

Chapter Three

Eco-Effectiveness

Here's a tale of three books.

The first is familiar. It is about five inches by eight, compact and pleasant to hold. Dark ink makes a crisp impression on the creamy paper. It has a colorful jacket and a sturdy cardboard cover. In many respects, it is an intelligently conceived object, designed—as were its very similar predecessors, hundreds of years ago—with portability and durability in mind. Hundreds of users may check it out of the library. They take it to bed, on the train, to the beach.

Yet attractive, functional, and durable as it is, the book will not last forever—nor, if it is “beach reading,” do we necessarily expect it to. What happens when it is discarded? The paper came from trees, so natural diversity and soils have already been depleted to keep us in reading matter. Paper is biodegradable, but the inks that printed so crisply on the paper and created the striking image on the jacket contain carbon black and heavy metals. The jacket is not really paper, but an amalgam of materials—wood pulp, polymers, and coatings, as well as inks, heavy metals, and halogenated hydrocarbons. It cannot be safely composted, and if it is burned, it produces dioxins, some of the most dangerous cancer-causing material ever created by humans.

Enter book number two. It too is rather familiar to contemporary eyes. It has the usual book shape and format, but the paper—a dull beige—is thin and porous. It has no jacket, and the

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cover, like the inside, is printed in a single shade of ink. It may seem a little drab, but it has a humble, “earth-friendly” look that is instantly recognizable to the environmentally minded. And indeed the book is the product of a concerted attempt to be eco-efficient. It is printed on recycled paper—hence the beige—with soy-based inks. In addition, its designers strove to “dematerialize,” to use less of everything; witness the thin, uncoated text stock and the absence of a jacket. Unfortunately, the ink shows through the flimsy paper, and the lack of contrast between ink and page strains the eyes. The skimpy binding is a little weak to boot. The book isn't exactly reader-friendly—good thing it's eco-friendly.

Or is it?

Its designers thought long and hard about what kind of paper to use; every choice had drawbacks. Initially they thought chlorine-free paper might be a good way to go, because they knew that chlorine presents a serious problem for ecosystems and human health (by creating dioxins, for example). But they discovered that totally chlorine-free paper required virgin pulp, because any recycled paper in the mix would already have been bleached. In fact, paper made from any kind of wood pulp probably contains some chlorine, because chlorinated salt occurs naturally in trees. What a quandary: pollute rivers or chew up forests. They ended up choosing paper with the greatest recycled content, avoiding what to their minds would be a greater offense. Soy-based inks posed another dilemma, because they might include halogenated hydrocarbons or other toxins that become more bioavailable in these water-soluble eco-friendly inks than they would be in conventional solvent-

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based inks. For acceptable durability, the cover was coated, so it isn't recyclable with the rest of the book, and because of its already high recycled content, the paper's fibers have about reached the limits of further use. Once again, being less bad proves to be a fairly unappealing option, practically, aesthetically, and environmentally.

Imagine if we were to rethink the entire concept of a book, considering not only the practicalities of manufacture and use but the pleasures that might be brought to both. Enter book three, the book of the future.

Is it an electronic book? Perhaps—that form is still in its infancy. Or perhaps it takes another form as yet unimagined by us. But many people find the form of the traditional book both convenient and delightful. What if we reconceived not the shape of the object but the materials of which it is made, in the context of its relationship to the natural world? How could it be a boon to both people and the environment?

We might begin by considering whether paper itself is a proper vehicle for reading matter. Is it fitting to write our history on the skin of fish with the blood of bears, to echo writer Margaret Atwood? Let's imagine a book that is not a tree. It is not even paper. Instead, it is made of plastics developed around a completely different paradigm for materials, polymers that are infinitely recyclable at the same level of quality—that have been designed with their future life foremost in mind, rather than as an awkward afterthought. This "paper" doesn't require cutting down trees or leaching chlorine into waterways. The inks are nontoxic and can be washed off the polymer with a simple and safe chemical process or an extremely hot water

bath, from either of which they can be recovered and reused. The cover is made from a heavier grade of the same polymer as the rest of the book, and the glues are made of compatible ingredients, so that once the materials are no longer needed in their present form, the entire book can be reclaimed by the publishing industry in a simple one-step recycling process.

Nor is the reader's pleasure and convenience an afterthought to environmentally responsible design. The pages are white and have a sensuous smoothness, and unlike recycled paper, they will not yellow with age. The ink won't rub off on the reader's fingers. Although its next life has already been imagined, this book is durable enough to last for many generations. It's even waterproof, so you can read it at the beach, even in the hot tub. You'd buy it, carry it, and read it not as a badge of austerity—and not only for its content—but for its sheer tactile pleasure. It celebrates its materials rather than apologizing for them. Books become books become books over and over again, each incarnation a sparkling new vehicle for fresh images and ideas. Form follows not just function but the evolution of the medium itself, in the endlessly propagating spirit of the printed word.

The assignment that leads to the design of this third book is to tell a story within the very molecules of its pages. Not the old tale of damage and despair, but one of abundance and renewal, human creativity and possibility. And although the book you hold in your hands is not yet that book, it is a step in that direction, a beginning to the story.

We did not design the materials of this book. After years of analyzing and testing polymers to replace paper, we were de-

lighted when designer Janine James happened to mention our search to Charlie Melcher of Melcher Media. Melcher was working with a paper adapted from a polymer blend that had been used to label detergent bottles, so that the labels could be recycled along with the bottles instead of being burned off. For “selfish” reasons, they wanted an alternative to the usual “monstrous hybrid.” Charlie was in search of a waterproof paper on which he could print books that could be read in the bath or at the beach. He knew its qualities extended beyond imperviousness to water and was eager to have us explore its eco-effective promise. When Michael tested it, he found that it off-gassed similarly to a conventional book. But it could be recycled, and more to the point, it has the potential to be *upcycled*: dissolved and remade as polymer of high quality and usefulness.

Once we set about designing with such missions in mind—the short-term usefulness, convenience, and aesthetic pleasure of the product together with the ongoing life of its materials—the process of innovation begins in earnest. We leave aside the old model of product-and-waste, and its dour offspring, “efficiency,” and embrace the challenge of being not efficient but *effective* with respect to a rich mix of considerations and desires.

Consider the Cherry Tree

Consider the cherry tree: thousands of blossoms create fruit for birds, humans, and other animals, in order that one pit might eventually fall onto the ground, take root, and grow. Who would

look at the ground littered with cherry blossoms and complain, “How inefficient and wasteful!” The tree makes copious blossoms and fruit without depleting its environment. Once they fall on the ground, their materials decompose and break down into nutrients that nourish microorganisms, insects, plants, animals, and soil. Although the tree actually makes more of its “product” than it needs for its own success in an ecosystem, this abundance has evolved (through millions of years of success and failure or, in business terms, R&D), to serve rich and varied purposes. In fact, the tree’s fecundity nourishes just about everything around it.

What might the human-built world look like if a cherry tree had produced it?

We know what an eco-efficient building looks like. It is a big energy saver. It minimizes air infiltration by sealing places that might leak. (The windows do not open.) It lowers solar income with dark-tinted glass, diminishing the cooling load on the building’s air-conditioning system and thereby cutting the amount of fossil-fuel energy used. The power plant in turn releases a smaller amount of pollutants into the environment, and whoever foots the electric bill spends less money. The local utility honors the building as the most energy-saving in its area and holds it up as a model for environmentally conscious design. If all buildings were designed and built this way, it proclaims, businesses could do right by the environment and save money at the same time.

Here’s how we imagine the cherry tree would do it: during the daytime, light pours in. Views of the outdoors through large, untinted windows are plentiful—each of the occupants has five

views from wherever he or she happens to sit. Delicious, affordable food and beverages are available to employees in a café that opens onto a sun-filled courtyard. In the office space, each of them controls the flow of fresh air and the temperature of their personal breathing zones. The windows open. The cooling system maximizes natural airflows, as in a hacienda: at night, the system flushes the building with cool evening air, bringing the temperature down and clearing the rooms of stale air and toxins. A layer of native grasses covers the building's roof, making it more attractive to songbirds and absorbing water runoff, while at the same time protecting the roof from thermal shock and ultraviolet degradation.

In fact, this building is just as energy-efficient as the first, but that is a side effect of a broader and more complex design goal: to create a building that celebrates a range of cultural and natural pleasures—sun, light, air, nature, even food—in order to enhance the lives of the people who work there. During construction, certain elements of the second building did cost a little more. For example, windows that open are more expensive than windows that do not. But the nighttime cooling strategy cuts down on the need for air-conditioning during the day. Abundant daylight diminishes the need for fluorescent light. Fresh air makes the indoor spaces more pleasurable, a perk for current employees and a lure to potential ones—and thus an effect with economic as well as aesthetic consequences. (Securing and supporting a talented and productive workforce is one of a CFO's primary goals, because the carrying cost of people—recruiting, employing, and retaining them—is a hundred times as great as the carrying cost of the average building.) In its

every element, the building expresses the client's and architects' vision of a life-centered community and environment. We know, because Bill's firm led the team that designed it.

We brought the same sensibility to designing a factory for Herman Miller, the office-furniture manufacturer. We wanted to give workers the feeling that they'd spent the day outdoors, unlike workers in the conventional factory of the Industrial Revolution, who might not see daylight until the weekend. The offices and manufacturing space that we designed for Herman Miller were built for only 10 percent more money than it would have cost to erect a standard prefabricated metal factory building. We designed the factory around a tree-lined interior conceived as a brightly daylit "street" that ran the entire length of the building. There are rooftop skylights everywhere the workers are stationed, and the manufacturing space offers views of both the internal street and the outdoors, so that even as they work indoors, employees get to participate in the cycles of the day and the seasons. (Even the truck docks have windows.) The factory was designed to celebrate the local landscape and to invite indigenous species back to the site instead of scaring them away. Storm water and waste water are channeled through a series of connected wetlands that clean them, in the process lightening the load on the local river, which already suffers serious flooding because of runoff from roofs, parking lots, and other impervious surfaces.

An analysis of the factory's dramatic productivity gains has shown that one factor was "biophilia"—people's love of the outdoors. Retention rates have been impressive. A number of workers who left for higher wages at a competitor's factory re-

turned in a few weeks. When asked why, they told the management they couldn't work "in the dark." They were young people who had entered the workforce only recently and had never worked in a "normal" factory before.

These buildings represent only the beginnings of eco-effective design; they do not yet exemplify, in every way, the principles we espouse. But you might start to envision the difference between eco-efficiency and eco-effectiveness as the difference between an airless, fluorescent-lit gray cubicle and a sunlit area full of fresh air, natural views, and pleasant places to work, eat, and converse.

Peter Drucker has pointed out that it is a manager's job to "do things right." It is an executive's job to make sure "the right things" get done. Even the most rigorous eco-efficient business paradigm does not challenge basic practices and methods: a shoe, building, factory, car, or shampoo can remain fundamentally ill-designed even as the materials and processes involved in its manufacture become more "efficient." Our concept of eco-effectiveness means working on the right things—on the right products and services and systems—instead of making the wrong things less bad. Once you are doing the right things, then doing them "right," with the help of efficiency among other tools, makes perfect sense.

If nature adhered to the human model of efficiency, there would be fewer cherry blossoms, and fewer nutrients. Fewer trees, less oxygen, and less clean water. Fewer songbirds. Less diversity, less creativity and delight. The idea of nature being

more efficient, dematerializing, or even not "littering" (imagine zero waste or zero emissions for nature!) is preposterous. The marvelous thing about effective systems is that one wants more of them, not less.

What Is Growth?

Ask a child about growth, and she will probably tell you it is a good thing, a natural thing—it means getting bigger, healthier, and stronger. The growth of nature (and of children) is usually perceived as beautiful and healthy. Industrial growth, on the other hand, has been called into question by environmentalists and others concerned about the rapacious use of resources and the disintegration of culture and environment. Urban and industrial growth is often referred to as a cancer, a thing that grows for its own sake and not for the sake of the organism it inhabits. (As Edward Abbey wrote, "Growth for growth's sake is a cancerous madness.")

Conflicting views of growth were a recurrent source of tension on President Clinton's original Council on Sustainable Development, a group of twenty-five representatives of business, government, diverse social groups, and environmental organizations that met from 1993 to 1999. The commercial members' belief that commerce is inherently required to perpetuate itself, that it must seek growth in order to fuel its continued existence, brought them to loggerheads with the environmentalists, to whom commercial growth meant more sprawl, more loss of ancient forests, wild places, and species, and more pollution, tox-

ification, and global warming. Their desire for a no-growth scenario naturally frustrated the commercial players, for whom "no growth" could have only negative consequences. The perceived conflict between nature and industry made it look as if the values of one system must be sacrificed to the other.

But unquestionably there are things we all want to grow, and things we don't want to grow. We wish to grow education and not ignorance, health and not sickness, prosperity and not destitution, clean water and not poisoned water. We wish to improve the quality of life.

The key is not to make human industries and systems smaller, as efficiency advocates propound, but to design them to get bigger and better in a way that replenishes, restores, and nourishes the rest of the world. Thus the "right things" for manufacturers and industrialists to do are those that lead to good growth—more niches, health, nourishment, diversity, intelligence, and abundance—for this generation of inhabitants on the planet and for generations to come.

Let's take a closer look at that cherry tree.

As it grows, it seeks its own regenerative abundance. But this process is not single-purpose. In fact, the tree's growth sets in motion a number of positive effects. It provides food for animals, insects, and microorganisms. It enriches the ecosystem, sequestering carbon, producing oxygen, cleaning air and water, and creating and stabilizing soil. Among its roots and branches and on its leaves, it harbors a diverse array of flora and fauna, all of which depend on it and on one another for the functions

and flows that support life. And when the tree dies, it returns to the soil, releasing, as it decomposes, minerals that will fuel healthy new growth in the same place.

The tree is not an isolated entity cut off from the systems around it: it is inextricably and productively engaged with them. This is a key difference between the growth of industrial systems as they now stand and the growth of nature.

Consider a community of ants. As part of their daily activity, they:

- safely and effectively handle their own material wastes and those of other species
- grow and harvest their own food while nurturing the ecosystem of which they are a part
- construct houses, farms, dumps, cemeteries, living quarters, and food-storage facilities from materials that can be truly recycled
- create disinfectants and medicines that are healthy, safe, and biodegradable
- maintain soil health for the entire planet.

Individually we are much larger than ants, but collectively their biomass exceeds ours. Just as there is almost no corner of the globe untouched by human presence, there is almost no land habitat, from harsh desert to inner city, untouched by some species of ant. They are a good example of a population whose density and productivity are not a problem for the rest of the world, because everything they make and use returns to the cradle-to-cradle cycles of nature. All their materials, even

their most deadly chemical weapons, are biodegradable, and when they return to the soil, they supply nutrients, restoring in the process some of those that were taken to support the colony. Ants also recycle the wastes of other species; leaf-cutter ants, for example, collect decomposing matter from the Earth's surface, carry it down into their colonies, and use it to feed the fungus gardens that they grow underground for food. During their movements and activities, they transport minerals to upper layers of soil, where plant life and fungi can use them as nutrients. They turn and aerate the soil and make passageways for water drainage, playing a vital role in maintaining soil fertility and health. They truly are, as biologist E. O. Wilson has pointed out, the little things that run the world. But although they may run the world, they do not *overrun* it. Like the cherry tree, they make the world a better place.

Some people use the term *nature's services* to refer to the processes by which, without human help, water and air are purified; erosion, floods, and drought are mitigated; materials are detoxified and decomposed; soil is created and its fertility renewed; ecological equilibrium and diversity are maintained; climate is stabilized; and, not least, aesthetic and spiritual satisfaction is provided to us. We don't like this focus on *services*, since nature does not do any of these things just to serve people. But it is useful to think of these processes as part of a dynamic interdependence, in which many different organisms and systems support one another in multiple ways. The consequences of growth—increases in insects, microorganisms, birds, water cycling, and nutrient flows—tend toward the positive kind that enrich the vitality of the whole ecosystem. The

consequences of a new strip mall, on the other hand, while they may have some immediate local benefits (jobs, more money circulating through the local economy) and may even boost the country's overall GDP, are gained at the expense of a decline in overall quality of life—increased traffic, asphalt, pollution, and waste—that ultimately undermines even some of the mall's ostensible benefits.

Typically, conventional manufacturing operations have predominantly negative side effects. In a textile factory, for example, water may come in clean, but it goes out contaminated with fabric dyes, which usually contain toxins such as cobalt, zirconium, other heavy metals, and finishing chemicals. Solid wastes from fabric trimmings and loom clippings present another problem, as much of the material used for textiles is petrochemical-based. Effluents and sludge from production processes cannot be safely deposited into ecosystems, so they are often buried or burned as hazardous waste. The fabric itself is sold all over the world, used, then thrown "away"—which usually means it is either incinerated, releasing toxins, or placed in a landfill. Even in the rather short life span of the fabric, its particles have abraded into the air and been taken into people's lungs. All this in the name of efficient production.

Just about every process has side effects. But they can be deliberate and sustaining instead of unintended and pernicious. We can be humbled by the complexity and intelligence of nature's activity, and we can also be inspired by it to design some positive side effects to our own enterprises instead of focusing exclusively on a single end.

Eco-effective designers expand their vision from the pri-

mary purpose of a product or system and consider the whole. What are its goals and potential effects, both immediate and wide-ranging, with respect to both time and place? What is the entire system—cultural, commercial, ecological—of which this made thing, and way of making things, will be a part?

Once upon a Roof

Once you begin to consider the larger picture, the most familiar features of human fabrication begin to shape-shift. An ordinary roof is a good example. Conventional roofing surfaces are infamously among the most expensive parts of a building to maintain: baking under the sun all day, they are exposed to relentless ultraviolet degradation, and dramatic variations between daytime and nighttime temperatures subject them to constant thermal shock. But in the larger context, they reveal themselves as part of the growing landscape of impervious surfaces (along with paved roads, parking lots, sidewalks, and buildings themselves) that contribute to flooding, heat up cities in the summertime (dark surfaces absorb and re-emit solar energy), and deplete habitat for many species.

If we viewed these effects piecemeal, we might attempt to address the flooding problem by calling for regulations requiring big retention ponds for storm water. We'd "solve" the heat problem by providing additional air-conditioning units to buildings in the area, doing our best to ignore the fact that the new units would contribute to the higher ambient temperatures that

made them necessary in the first place. As for shrinking habitat, well, we'd likely throw up our hands. Isn't wildlife an inevitable casualty of urban growth?

We have been working with a kind of roofing that responds to all of these issues, including the economic ones. It is a light layer of soil, a growing matrix, covered with plants. It maintains the roof at a stable temperature, providing free evaporative cooling in hot weather and insulation in cold weather, and shields it from the sun's destructive rays, making it last longer. In addition, it makes oxygen, sequesters carbon, captures particulates like soot, and absorbs storm water. And that's not all: it looks far more attractive than naked asphalt and, with the storm-water management, saves money that would be lost to regulatory fees and flood damage. In appropriate locales, it can even be engineered to produce solar-generated electricity.

If this sounds like a novel idea, it's not. It is based on centuries-old building techniques. (In Iceland, for example, many old farms were built with stones, wood, and sod, and grass for roofs.) And it is widely used in Europe, where tens of millions of square feet of such roofing already exist. Enhanced by today's sophisticated technology and engineering, this approach to roofing is effective on multiple levels, not least of which is its ability to capture the public imagination. We helped Mayor Richard Daley put a garden on the roof of Chicago's city hall, and he foresees a whole city covered with green roofs that will not only keep it cool but produce solar energy and grow food and flowers, as well as providing soothing green sanctuary from busy urban streets to birds and people alike.

All Sustainability Is Local

We begin to make human systems and industries fitting when we recognize that all sustainability (just like all politics) is local. We connect them to local material and energy flows, and to local customs, needs, and tastes, from the level of the molecule to the level of the region itself. We consider how the chemicals we use affect local water and soil—rather than contaminate, how might they nourish?—what the product is made from, the surroundings in which it is made, how our processes interact with what is happening upstream and downstream, how we can create meaningful occupations, enhance the region's economic and physical health, accrue biological and technical wealth for the future. If we import a material from a distant place, we honor what happened there as a local event. As we wrote in *The Hannover Principles*, "Recognize interdependence. The elements of human design are entwined with and depend upon the natural world, with broad and diverse implications at every scale. Expand design considerations and recognize distant effects."

When Bill traveled to Jordan with his professor in 1973 to work on a long-term plan for the future of the East Bank of the Jordan River Valley, the team's design assignment was to identify strategies for building towns of the future in which the Bedouin could settle, now that political borders had put a stop to their traditional nomadic migrations. A competing team proposed Soviet-style prefabricated housing blocks of a sort that became ubiquitous in the former Eastern Bloc and USSR, "anywhere" buildings that can be found from Siberia to the

Caspian Desert. The buildings themselves would be trucked down rough roads from an industrial center in the highlands near Amman and assembled in the valley.

Bill and his colleagues created a proposal to adapt and encourage adobe structures. Local people could build these with materials at hand—clay and straw, horse, camel, or goat hair, and (not least) abundant sun. The materials were ancient, well understood, and uniquely suited to the hot, dry climate. The structures themselves were designed to optimize temperature flux over the course of the day and year: at night their mass absorbed and stored the coolness of the air, which would keep the interior temperature down during the hot desert days. The team tracked down elder craftspeople in the region who could show them how to build the structures (especially the domes) and then train the Bedouin youths (who had grown up with tents) to build with and repair adobe in the future.

The question that helped to guide the team's work at every level was: What is the right thing for this place? Not prefabricated elements, or mastery of the landscape with a universal modern style, they concluded. They hoped their plan would enhance that particular community in several ways: the homes were built from local materials that were biologically and technically reusable. Employing these materials and the services of nearby craftsmen would generate local economic activity and support as many residents as possible. It would involve local people in building the community and keep them connected to the region's cultural heritage, which the structures' aesthetic distinctiveness itself helped to perpetuate. Enlisting local craftsmen to train young people in the use of local materials

and techniques would encourage an intergenerational connection.

Using Local Materials

The idea of local sustainability is not limited to materials, but it begins with them. Using local materials opens the doors to profitable local enterprise. It also avoids the problem of bioinvasion, when transfer of materials from one region to another inadvertently introduces invasive nonnative species to fragile ecosystems. Chestnut blight, responsible for wiping out chestnut trees in the United States, entered this country on a piece of lumber from China. Chestnuts were a dominant tree of the eastern forests. The other native species evolved together with them, and now they are gone.

We consider not only physical materials but physical processes and their effect on the surrounding environment. Instead of destroying a landscape with conventional hack-and-now practices, we imagine how to invite more local species in (as we did with the Herman Miller factory). By seeing sustainability as both a local and a global event, we can understand that just as it is not viable to poison local water and air with waste, it is equally unacceptable to send it downstream, or to ship it overseas to other, less regulated shores.

Perhaps the ultimate example of effective use of local materials lies in processing what we know as human waste—a fundamental application also of the principle “waste equals food.” We have been working on the creation of sewage treat-

ment plants based on bioremediation (the breaking down and purifying of wastes by nature), to replace the conventional harsh chemical treatment of sewage. Biologist John Todd calls these systems "living machines," because they use living organisms—plants, algae, fish, shrimp, microbes, and so on—instead of toxins like chlorine to purify water. These living machines are often associated with artificial environments created in greenhouses, but they have taken all kinds of forms. Some of the systems we are currently integrating into our projects are designed to work outside and year-round, in all kinds of climates. Others are constructed wetlands, or even reed beds floating on a toxic lagoon, outfitted with little windmills to move the sludge through.

For developing countries, this approach to sewage treatment represents a huge opportunity to maximize nutrient flows and implement a nutritious agenda right away. As the tropics rapidly develop, populations are expanding, and the pressure to clean up effluents (and the bodies of water in which they are routinely disposed) increases. Instead of adopting a one-size-fits-all design solution that is highly ineffective in the long run, we are encouraging these diverse cultures to develop new sewage treatment systems that make waste equal food. In 1992 a model waste treatment system developed by Michael and his colleagues was opened at Silva Jardim, in the province of Rio, Brazil. It was locally fabricated using clay pipes that carried wastewater from village residents to a large settling tank, then into an intricately connected series of small ponds full of an astonishing diversity of plants, microbes, snails, fish, and shrimp. The system was designed to recover nutrients along the way,

producing clean, safe drinking water as a by-product. Farmers competed for access to this purified water and to the sludge's valuable nitrogen, phosphorus, and trace materials as nutrients for farming. Instead of being a liability, the sewage was from the outset perceived and treated as an asset of great value.

A community we are working with in Indiana simply stores its septage (the solids from sewage) in underground tanks during the chilly winters. In the summer, when the sun shines long and bright, the septage is moved to a large outdoor garden and constructed wetland, where plants, microbes, fungi, snails, and other organisms purify and use its nutrients with the power of the sun. This system is locally relevant in several ways. It works with the seasons, optimizing solar power when it is available, instead of forcing treatment during the winter when solar heat is scarce. It uses native nutrients and plants for a process that returns quality drinking water to the aquifer and sustains a lovely garden. The community ends up with millions of sewage treatment "plants"—a living example of biodiversity.

A further point in this case, there was only one logical site for sewage treatment, on the edge of the community next to a major highway—which happens to be upstream. Because they have kept the effects of their sewage local, residents think twice about pouring a dangerous substance down the sink, or about mixing technical and biological materials. It renders palatable to them that their effluents do matter, not in some abstract way, but to real people and their families. But even if we had been able to situate the sewage site "away," we would have done well to act as if it were right where it is. In planetary terms, we're all downstream.

From Cradle to Grave

Imagine what you would come upon today at a typical landfill: old furniture, upholstery, carpets, televisions, clothing, shoes, telephones, computers, complex products, and plastic packaging, as well as organic materials like diapers, paper, wood, and food wastes. Most of these products were made from valuable materials that required effort and expense to extract and make, billions of dollars' worth of material assets. The biodegradable materials such as food matter and paper actually have value too—they could decompose and return biological nutrients to the soil. Unfortunately, all of these things are heaped in a landfill, where their value is wasted. They are the ultimate products of an industrial system that is designed on a linear, one-way *cradle-to-grave* model. Resources are extracted, shaped into products, sold, and eventually disposed of in a "grave" of some kind, usually a landfill or incinerator. You are probably familiar with the end of this process because you, the customer, are responsible for dealing with its detritus. Think about it: you may be referred to as a consumer, but there is very little that you actually consume—some food, some liquids. Everything else is designed for you to throw away when you are finished with it. But where is "away"? Of course, "away" does not really exist. "Away" has gone away.

Cradle-to-grave designs dominate modern manufacturing. According to some accounts more than 90 percent of materials extracted to make durable goods in the United States become waste almost immediately. Sometimes the product itself scarcely lasts longer. It is often cheaper to buy a new version of

even the most expensive appliance than to track down someone to repair the original item. In fact, many products are designed with "built-in obsolescence," to last only for a certain period of time, to allow—to encourage—the customer to get rid of the thing and buy a new model. Also, what most people see in their garbage cans is just the tip of a material iceberg: the product itself contains on average only 5 percent of the raw materials involved in the process of making and delivering it.

One Size Fits All

Because the cradle-to-grave model underlying the design assumptions of the Industrial Revolution was not called into question, even movements that were formed ostensibly in opposition to that era manifested its flaws. One example has been the push to achieve universal design solutions, which emerged as a leading design strategy in the last century. In the field of architecture, this strategy took the form of the International Style movement, advanced during the early decades of the twentieth century by figures such as Ludwig Mies van der Rohe, Walter Gropius, and Le Corbusier, who were reacting against Victorian-era styles. (Gothic cathedrals were still being proposed and built.) Their goals were social as well as aesthetic. They wanted to globally replace unsanitary and inequitable housing—fancy, ornate places for the rich; ugly, unhealthy places for the poor—with clean, minimalist, affordable buildings unencumbered by distinctions of wealth or class. Large sheets of glass, steel, and concrete, and cheap

transportation powered by fossil fuels, gave engineers and architects the tools for realizing this style anywhere in the world.

Today the International Style has evolved into something less ambitious: a bland, uniform structure isolated from the particulars of place—from local culture, nature, energy, and material flows. Such buildings reflect little if any of a region's distinctness or style. They often stand out like sore thumbs from the surrounding landscape, if they leave any of it intact around their "office parks" of asphalt and concrete. The interiors are equally uninspiring. With their sealed windows, constantly humming air conditioners, heating systems, lack of daylight and fresh air, and uniform fluorescent lighting, they might as well have been designed to house machines, not humans.

The originators of the International Style intended to convey hope in the "brotherhood" of humankind. Those who use the style today do so because it is easy and cheap and makes architecture uniform in many settings. Buildings can look and work the same anywhere, in Reykjavik or Rangoon.

In product design, a classic example of the universal design solution is mass-produced detergent. Major soap manufacturers design one detergent for all parts of the United States or Europe, even though water qualities and community needs differ. For example, customers in places with soft water, like the Northwest, need only small amounts of detergent. Those where the water is hard, like the Southwest, need more. But detergents are designed so they will lather up, remove dirt, and kill germs efficiently the same way anywhere in the world—in hard, soft, urban, or spring water, in water that flows into fish-filled

streams and water channeled to sewage treatment plants. Manufacturers just add more chemical force to wipe out the conditions of circumstance. Imagine the strength a detergent must have to strip day-old grease from a greasy pan. Now imagine what happens when that detergent comes into contact with the slippery skin of a fish or the waxy coating of a plant. Treated and untreated effluents as well as runoff are released into lakes, rivers, and oceans. Combinations of chemicals, from household detergents, cleansers, and medicines along with industrial wastes, end up in sewage effluents, where they have been shown to harm aquatic life, in some cases causing mutations and infertility.

To achieve their universal design solutions, manufacturers design for a *worst-case scenario*; they design a product for the worst possible circumstance, so that it will always operate with the same efficacy. This aim guarantees the largest possible market for a product. It also reveals human industry's peculiar relationship to the natural world, since designing for the worst case at all times reflects the assumption that nature is the enemy.

Activity Equals Prosperity

An interesting fact: the 1991 Exxon *Valdez* oil spill actually increased Alaska's gross domestic product. The Prince William Sound area was registered as economically more prosperous because so many people were trying to clean up the spill. Restaurants, hotels, shops, gas stations, and stores all experienced an upward blip in economic exchange.

The GDP takes only one measure of progress into account: activity. Economic activity. But what sensible person would call the effects of an oil spill progress? By some accounts, the *Valdez* accident led to the death of more wildlife than any other human-engineered environmental disaster in U.S. history. According to a 1999 government report, only two of the twenty-three animal species affected by the spill recovered. Its impact on fish and wildlife continues today with tumors, genetic damage, and other effects. The spill led to losses of cultural wealth, including five state parks, four state critical-habitat areas, and a state game sanctuary. Important habitats for fish spawning and rearing were damaged, which may have led to the 1993 decimation of the Prince William Sound's Pacific herring population (perhaps because of a viral infection due to oil exposure). The spill took a significant toll on fishermen's income, not to mention the less measurable effects on morale and emotional health.

The GDP as a measure of progress emerged during an era when natural resources still seemed unlimited and "quality of life" meant high economic standards of living. But if prosperity is judged only by increased economic activity, then car acci-

idents, hospital visits, illnesses (such as cancer), and toxic spills are all signs of prosperity. Loss of resources, cultural depletion, negative social and environmental effects, reduction of quality of life—these ills can all be taking place, an entire region can be in decline, yet they are negated by a simplistic economic figure that says economic life is good. Countries all over the world are trying to boost their level of economic activity so they, too, can grab a share of the "progress" that measurements like the GDP propound. But in the race for economic progress, social activity, ecological impact, cultural activity, and long-term effects can be overlooked.

Crude Products

The design intention behind the current industrial infrastructure is to make an attractive product that is affordable, meets regulations, performs well enough, and lasts long enough to meet market expectations. Such a product fulfills the manufacturer's desires and some of the customers' expectations as well. But from our perspective, products that are not designed particularly for human and ecological health are unintelligent and inelegant—what we call *crude products*.

For example, the average mass-produced piece of polyester clothing and a typical water bottle both contain antimony, a toxic heavy metal known to cause cancer under certain circumstances. Let's put aside for the moment the issues of whether this substance represents a specific danger to the user. The question we would pose as designers is: Why is it there? Is

it necessary? Actually, it is not necessary: antimony is a current catalyst in the polymerization process and is not necessary for polyester production. What happens when this discarded product is "recycled" (that is, downcycled) and mixed with other materials? What about when it is burned along with other trash as cooking fuel, a common practice in developing countries? Incineration makes the antimony bioavailable—that is, available for breathing. If polyester might be used for fuel, we need polyesters that can be safely burned.

That polyester shirt and that water bottle are both examples of what we call *products plus*: as a buyer you got the item or service you wanted, *plus* additives that you didn't ask for and didn't know were included and that may be harmful to you and your loved ones. (Maybe shirt labels should read: *Product contains toxic dyes and catalysts. Don't work up a sweat or they will leach onto your skin.*) Moreover, these extra ingredients may not be necessary to the product itself.

Since 1987 we have been studying various products from major manufacturers, ordinary things such as a computer mouse, an electric shaver, a popular handheld video game, a hair dryer, and a portable CD player. We found that during use they all off-gassed teratogenic and/or carcinogenic compounds—substances known to have a role in causing birth defects and cancer. An electric hand mixer emitted chemical gases that got trapped in the oily butter molecules of the cake batter and ended up in the cake. So be careful—you might unintentionally be eating your appliances.

Why does this happen? The reason is that high-tech products are usually composed of low-quality materials—that is,

cheap plastics and dyes—globally sourced from the lowest-cost provider, which may be halfway around the world. This means that even substances banned for use in the United States and Europe can reach this country via products and parts made elsewhere. So, for example, the carcinogen benzene, banned for use as a solvent in American factories, can be shipped here in rubber parts that were manufactured in developing countries that have not banned it. They can be assembled into, say, your treadmill, which will then emit the "banned" substance as you exercise.

The problem intensifies when parts from numerous countries are assembled into one product, as is often the case with high-tech items such as electronic equipment and appliances. Manufacturers do not necessarily keep track of—nor are they required to know—what exactly is in all of these parts. An exercise machine assembled in the United States may contain rubber belts from Malaysia, chemicals from Korea, motors from China, adhesives from Taiwan, and wood from Brazil.

There is no way, for example, that you are going to consume your car, and although it is made of valuable technical materials, you can't do anything with them once you finish with it (unless you are a junk artist). As we have mentioned, these materials are lost or degraded even in "recycling" because cars are not designed from the beginning for effective, optimal recycling as technical nutrients. Indeed, industries design products with built-in obsolescence—that is, to last until approximately the time customers typically want to replace them. Even things with a real consumable potential, such as packaging materials, are often deliberately designed not to break down under natural conditions. In fact, packaging may last far longer than the product it protected. In places where resources are hard to get, people still creatively reuse materials to make new products (such as using old tire rubber to make sandals) and even energy (burning synthetic materials for fuel). Such creativity is natural and adaptive and can be a vital part of material cycles. But as long as these uses are ignored by current industrial design and manufacturing, which typically refrain from embracing any vision of a product's further life, such reuse will often be unsafe, even lethal.

Monstrous Hybrids

Mountains of waste rising in landfills are a growing concern, but the quantity of these wastes—the space they take up—is not the major problem of cradle-to-grave designs. Of greater

concern are the nutrients—valuable "food" for both industry and nature—that are contaminated, wasted, or lost. They are lost not only for lack of adequate systems of retrieval; they are lost also because many products are what we jokingly refer to as "Frankenstein products" or (with apologies to Jane Jacobs) "monstrous hybrids"—mixtures of materials both technical and biological, neither of which can be salvaged after their current lives.

A conventional leather shoe is a monstrous hybrid. At one time, shoes were tanned with vegetable chemicals, which were relatively safe, so the wastes from their manufacture posed no real problem. The shoe could biodegrade after its useful life or be safely burned. But vegetable tanning required that trees be harvested for their tannins. As a result, shoes took a long time to make, and they were expensive. In the past forty years, vegetable tanning has been replaced with chromium tanning, which is faster and cheaper. But chromium is rare and valuable for industries, and in some forms it is carcinogenic. Today shoes are often tanned in developing countries where few if any precautions are taken to protect people and ecosystems from chromium exposure; manufacturing wastes may be dumped into nearby bodies of water or incinerated, either of which distributes toxins (often disproportionately in low-income areas). Conventional rubber shoe soles, moreover, usually contain lead and plastics. As the shoe is worn, particles of it degrade into the atmosphere and soil. It cannot be safely consumed, either by you or by the environment. After use, its valuable materials, both biological and technical, are usually lost in a landfill.

the very first time. When I am finished with it (special, unique person that I am), everyone is. It is history." Industries design and plan according to this mind-set.

We recognize and understand the value of feeling special, even unique. But with materials, it makes sense to celebrate the sameness and commonality that permit us to enjoy them—in special, even unique, products—more than once. What would have happened, we sometimes wonder, if the Industrial Revolution had taken place in societies that emphasize the community over the individual, and where people believed not in a cradle-to-grave life cycle but in reincarnation?

A World of Two Metabolisms

The overarching design framework we exist within has two essential elements: mass (the Earth) and energy (the sun). Nothing goes in or out of the planetary system except for heat and the occasional meteorite. Otherwise, for our practical purposes, the system is closed, and its basic elements are valuable and finite. Whatever is naturally here is all we have. Whatever humans make does not go "away."

If our systems contaminate Earth's biological mass and continue to throw away technical materials (such as metals) or render them useless, we will indeed live in a world of limits, where production and consumption are restrained, and the Earth will literally become a grave.

If humans are truly going to prosper, we will have to learn to imitate nature's highly effective cradle-to-cradle system of

From Cradle-to-Grave to Cradle-to-Cradle

People involved in industry, design, environmentalism, and related fields often refer to a product's "life cycle." Of course, very few products are actually living, but in a sense we project our vitality—and our mortality—onto them. They are something like family members to us. We want them to live with us, to belong to us. In Western society, people have graves, and so do products. We enjoy the idea of ourselves as powerful, unique individuals; and we like to buy things that are brand-new, made of materials that are "virgin." Opening a new product is a kind of metaphorical defloration: "This virgin product is mine, for

nutrient flow and metabolism, in which the very concept of waste does not exist. *To eliminate the concept of waste means to design things—products, packaging, and systems—from the very beginning on the understanding that waste does not exist.* It means that the valuable nutrients contained in the materials shape and determine the design: form follows evolution, not just function. We think this is a more robust prospect than the current way of making things.

As we have indicated, there are two discrete metabolisms on the planet. The first is the biological metabolism, or the biosphere—the cycles of nature. The second is the technical metabolism, or the technosphere—the cycles of industry, including the harvesting of technical materials from natural places. With the right design, all of the products and materials manufactured by industry will safely feed these two metabolisms, providing nourishment for something new.

Products can be composed either of materials that biodegrade and become food for *biological cycles*, or of technical materials that stay in closed-loop *technical cycles*, in which they continually circulate as valuable nutrients for industry. In order for these two metabolisms to remain healthy, valuable, and successful, great care must be taken to avoid contaminating one with the other. Things that go into the organic metabolism must not contain mutagens, carcinogens, persistent toxins, or other substances that accumulate in natural systems to damaging effect. (Some materials that would damage the biological metabolism, however, could be safely handled by the technical metabolism.) By the same token, biological nutrients are not designed to be fed into the technical metabolism, where they

would not only be lost to the biosphere but would weaken the quality of technical materials or make their retrieval and reuse more complicated.

The Biological Metabolism

A *biological nutrient* is a material or product that is designed to return to the biological cycle—it is literally consumed by microorganisms in the soil and by other animals. Most packaging (which makes up about 50 percent of the volume of the municipal solid waste stream) can be designed as biological nutrients, what we call *products of consumption*. The idea is to compose these products of materials that can be tossed on the ground or compost heap to safely biodegrade after use—literally to be consumed. There is no need for shampoo bottles, toothpaste tubes, yogurt and ice-cream cartons, juice containers, and other packaging to last decades (or even centuries) longer than what came inside them. Why should individuals and communities be burdened with downcycling or landfilling such material? Worry-free packaging could safely decompose, or be gathered and used as fertilizer, bringing nutrients back to the soil. Shoe soles could degrade to enrich the environment. Soaps and other liquid cleaning products could be designed as biological nutrients as well; that way, when they wash down the drain, pass through a wetland, and end up in a lake or river, they support the balance of the ecosystem.

In the early 1990s the two of us were asked by DesignTex, a division of Steelcase, to conceive and create a compostable

upholstery fabric, working with the Swiss textile mill Röhner. We were asked to focus on creating an aesthetically unique fabric that was also environmentally intelligent. DesignTex first proposed that we consider cotton combined with PET (polyethylene terephthalate) fibers from recycled soda bottles. What could be better for the environment, they thought, than a product that combined a "natural" material with a "recycled" one? Such hybrid material had the additional apparent advantages of being readily available, market-tested, durable, and cheap.

But when we looked carefully at the potential long-term design legacy, we discovered some disturbing facts. First, as we have mentioned, upholstery abrades during normal use, and so our design had to allow for the possibility that particles might be inhaled or swallowed. PET is covered with synthetic dyes and chemicals and contains other questionable substances—not exactly what you want to breathe or eat. Furthermore, the fabric would not be able to continue after its useful life as either a technical or a biological nutrient. The PET (from the plastic bottles) would not go back to the soil safely, and the cotton could not be circulated in industrial cycles. The combination would be yet another monstrous hybrid, adding junk to a landfill, and it might also be dangerous. This was not a product worth making.

We made clear to our client our intention to create a product that would enter either the biological or the technical metabolism, and the challenge crystallized for both of us. The team decided to design a fabric that would be safe enough to eat: it would not harm people who breathed it in, and it would

not harm natural systems after its disposal. In fact, as a biological nutrient, it would nourish nature.

The textile mill that was chosen to produce the fabric was quite clean by accepted environmental standards, one of the best in Europe, yet it had an interesting dilemma. Although the mill's director, Albin Kaelin, had been diligent about reducing levels of dangerous emissions, government regulators had recently defined the mill's fabric trimmings as hazardous waste. The director had been told that he could no longer bury or burn these trimmings in hazardous-waste incinerators in Switzerland but had to export them to Spain for disposal. (Note the paradoxes here: the trimmings of a fabric are not to be buried or disposed of without expensive precaution, or must be exported "safely" to another location, but the material itself can still be sold as safe for installation in an office or home.) We hoped for a different fate for our trimmings: to provide mulch for the local garden club, with the help of sun, water, and hungry microorganisms.

The mill interviewed people living in wheelchairs and discovered that their most important needs in seating fabric were that it be strong and that it "breathe." The team decided on a mixture of safe, pesticide-free plant and animal fibers for the fabric: wool, which provides insulation in winter and summer, and ramie, which wicks moisture away. Together these fibers would make for a strong and comfortable fabric. Then we began working on the most difficult aspect of the design: the finishes, dyes, and other process chemicals. Instead of filtering out mutagens, carcinogens, endocrine disrupters, persistent toxins,

and bioaccumulative substances at the end of the process, we would filter them out at the beginning. In fact, we would go beyond designing a fabric that would do no harm; we would design one that was nutritious.

Sixty chemical companies declined the invitation to join the project, uncomfortable at the idea of exposing their chemistry to the kind of scrutiny it would require. Finally one European company agreed to join. With its help, we eliminated from consideration almost eight thousand chemicals that are commonly used in the textile industry; we also thereby eliminated the need for additives and corrective processes. Not using a given dye, for example, removed the need for additional toxic chemicals and processes to ensure ultraviolet-light stabilization (that is, colorfastness). Then we looked for ingredients that had *positive* qualities. We ended up selecting only thirty-eight of them, from which we created the entire fabric line. What might seem like an expensive and laborious research process turned out to solve multiple problems and to contribute to a higher-quality product that was ultimately more economical.

The fabric went into production. The factory director later told us that when regulators came on their rounds and tested the effluent (the water coming out of the factory), they thought their instruments were broken. They could not identify any pollutants, not even elements they knew were in the water when it came into the factory. To confirm that their testing equipment was actually in working order, they checked the influent from the town's water mains. The equipment was fine; it was simply that by most parameters the water coming out of the factory was as clean as—or even cleaner than—the water going in. When a

factory's effluent is cleaner than its influent, it might well prefer to use its effluent as influent. Being designed into the manufacturing process, this dividend is free and requires no enforcement to continue or to exploit. Not only did our new design process bypass the traditional responses to environmental problems (reduce, reuse, recycle), it also eliminated the need for regulation, something that any businessperson will appreciate as extremely valuable.

The process had additional positive side effects. Employees began to use, for recreation and additional work space, rooms that were previously reserved for hazardous-chemical storage. Regulatory paperwork was eliminated. Workers stopped wearing the gloves and masks that had given them a thin veil of protection against workplace toxins. The mill's products became so successful that it faced a new problem: financial success, just the kind of problem businesses want to have.

As a biological nutrient, the fabric embodied the kind of fecundity we find in nature's work. After customers finished using it, they could simply tear the fabric off the chair frame and throw it onto the soil or compost heap without feeling bad—even, perhaps, with a kind of relish. Throwing something away can be fun, let's admit it; and giving a guilt-free gift to the natural world is an incomparable pleasure.

The Technical Metabolism

A *technical nutrient* is a material or product that is designed to go back into the technical cycle, into the industrial metabolism

from which it came. The average television we analyzed, for example, was made of 4,360 chemicals. Some of them are toxic, but others are valuable nutrients for industry that are wasted when the television ends up in a landfill. Isolating them from biological nutrients allows them to be *upcycled* rather than recycled—to retain their high quality in a closed-loop industrial cycle. Thus a sturdy plastic computer case, for example, will continually circulate as a sturdy plastic computer case—or as some other high-quality product, like a car part or a medical device—instead of being downcycled into soundproof barriers and flowerpots.

Henry Ford practiced an early form of upcycling when he had Model A trucks shipped in crates that became the vehicle's floorboards when it reached its destination. We are initiating a similar practice that is a modest beginning: Korean rice husks used as packing for stereo components and electronics sent to Europe, then reused there as a material for making bricks. (Rice husks contain a high percentage of silica.) The packing material is nontoxic (rice husks are safer than recycled newspapers, which contain toxic inks and particles that contaminate indoor air); its shipping is inclusive in the freight costs the electronic goods would incur anyway; and the concept of waste is eliminated.

Industrial mass can be specifically designed to retain its high quality for multiple uses. Currently, when an automobile is discarded, its component steel is recycled as an amalgam of all its steel parts, along with the various steel alloys of other products. The car is crushed, pressed, and processed so that high-ductile steel from the body and stainless steels are smelted

together with various other scrap steels and materials, compromising their high quality and drastically restricting their further use. (It can't, for example, be used to make car bodies again.) The copper in its cables is melted into a general compound and lost to specific technical purposes—it can no longer be used as a copper cable. A more prosperous design would allow the car to be used the way Native Americans used a buffalo carcass, optimizing every element, from tongue to tail. Metals would be smelted only with like metals, to retain their high quality; likewise for plastics.

In order for such a scenario to be practical, however, we have to introduce a concept that goes hand in hand with the notion of a technical nutrient: the concept of a *product of service*. Instead of assuming that all products are to be bought, owned, and disposed of by "consumers," products containing valuable technical nutrients—cars, televisions, carpeting, computers, and refrigerators, for example—would be reconceived as *services* people want to enjoy. In this scenario, customers (a more apt term for the users of these products) would effectively purchase the service of such a product for a *defined user period*—say, ten thousand hours of television viewing, rather than the television itself. They would not be paying for complex materials that they won't be able to use after a product's current life. When they finish with the product, or are simply ready to upgrade to a newer version, the manufacturer replaces it, taking the old model back, breaking it down, and using its complex materials as food for new products. The customers would receive the services they need for as long as they need them and could upgrade as often as desired; manufacturers would con-

