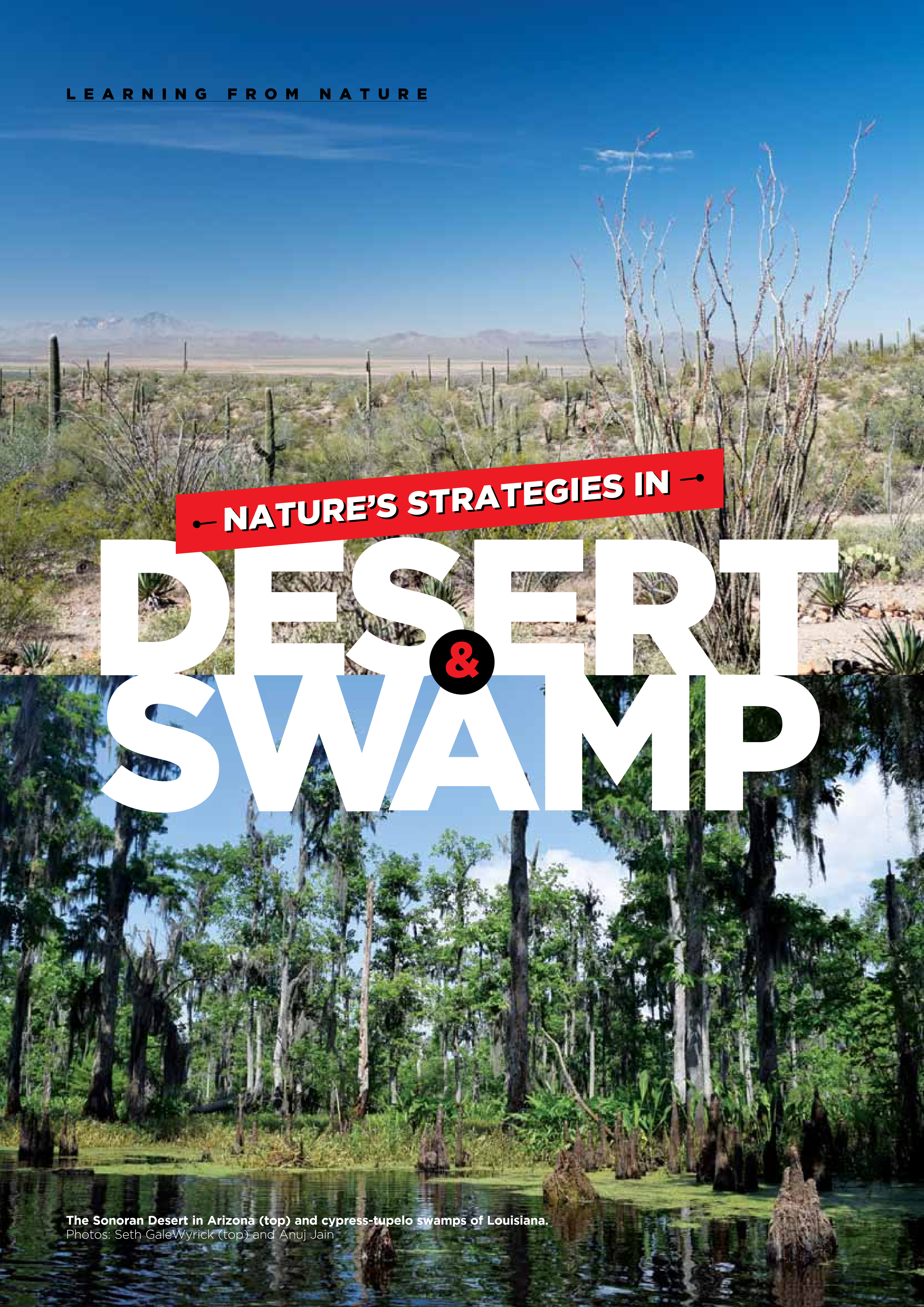
NATURE'S STRATEGIES IN DESERT & SWAMP



The Sonoran Desert in Arizona (top) and cypress-tupelo swamps of Louisiana.
Photos: Seth GaleWyrick (top) and Anuj Jain

In the first of a three-part series on learning from nature, **Anuj Jain** looks at how flora and fauna have adapted in the contrasting biomes of a swamp forest in Louisiana and a green desert of Sonoran in the US – adaptations which biomimicry practitioners might be able to use to find solutions to human problems.

Photos by **Anuj Jain**, **Seth GaleWyrick** and **Glenda Yenni**

What do a swamp forest and a desert have in common? Water! The abundance of it in the former and lack of in the latter. As a tropical biologist living in the lowlands and a degree north of the equator, my body is subconsciously tuned to the relative lack of abiotic changes – a cold day means 22°C, and a hot day 32°C. A dry month means a rainfall of 120mm. Wet months get as much as 250 to 320mm of rain. Life thrives in this sweet spot of temperature, rainfall, and elevation.

But I decided to step outside my comfort zone when I started an intense Biomimicry Professional certification course 1.5 years ago. Biomimicry is the practice of learning from and emulating or mimicking nature's time-tested strategies. It is about learning from the scales of butterfly wings to design biodegradable structural colours, adopting design principles of our rainforest trees and mangroves in tropical architecture, or understanding the ecosystem functioning of our natural habitats for ideas on circular economy and zero waste.

The course is administered online via the Arizona State University. In addition to the basic course, there are six week-long in-person sessions taught by a biomimicry consultancy – Biomimicry 3.8 in the USA. Each is spaced four to five months apart. The in-person sessions are designed such that we visit a different biome in each session and learn about the strategies through which life survives in that biome. In May 2016 we kayaked the cypress-tupelo swamps of Louisiana, and in March 2017, we trekked the Sonoran Desert in Arizona in time for the spring blooms, to learn and be amazed by how flora and fauna survive in these biomes.

SWAMPS OF LOUISIANA

The cypress-tupelo swamps of Louisiana sit at the Mississippi River Delta where the Mississippi River meets the Gulf of Mexico. This tapestry of forests, swamps, marshes, river channels, estuaries, and islands form a productive wetland ecosystem, particularly for neotropical migratory birds. The area also supports the largest mainland fisheries industry of the USA (second only to Alaska). But these habitats are in danger.

Louisiana is losing about one football field of land to open water every hour. Since the 1930s, nearly 5,000km^2 of land area has disappeared due to a variety of reasons, but most importantly due to dams upriver that trap sediment from Mississippi and Ohio rivers. These dams reduce the sediments in the Mississippi River by more than 70 per cent by the time it reaches Louisiana. Oil rigs that operate in the landscape also modify the coastal hydrology which accelerates erosion of the existing land.

As we set foot in the swamps of Louisiana, the presence of two dominant tree species made it obvious how the cypress-tupelo swamps got their name. Both of these trees – the Bald cypress (*Taxodium distichum*) and the Water Tupelo (*Nyssa aquatica*) – are adapted to a wet life by having swollen bases, knee roots and with up to 60 per cent of the stem and root tissue having air spaces that allow for greater gas exchange in an anaerobic environment. The permanently waterlogged soils in these swamps are relatively poor in oxygen and structurally loose which make it hard for plants to stay upright.

A fishing spider (*Dolomedes* sp.) carrying her egg sac on the water surface covered with duckweed in the swamp forest of Louisiana.
Photo: Anuj Jain

Despite the wet conditions, the swamp is rich with wildlife including alligators, rattlesnakes, turtles, beavers, otters and muskrats. The non-native and invasive Nutria (or Coypu, *Myocastor coypus*), a large semi-aquatic rodent that was introduced from South America for the fur trade, also abounds. Birds such as the Marsh Hawk (or Northern Harrier, *Circus cyaneus*) and many invertebrates such as clams, snails, shrimps, crawfish and insects make this a productive ecosystem.

Many of the swamp trees we saw were covered with Spanish moss (*Tillandsia usneoides*) giving the trees a ghostly appearance. Spanish moss is native to that region but is not a moss at all. It is an epiphytic bromeliad that does not damage the host and is, in fact, used by many animals. Birds use it as nesting material whereas bats, reptiles and amphibians use it for shelter.

Animals on the wet ground are not so lucky! They have to use more advanced strategies to protect sensitive resources from water. From my kayak, I observed a fishing spider (*Dolomedes* sp.) gently moving a few millimetres above the surface of water. She was carrying her egg-sac that was lined with duckweed to protect the eggs from water. Later, I read that some spiders in these swamps can even tolerate flooded conditions by going into a coma. Such spiders literally switch their metabolism from aerobic to anaerobic when oxygen is in short supply and then return to life when normal conditions return.

A fascinating aspect of the geology of Louisiana is that one hardly ever sees rocks. The Mississippi River has deposited more than a kilometre-thick sediment of sand, silt, clay and organic material on the rocky layer over millions of years, so one is unlikely to ever encounter rocks on the surface. Never thought I would have to search so hard for rocks on land!

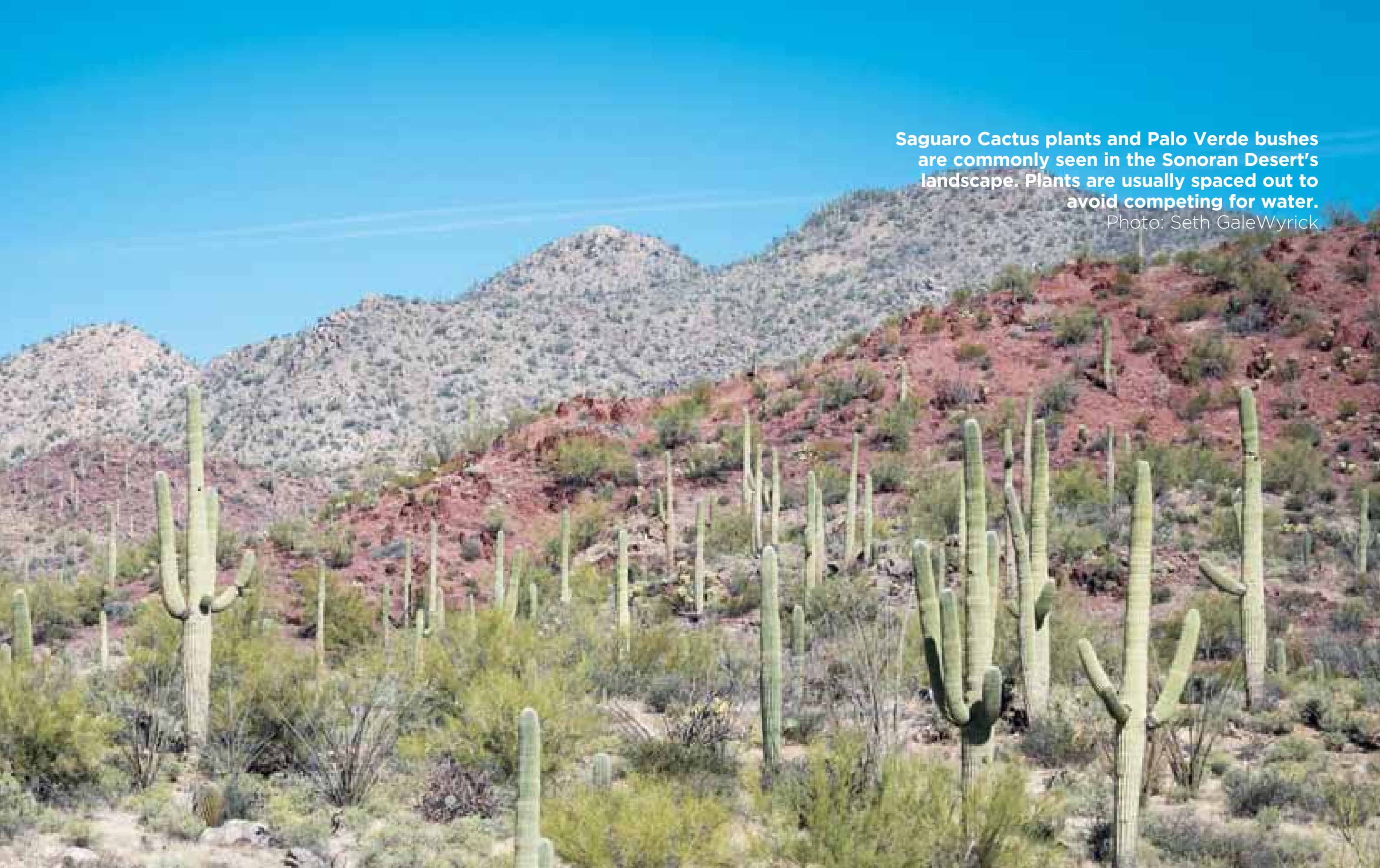
That night, over dinner at a local restaurant, I learnt that clam shells were traditionally used as construction material for lack of rocks in Louisiana. Food for thought. How might one design the built environment in swampy habitat to be locally attuned?

My days in the cypress-tupelo swamps brought memories of mangroves and tropical swamp forests that we are familiar with in Southeast Asia. I could not help but be reminded that these habitats in Louisiana and Southeast Asia do not just share similar conditions but also similar rates of habitat loss. A reminder of how quickly we are losing these rich and diverse ecosystems!

Spanish moss growing on a cypress tree in the swamp forest of Louisiana gives the tree a ghostly appearance. Photo: Anuj Jain

THE SONORAN DESERT

The green desert of the Sonoran Arizona is a complete contrast to waterlogged Louisiana. The Sonoran Desert is a harsh ecosystem exposing the flora and fauna to chronic acidity and periodic, extreme droughts. Our naturalist and biomimicry practitioner Heidi Fischer, says that the desert is a frugal innovator – creating abundance from scarcity. In her soon-to-be published book on biomimicry strategies from the Sonoran Desert, she hypothesises that cooperation increases in stressful environments. The result is the most diverse desert ecosystem in the world with 2,500 plant species, 350 bird species, 60 mammals – of which 15 heteromyid species (rodent relatives) are unrelated to other North American species – and more than 1,000 bee species.



Saguaro Cactus plants and Palo Verde bushes are commonly seen in the Sonoran Desert's landscape. Plants are usually spaced out to avoid competing for water.
Photo: Seth GaleWyrick

The Sonoran Desert is the wettest of the four deserts in the USA, which include the Chihuahuan, Great Basin and Mojave. We were in the wettest part of the Sonoran – the Oracle and Tucson area which receives higher rainfall than other parts of the Sonoran and is greener (hence called a green desert). Another characteristic of the Sonoran is the formation of sky islands – forested mountain "islands" surrounded by a "sea" of desert.

The sky islands are cooler and receive higher rainfall (300 to 550mm annually) which supports Mexican oak-pine woodlands on the mountain tops. Suitable microclimates make sky islands hotspots of biodiversity in a desert. In fact, Mount Kilimanjaro in Africa is also a sky island in a sea of desert grassland. In the Sonoran Desert, the drier rain shadow areas in the basin are dominated by desert plants such as the columnar or Saguaro Cactus (*Carnegiea gigantea*) – an Arizona state symbol – and others like the Cholla Cactus (*Cylindropuntia fulgida*), Prickly Pear Cactus (*Opuntia* sp.), and legumes like the Palo Verde (*Parkinsonia florida*). In contrast to swamp forests, the plants in the Sonoran Desert are spaced out to avoid competing for ground water.

Our days in the desert were set up such that early on, each of the cohort members shared their research about the biotic and abiotic conditions and the flora and fauna adaptations in this biome. Such an exercise is called a "genius of biome" exploration.

What strategies do desert plants use for survival in a hot and dry climate? We learned that the desert plants

A Prickly Pear Cactus eaten by a Javelina, despite the thorns.
Photo: Anuj Jain

have evolved three ingenious survival strategies – succulence, drought tolerance or drought evasion.

Succulents have a nearly 10-times more water efficient mechanism of photosynthesis called CAM (Crassulacean Acid Metabolism). CAM plants open their stomata for gas exchange at night and store carbon dioxide in the form of an organic acid. During the day, the stomata are closed and the plants are nearly completely sealed against water loss and photosynthesise using the stored carbon dioxide. The trade-off is that CAM photosynthesis is slower than standard photosynthesis, so CAM plants grow more slowly. Perhaps human water retention systems in the desert should function like succulents by actively operating at night?

It is not just the leaf function (CAM photosynthesis) but also the skin and leaf shapes that are adapted to hot and dry climate. Waxy coverings on the cuticles of the stems and leaves (thorns are modified leaves) of succulents help reduce water loss. The thorns also protect the plant from predators so they do not chew up the stems full of water, a scarce and valuable resource. However, the protection did not appear to be foolproof. We observed a Javelina (*Tayassu tajacu*), a wild boar-like animal, chew through the thorns and eat a Prickly Pear Cactus.

Succulents like the long-lived Saguaro Cactus have ribs that can expand and contract depending on the water availability. Similarly, the Cholla Cactus has holes in the stem that allow space for physical expansion and contraction. These were only revealed to us in a dead stem once the cuticle was lost. During biannual rains (summer and winter) in the Sonoran which tend to be light and brief, the Saguaro and Cholla cacti can absorb large quantities of water in a few hours of rainfall and swell up by storing water that can last through the hot summer. Perhaps there are uses for flexible water storage materials.

Another vital lesson from nature is of cooperation. Cooperation is abundant in nature during times of scarcity. The bushy Palo Verde legume acts as

Holes (as illustrated by the dead stem of this Cholla Cactus) allow space for physical expansion and contraction in desert plants. Living Cholla Cactus plants can be seen in the background. Photo: Anuj Jain

The Gila Woodpecker (*Melanerpes uropygialis*) often creates cavities in the Saguaro Cactus. A House Sparrow (*Passer domesticus*; pictured) is often a secondary user of the cactus cavity in the Sonoran Desert. Photo: Seth GaleWyrick

Many flowering plants were seen in full bloom in vibrant colours during springtime in the Sonoran Desert.
Photo: Seth GaleWyrick

Ruby throated Hummingbird incubating her eggs in the nest just outside our hut in Oracle, Arizona.
Photo: Seth GaleWyrick

Great Purple Hairstreak butterfly feeding on the spring blooms of the Fairy Duster nectar plant in Sonoran Desert.
Photo: Anuj Jain

the primary nurse plant for the Saguaro Cactus by fixing nitrogen (the backbone of photosynthesis) in the soil and creating a suitable micro-climate. The Palo Verde also shields hot and cold winds with its branching bark around which a slow-growing baby Saguaro Cactus often finds safe haven.

Another survival strategy of desert plants is drought tolerance. Plants such as the Brittlebush (*Encelia farinosa*) have the ability to withstand desiccation. That is, they are drought tolerant. They appear to be dead or dying during the dry season entering a state of dormancy. They come to life with the rains. We observed them in full bloom during our spring visit. Other annuals such as the Fairy Duster (*Calliandra eriophylla*) and Ocotillo (*Fouquieria splendens*) were also flowering, attracting butterflies such as the Pipevine Swallowtail (*Battus philenor*), American Snout (*Libytheana carinenta*) and Great Purple Hairstreak (*Atlides halesus*). To our delight, we also saw a Ruby-throated Hummingbird (*Archilochus colubris*) incubating her eggs in the nest just outside our hut.

One of the most spectacular desert adaptations is that of the drought evaders because these plants do not exist during the dry season. They complete their life cycles during brief wet seasons, then die after channeling all of their life energy to produce seeds. The seeds get buried in the desert soils that literally act like a granary. Blooms of drought evaders are rare events that are triggered by specific environmental clues. But when they do, the desert floor gets covered with carpets of wildflowers.

How do animals survive these harsh climates where food appears to be so scarce? This question used to linger in my mind whenever I saw photos of deserts. Thousands of seeds can be found in every square metre of desert soil which support numerous rodents that are adapted to desert life. The Kangaroo Rat (*Dipodomys* sp.) has cheek pouches to store seeds which it uses for the rest of the year. It also has several other adaptations to minimise water loss such as nocturnal lifestyles, production of "metabolic water" with the help of its high-carbohydrate diet, and fur on its body that prevents evaporative water loss from its skin. It also has long and convoluted air passages that cool the air which condenses on the mucous membrane of its nose. The Kangaroo Rat also has specialised kidneys that produce a paste-like urine (most hypertonic known among animals) and dry fecal pellets. Who thought we might learn a thing or two from rats?

A few days later, I also had a chance to camp at the Death Valley National Park in the Mojave Desert – the hottest place on the planet (56.7°C) and the lowest point (86m below sea level) in North America. The Death Valley only receives an average annual rainfall of 60mm. Speaking of temperature and rainfall variations, that's quite a difference from the tropics!

The Kangaroo Rat has many adaptations to living in the desert environment.
Photo: Glenda Yenni

The Kangaroo Rat has cheek pouches to store seeds which it uses for the rest of the year. It also has long and convoluted air passages that cool the air which condenses on the mucous membrane of its nose.

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