INTRODUCTION

New Yorkers had been anticipating his visit for months. At Columbia University, where French intellectual Henri Bergson (1859–1941) was to give twelve lectures in February 1913, expectations were especially high. When first approached by officials at Columbia, he had asked for a small seminar room where he could directly interact with students and faculty—something that fit both his personality and his speaking style. But Columbia sensed a potential spectacle. They instead put him in the three-hundred-plus-seat lecture theater in Havemeyer Hall. That much attention, Bergson insisted, would make him too nervous to speak in English without notes. Columbia persisted. So, because rhetorical presentation was as important to him as the words themselves, Bergson delivered his first American lecture entirely in French.[1] Among the standing-room-only throng of professors and editors were New York journalists and "well-dressed" and "overdressed" women, all fumbling to make sense of Bergson's "Spiritualité et Liberté" that slushy evening. Between their otherwise dry lines of copy, the reporters' incredulity was nearly audible as they recorded how hundreds of New Yorkers strained to hear this "frail, thin, small sized man with sunken cheeks" practically whisper an entire lecture on metaphysics in French.[2]

That was only a prelude. Bergson's "Free Will versus Determinism" lecture on Tuesday, February 4th—once again delivered in his barely audible French—caused the academic equivalent of a riot. Two thousand people attempted to cram themselves into Havemeyer. Hundreds of hopeful New Yorkers were denied access; long queues of the disappointed snaked around the building and lingered in the slush. According to legend, motorists on Broadway slowed to a standstill to observe the spectacle. Between the goose-necking and the meandering pools of onlookers, Bergson's lecture instigated the first traffic jam in the history of Broadway.[3] Though the traffic did not become a problem again, this level of overcrowding continued through nearly all of his Columbia University lectures. Bergson clearly touched a nerve in New York. He had nearly everywhere he spoke.

He claimed, self-deprecatingly, to have no well-articulated philosophical system, nothing to champion, no reason for his audiences to be this large, this engaged. His supporters in Europe and North America knew better. Bergson was a philosopher, of course, but his brand of philosophy felt fresh and new, not just a rehashing of Kant or Aristotle. Some called it *vitalism*. Living things, Bergson believed, possessed an élan vital, some animating force or spirit irreducible to mere chemistry or physics. Organisms, and by extension humans, were not mere automatons; according to Bergson, we were special. It was Bergson's notion of organic specialness—and the individualistic self-determination that seemed to come with the vitalism—that resonated with audiences in the early twentieth century.

Yet the ideas that motivated Bergson and drew his crowds were not originally his ideas at all. Two decades earlier, in Naples, Italy, a young German named Hans Driesch (1867–1941) squinted through his microscope at a developing sea urchin embryo. It had just divided: one egg into two gelatinous cells. He had decided to repeat an earlier experiment done by Driesch's well-known mentor, Wilhelm Roux. Roux had used frogs' eggs and had lanced one of the two developing cells with a hot needle, killing it. The second cell from that egg lived and continued to grow and divide, but it formed only half a tadpole. This result made sense to Roux. Any complex system that lost half of itself would, at best, form only halfway. But Driesch saw something else there, and he altered the experiment. Instead of killing one cell with a needle, he painstakingly teased the two cells apart, making them float alone. After several trials, the floating cells, separated from their other halves, grew not into half sea urchins, but full ones with all of their parts in their right places. What kind of machine, Driesch wondered, could lose half of itself yet continue to develop into a whole, functioning system? Only a living thing had the ability to do this. So, he thought, living things must be exceptional, crucially different from nonliving things, and this insight led Driesch to vitalism.

The ripples of Driesch's experiment and his endorsement of vitalism tore open an older debate that appeared to have been settled once and for all decades earlier. By the beginning of the twentieth century, Driesch, together with Bergson and others, stood for a reinvigorated vitalism against what they saw as the dehumanizing hegemony of mechanism. Theirs were only the first salvoes; this new battle between mechanism and vitalism would continue for decades.

The mechanism-vitalism debate originated in a set of perennial questions. Aside from superficial dissimilarities in size, shape, and density, what makes mountains distinct from mountain lions, stars unlike starfish, or sea anemomies crucially different than the seawater surrounding them? Do organisms possess certain attributes—the ability to replicate, for instance, or the need to breathe—that fundamentally set them apart from nonorganisms? Put another way, what makes something alive? Is organic life *essentially* different from the inorganic and nonliving, or is it just a wetter way of assembling the carbon, hydrogen, oxygen, and so on that chemists find in the earth and the earthworm alike? Traditionally, mechanists believe there is no real line between life and nonlife; vitalists believe that without something extra, something outside of physics and chemistry alone, nonliving material cannot live.

These questions preoccupied some of history's most influential natural philosophers. Long ago, Aristotle and Theophrastus wrestled over them while walking along the Aegean coastline; the Philosopher—Aristotle—insisted living beings were greater than the cold material causes imagined by Democritus and the atomists. Five centuries after Aristotle, Galen of Pergamon, surgeon to the gladiators, insisted that arterial blood carried *pneuma*, a vital fluid or spirit, unique to the living. Over a thousand years after Galen, in the seventeenth century, Britain's William Harvey corrected Galen's antique theories of anatomy but retained an almost commonsense faith in the need for an extra fluid or spirit to account for the complexity of life—that hallmark of vitalism echoed in Henri Bergson's élan vital. Harvey's seventeenth-century contemporary René Descartes, by contrast, maintained that organisms were little more than automata—mechanical devices. The modern conflict between mechanism and vitalism was born.

It continued to involve some of the most important thinkers in seventeenth-, eighteenth-, and nineteenth-century Europe. Gottfried Wilhelm Leibniz weighed in; so did John Turberville Needham, Lazzaro Spallanzani, Georg Ernst Stahl, William Hunter, and many others. The debate died down in the mid-nineteenth century due to, among other things, a decisive advance from four prominent German mechanists. Emil Du Bois-Reymond, Carl Ludwig, Ernst Brücke, and Hermann von Helmholtz vowed to explain life itself and every function of an organism solely through physicochemical means. Wilhelm Roux's work was in the lineage of these mechanists.

Surprisingly, given the effectiveness of the "Helmholtz school," vitalism was reinvigorated in the wake of Hans Driesch's embryological work. But it settled little. Once again, an aggressive mechanistic opposition met the new vitalism, this time through the work of Jacques Loeb (1859–1924). Like Driesch, Loeb was an adroit experimentalist who emigrated from his native Germany to better-funded American laboratories.

Sparked by Driesch, Bergson, and Loeb, the mechanist-vitalist dispute continued on into the new century. Between the First and Second World Wars, individual biologists, including Nobel laureates, would declare the defeat of one or the other position. Decades later, Francis H. C. Crick (1916–2004) reminded his audience that his work in molecular biology contributed to the final conquest of vitalism. But in the 1960s, another group of accomplished biologists gathered in Alpbach, Switzerland, to claim that Crick had overstated the strength of his mechanistic position. Some biologists took an even stronger stand for vitalism. Sewall G. Wright, founding father of the neo-Darwinian synthesis, for instance, held that some extramaterial substance or principle was required to explain the vast complexity of life and evolution.[4] Clearly, the conflict was still very much alive in the middle of the twentieth century.

Like any conflict, the mechanism-vitalism debate has gained a lot of attention from historians and philosophers over the years. This makes sense: The battle lasted so long and involved some of the most memorable names in biology. But, important as that debate is, this is not a book about it.

Instead, this book maps a comparatively understudied network of scientists who shared two features in common. The first is that they were not vitalists like Bergson and Driesch; the second is that they were not mechanists like Roux and Loeb, either. What they were instead of these two things was hard to define, even for them. Using their own idioms, each claimed that they were pioneers of a "third way," a path that cut across the mechanism-vitalism debate. They advocated a new manner of *seeing*—the way that, when given a fourth point and a triangle, one might create a pyramid instead of a trapezoid. It was a way of seeing life, even the universe, organically; advocates often called their approach the "philosophy of organism," "organic philosophy," "organismalism," or "organicism."

Their concepts require unpacking, not because they are counterintuitive or even unfamiliar, but because their "third way" was much more complex than the mechanism or vitalism it was intended to displace. There were more threads to hold in tension. Stated as a positive definition, the philosophy of organism was the belief that a whole organism is "*as essential to an explana-*

tion of its elements as its elements are to an explanation of the organism."[5] More frequently, however, advocates presented their organic philosophy simply as a negative—a rejection of the other two ways. As philosopher Morton Beckner pointed out in the middle of the twentieth century, this "third way" "may be described as an attempt to achieve the aims of the murky organismic-vitalistic tradition, without appeal to vital entities."[6] These "third way" biologists commonly insisted that highlighting the functional dependence of individual organs and elements (e.g., cells) on whole organisms was not an argument *for* vitalism, it was merely an argument *against* the mechanists' tendency to explain only parts, with the implication that the explanation of parts sufficed to define the wholes of which they were a part. As it turns out, this strategy—to define and attack the weaknesses of the opposition without being able to offer a positive replacement for that position—has been practiced so often in the history of science that we might envision it as the ordinary manner of theory change.[7]

The Life Organic, then, is an attempt to trace this sometimes murky "third way" tradition through its derivations and renegotiations. It is also an attempt to trace a *network of individuals*—often outsiders for political or cultural reasons as well as scientific ones—who were advocating for the acceptance of this "third way." Aside from a set of scientific concepts, organicists approached the world as richer and more complex than mechanists, less mysterious and inscrutable than vitalists.

I make four main arguments in *The Life Organic*. First, I argue that the century-long history of the organic philosophy, including the scientists who defined and refined it, deserves a place at the table with the rest of the history of biology—with the mechanism-vitalism debate, for instance, over which much ink has already been spilled. Secondly, I argue that the subfield of epigenetics as originally conceived was a product of "third way" thinking—an observation that has important consequences for the headline-making epigenetics of the twenty-first century. Third, I maintain that the organic philosophy did not die out, as has been claimed by some historians and scientists, but has continued to find prominent supporters among scientists of all stripes through the twentieth century and into the present. Finally, I argue that the discipline of biology visible through this historical lens seems not to conform to three widely referenced models for how biological concepts have changed: the models introduced by Julian Huxley, Karl Popper, and Thomas Kuhn. Let me explain each of these arguments in more detail.

First, why does this century-long history of the "third way" matter? Excellent accounts have been written on the origins and development of cell theory, the neo-Darwinian or "modern" synthesis, molecular biology, the race for the double helix of DNA, theoretical population genetics, and so on. Considerably less attention has been drawn to areas outside of these important foci of modern research, despite the fact that a half century ago, Herbert Butterfield implored historians of science to look beyond "the emergence of the views that we now regard as right."[8] As *The Life Organic* shows, organicism, though shoved to the margins over the last portion of the twentieth century for being not "right," has been a guiding philosophy of a significant number of scholars on both sides of the Atlantic Ocean for over a century. It motivated members of multiple disciplinary subfields, and it impacted both their experimental practices and the reflective pieces they later wrote about their work. In the 1970s, for instance, commentators spoke about a crisis in the life sciences regarding the persistence of biology as a field autonomous from biochemistry and, ultimately, physics. One could witness this crisis playing out, as philosopher J. Ronald Munson noted, just by observing the research pursuits biologists chose: "If a biologist is convinced that it is only a matter of time before we have physical explanations for all biological phenomena, then he will be inclined to choose research problems that are amenable to treatment by the methods and theories of physics and chemistry. Rather than studying the functions and interrelations of cells and groups of cells, for example, he will concentrate on the chemical processes that take place within cells." Commitments to these theoretical concepts have been "instrumental in directing the future course of biology," thought Munson.[9] For this reason alone, perhaps, we should include organicism in our standard histories as one of those core concepts that has influenced the course of the life sciences.

But it is not enough to argue that the history of organicism should be included in order to address a lacuna in the historical literature.[10] When we step back and take a broader look at the story of organic philosophy over the course of the late nineteenth and twentieth centuries, it is clear that—my second argument—it played a central role in the creation of *epigenetics*.

One need only listen to the morning news or glance at a popular science blog to learn that epigenetics is the hot new approach sweeping across the life sciences. These reports radically exaggerate its novelty, however. Epigenetics did not originate from a set of laboratory experiments in the 1990s or 2000s. It emerged from discussions in the 1930s and early '40s surrounding the definition of the "third way." Moreover, epigenetics was rooted in a specific place and in a specific social context: a group of scholars drawn from across England and the Continent known as the Theoretical Biology Club. The identities and trajectories of some of these figures comprise the core narrative of this book.

Commentators present twenty-first-century epigenetics as an amendment to standard genetic accounts of inheritance. Processes most often mentioned in twenty-first-century epigenetics, such as DNA methylation, insert a scintillating hint of Lamarckism into the orthodox story.[11] But in its original context, epigenetics offered something far more complex than occasional breaches of the central dogma: a way to conceptualize the organism as it develops from genotype to phenotype.[12] Unpacking the black box of the developing organism was a central concern of the original formulators of epigenetics. Ironically, lost amid the hyperbole regarding twenty-first-century epigenetics is the reason why development was so important to its mid-twentieth-century founders—namely, the role of development in evolution. They believed that the contours of the evolutionary landscape are written not in the language of DNA alone, as it is often misleadingly implied, but via the poorly understood syntax by which genotypes develop into phenotypes and phenotypes reciprocally alter genotypes.

My third argument is a historiographical one that flows out of the second historical point: Historians and scientists have claimed that the "third way" faded into obscurity after World War II, with historians suggesting that the concept was so tightly tied to fascism in the 1930s that the defeat of the Third Reich also signaled the demise of organic holism. If and when fascination with the organic whole did percolate upward in the second half of the twentieth century, they have claimed, it was often in service of New Age groups embracing a back-to-nature movement or some species of anti-intellectualism.[13] Yet the long history of the "third way" outlined in this book does not correlate with either of these cultural-political trends. Quite often, scientists on the political left—communists, Fabians, even Christian Socialists—found organicism compelling. And rather than being the purview of anti-intellectual or anti-establishment radicals, Cambridge dons and Stanford physicists championed the organic philosophy through the middle of the twentieth century—hardened experimentalists with solid records of empirical research.

By my lights, this history reveals something more profound than what other scholars have suggested. Instead of self-marginalization or adoption by fringe groups, here we witness a sustained aversion toward nonmechanistic thinking by a central group defending biological orthodoxy (or, at least as often, wholesale apathy about theoretical biology). It was this tendency on the part of notable scientists that pushed the "third way" to the margins, even though it did not extinguish the philosophy entirely. Perhaps the newfound popularity of epigenetics in the twenty-first century will reverse this trend, spurring renewed interest in theoretical biology and an increase in the status of theoretical research among important life scientists. Unfortunately, recent statements by respected science popularizers who discount the relevance of philosophy to science make this scenario seem both desperately needed and terribly unlikely.

Finally, my fourth argument: An examination of the century-long time line on offer here raises significant questions about how we should model the development of the discipline of biology. Since the middle of the twentieth century, the models most often applied to concept development in biology include the synthesis model championed by Julian Huxley, the Popperian conjecture-refutation model, and Thomas Kuhn's model of wholesale paradigm shifts. While *The Life Organic* makes no claims to be a detailed contribution to the history of the philosophy of biology, it seems worth noting that none of these three models fit the narrative presented here. Each model is predicated on the notion of *replacement*—some theory takes the place of another one. Huxley showed how neo-Darwinism replaced old Darwinism by synthesizing it with Mendelism. Popper stressed that concepts are floated until some experiment or set of experiments falsifies that concept. But it is Kuhn's language of paradigm shifts that historians and social scientists most often invoke to explain broad-spectrum concept change in science.[14]

Ordinarily, thought Kuhn, scientists are involved in solving various small puzzles in their fields, and they typically adopt the dominant terminology and methodology in which they were trained to address those puzzles. Over time, anomalies develop—unexpected results, puzzles that persistently resist solutions. When enough of these anomalies accumulate, the time is ripe, believed Kuhn, for scientists to reject the entire collection of concepts, the language, methods, and even the worldview in which they were trained. In a sweeping revolution that Kuhn compared to a gestalt switch, these scientists would adopt a new paradigm. Admittedly, the revolution might last for a while—perhaps until the old guard of scientists died off—but eventually it would culminate with a new paradigm replacing the old one. Naturally, that new paradigm solved the old, seemingly unsolvable anomalies. But it also helped with puzzles unrecognized in the old paradigm. In this way scientific progress could be preserved in the historical account.

Though Kuhn insinuated that his model applied to all natural sciences, he was particularly interested in what he called the "Copernican revolution." In his 1957 book with that title, Kuhn carefully illuminated the path by which sixteenth- and seventeenth-century European natural philosophers overturned the millennia-old geocentric model of the solar system. Such a revolution, Kuhn showed, required new concepts of motion, the composition of elements, mathematics, and even the way we acquire knowledge, as well as an alternate cosmology. The Copernican revolution and the more recent revolution in physics and astronomy inspired by Albert Einstein's work strongly suggested to Kuhn that such change was unidirectional. It would be ridiculous, for instance, to return to a pre-Copernican system. That would involve rejecting not only the whole of modern astronomy, but modern physics as well. In other words, according to Kuhn's model of scientific change, once the revolution has happened, there is no going back.

Instead of resolution or synthesis, revolution or replacement, the long history of organicism presented here reveals recycling and coexistence—a messier, back-and-forth, almost pendular action. Mechanism has seemed at times to be on the verge of Kuhnian replacement by some anti-mechanistic challenger. But mechanism always returns. Surprisingly, the reverse is also true: Despite popular accounts that celebrate the ultimate dominance of mechanism—Crick's *Of Molecules and Men* (1962) is among the most enduring—mechanism never successfully silences its opposition either. Instead, mechanism and anti-mechanism perpetually dance around each other, a yin and a yang. One is dominant for a time, the other dismissed as useless knowledge of the past. Then the once-discarded, discredited concept buoys up to the surface of biology again, reincarnated, old wine poured into new wineskins.[15]

Why, if this history is as important as I claim, have historians paid so little attention to it? A number of reasons come to mind. First, the main advocates for "third way" thinking were always a minority and often at the edges of the mainstream of their discipline during their lifetimes. Secondly, they generated less heat, and therefore drew less attention, than those who squarely argued for mechanism or vitalism. Thirdly, organicists often had a difficult time explaining their alternative in any light other than its rejection of mechanism, which goes some way toward explaining why historians, when they discuss these scholars at all, have lumped them with more vociferous, more straightforward vitalists. Finally, even the notion that biologists should be worried about long-standing questions regarding the ontology and epistemology of their field is controversial. As we will see at multiple points in this account, during the course of the twentieth century the practice of biology became increasingly segregated from the business of thinking about what biology means. Unlike the trajectory of physics, for instance, theoretical biology was not always crucial to the training and interests of life scientists later in the century. Advocates for an alternative to mechanism and vitalism could be safely ignored, even derided as *mere philosophers*.

By contrast, much earlier in the twentieth century, biologists often extolled the theoretical aspect of the field as their raison d'être. When scientists and philosophers took positions on the mechanism-vitalism debate, especially once joined by Bergson, the standoff began to seep onto the pages of popular newspapers and magazines. By this point, a generation of biologists in the UK and United States were already engaged in formulating the "third way" alternative—they will be the focus of chapter 1. Still, it was not until the advent of the First World War, and the palpable triumph of mechanized death over any romantic notion of organic life, that a critical mass of English-speaking scholars turned their attention toward examining the debate. The most concentrated public forum for that examination took place at the first American Philosophical Association (APA) meeting held after the 1918 Armistice. By the second decade of the twentieth century, physics had already undergone a revolution in its most basic concepts beginning with the work of Einstein and Bohr. Biology seemed close behind. Cambridge-mathematician-turned-Harvard-philosopher Alfred North Whitehead persuasively argued that the universe was not constructed primarily of isolated particles or mechanisms but relational wholes or *organisms*. He called his approach the philosophy of organism, and it resounded through European intellectual circles. (Indeed, ripples of their holistic alternative permeated that field where the word *organic* still connotes a similar meaning: agriculture. A persuasive early call for organic farming made by Oxford's Walter James, 4th Baron Northbourne, entitled *Look to the Land* [1940], borrows heavily from both Whitehead and a convinced Whiteheadian statesman, Jan Christiaan Smuts.[16])

The story did not end there; the philosophical shift signaled by Whitehead was not yet a fully experimental approach. Intending to sharpen and extend the work of Whitehead and the first generation of organicists, one group in particular met repeatedly over the 1930s to sketch out what this resolution could mean in the laboratory and for society. Called by some of its members the "Theoretical Biology Club," this network of polymathic, transdisciplinary British men and women (with occasional prominent visitors from the Continent and North America) worked throughout the 1930s to clarify what exactly was meant by concepts like *organic*.[17] Consistent members of this group included biochemists Joseph and Dorothy Needham, biomathematician Dorothy "Dot" Wrinch, biophysicist John Desmond "Sage" Bernal, embryologist-geneticist Conrad H. "Wad" Waddington, and—the glue that held the group together—Joseph Henry "Socrates" Woodger. The interactions of the members of this club (detailed in chapters 2 through 8) incubated some of the most fruitful organicist work. Most significantly, it was in the context of his work with the Theoretical Biology Club that Waddington took on the project that would make him best known: epigenetics. Thus, epigenetics was brought to life through the search for the "third way" embodied in the discussions of the Theoretical Biology Club and the work that Waddington conducted with members of the club. Epigenetics, as originally conceived, was organic. What that meant, exactly, would have to wait to be spelled out until after the Second World War.

In retrospect, the 1930s were the early zenith of the organic philosophy. While the pendulum had swung away from the vitalism exemplified by Bergson and Driesch, it did not cease swinging. Instead, the war and the ensuing geo-political tension between the United States and the USSR as highlighted by the Lysenko story served as a backdrop for the steady re-entrenchment of mechanism.[18] From the new analytical philosophy of science to the growing insistence that DNA was at the heart of nearly every important biological issue, the organic philosophy counted fewer open adherents. Despite the overwhelming popularity of epigenetics in the twenty-first century, Waddington's approach, first formulated in the 1930s and '40s, did not attract a large and devoted following in the decades after the Second World War. Funding and training were devoted to molecular biology. By the time of the deaths of the key members of the Theoretical Biology Club in the 1970s and '80s, popular and more aggressively mechanistic concepts like sociobiology and selfish genes further muted the influence of organicism. The marginalization of the "third way" in the second half of the century, and Waddington's perpetual struggle for its recognition against conventional wisdom regarding gene-centric mechanism, is at the heart of chapters 9 through 15. Finally, an epilogue reexamines the present standing of epigenetics in light of its roots in organicism using the analytical tools of the digital humanities.

Given the status of epigenetics today, one might believe *The Life Organic* details a triumphal story of professional recognition and scientific celebration—a "comedy," as Hayden White once styled it. I should say up front that this is not that kind of story. Organicists did not join the pantheon of great biologists alongside Darwin, Pasteur, Medawar, and Crick.[19] Nevertheless, I believe this historical account enlightens our present conception of the living world. By the beginning of the twenty-first century, at the very moment that a new version of epigenetics was drawing significant popular attention and funding, developmental biologist Scott Gilbert and philosopher Sahotra Sarkar argued that the organicism of the early twentieth century needed to be dusted off and brought back into the conversation.[20] They join a cadre of other scientists and philosophers who together assert that there is something about the organic philosophy that deserves reclaiming in the twenty-first century.[21] *The Life Organic*, then, is their story as well.