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Packaging Tips from the Porcupine Fish (and other Wild Packagers)

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www.biomimicry.net

From ancient pottery to plastic tubs, the trend is clear: we're a species that totes, stores, and shields our treasures from a capricious world. But we're not the only ones. Wild skins, auxiliary pouches, and egg and seed cases do exactly what our commercial packaging does: *contain* loose items, *protect* their contents from the outside world, and *connect* to the outside world via surfaces that signal. Given the similarities, what might we learn from other organisms about packaging with the least effort and no regrets? This process of asking our biological elders for sustainable advice is called biomimicry.

Packages that Contain

Expand and collapse: Many of life's containers are flexible, like the throat pouch of the Clark's nutcracker that expands to hold up to 150 pine-nut-sized seeds, or the pelican pouch that scoops three gallons of seawater, then returns to shape. What if we could design a juice bottle that would fill up like a sturdy balloon, then collapse to a small disk when its liquid is gone? You could store it in your pocket as a go-cup, or send hundreds back to the manufacturer in a single envelope.

A cellular matrix: Fruits and vegetables are bottles that don't slosh because their liquid is stored in and between cells. By weight, carrots are 92 percent water; lemons, cucumbers and tomatoes are 96 percent water; and lettuce tops them all at 97 percent water. What if we were to store precious or even dangerous liquids in such a cellular matrix, so that a puncture was not a crisis? Or how about using a cellular matrix for the skin of a bottle? An empty bottle could be eaten like an orange slice, and a bottle of shampoo could dissolve in the bath instead of the landfill.

Optimal packing: Gaze at the face of a sunflower, the seeds of a pine cone, or leaves spiraling around a twig. Leaves and seeds are arranged in what mathematicians call the Fibonacci sequence (each number added to the one before gives the next number: 1, 1, 2, 3, 5, 8…). Fibonacci spirals in seed heads allow uniform packing of seeds at every growth stage, with no crowding in the center and no sparse patches at the edges.

Color without paint: Packaging's final coat of paint or ink gives it an environmental black eye. Organisms use two methods to create color without paint: internal pigments and the structural color that makes tropical butterflies, peacocks, and hummingbirds so gorgeous. A peacock is a completely brown bird. Its "colors" result from light scattering off regularly spaced melanin rods, and interference effects through thin layers of keratin (the same stuff as your fingernails). What if packages could be dipped in something clear and nontoxic that played with light to create the illusion of color? Iridigm, in San Francisco (www.iridigm.com), is using structural color ideas from tropical butterflies to create a PDA screen that can be easily read in sunlight. In Japan, researchers are developing a liquid crystal display sign whose structure can be set using UV light, then reset for a different message, all without ink.

Packages that Protect

Grace under pressure: A great place to look for impact resistance is in the rock and roll of the tidal zone, where soft-bodied creatures like snails, barnacles, and mussels brave the waves. Their shells self-assemble from minerals in the sea water through a process called biomineralization. Among the sixty or more kinds of biomineralized materials is the abalone's mother-of-pearl, an organic/inorganic composite that's twice as tough as our high-tech ceramics. Alan Sellinger and Jeffrey Brinker at Sandia National Labs have devised a process to make ceramics without energy inputs by mimicking rudimentary shell production.

Scrapes and falls: For scrape-free packaging, we'd be wise to ask snakes, whose scales (hardened folds of keratin) seal out water, provide flexible traction, and buck constant abrasion.

To coddle fragile items, we might consider seed helmets—nuts. Brazil nuts are packed in a three-layer, highly reinforced pod that survives an 80-meter fall from the canopy, then defies opening by any animal except its ally, the agouti, a caching rodent with strong, angled teeth.

Just-in-time protection: Nature's packaging is rarely overbuilt. The pliable sea cucumber's skin stiffens just when it needs to, for instance when struck by a predator. Imagine closely packing items in their softer forms, using fewer materials and less space, knowing that if the box drops, the packaging will harden like a rock.

The porcupine fish's spines are set into its skin, erecting only when the fish is threatened. To trigger the inflation, the fish sip tiny gulps of water. A package that started to fall might be induced to puff up with air in the same way, bouncing on spines when it hit the ground.

Self-repair: Our bodies are packages within packages. Every cell has a fatty membrane that self-assembles when placed in water, then reassembles when a breach occurs. Imagine a polymer wrapper that would heal when ripped during use, but would eventually decompose when placed in a compost heap. The many models for this "timed degradation" in the natural world include the varnish-like sealant on the byssus filament that tethers a mussel. Tough on microbes when in use, the sealant becomes vulnerable after two years, when the mussel no longer needs the thread.

Protection from microbes: To protect against microbial squatters, a biomimic would look for clues in the skins of organisms that manage to keep themselves slime-free. Red and green algae (kelp) are able to stabilize a normally reactive compound called bromine to fend off microbes without harming the alga. Nalco engineer William McCoy borrowed this stabilization recipe to create Stabrex™, a chlorine alternative that keeps industrial cooling systems microbe-free.

And then there's always the good bacteria/bad bacteria strategy. When good bacteria occupy niches, bad bacteria struggle to get a foothold. It's why *Lactobacillus* helps in your digestive track, and adding good bacteria to surgical wounds keeps infections at bay. Could we create a favorable environment for good bacteria in our packaging, and actually welcome them as watchdogs?

Protection from air and water: Seed cases are champions of air- and watertight storage. Among the record-holders: a lotus that germinated after 1,288 years, a Polynesian box fruit that germinated after two years at sea, and the Mary's Bean, a liana seed that floated from the Marshall Islands to the beaches of Norway, more than 15,000 miles!

Steal this package: Imagine a thief grabbing a package encased in slime, and you begin to see what makes the eel-shaped hagfish so predator-proof. (To remove its slime, the hagfish ties itself into a knot and moves the knot along its body.) Bacteria, slugs, fish, and several amphibians and reptiles also secrete slime wrappers for waterproofing, infection guards, and more. While not recommended for gift packaging, this may be a slick strategy to protect goods in the warehouse.

Staying clean without detergent: If the goal is to keep packaging clean, inspiration is hiding in the microscopic surfaces of leaves. Plants like the swampland lotus can't afford to have dirt interfere with their sun bathing. Using powerful scopes, German scientists found that lotus leaves have mountainous surfaces that keep dirt particles teetering on the peaks rather than adhering. Rainwater balls up and rolls the loose particles away like a snowball removing leaves from your lawn. A number of new products are available in self-cleaning lotus-effect surfaces, including roof shingles, car paint, and a building façade paint, Lotusan, made by ispo (www.ispo-online.de/english/index.htm). The paint dries with lotus-like bumps, and rainwater cleans the building.

Failing on purpose: Another take on natural protection comes in the form of sacrificial layers like those in a horse's hoof. The outer layer is designed to slough off under pounding pressure, exposing the next layer of new hoof. Shaggy or platy tree bark is also sacrificial; fast-moving fires crisp the outside layer of ponderosa pine, then smolder to a stop. Perhaps packages could be designed to wear or break on purpose, dissipating stress and shielding the goods within.

The ultimate dematerialization might be to shuck the package altogether, and make wear-and-tear an asset, as it is in the self-sharpening beaver's teeth. What if we designed products to get *better* during transport and handling, the way distressed leather and sandblasted jeans do?

Packages that Connect

Active interfaces: Skin bristles with sensing and regulating devices, opening pores to help animals stay cool, or raising goose bumps to lift thermoregulating hairs. Leaf pores open to exchange gases when the sun shines, and close tight when the leaf needs to retain water vapor. "Smart packages" like these would be a godsend in the produce section, or in the transition from refrigerated trucks to hot, humid warehouses.

Berries go on sale: Fruits and berries are masters of focus-group advertising—colored to attract the birds, mammals, and even fish that will best spread their seed. The ripening process is highly orchestrated, with berries staying an unappetizing green, without much sugar content, until the seeds are fully grown. Once seeds are ready, berries go on sale, heightening their color and sugar content and becoming irresistible to impulse shoppers. Imagine packaging that changed color to signal a sale and help move inventory before it became stale.

Expiration past due: Another boon to retailers would be food or drug packages that announced impending expiration dates by changing color. In plants, the oxidation of limited-life span pigments such as anthocyanin turns flower petals brown. Perhaps a similar coloring mechanism could alert retailers to bruised boxes or expired contents.

Going my way? A winged seed puts up a sail so that wind currents will carry it to distant soils, while burrs cut down on shipping costs by hitchhiking. Might we design more products for co-packaging with related products, or to ride in buses, subways, or ferries going there anyway?

What Waste? How Organisms Make Packages

Nature's packages are designed from the get-go to return to natural cycles. Nature's materials demonstrate an inherent multifunctionality that we have yet to master. Candy wrappers may use five to seven layers. Take the Luna Bar, for instance: A "75-gauge polypropylene/ink/adhesive/60 gauge metallized-oriented laminate" provides mechanical protection, moisture control, ease of opening, and brand declaration. But the insect cuticle does all this in one material—a composite of polysaccharides whose functions are achieved by altering the shape of the polymers, their alignment, and how they are bonded together. Since chitin contains only four ingredients—carbon, hydrogen, oxygen, and nitrogen—shaped into tasty molecules, its afterlife is mercifully short.

The manufacturing of life's packages is a benign affair—chemistry performed in water, using local raw materials, powered by current sunlight, at body temperature, and without toxic chemicals. With the right models and the right humility, we might just be able to learn from the form, the process, and the ecosystem fit of life's packaging. When we finally get it right, we can tip our hats to our mentors, take a bow ourselves, and join the ranks of other organisms that package without harm.

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Janine Benyus is a biological sciences writer and author of six books, including *Biomimicry: Innovation Inspired by Nature*. She has worked as a backcountry guide as well as a translator of scientific stories at several research labs, along with acting as a "biologist at the design table" for various governments and sustainable companies. Her natural habitat is the northern Rocky Mountains of Montana, where she rows, backpacks, cross-country skis, and wanders, finding solace and endless inspiration.

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Janine Benyus and Dayna Baumeister are both members of the Biomimicry Guild, which helps communities and companies consult nature to create products, processes, and polices that are well adapted to life on Earth over the long haul. They consult with designers and offer research services, workshops, and "really cool talks about the genius that surrounds us."

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