Chapter Four

Waste Equals Food

Nature operates according to a system of nutrients and metabolisms in which there is no such thing as waste. A cherry tree makes many blossoms and fruit to (perhaps) germinate and grow. That is why the tree blooms. But the extra blossoms are far from useless. They fall to the ground, decompose, feed various organisms and microorganisms, and enrich the soil. Around the world, animals and humans exhale carbon dioxide, which plants take in and use for their own growth. Nitrogen from wastes is transformed into protein by microorganisms, animals, and plants. Horses eat grass and produce dung, which provides both nest and nourishment for the larvae of flies. The Earth's major nutrients—carbon, hydrogen, oxygen, nitrogen—are cycled and recycled. Waste equals food.

This cyclical, cradle-to-cradle biological system has nourished a planet of thriving, diverse abundance for millions of years. Until very recently in the Earth's history, it was the only system, and every living thing on the planet belonged to it. Growth was good. It meant more trees, more species, greater diversity, and more complex, resilient ecosystems. Then came industry, which altered the natural equilibrium of materials on the planet. Humans took substances from the Earth's crust and concentrated, altered, and synthesized them into vast quantities of material that cannot safely be returned to soil. Now material flows can be divided into two categories: biological mass and technical—that is, industrial—mass.

From our perspective, these two kinds of material flows on the planet are just *biological and technical nutrients*. Biological nutrients are useful to the biosphere, while technical nutrients are useful for what we call the *technosphere,* the systems of industrial processes. Yet somehow we have evolved an industrial infrastructure that ignores the existence of nutrients of either kind.

From Cradle-to-Cradle to Cradle-to-Grave: A Brief History of Nutrient Flows

Long before the rise of agriculture, nomadic cultures wandered from place to place searching for food. They needed to travel light, so their possessions were few—some jewelry and a few tools, bags or clothes made of animal skins, baskets for roots and seeds. Assembled from local materials, these things, when their use was over, could easily decompose and be "consumed" by nature. The more durable objects, such as weapons of stone and flint, might be discarded. Sanitation was not a problem because the nomads were constantly moving. They could leave their biological wastes behind to replenish soil. For these people, there truly was an "away."

Early agricultural communities continued to return biological wastes to the soil, replacing nutrients. Farmers rotated crops, letting fields lie fallow in turn until nature made them fertile again. Over time new agricultural tools and techniques led to quicker food production. Populations swelled, and many communities began to take more resources and nutrients than could be naturally restored. With people more tightly packed, sanitation became a problem. Societies began to find ways to get rid of their wastes. They also began to take more and more nutrients from the soil and to eat up resources (such as trees) without replacing them at an equal rate.

There is an old Roman saying, *Pecunia non olet*: "Money doesn't stink." In Imperial Rome servicepeople took wastes away from public spaces and the toilets of the wealthy and piled them outside the city. Agriculture and tree-felling drained soils of nutrients and led to erosion, and the landscape became drier and more arid, with less fertile cropland. Rome's imperialism—and imperialism in general—emerged in part in response to nutrient losses, the center expanding to support its vast needs with timber, food, and other resources elsewhere. (Tellingly, as the city's resources shrank and conquests grew, Rome's agricultural deity, Mars, became the god of war.)

William Cronon chronicles a similar relationship between a city and its natural environment in *Nature's Metropolis*. He points out that the great rural areas around Chicago, America's "breadbasket," were actually organized over time to provide services for that city; the settlement of the surrounding frontier did not happen in isolation from Chicago but was inextricably bound to the city and fueled by its needs. "The central story of the nineteenth-century West is that of an expanding metropolitan economy creating ever more elaborate and intimate linkages between city and country," Cronon observes. Thus the history of a city "must also be the history of its human countryside, and of the natural world within which city and country are both located."

As they swelled and grew, the great cities placed incredible pressure on the environment around them, sucking materials and resources from farther and farther away, as the land was stripped and resources taken. For example, as the forests of Minnesota disappeared, logging moved on to British Columbia. (Such expansions affected native people; the Mandans of the upper Missouri were wiped out by smallpox, in a chain of events resulting from settlers staking homesteads.)

Over time cities all over the world built up an infrastructure for transferring nutrients from place to place. Cultures went into conflict with other cultures for resources, land, and food. In the nineteenth and early twentieth centuries, synthetic fertilizers were developed, laying the ground for the massively intensified production of industrialized agriculture. Soils now yield more crops than they naturally could, but with some severe effects: they are eroding at an unprecedented rate, and they are drained of nutrient-rich humus. Very few small farmers return local biological wastes to the soil as a primary source of nutrients any longer, and industrialized farming almost never does. Moreover, the synthetic fertilizers were often heavily contaminated with cadmium and radioactive elements from phosphate rocks, a hazard of which farmers and residents were generally unaware.

Yet certain traditional cultures have well understood the value of nutrient flows. For centuries in Egypt, the Nile River overflowed its banks each year, leaving a rich layer of silt across the valleys when waters withdrew. Beginning about 3200 B.C., farmers in Egypt structured a series of irrigation ditches that channeled the Nile's fertile waters to their fields.

They also learned to store food surpluses for periods of drought. The Egyptians maximized these nutrient flows for centuries without overtaxing them. Gradually, as British and French engineers entered the country during the nineteenth century, Egypt's agriculture shifted to Western methods. Since the completion of the Aswan High Dam in 1971, the silt that enriched Egypt for centuries now accumulates behind concrete, and people in Egypt build housing on once fertile areas originally reserved for crops. Houses and roads compete dramatically for space with agriculture. Egypt produces less than 50 percent of its own food and depends on imports from Europe and the United States.

Over thousands of years, the Chinese perfected a system that prevents pathogens from contaminating the food chain, and fertilized rice paddies with biological wastes, including sewage. Even today some rural households expect dinner guests to "return" nutrients in this way before they leave, and it is a common practice for farmers to pay households to fill boxes with their bodily wastes. But today the Chinese, too, have turned to systems based on the Western model. And, like Egypt, they are growing more dependent on imported foods.

Humans are the only species that takes from the soil vast quantities of nutrients needed for biological processes but rarely puts them back in a usable form. Our systems are no longer designed to return nutrients in this way, except on small, local levels. Harvesting methods like clear-cutting precipitate soil erosion, and chemical processes used in both agriculture and manufacture often lead to salinization and acidification, helping to deplete more than twenty times as much soil each

year as nature creates. It can take approximately five hundred years for soil to build up an inch of its rich layers of microorganisms and nutrient flows, and right now we are losing five thousand times more soil than is being made.

In preindustrial culture, people did consume things. Most products would safely biodegrade once they were thrown away, buried, or burned. Metals were the exception: these were seen as highly valuable and were melted down and reused. (They were actually what we call early technical nutrients.) But as industrialization advanced, the consumption mode persisted, even though most manufactured items could no longer actually be consumed. In times of scarcity, a recognition of the value of technical materials would flare up; people who grew up during the Great Depression, for example, were careful about reusing jars, jugs, and aluminum foil, and during World War II, people saved rubber bands, aluminum foil, steel, and other materials to feed industrial needs. But as cheaper materials and new synthetics flooded the postwar market, it became less expensive for industries to make a new aluminum, plastic, or glass bottle or package at a central plant and ship it out than to build up local infrastructures for collecting, transporting, cleaning, and processing things for reuse. Similarly, in the early decades of industrialization, people might pass down, repair, or sell old service products like ovens, refrigerators, and phones to junk dealers. Today most so-called durables are tossed. (Who on Earth would repair a cheap toaster today? It is much easier to buy a new one than it is to send the parts back to the manufacturer or track down someone to repair it locally.) Throwaway products have become the norm.

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.

A Confusion of Flows

There may be no more potent image of disagreeable waste than sewage. It is a kind of waste people are happy to get "away" from. Before modern sewage systems, people in cities would dump their wastes outside (which might mean out the window), bury them, slop them into cesspools at the bottom of a house, or dispose of them in bodies of water, sometimes upstream from drinking sources. It wasn't until the late nineteenth century that people began to make the connection between sanitation and public health, which provided the impetus for more sophisticated sewage treatment. Engineers saw pipes taking storm water to rivers and realized this would be a convenient way to remove waterborne sewage. But that didn't end the problem. From time to time the disposal of raw sewage in rivers close to home became unbearable; during the Great Stink of London in 1858, for example, the reek of raw sewage in the nearby Thames disrupted sittings of the House of Commons. Eventually, sewage treatment plants were built to treat effluents and sized to accommodate waterborne sewage combined with added storm water during major rains.

The original idea was to take relatively active biologically based sewage, principally from humans (urine and excrement, the kind of waste that has interacted with the natural world for millennia), and render it harmless. Sewage treatment was a process of microbial and bacterial digestion. The solids were removed as sludge, and the remaining liquid, which had brought the sewage to treatment in the first place, could be released essentially as water. That was the original strategy. But

once the volume of sewage overwhelmed the waterways into which it flowed, harsh chemical treatments like chlorination were added to manage the process. At the same time, new products were being marketed for household use that were never designed with sewage treatment plants (or aquatic ecosystems) in mind. In addition to biological wastes, people began to pour all kinds of things down the drain: cans of paint, harsh chemicals to unclog pipes, bleach, paint thinners, nail-polish removers. And the waste itself now carried antibiotics and even estrogens from birth control pills. Add the various industrial wastes, cleaners, chemicals, and other substances that will join household wastes, and you have highly complex mixtures of chemical and biological substances that still go by the name of sewage. Antimicrobial products—like many soaps currently marketed for bathroom use—may sound desirable, but they are a problematic addition to a system that relies on microbes to be effective. Combine them with antibiotics and other antibacterial ingredients, and you may even set in motion a program to create hyperresistant superbacteria.

Recent studies have found hormones, endocrine disrupters, and other dangerous compounds in bodies of water that receive "treated" sewage effluents. These substances can contaminate natural systems and drinking-water supplies and, as we have noted, can lead to mutations of aquatic and animal life. Nor have the sewage pipes themselves been designed for biological systems; they contain materials and coatings that could degrade and contaminate effluents. As a result, even efforts to reuse sewage sludge for fertilizer have been hampered by farmers' concern over toxification of the soil.

If we are going to design systems of effluents that go back into the environment, then perhaps we ought to move back upstream and think of all the things that are designed to go into such systems as part of nutrient flows. For example, the mineral phosphate is used as a fertilizer for crops around the world. Typical fertilizer uses phosphate that is mined from rock, however, and extracting it is extremely destructive to the environment. But phosphate also occurs naturally in sewage sludge and other organic wastes. In fact, in European sewage sludge, which is often landfilled, phosphate occurs in higher concentrations than it does in some phosphate rock in China, where much of it is mined to devastating effect on local ecosystems. What if we could design a system that safely captured the phosphate already in circulation, rather than discarding it as sludge?

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

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 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 melded 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 continue to grow and develop while retaining ownership of their materials.

A number of years ago we worked on a "rent-a-solvent" concept for a chemical company. A solvent is a chemical that is used to remove grease, for example, from machine parts. Companies ordinarily buy the cheapest degreasing solvent available, even if it comes from halfway around the globe. After its use, the waste solvent is either evaporated or entered into a waste treatment flow, to be handled by a sewage treatment plant. The idea behind rent-a-solvent was to provide a degreasing service using high-quality solvents available to customers without selling the solvent itself; the provider would recapture the emissions and separate the solvent from the grease so that it would be available for continuous reuse. Under these circumstances, the company had incentive to use high-quality solvents (how else to retain customers?) and to reuse it, with the important side effect of keeping toxic materials out of waste flows. Dow Chemical has experimented with this concept in Europe, and DuPont is taking up this idea vigorously.

This scenario has tremendous implications for industry's material wealth. When customers finish with a traditional carpet, for example, they must pay to have it removed. At that point its materials are a liability, not an asset—they are a heap of petrochemicals and other potentially toxic substances that must be toted to a landfill. This linear, cradle-to-grave life cycle has several negative consequences for both people and industry. The energy, effort, and materials that were put into manufacturing the carpet are lost to the manufacturer once the customer purchases it. Millions of pounds of potential nutrients

for the carpet industry alone are wasted each year, and new raw materials must continually be extracted. Customers who decide they want or need new carpeting are inconvenienced, financially burdened with a new purchase (the cost of the unrecoverable materials must be built into the price), and, if they are environmentally concerned, taxed with guilt as well about disposing of the old and purchasing the new.

Carpet companies have been among the first industries to adopt our product-of-service or "eco-leasing" concepts, but so far they have applied them to conventionally designed products. An average commercial carpet consists of nylon fibers backed with fiberglass and PVC. After the product's useful life, a manufacturer typically downcycles it—shaves off some of the nylon material for further use and discards the leftover material "soup." Alternately, the manufacturer may chop up the whole thing, remelt it, and use it to make more carpet backing. Such a carpet was not originally designed to be recycled and is being forced into another cycle for which it is not ideally suited. But carpeting designed as a true technical nutrient would be made of safe materials designed to be truly recycled as raw material for fresh carpeting, and the delivery system for its service would cost the same as or less than buying it. One of our ideas for a new design would combine a durable bottom layer with a detachable top. When a customer wants to replace the carpeting, the manufacturer simply removes the top, snaps down a fresh one in the desired color, and takes the old one back as food for further carpeting.

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Under this scenario, people could indulge their hunger for new products as often as they wish, without guilt, and industry could encourage them to do so with impunity, knowing that both sides are supporting the technical metabolism in the process. Automobile manufacturers would *want* people to turn in their old cars in order to regain valuable industrial nutrients. Instead of waving industrial resources good-bye as the customer drives off in a new car, never to enter the dealership again, automobile companies could develop lasting and valuable relationships that enhance customers' quality of life for many decades and that continually enrich the industry itself with industrial "food."

Designing products as products of service means designing them to be disassembled. Industry need not design what it makes to be durable beyond a certain amount of time, any more than nature does. The durability of many current products could even be seen as a kind of intergenerational tyranny. Maybe we want our things to live forever, but what do future generations want? What about their right to the pursuit of life, liberty, and happiness, to a celebration of their own abundance of nutrients, of materials, of delight? Manufacturers would, however, have permanent responsibility for storing and, if it is possible to do so safely, reusing whatever potentially hazardous materials their products contain. What better incentive to evolve a design that does without the hazardous materials entirely?

The advantages of this system, when fully implemented, would be threefold: it would produce no useless and potentially dangerous waste; it would save manufacturers billions of dollars in valuable materials over time; and, because nutrients for new products are constantly circulated, it would diminish the extraction of raw materials (such as petrochemicals) and the manufacture of potentially disruptive materials, such as PVC, and eventually phase them out, resulting in more savings to the manufacturer and enormous benefit to the environment.

A number of products are already being designed as biological and technical nutrients. But for the foreseeable future, many products will still not fit either category, a potentially dangerous situation. In addition, certain products cannot be confined to one metabolism exclusively because of the way they are used in the world. These products demand special attention.

When Worlds Collide

If a product must, for the time being, remain a "monstrous hybrid," it may take extra ingenuity to design and market it to have positive consequences for both the biological and technical metabolisms. Consider the unintended design legacy of the average pair of running shoes, something many of us own. While you are going for your walk or run, an activity that supposedly contributes to your health and well-being, each pounding of your shoes releases into the environment tiny particles containing chemicals that may be teratogens, carcinogens, or other substances that can reduce fertility and inhibit the oxidizing properties of cells. The next rain will wash these particles into the plants and soil around the road. (If the soles of your athletic shoes contain a special bubble filled with gases for cushioning—some of which were recently discovered factors in global warming—you may also be contributing to climate change.) Running shoes can be redesigned so that their soles are biological nutrients. Then when they breaks down under pounding feet, they will nourish the organic metabolism instead of poisoning it. As long as the uppers remain technical nutrients, however, the shoes would be designed for easy disassembly in order to be safely recirculated in both cycles (with the technical materials to be retrieved by the manufacturer). Retrieving technical nutrients from the shoes of famous athletes—and advertising the fact—could give an athletic-gear company a competitive edge.

Some materials do not fit into either the organic or technical metabolism because they contain materials that are hazardous. We call them *unmarketables*, and until technological ways of detoxifying them—or doing without them—have been developed, they also require creative measures. They can be stored in "parking lots"—safe repositories that the producer of the material either maintains or pays a storage fee to use. Current unmarketables can be recalled for safe storage, until they can be detoxified and returned as valuable molecules to a safe human use. Nuclear waste is clearly an unmarketable; in a pure sense, the definition should also include materials known to have hazardous components. PVC is one such example: instead of being incinerated or landfilled, it might instead be safely "parked" until cost-effective detoxification technologies have evolved. As currently made, PET, with its antimony content, is another unmarketable: with some technological ingenuity, items that contain PET, such as soda bottles, might even be

upcycled to remove the antimony residues and to create a clean polymer ready for continuous, safe reuse.

Companies might undertake a *waste phaseout*, in which unmarketables—problematic wastes and nutrients—are removed from the current waste stream. Certain polyesters now on the market could be gathered and their problematic antimony removed. This would be preferable to leaving them in textiles, where they will eventually be disposed of or incinerated, perhaps therefore to enter natural systems and nutrient flows. The materials in certain monstrous hybrids could be similarly gathered and separated. Cotton could be composted out of polyester-cotton textile blends, and the polyester then returned to technical cycles. Shoe companies might recover chromium from shoes. Other industries might retrieve parts of television sets and other service products from landfills. Making a successful transition requires leadership in these areas as well as creative owning up.

Should manufacturers of existing products feel guilty about their complicity in this heretofore destructive agenda? Yes. No. It doesn't matter. Insanity has been defined as doing the same thing over and over and expecting a different outcome. Negligence is described as doing the same thing over and over even though you know it is dangerous, stupid, or wrong. Now that we know, it's time for a change. Negligence starts tomorrow.