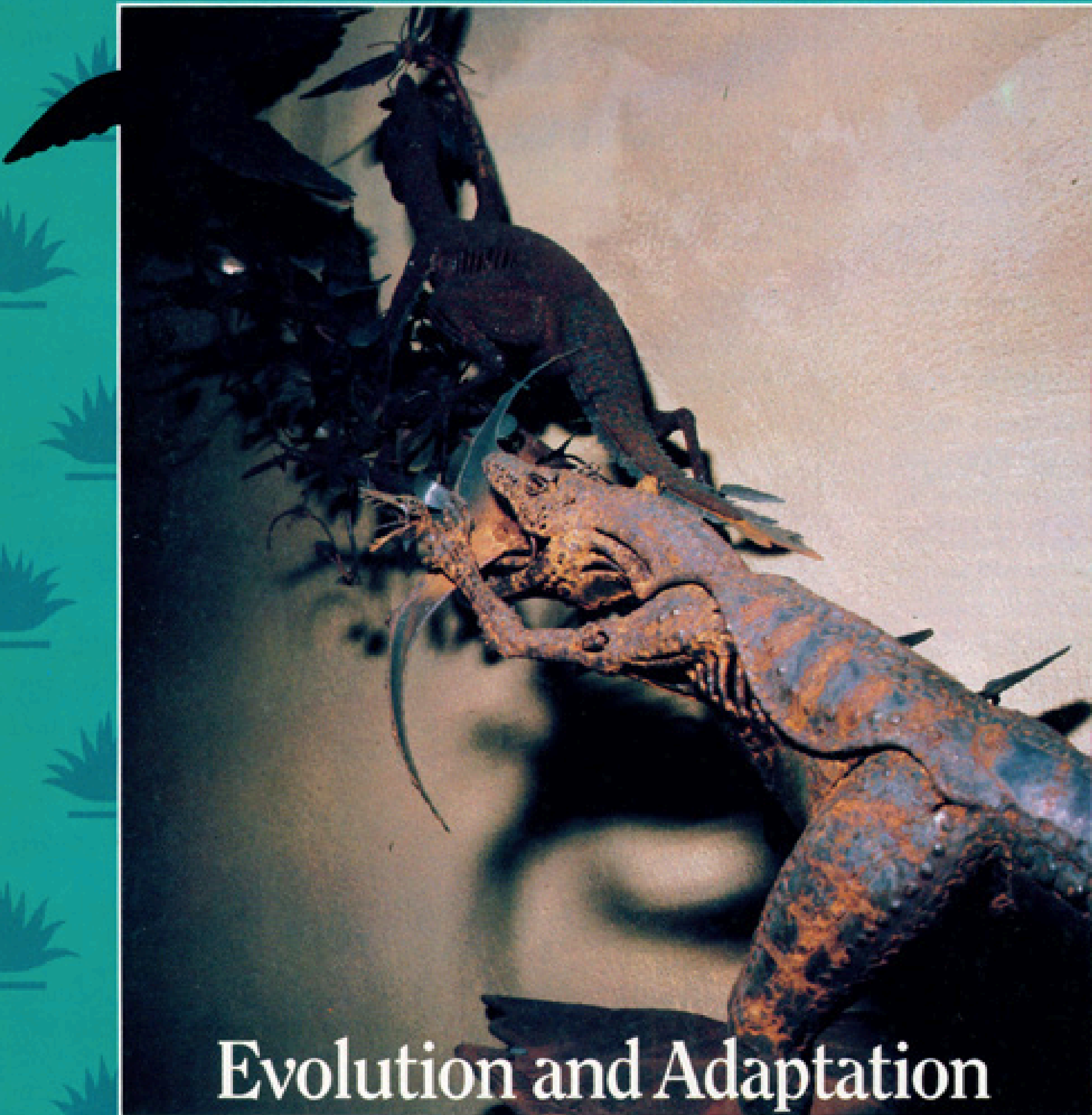
Arizona-Sonora Desert Museum Newsletter Fall, 1987

sonorensis



Evolution and Adaptation

sonorensis

ARIZONA-SONORA DESERT MUSEUM
NEWSLETTER • VOL. 8, NO. 3 • FALL 1987

The Arizona-Sonora Desert Museum
Co-Founded in 1952 by
Arthur N. Pack and William H. Carr

sonorensis is the Latin, scientific term indicating the species classification of many plants and animals of the Sonoran Desert region.

Special thanks to Tom Vandevender

Cover photo by Ann Simmons Meyers

Oops! we goofed . . .

The photograph on page five of the Endangered Species issue, labeled desert tortoise, is instead, a gopher tortoise.

Foundation's Directors Club off to excellent start

Last summer the ASDM Board of Trustees authorized the formation of the Foundation for the Arizona-Sonora Desert Museum, a separate, not-for-profit foundation to serve the long-term needs of the museum. The Trustees have charged the Foundation with the missions of raising endowment donations, donations for capital projects as determined by the Trustees, and other special projects which from time to time will benefit the ASDM. One of the most exciting aspects of the new foundation is the Directors Club, a group of special donors to the Desert Museum. We are delighted to list the following *Pioneer Members* of the Directors Club:

Caroline Bruhn
Mr. and Mrs. William Carpenter
Mr. and Mrs. Albert H. Cohn
Mr. and Mrs. David D. Cohn
Dick and Mary Rose Duffield
Kristie Graham
Rukin and Carolyn Jelks
Jack and Fay Ryan
Curtis Scaife
William C. Scott
Henry J. Stringer III
Priscilla G. Timken
Mrs. Arthur N. Pack
Robert T. Wilson Foundation

All ASDM members will soon be receiving information about how they may become part of the Foundation and the Directors Club. If you are interested in details before that time, please contact ASDM Development/Public Affairs Officer Christopher Helms at 883-1380, or write to him at the following address for information: The Foundation for the ASDM, 2021 N. Kinney Road, Tucson, Arizona 85743, ATT'N: Christopher Helms.

Hughes makes generous contribution

We are grateful to Tucson's Hughes Aircraft Company for its recent $9,000 contribution to the museum for planning funds for the next major animal habitat project and for unrestricted operating funding for 1987–88. The continued support of Hughes Aircraft Company is very much appreciated.

For Planning Ahead . . .

Mineral Mysteries Solved — a Workshop
Saturday, January 30

Nature Drawing at the Museum
February 27 — March 19

Santa Rita Minerals Sojourn — a One Day Collecting Trip
Saturday, March 19

Tucson Mountain Wildflower Walks
March 23, 26, or 27

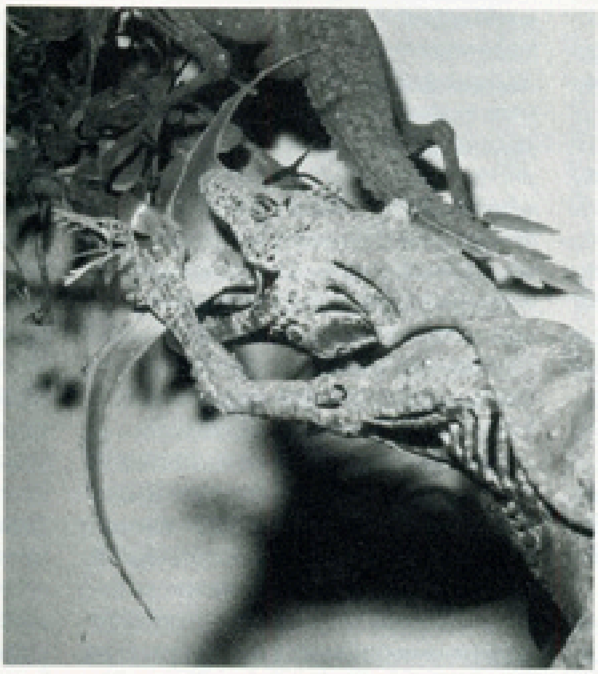
Spring Gem, Mineral and Plant Sale
April 9 and 10

Midriff Islands — Sea of Cortez
April 16–24 or April 24–May 2

Bisbee Mineral Tour — The Echoes of Cousin Jack
May 13–15

As a living museum ASDM interprets the life and land of the Sonoran Desert region through a combination of botanical, zoological, and geological exhibits. The Congdon Earth Sciences Center tells the story of the evolution of the earth's beginning, tracing not only the development of the earth and the Sonoran Desert region, but also the evolution of life itself through time periods measured in billions of years.

The exploration of "this view of life," Darwin's own term for his evolutionary world, is illustrated in the following text by ASDM's curatorial and research staff. This evolutionary perspective is the common thread sewn through the disciplines of natural history that underpin the museum's central function — to describe the "why," and the "how" of the region's plants, animals and geology, and the causal relationships that bind them together.



Curator of Small Animals, Howard Lawler states: "In looking at the world around us, it is evident that living organisms are a product of their environment. All have evolved interdependently with other organisms and the physical habitats in which they live. Adaptive change through natural selection cannot be viewed simply in the past tense. It is fundamental to the dynamic process of evolutionary creation."

The mechanisms of evolution discussed in this issue: adaptation, convergence, natural selection, the nature of the geological record with its "rarity of transitional forms," and the paleoecological lessons of time and change that point to the paradox of the evolution of the modern Sonoran Desert, all illustrate the "plurality of results that nature's complexity provides."

— Editor

Evolutionary Theory and its Advent

by Curator of Plants Mark Dimmitt

This issue of *sonorensis* celebrates the most fundamental principle of the biological sciences — evolution. Every science has a unifying concept that makes the discipline cohesive and comprehensible. In physics it's unification theory, in terrestrial geology it's the theory of plate tectonics. Without evolution, it is impossible to understand biology, the subject becomes only a huge body of unrelated facts. Yet 130 years after the first testable theory of evolution was published, it is still very poorly understood by most non-biologists.

Evolution is simply genetic change in populations of organisms through time. A corollary concept is that similar species are descended from common ancestors, and by extrapolation, most if not all life forms on the planet have a common origin in the distant past.

Evolution requires vast amounts of time, which is why the idea did not catch on until a little over a century ago. Until the early 1800s, most educated people accepted the religious doctrine expounded by biblical scholars that the earth was about 6,000 years old. Most notable of these was Bishop Ussher, who calculated an *exact* date of creation of 4004 B.C. At about that time (1800, not 4004 B.C.) early geologists, who had recently evolved from engineers and clerical scholars, were making some earth-shaking (or at least dogma-shaking) discoveries.

In the early 1880s William Smith, an English civil engineer mapping rocks for mines, roads, etc., and Georges Cuvier and Alexandre Brongniart of France observed that the lowest strata in a series contained the oldest fossils, and determined that fossil-bearing rocks could be aged relative to other such rocks by the types of fossils they contained.

Meanwhile, other geologists were beginning to measure erosion and sedimentation rates. Using this new concept of *uniformitarianism*, which holds that the processes that are observed today have always occurred, and at the same rate, they calculated how long it would take to form the landscapes they observed. These calculations led James Hutton (also championed by his more eloquent successor Charles Lyell, friend and consultant to Darwin) to propose that the earth was unimaginably old. In those days that meant twenty or thirty million years.

At this point things became rather sticky. Hutton had placed the earth's origin beyond the domain of what science could consider, or in a stranger claim, had denied that a point of origin could be inferred at all. These scientific findings were in direct conflict with church doctrine which had established a 6,000 year-old earth. Anyone who proposed otherwise became an enemy of the church, any departure from orthodoxy "was equated with social anarchy and saddled with the most serious indictment of all — atheism and impiety." Or, as Charles Lyell wrote (in *Principles of Geology, 1830*) ". . . although charges of infidelity and atheism must always be odious, they were injurious in the extreme at that moment of political excitement." A bitter battle quickly developed which has not yet completely subsided. It was a deja-vu experience for science; the same thing had happened a few centuries earlier when Copernicus and then Galileo dared to point out that the earth was not the immovable center of the universe, another biblical heresy which has finally been resolved.

Reason prevailed (at least in science), and development of the geologic time chart proceeded as a natural consequence of Smith and Cuvier's work. By the mid 1800's the time scale we use today was essentially complete, although it would be more than fifty years before it could be proved by radiometric dating. The important fact pertaining to our essay on evolution is that Charles Darwin was delving into his natural history studies during a time of great scientific (r)evolution.

Charles Darwin, contrary to common assumption, did not invent the concept of evolution. The idea had been around for quite some time; several scholars in the generation preceding him had studied the natural world and proposed that living things had changed. But none of these others could come up with a mechanism to cause the changes. Darwin's contribution was a plausible and eventually testable theory of cause — natural selection.

When Darwin returned from his five year voyage aboard the *Beagle*, in 1836, he had amassed a huge volume of data, but no concept of evolution. He had collected according to his creationist perspective: often taking only a male and female specimen of each animal, which was all that was necessary if species were immutable. He did return with a commitment to become a naturalist.

Several months after his return, when his multitude of specimens had been identified by the leading zoologists of the day, the real significance of his collections became evident to him. The fact that most of the specimens collected in the Galapagos Islands were unique species but were closely related to forms on the adjacent mainland, along with similar findings from his other collecting stops around the world, caused him to begin to doubt the fixity of species. Why, for instance, would a creator populate Australia with so many marsupials, when this type of mammal is so rare in the rest of the world? Within a year after the end of the *Beagle* voyage, Darwin had accepted the concept of evolution espoused by some of his colleagues, and began to search for a cause.

He used the ideas of many other scholars in working out a theory. Darwin stated that half his work came out of Lyell's brain. Quoting Stephen Jay Gould's analysis, Darwin transferred to biology Lyell's argument that "a historical scientist must work with observable, gradual, small-scale changes and extrapolate their effects through immense time to encompass the grand phenomena of history." Darwin also gained insight from Malthus' essay on economics, which postulated that human populations' potential for increase exceeded its capacity to increase food production, thus creating a "struggle for existence."

Using the above and other scholarly works plus his own considerable intellect, Darwin developed the theory of natural selection as an explanation of how evolution operates. His reasoning went as follows: (1) Fact: All living organisms have a nearly unlimited capacity to increase in numbers. (2) Fact: Yet most species tend to maintain about the same population levels over long periods of time. (3) Conclusion: Therefore there must be a struggle among individuals for reproductive success. Reasoning futher: (4) Fact: Individuals of a species vary from one another in structure, physiology, and behavior. (5) Fact: These differences tend to be inheritable and are passed on to the offspring. (6) Hypothesis: Some of these variations have greater fitness than others (they are better adapted to the environment). (7) Conclusion: In the struggle for survival, the fittest individuals contribute the most offspring to the next generation; thus a species gradually changes through time as the proportion of better adapted organisms in the population increases. (8) Grand Conclusion: Given the vast expanse of time indicated by geology, the great diversity of life forms could have evolved from a common ancestor, as is indicated by the continuity of variations throughout the living world.

That evolution and the theory of natural selection was an idea whose time had come is supported by the fact that someone else had developed a very similar theory at the same time. Alfred Russel Wallace, a naturalist working in the East Indies (he knew nothing of Darwin's work as it had not been published) was eventually instrumental in getting Darwin's work into print.

Reluctant to publish his theory, Darwin fully realized how controversial it would be. He initiated a massive, tedious project of gathering as much data as he could to corroborate his theory, planning a four-volume treatise. He may never have finished this work, except that in 1858 he received a letter from Wallace asking his opinion on a theory that Wallace had developed on how organisms evolved, a theory very similar to Darwin's. This galvanized Darwin into action. Being an honorable man, he saw to it that both papers were read at the Linnean Society later that year, giving both men credit for the theory. Then Darwin began to condense his major work, and published *On The Origin of Species* in 1859. So eloquent was his reasoning, and so thorough his documentation, that within a few years most of the scientific community embraced evolution *and* the Darwin/Wallace theory of natural selection, despite the raging religious controversy.

It is necessary to distinguish among conjecture, theory, fact, and natural law. In science fact is something which is *demonstrably* true; something which can be verified as real. A natural law is more than a fact; it is a fact which has been verified *repeatedly*, despite calculated attempts to disprove it. It is probably as close to absolute truth as humans can come. The Laws of Thermodynamics are familiar examples; every attempt to disprove them has further supported their veracity.

A scientific theory is not law, but it is more than conjecture. A theory is a *working explanation of an observed phenomenon that is consistent with the known facts* at a given time. A theory is also a challenge to other scientists to attempt to disprove it, which creates, in turn, the "crucial attitude of doubt — midwife of all creativity." As more facts become known and the theory is repeatedly tested, it is abandoned if disproved, or refined if only minor inconsistencies become apparent. Refinement continues until a theory is generally accepted as correct because it thoroughly explains the phenomenon, and all attempts to disprove it failed. In the physical sciences, theories can be positively proved, and become nearly the same as *natural laws*. Because biology is a very dynamic and complex field, it is virtually impossible to prove a theory beyond all doubt; hence we have no *laws* of biology. Some theories, however, are so consistent with such a huge body of facts that they are regarded to be as solid as any scientific truth can be.

Now to distinguish between the fact and theory of evolution. Evolution itself is a nearly incontrovertible fact. No competent biologist doubts that evolution occurs; it is as well proved as the existence of gravity or that the earth revolves around the sun. When scientists discuss the theory (more correctly, theories) of evolution, they are talking about mechanisms — how it occurs, not whether.

One problem that troubled Darwin was that he could not explain a mechanism for the variability of traits and their heritability; the science of genetics did not exist. If he had owned a computer and had access to biological abstracts, he would have found that a monk named Gregor Mendel had worked out the basic principles of genetics and published his results in 1865. But it was in such an obscure journal that the work remained undiscovered until 1903, after Darwin's death.

Genetics has provided us with an explanation of how natural selection, and therefore evolution, operates. We know now that traits are inherited through little packets of DNA called genes. Most organisms have thousands of them, in duplicate. In the process of sexual reproduction half of each parent's set of genes is passed on to the offspring. This recombination of genetic material is why progeny are never exactly like their parents, or each other unless they are identical twins: they inherit only half of each parent's genes. And not all genes express themselves; some are dominant, some recessive. Further variability is created by occasional mutations within genes.

Evolution can be summarized as a two-step process, as explained by Ernst Mayr, one of the deans among 20th century evolutionists (see Scientific American, September 1978): The first step is the production of variability through recombination and mutation. This variability is random; it is unrelated to the needs of the organism or the nature of its environment. The second step is selection, and this is not random. Organisms with combinations of traits which are more advantageous to their possessors in a given environment are more fit and have more offspring than less fit individuals. Therefore superior traits increase in frequency in future generations, and the population as a whole becomes better adapted. This is evolution. ■

Fossils — the Key to Evolution

by Curator of Earth Sciences Dave Thayer

Coelacanth, a direct ancestor of amphibians and higher vertebrates

"I could get along very well if it were not for those geologists. I hear the clink of their hammers at the end of every bible verse." *John Ruskin, 1851*

Archaeopteryx

Fossils are the remains or traces of ancient life. They include tracks and trails, coal, shells, bones, petrified wood, insects in amber, and plants in packrat middens. Give paleontologists a rock hammer, a canteen, and a couple of hours, and they will find and collect fossils just about anywhere on earth. It's not that fossils are so easily made. The key is the enormous number of individual plants and animals that the earth produces combined with the vast span of geologic time.

Your chances of becoming a fossil are exceedingly slim. The pharaohs figured it out — one's body must be protected from oxygen and buried soon after death in a place where worms and weather cannot intrude. The place must be free from decomposing organisms such as fungi and bacteria.

Considering those requirements, it seems a wonder that any creature is fossilized. Yet rapid burial can by itself meet most of the criteria. In river deltas and on lake bottoms, on continental shelves and coastal mud flats, sedimentation proceeds rapidly enough to do the job. Hard parts of an animal are most likely to be preserved. Bones, teeth, and shells might last a long time unchanged, and even longer if they are replaced by minerals, as in petrified wood.

Fossilization is also promoted by desiccation, entombment in the ash of an erupting volcano, or burial in peat bogs, stagnant waters, or other oxygen-free environments. None of these methods is very common in nature. The great majority of living things leave no trace of their lives. Despite their relative scarcity, fossils are essential to the study of evolution. Without them, scientists would be confined to short-term breeding experiments and genetic studies in order to unravel the history of life. Fossils give us the empirical evidence, they are the signs of evolutionary history.

Dating Fossils

In 1669, Nicolaus Steno, a Danish physician who lived in Florence, gave us the Law of Superposition: that all layers of sedimentary rocks were formed in sequence, with those at the bottom being the oldest. In the early years of the nineteenth century, Smith, Cuvier, and Brongniart simultaneously appended the Principal of Faunal Succession: that assemblages of fossils uniquely characterize the strata, and the oldest assemblage is found in the lowest stratum. But no one was ready to hypothesize a truly ancient Earth until James Hutton introduced his "doctrine of uniformitarianism" 1785.

Charles Lyell, friend and mentor of Charles Darwin, took the baton from the less eloquent Hutton and championed uniformitarianism in his great book *Principles of Geology*, first published in 1830. Uniformitarianism, simply stated, is the doctrine of a dynamic Earth where change proceeds at such a slow, uniform rate that we can't see the effects in our short lives. Thus, Earth, must be incredibly ancient. It was this doctrine that gave Darwin what he needed for his theory of evolution: plenty of time.

As geologists in England and elsewhere studied the rock strata, they developed a geologic time chart with designations for each of the eras, periods, and epochs of time. The designations are still used. Some are shown on the charts on the next page. But no one guessed the true enormity of geologic time until, in the early 1900s, Yale physicist Bertram Boltwood first dated rocks by their natural radioactive decay. Evolution's time clock was found ticking away inside rocks containing radioactive isotopes of such elements as uranium, rubidium, potassium, and carbon.

Using sophisticated instruments such as the tandem linear accelerator at the University of Arizona, geophysicists are assembling a complete chronology of Earth's history including dates of staggering magnitudes — over three and a half billion years since the origin of life. Now Darwin really has enough time for natural selection.

Missing Links

Darwin recognized the rarity of speciation in the fossil record. There is little tangible evidence for the development of any new species from its predecessors. He attributed this lack to an "extremely imperfect" geological record. The fortuitous and timely *Archaeopteryx* was discovered in 1861 just two years after the *Origin of Species* was published. *Archaeopteryx*, literally "ancient wing" and essentially a dinosaur with wings, was a perfect "missing link" between the reptiles and the birds. The fossil added insult to injury, practically confirming Darwin's theory in itself. In concept, there should be a missing link for every known species: an organism to be found at the node of every branch. Yet, except for *Archaeopteryx* and a few rare others, missing links are missing indeed.

Certainly the fossil record is incomplete. Most potential fossils rot away and their hard parts are eroded, scattered, and pulverized. Selective destruction of

"The mind seemed to grow giddy by looking so far into the abyss of time." *John Playfair, 1805*

organisms' last remains probably accounts for 98% of all species, leaving fossil records for only 2% of all living things. These scant records are usually incomplete fragments, hard parts only. Even the hard parts are biased — we find more thick, sturdy fossils than fragile ones making organisms with sturdy parts seem relatively more abundant than they actually were.

Finally, fossils can be preserved but never discovered. The great bulk of sedimentary rocks lies buried and out of sight. Suitable outcrops of fossiliferous rocks are uncommon. Rocks may erode before anyone even examines them. The Desert Museum geology collections include a mammoth tusk fragment that was found protruding from a mud bank of Avra Valley within sight of the museum. The fragment was very fragile and crumbly, and had to be impregnated with glue to stabilize it for collecting. Much of it had already washed away. One more good summer rain and the tusk would have been gone forever, after about twenty thousand years of preservation. Even organisms that are fossilized can be destroyed after lying undisturbed for thousands or millions of years.

For all the above reasons, the fossil record is very incomplete. But even so, more missing links should have been preserved than actually were. On December 18, 1912, Charles Dawson and Arthur Smith Woodward announced to the Geological Society of London, and the world, the discovery of the remains of an early human fossil, *Eoanthropus dawsoni*. Found in a shallow gravel pit near the village of Piltdown in the County of Sussex, it became known as: Sussex Man, Dawn Man, and then Piltdown Man, the name that stuck. In an age when the British Empire was still expansive, and when the antiquity of human evolution was still a fresh idea, the find appeared to confirm British primacy, as Gould states "great scientists are embedded in their cultures, not divorced from them." Older than anything the French or Germans or anyone else had yet dredged up, Piltdown Man became widely regarded as the earliest known human fossil.

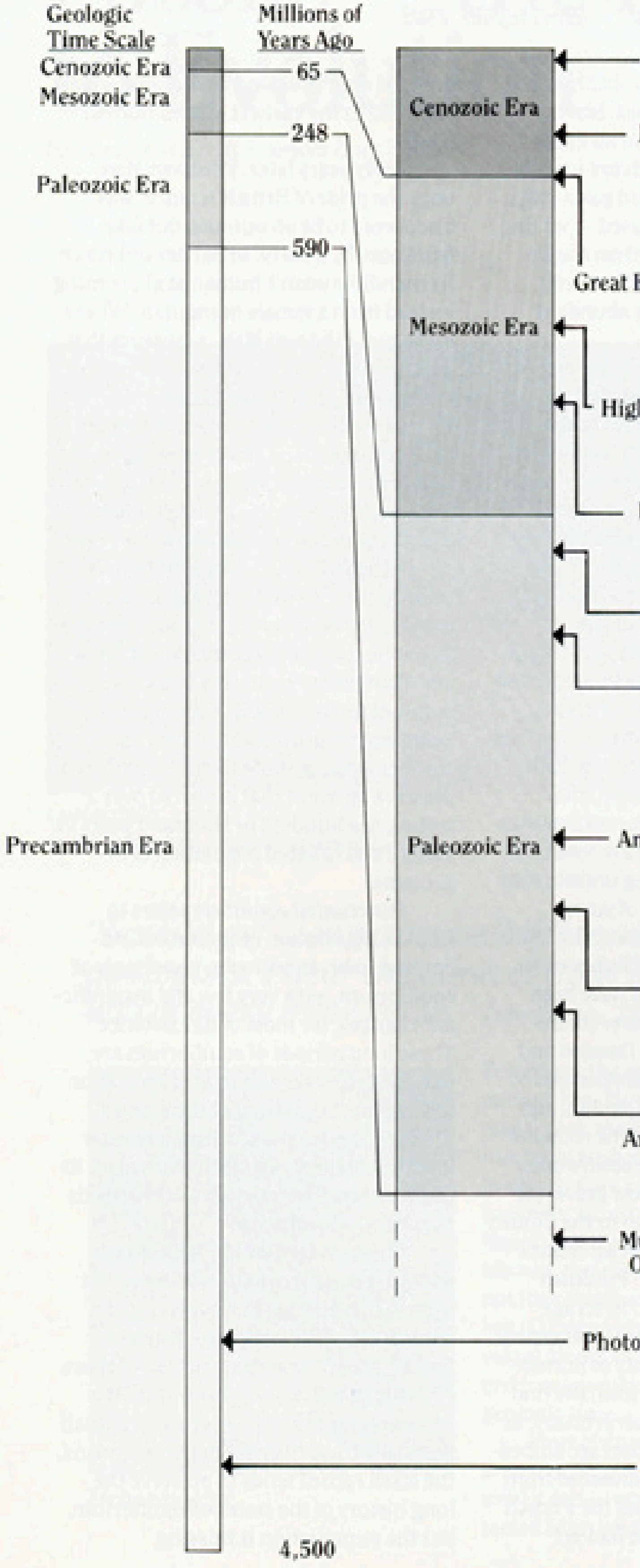
Forty years later, Piltdown Man, once the pride of British science, was discovered to be an out-and-out fake, fabricated by a party, or parties unknown. Its mandible wasn't human at all, coming instead from a female orangutan. Where is the *real* Piltdown Man, a creature that we haven't found, but must have existed at the junction between ape and human?

In modern times, new hypotheses have attempted to explain missing links. One of these is getting special attention from evolutionary theorists: Stephen Gould's *punctuated equilibria*, for example. In the 1970s, Gould and others developed the idea that missing links are missing for two reasons: because changes from one species to another are sudden and changes are restricted to a small segment or population of a species. Sedimentary processes are slow and cumbersome, and they would simply not preserve an event that occurred over a trifling few hundred or thousand years in a small and isolated population of organisms.

Punctuated equilibria refers to Gould's description of speciation. According to his hypothesis, a species is at equilibrium, with very few and insignificant changes, for most of its existence. These long periods of equilibrium are punctuated by rapid bursts of speciation in isolated populations of the species. The new species thus formed, remains itself in a state of equilibrium until on its fringes a small population undergoes its own burst of evolution.

Thus, under Gould's hypothesis, the old species is usually not wiped out when a tiny portion of it evolves into a new species. However, the chance of finding a fossil representing one of those evolving populations is rare, since the process is rapid and involves only a small number of organisms. For these reasons, the fossil record tends to preserve the long history of the states of equilibrium, but the punctuation is missing

Milestones in Evolution Throughout Geologic Time



Humans Human evolution was probably spurred by the combination of large brain, dexterous hand with opposable thumb, and upright posture. Dolphins and whales have larger brains than humans.

Mammals Adaptations of mammals include internal temperature regulation or warm-bloodedness, facilitated by fur. Also, unlike most lower vertebrates, mammals have specialized teeth including incisors, canines, premolars, and molars. Mammals are characterized by lengthy internal gestation in the womb followed by parental suckling and care.

Great Extinction The sudden extinction of the dinosaurs were accompanied by extinctions of many other life forms, including all terrestrial animals bigger than a rabbit. Similar mass extinctions have punctuated the history of life at other times, for example at the end of the Paleozoic Era.

Higher Plants This was a time of dramatic rise of the anigosperms, the flowering plants. The fossil record shows marked increase in species richness, community diversity, and dependence on animals for pollination and seed dispersal.

Dinosaurs & Birds Modern studies have shown the dinosaurs to be dynamic, active, possibly warm-blooded creatures that populated the Mesozoic world with incredible diversity. Dinosaurs are probably ancestors of birds, whose feathers allow body-temperature stability.

Conifers The Paleozoic Era saw a remarkable rise in the gymnosperms — the familiar cone-bearing trees. Forests of conifers have flourished ever since, expecially at higher elevations and latitudes.

Reptiles Reptiles arose from amphibians in the later Carboniferous or coal-swamp period. The reptiles' major contribution to evolution was the ability to permanently leave the water and inhabit even arid areas of the Earth. They accomplished this by developing a tough, drought-impervious skin, an improved way of walking, and most importantly the water-retaining amniote egg.

Amphibians Amphibians are transition creatures between fish and reptiles. They took the first steps in conquering the land for the vetebrates. Their major adaptive advances included limbs for crawling and improved ears (sound is easier to detect under water). Of course they breathed with lungs, but this adaptation belongs to the predecessor, the crossoperygian fish.

Fishes Early in the Paleozoic Era, the first animals with backbones arose — primitive jawless fish called agnathans. In the middle part of the ear, there was a great evolutionary increase in fish, probably brought about by the development of the first jaws, useful for grasping and eating.

Plants & Arthropods An important early adaptation of plants was the ability to draw moisture from the ground up into the plant. This was accomplished by the tracheophytes, which populated the land along with arthropods (including insects) long before any amphibian left the water.

Multi-celled Organisms The first known animals bigger than a single cell are found in rocks of the latest Precambrian Era. The major adaptation that characterizes these animals is the eucaryotic cell, a specialized kind of body cell that has an organized nucleus.

Photosynthesis Photosynthesis is a process used by plants to convert sunlight into the energy they need to grow. Primitive cells called procaryotes were the first to photosynthesize. This adaptation allowed a life-form, for the first time, to produce its own food. Blue-green algae, a type of procaryote, grew in mounds called stromatolites in or near the sea.

First Life No one knows how or when life originated. It has been speculated that life originated elsewhere in the Universe and was brought to Earth by accident or on purpose. Other researchers believe that the precursor of life is a natural combination of organic molecules that fortuitously evolved into life forms under conditions that no longer exist on Earth.

Geologic and Evolutionary Processes during the Cenozoic Era

Ice Ages → Pleistocene

Giant continental glaciers covered large areas of North America, and woodlands invaded the deserts during fifteen to twenty ice ages. Fluctuating climates fuelded rapid evolution in mammals and other groups. Humans entered the New World via Bering Land Bridge about 12,000 years ago.

Deserts → Miocene

Aridity peak five to eight million years ago marked the formation of North American grasslands and deserts, and the evolution of many warm desert animals and plants.

Miocene Revolution → Miocene

Uplift of mountains in western North America and global cooling combined to modernize and regionalize the biota. Archaic tropical forms were replaced by modern successful groups in major evolutionary radiations.

Immigrants to North America → Oligocene

The ancestors of many North American animals and plants immigrated to North America from Asia before the climatic cooling of the middle Miocene distrupted subtropical climates at high latititudes.

Tropical Climates → Eocene

Climates of the world were very warm. Tropical elements including palms, crocodiles, and tortoises lived north of the Arctic Circle. Evolution of deciduousness in plants and hibernation in reptiles and mammals may have been related to the six months of darkness at high latitudes. Mammals and plants moved freely between Eurasia and North America.

Mammals & New Reptiles → Paleocene

In the warm tropical climates of the early Tertiary mammals and the surviving reptiles underwent major evolutionary radiations. The earliest members of modern mammal groups including marsupials, insectivores, rodents, horses, and carnivores appeared in the fossil record at least by the Paleocene. Modern reptiles, including turtles, lizards, and snakes underwent major radiations in the Age of Mammals!

Millions of Years Ago	Cenozoic Time Scale
	Pleistocene
2.0	
	Pliocene
5.1	
	Miocene
24.6	
	Oligocene
38.0	
	Eocene
54.9	
	Paleocene
65.0	

Evolutionary Adaptation of Animals and Plants

by *Research Scientist Tom VanDevender*
Birds and Mammals Curator Peter Siminski
Small Animals Curator Howard Lawler and
Plant Department Curator Mark Dimmitt

The round-tailed squirrel (*Spermophilus tereticaudus*) can survive temperatures in excess of 115°F for at least two hours with body temperatures of up to 100°F because its basal metabolism is slow and produces less body heat.

Adaptation is one of the more tangible results of evolution. Advantageous heredity traits are accumulated through the process of natural selection, resulting in a population of organisms that is better adapted to the environment. For many, the concept of natural selection is not difficult to understand. However the idea that it is the sole mechanism of evolution is a common misconception. Natural selection is one specific way in which evolutionary change is facilitated. Other factors may also affect the rate and consequence of evolution. In deserts with their scarcity of free water, highly variable rainfall, and extremely high temperatures, adaptations can be especially unique structures, physiological processes, or behaviors.

The process of adaptation is never quite complete for several reasons. The environment is constantly changing on several time scales. This has been especially pronounced for the last two million years of the Pleistocene when woodland alternated with desertscrub in the Sonoran Desert for each of fifteen to twenty glacial/interglacial cycles. Adaptations that benefit organisms in an environment may cause problems in other ways. For example, a cactus conserves its stored water by having a greatly reduced surface area; but because this also reduces photosynthetic surface area, the water conservation is achieved at the cost of slower growth.

Some traits can be considered to have been "preadapted" when they evolve in one environment but function well or differently in another. Many of the adaptations to the long dry seasons of the relatively wet tropical and subtropical environments of North America that evolved twenty-five to forty million years ago, allowed animals and plants to survive and evolve when deserts appeared by eight million years ago in the Late Miocene. A few pre-adaptive examples in animals would be aestivation/hibernation in burrows by rodents, reptiles, and amphibians, nocturnal activity by mammals and snakes, and cheek pouches in heteromyid rodents (kangaroo rats and pocket mice). Examples in plants would be the succulence of cacti, the reduced leaves and photosynthetic bark of palo verdes (*Cercidium* spp.), and specialized types of photosynthesis in succulents (CAM) and annuals and grasses (C-4). Many Sonoran Desert animals and plants are generalists that also live in wetter habitats; specialists that evolved in and are restricted to deserts are not numerous.

Mammals: Mammals are adapted in the Sonoran Desert in many ways. Desert races tend to have lighter fur, smaller bodies, longer limbs, and larger ears than their relatives in wetter habitats. Some desert rodents have evolved remarkable physiological capabilities. The round-tailed squirrel (*Spermophilus tereticaudus*) can survive temperatures in excess of 115°F for at least two hours with body temperatures of up to 100°F because its basal metabolism is slow and produces less body heat. The large ears of the black-tailed jackrabbit (*Lepus californicus*) can radiate about a third of the body heat it produces.

Many desert mammals including Merriam's kangaroo rat (*Dipodomys merriami*) concentrate urine in the kidneys five times greater than humans. This helps to retain body fluids and allows them to drink salty water. Some desert rodents can go into a state of lowered metabolic activity called torpor when conditions are harsh. In torpor less body heat is produced, less energy is needed to sustain life, and water loss is reduced. Periods of torpor in warm seasons are termed aestivation, while similar states in the winter are hibernation. Heteromyid rodents like the kangaroo rat do not need free water because they produce enough metabolic water from the oxygen in air, and the sugars in seeds for their needs. This ability combined with their efficient kidneys and lack of sweat glands, allows the kangaroo rat to be very economical with its water.

Behavioral adaptations of desert mammals are very important for their survival in deserts. Most species avoid heat and dessication by nocturnal activity and retreating to underground burrows or shady retreats in the day. The microenvironment of a burrow or the interior of a packrat (*Neotoma albigula* or *N. lepida*) house have much cooler temperatures and higher humidities than the surface. Packrats are remarkable collectors that construct houses of branches or cactus joints and store food in caches within the houses.

Heteromyid rodents, with their cheek pouches, are specialists in seed collection and storage. The cheek pouches of a single kangaroo rat have been found to contain up to 900 seeds. Seeds are a good desert resource with 100 to 2400 seeds produced for each square foot in good years. Packrats have the ability to eat a great variety of desert plants in spite of their chemical defenses and bristling spines. In the driest areas packrats are often limited by the presence of cacti for a source of moisture.

Lower Vertebrates: Some fishes have evolved unique adaptations to survive in the sparse aquatic environments of the Sonoran Desert. The desert pupfish (*Cyprinodon macularius*)) can tolerate temperatures approaching 100°F, low oxygen levels, and high salinity which would spell disaster for most fishes. Now Endangered because of human interference, the pupfish is perhaps the epitome of a desert-adapted fish species in North America. Populations isolated in desert oases like Quitobaquito Springs in Organ Pipe Cactus National Monument have rapidly differentiated into distinct subspecies.

The razorback sucker (*Xyrauchen texana*) and the humpback chub (*Gila cypha*) are unrelated species that have evolved pronounced dorsal humps and downward oriented mouths in response to the powerful currents and turbity in the Colorado River. Ichthyologists believe that the hump provides stability in swiftly flowing water by forcing the body downward. In contrast the Colorado squawfish (*Ptychocheilus lucius*) is a streamlined predator well-adapted to speed swimming. This largest of North American minnows, unable to cope with changes in water conditions caused by dams and diversions, is now considered extinct in Arizona and Endangered in the upper Colorado River drainage.

Desert environments present great difficulties to amphibians which require water for their larval stages. The lowland leopard frog (*Rana yavapaiensis*) is a riparian obligate only found in the immediate vicinity of rare perennial streams or springs. True toads (*Bufonidae*) and spadefoots (*Pelobatidae*) have successfully entered the desert because of their ability to survive hot, dry periods in dormancy in burrows, and to accelerate reproduction and feeding during relatively brief wet periods.

Sonoran Desert species such as the Sonoran Desert toad (*Bufo alvarius*) and Desert spadefoot (*Scaphiopus couchi*) typically spend nine or ten months of the year underground. Spadefoots can bur-

Northern casque-headed tree frog
(Pternohyla fodiens)

row as deeply as three feet beneath the surface with the hardened spade on the heels of their hind feet. They retain body moisture in the burrow by means of a semipermeable epidermal membrane and a high tolerance for their own urea. Thus, they are able to retain most of the water absorbed during the brief summer monsoon.

The northern casque-headed treefrog, also known as the lowland burrowing treefrog (*Pternohyla fodiens*), is a terrestrial member of the mostly-arboreal treefrog family (Hylidae). It digs burrows with hardened callosities on its hind feet and then forms a cellophane-like "cocoon" by shedding outer layers of the epithelium (membranous skin tissue) that reduces water loss. The ultimate challenge for desert amphibians is to reproduce in the highly sporadic and localized water of a Sonoran Desert summer. Temporary rainpools may dry up in less than two weeks. Spadefoots have evolved an accelerated metamorphic rate which enables transformation from egg to tiny toadlet in less than two weeks in some species. Natural selection for shorter development times is intense in variable desert climates.

Desert regions around the world, including the Sonoran Desert, typically support a wide variety of lizards. Most desert lizards have evolved color patterns that match the rocks, branches, or sand where they live. Natural selection to match substrates of different color is very strong in the regal horned lizard (*Phrynosoma solare*) of the Sonoran Desert and the desert horned lizard (*P. platyrhinos*) of the Sonoran and Mohave Deserts. As ectothermic, or cold-blooded, animals, lizards utilize the sun's heat to fuel their metabolisms. Morphological and especially behavioral adaptations help ectotherms survive in hot, arid conditions. Broader bodies favor quicker solar warming in terrestrial species while higher vertical profiles are more favorable for arboreal (tree-dwelling) and saxicolous (rock-dwelling) species.

The Gila monster (*Heloderma suspectum*) of the Sonoran and adjacent Mohave Deserts, and its tropical relative the beaded lizard (*H. horridum*) are survivors of an early Tertiary tropical lineage and one of only two venomous lizards in the world. The Gila monster may be the only species ever to live in desert environments. For a large lizard it has a very slow metabolism, needing only a few meals a year. It is one of the few desert lizards to prey on mammals and birds. Both the Gila monster and banded gecko (*Coleonyx variegatus*) store fat and water in their tail, and can survive colder and warmer temperatures than their tropical relatives.

Lizards that live in sandy habitats can have some interesting adaptations. The flat-tailed horned lizard (*Phrynosoma mcallii*), endemic to the sands of the Yuma Mesa of southwestern Arizona, the Algodones Dunes of southeastern California, and the adjacent Gran Desierto of Sonora, is the only horned lizard that lacks an external ear. The fringe-toed lizard (*Uma notata*) lives in the same general area but is even more restricted to dunes of fine, wind-blown sand. Pointed, fringe-like scales on the elongated toes of the hind feet function in much the same way as snow shoes to give traction as it runs across loose sandy surfaces. The wedge-shaped head, counter-sunk lower jaw, nasal valves, fringed eyelids, scaly ear flaps, and fine body scales are important adaptations that allow this lizard to escape predators by diving headlong and rapidly burrowing into loose sand.

Chuckwallas have evolved a number of interesting desert adaptations. These herbivorous lizards are relatives of the green iguana (*Iguana iguana*) of the New World tropics that probably evolved after the Baja California peninsula split from the Mexican mainland about four million years ago. The common chuckwalla (*Sauromalus obesus*) of mainland Sonoran Desert and portions of the Mohave Desert is a large lizard that lives in rock crevices in desert mountains. To avoid predators it inflates its broad body to fill the crevices. Populations isolated on islands in the Sea of Cortez have grown to even larger sizes in the absence of terrestrial predators.

The piebald chuckwalla (*S. varius*) of Isla San Esteban and the spiny chuckwalla (*S. hispidus*) of Islas Angel de la Guarda, San Lorenzo Norte and Sur, and several small satellite islands closer to the Baja California Peninsula are examples of gigantism on islands. The evolution of large body sizes excluded the adults from using the crevice retreats of their mainland relatives. These lizards have evolved a pair of lateral lymph sacs in the sides of their bodies that allow them to store extracellular fluid, the succulents of the lizard world!

Behavioral adaptations are overwhelmingly important to desert lizards in regulating body temperatures in deserts. Activity is mostly limited to the warmer seasons, and daily activity in diurnal lizards shifts from midday in spring and fall to early morning, and late afternoon in summer. In the Sonoran Desert, only the banded gecko is nocturnal and avoids the sun altogether. As in desert rodents and amphibians, lizards retreat to the less stressful microenvironments of burrows when conditions are unfavorable. However, most lizards do not dig their burrows and instead use those of rodents.

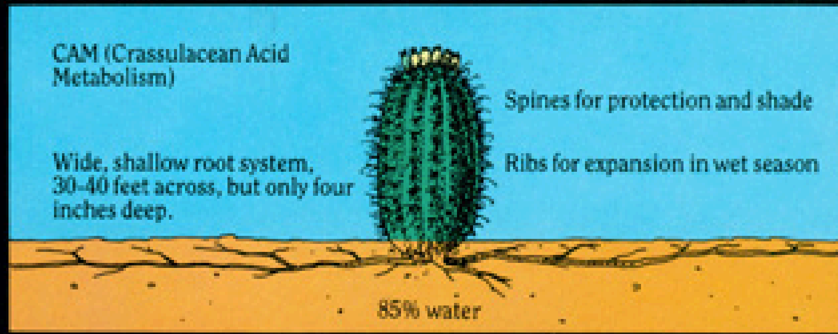
Gila monsters are great diggers that modify mammal burrows. Only the western whiptail (*Cnemidohorus tigris*) and the desert iguana (*Dipsosaurus dorsalis*) dig short rudimentary resting burrows. Many lizards restrict their foraging activities to bushes, trees, or rocks that provide shade and an easy retreat to a safe spot. Desert lizards often actively regulate body temperature by orienting their bodies broadside to the sun when first basking in the morning, later shifting their position so that the long axis of the body is parallel to the sun as temperatures rise.

The collared lizards (*Crotaphytus collaris* and *C. insularis*) often stand high when basking with their toes elevated, resting entirely on their heels as a means of reducing contact with the hot rock surface. In this position the lizard can actually radiate body heat to its own shadow as a cooling mechanism. Herbivorous lizards such as the desert iguana and the chuckwallas face additional thermal problems in the digestion of plants.

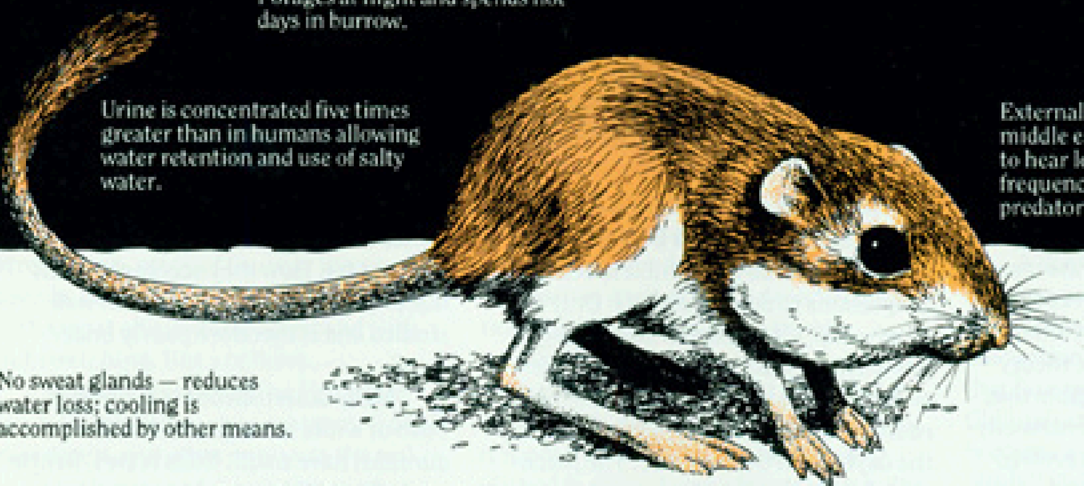
The processes of evolution are dynamic and still very much in progress. The story of the parthenogenetic whiptail lizards (*Cnemidophorus* sp.) is an exam-

Evolutionary Adaptation

Barrel Cactus



Kangaroo Rat

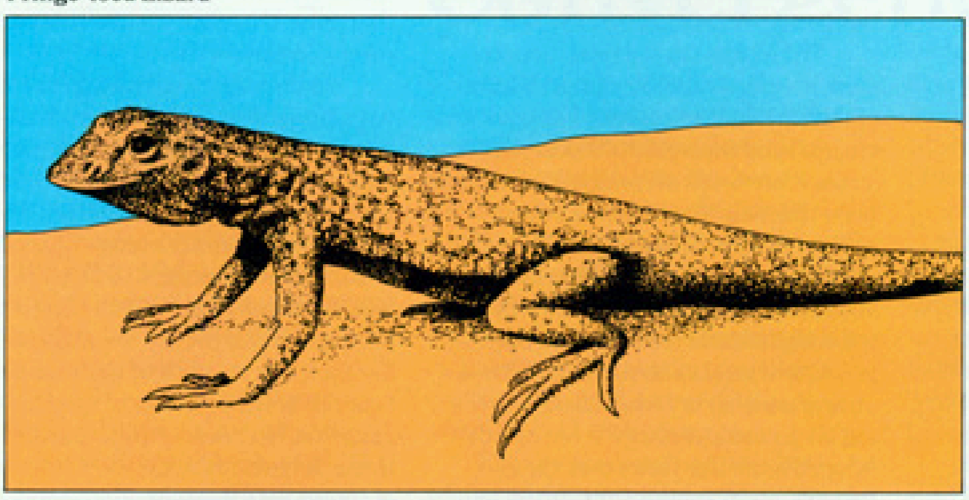


Tiny, firm, black fecal pellets have one-fifth the water content of those of a white laboratory rat.

Enlarged hind legs allow hopping or saltatorial gate for rapid movement over wide areas of open habitat.

Cheek pouches allow foraging over large area for seeds and transportation to burrow for consumption or storage.

Fringe-toed Lizard



Tail curls upward showing conspicuous light color and black bars to distort body shape as runs from predators. Body suddenly disappears as tail is lowered or lizard buries in sand.

Long legs and fringed toes for rapid and often bipedal run on loose sand to escape predators.

Wedge shape, counter-sunk lower jaw, nasal valves, fringed eyelids, and scaly ear flaps help to bury in loose sand to escape predators.

Pointed, fringe-like scales on elongate hind toes provide traction on unstable dunes.

Cryptic color pattern matches sandy background. Fine scales reduce friction in burying in sand.

Regal horned lizard (Phrynosoma solare)

ple of relatively recently evolutionary change resulting in new species. Approximately 30% of whiptail species are considered to be parthenogenetic (reproduction of organism without conjunction of gametes of opposite sexes). One theory explaining their evolution suggests that two or more parental species of normally-reproducing bisexual whiptails evolved in distinctive desert and grassland habitats. Climate change or other factors altered these habitats at their edges, causing an overlap of habitat characteristics.

This disturbed zone, or ecotone, became a marginal habitat for the parental species which began to interbreed, producing genetic hybrids that were able to back-cross with one of the parental species. This in turn produced a recombined polyploid (more than two sets of chromosomes) chromosomal package in the *parthenoform* whiptail, which enables the production of a clone offspring from the mother. Since the clone was identical in every respect to the single parent, it too was female. Because this parental species had evolved in concert with the characteristics of their original unaltered habitats, they were less competitive with the new parthenogenetic species in the new habitat. Thus, all-female species of whiptail lizards emerged as a result of habitat alteration and subsequent hybridation.

Although snakes are well-represented in the Sonoran Desert, most are nocturnal and do not exhibit specialized adaptations to desert habitats. Only the coachwhip, (*Masticophis flagellum*) known locally as the black or red racer and the desert patch-nosed snake (*Salvadora hexalepis*) are typically active in the daytime in the summer. The patch-nosed snakes and the leaf-nosed snakes (*Phyllorhynchus browni* and *P. decurtatus*) have broadened rostral scales on the end of their nose which turn up sharply, providing wide flat surfaces which may be useful in clearing debris from abandoned burrows or in rooting buried reptile eggs from loose soil to eat.

The wedge-shaped head, countersunk lower jaw, and very smooth scales of the banded sand snake (*Chilomeniscus cinctus*) and the western shovel-nosed snake (*Chionactis occipitalis*) are adaptations that help them burrow in sandy soils or to *swim* in loose sand. The sidewinder (*Crotalus cerastes*) has evolved an unusual form of locomotion where the body contacts the surface at only two points as it lurches along. This method of *sand walking* is very efficient for moving on unstable surfaces. It has also developed horn-like scales over the eyes that fold down along a scale suture to protect the delicate eye scale from abrasion by sand as it negotiates existing burrows.

Plants: Plants cannot cope with desert environments through behavior as animals do and have evolved morphological, physiological, and phenological/physiognomic solutions to the problems of aridity, heat, and rainfall variability. Most desert residents know that if one plants a typical house plant and doesn't water it, it will wilt and die in only a few days. But many desert trees and shrubs such as creosote bush (*Larrea divaricata*), jojoba (*Simmondsia chinensis*) and foothill palo verde (*Cercidium microphyllum*) can go months, even more than a year, without rain. Their extensive root systems allow them to take up water from much drier soil than non-desert plants. More importantly the tissue of these plants can dehydrate, and remain alive when soil becomes extremely dry. How they accomplish this feat physiologically has not been well studied and is therefore poorly understood.

Many desert shrubs like creosote bush or white bursage (*Ambrosia dumosa*) have small, thick leaves. Brittle bush (*Encelia farinosa*) has thick leaves in the summer and thinner leaves in its primary winter growing season. The leaves of ocotillo (*Fouquieria splendens*) magically appear within a few days of rain and fall rapidly with drought. The leaves of foothill palo verde are so tiny that most of its photosynthesis occurs in the green bark.

Another adaptive strategy to cope with drought is to store water inside the plant. Mutations or genetic recombinations which allow greater water retention were selected for in arid habitats. These eventually became the water-hoarders, or succulents. Succulent plants are found in most of the world's deserts and belong to about twenty-five different families, this means that the succulent trait has evolved from non-succlent ancestors at least twenty-five separate times. It is obviously an effective means of coping with drought. The Sonoran Desert is rich in succulent cacti ranging from small fishhook cacti (*Mammillaria microcarpa*, *M. tetrancistra*, *M. thornberi*) to giant arboreal saguaros (*Carnegiea gigantea*) and cardons (*Pachycereus pringlei*).

Once these species began the development toward succulence, numerous other related adaptations became essential to survival. One very obvious necessity is to protect the stored water from thirsty animals. It is no accident that most succulents are spiny or poisonous, and often both. The numerous species which have very dense spines also create their own shade and wind breaks, reducing water loss to the dry air. Water loss is further reduced by a water proof coating of wax on the skin of most succulents, and small or absent leaves minimize surface area through which water is transpired. Prickly pears (*Opuntia* spp.) also have a dense layer of calcium oxalate crystals within the epidermis which taste bad as well as retard water loss. Because the tough skin of succulents doesn't stretch well, many of the very juicy species have evolved pleats or ribs. This is the most efficient way to expand without stretching, like a bellows.

Obtaining water in the first place presents problems when moisture from a rare desert rain often only wets the soil to an inch or so and disappears in a few days. In drier portions of the Sonoran Desert the annual rainfall may only be a few inches and fall at irregular times while the potential evaporation is over nine feet a year! An extensive, shallow root system is the best adaptation to survive in such an environment. The roots of giant saguaro extend outward to over forty feet, about the height of the plant. In the driest desert areas, even more amazing root systems are developed. A two foot cholla in western Arizona (four inches average annual rainfall) had roots extending to more than thirty feet in all directions at two to four inches in depth. That's a root system covering 3400 square feet of ground to support a two-foot plant!

Succulents have evolved invisible, physiological adaptations as well as the visible, structural ones. The most interesting one of these is CAM. An acronym for Crassulacean Acid Metabolism, CAM is a special variation of photosynthesis in which carbon dioxide is taken up at night. Ordinary green plants open their stomates (pores in the leaves or stems) during the day to let in carbon dioxide, which is combined with water taken up from the soil and light energy from the sun to synthesize carbohydrates, the main energy source used by both plants and animals.

Succulents have gone one step further with their Crassulacean Acid Metabolism. In this special variation of photosynthesis the plants' stomates are open at night rather than in the day which greatly reduces water loss. Carbon dioxide is converted to an organic acid that can be synthesized later into carbohydrate using light energy from the sun. The carbon dioxide cannot be synthesized into carbohydrate in the absence of light, so it is stored as an organic acid; hence the middle letter of the acronym. The majority of succulents as well as semisucculent epiphytic orchids and bromeliads have developed CAM. As with succulence itself, this is a desert adaptation that has evolved many times worldwide.

A very important plant strategy for surviving in deserts is to live there when it is not a desert. This can be accomplished in several ways. Plants with bulbs like the Ajo lily (*Hesperocallis undulata*) can emerge from desert sands with showy flowers with wet spring rains. Other plants avoid drought by shortening their life cycles to coincide with the rainy seasons and surviving the dry season as dormant, resistant seeds. Annuals mature quickly and bloom profusely with a minimal energy investment in stems and leaves. The length of life, size, and number of seeds produced by an annual is directly correlated to the amount and duration of the rainfall.

A Saharan grass can complete its life cycle from seed to seed in eight days. Our spring annuals usually need two months or more. In the Sonoran Desert with its biseasonal rainfall, there are distinct winter-spring and summer-fall groups of annuals. In good years, the Mexican gold poppy (*Eschscholzia mexicana*) can color the slopes gold in the spring and the summer poppy (*Kallstroemia grandiflora*) in the summer.

A few desert plants are switch-hitters that can be either annuals or short-lived perennials. Fluff grass (*Erioneuron pulchellum*) is a small tufted perennial that flowers in the summer in the Chihuahuan and Sonoran Deserts but becomes a spring annual in the winter rainfall Mohave Desert!

Convergence

Convergence is the result of natural selection producing similar adaptations in unrelated species living in similar environments. Because the desert is a particularly rigorous environment, desert adaptations tend to be drastic and therefore conspicuous. This is why many desert plants and animals look so unusual. Examples of convergent desert organisms are thus easily recognized, even though the phenomenon is common in all environments.

The world's deserts all have very similar environmental stresses to which its inhabitants must adapt — scarcity of water, intense sunlight, and extreme temperatures. The result is that the deserts of northern and southern Africa have many species of plants and animals which closely resemble those of the Sonoran Desert, even though they are unrelated.

Mammals with desert adaptation in form, behavior, and physiology similar to the kangaroo rats (family Heteromyidae) of North America, include the jerboas (family Dipodidae) of Asia and North Africa and the gerbils (family Cricetidae) of southwestern Asia.

Many desert lizards around the world demonstrate varying degrees of evolutionary convergence. One of the best comparisons is the North American horned lizard (*Phrynosoma* sp.) of the

Family Iguanidae and the Australian thorny devil (*Moloch horridus*) of the Old World Family Agamidae. Although completely unrelated, both have evolved in desert environments where they move slowly and feed largely or exclusively on ants. Both rely on a "sit and wait" feeding strategy in which a minimum of energy is expended for a maximum caloric return, e.g., a large quantity of ants. Significant differences exist between these genera, however, particularly in stomach capacity and thermoregulatory behavior. These differences are directly attributable to corresponding differences in their desert habitats.

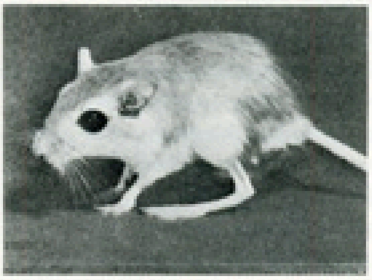
The convergence diagram illustrates a mesic (wet) habitat which slowly became arid in parts of North America and Africa. In North America the agaves (century plants) evolved in response to drought, from a non-succulent ancestor which may have resembled a modern non-succulent agave relative, the tuberose (*Polianthes tuberosa*). The agave leaves developed sharp teeth along their margins (the margin is the most likely place a large herbivore would take a bite), and powerful toxins which deterred smaller herbivores. The agaves also developed extensive, shallow root systems and CAM. In Africa a different plant group took a similar adaptive path. A non-succulent species which probably looked very similar to the modern red- hot poker (*Kniphofia uvifera*) developed succulence and became the ancestor of the aloes.

Tree-like euphorbias (*Euphorbia* in the Euphorbiaceae) of South Africa have very similar growth forms and physiologies to the various arborscent columnar cacti (*Cactaceae*) of North and South America. In most examples of convergence the animals will also have important differences along with the similarities. Here we present some examples of convergence in the deserts of North America and Africa. ■

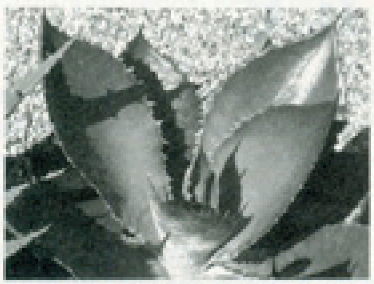
Sometimes similar environments have produced similar organisms. The desert is no exception. The deserts of North America, Australia, Africa, and Asia exert similar selective pressures on their inhabitants. Foremost in these pressures are extreme aridity in the form of low and infrequent rainfall, and extremes of temperature primarily on the high side. On these four continents, the deserts contain some animals and plants of similar form, physiology and behavior.

North America

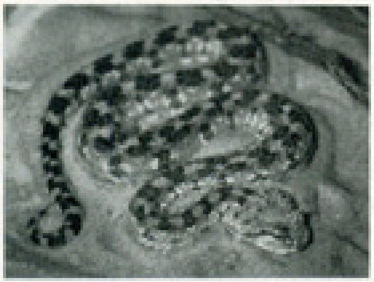
Africa

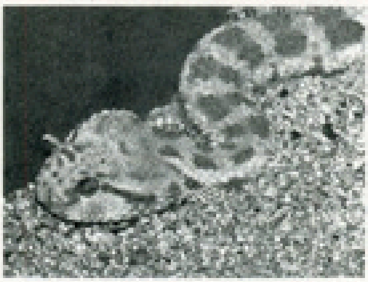


Both the kangaroo rat and the gerbil are small rodents between 20 and 40 grams in weight. They both have large hind legs, a saltatorial, bipedal gate, and a counter balancing, long, tufted tail. They are both buff colored like the pale sand that they live on. Both inhabit simple burrows which they dig themselves and spend the day inside them. They are only active at night. They both have the ability to concentrate their urine five times greater than a human can.

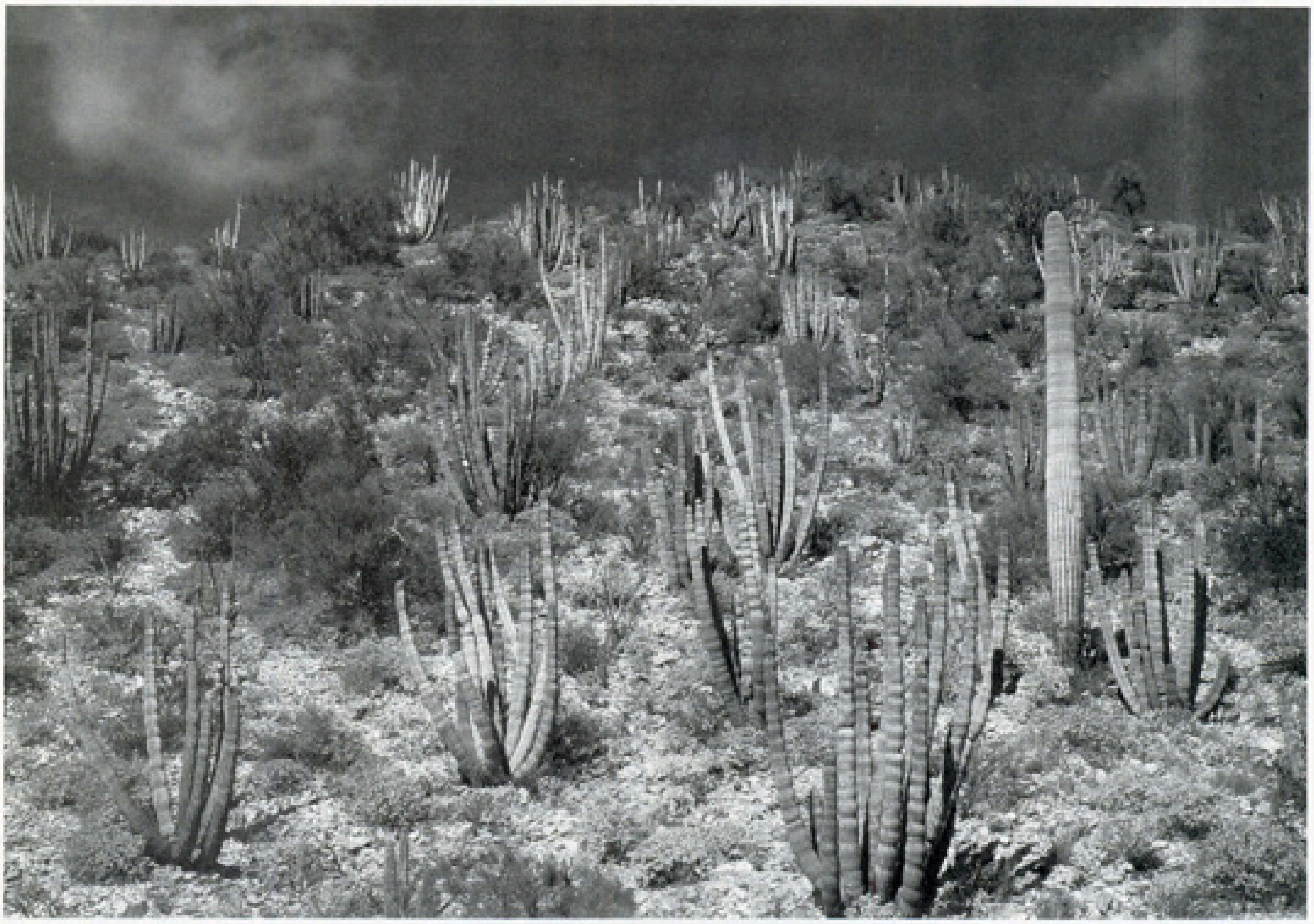


Aloes, like agaves, have rosettes of succulent leaves with marginal teeth and bitter taste, shallow roots, and CAM. The two groups strongly resemble one another in appearance, and some species of agave are almost identical to some aloes. *Agave cerulata* from Baja California and *Aloe glauca* from South Africa is one such pair, and *Agave Bovicornuta* of Sonora and *Aloe broomii* of South Africa another.





African horned vipers have evolved horn-like scales over the eyes very similar to those of the sidewinder. The scales fold down to cover the eyes, and protect the delicate eye scale when the snake enters a rodent burrow while hunting. Both snakes have evolved a cryptic color of brown or tan blotches on a light beige ground color. Both snakes move by "side-winding" — the only way to make progress on an unstable sandy surface.



Evolution and the Sonoran Desert Landscape

When we see a rich Sonoran Desert landscape like this organ pipe cactus (*Stenocereus thurberi*) community on a hillside in Organ Pipe Cactus National Monument, it is the result of various geologic and evolutionary processes. The volcanic rocks themselves and the Puerto Blanco Mountains are probably formed as part of the tectonism and block faulting in the Basin-and-Range Province about fifteen million years ago. Some of the animals that live in the community, including the desert tortoise (*Xerobates agassizi*) and the desert rosy boa (*Lichanura trivirgata*) are surviving members of subtropical groups that first evolved thirty to forty million years ago. Others like the black vulture (*Coragyps atratus*), the Organ Pipe shovel-nosed snake (*Chionactis palarostris*), and the tiger rattlesnake (*Crotalus tigris*) belong to families that immigrated to North America in the late Oligocene or early Miocene fifteen to twenty million years ago. Plant species in the community, including organ pipe cactus, saguaro, and brittle bush probably evolved in the latest Miocene as North America became more arid with deserts appearing by eight million years ago. A few species like the white-throated packrat (*Neotoma albigula*), the cactus mouse (*Peromyscus eremicus*) and the rock pocket mouse (*Perognathus intermedius*) are members of rapidly evolving groups that are probably no older than a million years or so. During the last 1.8 million years of the Pleistocene the geographic and elevational ranges of each animal and plant have been drastically contracted or expanded with each glacial/interglacial climatic cycle for fifteen to twenty ice ages! Relatively modern community composition was only established about 4000 years ago in the present interglacial, as more subtropical elements such as organ pipe cactus and foothills palo verde arrived from their glacial refugia in Sonora. The community is recovering from catastrophic freezes and droughts, the agents of natural selection, that occurred in the last few decades. Similar historical processes have been at work to produce all of our Sonoran Desert landscapes.

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Winter and Spring 1988

All the reading in the world may not teach us what we could learn in a few afternoon walks in the desert, or in an early morning spent silently watching and listening as the rocks and air begin warming, insects, lizards and birds begin their activity, and green stems and leaves start producing their daily food. We are fortunate in Tucson to have natural settings so close at hand for the learning! For those who enjoy the added benefits of having someone along to relate what they know and love about the Sonoran Desert, we are glad to provide the Special events study tours and workshops for members. We hope you will join us for one of these special learning experiences.

Mineral Mysteries Solved — A Workshop

Saturday, January 30
8:00 am – 12 noon
ASDM members only

Did you know that there are over 2,000 species of the mineral kingdom? Of course, to be a collector, there is no need to know all of them. In fact, of the 2,000, there are twelve common minerals found in the rocks around us. In this workshop our Earth Sciences staff will show you what a mineral is, how and where minerals form, which kinds are common or rare, and how to correctly identify them. You will learn to distinguish fine, museum quality mineral specimens from ordinary ones, utilizing select pieces from the Desert Museum's permanent mineral collection. "Mineral Mysteries Solved," comes just in time for the annual Tucson Gem and Mineral Show (the second full weekend in February), the *biggest and most spectacular* mineral show and sale in the world. This workshop introduces you to this fascinating mineral world in time to really enjoy this year's show.

The course fee of $8 covers handouts, refreshments, and hands-on instruction from our museum staff. Course meets in the ASDM classroom and is limited to ASDM members. Register early, as this promises to be a popular event!

Nature Drawing at the Museum

Four successive Saturday mornings beginning February 27 and ending March 19
9:00 am – 1:00 pm (bring sack lunch)
ASDM members only

Each of our senses teaches us about our surroundings in a different way, and often we neglect to train our visual perception in broadening our awareness. We are trained to fill our heads with interesting facts, facts about the desert which usually focus on verbal skills. All well and good, but it is an exciting "mind expander" to try our sight in refining our perception and understanding of the desert. Stopping to look and giving yourself time to *see* is the latch that opens the gate to a whole new world. This four week course is designed to encourage participants to use *drawing* as a tool for learning about the biotic communities represented at the Desert Museum, and to teach the kind of observation necessary to draw accurately and sensitively. There will be a slide lecture on the history of nature drawing, demonstrations of many media (pen and ink, ink wash, prisma color, pastel, watercolors) and basic drawing instruction. The emphasis, however, will be in the experience of drawing the plants and animal from life and the insight gained from that experience.

Our instructor, Ellen McMahon, received a masters degree in Biology with a speciality in scientific illustration in 1983. Since then she has taught several courses in botanical and animal illustration, nature drawing, and graphic design. Fee: $65.00 plus minimal supplies. Class size limited, so register early. *ASDM members only.*

For Planning Ahead . . .

Santa Rita Minerals Sojourn — a One Day Collecting Trip

Saturday, March 19
7:00 am – 5:00 pm
ASDM members only

Join us for a one-day collecting trip to some of the interesting mineral localities in the Tucson area. "The Santa Rita Sojourn" will take you to two unique mines. Brush close by some of the miner's ghosts at the Helvetia as we explore the adobe ruins and search the mine dumps for copper minerals, just as they did at the turn of the century. Not too far from Helvetia, still in the Santa Rita Mountains, is the Glove Mine outside of Amado. While Helvetia is noted for its copper minerals, the Glove's claim to fame is a suite of lead and zinc minerals including wulfenite, smithsonite, and galena. Participants will collect their own treasures from each of these mines.

Fee of $35.00 includes transportation, informational handouts, cold drinks, and expert leadership by ASDM Earth Sciences staff. Bring a sack lunch. Group size is limited so register early. ASDM members only.

Tucson Mountain Wildflower Walks

Wednesday, Saturday, or Sunday
March 23, 26, or 27 (9:00 am – 12 noon)

We can't promise hillsides of poppies, larkspurs and lupines straight out of **Arizona Highways** but even in our wildflower "off years" desert canyons hold pockets of delicate blooms. En route, our naturalists will lead you to these treasures and discuss the natural history and ethnobotany of the plants. Group size is limited, so be sure to sign up soon for this popular activity. Meet at the ASDM front entrance equipped with canteen, brimmed hat and hiking shoes.

Fee of $5 ($11 non-members) covers wildflower book, handouts and a naturalist guide.

Spring Gem, Mineral and Plant Sale

April 9 and 10
9:00 am – 4:00 pm

Midriff Islands — Sea of Cortez

Nine-day expedition
April 16 – 24
or April 24 – May 2, 1988

The Midriff Islands in the Sea of Cortez are extremely rich in the flora and fauna of both the desert and the sea. Clustered in the middle of the Sea of Cortez, this fascinating group of desert islands was uplifted as part of the active spreading center of the tremendous geologic fault which separated the peninsula of Baja California from the mainland some four to six million years ago. The plant and terrestrial animal life remaining on each separated little chunk of land has developed unique adaptations over the generations, so that now nearly every island boasts its own lifeforms, some of which are known nowhere else on Earth! In addition to these sights, our timing is arranged for observing flights of marine birds, rookeries of barking sea lions, and perhaps a sighting of fin whales, pilot whales or orcas. Accompanied by ASDM staff naturalists we will have many opportunities to observe, learn, photograph, and appreciate this important part of the Sonoran Desert.

Aproximate cost of this expedition is $1,250.00. Costs include guide services, information packets, meals and beverages on board, and a preview slide program within the month prior to the expedition. The accommodations include upper and lower bunks, single occupancy is not available. Not included in the cost is the flight from Tucson to La Paz (currently $90.00). The maximum tour size is eighteen people. Because of the popularity of this trip we have scheduled two expeditions.

Preregistration is required. For more details and a registration form, contact the Special Events Office, 883-1380, Ext. 105.

Registration Information: To preregister send a check or money order payable to the Arizona-Sonora Desert Museum, along with the name and date of the event, your name, address, and a daytime phone number. Send a *separate* check for each event and list ASDM membership number for each participant. Mail to:

ASDM Special Events
2021 N. Kinney Road
Tucson, AZ 85743

Cancellations and Refunds: All cancellations must be received in writing. No refund can be made within seven days of any day event or 14 days of an overnight event.

Bisbee Mineral Tour — The Echoes of Cousin Jack

A three-day collecting tour through southeastern Arizona's historic mining camps
Friday – Sunday, May 13 – 15
ASDM members only

The early Welsh miners who immigrated to America in the 1800's contributed much to mining in the early southeastern Arizona mining camps with their vast skill and knowledge of the trade. They were called "Cousin Jacks," and their wives were "Cousin Jennies." Four pound, hand-held sledge hammers called single jacks and eight pound double jacks gave rise to a melodic ring and rhythm underground, as the miners pounded hammer against chisel to loosen ore from the surrounding rock walls. Our three-day trip will be filled with mineral collecting, ghost town haunts, folklore, and mining history. We will visit the famous underground Queen Mine in Bisbee, and mining camps and ghost towns in the Dragoon and Patagonia Mountains as we follow in the footsteps of Cousin Jack and Jennie.

The trip fee of $185.00 includes expert guidance by ASDM staff, interpretive information packets, transportation, double-occupancy lodging and all non-restaurant meals (two breakfasts and two dinners in restaurants). Preregistration required. *ASDM members only.*

The Foundation for the Arizona-Sonora Desert Museum invites you to experience the mysteries of another desert in another place in time —

India

A 24-day luxury tour, March 13–April 5

You are invited to join ASDM Director Dan Davis and fourteen others on one of the most elegant and unique trips ever planned from Tucson — an unforgettable, twenty-four-day luxury tour of India planned in the style of the Maharajahs. Sponsored by the Foundation for the Arizona-Sonora Desert Museum, this exotic trip has been tailored especially for the foundation, by the renowned tour operator Abercrombie & Kent, to concentrate on legendary Rajasthan with three days and four nights in Ranthambore National Park, one of India's first tiger reserves. With the expertise of our special guide, Dr. Siddiq Wahid, we will gain a rare insight into the history and ecology of this desert area, not unlike our Sonoran Desert but with forts and palaces. Dr. Siddiq, a native of India, is the son of the former principal advisor to the Dalai Lama. A Ph.D. from Harvard, he is the author of "Ladakh: Between Earth and Sky," a book about his ancestral home in northeastern India. An expert in Central Asian and Tibetan Civilization, Dr. Siddiq now heads the Abercrombie & Kent Office in New Delhi. He does not normally lead trips, but has volunteered to personally escort the ASDM party throughout its journey of India.

This truly will be an around-the-world trip, too extensive to detail in this space. There are a few spaces left for this experience of a lifetime, but reservations must be made soon. If you're interested, call Dan Davis at 883-1380. He'll be happy to answer your questions and provide you with details.

First Notice — Australian Discovery Trip

This is your opportunity to visit Australian desert, Ayers Rock and the Great Barrier Reef as well as major cities of Australia. No other country has so many fascinating marsupial animals, and the bird life is outstanding.

Planning is underway for a members-only journey to the land "down under." Tentative schedule for the trip is the latter part of August and early September of 1988.

If you would like to receive information as it becomes available about this once-in-a-lifetime adventure, please contact Assistant Director Dave Beal or Administration Secretary Jean Morgan, (602) 883-1380 or by mail to ASDM. Group size is limited.

The Arizona-Sonora Desert Museum
2021 N. Kinney Road
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