

The Origin of Wealth



EVOLUTION, COMPLEXITY, AND
THE RADICAL REMAKING
OF ECONOMICS

Eric D. Beinhocker

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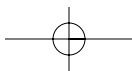
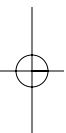
PART I



A Paradigm Shift

*It may be that universal history is
the history of a handful of metaphors.*

—Jorge Luis Borges, *Labyrinths*



The Question

HOW IS WEALTH CREATED?

I SAT PERCHED on a small ledge, with my back pressed against a dung wall, in the smoky center room of a thatched hut belonging to an elderly Maasai tribesman. The hut was in a remote village in southwestern Kenya. The Maasai elder, with his wise, weather-beaten face and sharp eyes, had been asking me polite questions about my family and where I came from. Now he wanted to get the measure of me. He fixed his gaze on mine across the cooking fire and asked, "How many cattle do you own?" I paused for a moment and then quietly replied, "None." A local Maasai teacher, who had befriended me and was acting as my guide, translated my reply. There was a murmur around the small room as various members of the village, curious about the stranger, digested this piece of information. After a few moments' consideration, the elder replied, "I am very sorry for you." But the pity evident in his voice and on his face was also tinged with puzzlement as to how someone so poor could afford to travel such long distances and own a camera. As the discussion turned back to questions about my family, I remarked that I have an uncle who once owned a large herd of cattle on his farm in Maryland. There was then a quick nodding of understanding as the mystery was solved—the visitor was clearly the ne'er-do-well nephew of a rich uncle, traveling and living off his relative's bovine wealth.

The Mysteries of Wealth

What is wealth? For a Maasai tribesman, wealth is measured in cattle. For most of the readers of this book, it is measured in dollars, pounds, euros, yen, or some other currency. Over two hundred years ago, the great economist

Adam Smith noted the rich variety of ways that people have measured their wealth throughout history: “In the [earlier] ages of society, cattle are said to have been the common instrument of commerce; though they must have been a most inconvenient one . . . Salt is said to be the common instrument of commerce and exchanges in Abyssinia; a species of shells in some parts of the coast of India; dried cod at Newfoundland; tobacco in Virginia; sugar in some of our West India colonies; hides or dressed leather in some other countries; and there is at this day a village in Scotland where it is not uncommon, I am told, for a workman to carry nails instead of money to the baker’s shop or the alehouse.”¹

Is wealth an intrinsic, tangible thing? Is there something inherent in cows, cod, and nails that gives them value? For a Maasai tribesman, the wealth embedded in his cattle is there for all to see. It provides him and his family with milk, meat, bone, hide, and horn. Yet, as Smith showed in his *Wealth of Nations*, wealth is not a fixed concept; the value of something depends on what someone else is willing to pay for it at a particular point in time. Even for a Maasai, the value of a cow today may not be the value of a cow tomorrow. For those who measure their wealth in the paper of currencies, wealth is an even more ephemeral concept. Most people in developed countries never see or touch the bulk of their wealth—their hard-earned savings exist only as electronic blips on a bank’s faraway computer. Yet those ghostly blips can be converted into the tangible goods of cows, cod, nails, or whatever else one desires (or can afford) with the swipe of a credit card or the click of a mouse.

But where does wealth come from in the first place? How does the sweat of our brows and the knowledge of our brains lead to its creation? Why has the world grown richer over time? How have we gone from trading cattle to trading microchips? This line of inquiry ultimately leads us to perhaps the most important mystery of wealth: how can we create more of it? We can ask this question out of narrow self-interest, but we can also ask the larger question of how the wealth of society can be increased. How can managers grow their companies to provide more jobs and opportunities for people? How can governments grow their economies and address issues of poverty and inequality? How can societies around the world create the resources needed for better education, health care, and other priorities? And, how can the global economy grow in a way that is environmentally sustainable? Wealth may not buy happiness, but poverty does buy misery for millions around the world.²

The questions this book will explore—What is wealth? How is it created? How can it be increased?—are among the most important questions for society

and among the oldest questions in economics. Yet, they are questions economics has historically struggled to answer. The thesis of this book is that new answers to these fundamental questions are beginning to emerge from work carried out over the past few decades. These new answers come not just from the work of economists, but also from biologists, physicists, evolutionary theorists, computer scientists, anthropologists, psychologists, and cognitive scientists. We will see that modern science, in particular evolutionary theory and the theory of complex adaptive systems, provides us with a radically new perspective on these long-standing economic questions.

In this chapter, I will outline the major themes of the book and give a brief preview of the ideas we will explore. But before we develop a new perspective on the answers, we need to shift our perspective on the questions. The economy is something most people take for granted in their daily lives and don't often think about. When we do think about the economy, it is often in the context of what Princeton economist Paul Krugman has called "up and down economics," as in "the stock market is up" and "unemployment is down."³ But we need to step back from the wiggling graphs of the economy's short-term ups and downs for a moment and consider the economy as a whole, as a system.

Humanity's Most Complex Creation

Take a look around your house. Take a look at what you are wearing. Take a look out your window. No matter where you are, from the biggest industrialized city to the smallest rural village, you are surrounded by economic activity and its results. Twenty-four hours a day, seven days a week, the planet is abuzz with humans designing, organizing, manufacturing, servicing, transporting, communicating, buying, and selling.⁴

The complexity of all this activity is mind-boggling. Imagine a small rural town, the kind of quiet, simple place you might go to escape the hurly-burly of modern life. Now imagine that the townspeople have made you their benevolent dictator, but in exchange for your awesome powers, you are responsible for making sure the town is fed, clothed, and sheltered each day. No one will do anything without your say-so, and therefore each morning, you have to create a to-do list for organizing all the town's economic activities.⁵ You have to write down all the jobs that must get done, all the things that need to get coordinated, and the timing and sequence of everything. No detail is too small, whether it is making sure that Mrs. Wetherspoon's flower shop gets her delivery of roses or that Mr. Nutley's insurance claim for his lumbago is processed. Even for a small town, it would be an impossibly long and complex list. Now think about what a similar to-do list might look like

for managing the global economy as a whole. Think of the trillions of intricately coordinated decisions that must be made every minute of every day around the world to keep the global economy humming. Yet, there is no one in charge of the global to-do list. There is no benevolent dictator making sure that fish gets from a fisherman in Mozambique to a restaurant in Korea to provide the lunch for a computer worker who makes parts for a PC that a fashion designer in Milan uses to design a suit for an interest-rate futures trader in Chicago. Yet, extraordinarily, these sorts of things happen every day in a bottom-up, self-organized way.

The most startling empirical fact in economics is that there is an economy at all. The second most startling empirical fact is that day in and day out, for the most part, it works. It provides most (but sadly not all) of the world's 6.4 billion people with employment, food, shelter, clothing, and products ranging from Hello Kitty handbags to medical lasers. If one thinks of other highly complex human-made systems, such as the International Space Station, the government of China, or the Internet, it is clear that the global economy is orders of magnitude more complex than any other physical or social structure ever built by humankind.⁶

The economy is a marvel of complexity. Yet no one designed it and no one runs it. There are, of course, CEOs, government officials, international organizations, investors, and others who attempt to manage their particular patch of it, but when one steps back and looks at the entirety of the \$36.5 trillion global economy, it is clear that no one is really in charge.⁷

Yet how did the economy get here? Science tells us that our history began in a state of nature, literally "without a shirt on our backs." Our immediate ancestors were hominid protohumans who had large brains and nimble hands and who roamed the African savanna not far from where I sat with the Maasai tribespeople. How did humankind travel from a state of nature to the stunning self-organized complexity of the modern global economy?

2.5 Million Years of Economic History in Brief

Intuitively, many people imagine that humankind's upward climb in economic sophistication was a slow, steady journey, a linear progression from stone tools to DVD players. The actual story, pieced together by archaeologists, anthropologists, historians, and economists, is not at all like that. It is far more dramatic.⁸

The story begins when the first hominids appeared on earth around 7 million years ago and their descendents, *Australopithecus africanus*, began to walk upright around 4 million years ago.⁹ By about 2.5 million years ago, *Homo*

habilis began to use its relatively large brain to begin making crude stone tools. We can think of these stone tools as the first products, and we can imagine that at some point two of our hominid ancestors, probably from the same band of close relatives, sat in the dust of the savanna and traded tools. We will use this very approximate point of 2.5 million years ago as the marker for the beginning of the human “economy.” It then took roughly another million years for *Homo erectus* to discover fire and begin to produce a wider range of tools made out of stone, wood, and bone. Biologically modern humans, *Homo sapiens*, appeared around 130,000 years ago and developed increasingly sophisticated and diverse tools. At some point—there is much debate on when—*Homo sapiens* evolved the critical skill of language. The economic activity of these first modern humans was primarily limited to foraging in roving bands of close relatives and to basic tool manufacturing.

It is not until around 35,000 years ago that we begin to see the first evidence of a more settled lifestyle, with burial sites, cave drawings, and decorative objects. During this period, archaeologists also begin to see evidence of trading *between* groups of early humans; the evidence included burial-site tools made from nonlocal materials, seashell jewelry found with noncoastal tribes, and patterns of movement suggesting trading routes.¹⁰ One of the great benefits of trade is that it enables specialization, and during this period, the record shows a dramatic increase in the variety of tools and artifacts. As Paul Seabright of the University of Toulouse notes, cooperative trading between nonrelatives is a uniquely human activity.¹¹ No other species has developed the combination of trading among strangers and a division of labor that characterizes the human economy. In fact, Richard Horan of Michigan State University and his colleagues argue that it was this unique ability of *Homo sapiens* to trade that gave them the critical advantage in their competition with rival hominid species such as *Homo neanderthalensis* (the Neanderthals), enabling our ancestors to survive while the other hominids became extinct.¹²

With permanent settlements, a variety of tools, and the creation of trading networks, our ancestors achieved a level of cultural and economic sophistication that anthropologists refer to as a *hunter-gatherer lifestyle*. From the archaeological record, we have some knowledge of how our hunter-gatherer ancestors lived and what their economy looked like, but we also have another rich source of information on this way of life. There are still a few very isolated places on earth where hunter-gatherer tribes continue to live with very little contact with the modern world, virtually unchanged from tens of thousands of years ago. Anthropologists think of these tribes as living time capsules of an earlier era.

A Tale of Two Tribes

Consider two tribes. First, we have the Yanomamö, a stone-tool-making hunter-gatherer tribe living along the Orinoco River on the remote border of Brazil and Venezuela.¹³ Second, we have the New Yorkers, a cell-phone-talking, café-latte-drinking tribe living along the Hudson River on the border of New York and New Jersey. Both tribes share the same thirty thousand or so genes that all humans do and thus, in terms of biology and innate intelligence, are essentially identical. Yet, the lifestyle of the New Yorkers is vastly different from the well-preserved hunter-gatherer lifestyle of the Yanomamö, who have yet to invent the wheel, have no writing, and have a numbering system that does not go beyond *one*, *two*, and *many*.

If we take a closer look at the economies of the two tribes, we see that Yanomamö employment is focused on collecting food in the forest, hunting small game, gardening a limited number of fruits and vegetables, and maintaining shelters. The Yanomamö also make items such as baskets, hammocks, stone tools, and weapons. They live in villages of forty to fifty people and trade goods and services among each other, as well as among the 250 or so other villages in the area. The average income of a Yanomamö tribesperson is approximately \$90 per person per year (this, naturally, is an estimate as they do not use money or keep statistics), while the average income of a New Yorker in 2001 was around \$36,000, or 400 times that of a Yanomamö.¹⁴ Without any judgments on who is happier, morally superior, or more in tune with their environment, there is clearly a wide gap in material wealth between the two tribes. The Yanomamö have shorter life expectancies than the New Yorkers, and during their lives, the Yanomamö must endure uncertainties, diseases, violence, threats from their environment, and other hardships that even the poorest New Yorkers do not face—one is eight times more likely to die in a given year living in a Yanomamö village than living in a New York borough.¹⁵

But it is not just the absolute level of income that makes New Yorkers so wealthy; it is also the incredible variety of things their wealth can buy. Imagine you had the income of a New Yorker, but you could only spend it on things in the Yanomamö economy.¹⁶ If you spent \$36,000 fixing up your mud hut, buying the best clay pots in the village, and eating the finest Yanomamö cuisine, you would be extraordinarily wealthy by Yanomamö standards, but you would still feel far poorer than a typical New Yorker with his or her Nike sneakers, televisions, and vacations in Florida. The number of economic choices the average New Yorker has is staggering.¹⁷ The Wal-Mart near JFK Airport has over 100,000 different items in stock, there are over 200 television channels offered on cable TV, Barnes & Noble lists over 8 million titles, the local supermarket

has 275 varieties of breakfast cereal, the typical department store offers 150 types of lipstick, and there are over 50,000 restaurants in New York City alone.

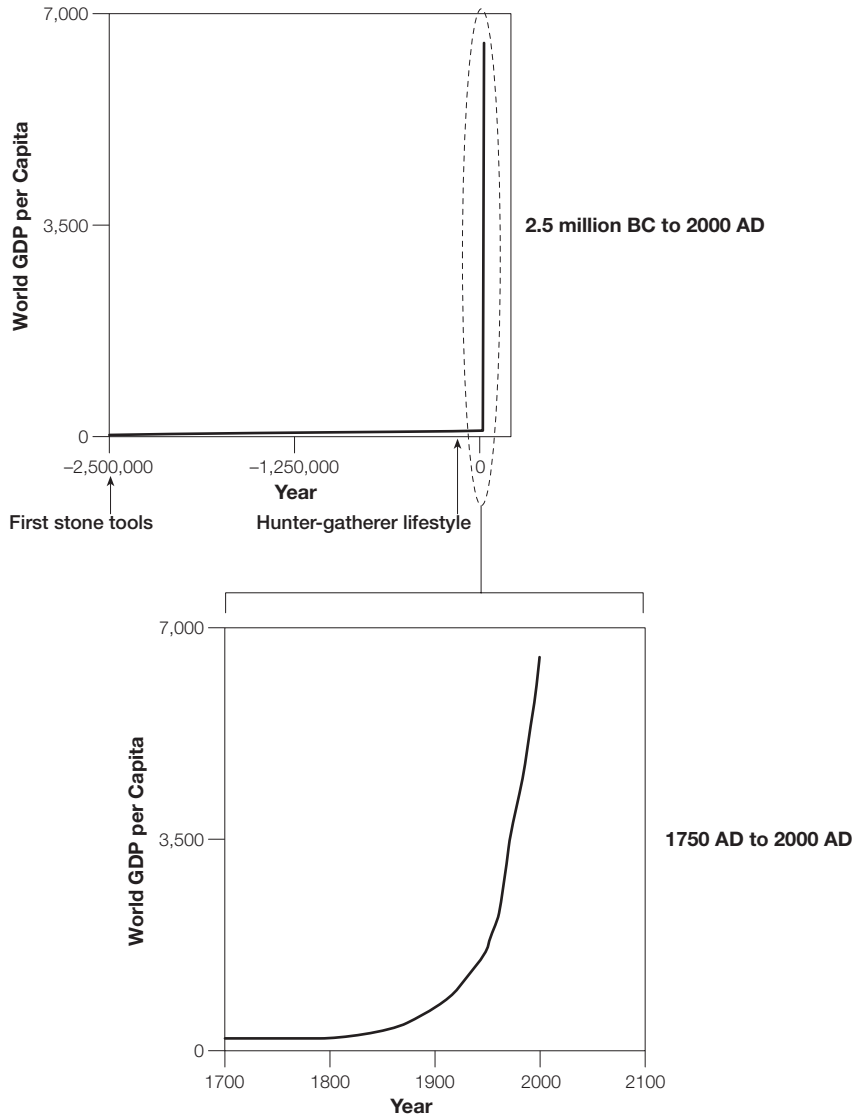
Retailers have a measure, known as *stock keeping units*, or *SKUs*, that is used to count the number of types of products sold by their stores. For example, five types of blue jeans would be five SKUs. If one inventoried all the types of products and services in the Yanomamö economy, that is, the different models of stone axes, the number of types of food, and so on, one would find that the total number of SKUs in the Yanomamö economy can probably be measured in the several hundreds, and at the most in the thousands.¹⁸ The number of SKUs in the New Yorker's economy is not precisely known, but using a variety of data sources, I very roughly estimate that it is on the order of 10^{10} (in other words, tens of billions).¹⁹ To put this enormous number in perspective, estimates of the total number of species on earth range from 10^6 to 10^8 . Thus, the most dramatic difference between the New Yorker and Yanomamö economies is not their "wealth" measured in dollars, a mere 400-fold difference, but rather the hundred-million-fold, or eight orders of magnitude difference in the complexity and diversity of the New Yorkers' economy versus the Yanomamö economy.

The lifestyle of the Yanomamö is fairly typical of our ancestors circa 15,000 years ago.²⁰ This sounds like a long time ago, but in terms of the total economic history of our species, *the world of the Yanomamö is the very, very recent past*. If we use the appearance of the first tools as our starting point, it took about 2,485,000 years, or 99.4 percent, of our economic history to go from the first tools to the hunter-gatherer level of economic and social sophistication typified by the Yanomamö (figure 1-1). It then took only 0.6 percent of human history to leap from the \$90 per capita 10^2 SKU economy of the Yanomamö, to the \$36,000 per capita 10^{10} SKU economy of the New Yorkers.

Zooming in for a more granular look into the past 15,000 years reveals something even more surprising. The economic journey between the hunter-gatherer world and the modern world was also very slow over most of the 15,000-year period, and then progress exploded in the last 250 years. According to data compiled by Berkeley economist J. Bradford DeLong, it took 12,000 years to inch from the \$90 per-person hunter-gatherer economy to the roughly \$150 per-person economy of the Ancient Greeks in 1000 BC.²¹ It wasn't until 1750 AD, when world gross domestic product (GDP) per person reached around \$180, that the figure had finally managed to double from our hunter-gatherer days 15,000 years ago. Then in the mid-eighteenth century, something extraordinary happened—world GDP per person increased 37-fold in an incredibly short 250 years to its current level of \$6,600, with the richest societies, such as the New Yorkers, climbing well above that.²² Global wealth rocketed onto a nearly vertical curve that we are still climbing today.

FIGURE 1-1

The Explosive Growth in Human Wealth



Source: Estimates for 1 million BC to 2000 AD from J. Bradford DeLong, University of California, Berkeley. Estimates for 2.5 million BC to 1 million BC are an extrapolation. GDP per capita is measured in 1990 international dollars.

To summarize 2.5 million years of economic history in brief: for a very, very, very long time not much happened; then all of a sudden, all hell broke loose. It took 99.4 percent of economic history to reach the wealth levels of the Yanomamö, 0.59 percent to double that level by 1750, and then just 0.01 percent for global wealth to leap to the levels of the modern world. Another way to think of it is that over 97 percent of humanity's wealth was created in just the last 0.01 percent of our history.²³ As the economic historian David Landes describes it, "the Englishman of 1750 was closer in material things to Caesar's legionnaires than to his own great-grand-children."²⁴



We now have a greater sense of just what kind of a phenomenon we are dealing with and can add some additional questions to our inquiry:

- How can something as complex and highly structured as the economy be created and work in a self-organized and bottom-up way?
- Why has the complexity and diversity of the economy grown over time? And, why does there appear to be a correlation between the complexity of an economy and its wealth?
- Why has the growth in wealth and complexity been sudden and explosive rather than smooth?

Any theory that seeks to explain what wealth is and how it is created must answer these questions. Although we know the historical narrative of *what* has happened in the history of the economy, for example, the advent of settled agriculture, the Industrial Revolution, and so on, we still need a theory of *how* it happened and *why* it happened. We need a theory that can take us all the way from early humans living in a state of nature, to the hunter-gatherer lifestyle of the Yanomamö, and from the Yanomamö to New York and beyond.

The Economy Evolves

Modern science provides just such a theory. This book will argue that wealth creation is the product of a simple, but profoundly powerful, three-step formula—differentiate, select, and amplify—the formula of evolution. The same process that has driven the growing order and complexity of the biosphere has driven the growing order and complexity of the "econosphere."²⁵ And the same process that led to an explosion of species diversity in the Cambrian period led to an explosion in SKU diversity during the Industrial Revolution.

We are accustomed to thinking of evolution in a biological context, but modern evolutionary theory views evolution as something much more general. Evolution is an *algorithm*; it is an all-purpose formula for innovation, a formula that, through its special brand of trial and error, creates new designs and solves difficult problems. Evolution can perform its tricks not just in the “substrate” of DNA, but in any system that has the right information-processing and information-storage characteristics.²⁶ In short, evolution’s simple recipe of “differentiate, select, and amplify” is a type of computer program—a program for creating novelty, knowledge, and growth. Because evolution is a form of information processing, it can do its order-creating work in realms ranging from computer software to the mind, to human culture, and to the economy.

Economics and evolutionary theory have a long history together (something we will return to). One of the criticisms of that history is that there has been too much loose analogizing about how the economy might be *like* an evolutionary system. For example, one might say that the computer industry is like an ecological niche, with different “species” of players such as chip designers, hard-drive manufacturers, software providers, and so on, engaged in a “survival of the fittest” struggle within that niche. Paul Krugman calls such metaphorical comparisons of economic and biological systems “biobabble.”²⁷ Most of the researchers discussed in this book would agree with Krugman that such “biobabble” is neither good science nor very illuminating. Modern efforts to understand the economy as an evolutionary system avoid such metaphors and instead focus on understanding how the universal algorithm of evolution is literally and specifically implemented in the information-processing substrate of human economic activity. While both biological and economic systems share the core algorithm of evolution and thus have some similarities, their realizations of evolution are in fact very different and must be understood in their individual contexts.

From a scientific standpoint, the distinction between a metaphorical versus a literal understanding of the global economy as an evolutionary system is critical. Saying that economic systems are *like* biological systems does not tell us much that is scientifically useful. But saying that both economic and biological systems are subclasses of a more general and universal class of evolutionary systems tells us a lot. This is because researchers believe that there are general laws of evolutionary systems.²⁸ Scientists consider certain features of nature universal. For example, gravity works the same way on the earth as it does in the farthest reaches of the universe, and it works the same way on atoms, apples, and galaxies. Modern evolutionary theorists believe that, like gravity, evolution is a universal phenomenon, meaning that no matter whether the algorithm is running in the substrate of biological DNA, a computer pro-

gram, the economy, or in the substrate of an alien biology on a distant planet, evolution will follow certain general laws in its behavior.

If the economy is truly an evolutionary system, and there are general laws of evolutionary systems, then it follows that there are general laws of economics—a controversial notion for many. Saying that there are laws of economics does not imply that we will ever be able to make perfect predictions about the economy, but it does imply that we might someday have a far deeper understanding of economic phenomena than we do today. It also means that economics in the future may be able to make prescriptive recommendations about business and public policy with a level of scientific authority that it has not had before.

Some might see the prospect of a more scientific economics as tremendously exciting and offering many potential benefits for the world. Others might see this as yet another misguided attempt to apply science to the problems of human society. Such critics would remind us of the often-repugnant views that came out of the Social Darwinist movement during the late nineteenth and early twentieth centuries, when philosophers such as Herbert Spencer attempted to crudely and metaphorically apply Darwin's theories to the social and economic realm.²⁹ The Social Darwinists viewed the principle of "survival of the fittest" (a phrase often misattributed to Darwin, but actually from Spencer) as justifying class inequalities, racism, colonialism, and other social injustices. The new views of economic evolution that we will discuss have nothing in common with the old views of Social Darwinism. In fact, they point in the opposite direction, noting that cooperation is as vital an ingredient in economic development as "survival of the fittest" individualism. Likewise, critics might point to the numerous disasters in social engineering caused by the "scientific" theories of Marxism. The cautions on social engineering are duly noted, and the new theories we will discuss help reveal why economic phenomena are so unpredictable and why most efforts at large-scale social engineering have historically failed.

The Creation of Fit Design

Just what kind of an algorithm is evolution? What does it do? The evolutionary philosopher Daniel Dennett calls evolution a general-purpose algorithm for creating "design without a designer."³⁰ Take for example, *Lumbricus terrestris*, the common earthworm, an ingenious design for the purpose of surviving and reproducing in the soil environment of forests, meadows, and household gardens of North America and Europe. It is in essence a tube that propels itself through the earth, ingesting soil in one end and passing it out the other, absorbing lots of nutritious microorganisms in between and gaining sufficient

calories for it to find more food and reproduce. This particular biological design comes fully equipped with touch and vibration sensors to help it avoid predators, and backup systems in most of its body segments so that if it is cut in two, it can regenerate itself. It can also reproduce in sufficient numbers to increase the odds that a good many of its offspring will survive to reproduce themselves. The brilliant design for *Lumbricus terrestris* was created by the algorithm of evolution without a rational designer (in this book I will take an unapologetically scientific stance toward evolution and not address religious debates around creationism or so-called “intelligent design”).³¹

Evolution creates designs, or more appropriately, discovers designs, through a process of trial and error. A variety of candidate designs are created and tried out in the environment; designs that are successful are retained, replicated, and built upon, while those that are unsuccessful are discarded. Through repetition, the process creates designs that are fit for their particular purpose and environment. If the conditions are right, competition between designs for finite resources drives the emergence of greater structure and complexity over time, as evolution builds on the successes of the past to create novel designs for the future.³² Then as the world changes, so too do the designs that evolution creates, often in brilliant and sometimes surprising ways. Evolution is a method for searching enormous, almost infinitely large spaces of possible designs for the almost infinitesimally small fraction of designs that are “fit” according to their particular purpose and environment. As Dennett puts it, evolution is a search algorithm that “finds needles of good design in haystacks of possibility.”³³

Perhaps one needs “design without a designer” to explain biological evolution, but why do we need “design without a designer” to explain the process of wealth creation in the economy when we have lots of human designers around? Aren’t we the gods of our own economic creation? We are accustomed to thinking of human rationality and creativity as the primary driving forces behind wealth creation. Wealth, after all, is created by smart, innovative people coming up with new ideas for products and services and lots of hard work to make and sell them. I will argue that human rationality and creativity do play an important role in wealth creation, but not the role we usually think of. Rationality and creativity feed and shape the workings of the evolutionary algorithm in the economy, but do not replace it.

Consider the shirt, the blouse, or any other kind of top you are wearing—where did its design come from?³⁴ Well, you might reply, it’s obvious; a clothes designer designed it. But there is more to the story than just that. What really happened was more or less the following. A number of clothes designers took preexisting ideas of what a shirt should look like and used their rationality and creativity to create all sorts of variations of “shirts” and

sketched them out. Those clothes designers then looked at their various sketches and selected a subset of the designs that they thought consumers would like, and made a limited number of samples. The designers then showed those samples to the management of a clothing company, which selected a subset of the designs that it thought consumers would like, and arranged for their manufacture. The clothing company then showed its wares to various retailers, which likewise selected a subset of the designs that they thought consumers would like. With orders in hand, the clothing company then scaled up its manufacturing and supplied the retailer with the shirts. You then walked into a store, browsed through a wide variety of shirts, and selected the one you liked and bought it. Differentiation of designs, selection according to some criterion of fitness, and amplification or scaling up of the successful designs to the next stage of the process—all of this happened both within the clothing company itself and within the overall fashion marketplace. Your shirt was not designed; it was evolved.

But why does the fashion industry go through this iterative, and in many ways, wasteful, process? The reason that your shirt was evolved rather than designed is that no one could predict exactly what kind of shirt you would want out of the almost infinite space of possible shirt designs. The old Soviet Union tried this kind of rational prediction in its infamous five-year plans, and the results included both economic disasters and major fashion errors. As we will see, despite all the strengths and virtues of human rationality, prediction in a system as complex as the economy over anything but the very short term is next to impossible. We use our brains as best we can in economic decision making, but then we experiment and tinker our way into an unpredictable future, keeping and building on what works and discarding what does not. Our intentionality, rationality, and creativity do matter as a driving force in the economy, but they matter *as part of a larger evolutionary process*.

Economic evolution is not a single process, but rather the result of three interlinked processes. The first is the evolution of technology, a critical factor in economic growth throughout history. Most notably, the sharp bend in economic growth around 1750 coincides with the great technological leap of the Industrial Revolution. But the evolution of technology is only part of the story. The evolutionary economist Richard Nelson of Columbia University has pointed out that there are in fact two types of technology that play a major role in economic growth.³⁵ The first is *Physical Technology*; this is what we are accustomed to thinking of as technology, things such as bronze-making techniques, steam engines, and microchips. *Social Technologies*, on the other hand, are ways of organizing people to do things. Examples include settled agriculture, the rule of law, money, joint stock companies, and venture capital. Nelson notes that while Physical Technologies have clearly had an immense

impact on society, the contributions of Social Technologies have been equally important and in fact, the two coevolve with each other.³⁶ During the Industrial Revolution, for example, Richard Arkwright's invention of the spinning frame (a Physical Technology) in the eighteenth century made it economical to organize cloth-making in large factories (a Social Technology), which in turn helped spur numerous innovations in the application of water power, steam, and electricity to manufacturing (back to Physical Technologies).³⁷ The stories of the agricultural, industrial, and information revolutions are all largely stories of the reciprocal dance between Physical and Social Technologies.

Yet the coevolution of Physical and Social Technologies is only two-thirds of the picture. Technologies alone are nothing more than ideas and designs. The Physical Technology for a cloth-spinning frame is not itself a cloth-spinning frame—someone actually has to make one. Likewise, the Social Technology for a factory is not a factory—someone actually has to organize it. In order for technologies to have an impact on the world, someone, or some group of people, needs to turn the Physical and Social Technologies from concepts into reality. In the economic realm, that role is played by business. Businesses fuse Physical and Social Technologies together and express them into the environment in the form of products and services.

Businesses are themselves a form of design. The design of a business encompasses its strategy, organizational structure, management processes, culture, and a host of other factors. Business designs evolve over time through a process of differentiation, selection, and amplification, with the market as the ultimate arbiter of fitness. One of the major themes of this book is that it is the three-way coevolution of Physical Technologies, Social Technologies, and business designs that accounts for the patterns of change and growth we see in the economy.

Complexity Economics

The notion that the economy is an evolutionary system is a radical idea, especially because it directly contradicts much of the standard theory in economics developed over the past one hundred years. It is far from a new idea, however. Evolutionary theory and economics have a long and intertwined history.³⁸ In fact it was an economist who helped spark one of Charles Darwin's most important insights. In 1798, the English economist Thomas Robert Malthus published a book titled *An Essay on the Principle of Population, as It Affects Future Improvements of Society*, in which he portrayed the economy as a competitive struggle for survival and a constant race between population growth and humankind's ability to improve its productivity. It was a race

that, Malthus predicted, humankind would lose. Darwin read Malthus's work and described his reaction in his autobiography:

In October 1838, that is fifteen months after I had begun my systematic enquiry, I happened to read for my amusement "Malthus on Population", and being well prepared to appreciate the struggle for existence which everywhere goes on from long-continued observation of the habits of animals and plants, it once struck me that under these circumstances favorable variations would tend to be preserved and unfavorable ones to be destroyed. The result of this would be the formation of new species.

Here then I had at last got a theory by which to work.³⁹

Darwin's great insight into the critical role of natural selection in evolution was thus inspired by economics.⁴⁰ It was not long after Darwin published his *Origin of Species* that the intellectual currents began to flow back the other way from evolutionary theorists to economists. In 1898, the economist Thorstein Veblen wrote an article that still reads remarkably well today arguing that the economy is an evolutionary system.⁴¹ Not long afterward, Alfred Marshall, one of the founders of modern economic theory, wrote in the introduction to his famous *Principles of Economics*, "The Mecca of the economist lies in economic biology."⁴² Over the following decades, a number of great economists, including Joseph Schumpeter and Friedrich Hayek, delved into the relationship between economics and evolutionary theory.⁴³ In 1982, Richard Nelson and Sidney Winter published a landmark book titled *An Evolutionary Theory of Economic Change*. It was the first major attempt to marry evolutionary theory, economics, and the then recently developed tool of computer simulation.⁴⁴

Despite these efforts by some of the finest minds in economics, evolutionary thinking has had relatively little impact on mainstream economic theory. Beginning at about the same time as Darwin's *Origin of the Species*, economics took a turn down a very different road. Since the late nineteenth century, the organizing paradigm of economics has been the idea that the economy is an *equilibrium system*, essentially a system at rest. As we will see, the primary inspiration for economists from the late nineteenth through the mid-twentieth centuries was not biology, but physics, in particular the physics of motion and energy. Traditional economic theory views the economy as being like a rubber ball rolling around the bottom of a large bowl. Eventually the ball will settle down into the bottom of the bowl, to its resting, or equilibrium, point. The ball will stay there until some external force shakes, bends, or otherwise shocks the bowl, sending the ball to a new equilibrium point. The mainstream paradigm of economics over the past hundred years has portrayed the economy as a

system that moves from equilibrium point to equilibrium point over time, propelled along by shocks from technology, politics, changes in consumer tastes, and other external factors.

While economists were pursuing their vision of the economy as an equilibrium system, during the latter half of the twentieth century, physicists, chemists, and biologists became increasingly interested in systems that were far from equilibrium, that were dynamic and complex, and that never settled into a state of rest. Beginning in the 1970s, scientists began to refer to these types of systems as *complex systems*. This is a term we will look at in detail later, but in brief, a complex system is a system of many dynamically interacting parts or particles. In such systems the micro-level interactions of the parts or particles lead to the emergence of macro-level patterns of behavior. For example, a single water molecule sitting in isolation is rather boring. But if one puts a few billion water molecules together and adds some energy in the right way, one gets the complex macro pattern of a whirlpool.⁴⁵ The pattern of the whirlpool is the result of the dynamic interactions between the individual water molecules. One cannot have a whirlpool with a single water molecule; rather, the whirlpool is a collective or “emergent” property of the system itself.

During the 1970s, as scientists came to know more about the behaviors of complex systems, they became increasingly interested in systems in which the particles were not simple things with fixed behaviors like water molecules, but were things with some intelligence and the capability of adapting to their environment. Water molecules cannot adapt their behavior, but ants, for example, can. An ant may not be terribly smart by human standards, but it can nonetheless process information from other ants and from its environment and modify its behavior accordingly. Like a water molecule, a single ant on its own is not terribly exciting. However, if you put a few thousand ants together, they interact with each other, communicate using chemical signals, and can coordinate their activities to do things such as build elaborate anthills and organize sophisticated defenses against attackers. Scientists refer to parts or particles that have the ability to process information and adapt their behavior as *agents* and call the systems that agents interact in *complex adaptive systems*.⁴⁶ Other examples of complex adaptive systems include the cells in your body’s immune system, interacting organisms in an ecosystem, and users on the Internet. With the advent of inexpensive, high-powered computers in the 1980s, scientists began to make rapid progress in understanding complex adaptive systems in the natural world and to see such systems as forming a universal class, with many common behaviors. In fact, many biologists have come to view evolutionary systems as just one particular type, or subclass, of complex adaptive systems.

Social scientists following this work increasingly began to wonder whether economies too might be a type of complex adaptive system. The most obvious characteristic of economies is that they are collections of people interacting with each other in complex ways, processing information, and adapting their behaviors. In the 1980s and early 1990s, researchers began to experiment with models of economic phenomena that were radically different from traditional models.⁴⁷ Rather than portraying the economy as a static equilibrium system, these models presented the economy as a buzzing hive of dynamic activity, with no equilibrium in sight. Just as the pattern of a whirlpool arises from interacting water molecules, these models showed complex patterns of boom and bust and waves of innovation emerging from the interactions of simulated agents, just as they do in the real economy. Interest and research in understanding the economy as a complex adaptive system has grown rapidly during the past decade, and over the course of this book, we will undertake a review of that work.

I will refer to this body of work as *Complexity Economics* (credit—or blame—for coining this term goes to the economist Brian Arthur, formerly of Stanford University and the Santa Fe Institute).⁴⁸ One should not assume from this label that there is currently a single, synthetic theory of Complexity Economics. Rather, my use of the term is intended to cover the broad range of theories, hypotheses, tools, techniques, and speculations that we will survey in this book. At this stage in its development, Complexity Economics is a work in progress, or what philosophers of science refer to as a “program” rather than a unified theory.⁴⁹

The Road Map Ahead

If the economy is indeed a complex adaptive system, then this has four important implications. First, it means that for the past century, economists have fundamentally misclassified the economy and that the mainstream economic theory reflected in textbooks, management thinking, and government policies today is either wrong or, at best, only approximately right. This is an argument we will explore over the remainder of part 1.

Second, viewing the economy as a complex adaptive system provides us with a new set of tools, techniques, and theories for explaining economic phenomena. We will discuss these new approaches in part 2.

Third, it means that wealth must be a product of evolutionary processes. Just as biological evolution summoned complex organisms and ecosystems out of the primordial soup, economic evolution has taken humankind from a

state of nature to the modern global economy, filling the world with order, complexity, and diversity along the way. In part 3, we will develop and discuss an evolutionary explanation for the creation of economic wealth.

Fourth and finally, history shows that each time there has been a major shift in the paradigm of economic theory, the tremors have been felt far beyond the academic world. Adam Smith's ideas had an important influence on the growth of free trade in the nineteenth century; Karl Marx's vision inspired revolutions and the rise of socialism in the early to mid-twentieth century; and the intellectual dominance of Anglo-American Neoclassical economics coincided with the ascendancy of global capitalism in the latter decades of the twentieth century. It will probably be several decades before the full socio-political implications of Complexity Economics become clear. Nonetheless, the outlines of Complexity Economics are sufficiently formed that in part 4 we can begin to explore its implications for business and society.

We will arrive at the end with a message of optimism: if we can better understand the processes of wealth creation, then we can use that knowledge to develop new approaches to create economic growth and opportunity for people. Complexity Economics will not be a cure-all for the challenges of management or the ills of society. But just as a more scientific understanding of natural phenomena has been a major contributor to bettering the human condition, a more scientific understanding of economic phenomena has the potential to help improve the lives of people around the world.