

and megalomaniacs, all of which are ready, willing, and able to kill the geese that lay the golden eggs to satisfy their own lust for power, fortunes, or vainglory or to impose their own visions of utopia, no matter what economic harm it does to the arenas in which they compete. The horrors of which they're capable could be expanded indefinitely: deadly weapons, germ warfare, genocide, ethnic cleansing, and campaigns to mobilize popular hysterias and hatreds that make the other horrors practically possible. What protection did evolution give us against this?"

"Not much, I'm afraid," Hiram replied as Kate hesitated and looked taken aback. "Only intelligence. No, wait a minute. Perhaps I'm wrong. We have some sense of morality—another gift of consciousness. Definitions of right and wrong don't cut across the board, but consciousness of right and wrong behavior is a very ancient and widespread trait. You know that yourselves, Armbruster, Kate, and Hortense. I read your book on the symbiosis between government and economic life, which at bottom deals with the subject you've just brought up. You're right that failure to respect that symbiosis and the morals upholding it dead-ends prospering economic life.

"But I'll add one more sin to the list that Armbruster has mentioned: ignorance, for which the remedies are awareness and knowledge. Why do you think I—"

The door of the dining room opened, and Murray poked in his head. "I must have dozed off," he said. "The garden's dried off enough. Come on outside."

"Can't; there's the recorder," said Armbruster.

"I've already rigged up an extension cord from the basement. Let's go. It's too beautiful outside to hang around indoors."

Chapter 7

UNPREDICTABILITY

Hiram's garden boasted two handsome sycamores, a thicket of lilac bushes, and a bed of English ivy on which a fox's head and foreleg were emerging from a block of red sandstone. "Young Joel's work, from when he was planning to be a sculptor," said Murray to Kate as they accepted gin and tonics from Hortense and made their way to a cluster of olive-green lawn chairs.

Armbruster, who had worried that extraneous noises would muffle the clarity of voices on tape, was gratified with the garden's serenity and quiet. Houses on Hiram's street shared common side walls, an arrangement that buffered their rear from street sounds. Musing on his good fortune that, owing to damp grass, neighbors were not using lawn mowers, he briefly mistook Hiram's opening remark about "the butterfly effect" for an ecological comment on the garden's insect life.

He was quickly put on track by Hortense. "It's so far-fetched—the idea that a butterfly beating its wings in a

Colorado meadow can lead to a storm and flood three thousand miles away. I'm surprised it's taken so seriously."

"The story behind the butterfly effect has profoundly revised ideas about predictable outcomes," said Hiram. "Classic experimental science for the past three centuries concentrated on discovering cause-and-effect relationships by excluding all but two, or at most three, variables. For instance, rats given diets lacking vitamin A could be compared with a group of rats exactly the same in all respects except that vitamin A was included in their diet. Any differences that emerged between the two groups could reasonably be attributed to effects of the vitamin. Furthermore, any laboratories repeating the experiment with the same care could be expected to get the same results; if they didn't, the validity of the first experiment was called into doubt. 'Can it be replicated?' was the first question demanded of an experiment. Cause-and-effect experiments of this type not only inform; they predict. The key to their success is reduction of the number of variables being investigated.

"In contrast, a cause-and-effect exploration that incorporates even four or five interacting variables is formidably complex. The difficulty is that any one variable may affect one or more of the other variables, which may then affect the others, including the variable at the start of the process, bewilderingly tangling causes and effects into complex webs. Such problems, not being linear and simple, are not susceptible to reductive experiments; the content can't usefully be separated into artificial fragments. This is the sort of problem, for instance, that can arise when scientists turn from *What* does vitamin A do? to *How* does it do what it does?

"Scientists have commonly supposed, or at least hoped,

that if only all the different interacting variables in a web-like relationship could actually be tracked, then multivariable interactions would be predictable, as well as more understandable. Computers hold out that promise because they can handle complexities which are impractical to analyze otherwise on account of the number of calculations and comparisons involved."

"Aha, a bifurcation in analytical techniques was needed," said Armbruster.

"For some complex problems, computers have fulfilled that expectation," Hiram continued, "but not all. Here's where we come to the butterfly beating its wings and generating a zephyr. In 1963, Edward Lorenz, a mathematician and meteorologist, hoped to demonstrate a method for making reliable long-range weather predictions. He entered into a computer an archive of weather-system patterns, complete with their measurable variables, such as temperatures, barometric pressures, wind directions and speeds, precipitation, and influence of adjoining weather fronts. Each pattern's characteristics were stored in the computer's memory. His idea was that a meteorologist could feed into a computer a current weather pattern and instruct the machine to find an exact match in its memory archive. Logically, the subsequent behavior of the past pattern should forecast the subsequent behavior of the matching pattern.

"He set about testing the method by requesting the computer to find matching patterns already in its archives, which it did. Then he examined whether subsequent behavior of those patterns continued to match. A huge surprise awaited him. After only a few days as a rule, and at most a week, matching weather patterns did not continue behaving alike; their subsequent behavior was as dissimilar to each

other's as it was to behavior of unmatched patterns. Lorenz says he realized then that reliably predicting weather for more than a week in advance was inherently impossible, but he also realized that he had unpredictably hit upon a discovery with wider and very important implications.

"The weather behaved unpredictably for interesting reasons. The immediate cause must be that obscure, unforeseeable, and idiosyncratic events were producing disproportionately large consequences, hence the shorthand expression *the butterfly effect*."

"The triviality of it—that's what's so far-fetched," said Hortense.

"Not really," said Kate. "The idea is that small events produce disproportionately large consequences owing to changes that become exaggerated as they reverberate among variables. We know that this happens. The amount of freon released by aerosol cans and discarded refrigerators containing the gas is a pittance in the great oceans of air. Yet because of the reaction of that pittance with ozone, freon causes holes in the canopy that shields earth from the full force of ultraviolet rays. Or think, Hortense, how a tiny, obscure encounter between an invading virus and one of your patrolling immune cells can set in motion a web of events within your body that determine whether you live or die."

"The symbolic butterfly doesn't mean merely that small causes can have disproportionately large consequences," said Hiram. "That's long been observed. As the old saying has it, the kingdom was lost for want of a horseshoe nail. Nor is the meaning of the butterfly merely that it can be impossible to take into account every cause, influence, and interrelationship in a complex system, owing to causes being too many, subtle, varied, and volatile.

"The major jolt packed into Lorenz's discovery was this: Even if every single influence on some types of complex systems could be accurately taken into account, their features would still be unpredictable."

"Why do you say that?" asked Hortense. "How can you know that?"

"A system can be making itself up as it goes along," said Hiram. "The weather is like that. Evolution is like that. Economies, if they aren't inert and stagnant, are like that. Since they make themselves up as they proceed, they aren't predestined. Not being predestined, they aren't predictable."

"That may be a novel idea for meteorologists, but it's old news to linguists," said Armbruster. "Speakers make a language and yet nobody, including its speakers or scholars, can predict its future vocabulary or usages, precisely for the reason you've said: Language makes itself up as it goes along. Even when languages start out the same, like those weather patterns, they diverge idiosyncratically. Who could have predicted French, Spanish, Portuguese, Mallorcan, Provençal, Romanian, or even Florentine Italian and Sicilian Italian from Latin? Who could have forecast the English we're speaking now by analyzing the English in *Beowulf*, or even *The Canterbury Tales*? Who can predict English vocabulary and usages in the year 2800? Or the differences it will display then in different places where it's spoken? Of course," he added reflectively, "languages do have rules of grammar, fairly consistent ways of adapting what they borrow from other languages, and even somewhat reliable patterns of pronunciation shifts."

"Yes, languages aren't gibberish," said Hiram. "Creative self-organization—which is what we're talking about—doesn't imply disorder. On the contrary. But it tells us that

order is not uniformity, and that what is created within a framework of orderly processes is not predestined or predictable.

"In an ecosystem," he went on, "plants and animals pursue what amount to plans for the future. They do this even though they lack consciousness of the future, at least in the same sense we're aware of it. They construct nests, dig burrows, establish families, locate food sources, put down roots, germinate fruits. Together they compose an ecosystem, much as collections of enterprises with their plans for the future compose a settlement's economy. The ecosystem doesn't and can't impose hierarchical command over the ensemble, which is self-organized and is making itself up as it goes along."

"That's beautifully elucidated in *The Beak of the Finch*, another book I reviewed," said Kate.

"Nobody commands an economy that has vitality and potential," said Hiram. "It springs surprise upon surprise instead of knocking down and doing what's expected of it, or wished for it."

"But surely if you had it in your power, Hiram, you'd get the government to mandate reforms eliminating vicious circles and tell enterprises what they must do with respect to pollution, waste of resources, and so on," said Armbruster.

"It's not in my power, but more to the point, it isn't in the power of governments to do that successfully, either—not in the sense of laying out just what is to be done. I don't know what's to be done or what's possible to do, and neither does anyone else, whether in government or out. Like my clients searching for ways to make materials at life-friendly temperatures and for materials and their products that will be benignly biodegradable when users are fin-

ished with them, some members of the ensemble may come up with what's needed, but they must depend on the rest of the ensemble—on the co-developments of other members, and on many, many others in the ensemble, to keep the whole precarious contraption stable enough and expanding enough to assimilate corrections and bifurcations."

"Hubris—overweening confidence," said Murray. "Economic history is stuffed with expensive duds undertaken by people who thought they could predict the future by shaping it. The foreign-aid import-substitution fiasco is an example: big, quick fixes for big problems. We have our own examples. By hindsight, it's apparent that nuclear power isn't the cheap and harmless energy it was expected to be. In addition to radioactivity's hazards for people who deal with it, radioactive wastes are so dangerous, far into the future."

"But nuclear power sounded promising for reducing atmospheric pollution and acid rain," Armbruster protested. "How can economies find out what's workable without trying? Hiram, you yourself favor experimenting. Shouldn't we at least try to plan corrections when it's plain that only a significant new fork in the road will answer? And push as hard as possible when we recognize that we need the new fork quickly?"

"The mistake is to conclude in advance that you already have the answer you need," said Hiram. "Maybe you do, but probably you don't. Successful bifurcations tend to start modestly and be tested out as they work their way into economic life—or else are dropped. While hundreds of billions of dollars were being force-fed into nuclear power, other possibilities were being starved, neglected, and derided. That's not an experimental approach."

"Hindsight is notoriously clear and foresight notoriously fallible," said Kate. "Fulton's Folly" was the popular epithet for the first American steamboat. Cries of 'Get a horse!' greeted early automobile users. The leading early computer manufacturer, IBM, was convinced that computers would remain too expensive and cumbersome for individual ownership."

"Experts on industrial materials dismissed plastics as useful only for kitchen gadgets and toys," said Murray.

"Who in the world thought that?" asked Hortense.

"For one, the technical editor of what at the time—this was in the early 1940s—was the leading U.S. trade journal for the metal industries."

"It's still common to dismiss ecologists and environmental activists as cranks, and organic farmers and proponents of solar energy as hobbyists," said Kate. "At least wind-generated energy and material recycling are being taken seriously and finding economic niches. Does initial skepticism matter?"

"It matters," Murray put in, "when potential bifurcations can't get capital or necessary permissions or are not allowed to break into monopolized fields."

"To be sure, it's possible for society to set goals, and in some cases even standards, for results wanted," said Hiram. "And, of course, it's possible to forbid arrantly destructive environmental behavior—in the same way as we forbid arrantly destructive behavior to one another, such as looting, cheating, and defrauding. But mandating environmental goals or standards doesn't mean mandating how they're to be reached."

"Nobody can predict better ways, let alone 'best' ways, of doing familiar things—to say nothing of things not previously done at all. Ancient as the problem of sewage-

contaminated water is, and ancient as some of its solutions are, we're still discovering new and better ways of addressing this environmental and economic problem. It's fine for governments to mandate permissible bacterial counts and parts per million of other contaminants, but the worst thing governments could do would be to mandate how standards are to be achieved. As I mentioned when discussing development and co-development, that would freeze development at its current and still unsatisfactory stage."

"Everybody talks about how amazing it is that the Internet is self-organized," said Hortense. "Also, how remarkable that a system which originated when a very few computer users in universities and government offices, who had common research interests, linked their computers by telephone lines—how remarkable that it's ramified itself into a 'World Wide Web' by making itself up as it went along. Nobody planned such a thing. Is the Internet unusual?"

"It's unusual in having grown so big so rapidly," Murray answered. "Notice the expression *World Wide Web* that you just used. Everybody understands the Internet as a web. As for its being self-organized, that isn't novel. We look at established ways of doing things, formalized in large and well-established organizations, and tend thoughtlessly to suppose they were born so. Take civilian postal systems, now largely superseded by E-mail, faxes, and courier services. It used to be that a person in Europe or America with a letter or parcel to send outside the locality entrusted it to someone going that way—a ship's officer, say, or a coachman, a merchant, or somebody in a merchant's entourage. Customarily, the recipient of the letter or parcel, not the sender, paid the carrier. That was a precaution against the

carrier agreeing to make the delivery but neglecting or being unable to do so. A self-organizing postal system can be said to have started when senders took letters to coaching inns or waterfront taverns and travelers hoping to pick up side money took to dropping by these posts and picking up letters awaiting carriage. Senders, carriers, and inn proprietors were creating proto-postal systems, mail depots linked together—a primitive Internet. When governments formalized the service in the nineteenth century, they monopolized it and incorporated improvements, among them payment by the sender, not the recipient. That change protected the postal systems' interests, and it was practical because governments guaranteed reliable delivery by enforcing honest and diligent behavior on carriers. But for all their power, governments eventually couldn't maintain their monopolies, although they tried. Independent courier services began illegally; they flourished because they occupied niches that the postal services weren't filling satisfactorily.

"Credit cards; equipment leasing; franchising; organic farming and marketing nowadays—and farming at all in the first place—don't be misled by their established appearances into thinking that they started out as they are today or that they were expected at the time they emerged.

"In 1992, on a visit to Hong Kong," Murray went on, "I saw a small yet global self-organized market in action. I was strolling and gawking along a street on the fringe of a vast outdoor jade-jewelry market—which, incidentally, had been self-organized by stall proprietors and had burgeoned to unanticipated size—when I noticed a knot of a dozen or so young men showing each other envelopes of rock fragments and jotting down notations, using the top of a parked car as their desk. I was told they were jade traders

and that the notations they were making would set world prices of jade for that day. It recalled to my mind that the New York Stock Exchange was started on a Wall Street sidewalk under a buttonwood tree. That's an old-fashioned name for a sycamore or plane tree, like those two that Hiram has."

"I like that about the parked car used as a desk," said Kate. "A desk is an extension of a lap. Technologies are extensions of our bodies: microscopes and telescopes, extensions of eyes; telephone receivers, extensions of ears; pens, extensions of fingers, and writing, extensions of voices; wheels, extensions of leg and back muscles; spears, extensions of arms. Weapons are still called arms."

"The bones inside an arm—you may not know this—" said Hiram, "are waste. Or were, to begin with. Excess calcium within cells is poisonous; they rid themselves of it. In the course of evolution, that particular discard found use as shells, skeletons, and teeth. Useful recycling of discards is an ancient stratagem of life. Of course human beings have long used that same stratagem consciously, but still not as marvelously as our own cells use it."

"Our seamless, total connectedness within nature—that's what Ben wouldn't hear of or think of in his contempt for what he called unnatural," said Kate.

"It would have interfered with his enjoyment of hating technology and business," said Armbruster. "Balderdash!"

"Of course the idea that we, and what we do, aren't natural is balderdash," said Hiram. "If our doings aren't natural, then by definition they must be supernatural. Spears, cars, and computers aren't supernatural. To get back to my own obsession, economies aren't supernatural, either, although economists act as if they are when they ignore such realities as that economies require diversity to expand, self-

refueling to maintain themselves, and co-developments to develop. No wonder well-intentioned people like Ben pick up the absurd notion that economic life is arbitrary and unnatural."

"Wait a minute," said Hortense. "Balderdash that may be, but balderdash is natural, too. Evolution provided us with consciousness, right? Because we have consciousness, we also have the ability to make mistakes. We make more mistakes—or, anyhow, different mistakes—than other animals can make. For us that's natural, isn't it?"

"Yes it is," said Murray, "but consciousness also gives us the ability to recognize mistakes."

"The saving grace that accompanies the hazard," said Armbruster. "But let's not get into a discussion of free will. Everything that can be said on that subject has already been said."

"Don't be too sure about that," said Hiram. "Consciousness itself is still a mystery. How can the mind observe itself as if it existed outside itself? It's the ability to separate ourselves from ourselves inwardly which leads to the conceit that we're above nature or, as Ben sees it, in an adversarial position."

"If and when neurophysiologists find out how a brain manages to be conscious of itself as a willful, judgmental 'me,' what they'll tell us will be about proteins, enzymes, cilia, and electrical nerve impulses," said Hortense. "It will be boring and incomprehensible to most of us."

"But it will be even more remarkable than we can imagine," said Hiram. "The more we know of nature's operations, the more wondrous nature is seen to be. And when and if we get a real science of economics—"

"And where will that come from?" asked Hortense.

"I don't know," said Hiram. "It doesn't look all that

promising. Maybe from a symbiosis of nonsupernatural economics with nonmisanthropoc ecology. We need it. So far, our horrible mistakes notwithstanding, we're still accepted within the great ensemble of species. So we still have opportunities to establish ourselves in the ensemble a bit more securely as symbionts than we're warranted to suppose we are now. Whether or not we'll muff it isn't predictable, because we'll be making ourselves up as we go along—just as we've always done so far.

"In spite of my panegyrics to nature's order," Hiram went on, "nature is far from perfect by criteria that would guide what we conceive of as intelligent, careful planning. Embryos go awry in their development. Species fail to adjust to changed circumstances and go extinct. A case can be made that development and co-development foster disorder by throwing new uncertainties into the pot. But within the confusion, redundancy, and unpredictability, the stupendous processes we've been discussing are operating: development and co-development through differentiation; expansion through diversification; continuation through self-refueling; stabilization through self-correction—all brought into order through unpredictable self-organization."

Murray raised his glass. "To the unpredictable, uncommandable future in the making. And to not forgetting that 'in the making' is always and forever *now*. And now I must leave. A farmer friend of mine wants a hive of bees, and I think one of mine is preparing to swarm. His daughter's at my place keeping watch, but she's a novice at handling them. The sooner they swarm the better, with June almost half gone already. An old jingle claims that a swarm in May is worth a load of hay, a swarm in June is worth a silver spoon, and a swarm in July is not worth a fly."

"Why is that?" asked Hortense.

"A swarm in July barely has time to lay up its food for the winter—none left over for the beekeeper. There's a principle you can count on, no matter what happens to the comparative prices of hay, silver, and honey."

"Before you go, one more question," said Hortense. "What are economies *for*? Of course I know they're to supply human needs, but surely human needs include fair and just sharing of economic production."

"You put me in mind of how my grandfather thought about nature," said Murray. "What is nature *for*? He'd have said, 'It's to supply the needs of mankind.' Being a pious man, he'd have added, 'So that mankind may bear witness to the abounding mercy of God.' Being a lawyer and humanist, you say, 'So that people may evince justice and fairness to one another.' Tell me, Hortense, would you give the same answer as my grandfather to the question of what nature is *for*?"

"No, of course not. Nature has value and integrity in its own right, regardless of human needs. I see what you're driving at. You think my idea of what economies are for is equally superficial. But people don't create or possess nature, and they do create and possess economies."

Hiram sighed and reentered the conversation. "To be sure, people create and possess things that they cast up by grace of the processes of economic life. But our naked, unlettered ancestors didn't create those processes of development and diversification and neither did we. This much I know: It's stupid to try to circumvent universal processes. I don't know what economies are for, ultimately, other than to enable us to partake, in our own fashion, in a great universal flow. What do the rest of you think?"

"I think economic life is for teaching our species its responsibilities to the planet and the rest of nature," said Kate. "At least that's my hope. In its own way, that isn't so far from bearing witness, Murray. It isn't so far, either, from Hortense's aim for justice and fairness, although I'm including other forms of life besides ours."

"I have two thoughts on the question," said Armbruster. "First, beware of drift into ideology. Economic ideologies are a curse. Carts before horses, tails wagging dogs, self-imposed blinders! I prefer Murray's dry proposal to look factually into import-stretching ratios, skeptical though I was when he suggested it."

"I think they'd give us some large surprises," said Murray.

"Second," Armbruster went on, "it seems to me that economies have a lot in common with language—a lot besides unpredictably making themselves up. What is language for? The glib answer is communication, which you could say of the yips of coyotes and pheromones of termites. Not an answer that does justice to the functions of language. How about this? Language is also for learning and to pass along learning, in the process permitting us to develop cultures and multitudes of purposes. Just so, economies are to fill material needs, which you could also say of the foraging of deer and the scavenging of buzzards. Not an answer that does justice to the functions of economies. Like language, economic life permits us to develop cultures and multitudes of purposes, and in my opinion, that's its function which is most meaningful for us."

"I'll go along with that," said Murray. "Now, I really must leave and pay attention to those bees."