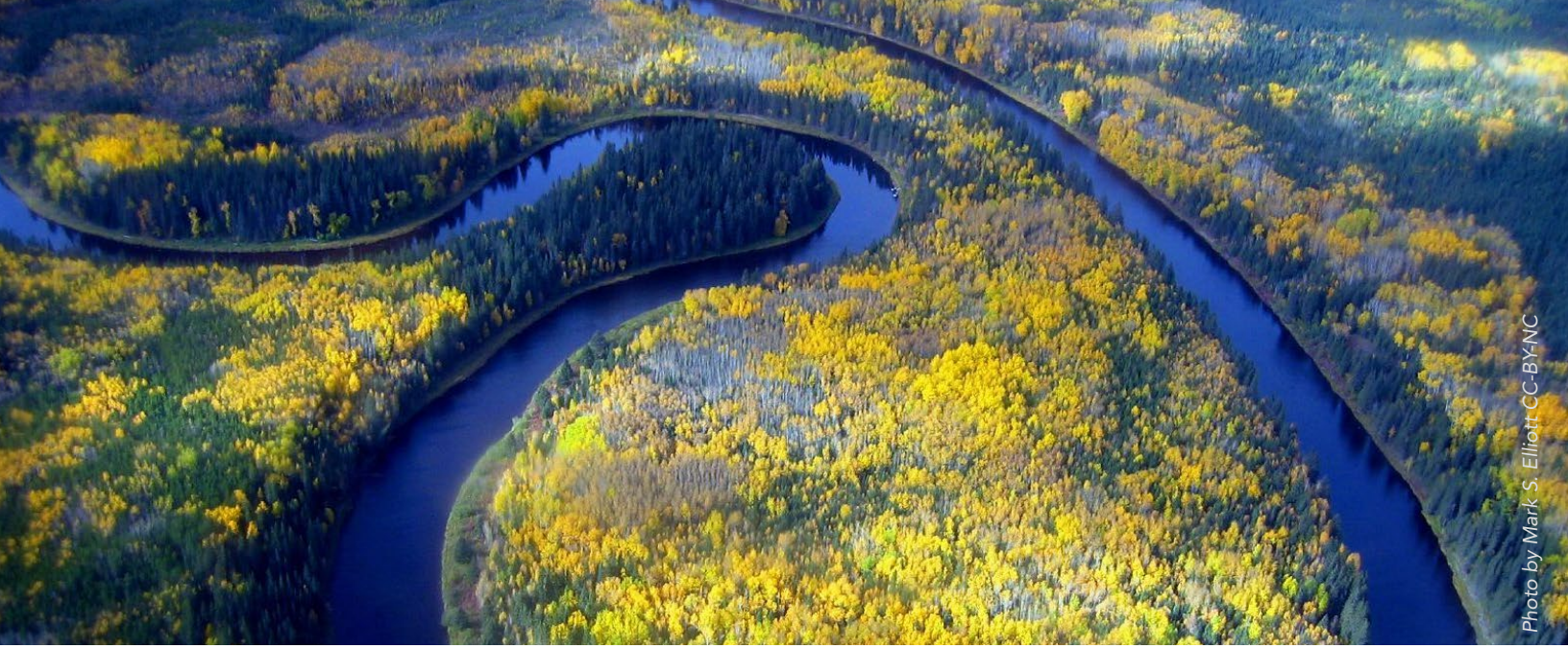

NATURE'S UNIFYING PATTERNS

10* lessons to consider every time you design something

**NOTE: This list is neither definitive nor exhaustive. Rather, it is a work in progress that we hope will be informed and enhanced by the growing community of biomimics who are applying nature's lessons to design.*

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 what actually 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 a fire, flood, blizzard,, or injury. Nature uses diversity, redundancy, decentralization, and self-renewal and self-repair to foster resiliency. These result in maintaining the functions of an organism or ecosystem despite a disturbance. Diversity at a systems level refers to including multiple forms, processes, or systems to 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 for 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 repair are terms that are more often applied at the cellular or organismal level, but self-renewal is also 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 optimizes rather than maximizes.

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 characteristics or insufficient energy reserves 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 rewards cooperation.

While there are many examples of predation, parasitism, and competition in nature, the prevailing relationships are those that are cooperative. Some common types of cooperation are mutualism—where both partners benefit from the relationship—and commensalism—where one partner benefits and the other receives neither benefit nor harm. Frequently, when studied broadly enough, cooperative relationships aren't just between two organisms, but occur among many different organisms, with a mixture of commensalism and mutualism occurring. In the long run, even predation, parasitism, and competition, while harmful to the individual prey, host, or competitors respectively, often have benefits at the systems level.

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 organisms sending and receiving signals to and from other organisms or even within their own bodies. 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 the sourcing or growing of materials, to the manufacture of products or goods, to transporting those goods, to considering what happens to the products 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 it's building something external to itself, like a termite mound or a nest, or assembling materials that go into 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. This pattern also means eliminating waste (e.g. through additive manufacturing), and 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. Another way to say this is that form follows function. 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.