

JANE JACOBS

THE NATURE OF
ECONOMIES



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NEW YORK

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2000 Modern Library Original

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LIBRARY OF CONGRESS CATALOGING-IN-PUBLICATION DATA

Jacobs, Jane.

The nature of economies / Jane Jacobs.

p. cm.

Includes index.

ISBN 0-679-60340-9

1. Economics—Environmental aspects. I. Title.

HD75.6.J325 2000

330—dc21 99-41014

Modern Library website address: www.modernlibrary.com

Printed in the United States of America on acid-free paper

2 4 6 8 9 7 5 3 1

For Burgin, Ned, and Jim

FOREWORD

Theories and other abstractions are powerful tools only in the limited sense that the Greek mythological giant Antaeus was powerful. When Antaeus was not in intimate contact with earth, his strength rapidly ebbed. The aim of the talkative characters in this book is to bring rarefied economic abstractions into contact with earthy realities, meaning universal natural processes of development, growth, and stability that govern economic life.

The theme running throughout this exposition—indeed, the basic premise on which the book is constructed—is that human beings exist wholly within nature as part of natural order in every respect. To accept this unity seems to be difficult for those ecologists who assume—as many do, in understandable anger and despair—that the human species is an interloper in the natural order of things. Neither is this unity easily accepted by economists, industrialists, politicians, and others who assume—as many do, taking understandable pride in human achievements—that reason, knowledge, and deter-

mination make it possible for human beings to circumvent and outdo the natural order. Readers unwilling or unable to breach a barrier that they imagine separates humankind and its works from the rest of nature will be unable to hear what this book is saying.

In describing natural processes and selecting examples to illustrate them, I have hewed to information from the fields of biology, evolutionary theory, ecology, geology, meteorology, and other natural sciences as the information is currently understood and interpreted by practitioners in these sciences. When, on infrequent occasions, my characters introduce their own interpretations of natural science, they make it clear that these are their own speculations. On economics they are much more opinionated in their insistence that it come down to earth, but again they state outrightly when they are being iconoclastic, and why.

I have used imaginary characters and didactic dialogue primarily because this venerable literary form is suited to expounding inquiry and developing argument, but also because the form implicitly invites a reader to join the characters and enter the argument too. A book is equipped to speak for itself, more so than any other artifact. But to be heard, a book needs a collaborator: a reader with a sufficiently open mind to take in what the book is saying and dispute or agree, but in any case think about it. Insofar as that process is enjoyably interesting as well as possibly useful—as I hope it may be—so much the better.

JANE JACOBS
Toronto, July 1999

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THE NATURE OF
ECONOMIES

CHAPTER 1

DAMN, ANOTHER ECOLOGIST

"Hortense and Ben have broken up," said Armbruster, waving a fax at Kate as she slid into the booth, balancing her cup of coffee.

"I'm sorry but not surprised," said Kate. "Remember how Ben used to gloat over industrial disasters? He thought everything industrial or technological was unnatural and that everything unnatural was bad."

"He meant well," Armbruster said. "We need Jeremiahs, but it must have been depressing for Hortense to live with one. It seems the breakup happened some time ago and she's gotten over it. She's interested in a new man. Mind if I finish this fax? I only got it as I was leaving the house."

In late morning they were sitting in an almost-empty coffee shop on lower Fifth Avenue, not far from Armbruster's Gramercy Square apartment. It was an unappealing restaurant in a stretch of New York rapidly going upscale. Armbruster liked it as his morning hangout because its well-deserved unpopularity guaranteed seats for acquaintances dropping by. He lived alone, and since his re-

tirement from a small book publishing company, he missed his work and its daily give-and-take with colleagues.

"Damn, Hortense has found another ecologist," Armbruster grumbled as he continued reading the fax.

"That's not surprising, either," said Kate. "She's an environmental lawyer, so those are the people she talks to, consorts with. Those and other lawyers."

"But listen to this: His name is Hiram Murray IV. The Fourth! What an affectation."

"He's not to blame if his family ran out of names."

"You drop off the numbers when they die. I dropped off my Junior when my father died. Only kings and popes hang on to numbers."

"Maybe the other three are still alive—you don't know."

"Let's see," Armbruster mused aloud. "Number two would be his grandfather, and number one—" His eyes widened, exaggerating his customary owlsh expression. "Good heavens, Hortense is fifty. You don't suppose—"

"No, I don't think Hortense is running around with a kid. Read on."

"Well, well, she's planning to come back from California," Armbruster read on. "He has a house in Hoboken. What's an ecologist doing in Hoboken? She says I'll like him and she's bringing him over a week from Thursday unless she hears otherwise, and so on."

"May I come too?" Kate asked. "It'll be wonderful to see Hortense again. And remember, Armbruster, I'm a fringe ecologist myself."

When Kate was denied tenure a few years previously in the biology department of the Long Island university where she taught and did neurobiological research, she found a job on a prospering science newsweekly, partly on the strength of her editing experience on *Systems of Sur-*

vival, a dialogue she and Armbruster had put together from conversations and reports by a little group Armbruster had got up to explore the different moral systems appropriate to different kinds of workers—such as police, legislators, clergy, and others holding positions of public trust, on the one hand, and manufacturers, bankers, merchants, and others in commercial pursuits, on the other. Hortense, who was Armbruster's niece, had been one of the group. During her first several months in her unfamiliar work on the weekly, Kate had frequently asked Armbruster for help and advice with her editing. After she no longer needed his guidance, she continued to drop in on him from time to time out of friendship.

A week from the following Thursday, at Armbruster's small apartment—crowded with books and signed photographs of authors on walls and tabletops—Hortense and Kate greeted each other affectionately and Hortense introduced Hiram. At tedious faculty meetings, Kate had learned to pass the time by imagining childhood versions of her colleagues' faces. Now, in Hiram, she saw a well-brought-up, thin-faced, eager boy grown into a good tweed suit and a receding hairline, his eagerness still intact.

As Hortense sat down on the sofa, Hiram remained standing, distractedly patting his jacket pockets. Kate glanced around the room in puzzlement. "Did you lose something, or mislay it?" she asked him.

"No, why—oh." He dropped his hands and smiled sheepishly. "I quit smoking five weeks and four days ago, and I still keep hunting for a cigarette." Hortense, Armbruster, and Kate, reformed smokers all, smiled sympathetically and Hortense patted his hand as he sat down beside her.

Knowing that Armbruster would be itching to deal with

Hiram's dynastic pretensions, as soon as they were settled with drinks Kate remarked offhandedly to Hiram, "That Four after your name is unusual. Not unheard-of, of course, but unusual."

Hiram made room between a book and a photograph on an end table and set down his drink. "My father's a splendid old man, but he insists on being Three, so I have to be Four. He's an economist and he would've liked me to be an economist, too, but after a try I dropped it for environmental studies. Most people I knew—this was thirty years ago—thought that it was like majoring in canoeing or bird-watching, but Pop took what I was doing seriously. I just mention this to show how minor his crotchet about the numbers is. 'Live and let live' runs both ways. But I did draw a line. My own son is named Joel."

"What do you do as an ecologist?" asked Armbruster. "Rally people around to save the woods and punish polluters?" Hortense and Kate exchanged glances, as if to acknowledge Armbruster's implicit, not very kindly, reference to Ben.

"No, although saving forests and reducing pollution are important. I'm a fund-raiser and facilitator. Specifically, I give organizational advice and help find grants for people—scientists—most of whom are trying to develop products and production methods learned from nature. Biomimicry, that approach is called. There's a book about it by that name. I'll get you a copy if you're interested. Two copies," he added, turning to Kate.

"Oh, I have it. I reviewed it," said Kate. "It's a good book, Armbruster. Broadly speaking, the aims are to make better materials than we manufacture now, but to make them at life-friendly temperatures and without toxic ingredients, like the filaments spiders make or the shell material

abalones construct, for instance. Ideally, by imitating the chemistry of nature, we should be able to make materials and products by methods that are benign and, at the end of their lives as products, return them to earth or sea to degrade benignly."

"So many other possibilities are being explored," said Hortense. "Think of the energy, soil, artificial fertilizer, and chemicals such as weed killers that could be saved if grain fields didn't require annual plowing or planting—if wheat or rye could grow like perennial grasses in prairies. All green plants capture sunlight, but it's a puzzle and wonder how duckweed captures sunlight so effectively and uses it so efficiently. That's worth learning from. You get the idea, Armbruster?"

"Interesting," Armbruster replied, "but it sounds like just another way for us to exploit nature—trying to get out of technological messes with more technological messes."

Kate suppressed a snicker at Armbruster's mischievous adoption of Ben's persona and glanced at Hortense to catch her reaction. Hortense, who usually remained cool and elegant under provocation, uncharacteristically bristled. "No! This isn't exploiting nature! It's learning from nature, with the object of undoing damage and getting along with nature more harmoniously. Biomimics are the last people deserving thoughtless dismissal, Armbruster. You have no idea how difficult these puzzles are, how hard and complicated it is to learn the way prairies manage to replenish themselves year after year. What's gotten into you? You didn't use to be so negative and glib. You sound like Ben!"

"Just curious. You've put me in my place. But if these endeavors are so difficult, they may not be practical."

When neither Hortense nor Kate replied, Hiram spoke

up again, rubbing his forehead thoughtfully. "Biomimicry is a form of economic development. So caring about biomimicry requires caring about economic development—hoping it continues vigorously. Otherwise, we can't hope for better products and safer methods. How else can we get them? Thinking about development has made me realize how similar economies and ecosystems are. That's to say, principles at work in the two are identical. I don't expect you to believe this just because I say so, but I'm convinced that universal natural principles limit what we can do economically and how we can do it. Trying to evade overriding principles of development is economically futile. But those principles are solid foundations for economies. My personal biomimicry project is to learn economics from nature."

"Bravo!" said Armbruster, sensing a book in the making. His eyes shifted to the tape recorder on a shelf.

"Uh-uh, Armbruster," said Hortense. "No symposium; no reports. Not again. Can't we have a conversation without that recorder? Can't we just talk? Can't you forget about trying to produce a book? There are so many other interesting things you could do, now that you have time." Kate caught Hortense's eye and, wagging her eyebrows, signaled to Hortense to pipe down.

"Producing a book never crossed my mind," Armbruster lied. "But it did cross my mind that I'd like a tape. Economic development interests me, too. What harm?"

"I don't mind if Kate and Hortense don't," said Hiram. He finished the last of his drink and set down his glass, with a questioning smile directed first to Hortense, then to Kate.

Hortense shrugged and Kate grinned while Armbruster moved his machine to the coffee table, pushed the record

button, nodded to Hiram, and said, "What did you mean about learning economics from nature? Economies are human, not natural. They're artificial, with the possible exception of primitive foraging."

"A common assumption, and one can see why," said Hiram. "After all, only human beings employ smart, educated border collies to herd sheep. Only human beings build hospitals and operate on cleft palates, or wrap snacks in plastic, or issue credit cards and send monthly bills. We differ from other creatures in the ways we make our living, but different doesn't necessarily mean artificial. We don't call bees' activities artificial because they manufacture honey, nor beavers' because they log and build dams, nor seahorses' because the males hatch and nurture the young. We don't call sunflowers artificial because they're so much taller than daisies. Our own manual dexterity and brains are created by nature. What we can do with those assets comes to us as naturally as the ability to spin webs and to sting netted prey comes to spiders."

"Not so fast," said Armbruster. "I didn't mean we're biologically artificial but that we create artificial things and impose them on the world of nature. We make artificial leather, artificial turf for stadiums, artificial teeth, artificial ice, and so on. How can you say human beings don't have artificial economies?"

"Armbruster, that's like accusing spiders of artificiality because they're spinning something other than cotton, flax, silk, wool, or hemp fibers," said Kate. "Please relax and let's listen before we argue."

"If we stop focusing on *things*," said Hiram, "and shift attention to the processes that generate the things, distinctions between nature and economy blur. That's not a new idea. Early ecologists were quick to see—"

"Who were the early ecologists?" asked Armbruster.

"Botanists who became interested in plant communities—groups of plant species whose interdependence seemed so similar to economic relationships that the naturalists coined a new word for natural communities of organisms and based it directly on the word *economy*. That was late in the nineteenth century."

"Wait!" said Armbruster, darting to his unabridged dictionary. "Aha, *economy* is derived from two Greek roots—*oiko*, meaning 'house,' and *nomy*, meaning 'management': house management. *Ecology* comes from the same root for 'house,' plus the root *logy* for 'logic' or 'knowledge.' So *ecology* literally means 'house knowledge.' Now, that's strange, isn't it? *Bio*, meaning 'life,' and *nomy*, 'management'—*bionomy*, 'life management,' would have been more to the point. Victorian scholars were well grounded in Greek. Odd that they embraced jargon as imprecise as *ecology*."

"Not odd when you realize they thought of ecology as 'the economy of nature,' " said Hiram, "a definition still in currency. The very sound of their new word tagged it as the twin of *economy*. That was their point, regardless of literal meaning. They were studying the economy of nature. I'm studying the nature of economy. Same affinity, glimpsed from an opposite angle."

"Natural processes obviously aren't founded on human behavior," Hiram continued. "Instead, nature affords foundations for human life and sets its possibilities and limits. Economists seem not to have grasped this reality yet. But many people engaged in various economic activities do realize it's important to learn from nature and apply the knowledge to what they do. For instance, modern metallurgists can observe the changes that take place in lattices of metallic crystals owing to temperature variations and

alloy combinations—information old smiths had no access to, because they didn't have X-ray crystallography. Architects and engineers accept the reality of natural forces of tension and compression and the help of tables of properties of construction materials. Wine makers, cheese makers, and bakers grasp and value their cooperative relationships with yeasts and bacteria; sanitary engineers, physicians, and organic farmers have learned to do the same and are still learning.

"In sum," he went on, "all kinds of people now understand that their success depends on working knowledgeably along with natural processes and principles, and respecting those processes and principles. That's very different from supposing that success depends on lore handed down from supernatural sources or on blind trial and error—and diametrically different from supposing that human beings are exempt from nature's dictates or that they are masters of nature."

"To repeat, I'm convinced that economic life is ruled by processes and principles we didn't invent and can't transcend, whether we like that or not, and that the more we learn of these processes and the better we respect them, the better our economies will get along."

"That sounds pretty pessimistic," said Armbruster. "Here we are, already loaded up with government regulations. And now you want to compile still more lists of economic rules and regulations decreed by nature?"

"Limits are part of it," replied Hiram. "Awareness of them can prevent futility. Alchemists did better after they gave up trying to turn base metals into gold and to discover a universal solvent and instead applied themselves to studying chemistry. But here's what interests me most: Natural principles of chemistry, mechanics, and biology

are not merely limits. They're invitations to work along with them.

"I think it's the same with economics. Working along with natural principles of development, expansion, sustainability, and correction, people can create economies that are more reliably prosperous than those we have now and that are also more harmonious with the rest of nature."

"I'm glad to hear you say 'the rest of nature,'" said Kate. "If it's actually true that natural processes rule human economic life—or could if we'd let them—it follows that we're an integral part of the natural world instead of its mere disturbers and destroyers."

"That's not necessarily a reassuring thought," said Hortense. "Plenty of other animal species have naturally gone extinct, along with their practices, whatever they were—you know that, Kate. Nothing is more unforgiving of error than nature. If we poison our own water and air with hormone-mimicking chemicals that we don't understand, it isn't reassuring to realize that nature's solution for maladaptations is extinction."

Armbruster cut short the potentially interesting point Hortense had raised. "Before we move on to anything else," he said, "I'd like to mention a few subjects that I consider economic fundamentals. You haven't said one word about money. But economics is first and foremost about money. What does nature say about money?"

"Nature says money is a feedback-carrying medium," Hiram replied. "Money is useful to economic self-regulation in the process we've come to call negative-feedback control. But the usefulness of money is far from enough to explain how economies work."

"What about the law of diminishing returns?" asked Armbruster. "First you cream off what's easiest and cheap-

est to exploit, then getting more is increasingly hard and expensive. That's certainly fundamental to economic life."

"The law of diminishing returns is truthful and harsh," said Hiram, "but it explains little about economic life in the absence of the converse law, which we might call the law of responsive substitution, meaning that people seek or contrive substitutes for resources that have become too expensive. Obvious examples have been domesticated animals in place of wild game; petroleum in place of whale oil and, later, coal; plastics in place of tortoiseshell and ivory. But that raises questions about development which demand some analysis of development in the rest of nature."

"What are you going to do with your project of economic biomimicry?" asked Armbruster.

"Write a book, I suppose," said Hiram. "Or put it on the Web. Or make practical use of it, advising clients. But that's premature. I've only partly formulated it. This isn't my work, just my hobby, a sideline. My main work is finding funds to keep other biomimics going—even though they're a frugal lot."

"I don't want to pry," said Armbruster, "but what do you live on? Commissions from grants you help to find?"

"No, I get paid for my time as a consultant. And I do some lecturing. Fortunately, I inherited my Hoboken house from my mother. It's enough room for my office and two apartments that I rent out, as well as my own apartment. I drifted into consulting after my father and I provided a little capital to a group in New Jersey working with novel and promising ways of treating sewage. I soon saw that development work of that sort needed more research and experimental capital than we could dream of affording, so I began hunting for more and turned out to be good at it. You could say I found a niche in the environment. I

can't imagine doing anything more interesting, because of the amazing people and ideas I get involved with, but it doesn't leave me much uninterrupted time."

"Which reminds me how late it is," said Hortense, rising.

"Wait," said Armbruster. "All you've told us is why you think learning economics from nature isn't outlandish. You haven't told us what you've learned. Can't you go a bit further?"

"Better not tonight. But we can arrange a time for me to bring you that book I promised and to talk some more." As Kate, Hortense, and Hiram were putting on their coats, Armbruster jubilantly stuck a Post-it note on his refrigerator door, reminding himself to stock up on blank cassettes.

CHAPTER 2

THE NATURE OF DEVELOPMENT

"Start where you like. I've no idea what to ask you," said Armbruster two weeks later as he switched on his recorder at the next session with Hiram, Hortense, and Kate.

"I'd like to start with development," said Hiram. "Where do new things come from? Why doesn't everything stay as it previously was? Let's define development as significant qualitative change, usually building up incrementally. But even single instances of qualitative change can be significant—for instance, resistance to specific antibiotics developed by some strains of bacteria."

"Oh, I thought you were going to talk about economic development," said Armbruster, his enthusiasm fading into disappointment.

"I am, but first come fundamentals applying to all development."

"Does that include inanimate development?" asked Kate.

"How can there be inanimate development?" Hortense protested.

"Think a minute," said Kate. "Rivers develop deltas by depositing silt. Waves develop sandbars. Volcanic eruptions develop mountains. Weather systems develop fronts and storms—"

"Let Hiram proceed," said Armbruster. "Otherwise we'll never get to economic development."

"Means of development vary enormously," Hiram continued, "as Kate has just indicated. A rabbit embryo and a bean sprout don't develop by exactly the same means, even though they're both alive. Yet an animal, a plant, a delta, a legal code, or an improved shoe sole—they all depend on the same underlying process for development."

"Don't expect me to take that outrageous statement on faith," said Armbruster. "You must mean it metaphorically."

"No, I'm not dealing in metaphors. Nineteenth-century embryologists and evolutionists were the first to try seriously to understand the development of one form from another as a natural process. The gist of their definitions of development was this: *differentiation emerging from generality*. Only four words—but they describe development on every scale of time and size, whether animate or inanimate.

"To take an example on a huge scale, consider the solar system. According to astronomers and physicists, it seems once to have been a vast cloud of matter. That was a generality. Differentiations emerged: the sun, fellow planets and their moons, along with various smaller debris and leftover generalized matter.

"Now, the next important point: Once the earth emerged as a differentiation, it became a new generality from which further differentiations could emerge. From the crust, in due course, emerged the kinds of differentiations Kate

mentioned. So here's the second universal principle of development: *Differentiations become generalities from which further differentiations emerge*. In other words, development is an open-ended process, which creates complexity and diversity, because multiplied generalities are sources of multiplied differentiations—some occurring simultaneously in parallel, others in successions. Thus a simple basic process, when repeated and repeated and repeated, produces staggering diversity.

"On a tiny scale—say, an embryonic human being—the generality is a microscopically small fertilized egg. At first it divides into repetitions of itself, forming a blob of multiplied generality. The first differentiations to emerge, depending on their locations in the blob, are layers of three distinctly differentiated kinds of cells, called ectoderm, mesoderm, and endoderm. These three differentiations are also three new generalities, from which more and more differentiations can emerge, both simultaneously and in successions, producing the diverse and complicated tissues and organs of the developing baby. In the infant's reproductive organ, a preserve of undifferentiated eggs or sperm is set aside for producing the next generation's differentiations."

"But babies aren't a new thing," said Hortense. "They're a multiplication of what already exists."

"To be sure, in one sense," Hiram replied. "But in another sense, each is a unique individual. In either sense, each new one emerges by the process I've sketched. Evolutionists, of course, were concerned not just with individuals but with how the species itself emerged—and all other species, living and extinct. They worked out long progressions of lineages—that is, sequential generalities and dif-

ferentiations. The diverging sequences are conventionally depicted as a tree or bush of life, with human beings on a topmost twig of the mammal branch on the tree.

"Sequences of more limited scope are conventionally depicted in linear, comic-strip fashion, such as the development of the horse from a smallish, fully-toed, nondescript quadruped to a magnificent hoofed steed. Or, to take an even narrower example, the various kinds of mammalian feet were differentiated from unspecialized feet of early mammals, which had five generalized toes with claws, apparently much like the unspecialized feet of modern rats.

"Differentiations that emerged from those ratlike feet included hooves of horses, wings of bats, flippers of whales, paws of cats, and our own hands, which happen to be closer to the unspecialized early mammal feet than those others. In our case, the significant digital development—not nearly as spectacular or specialized as hooves, flippers, or bat wings—was our opposable thumbs, which permit our superb manual dexterity."

"All you've told us so far, if you'll pardon me, is obvious to the point of banality," said Armbruster. "How else could differentiations emerge except from prior generalities?"

"My point exactly," said Hiram. "While this is obvious to you, it was not obvious to anybody until fairly recently. Aristotle, and other learned men long after him, thought a human embryo began as a minuscule infant that grew larger and stronger in the womb. And even today many people can't credit evolution, preferring to believe that the world and its creatures were preformed from the start, as stated in Genesis."

"Those evolutionary graphics," said Kate. "They're useful for identifying lineages, but they're incomplete and

misleading. A horse requires more than its own ancestors. A horse implies grass. Grass implies topsoil. Topsoil implies breakup of rocks, development of fungi, worms, beetles, compost-making bacteria, animal droppings—no end of other evolution and lineages besides that of the horse."

"Yes, I was coming to that next," said Hiram. "It's the last of three fundamental development principles: *Development depends on co-developments*. I mean that development can't usefully be thought of as a 'line,' or even as a collection of open-ended lines. It operates as a web of interdependent co-developments. No co-development web, no development."

"Aren't you and Kate talking about this process only when it gets pretty far along?" asked Armbruster. "When it's already very complicated? There surely had to be development without co-development before things became so complicated and webby."

"Co-developments may always have been necessary to the process of differentiation," Hiram replied. "Consider that the earth is not in the solar system by itself."

"Okay, the planets need the sun or they couldn't hold to orbits. But how does something like a delta need co-development?" asked Armbruster.

"A delta needs both water and grit. Neither, by itself, can develop a delta and each by itself is a result of co-developments," Hiram answered.

"As a practical matter, development doesn't occur in isolation. Every animal cell, including each of our own cells, of course, carries within it descendants of bacteria called mitochondria, which have their own lineage, different from that of the cell in which they live. Mitochondria have their own genetic material—they evolved separately—but now they and our cells are symbionts, mutually dependent,

although originally they may have co-developed as predators and prey.

"Mitochondria power our cells—generate energy—by combining sugar and oxygen; to oversimplify, mitochondria feed the flame of animal life by burning sugar. Cells of green plants benefit from co-developed symbionts called chloroplasts, which capture sunlight and use it as energy to free carbon—the basic food of plants—from carbon dioxide."

"The waste product of chloroplasts is oxygen, which animals require," said Kate. "The waste product of mitochondria is carbon dioxide, which plants require. Neither plants nor animals would have a feasible atmosphere to draw on or live in without the other."

"Of course, Armbruster, co-development webs have become increasingly intricate as development has proceeded," said Hiram. "But we've every reason to believe that mutually influential co-developments are as old as development. In their growing intricacy, they come to incorporate all degrees of cooperation—"

"Now you *are* drifting into metaphor," said Armbruster. "Cooperation implies conscious intent. Can you properly speak of cooperation among plants or animals that don't know they're cooperating? When it's just the way things are for them?"

"That's a blurry line," said Hortense. "An ecologist in Oregon, back home from Botswana, told me about the honey bird, a drab little thing notable for being able to digest beeswax. It can't get at honey or wax by itself, because it would be stung to death. So it enlists human help by getting the attention of a hunter and leading him to a hive. The hunter overcomes the bees with a smudge fire, breaks open the hive, and shares the goodies with the bird."

"I'll grant that as cooperation," said Armbruster, "because the hunter knows he's cooperating."

"Ah," Hortense replied, "but the honey bird has one other species of helpers: small, skunklike mammals. Naturalists suppose these were the bird's traditional helpers. Same routine: The bird gets the attention of one of these creatures, leads it on, the animal backs up to the hive, sprays it with his powerful odor, breaks into the hive, and shares its goodies with the bird. If using a smoke smudge is cooperative behavior, why isn't using a stink smudge?"

Before Armbruster could answer, Hiram admitted, "*Cooperation* was a poorly chosen word. Even among human neighbors, where cooperation indisputably exists, it can be inadvertent. My tenant told me he misses me when I'm out of town because he depends on hearing my morning alarm clock—inadvertent cooperation on my part. The world's full of it. From now on, I'll just speak of interdependence, leaving aside whether it's intended or not."

"All this co-development, cooperation, symbiosis, interdependence," grumbled Armbruster. "The three of you make nature sound like a barn raising, everybody pitching in together. Where's the fierce competition? Where's the nature red in tooth and claw? Where's survival of the fittest and devil take the hindmost?"

"Oh, competition's there, and so are winners and losers," said Hiram. "Losers die and winners eat. The honey bird, skunklike mammal and hunter in Hortense's example are predators and the hive is prey. But that's not the whole cast of characters. The bees and their honey wouldn't exist without flowers, but the flowers wouldn't exist without bees; and so on. Put it this way: Competitions for feeding and breeding take place in an arena. The arena is a habitat. The fittest panther in the jungle is a goner if its habitat

goes. And what is a habitat? It's an intricate, complicated web of interdependencies."

"An economy consists of interdependent relationships, competing and yet also knitting together co-developments," said Armbruster. "I agree with all that. Haven't you prepared us sufficiently to discuss economic development?"

"Yes," Hiram answered, "but first I'll remind you of the universal principles. Development is differentiation emerging from generality. A given differentiation is a new generality, from which further differentiations can potentially emerge. Thus the process is open-ended and it produces increasing diversity and increasingly various, numerous, and intricate co-development relationships. All this is the consequence of one simple sort of event repeated, repeated, repeated, and repeated."

"You've just identified a fractal," said Kate.

"I keep coming across references to fractals," said Hortense, "but what are they? And why should we care about them?"

"They're complicated-looking patterns that are actually made up of the same motif repeated on different scales," said Kate. "For instance, a muscle is a twisted bundle of fibers. Dissect out any one of those fiber bundles, and you find that it, too, is a twisted bundle of fibers. And so on. When you get down to the irreducibly smallest fiber, which you need an electron microscope to see, you find that it's a twisted strand of molecules. That's a real-life fractal. Mathematicians make computer-generated fractals, fascinating in their complexity and seeming variety, yet each fractal is made of repetitions."

"We should care about fractals," said Hiram, "because lots of things that seem impossible to comprehend become more understandable if we identify the basic pattern and

watch what it produces through repetition. It's a way of dealing with some complexities that otherwise are impenetrable—the way development as we've described it was impenetrable to Aristotle.

"Of course, development still embodies mystery. Why should there be a force driving the universe toward intricacy and away from simplicity? But if the *why* of development is impenetrable, at least the *how* of development is discernible, and this has practical value, not least for economic development—"

"At last!" said Armbruster. "Wait till I change the cassette."

"Economic development displays the same pattern as any other development," Hiram resumed after their drinks were refreshed and Hortense, rummaging in the kitchen, had produced a tray of crackers and cheese. "This is most obvious when the differentiations happen to be new varieties of animals or plants."

"Oh, please, let's not get diverted back to nature," said Armbruster.

"We're in economic life now," said Hiram, "specifically, agriculture and animal husbandry. Human beings have deliberately developed hundreds of new varieties—although not new species—of dogs, pigs, goats, and other animals, along with thousands of new varieties—and some new species—of edible and ornamental plants. They've done this by fostering desirable differentiations and selecting those worth further fostering. Have you ever tasted a wild orange? Awful, though beautiful. One of my clients has been developing cotton with color differences. No dye required.

"Our remote ancestors started developing tools and weapons with nothing that was of their own making. They