary environmental moment? Because without it, it is nearly impossible to understand what the prior historical analysis shows: that the emergence of synthetic plastics was driven by requirements of capital accumulation within a given social, political, historical, technological, and cultural setting. It is the relative uniqueness of synthetic plastics, its peculiar characteristics described above, that sets it apart from the materials it replaced. Further, it is these same historically, materially, and categorically unique properties that make plastics such an ecological quandary: its very distinctness, so valuable from the perspective of capital accumulation, and so individually suited to meet certain social needs, makes it seemingly impervious to and disruptive of the metabolic functioning of nature.

Natural Plastics, Celluloid, and Society/Nature Problematic

Here it is useful to return to the history developed in the preceding chapters, starting with natural plastics, and the emergence of celluloid. Celluloid, a so-called "semi-synthetic plastic," embodied a kind of transitory phase between plastics of natural origin and synthetics. It therefore highlights characteristics of both, elucidating their continuities and distinctions.

The impetus for celluloid was largely twofold. First, the shortages, both perceived and real, of natural raw materials spurred the quest for a more reliable source of productive material. And second was the demand for a homogenous, consistent, environmentally resistant, easily moldable material amenable to capital-intensive production methods and mass production. As Williamson states in his analysis of the early origins of the plastics industry:

> **This facility to produce moulded products more quickly and therefore more cheaply than their carved counterpart is the prime motivating force behind the development of plastics and the plastics industry as we know them today** (1994:4, bold in original)**.**

The inability of natural plastics—shellac, gutta percha, even vulcanized rubber—to fulfill this role, coupled with their rapidly depleting stocks, were what induced inventors such as Alexander Parkes and John Wesley Hyatt to experiment with nitrocellulose, in search of a generalized plastic mass. As Friedel, in his monograph on the development and use of celluloid, says:

> The arrival of the natural plastics was a major episode in the emergence of new materials in the nineteenth century. They were the first significant alternatives to the traditional solid materials of manufacture and reflected a widespread desire for materials that were freed from the limitations of metal, glass, clay, and wood. The natural plastics indicated the possibilities for materials that were easily moldable and yet stable in their final manufactured form, for substances that avoided the coldness, heaviness, and chemical and electrical activity of the metals, that beckoned to artistic imagination while avoiding the fragility, cost, and weight of the glasses and ceramics, and, finally, that were in some way liberated from the stinginess of nature by combining durability and beauty in a readily available form. None of the natural plastics were able to satisfy all of these desiderata, *but they clearly fostered a sense of what was really wanted* (1983:28, emphasis added).

This dialectic of natural plastics, which portended yet could not fulfill the role of this generalized plastic mass, squares with both its relation to, and distinction from, synthetic plastics. Made from a certain kind of organic polymer, natural plastics are, on one level, quite similar to the synthetics that later superseded them. They are pliant, easily moldable, can take form once heated, and have a basic degree of plasticity in that they readily take a given form and shape when worked on by human labor. Yet they lack the imperviousness to nature's workings, the lightness of weight, colorability, relative durability, cheapness, and apparent independence from the metabolic imperatives of nature. Thus, the distinction between natural and synthetic plastics is relative and, in one sense, a quantitative one—a matter of degree.

Celluloid bridged the gap, historically and analytically, between natural and synthetic plastics, as the first real attempt at creating a generalized plastic mass. A product of nineteenth century chemistry, celluloid was composed of ingredients from nature—camphor, extracted from the camphor laurel tree—and industry, such as cotton textile scraps, chemically altering the admixture with a liquid solvent, solid fillers, and the application of heat and pressure (Friedel 1983; Meikle 1995). The first plastic material created in a laboratory, it differed from its natural precursors both in its material composition and capital-intensive production requirements.

Celluloid, unlike the labor-intensive, extractive production methods of gutta percha, ivory, shellac, or hard rubber (although the latter was also chemically altered through vulcanization), "required considerable capital equipment, largely machinery, and was hence subject to major economies of scale." The requisite level of capital investment as a barrier to entry meant that its manufacture "was thus always concentrated in a few large factories, and its supply was in the hands of a few sizable companies" (Friedel 1983:18). Changes in the nature and composition of raw materials—derived from and interpenetrating with advances in science, technology, as well as the greater power of capital through increased concentration and centralization—which led to the creation of celluloid, were both the cause and effect of attempts to develop future, fully synthetic raw materials that built upon as well as transcended the properties of former.

As discussed earlier, celluloid's partial, largely illusory independence from nature—both in its origins, as a material produced in a laboratory, and in its limited resistance to decay and atrophy—whetted the appetites of inventors and investors for a more thoroughly human made material. This is clear from Meikle's description of what celluloid lacked:

> Plastics succeeded as a material of choice for manufacturing in the twentieth century not only owing to lighter, cheaper raw materials but because one-shot automatic molding operations eliminated the cost of separate fabricating, finishing, and assembling operations. But celluloid introduced no such savings. Manufacturing techniques remained those of the nineteenth century, with celluloid fabricators often directly borrowing techniques from the horn or tortoiseshell industries they were displacing. Despite the industry's claim that “standardization” was “the keynote of progress,” it remained a labor-intensive, craft-oriented business. Its competitive edge derived from its offering a somewhat more homogeneous raw material, an artificial substitute lacking some of the imperfections and irregularities of natural materials (1995:18).

Celluloid was a more standardized material than its natural counterparts, with its "inconsistency and impurity . . . seem[ing] minimal by comparison with that of natural materials" (Meikle 1995:26). Yet its fabrication required skilled labor, done by hand and/or with small machines—a form of craft production. It attempted to overcome the irregularities of natural raw materials for production—portending and imperfectly reflecting the desire of capital to simultaneously gain mastery and control over both nature and the production process. Both its promise and its limitations as a material were emblematic of its existence as a partially synthetic plastic.

Synthetic Plastics and Nature/Society

The emergence of synthetic plastics proper, as outlined in the preceding chapter, was the product of multiple intersecting, mutually interpenetrating phenomena. These include the scientific-technical revolution and concomitant advances in organic chemistry and chemical engineering; the rise of fossil capital and centrality of coal, and later oil, as a key source of energy; the shortcomings of natural raw materials in the service of accelerating, globalizing capital accumulation; among other factors (Braverman 1974; Geiser 2001; Lotta 1984; Malm 2016; Meikle 1995; Reboul 1994; Spitz 1988). Bakelite, the first synthetic plastic, and the wave of synthetic thermoplastics that followed in its wake, were simultaneously two things: polymers that were akin, similar in form and function, to their natural plastic forebears; and material of an entirely novel and unprecedented kind. Both aspects of this, and their interrelation, are important to grasp in understanding why synthetic plastics proliferated and why that proliferation is such an ecological quandary.

The development and rise of synthetic plastics—starting with thermosets like Bakelite in the early 20th century, produced from coal byproducts; followed by the thermoplastic explosion in the interwar period, dependent on petroleum byproducts and the nascent petrochemical industry—led to and coincided with an epochal shift in the volume and type of material and energetic throughput. Intrinsically bound up with fossil fuel production, synthetic plastics, particularly thermoplastics, are part of an "integrated production system," coupled with oil, automobile, and chemical capital (Geiser 2001). The byproducts of oil refinement to produce petroleum fuel provide the raw materials—including olefins such as ethylene and propylene—through which a host of polymeric assemblages are made. These synthetic polymers mimic, expand upon, and transcend an array of natural raw materials, both natural plastics and other materials like glass, metal, and wood. Their appeal as a generalized base material to produce capital—the physical substratum of globalized commodity production and exchange—is multilayered. Derived from the excreted waste material of a highly profitable and economically essential production process—oil extraction and petroleum production—it has a built-in competitive advantage over other raw materials. However, though not reducible to this factor as such, it is synthetic plastics' novel characteristics—as plastic qua plastic—that make it so economically profitable and socially useful within the context of generalized commodity production.

It is important to understand every aspect of synthetic plastics that make it so qualitatively distinct from both its predecessors and its fellow raw materials. These include its source as a byproduct of fossil fuel production, as mentioned above; its method of production, rapid, capital-intensive injection molding, and other highly mechanized forms of machine-based manufacture; its unique material qualities; and its comparative cheapness, which directly relates to its first two aspects. In each of these dimensions, and in its totality, these relative distinctions from other materials represent a rupture—the emergence of a novel physical property, humanmade, its development inconceivable not only without humans, but without the specific form of socioeconomic organization and level of productive power within which it was created. At the same time, as is clear from the preceding historical analysis of its development, there is continuity between natural and synthetic plastics. This relationship—of both qualitative and qualitative distinction, of both continuity and rupture, likeness and difference—is best understood dialectically. Below, I will return to the dialectical method and differing approaches to social metabolism, in light of the discussion on plastics, synthetics, and the emergence of the potential Anthropocene Epoch.

Dialectics, Plastics, and Social Metabolism

With the dialectical method, the centrality of contradiction—of things consisting of a unity of opposites, which simultaneously gives that thing its identity and forms the basis for its transformation—is important, as it presents boundaries and distinctions as both necessary and relative, with the latter being principal in an overall sense (Avakian 2009; Levins and Lewontin 1985; Ollman 1993; Wolff 1983). The predominance of change, permeability, fluidity, and emphasis on the whole has led some dialecticians to downgrade distinctions between the various parts that constitute such wholes, as well as their relative autonomy. As Ollman puts it, dialectical thinkers, or those who claim the mantle of dialectics, sometimes err by "play[ing] down or even ignore[ing] the parts, the details, in deference to making generalizations about the whole" (1993:17). In other words, in holistic thinking more generally, including some that draws on dialectics, there can be a tendency toward a one-sidedness that "stresses the connectedness of the world but ignores the relative autonomy of [the] parts" (Lewontin and Levins 2007:107). Both aspects are essential: 1) the need for distinctions between phenomena in order to analyze the world, but without reifying the parts; and 2) privileging not only the relations between phenomena or between different aspects of a phenomenon, but, more fundamentally, their interpenetration and interconnection. Bob Avakian (2009) approaches this synthesis as follows:

> [L]et's take the example of a cell within an overall human body. Such a cell itself has a discrete existence and identity as such—with its own relative identity . . . which itself is marked by contradiction (internal contradiction in that context, or at that level), while at the same time that cell exists within, and forms a part of, a certain organ of the body (a lung, heart, liver, etc.), and in turn that organ exists within, and forms a part of, the body as a whole. The discrete existence and relative identity of each of these things (or particular forms, or levels, of matter) once again is real, but is also relative—there is not an absolute separation between them, and they not only "interact" with each other but also are integrated, at different levels, as part of a larger whole (or universal).

Thus, while identity—or matter in its discrete forms or levels—is relative, in terms of their relationship to the whole, without making such analytic distinctions, a human body becomes one undifferentiated mass of undetachable parts, thus preventing cogent understanding and analysis. Or, as Lewontin and Levins (2007:108) argue, "despite Hegel's dictum that 'the truth is the whole' we cannot study 'the whole.'" It is essential, they also add, that dialectical analysis should emphasize "interpenetration, [the parts'] mutual determination, their entwined evolution, and yet also their distinctness. They are not 'One'" (Lewontin and Levins 2007:106). Lenin (1975:648; emphasis in original) also posits the question of dialectics and the analysis of the whole into parts as follows: "The splitting of a single whole and the cognition of its contradictory parts . . . is the *essence* . . . of dialectics."

While hybridist scholars emphasize unity and wholeness, what distinguishes dialectical materialism from a variety of holistic, or monist, philosophies is its emphasis on change, stemming from internal conflict, contradiction, and the division of one into two. As Lewontin and Levins put it:

> [T]he powerful impact of the realization that things are connected sometimes leads to claims that "you cannot separate" body from mind, economics from culture, the physical from the biological, or the biological from the social . . . Of course, you *can* separate [them] . . . We have to in order to recognize and investigate them. That analytical step is a necessary moment in understanding the world. But it is not sufficient. After separating, we have to join them again, show their interpenetration, their mutual determination, their entwined evolution, and yet also their distinctness (2007:106; emphasis original).

The splitting of wholes into their component parts; analysis of these parts, their interrelation, and how, through struggle, they further rupture, leading to the emergence of new contradictions, new identities of opposites, is fundamental, Lewontin and Levins (2007) argue, to the dialectical method.

The existence and historical development of synthetic plastics emphasizes the importance of analytic distinction, handled dialectically, to gain a concrete understanding of both the economic value and ecological liability of this novel material. Synthetics can be considered an imminently social phenomenon, as it relates to the social/natural problematic discussed above. Constituting complex molecular arrangements, requiring a high level of development of the productive forces and a particular set of social conditions, synthetic substances generally, including plastics, almost certainly could not have emerged without human intervention and agency. What makes synthetics "non-natural" becomes apparent in analyzing how they are created, how they function, and the ecological impacts of their post-use dissemination. In each phase of their existence—production, use, refuse—synthetic plastics are distinguished from their material counterparts.

Of course, synthetic plastics are derived from ingredients found within nature—how could it be otherwise?—specifically, the byproducts of fossil fuels like crude oil buried deep underground. This raw material source can itself be distinguished from others as a nonrenewable source, as opposed to being a renewable (solar) or replenishable (wood) one (Geiser 2001). This is an example of the metabolic relationship between society and nature that exists, dialectically and materially—in actuality. Society, as stated above, and its artifacts are an emergent form of nature, not ontologically distinct but nonetheless constituent of properties that are categorically novel. As an emergent property of nature, of matter in motion, society remains rooted in the former, while developing in ways that distinguish it from the whole (Carolan 2005; Malm 2018). While this might appear to be contradictory, that is, in fact, the point: applying the dialectical method allows us to understand that all real boundaries are simultaneously relative ones (Avakian 2009). The continuity with prior raw materials—themselves far from "purely" natural, having been transformed by human labor—and the rupture, through the emergence of synthetics that mimicked yet transcended (relatively) these natural materials, is a clear example of the analytic importance of maintaining, without ossifying, the natural/social distinction, and of applying theoretical frameworks such as the theory of metabolic rift that recognize both aspects of this dialectic.

Removing analytical distinctions from a social metabolic analysis, on the other hand, tends toward reification and conceptual flattening. Consequently, it risks naturalizing all manner and forms of social activity and structures, diminishing the significance of uniquely human agency and human creation; and of our specific (and scientifically determinable) causal responsibilities for the environmental problems we face. Malm's description of an oil spill illustrates the value of analysis that embraces distinction with powerful clarity:

> Think of an oil spill. A company unleashes the liquid into a delta. There is a novel unity in place—oil and water are mixed—but this gives us no reason to treat the two elements of the situation as identical, or (the same thing) declare that one has devoured the other. Rather, we would want to know more about their specific properties. On the one hand, we have the biological diversity of the delta, the birthing seasons of the dolphins, the birds migrating in and out, the food chain, the wave action; on the other, the operating procedures of the corporation, the workings of the profit motive, the level of competition in the oil industry, the function of petroleum in the wider economy . . . [W]e need to know how they interact, what sort of damage the one does to the other and, most importantly, how the destruction can be brought to an end (Malm 2018:61).

In the epoch of the Anthropocene, of climate change, widespread ecological collapse and peril, the need to distinguish between the social determinants of these phenomena and their manifold environmental effects have in fact never been greater (Foster 2016a; Malm 2018).

Embracing distinction can allow us to unpack the oftentimes contradictory associations that mutually constitute the whole. It is an important point of orientation in materialist dialectics that seemingly dichotomous opposites are in fact connected through contradiction. This means that both material and ideological "binaries" which appear mutually exclusive—life and death, animate and inanimate, hot and cold—upon deeper examination, form a unity. They are mutually dependent upon, and in fact transform into, one another. They derive their identity—their overall character and specific features—from one another, and thus "the two sides have a single identity" (Mao 2007/1937:95). And, while forming a unity of opposites, which consists of struggle between them, one aspect under a given set of conditions and given moment through time is principal and the other is secondary, meaning there is "unevenness of the forces that are in contradiction" (Mao 2007/1937:92).

Emphasizing contradiction also enables us to recognize that not every possible pair of things that are different from or appear to be in opposition to one another "actually [constitute] a unity of opposites, nor do things which under certain conditions form a unity of opposites always exist as such" (Wolff 1983:33). Here we can therefore pose the following question: In a social metabolic analysis of plastics, is it analytically advantageous to think of society and nature as a unity of opposites? And if so, under what conditions?

I argue that the most useful way to approach this question is in a materialist, and not in an idealist fashion. In other words, rather than treating "society" and "nature" as reified, binary, monolithic, and idealist categories, we must proceed from a concrete, historical analysis of the specific material manifestations of social arrangements and their relation to the rest of the natural world. In accordance with Mao's (2007/1937:79) thesis that "the living soul of Marxism, is the concrete analysis of concrete conditions," this question cannot be answered abstractly, divorced from historical analysis of material reality, in all its multilayered complexity.

Proceeding from this orientation, and considering the history of plastics as an example, it also becomes clear that it is impossible to analyze specific historical social arrangements—not as separated in some absolute sense from the larger material (natural) reality in which it is rooted, but with definite laws of motion and modes of operation that distinguish it from the whole (emergence)—without some notion of the social, which can and must be analyzed in its own right (Foster and Clark 2016; Malm 2019). The question, therefore, is not *if* analytic distinctions between social phenomena and other forms of nature should be drawn, but *how* this should be done in ways that maintain the fundamental unity—contradictory and dialectical, not monist and harmonious, unity—and rootedness of the former in the latter.

In this sense, I contend that the theory of metabolic rift is quite suitable to this dialectical and materialist approach—maintaining the analytic distinction between society and nature not in an absolute sense, but in the particular social forms that emerge historically, and how these forms incorporate, interact with, and come into conflict with the rest of the natural world (Malm 2019). This dialectical materialist approach can be traced back to Engels's efforts to clarify the analytical value of a dialectics of nature that transcended both idealist and mechanical materialist methods of analysis (Engels 1940; Foster 2020). Metabolic rift theory starts with the specific characteristics of capital's social metabolism—how its metabolic order's mode of operation is driven by the law of value—which generates historically novel, and quite dire, socio-environmental conditions, including the calamity of global plastics pollution, in its varied manifestations.

The capitalist mode of production is far from stagnant; particular political-economic shifts—most notably the transition from capitalism's "competitive"/industrial to its monopolistic/imperialist phase, but also other, less epochal changes as well—have intensified, recast and reframed capital's ecological contradictions. These are in dialectical relation to shifts in the changing nature of capitalism's—as a social metabolic order—relationship to the earth system. Yet, the basic antagonistic form of capitalism's social metabolism remains conceptually because the system itself remains materially, in objective reality. Capitalism continues, and its laws of motion continue to come into direct, antagonistic contradiction with the laws of motion of the planet's manifold and interwoven ecosystems and cycles. Starting from here—the concrete, material conditions, and underlying dynamics of an emergent socioeconomic system and metabolic order, and not the abstract, idealized categories of "Nature" and "Society"—such an antagonistic unity of opposites can in fact be identified. In short, allowing for this analytical distinction enables a thoroughgoing concrete analysis of the contradictions and antagonisms that constitute this unified whole.

Conclusion

In this chapter I have examined two approaches in Marxist socioecological thought that draw on the metabolism concept—metabolic rift and hybridist—in relation to the society/nature problematic, particularly as it relates to the phenomenon of synthetic plastics. I contend that hybridist approaches to social metabolism are undialectical, in that they overemphasize unity and the whole while ignoring or downplaying distinctions between parts. Further, hybridist approaches to metabolism discount the multilayered and multileveled nature of reality, as understood through the concepts of rootedness and emergence. In contrast to the criticisms of its dualist orientation, I contend that the theory of metabolic rift is dialectical. It enunciates unity—human configurations of nature as emergent properties, embedded and rooted within the universal natural metabolism. And it also emphasizes *conflict*—between the specific properties and laws of the capitalist epoch of social history and the imperatives of ecological sustainability. Further, it is dialectically materialist, in that its starting point is not discursive framing or ideal constructions, but the actually existing, historically unfolding material contradictions that arise from the capitalist mode of production. As a result, metabolic rift theory offers useful and necessary analytical insights into ecological crises and sustainable alternatives.

Capitalist social relations possess their own, historically specific tendencies that cannot be found in non-human nature. Society as such is thus an emergent property of nature. It is of the same substance but has unique properties. It is thus irreducible to, yet inseparable from, nature (Malm 2018). Hybrid approaches thus fail to reveal the precise conditions and political-economic processes that drive ecological crises. These conditions can only be found and understood through an analysis of capitalism as a form of social organization that brings it into an antagonistic relationship with that from which it emerges, the universal metabolism of nature. A dialectical method that allows for, and in fact encourages, analytical distinction makes these kinds of insights possible. Blurring categories and over-emphasizing fluidity and unity risks obfuscating the social forces behind ecological crises. As a materialist dialectical approach, metabolic rift theory provides important potential for advancing socioecological analysis in an era of anthropogenic environmental change.

The historical development of plastics—from natural sources, to celluloid, to synthetic proliferation—and its relation to the post-World War II Great Acceleration and emergence of the Anthropocene epoch help clarify the important role of dialectical analysis and distinction. A clear grasp of the emergent properties of the social—not in an absolute, reified form, but as a fluid, relatively distinct realm—which have developed phenomena that exist nowhere else in nature, and which associate antagonistically with the universal metabolism of nature; is essential to understanding why synthetic plastics are simultaneously economically valuable and ecologically harmful.

CHAPTER 6: PLASTICS, HISTORY, AND SOCIETY

Summation, Findings, and Contributions

Throughout the course of this dissertation, I analyze both the history and contemporary moment of plastics development from the perspective of political-economy and socioecology. By applying a Marxist theoretical framework of political economy, via the theory of monopoly capitalism, and socioecology, by way of the theory of metabolic rift, I have attempted to converge the two. In doing so, with the methodology of historical sociology, my aim has been to simultaneously uncover the historical movement of plastics as a raw material of capital production as well as further elaborate and expound upon these theoretical frameworks.

I start by outlining a Marxian understanding of the relationship between the economic foundation of society and its other characteristics, as well as between technological development and social change—a framework of the productive forces-production relations and economic substructure-political/social/cultural superstructure nexus. This is an important point of basic orientation and method, that sets the overall framework for what follows. I then dig into the two main theories that guide my analysis: monopoly capitalism-imperialism and the theory of metabolic rift. In doing so, I focus on some of the debates within these frameworks.

Next, I begin to analyze the historical development of plastics starting with plastics of natural origin in the 19th century, and the shift from natural to synthetic plastics. I focus on the incorporation of rubber, gutta percha, and other natural plastics into the production of capital, and the role these materials played in some important technological, and political economic, developments of the time.

These natural plastics were contradictory. In a beginning way, they revealed the potential for a productive raw material that was pliable, moldable, tensile, and inert—many of the characteristics that made synthetics so valuable. These materials' unique properties helped propel technological breakthroughs—for example, gutta percha's role in the development of transoceanic telegraphy—that coincided with major political economic transformations, like the rise and consolidation of British imperialism. Similarly, rubber vulcanization both liberated rubber from its material limitations and precipitated future infusions of chemistry into the raw materials-making process. Also, the shift from wild rubber extraction to cultivated rubber plantations signaled a larger pivot to production and extraction methods more capital-intensive and less reliant on the exigencies of nature—an (ongoing and incomplete) rupture with prior, labor-intensive, and more ecologically bound divisions of labor and methods of production.

On the other hand, these natural plastics exhibited shortcomings in their material integrity, in their sourcing, and in their production methods, that limited their applicability. Thus, these protoplastics heralded yet were unable to fulfill the role of a basic, generalized plastic material.

Celluloid in many respects represented a leap beyond these natural plastics, in terms of its ability to realize the characteristics of a generalized plastic mass for commodity production, and celluloid played an important innovative role in some key information and communication technologies of the late 19th and early 20th centuries. Yet its partially synthetic nature both signaled this material's attempt to transcend the limitations of natural materials and its inability to fully do so. Celluloid embodied certain characteristics of both monopoly capital, with its relatively centralized ownership and production; and synthetics, through its chemical composition and transformation. And yet it also lacked the level of material and technical development to make its production sufficiently capital-intensive or amenable to mass production. Nor does celluloid actually consist of entirely human-made molecular configurations.

Historically, celluloid marked the first real attempt at overcoming the limitations of raw materials derived from nature. This experience is instructive—it gives real insight into the qualities sought after by capital for a generalized plastic mass. Further, celluloid's role as an intermediate material, not fully synthetic but sharing certain characteristics with the class of synthetic plastics that would emerge later, highlights the relative (but real) distinction between the synthetic and natural.

The emergence, at the turn of the 20th century, of synthetic plastics represented a pivotal shift in the material underpinnings of the social world, with important ecological consequences. Bakelite, the first synthetic plastic, was not only bound up with crucial information, communications, and transportation technologies of the early 20th century, but it coincided with, and codetermined, epochal political-economic transformations related to further growth and consolidation of monopoly capitalism. It was in fact the very characteristics of synthetic material—seemingly impervious to the natural elements, to decay and degradation, entropy and weathering—that made Bakelite uniquely suited for electrical, chemical and industrial purposes. The need for acute advances in ICT and transportation was fundamentally related to the political-economic changes of monopoly capitalism: increased globalization, the emergence of a more expansive consumer economy, competition between imperialist powers over global "spheres of influence," among other factors. Bakelite, a material component of "the hidden abode" of industrial production of such technologies, was essential to these advances. Invented as a substitute for natural plastics, the material opened brand new vistas for the generation and development of epoch-shaping technologies and inventions.

Bakelite is a thermoset plastic. In the inter- and postwar periods, a whole class of new synthetic thermoplastics emerged. These plastics remedied some of the shortcomings of Bakelite: its limited color range, relatively time-consuming and labor-intensive production methods, dependency on coal liquefication, inability to be remelted and remolded. This allowed for the outward expansion of plastics into the world of consumer goods, and into new industries, such as construction and agriculture. And it is this class of synthetic thermoplastics that would become the dominant material substructure upon which much of the contemporary world is built.

World War II facilitated the rise of plastics, injecting it into the economy on an unprecedented scale. This is directly related to the role that world wars in the epoch of monopoly capitalism-imperialism. A convergence of factors—from the command role of the state in economic decision-making; to the reallocation and scaling up of production for the war effort; to shifts in the geoeconomic landscape, such as resource shortages and military blockades—gives wars of this scale a certain "purgative function," along with their rationalization of production and reshuffling of geopolitical-economic relations (Lotta 1984:148). The experience of World War II and plastics, as well as synthetics more generally, demonstrates the interconnection between the political economy of capitalism-imperialism, and the synthetization of the social metabolism.

Next, I wade into the theoretical debate regarding different iterations of social metabolic thought and their approach to the society/nature problematic. I consider the contending social metabolic approaches of urban political ecology and world ecology, with its hybridist interpretation of metabolism, particularly as it relates to the relationship between social and natural phenomena, in light of the history and nature of plastics. I do so through the lens of dialectics, an epistemological framework that is foundational to social metabolic theory, as well as Marxist thought overall, and which each school of social metabolism wields in order to make their case regarding this problematic. What the historical development of synthetics helps to reveal is that, rather than a subsumption of the social within nature, or a hybridization of the two, the emergence of this humanmade material strengthens the need for analytic distinction, dialectically understood, between social and non-social phenomena to understand, and on that basis change, the world.

This is because the development synthetic plastics, while having "evolved" from plastics of natural origins such as rubber, and sharing some definite characteristics with natural polymers, marks a qualitative leap into the realm of the humanmade. Synthetic plastics are material configurations that could not have emerged without the intervention of humans, within a particular political, economic, social, and technological context. As I show in the preceding chapter, application of the dialectical method, on a materialist foundation, clarifies both aspects of this contradiction: the relative continuity with, and definition distinction from, natural plastics, polymers, and productive raw materials.

The widespread proliferation of synthetics broadly, and synthetic plastics specifically, coincided with what is called the Great Acceleration period, as well as the proposed Anthropocene Epoch, following World War II. Along with the rise of synthetics as the substructure upon which much of the world's economy is now built, the emergence of the United States as the new global hegemon is a second key change that characterized the post-WWII era. These two phenomena are in fact linked. The petrochemical industry, from which plastics and other synthetics are derived, was largely born in the United States. And the further globalization of capitalism that coincided with the post-war era facilitated both the increased use (and strategic importance) of fossil fuels, and of plastics. These linkages are important: the definite shift to the so-called Synthetic Age took place within, was anchored and driven by, and codeveloped with a particular arrangement of the political, economic, social, and technological forces and relations.

In a similar way, both the economic value and ecological peril of plastics are also linked. It is in many respects the very qualities that make synthetic plastics so socially and economically useful that also make them an ecological quandary: derived from nonrenewable fossil fuels, designed to resist degradation and decomposition, uniquely engineered to be molded into an abundance of different shapes and forms, and chemically composed of molecular arrangements without a corresponding enzymatic counterpart. Thus, not only does the historical development of plastics reveal both the unity and contradiction between social and natural phenomena, but it also presents openings in terms of understanding the relationship between the political economy and ecology of capitalism.

Shortcomings and Future Research

The aim of this dissertation was to understand the emergence of plastics in the context of the larger system of capital accumulation, particularly in the United States, and in relation to the contemporary debate among social metabolism scholars regarding the society/nature problematic. As stated in the introduction, the topic of plastics has been almost universally ignored by sociologists. Thus, my hope is that this work will provide a beginning basis from which other social scientists can make further leaps and inroads on these questions and others. Here I will suggest a few avenues of future inquiry and study based on questions posed in this study, both explicitly and because of omission. In other words, this dissertation both presents questions for further investigation, and fails to adequately address certain important questions.

As suggested in the preceding analysis, the post-World War II Great Acceleration period is pivotal in the history of plastics development. Within the period of 1950 to the present, there are many different phases of plastics expansion which should each be further analyzed. Because I wanted to start from the beginning and set the stage and scaffolding upon which plastics have performed, in this dissertation I was only able to touch on this period in broad strokes. Yet many of the instances I cited of early plastics playing a pivotal role in the development of crucial information and communication, as well as transportation and other technologies, has occurred in the Great Acceleration period as well, often on an expanded basis. The rise of computer technology, the Internet, and smart devices, for example, is in part dependent on plastics for its production. As during the late 19th and first half of the 20th centuries, plastics as a raw material of production, because of its novel qualities, had a co-determinative relationship with these technologies that were so essential to the ongoing progression and development of capitalism-imperialism as a global system.

This dissertation focuses largely on the United States as the birthplace of the plastics industry. Yet the story of plastics today, and particularly since the post-WWII period, is fundamentally a global one. Its production, consumption and dispersion are, like many of the circuits of production today, thoroughly globalized. One acute expression of this is the global plastic waste trade, where plastic waste, purportedly to be recycled, is sold, generally travelling from imperialist nations like the United States to oppressed nations of global South, such as Vietnam or Thailand (Wang et al. 2020). There are many others: for example, the case of China, which produces vast quantities of plastics-based commodities for the world market and was formerly the largest importer of plastic waste. In 2018, China implemented its new National Sword policy, which banned the import of nonindustrial plastic waste (Wang et al. 2020). Not only did this completely transform the flow of global plastic waste, but it is also indicative of China's changing position in the world system, as it can increasingly rely on domestic plastic waste from rising domestic consumption. Again, the relationship of plastics with larger political-economic, and ecological, trends and patterns is inextricably bound, and ripe for further analysis.

In this dissertation, I attempt, in a beginning way, to synthesize two distinct Marxist theoretical frameworks: monopoly capitalism-imperialism and social metabolism/metabolic rift. The former is principally a political-economic framework, while the latter is generally seen as a socioecological framework. I try to show, through the lens of plastics, the interrelation between the political-economic and the socioecological. For example, I demonstrate that the economic value of synthetics is bound up with its material-ecological characteristics. While my analysis points to the close association, and interpenetration, between the socioecological and the political-economic, I nonetheless maintain the importance of some analytic distinction between the two (as between society and nature generally), as is detailed in the preceding chapter. There is further work to do here: in terms of bringing together, without blurring the relative distinction between, the frameworks of monopoly capitalism-imperialism and social metabolism. Such theoretical elaboration can take many forms and is not limited to an analysis of plastics.

While this work is explicitly both political-economic and socioecological, and a primary aim is to bring these two approaches into engagement and conversation, there is overall greater emphasis on the former framework than the latter. This is mainly because, as part of excavating the historical development of plastics as a raw material of production, starting from the beginning, much of my analysis focused on the first one hundred or so years of this process. This was before plastics became a major economic as well as material force in the world, and before much of calamitous effects of this widespread production and dissemination on the planet were either well known or in existence. I do address, incipiently, the beginning changes to the social metabolic order ushered in by a new, rising synthetization of the material and energetic underpinnings of society. And in the fifth chapter, I give a general overview of some of the contemporary environmental impacts of plastics. Nonetheless, a socioecological analysis of plastics, and how it relates to changes in humanity's relationship with nature under late-stage monopoly capitalism, should be an object of future sociological analysis.

My analysis focuses on both the role of capitalism as an economic system, and of capitalist nations, in relation to the development and dissemination of plastics as a raw material of production. It is also true that countries in part of the Eastern Soviet bloc both generated environmental crises of their own and produced as well as consumed synthetic plastics (Rubin 2008). Yet my argument that capitalism was a driving force in the development of synthetics as a raw material of production stands. An analysis of the nature of the Soviet Union and Eastern bloc, and why they were, by the mid-1950s, no longer socialist but rather state-capitalist nations is beyond the scope of this dissertation. For discussion of these questions, I recommend *The Soviet Union: Socialist or Social-Imperialist?*, a set of essays compiled by the Editors of the journal *The Communist*.

A central thematic of Marxist historical materialism is the contradiction between the forces and relations of production, whereby the relations of production are, in the final analysis, developed on the basis of the level and nature of the productive forces (Avakian 2019; Marx and Engels 1978b). Here I primarily focus on the productive forces, and only briefly discuss the ramifications of the development of the productive forces on the productive relations. A fuller elucidation of these impacts, dialectical interplay between the relations and forces of production, is beyond the scope of this project, but is nonetheless an important subject for future research and analysis.

Finally, regarding my choice of data sources mainly consisting of secondary accounts, rather than primary, archival sources: I made this decision largely because of the scope and breadth of my analysis—tracing the trajectory of this material over more than a hundred-year span. Instead of focusing on archival material that provided greater detail on particular moments of this history, I instead relied more on a variety of sources that served to put these moments into their larger historical context and sweep. That being said, there is a lot of future sociological research to be done that makes use of the materials, including plastics industry trade journals and primary accounts from key players in the many chapters of this important history.

Concluding Remarks

Before concluding, I briefly want to consider further this synthetization of political economy and ecology, and of monopoly capitalism and social metabolism. Here the word "synthetization" has dual meaning: the admixture of the two realms, and theoretical frameworks, as well as the wholesale injection of synthetic materials into each, perhaps conjoining the two as never before. Does the latter, the existence and proliferation of these materials, redefine and reshape how we must consider the relation between society and nature, and political economy and ecology? I think it does, in two overlapping ways.

The existence and impact of these materials, like the burning of fossil fuels and resulting climate change, has in certain ways forced us to rethink our relationship to the rest of nature. It is a challenge to the "Human Exceptionalist Paradigm," which still too much of the discipline of sociology, and society as a whole, labors under (Catton and Dunlap 1978). Synthetic plastics are a clear manifestation of environmental blowback, through which our attempts at overcoming the parameters of the natural world result in ecological, and thus invariably, human peril (Dawson 2017). It is because of the clear mutuality between and entanglement of the natural and the social that such a synthesis of the political-economic and the ecological is required.

Yet at the same time, synthetics makes us rethink our place within and relation to the natural world from a different angle. While it is clear that no untraversable boundaries exist in reality—that the social bleeds into the environment within which it is seated—it is equally apparent that we have created a substance that defies attempts to demolish the relative novelty of humanness. Plastics will outlast most of the organic matter within which it is dispersed, and its effects require human agency to remedy. Thus, while the tale of plastics implores us to rethink just how divorced our actions are from the biosphere which we call home, challenging illusions of our exemption from the laws of nature, it also compels us to ponder our distinctiveness.

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