**Biomimicry: Nature’s Time-Tested Framework for Sustainability**

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Biomimicry (from bios, meaning life, and mimesis, meaning to imitate) is a scientific design discipline that seeks sustainable solutions by emulating Nature’s time-tested patterns and strategies. The core idea is that Nature, after 3.8 billion years of research and development, has already solved many of the problems we are grappling with in industry, government and agriculture, such as packaging, transportation, energy production, non-toxic chemistry, carbon sequestration, crop production and a whole lot more.

**BIOMIMICRY’S**

**LIFE PRINCIPLES**

**Evolve To Survive**

- Replicate strategies that work

- Integrate the unexpected

- Reshuffle information

**Be Resource Efficient**

- Use multi-functional design

- Use low energy process

- Recycle all materials

- Fit form to function

**Adapt to Changing Conditions**

- Maintain integrity thru self-renewal

- Embody resilience thru variation,

 redundancy, & decentralization

- Incorporate diversity

**Integrate Development & Growth**

- Combine modular & nested components

- Build from the bottom up

- Self-organize

**Be Locally Attuned & Responsive**

- Use readily available materials & energy

- Cultivate cooperative relationships

- Leverage cyclic processes

- Use feedback loops

**Use Life-Friendly Chemistry**

- Build selectively with a small subset of

 elements

- Break down products into benign

 constituents

- Do chemistry in water

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**Life Creates Condition**

**Conducive to Life**

**Life Adapts and Evolves**

[www.biomimicryinstitute.org](http://www.biomimicryinstitute.org)

[www.biomimicryguild.com](http://www.biomimicryguild.com)

[www.asknature.org](http://www.asknature.org)

Animals, plants and microbes’ are the consummate engineers. They have found what works, what is appropriate and most importantly, what lasts here on earth. Biomimicry differs from other “bio-approaches” by consulting organisms and ecosystems and applying the underlying design principles to human innovations and processes. Science has been studying nature for centuries, trying to unlock its secrets. Looking at this body of knowledge, patterns emerge. In biomimicry these patterns are called deep principles. The Biomimicry Institute and the Biomimicry Guild, along with many partners, have distilled this collection of scientific research to create a collection of the most fundamental principles into the list of **Life’s Principles** (see side bar).

Life’s Principles represents the overarching patterns found among species surviving and thriving here on Earth. It’s Nature’s strategy for sustainability. Biomimicry provides humans with aspiration ideals to view Nature as our mentor, innovative strategies to view Nature as our model and sustainable benchmarks to use Nature as our measure (1).

The value of using Nature’s operating principles is that we know this approach is possible; all other species that have survived on Earth have already tested this set of guidelines. Using these principles to guide our decisions and actions, humans can reconnect with Nature and begin to see ourselves as part of the Earth’s system, not independent from it, and increase our chances of survival.

Biomimicry reminds us that life is directly or indirectly subject to Earth’s operating conditions:

**Earth is in a state of dynamic non-equilibrium.**

**Earth runs on sunlight, water and gravity**

**Earth is subject to limits and boundaries**.

**Nature uses cyclic process**

Stating that the *earth is in a state of dynamic non-equilibrium* means that the conditions are always changing and only organisms that have the ability to adapt and evolve can thrive in this system. *Earth runs on sunlight, water and gravity* means that almost all but a few unique organisms on Earth receive their life’s energy from the sun. Water is just as important. It is how information flows on earth, and organisms that recognize the value of water in earth’s system are successful. Life has developed mechanisms to respond to the pull of gravity, either by relying on it to stay put on the planet, or in developing mechanisms to overcome gravity such as growing tall or moving water up a tree trunk. *Earth is subject to limits and boundaries* means that we have limited water and limited air in our atmosphere; these are real parameters that all life is subject to. Because there is a limited environment, all actions must support life. *Nature uses cyclic processes* because they hold a measure of predictability in a system that is always changing. Temperature changes between night and day, seasonal changes, and cycles of the tides are examples of cyclic processes that life has adapted to. These cycles also provide opportunities for organisms to leverage the differences in each cycle to their advantage.

The Life Principles framework considers two essential strategies of all natural systems:

* **Life creates conditions conducive to life**
* **Life adapts and evolves**

Nature has adopted these strategies in order to move into a state of equilibrium, despite a constantly changing environment. *Life creates conditions conducive to life* means that organisms that survive on this planet are the ones that “obey” the laws of physics and respect the limits and boundaries of the earth’s resources. As an example, think that earth is like a bowl. The bowl is dynamic, it is always moving and shifting. Life is like a marble in the bowl, it always has to move when the bowel moves in order to find the state of equilibrium. Life does this by *adapting and evolving*. Humans design things that are square, which makes our designs less adaptable, and we compensate by trying to hold the bowl still. For example, we design air conditioning units that will hold the temperature at a constant setting, so that no matter what the outside temperature is we have a constant temperature inside. We like to think we can operate this way, but any disruption in the system, a hurricane or change in climate, our design is stuck because it cannot move to the new state of equilibrium.

Each of Life’s Principles represents a strategy that Natures must follow in order to survive. It can be viewed as a short-hand version of “biology 101” and used as a lens to view our design strategies. To better understanding this basic set of principles, we can look at each one and see how life has decided to fit into the condition on Earth. It is important to recognize that there is a relationship between these principles; they are not a list of individual components, but rather an interconnected system.

**Life’s Principles Definitions**

**Evolve to Survive**

*Definition:* Continually incorporate and embody information to ensure enduring performance.

Evolution is change that endures across generations as the new traits are passed on to the young thorough genetic material. As the environment changes, adaptation is often not enough to secure survival of the species. The solution, achieved through the trial and error of genetic mutations, imbeds the successful traits within the entire population, thus promoting survival. A biological example is antibiotic bacterial that have evolved to survive human-made anti-bacterial chemicals. Democracies are a human example of an evolving system where changes are imbedded in the system through changes in laws and culture.

Nature evolves to survive by replicating strategies that work. As organisms experiment with different adaptation strategies, those that work get adopted and are passes along to others. A biological example is the crow, which is able to use tools to access food. This behavior is observed and imitated by others in the flock until, eventually; this behavior is imbedded in the genetic code. A human example is the design of the bicycle, which looks and operates very different since its invention in the early 1800’s. Nature integrates the unexpected by incorporating mistakes in ways that can lead to new forms and function. Genetic mutations are the catalyst for many new strategies and the ones that help an organism survive get passed on through genetic material. A biological example is the elephant, who owes its size to a mutation that caused wrinkled skin. This trait allows for more heat loss due to the increased skin surface and prevents overheating. A human example is the “invention” of Silly Putty. It started out as a failed experiment in 1944 to make rubber using silicon. The rubber never worked for its intended purpose, but the inventor integrated this unexpected failure to produce a much loved toy. Nature also reshuffles information by exchanging and altering information to create new options because the recombination of genetic material through reproduction guarantees variety. Apples are a great example of strategy. The ones we eat today bear little resemblance to the original fruit tree, as nature reshuffled the genetic material over time to produce the sweet fruit we enjoy. Humans reshuffle information by changing jobs and brining knowledge and ideas from one company to another.

**Be Resource (Material and Energy) Efficient**

*Definition:* Skillfully and conservatively take advantage of resources and opportunities. Organisms that survive develop strategies to utilize resources, both the tangible (materials) and intangible (energy and information) efficiently. They are able to perform necessary functions while minimizing waste. An example from nature is the hollow bones of birds. They have eliminated unnecessary material by putting bone cells only in areas of stress, thus producing a lightweight structure that allows for flight but is strong enough to support the wings. Conducting an energy audit on your home and implementing the findings is a human example of this strategy.

Nature uses multi-functional design to meet multiple needs with one elegant solution. One component of the system performs many functions that are critical to the integrity of the entire system. Ducks demonstrate this strategy by preening to clean its feathers while also spreading preen oil that waterproofs feathers and moisturizes the beak. The oil breaks down in sunlight into vitamin D, contributing to the health of the bird. A human example is the iPhone. Nature uses low energy processes to minimize energy consumption by reducing requisite temperatures, pressures, and/or time frames for reactions. Life does this by employing strategies whenever possible that leverage energy flows to their advantage. Prairie dogs, for example, orient their burrows to take advantage of the prevailing winds to cool their homes. A passively heated or cooled solar home is a human example. Nature recycles all materialsby keeping all materials in a closed loop. The design uses degradable and/or reusable materials and resources. The recycling of these materials should be a chain of cooperation and interaction, where one player will take advantage of and use what another would consider as waste. In Nature it is a system-wide loop. Humans in general understand the concept of recycling, but we turn paper back into paper, cans into cans. Nature does not turn leaves into leaves; the carbon is recycled throughout the ecosystem. Trees for example, reuse rare elements by storing them to use later, but the abundant ones, like carbon, are recycled widely when they lose their leaves in the fall. Take back programs sponsored by product manufacturers are a human example of this strategy and products that are design to be disassembled for reuse take the strategy one step further. Life is efficient by fitting form to function. The design selects for shape or pattern based on need. It takes advantage of shape in order to perform the desired function, instead of adding more material. In Nature, the beaks of birds form to fit the function of opening specific kinds of nuts that are available in their ecosystem. Humans design farm equipment for harvesting specific types of crops.

**Adapt to Changing Conditions**

*Definition:* Appropriately respond to dynamic context. Organisms are constantly trying to reach a steady state with their environment. To do so, it must be constantly aware of the changing conditions in their locale and adapt as needed. If not, it will not survive. Adaptation is a long-term strategy based on the degree of change in that locale. A biological example is the arctic fox that changes its fur from brown in the summer to white in the winter in order to blend in. A human example is how the movie rental industry has adapted to VCR, DVD and Blue-Ray disks. Companies that did not adapt went out of business.

Nature is able to maintain integrity through self-renewal, a strategy that allow it to persist by constantly adding energy and matter to heal and improve the system. To avoid stagnation, organisms actively turnover parts of the system by continuously disassembling and remaking parts instead of waiting for a part to fail and then replacing it. Using this strategy, the organism can guarantee a consistent level of performance and incorporate changes as a way to adapt without causing gaps in the whole system. For example, rhinos depend upon their horns for survival and cannot grow new horns if a loss occurs. They do this through a protein in the horn, that when exposed to air or damage, fills in any cracks. Humans have invented a self-healing concrete that mimics this strategy. It contains microcapsules filled with resins that break open upon exposure to a micro fracture and repair the structure. Nature incorporates diversity to adjust to changing conditions. It is a systematic approach or design that incorporates multiple forms, processes, or systems to meet a functional need. Diversity is important because you don’t know which way the bowl is going to tip. A city that incorporates walking and bike paths, roads, trains and busses has a diverse transportation system. If one system is impacted, others can perform the function of moving people. Life embodies resilience through variation, redundancy and decentralization. This way it can maintain function following a disturbance by incorporating a variety of duplicate forms, processes, or systems that are not located exclusively together, making for a resilient system that can maintain function following a disturbance. The capacity for resiliency depends on the interconnectedness and functional diversity of multiple systems. Organisms must be able to regain function because they cannot predict when a disturbance will occur. Variation is the capability of carrying out the same function in many different ways. Redundancy means that there are many units that perform the same function so that if one unit is disturbed, other will take its place. In decentralized design, functions are spread out in ways that if a malfunction or disturbance occurs somewhere it does not have a critical impact on other functions or parts of the design. It’s also a way of placing a function close to necessary resources, avoiding the energy cost of transportation. The local food movement that develops a larger food shed is a positive example of this strategy. Our immune system is geared to deal with many types of attacks from bacteria and viruses throughout the whole body and is a natural example of this strategy.

**Integrate Development With Growth**

*Definition:* Invest optimally in strategies that promote both development and growth.

Growth is necessary for organisms to survive, but sustaining life over the long haul requires a balance between growth and development. Development is the investment in the infrastructure as a platform for growth to occur. In the development stage of a human embryo, cells differentiate to produce organs, bones, tissues, etc. In the growth phase, these cells increase in size. A city is built in balance when growth is tempered by development. High growth in one area is support by development of the infrastructure. When suburbs are built without developing the corresponding road corridors traffic gridlock occurs.

Nature integrates development and growth through combining modular and nested components. Life fits multiple units within each other progressively from simple to complex. By repeating common elements to build on successful designs, Nature saves energy and time. Nature is self-organizing. It creates conditions to allow components to interact in concert to move towards and enriched system. Organisms come together and as a result, the system does more than the individual parts. An example in Nature is the natural prairie grasslands that laid down 30 feet of top soil over 11,000 years because of the mixed-species poly-culture. A human example is a grass roots organization or internet coffee shops. Nature builds from the bottom up. For example, a tree does not produce leaves by making a big sheet of leaf material, then cutting it into leaves; trees build leaves one cell as a time. A brick house can be built to shape because it is built from the bottom up. A stick home must be built to a pre-designed shape, producing wasted materials.

**Be Locally Attuned and Responsive**

*Definition:* Fit into and integrate with the surrounding environment. Organisms are attuned to their immediate environment and respond accordingly. It is not enough to know that the bowl (Earth) is moving, but being able respond to the movement. Nature increases its chance to survive as it becomes more adapt at recognizing local conditions and responding to them. For example, the Namibian desert beetle lives in a water stressed environment. In order to survive, the beetle climbs to the top of the tallest dune until it reaches an altitude with a high humidity level. Then it exposes its wings to the fog and collects the droplets of moisture which are directed towards its mouth. Sustainably designed homes respond to local conditions such as heat and cold by being designed to these localized conditions. Nature is able to respond locally by using readily available materials and energy to build with abundant, accessible materials while harnessing freely available energy. With limited resources, Nature has found ways to fulfill its own needs with what is available. For example, prairie dogs burrow underground and orient their burrow to catch the prevailing wind, a direction determined by local conditions. Humans who orient their homes to make use of solar gain and build with materials that are manufactured locally demonstrate this strategy. Nature uses feedback loops as the process of engaging in cyclic information flows to modify a reaction appropriately. The difference between a good feedback loop and a bad feedback loop is the length of time it takes to receive the feedback, if it comes at all. In conserving energy, people who have a visible meter in their home instead of a monthly bill reduce their energy use because of the instant feedback. In Nature many animals change colors as a response to the change in season in order to blend into the environment. Nature leverages cyclic process to take advantage of phenomena that repeat themselves. Cyclic processes are one of Earth’s operating conditions. Life takes advantage of these cycles in order to have a better chance at survival and to reduce their need for energy and materials. Due to the predictability of the abiotic and biotic cycles, life can evolve in stages that optimize these repeating patterns. The way plants bloom in a pattern with the life cycle of pollinating insects is an example of this strategy. A school schedule that lets student “off’ during the months of nice weather (when they may be less attentive) is a human example. Life fosters cooperative relationships as a way to survive and finds value in win-win interactions. Nature finds value by creating conditions that encourage different components or actors in the system to make use of each other in ways that are mutually advantageous.

Nature is more cooperative than competitive and uses niche differentiation to avoid direct competition. A human example is our Cooperative Supported Agriculture, where all the members share the risks and the rewards of the harvest.

**Use Life-Friendly Chemistry**

*Definition:* Use chemistry that supports life’s processes. The backbone of life is biochemistry, the process of assembling molecules to achieve a needed function. For example, birds add colors to their feathers through use of structure that refracts light rather than harmful dyes that contain heavy metals. A company in Japan is mimicking this structural strategy in the weave of its cloth to produce brilliantly colored fabric that uses no dyes or harmful chemicals to produce color. Nature breaks down products into benign constituents. Organisms produce toxins on-demand for a specific purpose and only in small quantities. Once these toxins are released into the environment and have served their function, they break down into benign, reusable substances. For example, snake venom is very deadly for any prey, but once the prey is immobilized, the venom is digested by the snake and has no harmful effect (other than to the dead animal) and there is no trace of the toxin in the feces of the snake. A human example is products made with compostable materials, such as disposable silverware made of cornstarch. Do chemistry in water by using water as a solvent. In Nature, organisms take advantage of the properties of water to do chemistry without using toxic substances or high energy inputs. All of life’s chemistry is done in water. For example, your teeth form a strong durable enamel much better than most human made coating, and does so right in your body. Green chemistry is a human example. Nature builds selectively with a small subset of elements by assembling relatively few elements in elegant ways. Life uses common elements from the periodic table that are locally available: carbon, nitrogen, hydrogen, oxygen, phosphorous, calcium, magnesium, iron, copper and zinc. Elements such as mercury and lead are used sparingly, if at all.

**Final thoughts:** *“After 3.8 billion years of evolution, nature has learned what works, what is appropriate, and what lasts here on earth.”* (1) This set of Life’s Principles is a sustainability tool that can be used as a design standard, a reference for integrating life into your design, an indication of how well your design fits into the natural world or an indication of where your design will fail or create pollution (where it does not meet these principles). It can even be integrated into the framework of how you live your life.

1. *Biomimicry: Innovation Inspired by Nature,* Janine M. Benyus, Harper-Collins Publishers, 1997.

*\** Additional information from the Biomimicry Resource Handbook [www.biomimicrygroup.com](http://www.biomimicrygroup.com)