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Introduction

To my childhood ears, my dad sounded like an alien. While my brother and I were wrestling in the living room or eating breakfast, our father would pick up the phone and proceed to vocalize a string of mysterious sounds. From overhearing these conversations, we eventually figured out that *ema* meant mother (he was talking to Grandma), and when Grandma scolded us with *paha poiss!* the meaning was clear enough (bad boy!). But otherwise, Dad and Grandma could carry on in total secrecy. They were speaking Estonian.

The Cheerios box on the breakfast table presented its own set of mysteries. A groggy, disheveled, hungry child who has just rolled out of bed tends to stare blankly over their cereal bowl at whatever is right in front of them. I must have read that ingredient list thousands of times. On one side of the box, it said oats, corn starch, sugar, and salt, along with a handful of other items with peculiar names. (I still don't know what tocopherol means without looking it up.) On the other side of the box—in Canada—it said *avoine entière*, *amidon de maïs*, *sucre*, and *sel*. I congratulated myself on identifying the connection between *sucre* and sugar, and between *sel* and salt, and I drew the obvious conclusion that knowing English might help me make sense of roughly half the French language.

My childhood adventures with language got stranger still on Friday nights at my aunt and uncle's house. For Estonian and French, I could see the same basic alphabet I knew from English. But when one of my cousins opened the Torah for a short reading before Shabbat dinner, not only did I fail to understand the spoken words, I couldn't even guess at how to pronounce the Hebrew symbols on the page. It didn't help that they were being read right to left. I had memorized a decent bit of the short blessing phonetically (*Baruch Atah Adonai . . .*), but the sounds held no more meaning to me than the end of the Beatles' song "Hey Jude": *Naaa Naa Naa, Nanana Naaa*.

I like to think that even as a child I could have ranked these four languages based on how similar they are to one another. Starting with English, French is most similar, followed by Estonian, and then Hebrew. A good teacher could have even nudged me to organize them into a genealogical tree, much like I might have done for my siblings and cousins, tracing our ancestry back to parents, grandparents, and so on. My language tree might have looked like figure 1.1. The visual immediately suggests the idea that once upon a time there were other languages from which the current set originated, and that the most recent ancestor shared by English and French (the rightmost circle) was spoken more recently than the common ancestor of all four languages (the circle at the left). The tree also suggests that languages must change drastically over time—enough to produce English and Hebrew from the same starting point—an idea that clashes with a child's sense that the vocabulary and grammatical rules of their mother tongue are fixed and enforced for all eternity by an evil cabal of teachers with red pens. So, what do the experts think?

Few topics have sparked the interest of researchers as much as language. As long as one is exposed to only one language, the *concept* of language goes largely unnoticed. But once exposed to multiple languages, it is near impossible not to feel a certain curiosity and wonder at the equally profound differences between languages (I can't understand a word those people are saying) and their essential sameness (they seem to be communicating just like I do). The differences can create frustration, but also a strong motivation to learn.

Sir William Jones was a prolific learner of languages. Born in London, England, in 1746, he went on to learn more than a dozen languages, including Greek, Latin, Hebrew, Sanskrit, and German, along with his native English and Welsh. Having studied languages as a child and as a

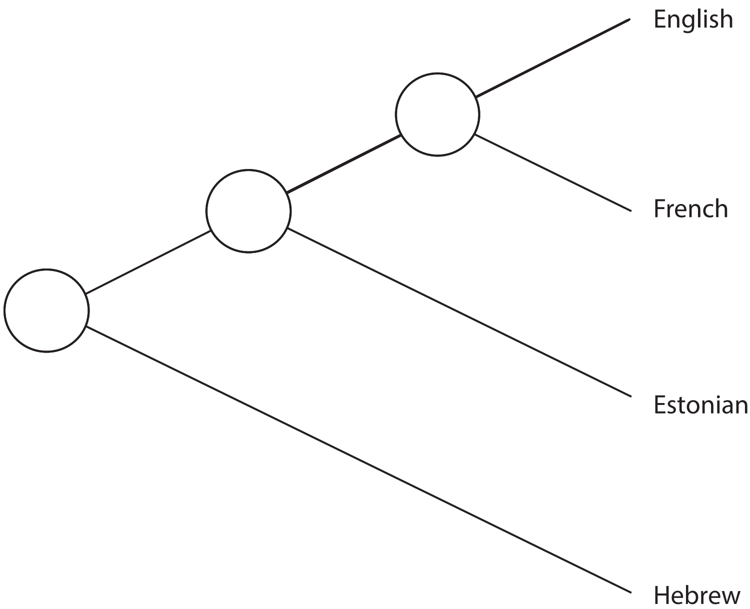

FIGURE 1.1. A child's-eye view of language similarities.

student at Oxford, Sir William later became a judge in Calcutta, India, and a reputed scholar of philology—the historical study of languages. His intimate knowledge and analysis of many languages led him to the striking insight that modern languages could indeed be traced back in time to common ancestors, a conclusion that ran counter to some contemporary ideas about languages being designed and fixed in time, divinely or otherwise. Speaking specifically of Sanskrit, Greek, and Latin, Jones said that "no philologer could examine them all three, without believing them to have sprung from some common source, which, perhaps, no longer exists."

Following Jones's lead, for the past two centuries linguists have analyzed how and why languages change over time. Some kinds of change follow systematic patterns—that is, they are more than random happenstance. For example, across hundreds of different languages, the most frequently used words tend to be the shortest (in English, think of *a*, *the*, and *of*), and the longest words are hardly ever used (try slipping "antidisestablishmentarianism" into your next conversation). This tendency is known as Zipf's law of abbreviation, named after the American linguist George Kingsley Zipf, who brought it to wide attention in the 1930s. Other kinds of consistent trends in language evolution had been identified in the first half of the nineteenth century by German philologists, such as Jacob Grimm (these are called Grimm's laws).

These regularities tell us that some language variants provide systematic advantages over others in terms of the efficiency of speech and communication. Other changes seem to be without rhyme or reason. When my Canadian ears hear a British person saying "lorry" or "trainers," it takes me a second to connect these words with "truck" and "running shoes." But there's no obvious advantage to wearing running shoes instead of trainers just because my feet are in North America. Still other changes can be traced to the movement of whole words or phrases from one language to another. When English was still the only language I could speak, my vocabulary nonetheless already included a few bits of French (*bon appétit, hors d'oeuvre*), a language I can now speak reasonably well, and even Yiddish (*klutz, schmooze*), which I never learned.

Individually, each of these observations about language is unremarkable. But if you put them together and look at them with blurred vision—abstracting from the details—in fact they contain all the ingredients needed to understand evolutionary change in a way that applies well beyond languages. When most people think of evolutionary change, they first think of Charles Darwin, who is credited with presenting the modern theory of evolution in his book *On the Origin of Species* (1859). As we shall see, however, the core ideas go back much further, and the fact that we draw a tight association between evolution and biology—instead of also including language and other aspects of culture—is due to a quirk of history. To see what I mean, let's rewind to the mid-nineteenth century for a thought experiment.

An Imaginary Scholar

Imagine a clever young mind circa 1850, digesting the observations about language just laid out. Intrigued by their sameness and differences, she is devising a theory of language change. How did we get from one or a few early languages to thousands of mutually incomprehensible tongues? What kinds of processes got us from the English in a Shakespeare sonnet to the English in a Charles Dickens novel? She was aiming for something that applied to any and all languages, and her theory had several components.

First, for meaningful change to happen in language, one or more sources of novelty are required. We need new variants for things to change. No problem: People experiment with language all the time. We are constantly trying out new pronunciations or meanings of old words, inventing words for new discoveries or technologies, altering the ordering of words in phrases, and so on. Before there were knives, engines, and bicycles, those words—or at least certain meanings of them—didn't exist. In short, there are plenty of ways in which people produce new language variants.

If language changes are to accumulate over time, rather than just disappearing as quickly as they appeared, we also need a means by which new variants can be passed on from one person to another. That is, we need a mechanism of inheritance. Learning fits the bill here. Everyone learns their mother tongue from parents, relatives, teachers, friends, acquaintances, and written materials (to which we can now add recordings and broadcasts). We can inherit language variants from any one of these influences, and then pass them on to our own children, friends, students, and so on. Each person has a slightly different combination of influences, so the version of a language that any one of us speaks will be at least slightly different from everyone else's.

Next, we need to account for why some variants in a language never catch on (the French term *chien chaud* didn't manage to displace the anglicized *hot dog* in Québec), why some variants quickly become widespread ("app" has now largely replaced "software"), and why some formerly common variants are no longer used outside of literature class ("wherefore art thou Romeo"). As we saw from the tendency for the most common words to become the shortest ones, some changes are driven by a process of systematic selection among different variants, given that some variants do a better job than others at facilitating communication (it's easier to say "can't" than "cannot"). Other changes appear entirely random with respect to serving any function, allowing languages to drift apart haphazardly. *Hello* (English), *tere* (Estonian), *bonjour* (French), and *shalom* (Hebrew) are effectively equivalent greetings, none better than the others, just different.

Finally, to generate a diversity of languages, we need for people to be clustered into sufficiently isolated groups to allow differences to accumulate between them. Geography does the job here. Geographically isolated groups of people will come up with different modifications to a language, and as those changes accumulate over time, multiple languages will emerge where previously there was just one. It is unlikely that English, German, and Dutch would have diverged into distinct languages without some geographic separation between the groups of people speaking early versions of each. In addition, a small amount of movement might permit languages to both remain distinct while also influencing one another, via the borrowing of words, phrases, or structural features.

So far, our hypothetical nineteenth-century prodigy has a theory of language change requiring just a few ingredients: constant sources of new variants, a means of inheritance, two types of internal dynamics (selection and drift), and movement between populations that is constrained to some degree. Taking the thought experiment a step further, we can imagine that she also started to note some features of her nascent theory that indicated she might be onto something applicable well beyond language. Could other aspects of culture or life change according to the same recipe? The ingredients show some striking similarities with factors thought to be important in other areas of inquiry that were well-known or just emerging at the time.

In the eighteenth century, Adam Smith had described efficient economic markets resulting from variation among people in what they needed and what they had to offer, and systematic adjustments in their behavior (selection among alternatives) that maximized individual net benefit. At the dawn of the nineteenth century, naturalists like Jean-Baptiste Lamarck in France were steering explanations of biological evolution away from the divine and toward the natural. Lamarck invoked new traits arising (e.g., a giraffe stretching its neck longer) that offspring could inherit, slowly allowing species to adapt to their environments and to diverge in form and function from other species. Plant and animal breeders were enjoying great success in identifying potentially useful varieties and then serially mating and selecting the "best" ones to produce potatoes or sheep that were higher-yielding or better-tasting. Reading Smith, Lamarck, and others would have revealed some striking parallels between the forces of change in language evolution and those at work in economic markets and in biological species.

By the time she caught wind of two British naturalists—Charles Darwin and Alfred Russel Wallace—in a race to get the word out on their ideas about biological evolution in the 1850s, our intrepid scholar had already devised a Generalized Theory of Evolutionary Change. The theory applies to any *evolutionary system*, which can be defined by three key ingredients: (1) entities that vary one to the next in some characteristics; (2) some means by which characteristics can be passed on over time; (3) a variable degree of success among entities in passing on their characteristics. Languages, technologies, markets, plants, and animals all fit the bill. Restricted movement and the consequent (partial) isolation of different parts of the system—based on geography or other barriers—are often involved, but they are not *necessary* ingredients. Evolution can happen even in one small place.

Since she was excluded from intellectual discourse at the time, our imaginary scholar's thoughts and notes were all kept to herself; they did not survive to the present day. As a result, the elegant idea of Darwin and Wallace—having emerged as the winner in the competition of ideas—came to be known as *the* theory of evolution. But over the years, many other scholars have seen what she saw: Darwin and Wallace's ideas are better described as constituting *a* theory of evolution—one specific application of the generalized version. Indeed, Darwin himself noted the parallels between biological change and language change, taking inspiration from linguistics for his own theory. The economist J. Stanley Metcalfe captured the situation nicely: "Evolutionary theory is a manner of reasoning in its own right quite independently of the use made of it by biologists."

The Darwinian Distraction

Although the elements of contemporary evolutionary theory go back many centuries, these elements had not, in fact, been assembled into a Generalized Theory of Evolutionary Change by the early nineteenth century. This is why our scholar is imaginary. Credit for the first coherent, compelling, and ultimately successful theory of evolution is almost universally attributed to Charles Darwin (usually given more credit than Wallace), whose biological theory of evolution by natural selection was published in its full form in 1859. Few ideas have had as profound an impact on science and society as Darwin's, not only by advancing our basic understanding of life on Earth, but also by permanently unseating humans from their presumed position of supremacy among living beings. However, it is quite easy to imagine the same essential theory having been first devised for language or technology, rather than biology. In chapter 2 we will delve into the history of evolutionary ideas across many disciplines. For now, a quick summary of the modern theory of biological evolution helps to illustrate what I call the Darwinian Distraction.

The biologists to whom Darwin passed his theoretical torch have built an elegant mathematical theory that has stood the test of time in impressive fashion. The modern version of evolutionary theory in biology, often referred to as neo-Darwinism, involves random mutations in DNA, a molecule unknown to Darwin. Stretches of DNA that provide instructions on how to make proteins are called *genes*, and proteins ultimately do most of the things in cells that give organisms characteristics like their size, shape, color, or metabolism (their "phenotype"). Genes are passed on to offspring, so any change in phenotype that benefits survival and reproduction (fitness), such as antibiotic resistance in the face of antibiotics, will spread in a population. In essence, nature selects the variants best suited to local conditions, so we call it *natural* selection. Because this theory is so well worked out and widely applicable, it has frequently created a strong force channeling thinking about other manifestations of evolution toward analogies with the biological version. Such analogies can sometimes be fruitful, but sometimes they can do more harm than good.

The temptation to make direct analogies from biological concepts such as the gene, genome, or phenotype to components of other evolutionary systems is hard to resist. Language is a good example. The building blocks of DNA are frequently referred to as letters in a four-letter alphabet: A, G, C, and T, for Adenine, Cytosine, Guanine, and Thymine. These are four types of nitrogen-rich base that distinguish each link in the DNA chain. So, it seems like a stretch of DNA is kind of like one long text, in which case it should be a short step from neo-Darwinism to understanding evolutionary change in strings of letters from a twenty-six-letter alphabet (along with punctuation and spaces). But then, what's the equivalent of a gene? Maybe a word . . . or a phrase . . . or a sentence? And maybe the phenotype is the *meaning* of the word or phrase or sentence? Maybe. Maybe not. You can probably sense that we're already holding on by a narrow thread. Try taking the analogies much further and the thread snaps.

To be sure, linguists have meticulously dissected languages into many component parts, but attempting to map phonemes, morphemes, or lexemes onto codons, genes, or chromosomes is unlikely to lead anywhere but to some laughs at the bar (if you're a linguist, anyway). And if the analogy project falls apart for language, it barely gets off the ground for information technology or religion, both of which undergo the same essential kind of evolutionary dynamics. In short, starting with neo-Darwinian concepts in biology and working out from there via analogy distracts us from seeing the true breadth of application of evolutionary ideas. It is no more important to find analogies for genes outside of biology than it is to find an analogy for verb tenses in a genome. Analogy projects are also misguided in assuming that key concepts have clean, unambiguous definitions in biology itself. As we shall see throughout this book, biology is itself quite messy.

Although attempts at making precise analogies often lead to dead ends, there must be *some* comparable features of languages, technologies, plants, and animals if a generalized theory is to apply to all of them. The trick is to find the level at which comparisons work, which is unlikely if we start with one particular kind of system (e.g., a neo-Darwinian biological one) and then insist on finding analogies elsewhere (e.g., looking for genes in technology). Within evolutionary biology, general theories do not make reference to specific characteristics of animals like their blood or their teeth, since there are no such things in plants, fungi, or bacteria, and we expect the theory to apply to all of them. Instead, blood and teeth are considered as two examples of characters or phenotypes, and it is these more abstract concepts that allow biological evolutionary theory to apply to any measurable attribute of any organism. For a generalized evolutionary theory (within which biology is but one example), some clues as to the appropriate level of abstraction and comparison can already be seen in the definition of an evolutionary system given earlier: We will at least need the concept of an "entity" and some measure of their "success." While languages and species both share the essential features needed for evolution, we don't need gene-like things in language, we don't need verb-like things in biology, and we don't need to begin with Darwin.

Beyond analogies, there is a second important element to the Darwinian Distraction. In the social sciences—where scholars study human social relationships and culture—there is great potential for generalized evolutionary thinking, but just the word *Darwinian* can create a major distraction. Following the publication of Darwin's theory, it was quickly seized on to support racist ideologies, with arguments along the lines of it being only "natural" for powerful white men to subordinate everyone else. The field of eugenics was born with the aim of improving the human race by placing restrictions on who was allowed to reproduce. Nazi Germany was the pinnacle of evil invocations of "social Darwinism." A superficial analysis would suggest that we must heed the social dangers inherent in evolutionary thinking. However, social Darwinist projects actually involve misrepresentations of evolutionary theory, invoked to advance particular political agendas. One can be adamantly opposed to racist ideology and in favor of generalized evolutionary theory.

For more than 150 years, scholars have been hinting at, noting, or formally analyzing the potential for generalized evolutionary theory. But almost all such efforts begin with a focus on Darwin. Evolutionary biologist Richard Dawkins proposed "Universal Darwinism," while others prefer "Generalized Darwinism," with book titles referring to "Darwin's conjecture," "Darwin's dangerous idea," "the second Darwinian revolution," or "how Darwinian theory can explain human culture and synthesize the social sciences." Subsequent discussions can become mired in distracting analogies or knee-jerk objections to any sentence combining "Darwin" and "social." This book is an attempt to break free from the Darwinian Distraction and to show that a generalized theory can be applied to all evolutionary systems. In the realms of life and culture, *everything* evolves.

Two Kinds of Science

Generalized evolutionary theory cuts across what has traditionally been the biggest and seemingly most fundamental disciplinary boundary in science: the one between the natural and the social sciences. The natural sciences include physics, chemistry, biology, and their extensions, such as astronomy, biochemistry, and ecology. The social sciences are about people, with subdisciplines that include sociology, economics, history, political science, and anthropology. Generalized evolutionary theory not only cuts across the natural-social divide, but it suggests a very different fundamental feature that distinguishes different branches of science.

Within the natural sciences, there is conceptual unity between physics and chemistry, because chemistry is essentially physics applied to molecules. This unity also extends part way into biology: If you want to know what makes your muscles feel sore the morning after a day of intense exercise (physiology), how lizard feet stick to walls (biophysics), or how plants make sugar out of air and water (molecular biology), the answers will be expressed in terms of physics and chemistry. Other parts of biology fall outside of this sphere of unity. If you want to understand how the world came to have humans, lizards, or plants in the first place, physics and chemistry are of little help. What you need for that is evolution: the process by which the generation of variation, inheritance, and differential success lead to exquisite adaptations. And as it turns out, the very same general process of evolution—this time in the social and cultural realm—explains how human societies came to have the English language (linguistics), gender roles (sociology), central banks (economics), democracy (political science), and iPhones (technology). In other words, there is a more meaningful divide in science than the natural-social one. On one side, there are questions that can be answered entirely with reference to physical processes. On the other side are questions for which answers require the addition of evolutionary processes.

So, if evolution is the key distinguishing feature of systems that can't be reduced to physics alone, then perhaps there are two—and only two—truly fundamental branches of science. Physics can be considered the first branch, held up by historians and philosophers as the paragon of scientific achievement. Physicists and chemists have identified a set of laws from which they can understand and predict the behavior of everything from planets and continents to atoms and subatomic particles. We can call this the "First Science." The second fundamental branch of science is the science of evolution, applying to everything from coronaviruses to computers. Biologist Graham Bell has dubbed this the "Second Science." The proposition is that physics and evolution together can explain everything. But in explaining how life and its products came to be as they are now, the First Science has but a supporting role to play. The lead actor in that play is the Second Science.

Even if most people (this author included) do not fully understand the laws of physics, especially at a subatomic level, no one can say that the universality of these laws is underappreciated. With Albert Einstein as the personification of science and genius, the First Science gets plenty of limelight. The Second Science, not so much. To be sure, Charles Darwin occupies rarefied air like few others in the scientific pantheon, but the idea of evolutionary systems is mostly seen to be left behind once you exit the confines of biology. As a biologist, my own students have learned evolutionary theory as it applies to biology, but they are mostly unaware that folks on the other side of our university campus apply the generalized version of evolutionary theory to culture, language, and economics. Despite many decades of formal and informal application of evolutionary ideas, well beyond the borders of biology, the Second

Science—as a unified branch of science—remains in the shadows. The Second Science deserves greater recognition as one of the two pillars holding up the entire scientific enterprise.

If one is accustomed to thinking about scientific theories and models from the point of view of the First Science, the Second Science might seem a bit odd. Mathematical models in physics produce some long-term predictions of astonishing accuracy. In 1705 Edmond Halley used theories of gravity and planetary movement to correctly predict that one particular comet orbiting the sun—now known as Halley's Comet—would return to viewing distance from Earth in 1758. Using the same theories, we now anticipate the next closest visit of Halley's Comet to our sun on July 28, 2061. Evolutionary theory, in contrast, does not have a lot to say about the specifics of what will be happening on that day. We could say that between now and then, some of the currently rarest species will go extinct, while other species will look pretty much like they do now, notwithstanding some minor evolutionary changes. New technologies and technology companies will have arisen, displacing old ones, with products that are faster and more powerful. Teenagers will communicate using platforms that don't currently exist. While evolutionary models can make some very useful short-term predictions (e.g., the rate of spread of a new virus), over the long term, predictions get increasingly uncertain.

Evolutionary dynamics are fundamentally unpredictable because each step in the evolutionary process is contingent on the previous steps, and there are an astronomical number of possible pathways that can be taken. Consider the virus that causes Covid-19 (called SARS-Cov-2), which is quite simple as evolutionary systems go, with a genome of about 30,000 DNA letters. With four letters in the DNA alphabet, each one can be changed from its current state in three ways. So, if we randomly choose just one letter and switch it to one of the other three, there are 90,000 possible DNA sequences for the new genome. The next DNA change also has 90,000 possibilities, so looking two mutations ahead, there are 8.1 billion possibilities ($90{,}000 \times 90{,}000$). Similarly, with roughly 500,000 words or phrases in the English language (according to the *Oxford English Dictionary*), a sequence of two random changes to word or phrase meanings also generates billions of trajectories (500,000 × 500,000 = 250 billion). Evolution is fundamentally a process of trial and error, and it's hard to know what will be tried and which trials will stick around (or not).

So, if evolutionary theory doesn't make precise predictions about the distant future, what does it do exactly? Two things. First, the Second Science has excelled at teaching humanity the critically important lesson that the dynamics of biological and social systems involve some fundamental unpredictability in the long term, frustrating as this lesson might be to a physicist. Second, and more important for this book, the Second Science provides a unified theory for understanding how and why evolutionary systems change in general, for explaining what has happened in the past, and for anticipating, to some degree, possible changes in the future (with greater uncertainty the further you look ahead). Evolutionary systems include everything from languages and computers to viruses and whales, so achieving theoretical unification has not been easy. As mentioned earlier, the key has been to find the right level of abstraction, which requires a focus not on the differences among such diverse systems but on their commonalities.

The Second Science explains how we came to have not only eyes but also iPhones. It explains how different kinds of animals came to have different kinds of eyes, and why cell phones show so much diversity in form and function. In short, the Second Science helps us make sense of two of the most striking features of life and its products: their remarkable degree of adaptation for some function, and their diversity.

Everything Evolves: The Second Science Is Everywhere

The importance of the Second Science goes far beyond its role in underpinning our fundamental understanding of life and culture. In ways that are sometimes obvious, sometimes obscure, evolution lies at the core of countless human endeavors of profound importance. Whether consciously or not, people have been applying evolutionary principles for millennia. We have transformed wild plants and animals into the domesticated forms that make up most of our food supply. Cornfields in the United States now yield 700% more bushels per acre than they did one hundred years ago, a staggering increase achieved by selective hybridization and breeding (biological evolution under human selection) and the cultural evolution of agricultural practices and technology. We have produced some microbes that are little factories for the production of antibiotics or for the neutralization of harmful pollutants, and others that can eliminate pathogens that have evolved resistance to antibiotics.

Evolutionary principles are applied when developing all new technologies, whether a better kind of hammer or a space shuttle. The widespread idea that such technologies spring fully formed from the minds of lone geniuses is badly misguided. All such technologies have involved countless rounds of trial and error and gradual refinement via a profoundly evolutionary process: Ideas are generated, tested, and passed down to the next generation of inventors. The advancement of science is itself an evolutionary process, with each new theory built on the successes and failures of a long line of predecessors. Charles Darwin's theory of biological evolution by natural selection is a prime example, as is the perspective put forth in this very book. As the chemist Leslie Orgel once famously said, "Evolution is cleverer than you are."

One of the defining challenges for humanity in the twenty-first century will be grappling with the power of artificial intelligence, which is at its core an evolutionary algorithm. Artificial intelligence starts with scientists creating evolutionary systems in silico, allowing computers to evolve solutions to the thorniest of challenges, giving us self-driving cars, facial recognition software, and chatbots. Their level of "intelligence" can only be described as spooky.

With the accelerating movement of people, ideas, and species across the globe, the diversity of life and culture found in ecosystems, in cities, and in countries is changing rapidly. The Second Science guides us to an understanding of not only how and why diversity changes over time, but also what the consequences of such diversity might be for the productivity of economies or the stability of ecosystems. Evolutionary trajectories in economies, ecosystems, and political systems can sometimes involve tipping points—massive and difficult-to-reverse changes in response to a modest stimulus. Sparking and promoting social and political change and identifying tipping points we might like to traverse or avoid are also, at their core, applications of evolutionary principles.

All these topics—and many more—will be explored throughout this book. Their unifying feature is the same underlying process of evolution. The scientists, engineers, agronomists, politicians, businesspeople, health practitioners, and computer programmers working on these topics have a great deal to gain from recognition of a unified Second Science. Lessons learned in one corner of the Second Science (e.g., artificial intelligence) might have important lessons for others (e.g., selective breeding), but without a common language and conceptual framework, those lessons can go unlearned. In some parts of the world, there has been strong resistance to the teaching of evolution in biology, given a conflict between the idea of gradual evolution and the biblical account of the creation of life. In keeping evolution out of the classroom, we are robbing children not only of an understanding of how life works but also of one of the two fundamental kinds of process in science—the one that produces change in biological species, economies, cultures, technologies, and societies.

The rest of the book is structured as follows. Chapter 2 will establish the historical depth and disciplinary breadth of evolutionary thinking, from ancient history to the present, in disciplines ranging from linguistics and the philosophy of science to economics and biology. In chapter 3 I will more explicitly define evolutionary systems and establish the key concepts underlying the Second Science and their breadth of application. Next, we will delve into the core processes underlying the dynamics of all evolutionary systems: origination of variation, inheritance, selection, randomness, and movement (chapters 4–6). These chapters will lay out the essentials of the Second Science. The next three chapters will explore the profound importance of evolutionary thinking and understanding for human concerns and endeavors. Specific applications include artificial intelligence, animal and plant breeding, identification of system tipping points, and the causes and consequences of diversity of all kinds. Chapter 10 will step back and apply a wide-angle lens to seeing the importance of the Second Science and how it fits into the scientific enterprise as a whole.

Big-picture appraisals of science invariably gravitate toward physics as the epitome of success, with its universally applicable laws and models. Outside of physics is a jungle of more narrowly applicable and partially overlapping theories, among which we struggle to see common threads. Generalized evolutionary theory suggests that there is indeed a common core to all this. To understand the game of life and all its products, the First Science establishes the constraints, but the Second Science sets the rules.

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