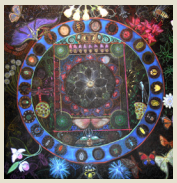
Mandalas:
Eight Drawings of Biological Systems



Informational addendum by Caryn Babaian

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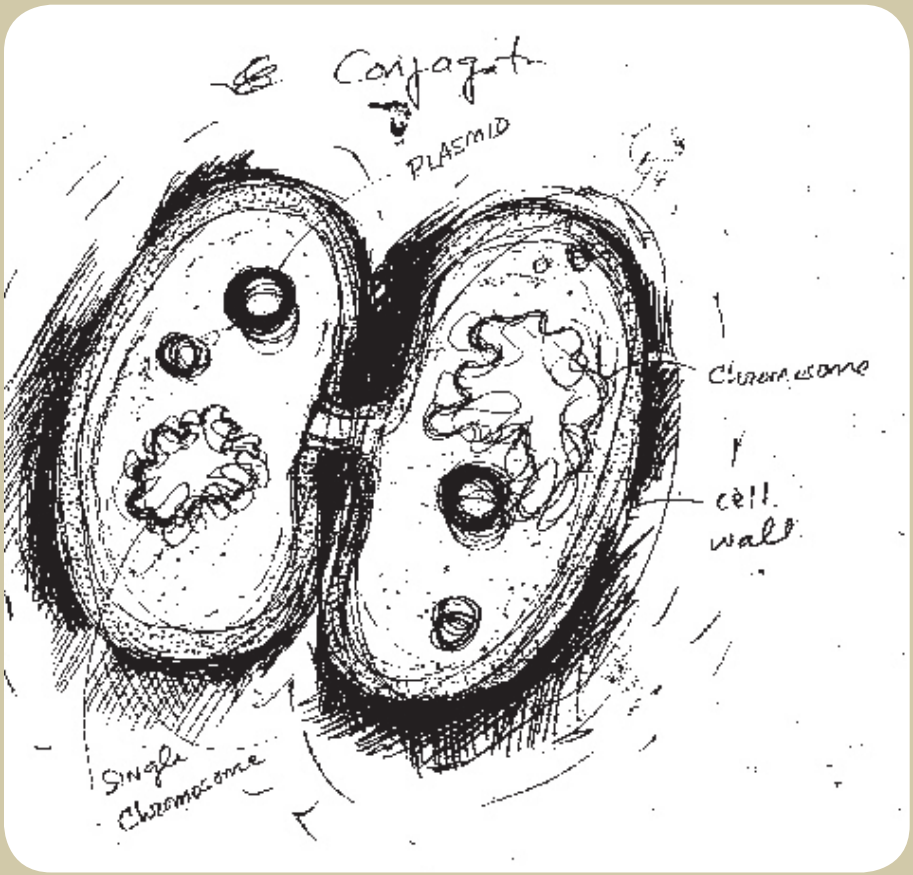
1. *The Magical Evolution and Diversity of Cellular Life*

What is life? In order to appreciate just some of the qualities of the most astonishing phenomenon in the universe, it helps to start at the very smallest level and to examine the story of the life on our planet earth. No matter how much evidence we gather there may be multiple ways in which life, or rather the fundamental unit of life— the cell, came to be.

Although we talk about the technical details of life, the cell is still a huge mystery. Many cultures formulated creation myths. Many of these myths have had fascinating insights into the origins of life. However it was not until the advent of microscopy that we could actually see the parts and little forms that made up the larger groups of tissues and organs in living organisms. These parts however, could never explain the whole of the organism nor the cycles that cause its life to emerge.

How did the cell come to be? Was it the energy of lightening zapping the basic molecules into more complex



relationships? Did this event happen in soil or clay, with crystals, geodes, and piezoelectric effects traversing their periodic lattice and converting to aperiodic as suggested by one Erwin Schrödinger?

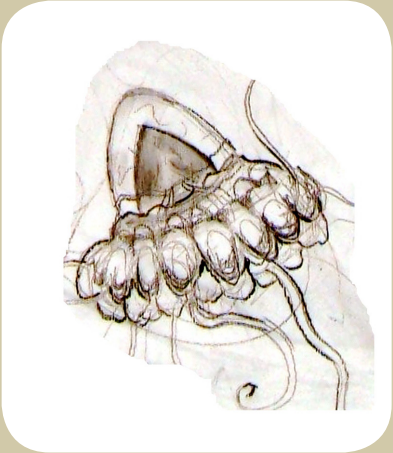
Cells exist all over the planet in the form of prokaryotes, the simplest of cells found in the coldest regions of Antarctica, or in the hottest thermal vents off in the Pacific, or mountain tops, or giesers, and belly buttons. These remarkably versatile and adaptable cells at some point in the life history of the Earth had to come together, exchange, engulf, or both to produce the next level of complexity in Earth's physiology—the Eukaryotic cell.

Could cells have emerged, not as free-living but within the matrix of mineral confined spaces deep in the Earth's crust? The universal ancestor may have been a chemiosmotic, living off iron and sulfide and incorporating lipid biosynthesis to make membranes that inherited complexity through symbiosis as time marched on. And yet, even now the cell is still the real "brains" of the whole operation.

Cells are in fact the architects of multicellular life forms, and are essentially who we are. However cells emerged, one thing is certain. Organisms became vessels of cells so those cells could reproduce to grow and connect with the rest of Nature. •

2. *A Bioluminescent Home: 20,000 Leagues Under the Sea*

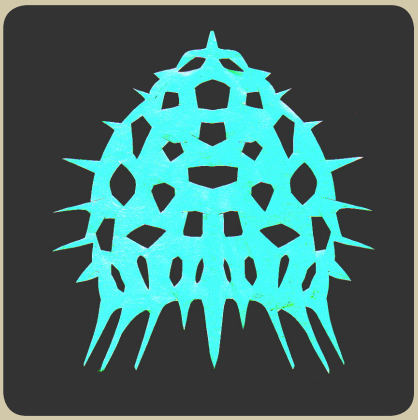
Deep-water ecosystems are an eternal reminder that life is Earth's physiology and it can be found even in places we can't imagine existing. The life in this part of the ocean lets us see just how evolution can take preexisting forms and structures and build a beautifully adapted ocean citizen befitting its new home.



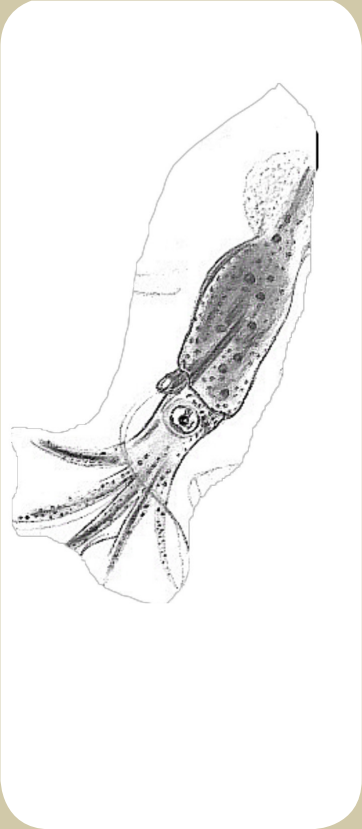
About a mile down we start to encounter really cold, dark places, habitats that seem unlikely to support life. Yet a multitude of adaptations take place in what become highly evolved organs and organ systems that allow these deep dwelling citizens of the sea to establish their existence in such unique environments.

The darkness of the deep seems quiet and still. At these deep depths no plants can grow. Instead of photosynthesis, chemosynthesis is taking place which produces gases other than oxygen. Shrimp appear bright red and their eyes grow much larger to accommodate seeing in the darkness while looking for food. Much of the food that enters this space

falls from above like snow and includes the dead remains of plankton, fish, whales and other animals. This food source, literally called "marine snow", provides a blanket of nutrients for the inhabitants of the deep sea. Another essential part of the deep sea food supply is a type of marine plankton called dinoflagellates. They give off a glow which is a mixture of bacteria they have eaten with their own light emitting compounds. Because of their bioluminescence, when they glow in the dark these fascinating plankton are called by some to be the "living flashlights" of the sea.



Deeper down many fish have some or no vision at all, while others have huge eyes and predatory teeth. Photophore organs are well-developed and a variety of them are used for finding mates, finding food, disappearing, communicating, signaling, confusing predators and seeing. Deep sea creatures can float in the open ocean darkness like a siphonphore or a deep sea jelly with photophores around its bell, they can inhabit complex spaces in a deep sea coral, or they can make homes along deep slopes, or even live at the very bottom of the ocean floor. At five miles below sea level the pressure is intense at nearly 415 kilograms per square centimeter! These amazing organisms have evolved so well that they could never survive outside of their habitat.



Sadly, a new study reveals deep down on the ocean floor of the Pacific are tons of toxic plastics, tires, plastic bags, hangers, markers, electronics, toys and other throw-a-way lifestyle products that leech poisons and barely degrade over time. The deep sea reminds that biophilia must extend to all life, no matter how different or "alien" it might seem or wherever on the Earth it might be.

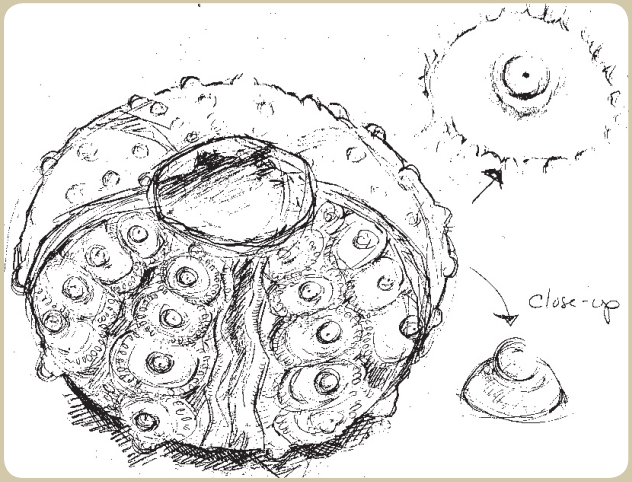
3. *A Coral Reef Ecosystem Renewal*

It is the stony corals and their association with zoozanthellae that laid the foundation for the reef. One modest animal and one modest plant forge a wonderful friendship creating a magical stone garden of coelenterates, fish, cephalopods, mollusks, zooplankton and phytoplankton. The simple cnidarian type known as a polyp, coral polyp, is responsible for this complicated ring of life.

Coral polyps are simple animals that secrete limestone casings known as corallites under and all around themselves. The part of the coral that is the "plant" is technically a protist known in the general term as phytoplankton. Also known as dinoflagellates, these small single celled organisms possess two flagella to help them propel through the water. Some species of phytoplankton live in association with the polyp, embedded in its tissue layer.

These are known as the zoothanthellae. The coral's wonderful array of colors is partially due to this species. The association results in the protist providing a reservoir of photosynthetic energy to the coral polyp. The polyp gets most of its nutrition from the association with the protist and rarely needs to feed on its own. The protist of course receives a protective limestone fortress and is also able to absorb nutrients directly from the water. This stunning combination allows coral reef polyps to build large structures that ultimately act as starter habitats for many other aquatic animals.

A living coral is truly a magnificent flow of energy into living art and is above all else home to many organisms. But what happens when the tiny phytoplanktons are killed? Why are the coral reefs in such distress and peril today? Because this is a community built on living "stone", the life in that stone can be injured, damaged, and killed. When the scaffolding of life dies, so do the coral reef fish, the flatworms, the bristle worms, the moray eels, the sea urchins, the sponges and the brittle stars, and everything that the life system of the coral supports.



It is estimated that by 2100, coral reefs will be completely decimated. Coral reefs may very well become "bleached" and no longer able to carry out photosynthesis. Ocean acidification, warming water, over fishing, and coastal pollution could drastically lower the pH level of the ocean and cause the extinction of many species in the coral reef community. It is apparent that our actions are connected to these environments. Everything starts with awareness. Make the coral reef and its declining condition a topic in your classroom, among friends and in casual conversation because these habitats are irreplaceable. •

4. *Partnerships in Time: Co-Evolution of Insects and Flowering Plants*

Insect and flowering plant co-evolution is one of the greatest mergers in the history of life on Earth. Insects and flowering plants inspired each other. Imagine late in the Mesozoic when the first flower blossomed. This was an event that over millions of years begans an intertwining of creativity that would stimulate the senses of all the creatures on earth and that would fill the earth with color, scent and a profusion of amazing complementary forms.

Most insects began their evolution in the Devonian period (around 419 million years ago) and continued on into the Carboniferous, (around 310 million years ago). They have always evolved closely with plants. One could say this is due to how much insects feed off plants in such a variety of ways. As a matter of fact, 70% of existing flowering plants are pollinated by insects. Other pollinators include birds and mammals. The services exchanged between plants and insects created the synergy of an amazing relationship— the continuation of the plant's genome and food for the insects. Interestingly, pollen grains examined under the microscope show a stunning variety of beautiful shapes and structures. Not every flower gives off nectar for pollen, some just use simple trickery to get pollinated.

Charles Darwin recognized this depencency in one of his famous studies on orchid and insect fertilization published in 1862. He noted the remarkable similarties between orchid flowers and the pollinating insects' shape and structure. He deduced that insects locate flowers visually and are attracted to their colors. Specifically, insects who pollinate orchids were seeing a potential mate in the orchid and were seduced by its similiarty. In short, the insects' visual ability is strongly connected to flowering plant evolution by its ability to recognize and target a plant utilizing its eye structure and pigment recognition.

The princple insect pollinators may suprise you. Besides the bees, which belong to Hymenoptera order of insects or "membrane winged", other pollinators are often thought of as nusinaces. These include flies, wasps, and ants. Flies and wasps can be both scavengers and predators. Many might ask, "what are they good for?" The answer is easy—they are good for their niche in the web of life. They are part of a planet's life cycle, and they are pollinators too. Actually, flies prefer dark colors and odors of decay. Another group of major pollinators are the Coleóptera order of insects, meaning "sheathed wing" and are more commonly referred to as beetles. They often will be working busily around various types of wildflowers, or simply soaking up the sun. In general, beetles tend to like dull light colored flowers with a strong scent. The other most familiar group of insect pollinators are the moths and butterflies (Lepidoptera or "scale winged"). Their association with flowers is one of the most intimate, and they prefer bright colors especially yellows and reds.

Major concerns in the plant and insect world include the decline of wildflowers and the elimination of "pest-like" insects. We show little regard for their complex social lives and interwoven niches and the fact that many other life forms depend upon them. It's time to switch up our thinking and imagine a planet filled once again with brightly colored fragrant plants and their amazing pollinators.

Whenever you can, plant native plants in place of ornamental shrubs and encourage all the major orders of insects to come into your garden.

5. *A Wetland Restoration*

Wetland Ecosystems are home to a vast array of lifecycles. The toad, the frog, the heron, the cottontail rabbit, turtles, raccoons, bulrushes and cattails all remind us of the fascinating world of wetlands and marshes. These amphibious environments in earth's physiology and over Earth's lifespan are ancient conduits that circle between water and land. They remind us of the pivotal transition in our own phylogenic history between aquatic life and tetrapod evolution. The primeval wetlands millions of years ago provided — and still do provide — a nutrient rich pool and protective habitat. It is a place to have and raise offspring and instigates the ebb and flow of genes from aquatic environments to terrestrial ones.

Some of the variations of these wetlands include bogs, marshes, swamps, and sedge meadows. The webs of life in wetland environments are complex. This complex system is sometimes visible when we observe swimming tadpoles or hear adult bullfrogs singing their mating songs.

Interestingly enough, many forms of wildlife actually just pass through the wetlands and are not permanent residents. However their presence is still integral to the wetlands' unique and complex webs of life. The high biological productivity of a wetland draws many interesting organisms into it. The rhythmic rise and fall of water distributes nutrients for a wide variety of species including numerous aquatic plants and insects. Among these organisms lie entire hidden worlds of arthropods and protozoa (insects and algae types of organisms) that make up the foundation of this ecosystem's dynamics and food chain. Some of these fascinating beings include the cyclops, water fleas, euglenas and various diatoms (forms of algae).

These micro-worlds remind us of the astonishing beauty in a single drop of pond water. One look at a drop of pond water under a microscope and a new universe of patterns and complexity is revealed. Within these ecosystems certain plants have specifically adapted to photosynthesize in these unique

conditions. These beautiful and complex environments provide uniquely integrated habitat of water and soil where unique organisms like tubeworms, sponges and water bears can thrive. Animals have also adapted to not just prosper, but survive. Young organisms learn to fend for themselves. One examples of protective adaptation in a wetland environment is when frogs lay eggs. Their little larval babies swim out for food, but know to hide for cover when larger predators come near. Even this larger predator has adapted- the baby snapping turtle will emerge as miniatures of their strong jawed and efficient predatory parents and snap its jaws tight because its survival depends on the turtle protecting itself. Many birds camouflage themselves in the bulrushes and bitterns.

Many organisms have developed unique ways of acquiring food. The muskrat builds its home in aquatic plants and mud right on top of where it can find its favorite foods— mussels, crayfish and nutrient rich decaying cattails. Other animals, like the heron, take a more active approach and stalk their prey. Certain carnivorous plants with their roots in the black muddy ooze wait for unsuspecting insects to land on them and then snap up their prey such as dragonflies that come to rest in the sun. Reptiles and amphibians love the wetland areas for eating insects and building homes. Some animals such as white tailed deer, bobcats and skunks that simply pass through to look for a meal. Hawks visit frequently while on the hunt for mice and voles hidden in the sedge blades.

Wetlands once mixed with deciduous forest ecosystems to produce a spectacular continuation from water to land. Man has been tampering with wetlands since ancient times when they were drained for agricultural nutrients. Now with the rapid increase in human population and the advent of the car, half of all wetlands have been filled in and paved over. Many have become dumping grounds for toxic waste.

With the wetlands disappearing, so are the homes and the species that inhabit them. Help support what remains of these amazing ecosystems by building ponds and habitats that encourage nature and to take over. Bring awareness to the life that lives in these places by drawing and sketching the cattails, reeds, ducks, heron, frogs, and insects, that thrive in them. Wetlands are more beautiful and important than any building or road could ever be.

6. *Return to the Deciduous Forest Primeval*

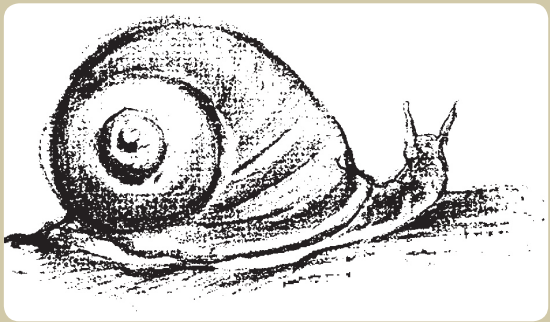
Only a few hundred years ago the earth was almost entirely covered with rich beautiful multi-layered forest communities. The forest is often described as wild and untamed. However, like all living systems, it is a highly organized civil exchange of energy between a variety of life forms strongly dependent upon the trees and plants that create its complex scaffolding of life.

Eastern deciduous forest ecosystems are the type of forest that once dominated the mid-Atlantic region. Sadly 97% of the forest that once thrived in these areas is now gone. All through out the forests of the eastern United States, cougars, bobcats, wolves, coyotes and foxes once roamed unimpeded through these vast forested areas. Many other organisms including a variety of insects, reptiles, birds and amphibians also lived in these areas. Enabling this great diversity of organisms to survive is a complex food web. This web includes consumers like cottontails, cankerworms, hawks and decomposers like turkey vultures, ground hogs, squirrels, raccoons, skunks, opossums, and white tailed deer, as well as several varieties of green plants. All of these organisms contribute to the flow of matter from soil and air through plants and animals. However, trees are the most dominant organisms in the deciduous forest and are responsible for the manufacturing of glucose through photosynthesis.

In a deciduous forest there is a canopy layer, an under story, a shrub layer and an herb layer of trees and leafy plants as well as many nonvascular plants like mosses and ferns. The characteristic appearance of a woodland forest is the result of the staggering of plants attempting to receive sunlight. The forest floor catches

the fallen and dying nutrients from above slowly changing and transforming the surface where bacteria, protists and many fungi participate in the disassembly and recycling of matter. One unseen conduit of recycled matter, energy and nutrients is the superhighway of the mycelium that connects many of the vegetation together. The mycelium of a fungus is what absorbs nutrients from the environment. This fungal network is not visible to the naked eye, but can actually span the entire forest floor.

Part of this conduit includes when seeds fall during the change of seasons. This action ensures new life will emerge during the following the spring. Soon enough that spring will turn to autumn and deciduous trees lose their leaves. Small animals will forage and store food before hibernating for the winter. Raccoons and skunks, and all kinds of other forest animals will find old logs to live in during the long winter before reemerging. This pattern of succession happens in the forest and in many ways the forest is the ecosystem that all succession hopes to return to.



Each year, over 4 million animals are killed on roads and highways, many of which are the indigenous mammals that inhabit the deciduous forest. Cars and roads cause untold damage and death to forest dwellers who must now attempt to find food, mates, raise their young and find new homes navigating their lives in a fragmented system. Fragmentation of any ecosystem leads to its further decline.

Our biophilia teaching point is to walk through the woods as much as possible with great respect, to revisit the teachings of Native Americans, Muir and Thoreau and embed them in as many teaching and learning experiences possible. Recognize the deciduous forest ecosystem as someone's home where many wonderful creatures, great and small, carry on their evolutionary purposes.

7. *Rise and Return of the Apex Predator: Evolution and Diversity*

Predators and their evolutionary tails and trails in time point to a specialized group of animals that are highly skilled, well adapted, and complementary of the prey they pursue. Predators can take many forms. They can be deer preying upon plants, frogs preying upon insects, or robins preying upon worms. Most people look at predators in terms of the terrestrial mega fauna mammals such as bears, dogs, big cats and sometimes smaller animals like weasels. This mandala represents the terrestrial family of major land predators. The cat family is the most specialized, advanced and effective by design and behavior. But each group exhibits its own unique way of directing the flow of energy in ecosystems. Apex predators such as these are truly the managers and "lords" of ecosystem dynamics. They have evolved relationships, communication, life style, teeth, claws, stealth, senses, enzymes, physical power, walking behavior and "predator intelligence," during the course of their evolution over the past 40-60 million years.

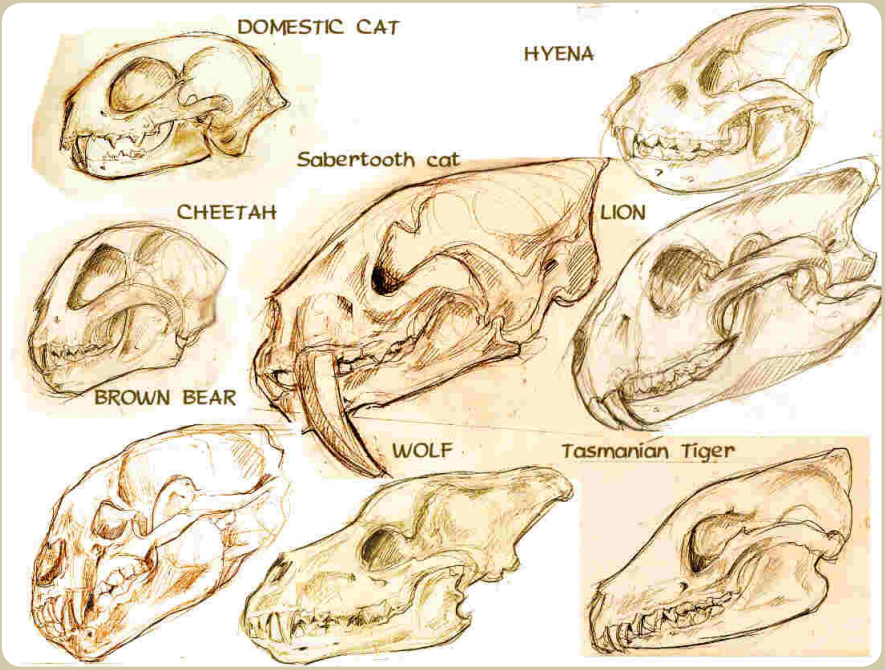
Cats are unique from the other carnivores as being a truly obligate carnivore group and the only terrestrial land animal with a precision killing bite. Twenty million years ago, one of the earliest forms of carnivorous mammals evolved— the miacids. The miacids gave rise to both sides of the carnivore tree— the earliest cat families and dog/bear families. The cat's great ancestor eventually separated into two distinctive groups: the neofelids and the paleofelids. Fossil evidence suggests parallel evolution regarding these two cat-like groups. About 20 million years ago a genus pseudaelurus gave rise to both modern cats and the well known smilodon fatalis, or saber-toothed cats. A variety of forms have come and gone, but both large and small cats of today exhibit an incredible orchestration of power, stealth, agility and intelligence.

Many of the apex predatory felines such as the cougar, panther, cheetah, jaguar, lynx, bobcat, tigers and lion are continually threatened by man. If these animals are killed, hunted or regulated to life in zoos and animal parks, they are not living for the purposes to which they evolved. This could result in dramatic shifts in prey populations and planetary health.

The ursids and mustelids, (bear and weasel families) branched off approximately 35 million years ago and evolved to become specialized for woodland and mountainous climates. The canids (dog family) developed to become lighter and more agile than bears. However, because of their limited physical power, they have evolved to work in groups, or packs. Others related to the canids include jackals, foxes, coyotes and hyenas. Wolves are the largest species and one of most well known in the canid family. They work in packs as small as two or as large as fifty.

This legendary predator is a rich figure among folklore legends and as a symbol of man's destructive nature.

Wolves once roamed over vast expanses of North America and Canada. Their only known enemy was man. Due to the colonization of North America, the gray wolf was almost driven to extinction. The debate regarding its status as "protected" continues while poachers, farmers and organized government culling practices kill thousands of wolves and cougars each year. Man does not have the complex interwoven relationship with these ecosystems that predators have developed, and this is contributing to the downfall of these predators. The grave effects of these actions are very clear—we should not tamper with evolutionary predation. We should not be asking how will we manage our ecosystems, but rather how will we manage ourselves.



8. *Wildflower Succession and Transformation*

Succession happens in all communities of life and it involves a changing of places in the ancient story of a habitat, with perhaps the happiest ending of all— a climax community. The climax community is like ecological Nirvana. It is the earth's spaces becoming whole again. And Succession might be looked upon as a set of characteristics that suit the climate best, but it is more than that. It is restoration to a healthy dynamic system where entropy is kept sufficiently low through cycles of tiny energetic interactions and growing networks and diverse partnerships. It is Nature achieving homeostasis. Succession is a pulsating of change that alters the conditions to reach a balance that restores to the highest level of function. Undaunted by human attempts to change the ecosystem's intention, plant and animal populations unfold and emerge to reach that state of greatest complexity. This amazing transformation can happen right before our eyes, as we are often the purveyors of the very imbalances the system wishes to correct.

In time our desire to control may be usurped by better and more efficient networking organisms that work with Nature instead of against it, like humans do. Can the wildflower succession that takes place in so many common areas become your symbol for freedom to seek what is just and true for all ecosystems and for all life forms? Just watch asphalt left unattended over the years. Without continual force needed to suppress the underlying natural rhythm of earth, cracks begin to form as the life of the planet slowly breaks through the stagnant, lifeless chemicals poured on top of it. The concrete is not part of the living processes of the earth and serves no useful purpose until it is broken down to its most basic molecules. Succession wins in the end because within succession are microhabitats, invisible and far too dynamic to be documented, that are at work weaving

complex webs of intricate interactions. This is often an impossible task for science to measure. Humans simply cannot measure every minute change found in rotting logs, abandoned birds nests, decaying leaves and the millions upon millions of small energy exchanges that occur all around us everyday.

These small successions contribute to the whole and then we see a field emerge, then a forest, a wetland, a reef, a deep sea world, which are all incredibly intricate, beautiful, and constantly changing complements of living energy. Wildflowers attract pollinators, pollinators attract each other— birds, amphibians, reptiles and mammals. The immense power of plants as an extension of earth's physiology is evident when you return to that neglected road to find that even the smallest and most delicate of plants has broken through to beckon the pollinators it evolved with.

This representation of succession, the wildflower, is in grave decline and disappearance due to rapid human construction and the use of pesticides, herbicides, and other biocides. This endangerment of such a beautiful natural phenomenon results in damage to the web of succession and is carried in biogeochemical cycles around the globe. Fueled by the need to control nature, over 78 million households in the United States use garden pesticides, equaling 90 million pounds per year. Many of the plants and flowers used to create this mandala would in fact be called "weeds" and the insects would be considered "pests". But by attempting to control nature and eradicate what humans deem unpleasant, such as weeds and pests, humans become more disconnected with nature and natural succession. One of our greatest challenges as humans is to overcome our intolerance of other life forms. What you can do? Plant organic fields of wildflowers where ever you can. Leave wasps nests and other insects alone. Instead, notice and observe them. Learn to draw them, see if you can capture a glimpse of their rapid wing movement or their interesting body armor. Help the ecological community of life spread the remarkable color and patterns of wildflowers by throwing wildflower seeds and blowing on a dandelion wherever there is a barren lawn. Succession will do the rest.

Mediations on Nature

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