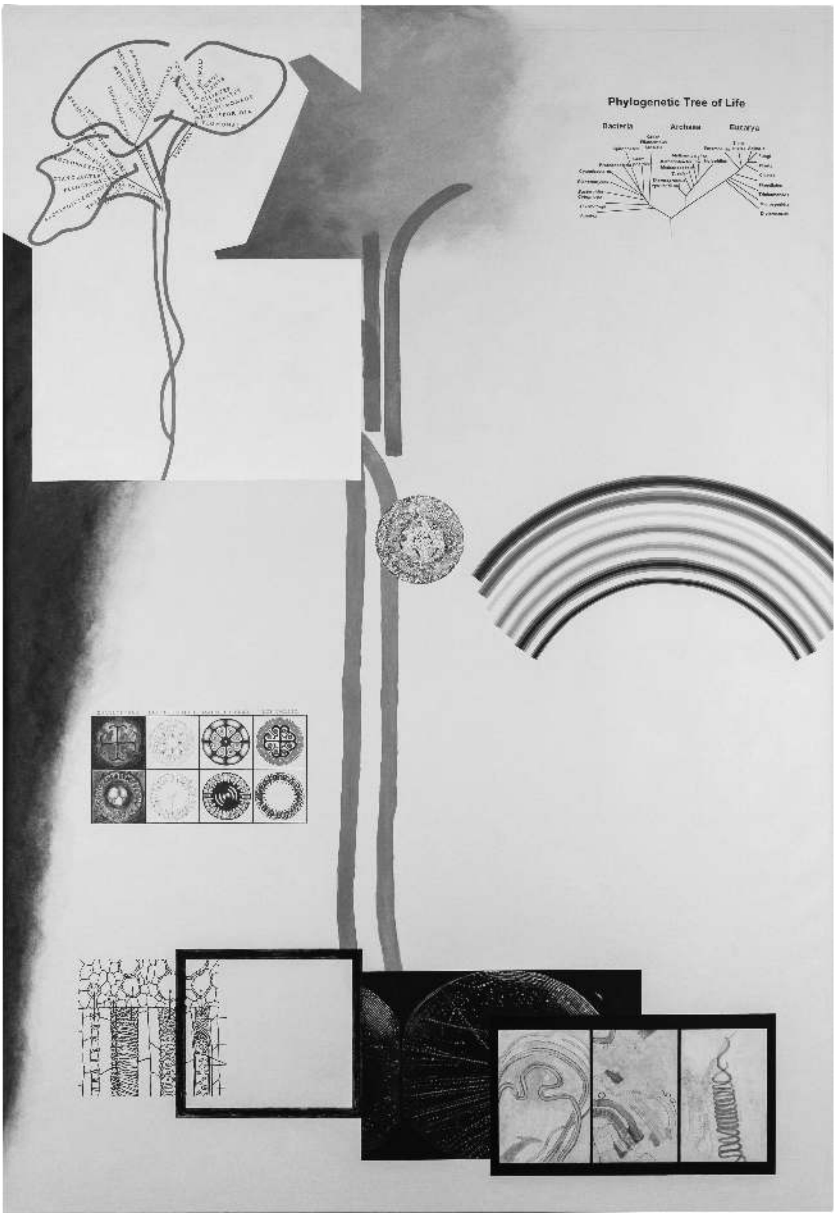

Figure 1.1. Plant Perception 2
A map of the perception of plants, including a cellular-level intersection of a plant stem (center) and a phylogenetic tree (based on work by Carl Woese, who used 16S ribosomal RNA to discover a new kingdom, or domain, of microorganisms – the Archaea). Shared ancestry and genetic hereditary systems connect the entire tree

1 · *Introduction*

As humans, we have a graspable identity that has been shaped by our individual and collective attempts to seek answers to fundamental questions: *Who am I? Where did I come from? Where am I going? Where and to whom do I belong, and how can I help myself and others?* The persistence of such questions may signal the insatiability of our human curiosity, but they also offer evidence of our possibly endless search for substantive, finite meaning. We yearn to identify who we are and to be part of something greater than our own limited individuality. This desire leads people to draw strong, even vicious, us-versus-them boundaries in political and social life. But it is also a spiritual wish to connect to all of humanity, indeed to all of life and the cosmos, and to take benevolent action accordingly (Figure 1.1, chapter opener). Even when answers to our questions about identity prove inconclusive, changeable, or otherwise unsatisfying, our search continues apace.

In our quest for identity, we often discover that in addition to being an active and intentional *subject*, we are perhaps as much a passive *object* dancing to the tune of greater forces of many kinds – familial, social, political, ecological, and even spiritual. In fact, the search for identity and

Caption for Figure 1.1. (*cont.*) of life, not just eukaryotes. The rainbow represents light, photosensitivity, and how plants can orient themselves by identifying colors. On the left is a schematic image of electromagnetic patterns in the development of a vegetable; in *Clavis Medicinae Duplex*, Carl Linnaeus concludes that all life consists of bark, marrow, and electricity. The depictions of xylem and phloem, osmosis, and cell morphology at the bottom reflect Nikola Tesla's attempts to decipher electrical brain waves. Ödlund keeps a black frame empty, opening our imagination for speculation on connection, intelligence, and the possibility of communication with other life forms – the privilege of the artist. (Co-written with Ödlund.) *Plant Perception 2* by Christine Ödlund (2015), painting. Copyright by the artist. Photo by Christian Saltas. Reprinted with permission. (A black and white version of this figure will appear in some formats. For the color version, please refer to the plate section.)

belonging can become especially urgent when these greater forces for maintaining identity are weakened. We see this in the worker who has lost her job, the refugee who has lost his state, or in the individuals who are discriminated against due to basic sexuality or ethnicity. Threats to our identities force us to a radical outside, like a fish out of water.

Who am I? This fundamental question is so central to religious and philosophical traditions across the globe because it suggests discoverable origins: *Where did my talents, skills, and weaknesses come from? Where did my ancestors, and my family, come from? Which group(s), not to mention ethnicities or tribes, might have a claim on me? Why do I have the body I have?* It also suggests fungibility and futurity: *Can I change? Can I freely alter any of the talents, skills, and weakness that originated within me? Now? Later?* So many of us, across varied cultural contexts, have sought answers both in and outside ourselves, in appeals to the soul, supernatural creation, or human nature. We look to religion, to philosophy, and to other sources for the possible causal powers and explanations we seek.[1]

Of course, we also look to science. Indeed, some of the most fecund and provocative answers to our questions of origins have been pursued within the natural sciences. In the West, the field of natural science dates back to the Greeks and the very origin of reason and philosophy, but it was rebooted in the seventeenth century, when the founding of the British and French academies of sciences in the 1660s helped usher in the Scientific Revolution. Physics, chemistry, and physiology were reborn and became newly applicable to humanity's age-old questions. Discoveries and inventions furthered our search. In England, Isaac Newton (1643–1727) articulated the universal law of gravitation and was a co-developer of calculus; Robert Boyle (1627–1691) and Robert Hooke (1635–1703) invented the air pump to create a partial vacuum and thereby started articulating the physical laws of heat and work; and William Harvey (1578–1657) discovered closed blood circulation in the body of many animals, including humans. Scientific theory and experiment took up new meanings. Mathematics became the theoretical gold standard for developing explanations, predictions, and understanding. Controlled and idealized experiments, with the air pump as a paradigm, came to be seen as central to acquiring scientific knowledge.[2]

[1] A useful text is Partridge (2018).
[2] See Shapin and Schaffer (1985), Shapin (1996), and Dear (2019).

Natural science, in both content and method,[3] has proven effective in providing the platform and tools for understanding how the world works. By measuring objects and processes of many kinds, organizing and managing data, and postulating and abstracting out hypotheses, models, and theories, science builds integrated best guesses of why and how the causal swirls within and outside us happen. Background theory and empirical information feed on each other, and novelty and discovery emerge. Science is partial, dynamic, and a communal effort of inquiry. We use it to answer questions of all kinds, including those that concern us about ourselves and each other.

However, philosophy also supplies an avenue for pursuing answers to our questions of identity. Viewed as the practice of asking big questions about the nature of knowledge, reality, and human life, and as a set of methodologies for answering such questions, philosophy may not provide answers, but it certainly helps clarify our questions. As a historical intellectual tradition, it, too, can be traced in the West back to ancient Greece, where it was inseparable from science. Among the important questions posed by ancient and modern philosophers alike, philosophy helps us to ask and answer these questions:

- Why is there something rather than nothing?
- Are ideas real? And if so, how so?
- What is human nature? Is it anything?
- How is knowledge justified and tested?
- What is the relation between theory and experiment, and theory and data?
- What is it to be rational?
- How might thoughts and feelings relate?
- What is happiness? What is wisdom? What is suffering?
- What do we owe to each other? To nonhuman animals? To nature?
- What is the role of science in a just and fair society?
- Are we free? What should we do with our freedom?
- Does God or gods or any kind of spiritual dimension of reality exist? How might spirituality influence us?

These are not questions easily solved: Nearly all of us think about some of them occasionally – or we almost certainly did as children or teenagers, even if we now keep them in a glass jar in the back of our heart's closet.

[3] See, e.g., Hacking (2002), Longino (2002), and Winther (2012a, 2020a).

Some of us study these questions professionally. We see philosophy as a medium by which to ask questions, and by which to trouble or nuance our answers. Why? Because, in the words of John Dewey, "philosophy is criticism":

> criticism of the influential beliefs that underlie culture; a criticism which traces the beliefs to their generating conditions as far as may be, which tracks them to their results, which considers the mutual compatibility of the elements of the total structure of beliefs.[4]

When asking big questions, we return to the fundamental issues of our existence and our identity. When we ask big questions critically, we refuse to automatically accept the answers handed to us by tradition, society, or family. As British philosopher Bertrand Russell said:

> Philosophy, though unable to tell us with certainty what is the true answer to the doubts which it raises, is able to suggest many possibilities which enlarge our thoughts and free them from the tyranny of custom. Thus, while diminishing our feeling of certainty as to what things are, it greatly increases our knowledge as to what they may be; it removes the somewhat arrogant dogmatism of those who have never travelled into the region of liberating doubt, and it keeps alive our sense of wonder by showing familiar things in an unfamiliar aspect.[5]

Far from existing cleaved from natural science, philosophical questions help drive the development of science. Albert Einstein (1879–1955) asked penetrating questions about space and time, energy, and matter as he developed his two relativity theories.[6] Isaac Newton's conceptual questions about what makes for a proper and effective theory, and what confirms a theory experimentally, were central to his own mechanistic project and to his great influence during the Scientific Revolution and beyond. In fact, the philosophical cadence of *Who am I?* and related questions about identity, origins, futurity, and fungibility have a special relation to the sciences of life and mind. In addition to the variety of creation stories about how humans came to be, and to the religious narratives that seek to explain human nature, such questions have explicitly driven work on evolution and genetics. Questions about our features, our personalities, and our predilections, and about the nature and dynamics of the groups and collectives to which we each belong in

4 Dewey (1985 [1931], p. 19).
5 Russell (1997 [1912], p. 157).
6 See Galison (2003) and Ryckman (2017).

multiple ways, are central to the birth and progress of evolutionary theory from the nineteenth century onward.[7] Indeed, human evolutionary genomics offers a particularly rich, if also necessarily limited, way to explore philosophical questions about why we – and not just *we*, but other life forms, as well – are as we are, and why we desire what we desire.

⋆⋆⋆

This book sits at the crossroads of natural science and philosophy. In it, I zoom in on crucial causal objects that help co-make who we are – genes. I argue that the field of human evolutionary genomics in general, and the study of genes in particular, permits researchers, critical thinkers, and the lay public to integrate and substantiate philosophical questions about identity and collectivity within the natural sciences. After all, genetics and genomics ultimately concern processes of the emergence, as well as the potentials and limits, of our bodies, our minds, and our selves. Through the study of genes, we learn more about who and what we are, and who and what we are not.

The scientists who brought forth genetics and statistics in the nineteenth and twentieth centuries were, like us, motivated by their curiosity about questions of origins and evolution. They were also, like us, driven by a political desire to intervene in society. Early men of genetics seem to have assumed the superiority of a specific class of educated, moneyed, white male Anglo, as well as the ubiquity of strongly heritable differences in physical features and cognitive capacities among individuals. Their work reflects that. Some, especially Francis Galton (1822–1911) and his protégé (and a committed socialist) Karl Pearson (1857–1936), promoted eugenic discoveries that proved profoundly problematic in ideation and execution.[8] Others, like strongly left-wing J.B.S. Haldane (1892–1964),

[7] Although *evolutionary genetics* and *evolutionary genomics* are used somewhat interchangeably throughout the book, they mean different things. Whereas evolutionary genetics (or population genetics) is more the mathematical evolutionary theory first developed by, especially, R.A. Fisher, Sewall Wright, and J.B.S. Haldane and integrated into the "modern synthesis" of Darwinian evolutionary theory and chromosomal, material genetics by their less mathematically inclined colleagues (e.g., Theodosius Dobzhansky, Julian Huxley, Ernst Mayr, and George Gaylord Simpson), evolutionary genomics is more about the data-driven knowledge surrounding demographic, genealogical, forensic, and medical applications of contemporary genomics (see the glossary at the end of Chapter 2).

[8] As just one peek into their contributions to the history of statistics, Galton discovered, not to say invented, the very concept of *correlation* between two statistical variables, and Pearson developed the chi-square test of statistical significance.

worried about the medical promises and perils of genetics. It cannot be forgotten that eugenic views, so prevalent among geneticists until roughly World War II, cut across the political spectrum, from left to right.[9] In our age of hopeful diversity and equality, we justly find many of these pursuits morally suspect, if not reprehensible. Yet our contemporary investigations into the discoveries these researchers made offer insight into the questions we continue to ask of science and of philosophy about the origin and nature of body and mind, over evolutionary time and over our individual and collective lifetimes.

Biological scientists and practitioners like those mentioned above were as obsessed with questions of identity, of ancestry, and of futurity as we are today. They sought answers not in religion or philosophy, but in measurable analyses, especially as applied to questions about nature versus nurture. Statistics offered a stable, operational tool with which to locate continuity and ascertain the future. In the hands of R.A. Fisher (1890–1962), in particular, efforts to hone statistics through interpretation and application resulted in the development of evolutionary genetics. Of course, we have learned much since this time. In particular, we have learned (and continue to learn) that statistics cannot fix the future, in the sense of either prediction or repair. It is a tool, and as such it has and will always be used to serve explicitly political, and therefore limited, ends.

Nonetheless, statistics helps us negotiate the space between what is measurable and what is unmeasurable. This is to say, statistics constructs one bridge between the meaningful and knowable on one side *and* the meaningless or unknowable on the other. Its earliest inventors and practitioners likely grasped this, applying statistics to the space and links between similarities and differences, individuals and populations, and past, present, and future, to find answers to their most persistent questions. The answers yielded by statistics are necessarily partial and therefore fraught. In fact, the essential limitations of statistics informed the field of evolutionary genetics: Even today, evolutionary genetics is frequently understood in terms of a history theorizing and emphasizing eugenics, race, and IQ. The so-called IQ wars, which made evolutionary genetics culturally important, stand as a case in point: In 1969, on the political right, Arthur Jensen (1923–2012) argued for *intelligence* as a legitimate scientific concept and trait, of which genetic variance both across and

[9] See Paul (1984).

within populations is highly explanatory and predictive. In the early 1970s, Richard Charles Lewontin (1929–2021), and later, Stephen Jay Gould (1941–2002), responded from the left, arguing for the effective irrelevance of genetic variance to intelligence. Meanwhile, *intelligence* itself came to be seen as a problematic and ambiguous property and process to define. The IQ wars raged half a century ago, but the debates, which continue to this day, as we shall see in Chapters 8 and 9, help illustrate the limits of the field.

Evolutionary genetics is not just a limiting lens, however. We can also use genetics and genomics – fields dedicated to human variance and difference – to *expand* rather than contract our knowledge of human identity and origins, particularly in terms of understanding community, connectivity, and collective and individual potentials. When released from the political agendas in which they are often trapped, genetics and genomics, informed by statistics, can tell us incredible things about ourselves and other species. We can learn about the past through the study of our ancestral populations; we can learn about the present through the study of our individuated and yet common experience with our bodies and minds, their presentations, and their degradations; we can learn about the future through the study of adaptation to extreme environments, the genetic basis of diseases, sexualities, and cognitive capacities, and the way genes and environment richly interact during the history and development of the individual.

Because evolutionary genomics provides a varied candidate set of answers – ranging from contemporary "genetic reductionists" and "genetic determinists" emphasizing selfish genes and human nature (Richard Dawkins and Steven Pinker) to "group selectionists" and "developmental interactionists" defending a complex human reality of genomes, brains, and bodies in social and cultural environments at many emergent levels of analysis (David Sloan Wilson and Richard Lewontin) – to our deepest questions about our place in the world. Because of this, the field has, can, and will continue to address the questions growing out of that kernel query *Who am I?* in political and politicized ways. Further, reasonable questions remain about the best interpretation of genomic data, statistical analyses, and theoretical results; the role of assumptions and other background context in theoretical development and mathematical modeling; and the nature of self, causation, and equality, given genomic results.

Ultimately, human evolutionary genomics can tell us much about who we are as individuals and as a collective or collectives. But also, and as I make clear throughout *Our Genes*, it has limited power in fully answering some of our deepest questions. The *population* is that entity which, according to biologists, *evolves*. Over the past few decades, experimental and diagnostic technologies across the life sciences and biomedicine have grown, and computational machinery has greatly increased in power and capacity. The study of the genomics of populations – especially human populations – has therefore also evolved in many new theoretical and conceptual directions, including:

- developing fundamental Darwinian evolutionary theory;
- reconstructing the evolutionary history within and among species, both extinct and extant, and even the entire tree or network of life;
- suggesting consequences of various conservation actions for biodiversity (and other ecological measures and metrics);
- enabling inferences about human population history and demography, including the history and demography of other species in the genus *Homo* and beyond;
- studying the structure of human genomic variation for biomedical or neuroscientific purposes (e.g., disease etiology identified through genome-wide association studies, or GWAS);
- assisting an understanding of the role of genes in development;
- identifying genes that are targets of natural selection, for example, genes increasing survival and reproduction in epidemics and pandemics, at high latitudes or elevations, or underwater;
- inferring the ancestral populations for a given individual (e.g., 23andMe or AncestryDNA); and
- assessing candidate suspects in forensic criminology.

In the pages that follow, and in an effort to produce yet more answers to questions about identity, origin, and community, we shall try to make sense of the accelerating work emerging out of theoretical population genetics and human genomics, including biomedical genomics. Geneticist Kärt Tomberg brought to life genetic methods and concepts in her painting *Acrylic Genetics* (Figure 1.2). My main perspective is *population-level phenomena*: I want to know how much individuals differ genetically, both within their own groups and populations, and with respect to very different groups and populations, such as those on other continents, and how this difference is measured, and what it means. How can we use comparative studies of individuals – twin studies or genome-wide association studies (GWAS), for instance – to draw inferences about the relative causal role of genes and environment (or their interaction) in

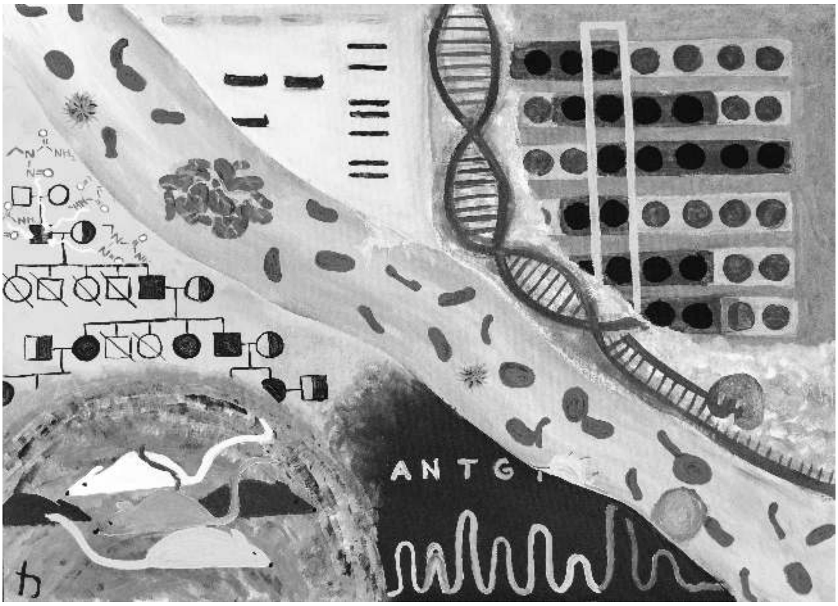

Figure 1.2. Acrylic Genetics
The blood vessel in the center of the painting contains a thrombus, the phenotypic target for Tomberg and her collaborators' genetic screen. The painting's left side illustrates a pedigree generated from a male mouse following treatment with the chemical mutagen ENU (red or gray formula) as well as a DNA sequence tracer sequence (the bottom curves, with corresponding nucleotide sequence, where "N" indicates unknown or error), with a representative ENU-induced DNA variant sequence. The right side of the painting depicts (left) electrophoretic genotyping and (right) genetic region mapping across experimental mice to identify the causal gene variant. *Acrylic Genetics* by Kart Tomberg (2018), painting. Copyright by the artist. Reprinted with permission. (A black and white version of this figure will appear in some formats. For the color version, please refer to the plate section.)

building the individual's observable characteristics, or about the relatively recent human history of migrations and invasions over the past 12,000 years or so, or about the deepest origins of *Homo sapiens* and our nearest kin species and subspecies? How can we design studies and experiments using model systems such as mice or fruit flies, informed by necessarily limited interpretive frames, and assay different human populations for genetic susceptibility to disease, to try to develop medical diagnoses and treatments? By pursuing answers to these questions, we stand to learn much about our ancestry and population structure. We also stand to gain a view into the future of human evolutionary genomics, including its