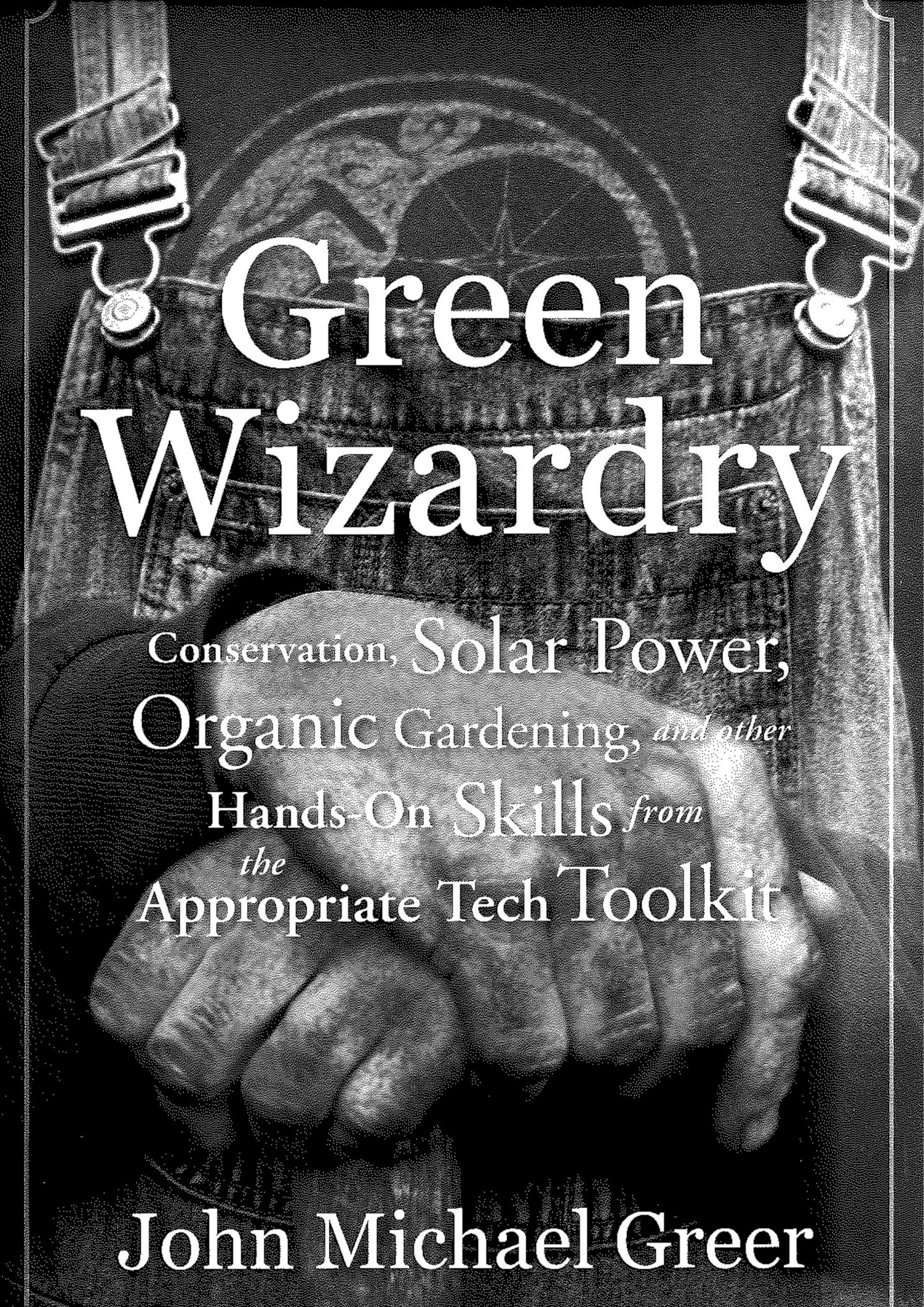

Green Wizardry

Conservation, Solar Power, Organic Gardening, *and other* Hands-On Skills *from the* Appropriate Tech Toolkit

John Michael Greer

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PART ONE

Principles

LESSON 1

Introducing Energy

It's not accidental that the appropriate tech movement of the 1970s was brought into being by the experience of energy crisis, or that tools and insights having to do with energy played a central role in that movement. In the most pragmatic of senses, understand energy and you understand the whole art of appropriate technology. In the broadest of senses, understand energy and you understand the predicament that is looming up like a wave in front of the world's industrial societies, and you also understand what we can and cannot expect to get done in the relatively short time we have left before the pressures unleashed by that predicament crest, break, and wash most of the modern world's certainties away.

Important as it is, though, energy doesn't stand alone. Two other concepts join the concept of energy to provide the central triad of principles that undergird this book and the perspectives and practices it explores. The first of these additional concepts is matter; the second is information. These three—energy, matter, and information—flow constantly through every whole system, in nature or in human society. Understand these flows and you understand the system. Each of the three, though, follows its own rules, so we'll explore them one at a time.

We can start with some basic definitions. Energy is the capacity to do work. It cannot be created or destroyed, but the amount and kind of work it can do can change. The more concentrated it is, compared to its surroundings, the more work it can do; the less the difference in its concentration and the background level of energy around it, the less work it can do. Left to itself, it moves from more concentrated to more diffuse forms over time, so everything you do with energy has a price tag, measured in a loss of concentration. These are the groundrules of thermodynamics, and everything a green wizard does comes back to them in one way or another.[3]

Some examples will help show how these rules work. In energy terms, for instance, a garden bed is a device for collecting solar energy by way of the biochemical dance of photosynthesis. Follow a ray of sunlight from the seething thermonuclear cauldron of the sun, across 93 million miles of hard vacuum and a few dozen miles of atmosphere, until it falls on the garden bed. About half the sunlight reflects off the plants, which is why the leaves look bright green to you instead of flat black; most of the rest is used by the plants to draw water up from the ground and expel it as water vapor into the air; a few percent is caught by chloroplasts—tiny green disks inside the cells of every green plant—and used to turn water and carbon dioxide into sugars, which are rich in chemical energy and power the complex cascade of processes we call life.

Most of those sugars are used up keeping the plant alive. The rest are stored for the plant's future needs, though a percentage of them get hijacked if some animal eats the plant. Most of the energy in the plants the animal eats gets used up keeping the animal alive; the rest get stored until another animal eats the first animal, and the process repeats. Sooner or later, an animal manages to die without immediately ending up in something else's stomach, and its body becomes a lunch counter for all the creatures—and there

are a lot of them—that make a living by cleaning up dead things. By the time they're finished with their work, the last of the energy from the original beam of sunlight that fell on the garden bed has been lost to the food chain.

What happens to it then? It turns into diffuse background heat. That's the elephant's graveyard of thermodynamics, the place useful energy goes to die. When you do anything with energy—concentrate it, move it, change its form—a price has to be paid in diffuse heat. All along the chain from the sunlight first hitting the leaf to the last bacterium munching on the last scrap of dead fox, what isn't passed onward is turned directly or indirectly into heat so diffuse that it can't be made to do any work other than jiggling molecules a little. The metabolism of the plant generates a trickle of heat; the friction of the beetle's legs on the leaf generates a tiny pulse of heat; the mouse, the snake, and the fox all turn most of the energy they take in into heat, and all that heat radiates out into the great outdoors, warming the atmosphere by a tiny fraction of a degree, and slowly spreading up and out into the ultimate heat sink of deep space.

That's one example. For another, let's take a solar water heater, the simple kind that's basically a tank in a glassed-in enclosure set on top of somebody's roof. Once again we start with a ray of sunlight crossing deep space and Earth's atmosphere to get to its target. The light passes through the glass and slams into the black metal of the water tank, giving up much of its energy in the form of heat. Inside the metal is water, maybe fifty gallons of it; it takes a fair amount of heat to bring fifty gallons of water to the temperature of a good hot bath, but the steady pounding of photons against the black metal tank will do the trick in just a few hours.

Most of what makes building a solar water heater complex is a matter of keeping that relatively concentrated heat in the water where it belongs, instead of letting it leak out as—you guessed it—diffuse background heat. The glass in front of the tank is there to keep moving air from carrying heat away, and it also helps hold heat in by way of a clever bit of physics: most of the energy that matter absorbs from visible light downshifts to infrared light as it tries to escape, and glass lets visible light pass through it but reflects infrared back the way it came. (This is known as the greenhouse effect, by the way, and we'll be using it later on in this book, not least in the context of actual greenhouses.) All the surfaces of the tank that aren't facing the sun are surrounded by insulation to keep heat from sneaking away, and the pipes that carry hot water down from the heater to the bathtub and other uses are wrapped with insulation. Even so, some of the energy slips out from the tank, some of it makes a break for it through the insulation around the pipes, and the rest of it starts becoming background heat the moment it leaves the faucet.

There are five points I'd like you to take home from these examples. The first is that both the plant and the solar heater function as a result of the same process: the flow of energy from the sun to Earth. Start looking at everything that goes on around you as an energy flow that starts from a concentrated source—almost always the sun—and ends in diffuse heat. If you do this, you'll find that a great deal of the material in this book is simply common sense—and a great many of the habits that are treated as normal behavior in our society will suddenly reveal themselves as stark staring lunacy.

The second point to take home is that natural systems, having had much more time to work the bugs out, are much better at containing and using energy than most human systems are. The solar water heater and the house with its natural gas furnace take concentrated energy, put it to one use, and then lose it to diffuse heat. A natural ecosystem, by contrast, can play hot potato with its own input of concentrated energy for a much more extended period, tossing it from one organism to another for quite a while before all of the energy finally follows its bliss. The lesson here is simple: by using existing natural systems to do things, green wizards can take advantage of two billion years of evolution, and by paying close

attention to the ways that natural systems do things, green wizards can get hints that will make human systems less wasteful.

The third point is that energy doesn't move in circles. In the next lesson, we'll be talking about material substances, which do follow circular paths; in fact, they do this whether we want them to do so or not, which is why the toxic waste we dump into the environment ends up circling back around into our food and water supply. Energy, though, follows a trajectory with a beginning and an end. The beginning is always a concentrated source, which again is almost always the sun; the end is diffuse heat. Conceptually, you can think of energy as moving in straight lines, cutting across the circles of matter and the far more complex patterns of information gain and loss. Once a given amount of energy has followed its trajectory to the endpoint, for all practical purposes, it's gone; it still exists, but the only work it's capable of doing is making molecules vibrate at whatever the ambient temperature happens to be.

The fourth point is that while energy is the capacity to do work, it can't do work in a vacuum. To make energy do whatever work you have in mind for it—whether that work consists of growing plants, heating water, or anything else—matter, information, and additional energy have to be invested. The plant needs carbon dioxide, water, and an assortment of minerals, as well as the information in its DNA and a stock of energy stored up in sugars from previous sunlight, in order to turn each new photon into useful energy. The solar water heater has equivalent requirements. Far more often than not, these secondary requirements impose limits that are far stricter than the limits imposed by the energy flow itself.

The fifth and final point, which follows from the third and fourth, is that for practical purposes, energy is finite. It's common for people these days to insist that energy is infinite, with the implication that human beings can walk off with as much of it as they wish. This is an appealing fantasy, flattering to our collective ego, and it plays a central role in backing our culture's myths of perpetual technological progress and limitless economic growth.

As ecologist Garrett Hardin pointed out quite a while ago, though, it's also nonsense. In his useful book *Filters Against Folly* (which should be required reading for any student of green wizardry), Hardin showed that words such as "infinite," "limitless," and "boundless" are thoughtstoppers rather than useful concepts because the human mind can't actually think about infinity.[4] When people say "X is infinite," what they are actually saying is "I refuse to think about X."

Still, there's a more specific sense in which talk about infinite energy is nonsense. At any given place and time, the amount of energy that is available in a concentration and a form capable of doing any particular kind of work is finite, often distressingly so. Every ecosystem on Earth has evolved to make the most of whatever energy is available, whether that energy takes the form of equatorial sunlight shining down on the Amazon rain forest, chemical energy in sulfur-laden water surging up from hot springs at the bottom of the sea, or fat stored up during the brief Arctic warm season in the bodies of the caribou that attract the attention of a hungry wolf pack.

Thus it's crucial to recognize that useful energy is always limited, and it usually needs to be coaxed into doing as much work as you want to get done before it gets away from you and turns into diffuse background heat. This is true of any whole system, a garden as much as a solar hot water system, a well-insulated house, or any other project belonging to the field of appropriate tech. Learn to think in these terms and you're well on your way to becoming a green wizard.

Exercise for Lesson 1

Draw a rough flow chart for the flow of energy through some part of your life. Take a piece of paper, draw a picture of the sun at the top, and draw a trash can at the bottom; label the trash can "Background Heat." Now draw the important components in any system you want to understand, and draw arrows connecting them to show how the energy moves from one component to another. If you're sketching a natural system, draw in the plants, the herbivores, the carnivores, and the decomposers, and sketch in how energy passes from one to another, and from each of them to the trash can; if you're sketching a human system, the energy source, the machine that turns the energy into a useful form, and the places where the energy goes all need to be marked in and connected.

Do this with a variety of different energy flows, and do at least a little research on the internet or at your local public library to check your facts. It doesn't matter at this stage if you get all the details right; the important thing is to start thinking of energy in terms of finite flows, and get past the fantasy of limitlessness.

LESSON 2
Introducing Matter

Of the three factors that flow through every whole system—energy, matter, and information—matter is the messiest. If you have small children in your house, you have an advantage in making sense of matter, because you already know the most important of the rules that govern matter: it does not behave itself. It does not do what it's told. As you found out around the age of two, to your ineffable delight and your mother's weary annoyance, matter gets all over everything, especially when stomped. Most people discover this in childhood and then spend the rest of their lives trying to forget it. One of the ways they forget it in modern industrial cultures is by pretending that matter acts like energy.

Get a piece of paper and a pen, and I can show you how that works. At the top of the paper, draw a picture of Santa Claus in his sleigh, surrounded by an enormous pile of gifts. Label it "infinite material resources." In the middle, draw a picture of yourself sitting on heaps of consumer goodies; put in some twinkle dust, too, because we'll pretend (as modern industrial societies do) that the goodies somehow got there without anybody having to work sixteen-hour days in a Third World sweatshop to produce them. Down at the bottom of the paper, draw some really exotic architecture, and put a Chamber of Commerce sign out in front that says "Welcome to Away." You know, Away—the mysterious place where no one has ever been, but where stuff goes when you don't want it around anymore. Now draw one arrow going from Santa to you, and another from you to Away.

Does this picture look familiar? It should. It has the same pattern as a very simple energy flow diagram, just like the one you sketched in the previous lesson. Here, Santa is the energy source and Away is the diffuse background heat that all energy turns into sooner or later. Although this sort of diagram works perfectly well with energy, it doesn't work worth beans with any material substance. Nevertheless, this is how people in modern industrial societies are taught to think about matter.

As an antidote to that habit of thinking, take your Santa diagram, crumple it up with extreme prejudice, and throw it across the room. It would be particularly helpful if Fido is in the room with you, decides you've thrown a ball for him to chase, and he comes trotting eagerly back to you with the diagram in his mouth, having reduced it to a drool-soaked mess. At that moment, as you meet Fido's trusting gaze and try to decide whether it's more bother to go get a real ball for him to play with or take the oozing object that was once your drawing and then wipe a couple of tablespoons of dog slobber off your hand, you will have learned one of the great secrets of green wizardry: matter moves in circles, especially when you don't want it to do so.

Back in my schooldays, corporate flacks trying to head off the rising tide of popular unhappiness with what was being done to the American environment had a neat little slogan: "The solution to pollution is dilution." They were dead wrong, and because their slogan got put into practice far too often, a sizable number of people and a much greater number of other living things ended up just plain dead. Dilute an environmental toxin all you want, and it's a safe bet that a food chain somewhere will concentrate it right back up for you and serve it on your plate for breakfast. It's hard to think of anything more dilute than the strontium-90 dust that was blasted into the upper atmosphere by nuclear testing and scattered around the globe by high-level winds; that didn't keep it from building up to dangerous levels in cow's milk, and shortly thereafter, in children's bones.

A similar difficulty afflicts the delusion that we can put something completely outside the biosphere and make it stay there. Proponents of nuclear power who don't simply dodge the issue of radioactive waste altogether treat that issue as a minor matter. It's not a minor matter; it's the most critical of half a dozen disastrous flaws in the shopworn 1950s-era fantasy of limitless nuclear power still being retailed by the nuclear industry's few remaining cheerleaders. A nuclear fission reactor—any nuclear fission reactor—produces wastes so lethal they have to be isolated from the rest of existence for a quarter of a million years—in other words, fifty times as long as all of recorded history. In theory, containing high-level nuclear waste is possible; in practice, Murphy's law is the safer guide. In the real world, it's certain that sooner or later, things go wrong.

Despite the best intentions and the most optimistic rhetoric, in a hundred years, or a thousand, or ten thousand, by accident or malice or the sheer cussedness of nature, that waste is going to leak into the biosphere, and once that happens, anyone and anything that comes into contact with even a few milligrams of it will suffer a miserable death. The more nuclear power we generate now, the more of this ghastly gift we'll be stockpiling for the people of the far future. If one of the basic concepts of morality is that each of us ought to leave the world a better place for those who come after us, there must be some sort of gold medal for selfish malignity in store for the notion that, to keep our current civilization going a little longer, we're justified in making life shorter and more miserable for people whose great-great-great-grandparents haven't even been born yet.

This extreme case illustrates a basic rule of green wizardry: *There is no such place as Away.* You can throw matter out the front door all you want, but it will inevitably circle around while you're not looking and come trotting up the back stairs. There's a great deal of pop mysticism these days about how wonderful it is that everything in the universe moves in circles; it's true enough that matter moves in circles, though energy and information don't, but it's not always wonderful. If you recognize matter's habits and work with them, you can get it to do some impressive things as it follows its rounds, but if you aren't watching it closely, it can just as easily sneak up behind you and clobber you.

The trick to making matter circle in a way that's helpful to you is twofold. The first half is figuring out every possible way it might circle; the second is to make sure that as it follows each of those pathways, it goes through transformations significant enough to make it harmless. I hope I won't offend anyone's delicate sensibilities by using human feces as an example. The way we handle our feces in most American communities is frankly bizarre; we defecate in clean drinking water, for heaven's sake, and then flush it down a pipe without the least thought of where it's going. Where it's going, most of the time, is into a river, a lake, or the ocean, and even after sewage treatment, you can be sure that most of what's in your bowel movements is going to land in the biosphere pretty much unchanged because mushing feces up in water and then dumping some chlorine into the resulting mess doesn't change them enough to make a difference.

Consider the alternative of a composting toilet and a backyard garden. Instead of dumping feces into drinking water, you feed them to hungry thermophilic bacteria. When the bacteria get through with the result, you put the compost into the middle of

your main compost pile, where it feeds a more diverse ecosystem of microbes, worms, insects, fungi, and the like. When those organisms are done with it, you dig the completely transformed compost into your garden, and soil organisms and the roots of your garden plants have at it. When you pick an ear of corn from your garden, some of the nutrients in the corn got there by way of your toilet, but you don't have to worry about that. The pathogenic bacteria that make feces dangerous to human beings, having grown up in the cozily sheltered setting of your bowels, don't survive long in the Darwinian environment of a composting toilet, and any last stragglers get mopped up in the even more ruthless ecosystem of the compost pile.

In the same way, the inedible parts of garden vegetables can be put into the compost pile or, better still, fed to chickens or rabbits, whose feces can be added to the compost pile, so that plant parasites and diseases have less opportunity to ride the cycle back to the plants in the garden. You can cycle other parts of your household waste stream into the same cycle; alternatively, if you need to isolate some part of the waste stream from the rest of it—for example, if somebody in the house is ill and you don't want to cycle their wastes into your garden soil, or if you want to collect and concentrate urine as a rich source of fertilizer—you can construct a separate cycle that takes the separate waste stream in a different direction and subject it to different transformations, so that whatever cycles back around to you is a resource rather than a problem.

Notice, however, that one of the limitations on energy discussed in the previous lesson also applies to matter: matter doesn't move in circles all by itself. It needs energy, information, and additional matter to ride that cycle back around to you. In one case, the energy that moves the matter in its circle is the gravity that makes water flow downhill; the additional matter is the water of the river where your town's sewage plants discharge their waste, and the information is the biological programming that makes the fish you're going to eat next week recognize and snap up the aquatic critters that just ate little bits of your feces. In another case, the energy is the heat released by thermophilic bacteria in your compost pile; the additional matter is the garden and kitchen waste that makes up most of the pile, and the information is partly tucked away in bacterial DNA and partly your own knowledge of how to run a compost bin. Either way, the same limitation applies. Much more often than not, it's these additional requirements, rather than the nature or available quantity of the matter you're working with, that imposes hard limits on what you can accomplish.

The same principles that allow you to make the cycle run the way you prefer, and the same requirements of energy, matter, and information, apply equally wherever matter is involved in the green wizard's work. It's crucial to recognize, though, that not everything can be transformed into a useful form, or even a harmless one, by guiding the circles in which it moves. One of the essential boundaries of appropriate tech is the boundary between the kinds of matter you can change with the tools you have on hand, and the kinds you can't, and if you can't change it into something safe, it's a bad idea to produce it in the first place. It really is that simple: If you can't transform it, don't produce it.

Exercise for Lesson 2

Take at least one material item or substance you currently get rid of, and figure out where it goes once it leaves your possession. Don't cheat yourself by choosing something you already know about, and don't settle for abstractions. With the internet at your fingertips, it takes only a modest amount of work to find out which landfill gets your garbage, which river has to cope with your sewage, and so on. Your ultimate goal is to trace your chosen item or substance all the way back around to your own front door—for example, by tracing your plastic bottles to a particular landfill, the polymerizers in the bottles to the groundwater in a particular valley, the groundwater to a particular river, and the river to the particular coastal waters where the local fishing fleet caught the fresh cod you're about to have for dinner.

This may be an unsettling experience. I apologize for that, but it can't be helped. One of the few effective immunizations against the sort of airy optimism that assumes that pollution can't hurt us is to spend time wrestling with the muddy, material details of our collective predicament. If your wizardry is going to amount to more than incantations that make people feel better about themselves even as society consumes its own future, it needs to get into the nitty gritty of the work—first with the mind, then with the hands.

LESSON 3
Introducing Information

Information is the third element of the triad of fundamental principles that flow through whole systems of every kind. All three need to be understood to build viable systems using appropriate technology. In making sense of this third factor, the appropriate tech movement had a huge advantage that people only a few decades earlier didn't have: the science of cybernetics, which is the science of information flow. It is one of the great intellectual adventures of the twentieth century, and it deserves much more attention than most people give it these days.

Unfortunately, in trying to pick up where the appropriate tech movement left off, we now have a huge disadvantage that people a few decades didn't have. The practical achievements of cybernetics, especially but not only in the field of computer science, have accidentally midwifed a set of attitudes toward information in popular culture that impose bizarre distortions on the way most people nowadays approach the subject. You can see these attitudes in their extreme form in the theory of the Singularity, promoted by computer scientist Ray Kurzweil and popular in some circles. That theory suggests that since the amount of information humanity has is supposedly increasing at an exponential rate, and exponential curves approach infinity asymptotically in a finite time, then at some point not too far in the future, industrial humanity will know everything and achieve something like godhood.[5]

Believers in this prediction insist that it's an avant-garde scientific concept backed by all sorts of data. In point of fact, it's nothing of the kind; it's simply a rehash of Christian apocalyptic myth in the language of cheap science fiction, complete with a techno-Rapture into a heaven lightly redecorated to make it look like outer space.

The entire notion of the Singularity is rooted in a basic misunderstanding of what information is and what it does. This is all the more embarrassing in that this misunderstanding was dealt with conclusively decades ago by the pioneering theorists of cybernetics. Gregory Bateson was one of those pioneers, and his work—which you would have found on the shelf of any serious appropriate tech geek back in the day—is a good place to start clearing up the mess. Bateson defines information as "a difference that makes a difference."[6] This is a subtle definition, much more subtle than it seems at first glance, and it implies much more than it states. Notice in particular that whether something "makes a difference" is not an objective quality possessed by a difference; it depends on an observer, to whom the difference makes a difference. To make the same point in the language of philosophy, information can't be separated from intentionality.

What is intentionality? The easiest way to understand this concept is to turn toward the nearest window. Notice that you can look *through* the window and see what's beyond it, or you can look *at* the window and see the window itself. If you want to know what's happening in the street outside, you look through the window; if you want to know how dirty the window glass is, you look at the window. The window presents you with the same collection of photons in either case; what turns that collection into information

of one kind or another—what makes the difference between seeing the street and seeing the glass—is your intentionality.

The torrent of raw difference that deluges every human being during every waking second, in other words, is not information. That torrent is data—a Latin word that means "that which is given." Only when we approach data with intentionality, looking for differences that make a difference to us at that moment, does data become information—also a Latin word, meaning "that which puts form into something." Data that isn't relevant to a given intentionality, such as the dirt on a window when you're trying to see what's outside, has a different name, one that doesn't come from Latin: noise.

Thus the mass production of data in which true believers in the Singularity place their hopes of salvation is much more likely to have the opposite of the effect they claim for it. Information only comes into being when data is approached from within a given intentionality, so it's nonsense to speak of it as increasing exponentially in any objective sense. Data can increase exponentially, to be sure, but this simply increases the amount of noise that has to be filtered before information can be made from it. This is particularly true in that a very large portion of the data that's exponentially increasing these days consists of such important material as, say, internet gossip about the current color of Lady Gaga's pubic hair.

Data, in other words, must be filtered in order to turn it into information. The process of filtering data to produce information and get rid of noise, in turn, always requires energy, matter, and additional information. Like energy and matter, information doesn't function in a vacuum; whether the information is in a plant's DNA, a human brain, or an electronic device, it has to be stored in matter, by the application of some kind of energy, using some additional set of information that governs how it is encoded. As with energy and matter, in turn, it's usually these additional factors that impose hard limits on the kinds and amounts of information that can be used in any given situation.

Once information is created and used, in turn, it has to be dealt with. A buildup of too much information in a system is just as damaging as a buildup of too much energy or too much matter. A blackboard soon becomes useless if there's no eraser to clear away one set of markings and make room for another, and the equivalent rule applies to every kind of system: information has to be sorted for long-term relevance, and anything that is only relevant in the short term needs to be purged ruthlessly once its usefulness has expired. This is why so much of what goes into your short-term memory, for example, never makes it into long-term memory. Once again, energy, matter, and more information have to go into the purging process we call forgetting, and these requirements also impose limits on what can be done with information.

The need to filter data so that information can be extracted from it explains why the sense organs and nervous systems of living things have been shaped by evolution not to expand but to restrict the kinds and volumes of data they accept. Every species of animal has different information needs, and each limits its intake and processing of data in a different way. You're descended from mammals that spent a long time living in trees, for example, which is why your visual system is very good at depth perception and seeing colors (important in differentiating ripe from unripe fruit) and very poor at many other things.

A honeybee has different needs for information, so its senses select different data. It sees colors that extend well up into the ultraviolet, which you can't, because many flowers use reflectivity in the ultraviolet to signal where their nectar is. The bee also sees the polarization angle of light, which you don't, since this helps it navigate to and from the hive. You don't "see" heat with a special organ on your face, the way a rattlesnake does, or sense electrical currents the way many fish do. Around you at every moment is a world of data that you will never perceive. Why? Because your ancestors, over millions of generations, survived better by excluding that data, so they could extract information from the remainder, than they would have done by including it.

Human social evolution parallels biological evolution, so it's not surprising that much of the data processing systems in human societies are ways of excluding most of the available data so that useful information can emerge from the little that's left over. This is necessary, but it's also problematic: a set of filters that limit data to what's useful in one historical or ecological context can screen out exactly the data that might be most useful in a different context, and the filters don't necessarily change as fast as the context. One very common consequence of the lag time between social change and human cultural filters is the emergence of persistent logical mistakes that cripple a society's ability to deal with changing times.

Belief in the Singularity, and less obviously religious forms of faith in perpetual progress, are based on exactly such a logical mistake. Believers in these notions have forgotten that the words "it can't be done" also convey information, and a very important kind of information at that. It's entirely plausible that even if we did achieve infinite knowledge about the nature of the universe, what we would learn from it is that the science fiction fantasies being retailed by believers in the Singularity are out of reach, and we simply have to grit our teeth and accept the realities of human existence after all.

Information always implies an intentionality because data doesn't turn into information until it passes through a filter oriented toward a particular intentionality. Even something as simple as a thermostat connected to a furnace has an intentionality—the thermostat "looks" at the air temperature, and "sees" if that temperature is low enough to justify turning the furnace on, or high enough to justify turning it off. The better the thermostat, the more completely it ignores data that has no bearing on its intentionality. Conversely, most of the faults thermostats can suffer are ways that other bits of data slip through the filter (for example, the insulating value of the layer of dust on the thermostat) and insert themselves where they're not wanted.

The function of the thermostat in the larger context to which it belongs—the system of the house that it's supposed to keep at a more or less stable temperature—is another matter, and it requires a subtly different intentionality. The homeowner, whose job it is to make information out of the available data, monitors the behavior of the thermostat and, if something goes wrong, has to figure out where the trouble is and fix it. The thermostat's intentionality is to respond to changes in air temperature; the homeowner's intentionality is to make sure that this intentionality produces the effect that it's supposed to produce.

One way or another, this same two-level process plays a role in every part of the green wizard's work. It's possible to put additional levels between the information filter on the spot (in the example, the thermostat) and the human being who manages the system, but in appropriate tech it's rarely a good option. The Jetsons fantasy of the house that runs itself is one of the things that most deserves a place in history's compost heap as the age of cheap energy comes to a close. As a green wizard, your goal in crafting systems is to come up with stable, reliable information filters that will pursue their own intentionalities without your interference most of the time, while you monitor the overall output of the system and keep tabs on the very modest range of data that will let you know if something has gone haywire.

Notice what's happening in the two levels of processing in the example of the thermostat: the total amount of data is being filtered in two ways, one narrow and one broad, so that useful information can be separated from noise. The thermostat focuses precisely on the narrowest set of data that will allow it to do its job, while the homeowner pays attention to the overall comfort level in the house, as well as to such details as how often the furnace cycles on and off, and how much the monthly fuel bill is running. Machines are good at tight filtering of data to produce precise but narrow flows of information; human beings are good at broad overviews of data to produce imprecise but global flows of information. Both these flows are needed to keep a system working—and the privileging of narrow, machine-filtered flows of information over broader,

human-filtered flows goes a long way to explain why industrial civilization is facing the rising spiral of crises that dominates today's headlines.

Exercise for Lesson 3

Take at least one flow of information that shapes the way you live your life, and trace the following factors: the underlying data that has to be filtered in order to extract information, the thing that does the filtering, the intentionality of the filter, and the means for disposing of old information no longer relevant to the intentionality. This will be much easier for you, especially at first, if you choose something as narrowly specific as the thermostat example: for instance, a set of data you have to monitor at your job, or the specific variations in local weather that affect how you spend your weekends.

Once you've identified the flow and explored the factors just listed, see if you can find the two kinds of information filtering described above: the narrow and precise kind that is often best handled by a machine (such as the temperature and rainfall measurements during the week) and the broader and imprecise kind that is usually best handled by a human being (such as the forecast of the weekend's weather). If one of these is lacking, think of ways in which it could be introduced into the way that the information is handled.

LESSON 4
Thinking in Systems

The three factors just outlined—energy, matter, and information—are basic to an ecological understanding of the world, and they form the threefold foundation of the green wizardry of appropriate tech. A foundation isn't a building, though, and it's entirely possible to start from a good working knowledge of one or more of the three factors and still end up with something that's hopelessly unworkable in practice. The blueprint that makes it possible to construct a viable building on that foundation—to extend the architectural metaphor a little further—is a solid, basic knowledge of what systems are and how they work.

What is a system? In the 1960s and 1970s, when systems theory was in its golden age, students of appropriate tech had their choice of any number of carefully drawn definitions. For practical purposes, though, we can condense those definitions down to the following: a system is any set of interacting components in which the behavior of the whole set is determined by the sum of the interactions among its components.

Got that? Now let's go through it in detail.

A system is a set—that is, it consists of two or more things, which we'll call components of the system. Those components are interacting—that is, each of them acts on other components of the system, and each of them responds to the actions of other components. The whole system has its own behavior, which is distinct from the individual actions and responses of the components of the system. To use some systems jargon, the behavior is an *emergent property* of the system; this means that it emerges out of the sum of all the actions and responses of the components to each other, rather than out of any individual component.

The thermostat we examined in the previous lesson sits at the core of a very simple system. The components of the system are the thermostat, the furnace, and the air inside the house. The thermostat measures the temperature of the air, and turns the furnace on and off. The furnace receives signals from the thermostat and either heats or doesn't heat the air. The air receives heat from the furnace, and the heated air affects the behavior of the thermostat. None of the individual components of the system—the thermostat, the furnace, or the air—is responsible for the behavior of the whole system; all three of them must work together to produce the effect of the whole system, which is to keep the air temperature inside the house close to some desired value.

This very simple system has two features that are common to every other viable system. The first is that the thermostat system is not and cannot be isolated from its surroundings; it can only function because it receives inputs from, and returns outputs to, its surroundings. The thermostat can signal the furnace only because electricity carries the signal; the furnace can heat the air only because it receives fuel and vents combustion wastes up the chimney; the air is able to hold an even temperature only because the walls of the house keep the heat from diffusing itself out into the atmosphere as a whole. Thus the system of thermostat, furnace, and air is a subsystem of a larger system, and that larger system is a subsystem of an even larger system. Trace the inputs and outputs of any system far enough, and they extend to the limits of the universe.

It's sometimes convenient to think of systems as having neatly defined edges, but this habit of thought has its downsides. What systems have, more precisely, are interfaces, which function very much like the walls of a cell or the borders of a country: that is, they limit the interactions between what's inside and what's outside in ways that tend to preserve the system on the inside. There are normally several different interfaces surrounding any system, each one limiting a different set of interactions between the system and its surroundings. It can be useful to think of interfaces as hard limits, in order to concentrate on the behavior of whatever system you're trying to understand, but that narrow focus can be a potent source of disasters if what's outside gets ignored too often. The frequency with which this happens can be credited to the simple fact that most people in the world's industrial nations are stupid about systems.

There's really no gentler way to put it. Listen to the media, the internet, or everyday talk these days, and you're guaranteed to hear somebody insisting that worrying about the limits to growth is just plain silly because science, technology, progress, the free market, the space brothers, or some other convenient *deus ex machina* will let us keep extracting an ever-increasing supply of energy and raw materials from a finite planet without ever running short, and always find places to dump the rising tide of waste without having it turn up again to give us problems. Now, of course, much of that rhetoric comes from flacks-for-hire pushing the agenda of various corporate or political pressure groups, but the illogic is pervasive enough that I suspect a lot of it comes from ordinary people who basically haven't yet noticed that the world isn't flat.

Watch what passes for political and economic debate these days, and you can count on hearing the same thing. Take "sustainable growth," the mantra of the business-as-usual end of the green movement. Even the most elementary grasp of systems theory makes it clear that there's no meaningful sense of the adjective "sustainable" that can cohabit with any meaningful sense of the noun "growth." In a system—any system, anywhere—limitless growth is always unsustainable; every system that works, anywhere in the cosmos, has mechanisms to prevent limitless growth. This is the second feature the very simple system just described shares with all other viable systems: it embodies negative feedback.

The phrases "negative feedback" and "positive feedback" are among the most misunderstood terms in systems theory, which is saying something. Negative feedback is not negative in a moral sense—it's not "bad feedback"; it's negative in the sense that it says "no" to changes in an environment. When the temperature of the air goes up too far, the thermostat turns off the furnace and lets it cool down; when it cools down too far, the thermostat turns the furnace back on and heats it up. Positive feedback works the other way: a thermostat set to positive feedback would respond to rising temperatures by turning on the furnace and heating the air even further. The result would be a house that's unbearably hot, and, if nothing keeps the temperature from rising indefinitely, the house will eventually catch fire and burn to the ground. Where feedback is concerned, in other words, positive isn't good and negative isn't

bad; systems that have negative feedback sustain themselves, while systems with positive feedback destroy themselves.

The modern industrial economy is a system with positive feedback—that's what "limitless economic growth" means in systems terms—and therefore, with mathematical certainty, it will destroy itself unless negative feedback kicks in first. Climate instability is part of that negative feedback because an industrial society ravaged by droughts, floods, tornadoes and hurricanes will experience less growth than it would in the absence of these little problems. The depletion of fossil fuel reserves is another form of negative feedback; an industrial society that has to put a rising portion of its available resources into extracting fossil fuels from the ground will experience less growth than it would if it somehow got a limitless supply of energy from somewhere. How hard will these and other forms of negative feedback hit the industrial world? Over the next few decades, we're going to find out.

A basic grasp of systems thinking would make it easier to avoid such follies, but that same grasp would also make it impossible to pretend that we can go on living our current lifestyles much longer. That's an important reason why systems thinking was dropped like a hot rock in the early 1980s and why, outside of a narrow range of practical applications where it remains essential, it's been shut out of the collective conversation about our society ever since. For the aspiring green wizard, on the other hand, there are few habits of thought more important than thinking in whole systems. Most of what this book covers, even those things that seem strictly practical in nature, are explorations in systems thinking. Most of the work of green wizardry is simply the application of a systems approach to some aspect of working with nature.

The points already made should be applied to any system you are trying to understand. Start with the main components of the system and trace out the way they interact with one another; figure out where the interfaces are that manage the system's interactions with the rest of the universe; track the negative feedback that keeps the system from straying outside the conditions that allow it to function. Then work out how energy flows through that system, how matter cycles into and out of that system, and how data is filtered by that system to separate the information the system needs from the noise it needs to exclude. Once you know all these, you'll be in a good position to make sense of the system. If this reminds you of the exercise at the end of Lesson 3, it should; the habit of sorting out systems behavior suggested by that exercise is worth cultivating throughout your work as a green wizard.

In the case of the thermostat system we've been discussing, all these factors can be sketched out easily enough. We've already discussed its boundary zones and the way it relies on negative feedback. Energy comes into the system directly in the form of electricity and whatever fuel the furnace uses, and energy leaves the system by way of diffuse heat leaking out from the house into the outside air and heat going up the chimney. Matter comes into the system partly via the manufacturing, distribution, and installation processes that put the system in place, and partly as the fuel the furnace is burning—fuels are substances that contain energy, remember, and have to be included in both categories. Matter leaves the system partly when the system components are scrapped at the end of their useful lives, and partly in the form of carbon dioxide and other pollutants released by burning the fuel. The filtering of data into information follows the twofold pattern already noted.

Other systems are much more complex, and it may take you quite a bit of careful attention to figure out, for example, the tangled flows by which energy, matter, and information structure a backyard garden plot. Still, understanding the basic patterns will help keep you from making a number of very common mistakes, and they will help each of your projects in green wizardry achieve the negative feedback that will keep it in balance with its surroundings.

Exercise for Lesson 4

For this lesson's exercise, your task is to take a single system and trace the flows of energy, matter, and information that keep it functioning. The system in question is you.

You are a system, after all, in every sense of the word. You are a set of interacting subsystems—organs, tissues, and so on—and the interactions among these subsystems give rise to behavior that none of the individual subsystems can produce on its own. Negative feedback of various kinds keeps you alive and functioning, and boundary zones mediate your interactions with the world around you. Energy enters you in the form of food, and leaves you in the form of waste heat; matter has its own routes through you; and you filter data constantly to extract the information you need from a great deal of background noise.

Trace as many of these systems processes in yourself as you can by drawing a diagram, writing out a description, or in any other way that works for you. Make this as complete as you can manage, using whatever reference sources you need.

LESSON 5
Flows and Funds

The points covered in the first four lessons are meant to give you a very basic grasp of the ways that whole systems function in the real world. If you're interested in learning more—and you should be, if you want to learn appropriate tech—the books on ecology and systems thinking in the Resources section at the end of Part One will give you a good start on the theory, and working your way through the rest of the lessons in this book will give you an equally good start on the practice. Still, there are two more points that ought to be covered before we finish talking about principles, because they bear directly on the challenges that a revived appropriate technology movement will need to face as the age of cheap energy comes to an end.

The first of these points is the difference between flows and funds. It's a simple, straightforward distinction that most people in today's industrial societies use constantly in their daily lives. Try to suggest that they ought to apply the same distinction to energy, raw materials, or information, though, and you can count on getting either a blank look or a diatribe, because next to nobody these days wants to think about the consequences of applying common sense to resource issues.

The relation between flows and funds is complex, but it can be simplified in a useful way by using money as a metaphor. You can think of a flow as a paycheck. If you make five hundred dollars a week in take-home pay, that's how much you have available to spend from one Friday to the next, and if the potential uses for that money add up to more than five hundred a week, you have to prioritize. So much has to be set aside for rent, so much for food, so much for utilities, and so on, before you decide how much you can spend when you go out on Saturday night. Neglect that limit, and you can end up scrambling to get by until Friday comes around and you get your next paycheck.

You can think of a fund, in turn, as a lump sum of money, such as a lottery prize. If your lottery ticket wins you the jackpot, and suddenly you have ten million dollars in the bank, you may think that you don't have to prioritize at all. Still, unless you have money coming in from some other source, that ten million dollars is all you have to spend, and unless there's less than ten million dollars worth of expenditures you want to make over the rest of your life, you have to prioritize, just like the guy making five hundred a week.

Notice, though, that if you have a fund rather than a flow, there's a strong temptation to ignore priorities and run amok with your wealth, because you don't have to worry about the limits to a fund until the fund's nearly gone. The limit to a flow is a constant factor; each week, you've got just five hundred dollars to spend, but seven days later you'll have five hundred more. The limit to a fund is not a constant factor, and it only affects you late in the game—but when it does show up, unless you've been unusually prudent, it clobbers you.

There are at least two ways to dodge the downside of using up a fund, and both involve turning it into a flow. The first is to calculate how long you're going to need to live off the fund, figure out how much you can take from the fund each week and still have some left as long as you need it, and then stick to that budget. The second method is to invest at least some of the fund in assets that give you a steady return, make the resulting flow the bedrock on which you build your financial life, and then don't touch the principal. Both those choices require you to accept hard limits now, in order to avoid bankruptcy when the fund runs out.

You can also convert a flow into a fund. Imagine that you have a small flow—say, an investment that pays a modest sum every month. If you put that money into a savings account and let it accumulate, you can find yourself with a nice lump sum after a few years—which can pay for things you might not be able to afford with your weekly paycheck. As the flow turns into a fund, though, the same temptations that affect any other fund apply to it, and it may take a certain amount of self-control to avoid running amok with it.

Apply the model of funds and flows to human ecology, and you've got the history of the modern world. Until our species broke into the Earth's store of fossil fuels and started going through it like a lottery winner on a spree, we lived from paycheck to paycheck on the energy flow from the sun and the material and information we could extract and maintain with that much energy. We got fairly good at it, too. Growing crops, raising livestock, building windmills and waterwheels, designing houses to soak up solar heat in winter and shed it in the summer, and many other ingenious tricks gave us the annual paycheck we used to support ourselves and cover the costs of such luxury goods as art, literature, philosophy, science, and the occasional Great Pyramid.

During that time, nature turned a variety of flows into funds—for example, converting the steady flow of sunlight through photosynthesis into forests and topsoil. All too often, human societies stumbled across these funds and ran amok with them, wasting them casually, disrupting the natural systems that produced them, and then running into deep trouble when the funds were exhausted. Some human societies learned the hard lesson taught by these experiences and figured out how to draw wealth out of nature's funds without exhausting them; other human societies failed to do so, and went extinct.

With the transformation of coal from ugly black rock to energy resource over the course of the eighteenth century, the human relationship to ecological flows and funds changed radically. Our species won the lottery, and it wasn't a paltry ten million dollar prize, either—it was the great-great-grandmother of all jackpots, half a billion years of stored sunlight in highly concentrated and easily accessible forms. For most of three hundred years, the main constraint on how fast we burnt through the Earth's fossil fuel supply was how fast we could find clever ways to use it. What nobody noticed at the time—or for a long time thereafter—was that we'd switched from a flow to a fund, and the faster our fossil fuel use accelerated, the faster the bank balance depleted.

We could have done the smart thing and converted the fund into a source of flows. That was a good part of what the appropriate tech movement of the 1970s was trying to do: figuring out ways to use the world's remaining fossil fuel reserves to bridge the gap to a renewable energy technology that could last after the fossil fuels were gone. Even then, it was a gamble; nobody knew for sure if it would be possible, with the world's remaining fossil fuel reserves, to create a renewable infrastructure sturdy and productive enough that it could keep providing ample energy into the far future. Still, it was probably the best chance that we had left.

A great many people these days insist that a massive buildout of green technology is still an option. It isn't, and the reason for that comes from a core difference between money, on the one hand, and the three basic factors of ecology—energy, matter, and information—on the other. You can take money out of a bank account at whatever rate you wish, and for all practical purposes there's no cost to doing so, except for that final accounting when you can no longer cover your bills. It doesn't work that way with energy, matter, or information: the more of these that you want, the more energy, matter, and information you have to invest in the process. These costs can't be evaded, and they have to be factored into any decision in the real world.

There's a boobytrap here, though, because these costs behave in one way when applied to flows and in another, much more dangerous way, when applied to funds. For example, the annual supply of sunlight to the Earth is a flow. (Strictly speaking, that flow comes from a fund—the fund of the sun's reserves of hydrogen—but in any timescale meaningful to human beings, it's a flow.) The amount of energy, matter, and information you need to invest in order to tap into that flow by building a solar water heater, say, is roughly the same now as it was in the 1970s, and it'll be roughly the same twenty million years from now, too, when intelligent beings descended from raccoons get to work building their own solar water heaters.

As a general rule, in other words, the amount of energy, matter, and information you need to invest to tap into a flow remains more or less stable over time. The amount of these things you need to invest to tap into a fund, by contrast, does *not* remain stable over time; the cost increases as the fund depletes. For example, rock phosphate, a vital ingredient in chemical fertilizers, is one of the essential resources for industrial agriculture. Over any timescale relevant to human beings, the total amount of rock phosphate that can be mined is a fund, not a flow, and the geological processes that lay down deposits of rock phosphate follow what's called the *power law*—the rule, applicable across an astonishing range of natural phenomena, that whatever's ten times as large, or ten times as concentrated, is by and large ten times as rare.

What this means in practice is that rock phosphate, like every other natural resource, occurs in a small number of very large, very concentrated deposits, a moderate number of midsized and modestly concentrated deposits, and a very large number of very small and poorly concentrated deposits. All other things being equal, the big, concentrated deposits get discovered and extracted first, since they are both easier to find and more lucrative to extract; once those are exhausted, the industry moves to the next largest and most concentrated deposits, and so on down the scale until little pockets of rock with a bit of phosphate in them are all that's left.

Thus, the cost in energy, matter, and information needed to extract a pound of rock phosphate goes up over time, because it takes more of each of these things to find, dig up, and process a pound of phosphate from those little pockets than it did to get a pound of rock phosphate from the huge and highly concentrated deposits that were available at the beginning. The same thing is true of energy resources that exist in the form of funds, and it's equally true of funds of information—for example, scientific research is subject to a close equivalent to the power law; there are always some facts about nature that are easy to find, others that are harder, and still others that are theoretically learnable but that no one in the history of the universe will ever manage to learn because it would take the gross domestic product of a good-sized galaxy to fund the research program needed to discover them.

This is the point that's missed by all those loudly ballyhooed claims that the industrial world can simply keep on extracting raw materials from more and more diffuse sources, until finally we're feeding ordinary rock and sea water into our factories and pulling out individual atoms of whatever we want. In a purely abstract sense, that's possible; in the real world, long before you get to that point, the world's annual production of energy, economically useful matter, and information would have to be put into the job of extracting raw materials, with nothing left over to do anything with the raw materials once you got them. In terms of our money metaphor, that's when you go bankrupt; in terms of the real world, long before that point arrives, the skyrocketing costs of raw materials force the global economy to its knees.

If you're going to transform a fund into a flow, as a result, you have to do it before you reach the point where the costs of extraction from the fund swallow up all the leeway you have. This is why a grand transition to a green industrial future isn't going to happen at this point: the costs of extracting fossil fuels and most other energy resources—costs, that is, in terms of energy, matter, and information, not in terms of the easily manipulated tokens we call money—are climbing steeply, and so are the costs for most of the raw materials essential to industrial society, from rock phosphate to the rare earth minerals that go into high-tech gadgetry. There isn't enough leeway left to allow for the transition without bankrupting the global economy in the process.

This is one of the reasons why the lessons of the appropriate tech movement are so relevant now. Many of the pioneers of that movement deliberately turned away from the grand fantasy of a vast top-down transition to green industrialism, and instead embraced change on a scale that can still work today: the local, personal, inexpensive, do-it-yourself end of building a green society. That approach remains an option because growing at least some of your own food, making the most of modest amounts of energy, and the other practices in the appropriate tech toolkit cost less energy, matter, and information than the ways that people feed themselves and use energy today. The logic is the same as in the metaphor of money: if you depend on a fund for survival, and the fund is running out, cutting your expenses until you can meet them with whatever flows are available to you—no matter how modest those flows may be—is the one and only way to avoid disaster.

Exercise for Lesson 5

It's crucial to understand funds and flows on the large scale, but the same principle plays just as important a role on the scale of a backyard garden or an insulated home. Your assignment for this lesson, therefore, is to choose three forms of energy, three forms of matter, and three forms of information that support the way you live today, and figure out whether each of them comes from a fund or a flow. For each fund that supports your lifestyle, think of a flow that you could use to replace it—not in some abstract future when somebody else will hand you the necessary technology, but here and now, with the tools and technologies you yourself can afford.

LESSON 6
Sustainability and Resilience

The principles already covered provide most of the grounding you'll need to venture into the world of green wizardry, but one more point needs to be made before we put on overalls, boots, and work gloves and head for the backyard to get to work. That point, oddly enough, depends on the awkward process of remembering what a couple of today's popular buzzwords actually mean. This process is more than a little reminiscent of fishing scrap metal out of a swamp; in the present case, the words that need to be hauled from the muck, hosed off, and restored to their former usefulness are "sustainability" and "resilience."

Both of these terms have seen heavy use as rhetorical weapons in recent years, and they've come through the experience much the worse for wear. Sustainability was picked up first, but turned out to have some highly problematic dimensions. To be sustainable, something—a technology, a lifestyle, or what have you—has to be able to keep going indefinitely no matter what the future throws at it. Two things the future can throw at it deserve particular attention

in this context. The first is *ecosystem limits*. If a technology that's supposedly sustainable depends on using nonrenewable resources, for example, or on using otherwise renewable resources at a rate that exceeds the biosphere's ability to renew them, it's just flunked its sustainability test. In the same way, if a technology puts things into the biosphere that disrupt the natural cycles of matter, energy, and information that keep the biosphere going, it's not sustainable no matter how much green spraypaint you apply to it.

Less often grasped, because of its unwelcome implications, is something else the future can throw at a technology, which takes the form of *complexity limits*. This category sums up the relation between a supposedly sustainable technology and the social, economic, and technical dimensions of human society, now and in the future. If those systems have a significant chance of dropping below the level of complexity that your supposedly sustainable item needs in order to stay fueled, maintained, stocked with spare parts, and the like, no matter how green it looks or how enduring it might be in the abstract, it's not sustainable. Since most of today's supposedly sustainable technology can't be manufactured or repaired without a fully functioning industrial society powered by cheap abundant energy, complexity limits are a massive issue, and this awkward fact started to sink in about the time "sustainability" peaked as a buzzword.

Around the beginning of 2012, therefore, the word "sustainability" began to lose its privileged place in the jargon of the time, as it began to sink in that no matter how much manhandling was applied to that much-abused term, it couldn't be combined with the phrase "modern middle-class lifestyle" without resulting in total absurdity. Enter "resilience," which was enthusiastically embraced as another way to talk about what too many people nowadays want to talk about (to the exclusion of more useful conversations): the pretense that a set of lifestyles, social habits, and technologies that were born in an age of unparalleled extravagance can be maintained as the material basis for that extravagance trickles away.

The word "resilience" is guaranteed to suffer the same fate as "sustainability," and for exactly the same reason: it has a perfectly clear meaning. So far, nobody's been rude enough to talk about that meaning, so the green blogosphere is awash with talk about resilient this and resilient that. Once people start to figure out what resilience actually means, though, it's a safe bet that they'll be hunting for another buzzword in short order, because resilience can be defined very precisely: it's the opposite of efficiency.

Now that you've stopped spluttering, let me explain.

We can define efficiency informally but usefully as the practice of doing the most with the least. An efficient use of a resource—any resource, whether we're discussing energy, matter, or information—is thus a use that puts as little of the resource in question as possible into places where it sits around doing nothing. The just-in-time ordering process that's now standard in the retail and manufacturing sectors of the economy, for example, was hailed as a huge increase in efficiency when it was introduced; instead of having stockpiles sitting around in warehouses, items could be ordered electronically so that they would be made and shipped just in time to go onto the assembly line or the store shelf. What few people asked is what happens when something goes wrong.

This is not a minor problem, as every significant natural disaster in an industrial region reminds us. In the inefficient old days, when parts jobbers scattered all over the industrial world had warehouses full of parts being produced by an equally dispersed array of small factories, such events were only a problem for those directly affected; stocks of spares could satisfy demand until sidelined factories recovered. However, now that production is efficiently centralized in very few factories, or in some cases only one, and warehouses full of parts have been rendered obsolete by efficient new ordering systems, delays and resulting costs that would have been negligible in 1970 are proving to be very substantial today.

Efficiency, in other words, is not resilient. What makes a system resilient is the presence of unused resources, and these are

inefficient, by definition. A bridge is resilient, for example, if it contains more steel and concrete than is actually needed to support its normal maximum load; that way, when some outside factor such as a hurricane puts unexpected stresses on the bridge, the previously unnecessary structural strength of the extra steel and concrete comes into play and keeps the bridge from falling down. Most bridges are designed and built with that sort of inefficiency in place because the downside of too little efficiency (the bridge costs more to build) is less troubling than the downside of too little resilience (the bridge collapses in a storm). Like every project worth doing, a good bridge has to strike a balance between many conflicting factors, no one of which can be maximized except at the expense of others of equal importance.

That may seem straightforward, but there's another dimension here that nobody likes to talk about. There's a reason why contemporary industrial culture is obsessed with efficiency, and it's not because we're smarter than our grandparents. Every civilization, as it nears the limits of its resource base, has to deal with the mismatch between habits evolved during times of abundance and the onset of shortages driven by too much exploitation of that abundance. Nearly always, the outcome is a shift toward greater efficiency. Localized governments give way to centralized ones; economies move as far toward mass production as the underlying technology will permit; precise management becomes the order of the day; waste gets cut and so, inevitably, do corners. All this leads to increased efficiency and thus decreased resilience, and sets things up for the statistically inevitable accident that will push things past the limits of the civilization's remaining resilience and launch the downward spiral that ends with sheep grazing among ruins.

I've come to think that a great many of the recent improvements in efficiency in the industrial world derive from this process. Loudly ballyhooed as great leaps forward, they may actually be signs of the tightening noose of resource constraints that, in the long run, will choke the life out of our civilization. Although it's a great idea in the abstract to demand a society-wide push for resilience, in practice, that would involve loading a great many inefficiencies onto the economy. Most things would cost more, and fewer people would be able to afford them because the costs of resilience have to be paid and the short-term benefits of excess efficiency would have to be foregone. That's not a recipe for winning an election or outcompeting a foreign rival, and the fact that it might just get us through the waning years of the industrial age pays nobody's salary today. It may well turn out that burning through available resources, and then crashing into ruin, is simply the most efficient way for a civilization to end.

Where does that leave those of us who would like to find a way through the crisis of our time and hand down something of value to the future? This is a less challenging issue, since individuals, families, and local communities often have an easier time looking past the conventional wisdom of their era and doing something sensible even when it's not popular. The first thing that has to be grasped is that trying to maintain the comfortable lifestyles of the recent past is a fool's errand. It's only by making steep cuts in our personal demand for resources that it's possible to make room for inefficiency, and therefore resilience.

Most of the steps proposed in this book are inefficient. It's inefficient in terms of your time and resources to dig up your backyard and turn it into a garden, but that inefficiency means that if anything happens to the hypercomplex system that provides you with your food—a process that reaches beyond growers, shippers, and stores to the worlds of high finance, oil production, resource politics, and much more—you still get to eat. It's equally inefficient to generate your own electricity, to retrofit your home for conservation, to do all the other things that will be discussed in this book. Those inefficiencies, in turn, are measures of resilience; they define your fallback options, the extra strength you build into the bridge to your future, so that it can hope to stand up to the approaching tempests.

One of the crucial details of this approach involves the hugely unpopular step of relying on older technologies instead of their up-to-date equivalents. By and large, older technologies are less efficient. That means, in turn, that older technologies tend to be more resilient. Using those technologies means accepting downscaled expectations; a tube-based radio is easy, a tube-based television is challenging, and a tube-based video game would be about the size of a mobile home and use as much power as a five-story office building. This is why, sixty years ago, radios were cheap, televisions were pricey, and games were played on brightly colored boards on the kitchen table without any electronics at all.

Downshifting to that less complex approach may be a bit of a challenge for those raised to believe that technological progress only goes one way. Still, downscaled expectations will be among the most common themes of the decades ahead of us, and those who have the uncommon sense to figure this out in advance and start getting ready for a less efficient future will very likely benefit from their increased resilience.

Exercise for Lesson 6

For this lesson's exercise, go back to the three forms of energy, three forms of matter, and three forms of information you listed in the exercise for Lesson 5. Ask yourself what you would do if your access to each of them was suddenly interrupted (a) for one day, (b) for two weeks, or (c) forever. What would you have to have on hand to weather those interruptions without serious crisis? How inefficient would it be for you to have those things on hand?

RESOURCES FOR PART ONE

Our time, as the media never tires of telling us, is the information age, an era when each of us can count on being besieged and bombarded by more information in an average day than most premodern people encountered in their entire lives. While this is true in one sense, it's important to remember that it only applies if the meaning of the term "information" is restricted to the sort of information that comes prepackaged in symbolic form. The average hunter-gatherer moving through a tropical rain forest picks up more information about the world of nature through his or her senses in an average day, after all, than the average resident of an industrial city receives through those same channels in the course of their lives.

Still, the information the hunter-gatherer receives is the sort that our nervous systems, and those of our ancestors back down the winding corridors of deep time, evolved to handle. The current glut of symbolic information—words and images detached from their organic settings and used as convenient labels for abstractions—is quite another matter. There are certain advantages to the torrent of abstract information available to people in the industrial world these days, to be sure, but there's also a downside, and one major part of that is a habit of shallow thinking that governs most of our interactions with the information around us.

A hundred years ago, a student pursuing a scientific or engineering degree might need half a dozen textbooks for the entire course of his studies. Every chapter, and indeed every paragraph, in each of those books would be unpacked in lectures, explored in lab work, brought up in tests and term papers, so that by the time the student graduated, he had mastered everything those textbooks had to teach. That kind of study is almost unheard of nowadays, when students shoulder half a dozen huge textbooks a term, and have so little time to process any of them that the bleak routine of memorize, regurgitate, and forget is usually the only option. This is problematic in any sense you care to contemplate, but it has a special challenge for potential green wizards, because very few people these days actually know how to study information the way that a project of this nature demands.

Treat the material I'll be covering in this book as a collection

of hoops to jump through on the way to some nonexistent degree in green wizardry, and the result will be abject failure. If you plan on studying this material, you need to pursue it with the same intensity the average twelve-year-old *Twilight* fan lavishes on sparkly vampires. You need to obsess about it the way a computer geek obsesses about obscure programming languages. You need to drench yourself in it until it shows up in your dreams and seeps into your bones.

You need to do these things because the ideas central to the old appropriate technology contradict the conventional wisdom of today's industrial cultures at every point. All the things that we learned about the world by osmosis, growing up in a society powered by cheap abundant fossil fuels and geared toward a future of perpetual progress, have to be unlearned in order to understand and use appropriate tech. It's precisely because many of us haven't yet unlearnt them that you see so many grand plans for dealing with peak oil that assume, usually without noticing the assumption, that all the products of cheap abundant energy will be readily and continuously available in a world without cheap abundant energy.

In my experience, the best way to begin this process is to go to a used book store. It needn't be the biggest and best in your area, if your area has more than one—in fact, you'll be more likely to get good results by going to one of those out-of-the-way places where the stock doesn't turn over too quickly and some of the books have been there for a good long time.

You're looking for books from the original appropriate technology movement of the 1970s and 1980s. There were thousands of books that came out of that movement, a small number from the large publishing houses of the time and a much vaster supply from small presses run by individuals, or by the little nonprofit groups that created so much of the appropriate tech movement in the first place. You may find anything from professionally bound hardbacks with dust jackets down to staplebound pamphlets with hand-sketched illustrations. You may find them in the gardening section, the home repair section, the science section, the nature section, or in a special section all its own labeled "Homesteading" or "Back to the Land" or something like that. (I haven't yet found a store that labeled it "Naked Hippie Stuff," but hope springs eternal.) You may even find it jumbled up all anyhow with the general nonfiction because the proprietor of the used book store had no idea where to put it.

Wherever it turns up, you're looking for books on organic gardening, conservation, renewable energy, or anything related to them. If you get one of the classics—*The Integral Urban House, Other Homes and Garbage, Rainbook, The Book of the New Alchemists, The Food and Heat Producing Solar Greenhouse,* or the like—that's good, but it's not required. It counts as much if you find a little staplebound pamphlet on composting, or a ragged trade paperback from a small press on building a solar oven, or an old Rodale Press hardback on insulated window coverings, or what have you.

There are two points to this exercise—well, actually, two and a half. The first point is that your work with green wizardry shouldn't be limited to what one middle-aged archdruid studied and practiced, under sometimes sharply limiting conditions, over the last thirty years or so. If you want to make green wizardry part of your life, a modest library of books on the subject is essential. You'll develop your own personal vision of appropriate tech, and your own personal style in putting it to work; the books you read and study, whether you agree with them or not, will help you start the process of bringing the vision and style into being.

The second point is that many of these books are nearing the end of their useful lives. The limited budgets available to most of the appropriate tech presses meant that most of the books were printed on cheap paper and bound by cheap methods. If they're going to become anything but landfill, and if the information they contain is going to find a new home, somebody needs to take responsibility for making that happen and, dear reader, it might as well be you.

The half point is that the appropriate tech movement had its own quirky culture and its own distinctive take on things. This is true of any specialized field. If you study a martial art, let's say, an important part of your early learning curve has to do with picking up the customs and traditions and little unspoken rituals of the art, which have nothing to do with how to block a punch and everything to do with navigating the learning process and interacting with your teachers and fellow students. This subtle learning remains important even when the movement no longer exists and the surviving participants have either gone on to other things or have spent the last thirty years laboring away in isolation at ideas and practices nobody else cares about; your task is harder, that's all, and one of the few ways you can get a sense of the culture of the movement is to spend time with its writings and its material products.

While you're at it, by the way, get a good basic book on ecology. Ecologist William Catton, whose book *Overshoot* was required reading back in the day, neatly defined ecology as the study of the processes that matter;[7] if anything, that's an understatement. If at all possible, the book you choose should be from the late 50s, 60s or 70s, when the concept of the ecosystem was made the central focus of study in a way that hasn't always been the case since then; the ecosystem approach is central to the way of thinking we'll be exploring in the pages to come, and a good grounding in it will be essential.

Each section of this book ends with a resource section listing some of the classic works from the old appropriate tech movement, or from the traditions and movements that helped launch it and guide it on its way. There have been plenty of good books on similar subjects written since the end of the movement, to be sure, but those latter are relatively easy to find. Many of the older books are not; a troubled collective conscience has shoved them down our culture's memory hole, and unless you happen to have an old copy of *The Whole Earth Catalog* or *Rainbook* handy, your chances even of finding out that they exist are not good. I have tried to include as many of the classics as possible, and a good selection of the merely useful books as well; still, plenty of gems will have been missed. What follows is simply my best attempt at what would have been considered, back in the day, a good collection of books on the basic principles of appropriate tech, with a few notes on each.

Bateson, Gregory, *Mind and Nature: A Necessary Unity* (New York: Bantam, 1979).

——, *Steps to an Ecology of Mind* (New York: Ballantine, 1972).

One of the major figures in the emergence of cybernetics, Bateson had the gift of communicating complex systems concepts in readable language. *Mind and Nature* is his most important book; *Steps to an Ecology of Mind* collects many of his papers and essays.

Brewer, Richard, *Principles of Ecology* (Philadelphia: Saunders College Publishing, 1979).

A good introductory textbook of ecology.

Buchsbaum, Ralph and Mildred, *Basic Ecology* (Pacific Grove, CA: Boxwood Press, 1957).

Perfectly titled, *Basic Ecology* explains the core concepts of ecological thinking in terms that a bright eight-year-old can follow.

Catton, William R., Jr., *Overshoot: the Ecological Basis of Revolutionary Change* (Urbana, IL: University of Illinois Press, 1980).

A constant intellectual companion in my college days, this is both a solid introduction to ecological thinking and a stark warning of the future into which industrial society has backed itself. If I could hold the entire American political establishment at gunpoint and make them read one book, this would be it.

Ehrlich, Paul R., Anne H. Ehrlich, and John P. Holdren, *Ecoscience: Population, Resources, Environment* (San Francisco: W. H. Freeman and Co., 1977).

A big textbook, *Ecoscience* covers most dimensions of the crisis of industrial society; while the details need updating, the basic concepts remain valid today.

Hardin, Garrett, *Filters Against Folly* (New York: Penguin, 1985).

Always controversial but always insightful, Hardin's writings have lost none of their value over the decades. This is the most useful of his books for the aspiring green wizard.

Johnson, Warren, *Muddling Toward Frugality* (San Francisco: Sierra Club Books, 1978).

Widely and deservedly praised, this book sketched out the strategy of local and personal change that undergirded most of the appropriate tech movement.

Kormondy, Edward J., *Concepts of Ecology* (Englewood Cliffs, NJ: Prentice-Hall, 1969).

Another good introductory textbook of ecology.

Laszlo, Ervin, *Introduction to Systems Philosophy: Toward a New Paradigm of Contemporary Thought* (New York: Gordon and Breach, 1972).

——, *The Systems View of the World* (New York: George Braziller, 1972).

Laszlo was probably the most intellectually ambitious of the 1970s systems theorists; the first of these books uses systems theory as the basis for a comprehensive philosophical stance, the second was among the standard textbooks in introductory systems theory classes.

Leopold, Aldo, *A Sand County Almanac* (New York: Oxford University Press, 1949).

If you were into appropriate tech back in the day, you inevitably read this classic of American ecological thought. If you want to learn about appropriate tech now, it's still an excellent place to start.

Meadows, Donnella, Dennis Meadows, Jorgen Randers, and William W. Behrens III, *The Limits to Growth* (New York: Universe, 1972).

Still the best guide to the future ahead of us, and thus inevitably the most thoroughly denounced of all the works in its genre. The several updates are also worth reading.

Odum, Eugene P., *Fundamentals of Ecology* (Philadelphia: W. B. Saunders, 1971).

The bible of ecosystem-based ecology, this used to be the standard textbook in upper-division ecology classes, and it beats the stuffing out of most modern books on the subject.

Roszak, Theodore, *Where the Wasteland Ends: Politics and Transcendence in Postindustrial Society* (Garden City, NY: Doubleday, 1972).

A brilliant critique of the mythology of progress, this was another of the books you could expect to find on most appropriate tech geeks' bookshelves.

Schumacher, E. F., *A Guide for the Perplexed* (New York: Harper Perennial, 1977).

——, *Small is Beautiful: Economics as if People Mattered* (New York: Harper, 1973).

Schumacher was the founder and patron saint of appropriate tech, and his books are as timely now as they were in the 1970s. *Small is Beautiful* provides the basic intellectual framework for appropriate tech; *A Guide for the Perplexed* is a deeper and more philosophical work, exploring the blind spots in modern thinking.

Weinberg, Gerald M., *An Introduction to General Systems Thinking* (Somerset, NJ: John Wiley & Sons, 1975).

If your introductory course on systems thinking back in the day didn't assign Laszlo's The *Systems View of the World* as its textbook, it used Weinberg's *Introduction*. A solid practical guide, worth detailed study.

PART TWO

Food

LESSON 7

The Small Garden

Food and energy were the two core concerns of the appropriate tech movement in its heyday. Though the most innovative ventures of that movement combined the two, it's best to take them one at a time, so we'll begin with food. More precisely, we'll begin with the framework by which food is grown and distributed in a society that doesn't have fossil fuels to throw around casually. Fortunately, it's only been a hundred years or so since cheap energy twisted the industrial world's food system into its present unsustainable shape, so the basic pattern of the older and less extravagant system is still fairly easy to reconstruct.

If you hopped into a time machine and went back to visit farm country a century ago, in the days when sprawling interstate highway systems and fleets of trucks hadn't yet made distance an irrelevance over continental scales, you'd notice something about the farms of that time that you won't find in most farms today: each farm had, apart from its main acreage for corn or wheat or what have you, a kitchen garden, an orchard, a henhouse, and a bit of pasture for a cow or two. These had a completely different