# NATURE'S UNIFYING PATTERNS

## Ten lessons to consider every time you design something

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*The patterns described here reflect some of the ways organisms have adapted within Earth's limits and boundaries over long time periods, in the process creating diverse and resilient biological communities. These patterns are worth paying attention to because they can have profound implications for human design. If we aim to build a world that is compatible with life on Earth over the long haul, we need to consider nature's lessons in a systems context.*

### 1. Nature uses only the energy it needs and relies on freely available energy.

Energy is an expensive resource for all organisms; the risk of using excess energy is death or the failure to reproduce. Therefore, they use it sparingly, tailoring their needs to the limited amount of energy available. While no energy is "free," because all energy requires expenditure of energy to obtain it, nature's sources for energy are freely available because they are renewable, are found locally, and don't need to be mined. Freely available energy includes sources such as electrons from sunlight used by plants for photosynthesis, rising air currents, wind, dissolved minerals from deep sea vents, decomposing organic materials, and nutrients from plants and animals that organisms feed upon.

Two major energy expenditures for organisms are obtaining the energy (e.g., through photosynthesis or finding and capturing food) and growing materials that make up their bodies and homes. Organisms use low-energy processes to reduce the amount of energy they need. Those processes usually involve self-assembly, building from the bottom-up (small elements to large), using modular or nested structures, building at ambient temperatures and pressures, and making use of multi-functional design.

### 2. Nature recycles all materials.

In nature, one organism's waste or decomposing body becomes a source of food and materials for other organisms. While we talk about "recycling," "upcycling" is a more accurate description of what happens in nature. There are usually many organisms, or more accurately, ecosystems of organisms, that break down complex organic materials and molecules into smaller molecules that can then be taken up and reassembled into completely new materials. Just as there is a hydrological cycle, there are many other cycles involving organic matter (carbon cycle, nitrogen cycle, etc.) that function as local, regional, and whole-earth systems.

## 3. Nature is resilient to disturbances.

Being resilient is about having the ability to recover after disturbances or significant, unpredictable changes in the local environment, such as those caused by a fire, flood, blizzard, or injury. Diversity, redundancy, decentralization, self-renewal, and self-repair can all enable resiliency in nature and the ability to maintain function despite a disturbance. At a systems level, "diversity" refers to the presence of multiple forms, processes, or systems that meet a functional need. Diversity can include a variety of behavioral, physical, or physiological responses to a change in the environment. "Redundancy" means that there's more than one representative system, organism, or species that provides each function, and that there's overlap so the loss of or decline in one representative doesn't destroy the whole system. "Decentralization" means that the mechanisms maintaining those functions are scattered throughout the system, not located exclusively together, so that a localized disturbance doesn't remove one or more vital parts of the whole system. "Self-renewal" and "self-repair" are terms that are more often applied at the cellular or organismal level, but self-renewal can also be applied in ecological contexts. For the former, the terms mean that organisms have the capacity to generate new cells, heal wounds and damaged organs, respond to bacterial and viral threats, and more.

## 4. Nature tends to optimizes rather than maximize.

Because energy and materials are so precious, nature seeks a balance between resources taken in and resources expended. Energy spent on excess growth, for example, could result in insufficient energy reserves or characteristics that harm an organism's ability to survive and reproduce, which means that it won't be able to pass on its genes. There are checks and balances in both organisms and ecosystems, some of which occur over generations. Growth for growth's sake will result in harmful side effects. Sometimes these side effects are immediately apparent and possibly reversible, and sometimes they remain hidden for a long time until reversal is too late.

## 5. Nature provides mutual benefits.

Among the variety of ways that organisms interact with each other, there are many examples of interactions that provide mutual benefits. The benefits may be simple byproducts of specific behaviors—for example, when one organism's waste is another organism's resource—or they may arise out of close relationships that evolved over time. Mutualistic symbioses are one example of a close relationship between different kinds of organisms, where all the partners benefit from the relationship. Another kind of close relationship includes cooperation among members of a family group.

Even interactions that normally harm an organism, like predation or parasitism, can include benefits when viewed at a different level. For instance, a male praying mantis might be eaten by his female mate after mating, providing beneficial nutrition to the female that will eventually bear his offspring.

## 6. Nature runs on information.

To be attuned to their environment, organisms and ecosystems need to receive information from the environment and be able to act appropriately in response to that information. This includes sending and receiving signals to and from other organisms or even within the body of an organism. This system of send, receive, and respond has been finely tuned through millions of years of evolution. Some living systems work within narrow ranges of optimal conditions, so they need to constantly monitor their environment and respond. Others have broader ranges, but still need to be able to detect and respond when conditions are such that they approach their limits (e.g., maximum survivable temperature or oxygen availability). Using feedback loops is one way to monitor

those conditions. Both negative feedback loops (those that slow down a process), and positive feedback loops (those that speed up a process) are important in natural systems.

## 7. Nature uses chemistry and materials that are safe for living beings.

Organisms do chemistry within and near their own cells. This makes it imperative that organisms use chemicals, chemical processes, and chemistry-derived materials that are supportive to life's processes. Life's chemistry is water-based and uses a subset of chemical elements configured into precise 3D structures. The combination of 3D architecture and composition is the key to maximizing self-assembly, guiding chemical activity and material performance, and allowing for biodegradation into useful constituents when their work is done. With regard to our production systems, the importance of using life-friendly chemistry and materials is applicable at various system scales, from sourcing or growing of materials, to manufacturing products or goods, transporting those goods, and considering what happens to them at the end of their life cycle.

## 8. Nature builds using abundant resources, incorporating rare resources only sparingly.

Nature's materials are abundant and locally sourced. This is true whether an organism is building something external to itself, like a termite mound or a nest, or assembling materials that are part of the body, e.g., a wing, shell, leaf, or horn. The most common and abundant basic building blocks—chemical compounds—are those that are formed from the most common and readily found elements on earth: carbon, nitrogen, hydrogen, and oxygen. A few rarer minerals are also used, but these are found locally and are readily available, not mined, processed, or shipped thousands of miles. Waste is eliminated waste through additive manufacturing and by building processes around readily available and low cost sources of materials and energy.

## 9. Nature is locally attuned and responsive.

Chances of survival increase when individuals are good at recognizing local conditions and opportunities and locating and managing available resources. Survival also depends on responding appropriately to information garnered from the local environment. Organisms and ecosystems that are present in a location evolved in direct response to local environmental conditions. Some of those environmental conditions change in a cyclic pattern, such as tides, day and night, seasons, and annual floods or fires. Organisms use those predictable cyclic patterns as an opportunity, evolving to fill a particular niche. Within a particular location, there are micro-environments, such as a low spot that is moister than the surrounding area or an area that experiences more wind than others. These also provide opportunities for organisms to have an advantage over others and thrive. Some environmental conditions change slowly over time as the climate changes or as the organisms and ecosystems influence the local conditions. Being able to respond to these changes, again using them as opportunities, allows organisms and ecosystems to flourish.

## 10. Nature uses shape to determine functionality.

Nature uses shape or form, rather than added material and energy, to meet functional requirements. This allows the organism to accomplish what it needs to do using a minimum of resources. Forms can be found in the shape of a beetle's back and in the multi-layer structure of a tropical rainforest. If we notice a form in nature, with very rare exceptions, there's almost always a functional reason behind that form.