

A lifetime of...
...the recycled rather than recycled...
...basic computer case for example...
...for high quality products like a car...
...more and longer...
...original material from which it...

2010

...the use of...
...biological nutrients...
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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 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-

time 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.

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.