

# Plant Press Arizona

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## In this Issue

**An Introduction to Arizona's "Lower Plants" and Plant-Like Wonders**



### Plus



### With Regular Features



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A wild moss and lichen garden. *Photo credit: Doug Ripley*

# An Introduction to Arizona's "Lower Plants" and Plant-Like Wonders

*by Douglas Ripley, Cochise Chapter, Arizona Native Plant Society*

Arizona's native plant admirers are most likely to focus their botanical attention on what are known as the "higher plants" for several fairly obvious reasons. Among those are the fact that the higher plants are normally the dominant component of most floras and that thanks to their highly evolved reproductive structures (i.e., flowers in the Angiosperms, the flowering plants), and typically interesting cones and foliage in the Gymnosperms (e.g. conifers), as well as beautiful leaf patterns in the ferns and their allies (e.g., the horsetails), these plants are a joy to discover, explore, and study.

However, there are many other types of fascinating "lower plants" and plant-like organisms that await discovery for those who may have focused their attention mainly on the "higher plants." In this issue of *Plant Press Arizona* we wish to provide an overview of some of the major groups of fascinating "lower plants" and plant-like organisms by describing the general characteristics of each group and briefly outlining typical locations in Arizona where they can be found.

Early biological classification systems can be traced as far back as Aristotle (384–322 BC) in ancient Greece. The first modern successful attempt to classify all life on earth was

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# President's Note

*by Douglas Ripley* jdougripley@gmail.com

Figure 1. Arizona Poppy or Orange Caltrop (*Kallstroemia grandiflora*) on the western slopes of the Dragoon Mountains, Cochise County. August 2021. Figure 2. Close-up view. *Photo credits: Doug Ripley*

As we begin a new year I wish to thank all the officers and members of the Arizona Native Plant Society for their support and participation in our society in 2021. Last year at this time we were lamenting our sad state of affairs with the Covid pandemic in full swing and Arizona and most other regions in the Southwestern United States suffering the effect of an unprecedented drought. I think we can say that in those two regards 2021 was definitely a better year than its predecessor. At least the record-setting monsoon season this year finally materialized in a way that brought torrential rains to most of Arizona that, in turn, stimulated spectacular displays of wildflowers and restored many long-suffering plant communities and their representative species. Unfortunately, the Covid pandemic, complicated by a number of new variants, is far from over even though some of the early restrictions it caused have been eased. The leadership of the Arizona Native Plant Society made the decision to continue a very cautious approach with its activities in 2021. Consequently all of our chapter meetings were held remotely via Zoom conferencing. We anticipate that we will continue with that approach with our meeting into 2022 until such time as the Covid pandemic is better understood and we are convinced it will be safe to meet in person.

Despite the pandemic we were able to hold our annual botany meeting in early November once again via Zoom conferencing. Thanks to the hard work of the meeting organizing committee and a number of excellent speakers, we were able to continue a long-standing tradition of the Arizona Native Plant Society. The theme of the meeting this year was: *Arizona Native Plants to the Extreme: Exploring the Botanical Diversity, Ecology, Adaptability, and Resilience of Arizona's Native Flora in an Era of Environmental Change.* I hope you were able to attend the meeting which was held in two-hour sessions over three evenings. But if you were not able to attend, the entire meeting was recorded through the Zoom conferencing protocol and you can watch it any time on YouTube. Simply check the AZNPS website for directions to viewing (aznps.com).

Another significant accomplishment in 2021 was the continuing improvement of the Society's website. Thanks to a dedicated Website Committee led by Lyn Loveless and Diane Kelly, many improvements and expanded options were added to the website this year. Please check it out to learn of the wealth of useful information it provides. Also of note were the continuing efforts of our Conservation Committee led by John Scheuring, which undertook a fundraising effort last summer to implement a major highly successful buffel grass eradication effort on the "A" Mountain in Tucson.

A major highlight of the past year for native plant lovers was the spectacular display of wildflowers and other flowering plants that occurred with the start of the monsoon season in July. At my home in the Dragoon Mountains of Cochise County, the wildflower displays were amazing and beyond anything I had seen in the 13 years I have lived there. Let's hope that the monsoon season in 2022 continues in the manner of 2021!

In conclusion, let me again thank all members of the Arizona Native Plant Society for their continued support of our mission. In the past year we acquired well over 100 new members, a rate of new memberships that I hope we will be able to maintain in the New Year.


Figures 1 A–D. Lower-plants and other plant-like organisms to enjoy. A. Liverwort. B. Fleshy fungus (*Pholiota squarrosa*). C. Lichens. D. Slime mold. *Photo credits: A–C: Doug Ripley; D: Jillian Cowles*


# An Introduction to Arizona's "Lower Plants" and Plant-Like Wonders

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accomplished by the Swedish botanist Carl Linnaeus (1707–1778). Both Aristotle and Linnaeus divided all living things into two Kingdoms: Plants and Animals. In modern times, it became clear that such a simple classification system was inadequate for understanding and defining the complexities of life on earth. Today, the most recent classification system consists of six kingdoms. We will explore organisms classified in four of those kingdoms. First will be the most primitive members of the Plant Kingdom which include the bryophytes (mosses, liverworts, and hornworts). Next we'll explore the Kingdom Fungi and then the amazing world of lichens which are fascinating organisms that are formed through a symbiotic relationship between a fungus, a green alga (Kingdom Protista) or a cyanobacterium (Kingdom Monera), sometimes even both. The algae are a group of environmentally significant and often strikingly beautiful organisms that are also classified in the Kingdom Protista. They are predominantly aquatic photosynthetic organisms that exhibit many types of life cycles and range in size from microscopic species to marine giant kelps that reach 60 metres (200 feet) in length. Since the most common algae occupy marine habitats, we have not included them in our discussion of Arizona's lower plant-like organisms even though they can be found in many freshwater habitats in Arizona (e.g. ponds, streams, etc.). Finally we'll delve into the truly bizarre world of slime molds (Kingdom Protista).

We hope the accounts of these fascinating organisms, each prepared by experts, will expand your appreciation for some of Arizona's sometimes overlooked and less appreciated "lower plants" and plant-like organisms.

# Mosses

*by Ries Lindley[1] and Douglas Ripley[2]*

The patches of emerald hues that grace the trunks and branches of trees and shrubs, or fill the crevices of rock faces, or line the banks of streams and rivers, are known to everyone as mosses. Depending on their habitat, mosses may be a major component of the landscape, such as in Washington State's Hoh River Valley on the Olympic Peninsula which receives an average annual rainfall of 130 inches (Figure 1). Mosses occur even in environments as harsh as in Antarctica (Figure 2). In drier climates, such as found in Arizona, mosses are more subdued (Figure 3). But regardless of where they occur and their dimensions, mosses are a beautiful component of the overall flora and very worthy of our attention and study.

Although mosses are *bona fide* members of the Plant Kingdom (i.e., contain chlorophyll for photosynthesis, are composed of cells with a cell wall, etc.), they occupy one of the lowest rungs of the Plant Kingdom evolutionary ladder. That is because they have retained many very primitive plant characteristics. Among those are the lack of vascular tissue (specialized tissue for conducting water and nutrients throughout the plant), the lack of which results in mosses being largely confined to habitats that are typically moist for a good part of the year. Unlike the higher plants, mosses cannot obtain moisture through a complex root system as in those plants with vascular tissue.

Sexual reproduction in mosses is a somewhat complicated affair even though asexual reproduction can be achieved through the

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[1]Tucson Chapter, Arizona Native Plant Society, University of Arizona Herbarium. [2]Cochise Chapter, Arizona Native Plant Society

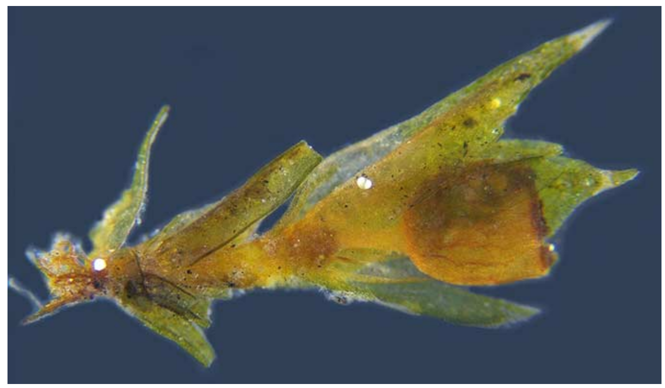
From top: Figure 1. Mosses in the Hoh River Valley Rainforest, Olympic National Park, Washington. *Photo credit: Doug Ripley*

Figure 2. Mosses (and Crabeater Seal) at Cierva Cove, Antarctica Peninsula. *Photo credit: Doug Ripley*

Figure 3. Moss growing on north side of a tree trunk, Garden Canyon, Fort Huachuca , Cochise County. *Photo credit: Doug Ripley*

Figure 4. A large boulder covered with *Grimmia* species from the Santa Rita Mountains in southeastern Arizona. *Photo credit: Ries Lindley*

Figure 5. *Ceratodon purpureus*, a common and widespread moss of mid-high elevation. *Photo credit: Ries Lindley*

From left: Figure 6. Hair-like gemmae on the leaf surface of *Orothotrichum diaphanum*. *Photo credit: Ries Lindley*

Figure 7. The gemmae from *Hyophila involuta* grow on branched stalks in the leaf axils. *Photo credit: Ries Lindley*

Figure 8. Moss sporophytes. *Photo credit: Wikipedia Commons*

Figure 9. Sporophyte of *Schistidium rivulare*. The urn-shaped structure is the capsule in which the spores are formed. *Photo credit: Ries Lindley*

## Mosses *continued*

formation of gemmae (small masses of tissue produced on various parts of mosses that can develop into an entire new plant). Sexual reproduction is achieved first through the production of spores in specialized urn-shaped structures called *capsules* which are born on a thin stalk (seta) on the body of the moss plant

The spores are dispersed by wind and water and grow into either bisexual plants or separate male or female plants. These plants are known as gametophytes and are the dominant moss forms that produce specialized structures from which either eggs or sperm (the gametes) are formed. When mature, the sperm is released from the gametophyte and swims in water with the assistance of numerous flagella to the egg located in a specialized structure also produced on the gametophyte. Following fusion of the egg and sperm, a new spore-producing structure (sporophyte) grows out of the gametophyte and eventually produces spores to begin the whole cycle anew.

Where might mosses be found in Arizona? Although they are sometimes obvious, mosses can be surprisingly easy to miss if you aren't paying attention, but it is unlikely you would have to go far to find some. Try looking around the walls of the buildings on the property where you live. Maybe you have heard the nature-wisdom of looking for moss on the north sides of trees. It might work for buildings too. Look near walls where they come down to the soil on the north side of buildings. Look anywhere there is shade, with a little extra water. That extra water might be from sprinklers, air-conditioning condensate lines, leaky hose bibs, and places where it's just plain hard for the sun to get to. Mosses are easiest to find a day or two after a good rain. If they are wet, they turn green, and if they don't suddenly dry out, they will grow during any sustained wet period.

Mosses are most easily found in wetter climes. A trip to higher altitudes, where there is better rainfall, will be productive. If you are in a mountainous area, you might find mosses where they are protected from the sun — downed trees, rock, soil, stream sides, etc. The same ideas work well in dry areas. Look closely in very steep protected areas of any desert or grassland. Moss will generally grow on the north side of deep, narrow ravines or steep rocks with a protected aspect. In wetter areas, it's not uncommon to find downed trees, exposed roots, and tree bark with moss on them.

An experienced bryologist can often identify a moss on sight, or sometimes with no more than a hand lens. But even more often, a microscope and dissecting skills are needed to accurately determine the name for a moss. Identification

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## Mosses *continued*

generally involves collecting a specimen and taking it back to a herbarium, a lab, or somewhere that the moss can be dissected and examined under a compound microscope. A collector (with permit or permission in hand) collects a small bit of the moss, anywhere from a teaspoon to a patch the size of a business card. This is deposited in a small paper bag or moss packet and the collector's number, the date, and location area noted directly on the bag or packet. Other data are also collected, e.g. information about the substrate, sun exposure, elevation, etc. The moss specimen is then dried, at which point it can be kept for years (Figures 10A and 10B).

In Arizona, the larger collections of mosses reside at either the Arizona State University Vascular Plant Herbarium with about 900 specimens, or the University of Arizona Herbarium with 3,700. There are also smaller collections at the Deaver Herbarium (Northern Arizona University) and the Museum of Northern Arizona in Flagstaff. Not far from Arizona in Silver City, New Mexico, there is a collection of 4,000 moss specimens at the Dale A. Zimmerman Herbarium of Western New Mexico University.

Probably because mosses demand microscopy for identification, they don't enjoy the rich catalog of field guides and botanical treatment available to Arizona's vascular plants. On the other hand, because moss species tend to be more widespread, there are other resources that were written for neighboring states that are very useful here in Arizona.

The most up-to-date key that covers many Arizona mosses is from New Mexico. Written by Kelly Allred, Russ Kleinman, and Karen Blissard, these keys cover almost all the common mosses of Arizona, and a great deal of the those that are less common. With a little study and practice, keys are easy to use, and there are photos for many of the species. This guide can be found in digital form at **https://floraneomexicana.org/**, or purchased in printed form at **https://www.lulu.com/**.

There is one key that was written specifically for Arizona in 1978: *Key to the Mosses of Arizona*, by Ardith Johnsen. Although name changes since it was written cause a few challenges, the keys are also easy to use. This publication is long out-of-print, but a digital copy may be purchased from the Museum of Northern Arizona.

The Consortium of North American Bryophyte Herbaria maintains a database (**http://bryophyteportal.org**) for bryophytes similar to the very useful SEINet data portal for higher plants. As with SEINet, it was created to serve as a gateway to distributed data on bryophyte resources of interest to the environmental research community within Arizona and New Mexico.


Figure 10. A specimen of *Dicranum* after being dried for preservation — A. University of Arizona Herbarium Moss Collection Label. B. University of Arizona Herbarium Moss Collection (*Dicranum rhabdocarpum*). *Photos credit: Doug Ripley*

An indispensable book for anyone interested in bryophytes, is Bill and Nancy Malcolm's *Mosses and other Bryophytes, an Illustrated Glossary*. This book is thoroughly illustrated with incredibly precise photo images, and it provides understandable definitions for just about any bryology term anyone will ever need to know. The Malcolm's have also published *California Mosses* with co-authors Jim Shevock and Dan Norris. This book is a rarity, because it is a true field guide — it has no keys and many photos and drawings of the more common mosses from California. *California Mosses* is available from the California Native Plant Society at **https://www.cnps.org/**.

While somewhat more difficult to identify than the higher plants, observing and getting to know the mosses in the world around us can add a very rewarding dimension to the study of the Plant Kingdom.

Figure 1. "Selfie" (notice the blurred cord to the right) of Cyrus G. Pringle with bulging plant presses in front of his covered wagon. *Photo credit: Wikipedia*

# Arizona Bryophytes *by Russ Kleinman[1] and John Spence[2]*

The mosses, liverworts, and hornworts are collectively known as the "bryophytes." They are small, green, spore-producing plants that lack a lignified vascular system and that are easily confused with lichens, algae, and spike mosses (which are actually not mosses at all but vascular plants in the genus *Selaginella*). Even though bryophytes make up a significant percentage of the total number of plants in temperate areas of the world, including Arizona, these frequently inconspicuous plants are often ignored, by botanists conducting plant inventories and by enthusiasts who spend more time with flowering plants — the angiosperms. Historically though, the bryophytes in Arizona have been studied for almost 150 years.

Cyrus Guernsey Pringle was one of the first notable botanists to collect moss specimens in Arizona. Pringle's specimen records can be found online (Consortium of North American Bryophyte Herbaria — **https://bryophyteportal.org/portal/**) dating from 1881 and were probably collected for Asa Gray, the eminent 19th century Harvard University botanist who sponsored and encouraged many botanists collecting in the Western United States. Pringle collected bryophytes in Arizona in 1884 for the Smithsonian Institution. Many of these specimens were collected in the Santa Rita and Santa Catalina Mountains near Tucson.

Elmer Ottis Wooton, a professor of chemistry and botany at the New Mexico College of Agriculture and Mechanic Arts (later to become New Mexico State University), collected bryophytes in Arizona in 1892. C.E.O. Jensen, E. Palmer, E.A. Mearns, Frank H. Knowlon, James W. Toumey, Henry H. Rusby, Richard E. Kunze, T.E. Wilcox, Delia W. Marble, Alfred J. McClatchie, C.H. Merriam, N.W. Price, E.L. Greene, and R.E Kruzi were other notable collectors of Arizona bryophyte specimens prior to 1900.

Another 30 or so names are associated with Arizona moss collections between 1900 and 1940. Of these, Edwin Bunting Bartram was perhaps the most notable. Bartram was a high school dropout but is credited with describing hundreds of

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[1]Western New Mexico University, Silver City, New Mexico.
[2]Chief Scientist (Retired), Glen Canyon National Recreation Area, National Park Service.

# Arizona Bryophytes *continued*

new species of bryophytes from around the world. During his career, he collected over 200 species of bryophytes within 60 miles of Tucson.

In 1940, Inez M. Haring established the bryophyte herbarium at the University of Arizona in Tucson. Her collections cover the entire state. Haring's checklist of the mosses of the state of Arizona included 249 species in 1947. This list expanded to 351 species in 1954. She founded the Haring Bryophyte Herbarium at the Museum of Northern Arizona (Flagstaff) in 1957. In 1961, her checklist consisted of 400 moss species and varieties in Arizona.

Figure 2. Sporophyte of *Hedwigia ciliata*, a moss collected by Jacob C. Blumer in Arizona in 1906. *Photo credit: Russ Kleinman*

Ardith B. Johnsen wrote a research paper entitled "Keys to the Mosses of Arizona" for the Museum of Northern Arizona in 1978. Her keys included a total of 381 species and varieties. She also co-authored a catalog of the lichens of Arizona. Although the nomenclature is long out-of-date, Johnsen's keys are still useful and available today.

Haring and Johnsen were the first to systematically approach the bryophytes of Arizona and create checklists and then keys. However, no further revisions of their work were undertaken for nearly 40 years. In 2007, a bryophyte bioblitz was held at the Southwestern Research Station in the Chiricahua Mountains where more than 30 bryologists gathered to collect for three days. They collected about 200 species, many new to the state, as well as two species new to science. Finally, in 2014, while serving as the Chief Scientist for the National Park Service at Glen Canyon National Recreation Area, John Spence updated the checklist of mosses known from Arizona. His data included his own collections, work by Lloyd Stark and John Brinda on bryophytes of the Parashant National Monument, as well as very significant contributions by Theresa Ann Clark who published the "Bryophyte Floristics and Ecology in Grand Canyon National Park" in fulfillment of her master's degree while at Northern Arizona University in 2012, under John's tutelage.

The current Arizona list includes 406 mosses, 67 liverworts, and one hornwort for a total of 474 bryophytes. The total flora includes 45 families and 146 genera of mosses, 21 families and 30 genera of liverworts, and one family and genus of hornworts. The largest moss families include the Pottiaceae (106 species, 26% of the total), Grimmiaceae (43 species, 11% of the total), Bryaceae (41 species, 10% of the total), and Brachytheciaceae (27 species, 7% of the total). These four families contain over half of all the moss species known from Arizona as of 2020. The largest liverwort family is the Jungermanniaceae (13 species) followed by the Ricciaceae (12 species). Current projects include a bryophyte inventory of the Kaibab Plateau, and a potential upcoming bryophyte inventory of the San Francisco Peaks near Flagstaff.

The bryophytes have fascinated collectors in Arizona since the mid-1800s. Work continues as modern researchers find more species and learn more about their evolutionary history. Bryology is a field in which amateurs are making meaningful contributions—it just takes a little time and effort to get to know the mosses, liverworts, and hornworts!

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Figure 1. *Gemmabryum tenuisetum* Herbarium Collection. *Photo credit: Ries Lindley*

# A New Moss Record for Arizona:

## *Gemmabryum tenuisetum* (Limpr.) J.R. Spence & H.P. Ramsay

*by Ries Lindley, Arizona Native Plant Society, Tucson Chapter; University of Arizona Herbarium*

In the Santa Catalina Mountains, north of Tucson, there is a hairpin turn in the Catalina Highway that marks the site of an ephemeral waterfall. Completely hidden from the highway by ragged rock cliffs, the waterfall drops some fifteen or twenty meters into a pool with a solid rock bottom. The vegetation surrounding the waterfall is largely Madrean Evergreen Woodland. Trees here are Emory oak (*Quercus emoryi*) and Arizona white oak (*Q. arizonica*); shrubs are represented by Pringle manzanita (*Arctostaphylos pringlei*), pointleaf manzanita (*A. pungens*), littleleaf mock orange (*Philadelphus stramineus*), holyleaf buckthorn (*Rhamnus crocea*); the vine known as canyon grape (*Vitis arizonica*), the grass-like beargrass (*Nolina macrocarpa*); herbs like *Acmispon*, *Mirabilis*, *Penstemon*, *Plantago*, *Sphaeralcea*; ferns, and grasses. The sharp changes in topography offer various micro-habitats for plants with varying needs, including the moss *Gemmabryum tenuisetum*.

*Gemmabryum tenuisetum* is an acrocarpous (said of a moss that is upright and produces sporophytes at the apex of a stem or branch) moss in the family Bryaceae. It is small with stems under two centimeters long, yellow to green and sometimes with a reddish tinge. This moss reproduces asexually by rhizoidal tubers, which are yellow (sometimes orange), spherical, and about 100–200 microns in diameter. *G. tenuisetum* grows on acidic soil. It has been collected in Australia, Africa, Eurasia, Atlantic Islands, and scattered locations in North America. In North America, the bulk of collections have been in California. The closest collection to the recent Arizona collection was collected by James R. Shevock in the Virgin Mountains of Clark County, Nevada. Both the Nevada and Arizona specimens were identified by J.R. (John) Spence.

The Arizona specimen is Ries Lindley 1227 (ARIZ [not yet accessioned]). The collection locality is Arizona, Pima

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# A New Moss Record for Arizona *continued*

County, Santa Catalina Mountains, Coronado National Forest, on Catalina Highway 2.3 kilometers above the turnout to Gordon Hirabayashi Campground (32.3546N, -110.72236W). The specimen was collected on October 22, 2020. There were no sporophytes found.

Spence notes that this species may be introduced to North America, which would help explain its mostly disjunct collection points. The denser concentration of collections in California may represent the original introduction(s). Lindley 1227 is about 600 kilometers from the Shevock collection in Nevada and further than that from any collections in California. The northernmost specimen in North America is from Thurston County, Washington, the southernmost is the new Arizona collection.

I thank John Spence for his willingness to identify mosses, his patient explanation of diagnoses of various mosses, and review of this range-extension note. Thank you Russ Kleinman, for pointing out that range extensions sometimes need to be formally documented and for mentoring a moss neophyte with the attention span of a gnat.


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*Gemmabryum tenuisetum* — from above:

Figure 2. Leaf.

Figures 3 and 4. Tuber.

*Photo credits: Ries Lindley*

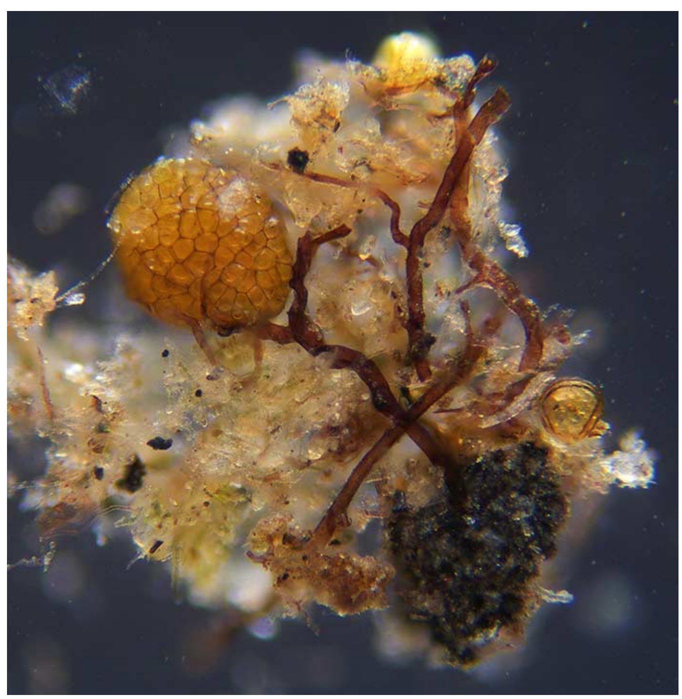

Figure 1. Gemmae Cups in *Marchantia polymorpha. Photo credit: Bernd Bäumler, iNaturalist*

# A Brief Introduction to Liverworts *by Karen Blisard*[1]

Bryophytes, i.e., mosses, liverworts, and hornworts, are thought to be among the earliest land plants. Liverworts are also called *hepaticae* due to the superficial resemblance of some of them to the mammalian liver. They do not have a traditional vascular system as found in higher plants — e.g., the ferns and fern allies, gymnosperms (conifers), and angiosperms (flowering plants) — for conducting water and nutrients. Asexual reproduction, involving small structures called *gemmae* (single cells or small groups of cells) is common (Figure 1). Sexual reproduction involves first the production of spores, which germinate and produce the dominant and conspicuous form of the plant (gametophyte) which eventually produces both eggs and mobile sperm to achieve sexual reproduction. The mobile sperm can only fertilize the egg if water is present, a significant limiting factor not found in higher plants with much more advanced reproductive mechanisms.

There are three basic morphologies of liverworts: leafy, simple thallous, and complex thallous.

**Leafy Liverworts**

These plants superficially resemble mosses, but they can be distinguished by visual and microscopic examination. For example, the leaves of leafy liverworts are basically in the same plane as the stem, whereas in mosses, the leaves are arranged radially around the stem. Liverwort leaves virtually never have a mid-vein (costa); mid-veins are found in the leaves of a majority of mosses. Liverwort leaves are often divided into multiple lobes, a characteristic rare in mosses. Most leafy liverworts have microscopic oil bodies within their cells, which can be important in species identification; mosses never contain oil bodies. Although oil bodies can be transient and are best examined in fresh specimens, they often persist for months in specimens collected from arid environments.

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[1]Silver City, New Mexico

Figures 2A and B. The leafy liverwort *Plagiochila asplenoides. Photo credit: Russ Kleinman*

## A Brief Introduction to Liverworts *continued*

*Plagiochila asplenoides* (Figures 2A & 2B) is a good example of a leafy liverwort found in the southwest, most often near streams or other moist areas. It is a rather large plant, often 4–5 mm wide. The leaves have small teeth around the margin. Notice how the leaves are in the same plane as the stem.

*Radula complanata* (Figures 3A & 3B) is another familiar leafy liverwort. It is an example of a complanate-bilobed liverwort. In these plants, the leaf is folded into two lobes, and joined by a "keel." This feature can be seen with a hand lens, but is more apparent using a compound microscope. Under the microscope, *R. complanata* is easily identified by the single oil body that occupies almost half of the cell. The exact function of oil bodies is poorly understood.

### Thallous Liverworts

These plants are comprised of elongate thalli instead of leaves and stems. Simple thallous liverworts have an undifferentiated thallus which is quite thin, often only one cell thick. They are quite uncommon in our area (only five species have been identified from New Mexico). We found *Fossombronia pusilla* (Figure 4) in the Gila National Forest in New Mexico which, at the time, was a state record. *Fossombronia* requires spores to be identified to the species level. We were able to find the reproductive plants in a second location, and thus identify it to species. A quick search of the *Consortium of North American Bryophyte Herbaria* revealed that few species of simple thallous liverworts have been identified in Arizona.

### Complex Thallous Liverworts

These liverworts have thick, fleshy thalli whose cross-sections show differentiated layers with air pores. The undersurface of the thalli is covered with deep purple scales, which are important in identification. Complex thallous liverworts are

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Figures 3A and B. The leafy liverwort *Radula complanata. Photo credits: Russ Kleinman* generally drought-tolerant, and are commonly found in arid locales. As they dry, the thalli of many species roll up into black tubes, with the deep purple scales now on the outside of the tubes. These flatten out again with rehydration. *Reboulia hemispherica* (Figure 5) is a species in the family Aytoniaceae, and is one of the more common complex thallous liverworts. The pores are seen in this photograph as tiny white dots on the upper surface of the thalli. The scales on the undersurface must be teased off and the scale appendages examined by compound microscopy to identify the species.

Liverworts are found in various habitats, including forest, riparian, and desert. They grow on a variety of substrates, including wood (especially downed trees), soil, and rock. As more botanists become familiar with liverworts, more species are likely to be identified in Arizona and surrounding states. Finding and observing these interesting little plants can add a valuable dimension to one's botanical adventures.

Figure 4. The thallous liverwort *Fossombronia pusill*a, showing the sporangium. *Photo credit: Russ Kleinman*

Figure 5. The complex thallous liverwort *Reboulia hemispherica*. *Photo credit: Russ Kleinman*

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BOOK REVIEW *Ries Lindley, University of Arizona Herbarium, Tucson; and Arizona Native Plant Society, Tucson Chapter.*

# Common Grasses of the Central Arizona Highlands by Debbie DeWolf Allen

2021. 134 pp. ISBN 978-1-7368453-0-1. Available at selected bookshops in Arizona — Peregrine Bookstore and Jay's Bird Barn in Prescott, Arizona-Sonora Desert Museum in Tucson. Also available directly from the author, Debbie DeWolf Allen, 100 Horse Shoe Loop, Prescott, AZ 86303, debbiedewolfallen@gmail.com: $20.00 plus $4.00 postage.

For those of you who have learned to accept that there is no app on earth that can correctly identify your phone-image of a grass, then here is a bit of good news. Technological advancements and author experimentation have brought us a new level of field guide. *Common Grasses of the Central Arizona Highlands* is an interesting, incremental, and usable improvement on older-style field guides. It is labeled a beginner's guide and should prove a good starting point for new-to-grasses enthusiasts or, alternatively, a new beginning for those who tried grasses before and got lost.


There are over 450 species of grass in Arizona. Because of the high diversity in the highlands, most of those species likely occur there. But that's too many species for a beginner's guide to a difficult family. This guide covers 61 common grasses of the Central Arizona Highlands, and that makes sense. Covering common grasses keeps the numbers manageable, and common grasses will be the ones a grass-buff would likely encounter. Most importantly, the smaller number won't be overwhelming for the user. The key will also work for a lot of places in Arizona that are not in the Central Arizona Highlands, i.e., many of the common grasses are widespread. This guide would be useful to most of the people in Arizona who want to start learning grasses.

*Common Grasses* is principally organized around photographic keys. This seems a relatively novel idea, and it wouldn't have worked a few years back, because the photographic technology was either non-existent or prohibitively expensive. That has changed. The photos in this book were shot by the author's husband, Harry Allen, using a photo-stacking or extended-focus technique, which means for the reader *all* the grass in the image is in focus.

These sharp photos allow for small images to be used for a category key, which breaks the grasses into manageable groups based on appearance. The category key consists of all the photos of grass inflorescences that represent a visual type. For example, a thumbnail of common barley represents a category labeled "bristly, long bristles." The user can then turn to the species-image key where she can compare her grass with those images in the "bristly" category.

Once a species has been selected, the user can turn to the species accounts. Each species account is two pages. The first page of each species account has larger images of the most critical parts of the grass. The second page will have some general facts about the grass, some illustration thumbnails that also have important visual cues, and a

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From left: Hairy Grama Grass (*Bouteloua hirsuta*), Cane Beardgrass (*Bothriochloa barbinodis*), Bulb Panicgrass (*Zuloagaea bulbosum*). *Photo credits: Harry Allen*

## BOOK REVIEW **Common Grasses of the Central Arizona Highlands**

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section called "look for," which consists of bulleted items that would help affirm or disaffirm the user's diagnosis.

*Common Grasses* has some very useful navigation devices for the user. The category keys are printed on an all-yellow background. When the pages are fanned this all-yellow key is very easy to find. While thumbing the pages, little color-coded tabs appear that mark both the species key and the species accounts for everything in a single category. The common barley tab is pink, and the species accounts for all the "bristly, long bristle" species are also pink. There is also a thorough index with both common names and scientific names.

A series of appendices cover a nicely condensed version of many of the niggling things one needs to know to identify grasses. There is a glossary that has been pared down to the bare essentials, a separate appendix of grass parts with definitions, drawings of generalized grass parts, and drawings of spikelets of common Arizona grasses. The appendices are like a whirlwind tour of Agnes Chase's *First Book of Grasses*, but with a lot less technical talk.

*Common Grasses* will be a valuable tool for people who want to start learning grass identification. It offers an easy entry into a difficult subject. The technical language is minimized, and the appendices offer access to technical terms for when they do become necessary. The visual nature of the key will help eliminate a lot of poring over glossaries and cross-referencing unfamiliar words. And for all its simplification, there are a lot of resources in this field guide. If you want to learn grasses, use this guide for a while, and then you will be ready for Agnes Chase.

# A Glorious Fungal Season:

## *A Strong Showing by the North American Monsoon Helps Arizona's Remarkable Fungal Diversity Come to Light*

*by A. Elizabeth Arnold[1,2,3], Joseph A. Myers[1,3], and Alison H. Harrington[2]* All photos courtesy A. Elizabeth Arnold

*"Nature doth thus kindly heal every wound. By the mediation of a thousand little mosses and fungi, the most unsightly objects become radiant of beauty." – Henry David Thoreau*

The summer rains in 2021 were a long time coming**.** Botanists and mycologists alike recall the extended dry seasons of 2020, without the greening and sense of calling that makes the naturalist in Arizona thrill to the chase. But with the first thunderheads in this year's southeastern sky, came a treat many haven't enjoyed in far too long. With the wettest month on record in Tucson and many similar records around the state falling aside, our landscapes became lush, our streams flowed again, and both desert- and mountain-dwellers alike — on glancing around gardens, or grasslands, or the forest floor — found themselves reflecting upon the age-old question: "now what the heck is *that?*"

Such are the joys of a glorious fungal season, and 2021 is certain to be one for the record books. From Arizona's lowest elevations to the highest peaks, the abundance and diversity of mushrooms were show-stopping on all fronts. Those in the Sonoran Desert biome noted a thrilling show by *Podaxis pistillaris* (Figure 1A), a stalked puffball that has become a

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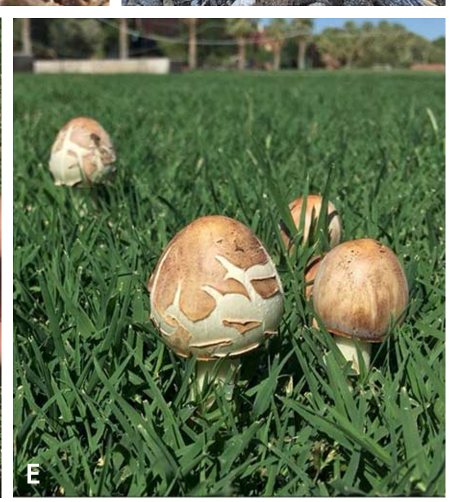

Figure 1. Common mushrooms in the Sonoran Desert biome and its urban areas: A. *Podaxis pistillaris*, along the Rillito River path in Tucson. B. *Itajhaya galericulata*, from the base of cultivated eucalyptus in central Tucson. C. *Battarrea phalloides*, with a bicyclist for scale, in sandy soil near non-native pines in central Tucson. D. & E. *Chlorophyllum molybdites*, common in the watered, grassy lawns at the University of Arizona.


Figure 2. Some of the subtle inhabitants of our mid-elevation grasslands, oak woodlands, and forest in Arizona: A. *Cyathus olla* on soil over woody debris, in the Catalina foothills north of Tucson. B. *Lycoperdon marginatum* on fallen needles of Ponderosa pine, Iron Springs. C. *Astraeus* sp., on granitic soil at the interface of *Quercus* woodlands and pine stands, near Prescott. D. Assorted bacteria and a robust fungal strain (large, blue-green culture) from nectar of *Datura wrightii*, Santa Rita Mountains. E. Common lichens of the Sonoran desert/oak woodland transition, including *Xanthoparmelia* and *Acarospora*.

## A Glorious Fungal Season *continued*

familiar friend along cycling paths, in curbside boulevards, and even in the gravel used for landscaping around parking garages at the University of Arizona campus. This desert *saprotroph* (a fungus that derives nourishment from decaying organic matter), ages to a golden brown, and holds its copious, coffee-colored spores in its stalked chamber, releasing them as conditions dry (or when fed upon by hungry crickets in our more urban settings). Check them out at night with a headlamp to see crickets at the feast.

Accompanying *Podaxis* in our urban-suburban-wildlands continuum are fungi that delight the senses — at least, if you are a fly. Our regionally distinctive stinkhorn, *Itajahya galericulata* (Figure 1B) is sometimes smelled before it's seen in rings around the trunks of eucalypts and mesquites. But what a delightful find! Look for cracks in the soil near the first fruiting body and beneath are "eggs" filled with slime and structure that sometimes make city dwellers wonder what strange reptile has nested in their yard. The spores of these "little towers of stinky power" are moved about by insects who find the hints of old rubbish and wet socks to be enticing.

Those of us who might disagree can shift our attention to another star of this monsoon season — *Battarrea phalloides* (scaly-stalked puffball) (Figure 1C) — or if we're looking for that *je ne sais quoi* of "mushroom" smell, *Chlorophyllum molybdites* (false parasol) (Figures 1D & 1E). Neither of these should tempt the sense of taste though. The former is not edible, with its woody stalk and cloud of cocoa-powder spores. For its part, *C. molybdites* has the unfortunate status of being the poisonous mushroom that is most frequently consumed in the United States. With its fairy-ring arrangement, enticing scent, and overall aspect, it is reminiscent of edible parasols from other settings. It is quite common in watered, grassy lawns during our summer rains, and it was out in force in 2021, with surprising reports as high as 6,000 ft (1,828 m) above sea level, even where grassy lawns are not established. We wonder if its range is expanding in Arizona, as the climate warms and as landscaping material is used more widely in otherwise natural areas, such as parks, playgrounds, and degraded roads and paths.

The showy desert fungi sometimes distract the eye from others that, while subtle, are no less compelling. A hands-and-knees look at woody debris turns up tiny birds-nest fungi like *Cyathus olla,* with "eggs" that splash from cups when fat monsoon raindrops hit home (Figure 2A). It's more common

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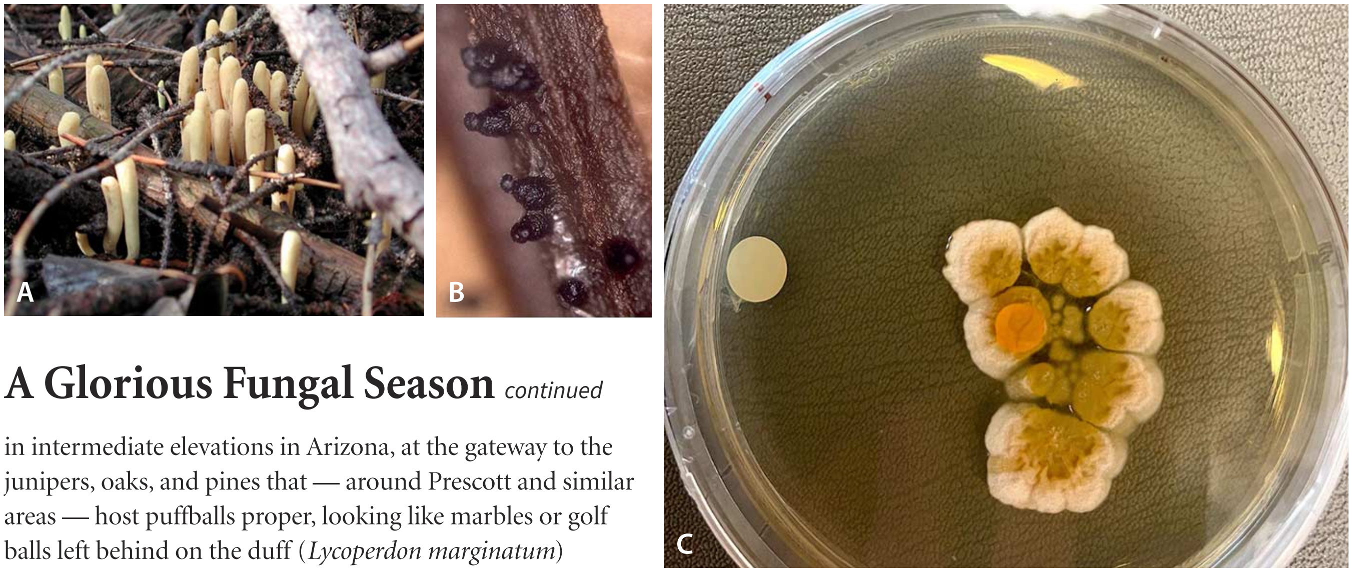

Figure 3. In the high-elevation forests of Arizona, a close look can often be rewarding. Here we find: A. *Clavaridelphus ligula* standing in troupes just a few centimeters high, emerging from the thick carpet of fallen needles of *Pseudotsuga* and *Abies,* Mt. Lemmon. B. A careful look at pine needles can bring the fruiting bodies of diverse Ascomycota into view. Here, perithecia of a newly described species of *Coniochaeta* emerge, each only ~ 100 μm long. C. The mycological eye is so often drawn to terrestrial environments, but hidden gems can be found even in aquatic plant communities. Here, a soon-to-be described species of *Coniochaeta* grows in culture, isolated from the interior of a healthy leaf of *Stuckenia pectinata* (Potamogetonaceae), submerged in the waters of Lower Lake Mary near Flagstaff.

## A Glorious Fungal Season *continued*

in intermediate elevations in Arizona, at the gateway to the junipers, oaks, and pines that — around Prescott and similar areas — host puffballs proper, looking like marbles or golf balls left behind on the duff (*Lycoperdon marginatum*) (Figure 2B), as well as subtle, hard-skinned, false earth-stars (*Astraeus* spp.) that open and close their arms with the ebb and flow of seasonal humidity (Figure 2C). Both have enclosed spores that puff out when the dry season returns, but they arrived at that characteristic via different evolutionary routes: *Lycoperdon* is in the order Agaricales, whereas *Astraeus* is aligned with the Boletales, and neither has much to do phylogenetically with the "true" earth stars (*Geastrum*, in the Geastrales), which are nice finds in the Arizona monsoon as well. *Astraeus* is ectomycorrhizal (not penetrating the host-plant root-cells) on oaks, particularly in sandy and granitic soils. Its robust fruitbodies can survive for years on the soil surface, lingering far after the rains are memories and the landscape has dried again. Far more ephemeral are the microscopic fungi that hide within nectar, such as those in the hawkmoth-pollinated flowers of the Sacred-thorn Apple (*Datura wrightii)*, which often occur alongside colorful lichens that can persist for hundreds of years — two flavors of Ascomycota, each with its style of symbiotic interactions (Figure 2D & 2E).

At Arizona's high elevations — where forests of mixed conifers and hardwoods grace our Sky Islands and mountain slopes — we find the diversity of mushrooms that often most excites the forager (Figure 3). From *Amanita* to turkey tails, to cauliflower mushrooms, to *Ganoderma* and to mycorrhizal *Russula* and *Suillus,* to the "little brown jobs" that confound even the practiced eye, 2021 was a year for learning — for first encounters with some taxa, and familiar reunions with others (Figure 4). This season reminded us of the joy of teaching, engaging friends and students in discovery, and — whenever possible — leaving mushrooms in place, with photographs and memory sustaining perfect pictures of the day.

Of course, the slopes were bustling with groups far beyond the ranks of university professors and graduate students, and palpable enthusiasm for fungi was in the air. Perhaps inspired by the feature film *Fantastic Fungi,* or with a desire to explore outdoors fostered by the many hardships and grief of the pandemic, this summer was a banner year for community members on the hunt for edible species. Surely this meant many foraging baskets of prized specimens, ready for frying, pickling, or even making cookies (see the classic recipes in Lincoff (1995) for a wonderful reminder that mycological field guides so often go from the forest to the table). For several of us, the busy season also meant many calls from Arizona Poison Control, as individuals reacted to mushrooms that were less edible than they thought — or worried that they might.

This reminds us that today in so many walks of life collaboration and cooperation are key — a principle illustrated by the conversations among mycologists and with our knowledgeable friends in the Arizona Mushroom Society as we tried to identify specimens from photographs. Indeed, we are fortunate to have a growing number of experienced "paraprofessional mycologists" across the state whose regional knowledge is important not only for identifying specimens,

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## A Glorious Fungal Season *continued*

but also for pushing forward the boundaries of knowledge regarding the distributions of known species, new records for Arizona, and species new to science.

It is this spirit of wonder and discovery that motivates so much enthusiasm about fungi: their hidden mycelia, their microscopic hyphae, their fruiting bodies that range from the most subtle to the most grand. We mycologists have a long friendship with botanists and a growing partnership with our knowledgeable neighbors whose enthusiasm and experience grow our collective knowledge about fungi. In Arizona, some 1,290 species of macrofungi were recorded in our best and most complete summary to date (Bates 2006), with more recent resources, such as MyCoPortal.org, bringing together fungarium (fungal herbarium) records that enumerate at least 1,897 species (Bates, Chapman, and Clements, Fall 2021: **https://mycoportal.org/portal/ident/key.php?cl=6&proj=2&taxon=All+Species**). The growth of digital resources, community knowledge, university-community partnerships, and enthusiasm — with the return of our summer rains — means this number is set to "mushroom" spectacularly in the years ahead.

Figure 4. Showy fungi in our forests bring out collectors in search of new species and the familiar fungi that mark Arizona's summer rainy season. Well-studied genera with new species are being described frequently… and European names, long applied to North American species, are being updated via new collections paired with molecular systematics approaches. Specimens shown here were accessioned into the Robert L. Gilbertson Mycological Herbarium at the University of Arizona for teaching and research purposes.

### Resources

Arizona Mushroom Society, with activities and resources: **www.arizonamushroomsociety.org**

The Fauna, Flora, Funga Initiative, regarding fungal diversity and conservation: **https://faunaflorafunga.org**

iNaturalist records of observations/occurrences: **www.inaturalist.org**

Mushroom Observer, with observations and species records: **www.mushroomobserver.org**

MyCoPortal, the Mycology Collections Portal: **www.mycoportal.org**

North American Mycological Association, with diverse resources: **www.namyco.org**

Robert L. Gilbertson Mycological Herbarium: **www.gilbertsonherbarium.net**

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Photo credits: Sue Carnahan

SPOTLIGHT ON A NATIVE PLANT *by George Ferguson, University of Arizona Herbarium, Arizona Native Plant Society, and Douglas Ripley, Arizona Native Plant Society, Cochise Chapter*

# Bartram's Stonecrop (*Graptopetalum bartramii*)

A member of the Stonecrop Family (Crassulaceae), Bartram's Stonecrop (*Graptopetalum bartramii*) was described by Smithsonian Institution botanist Joseph N. Rose (1862–1928) and named for the eminent bryologist Edwin B. Bartram (1878–1964) who discovered the plant in Flux Canyon of the Patagonia Mountains, Santa Cruz County, in 1923 (Rose 1926). The species occurs in Arizona, although not overlapping with Rusby's Stonecrop (*Graptopetalum rusbyi*), which is more common and widely distributed. The distributions of both plants in Arizona are the only known records for the genus in the United States. However, both of these species occur in Northwestern Mexico along with four other species of *Graptopetalum* (Acevedo-Rosas, R., *et al.* 2004; Austin and Montgomery 2013; Moran 2009). Eleven other species occur farther south in Mexico.

Like many members of the Stonecrop Family, Bartram's Stonecrop is a very handsome perennial succulent that grows on rocky outcrops in deep, narrow canyons in a number of the Sky Islands of southern Arizona and northern Mexico at elevations ranging from 3,500 to 6,800 feet. The plant forms a basal rosette comprised of 20 or more flat to concave, smooth, blue-green leaves. The striking inflorescences of up to 12 inches tall are produced between September and November.

Owing to its relative rarity and vulnerability, the species is classified as Imperiled (S-2) in the State of Arizona Natural Heritage Program (NatureServe Explorer 2021). Furthermore, the species was listed on September 29, 2021, as a threatened species under the U.S. Endangered Species Act by the U.S. Fish and Wildlife Service (U.S. Fish and Wildlife Service 2021).

As such, it becomes the 25th Arizona plant species to receive such federal protection. A provision of the Endangered Species Act calls for the designation of critical habitat for listed species. However, the U.S Fish and Wildlife Service has determined that the establishment of critical habitat for this species would not be practical or of benefit at this time.

With less than 4,000 adult plants known, and high or very high threats to the remaining populations, including various threatening effects of drought and wildfire to these plants, the establishment of the recent protection for Bartram's Stonecrop under the Endangered Species Act will hopefully enhance its chances for survival.

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Figure 1. Abundant crustose and foliose lichens painting rhyolite rocks in the Superstitions east of the Phoenix Metropolitan Area. Among the most conspicuous lichens are the crustose *Acarospora radicata* (bright neon yellow), *Squamulea subsoluta* (deep orange), and *Candelina submexicana* (deep yellow), and several species of the foliose *Xanthoparmelia* (pale yellowish green), all against the pale pinkish background of the rock.

# Lichens in Arizona—More than Meets the Eye!

*by Frank Bungartz[1]*

When you hear about lichens, you are tempted to think of lush, fairy-tale forests, ancient trees draped in "old man's beard," or broad-lobed "lungwort." You might be surprised to learn that lichens are equally abundant and just as diverse in the dry lands of the Southwest. In Arizona, lichens can be found in all parts of its varied landscape: in the lowlands and uplands of the desert, throughout the chaparral, in the oak woodlands and pine forests, in alpine conifer forests, and beyond the timberline. Arizona's impressive landscape diversity is reflected by an astounding diversity of lichens. Though these organisms are generally less conspicuous than in temperate rainforests of the Northwest, lichens of Arizona are just as diverse and equally as abundant. In fact, the Greater Sonoran Desert Region, which includes southern California, Arizona, and parts of northwest Mexico, accommodates more than a quarter (35%) of the number of species known from North America. And almost a fifth of the 5,618 species currently known from North America occur in Arizona (17%).

If you ever visited the Superstitions east of the Phoenix Metropolitan Area, you will have noticed that much of the pink rhyolite cliffs is painted bright neon-yellow. This vibrant color can hardly be overlooked; it is caused by one of the most abundant genera of Arizona lichens, the genus *Acarospora*.

But what are lichens? And how can they even thrive in a climate as dry as a desert?

People regularly mistake lichens for bryophytes. They lump them together with mosses, liverworts, and hornworts, which

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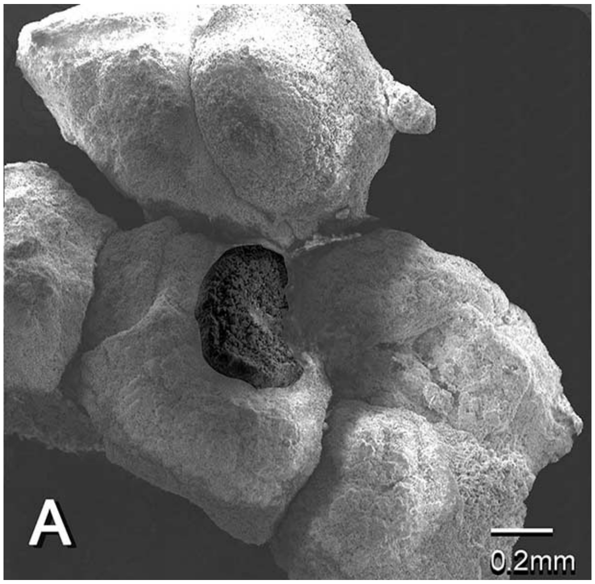


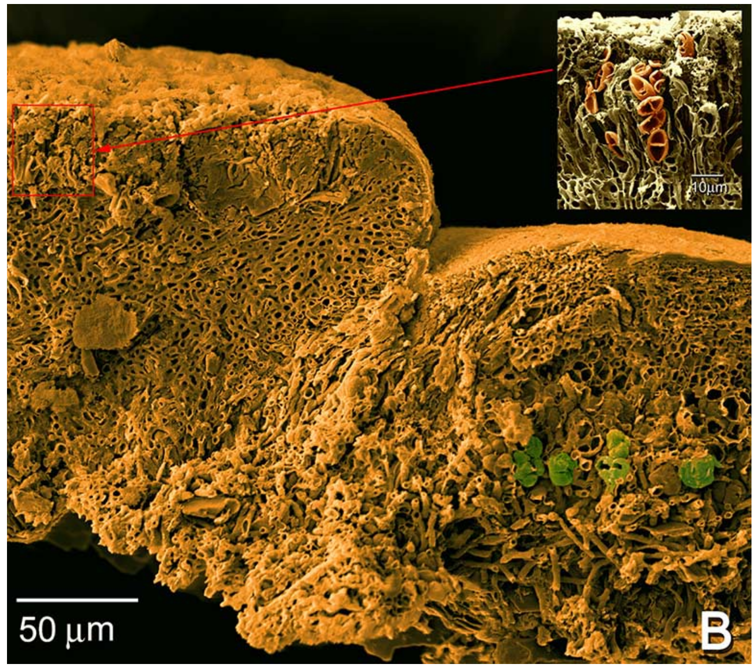


Figure 2. Scanning electron micrographs of the crustose Sonoran Desert lichen *Buellia dispersa*. A. Thallus with apothecium (artificially colored, the disc-like apothecium shown in black). B. Cross-section through thallus and apothecium (artificially colored, the mycobiont in rust-reddish brown, photobiont bright green); on the left an apothecium [a disc-like fruiting body, sectioned in half]; on the right the main body of the lichen [i.e., the thallus]. The insert shows a part of the hymenium, i.e., the layer of the fruiting body where the spores are produced. *Buellia dispersa* forms two-celled spores with a small pore in the spore septum. The image illustrates that the fungus makes up the bulk of the biomass and is the dominant partner in this symbiosis.

## Lichens in Arizona—More than Meets the Eye! *continued*

are miniature plants that lack vascular bundles and flowers, but reproduce by spores. Lichens may grow in the same habitats as these miniature plants, but they are very different…

Although you might perceive them as such, lichens are *not* a single organism. They are composed of at least two very different partners called *symbionts*. If you carefully scrape off the surface of a bright-yellow *Acarospora*, you will notice a layer of minute bright green dots just below. The body of a lichen is called the *lichen thallus* and is composed of at least two different organisms. The major biomass of a thallus is formed by the mycobiont, a fungus which builds most of what you see. Inside this structure constructed by the fungus resides a population of photobiont cells, either green algae or cyanobacteria, sometimes even both. Biologists call such a relationship of closely intertwined organisms a *symbiosis*. We often assume that a symbiosis must be mutualistic, where both symbionts are obviously benefiting from living together. In the case of lichens, things are not quite as obvious. The fungus is the dominant partner. It controls cell division of the photobiont — the photosynthetic cells are typically larger within a lichen than outside the symbiosis. The fungus suppresses sexual reproduction — algae inside the lichen thallus do not form gametes. And the mycobiont feeds on sugars that the photobiont produces — cell walls of the algae leak sugars that the fungus absorbs. Some scientists have called this *controlled parasitism* — the mycobiont dominating the photobiont.

But another view is generally becoming more popular. Lichens could be called "fungi that have taken up agriculture." This is a reasonable argument, where these mycobionts have adapted to a lifestyle "caring" for their photobionts. By hosting algae and/or cyanobacteria, these fungi "provide" for them. Some imitate the structure and appearance of a leaf — pretending to be plants. But lichens are not good at competing with plants for an environmental niche to occupy. Under "normal" circumstances they are easily pushed aside by the "real" plants.

Lichens, however, are adapted to extremes. On a bare rock surface, vascular plants cannot grow. There is no soil for their roots. Even mosses have a hard time adhering to bare rock surfaces. In these habitats, lichens are abundant, but only because they successfully shield their photobionts from excess UV-radiation. That's where the pretty colors come in. During symbiosis, lichen mycobionts produce an immense array of secondary metabolites, many of them not only colorful, but also very efficient in protecting their photobionts against

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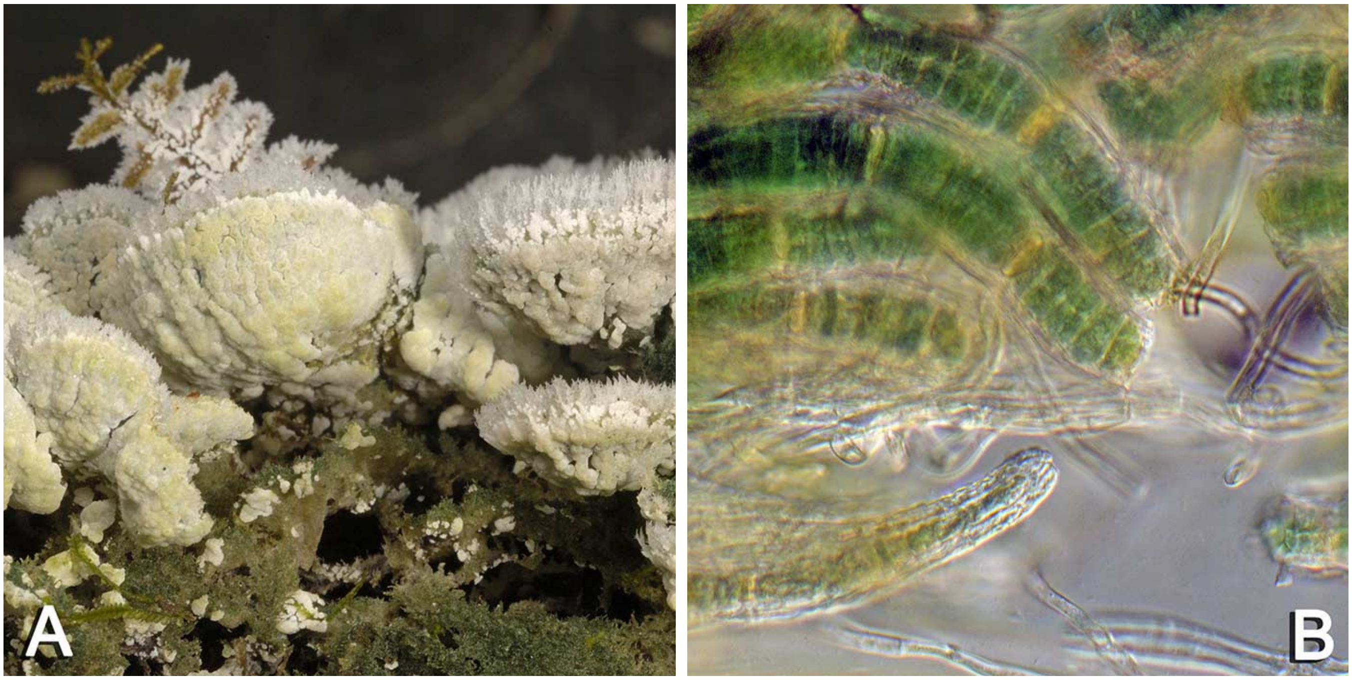


Figure 3. *Dictyonema barbatum*, a basidiolichen endemic to the Galapagos Islands. Most lichens are sac-fungi (ascomycetes; producing spores inside a sac-like structure, the ascus); only a few are club-fungi (producing spores on club-like stalks). A. Macro-photo of the lichenized shelf-like fruiting bodies (basidiocarps). B. The photobiont of *D. barbatum*, the cyanobacterium *Rhizonema*, the bluish green cells resembling a stack of coins. In this image colorless fungal hyphae are wrapped around these stacks of cyanobacterial cells. Some photobiont cells are yellow instead of bluish green. These yellowish cells are called *heterocytes*; they fix atmospheric nitrogen. Therefore these lichens can grow even in nutrient-deficient habitats.

## Lichens in Arizona—More than Meets the Eye! *continued*

"sunburn." Some of these complex organic lichen acids also protect against herbivory — from snails and slugs, caterpillars, and mites — all would love to have a bite of the algae inside. But they are being deterred by unsavory crystals, salts of the lichen acids packed into the lichen cortex. Thus, one could argue that the lichen mycobionts indeed "care" for their photobionts. Even though they "milk" them for sugars, they also provide a "greenhouse" — a fungal infrastructure that allows algae to occupy a habitat as hostile to life as a bare rock surface.

One can truly say they are "fungi that have taken up agriculture." The photobionts are the crops being cared for. There are some evolutionary arguments that favor this view. The green algae most commonly found in lichens are *Trebouxia*. Most species of *Trebouxia* can no longer be found free-living. They are confined to the lichen symbiosis. If you will, they are the preferred crop of the fungal farmer. For some cyanobacteria this is equally true. A common cyanobiont is the genus *Rhizonema*. Although this cyanobacterium looks like free-living *Scytonema*, we now know that these morphologically identical cyanobacteria are not closely related. *Rhizonema* is exclusively found only in lichens.

None of this of course explains how lichens manage to survive in the harsh deserts of Arizona. Or how can they live beyond the timberline, in some of the most windswept, cold, and dry environments? Even up there, where trees are no longer able to grow, lichens abundantly cover exposed rock surfaces.

You might be familiar with animals not being able to control their body temperature: the cold-blooded lizards are poikilothermic (warm-blooded mammals are called *homiothermic*). Lichens are poikilo*hydric.* This means, unlike plants, they cannot control their water content. In the desert, a cactus stores gallons of water to survive. When rainfall doesn't replenish its water supply, even a cactus will eventually dry out and die.

When lichens dry out, they do not die! They are dormant, their physiology at a stand still. Their cells are adapted to withstand long periods of being completely dried out. They contain enzymes and repair mechanisms that quickly restore their physiology up to speed as soon as water becomes available.

In the desert, lichens go through a daily "resurrection routine." In the early morning, when there is enough humidity, especially in the shade, and just enough sunlight for

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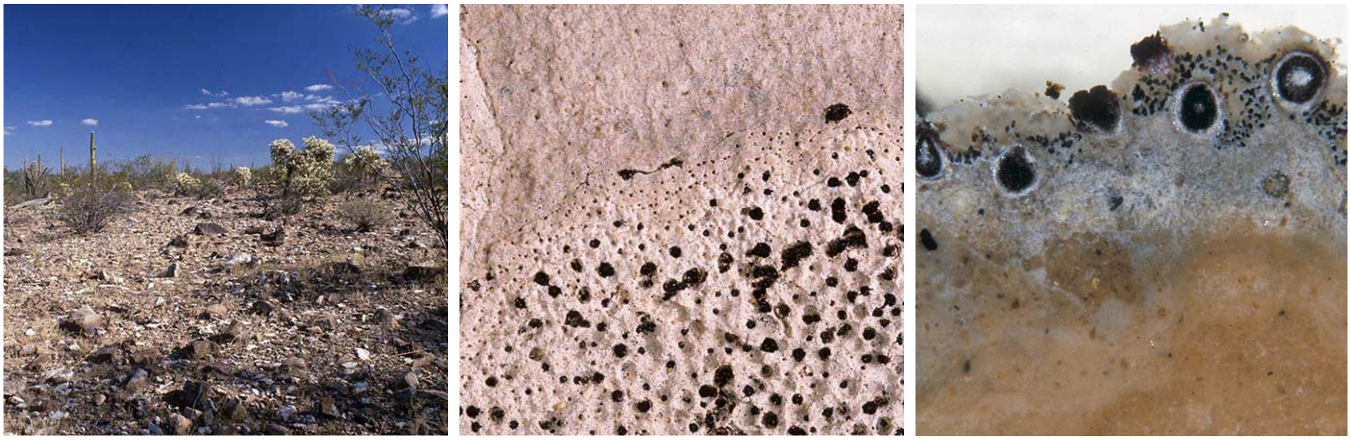

Figure 4. *Baglietta rubrocincta* from the South Maricopa Mountain Wilderness. The desert pavement of mostly volcanic rock is strewn with white shingles of caliche, a calcite rock that provides the habitat for this endolithic lichen species. A cross-section through the rock illustrates the lichen hyphae penetrating deep into the rock, the black, flask-shaped fruiting bodies (perithecia) opening with a pore that is stained wine-red, the photobiont cells much more minute, stained black by osmium tetroxide, and a fine calcite layer at the top, newly formed, shielding the lichen living inside the rock from the harsch environmental conditions of this extreme habitat.

## Lichens in Arizona—More than Meets the Eye! *continued*

photosynthesis, the photobiont cells become active. Photosynthesis now begins producing sugars, the necessary resources that the entire symbiotic system thrives on. But as soon as the merciless sun hits, the lichen are again deprived of any metabolic activity. Where there is no water, any metabolic processes grind to a halt. The lichen symbiosis endures the harsh midday sun in a dried-out dormant state. It becomes active a second time, when humidity again rises in the evenings. This of course is a fragile balance. At night, when humidity is high, but no sunlight available the net balance of photosynthesis is negative. During the day, the photobionts must have produced enough resources for this symbiotic system to survive and not starve during the night, when humidity still allows the fungus to feed, but the algae no longer produce. Thus, in the desert you may find lichens on shaded parts of a cliff, on the north-facing side of a boulder, everywhere that at least during some part of the day both humidity and sunlight suffice to tip that balance towards net positive gain of resources from photosynthesis.

Cyanobacteria and green algae are quite different types of photobionts. Cyanobacteria need liquid water for a positive photosynthetic balance. In the desert, you will find them as "tintenstriche" — black streaks looking like ink that run along seepage tracks, where after heavy rainfall, water runs off the rocks. Green algae are able to sustain themselves even without liquid water, obtaining water just from the humidity in the air. Thus, lichens with green algae as their photobiont are much more widely found throughout the desert.

One environment in the deserts that is even extreme for lichens are desert pavements, where there is no shade and the sun blasts the rocks mercilessly. But even there, some lichens manage to survive, by growing *inside* rock. Most of Arizona's geology is volcanic; only a few sites are characterized by calcareous rock. But even where volcanic rock dominates, a type of calcite rock is formed by evaporation, called *caliche*. These white caliche plates are inhabited by the lichen *Bagliettoa rubrocincta*. The lichen hyphae deteriorate and penetrate deep into the calcite, but at the same time the physiology of the lichen induces the formation of a much finer-grained new layer on top, which shields the algae below from the harsh environmental conditions.

But desert lichens do not just inhabit rocks. They also form extensive soil crusts. Where rainfall is insufficient for plant growth, a daily routine of dewfall nevertheless sustains a complex ecosystem that plays a major role in arid lands by preventing soil erosion. These soil crusts are diverse mixture of cyanobacteria, soil fungi, free-living green algae, lichens, mosses, and liverworts. It is an ecosystem that has become increasingly rare in the drylands of Arizona. Soil crusts are among the most threatened ecosystems of our state. Disturbance of desert soils is all too common: farming, herding cattle, off-roading, mountain-biking, and everyone venturing off the beaten track. It has been estimated that these complex, highly diverse soils may need up to two hundred years to fully recover from disturbance.

Other unique habitats are the high mountain peaks. In the south of the state, Sky Islands form inselbergs, emerging isolated from a surrounding "desert sea." *Omphalora arizonica* is an endemic species on these insular mountain peaks. It

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# Lichens in Arizona—More than Meets the Eye! *continued*

looks quite different from the crustose species. It is as large as the palm of a hand, lobed and attached only in the thallus center.

Generally, lichens come in three growth types: Crustose, foliose, and fruticose:

Crustose lichens lack a lower surface; they directly adhere to their substrates, and like paint they cannot be scratched off without damage. The genus *Acarospora* painting entire cliffs a bright neon-yellow is only one example; generally two thirds of all lichens are minute, they are often called *micro-lichens*, most of these are crustose.

Foliose lichens are internally organized like a leaf; they have a distinct upper and lower surface. *Omphalora arizonica* is foliose with a distinct upper and lower side, but unlike most foliose lichens the species is attached only by a single holdfast, a structure called an *umbilicus*; *Omphalora* is thus an umbilicate foliose lichen.

Most foliose lichens have several attachment points: small root-like outgrowths called *rhizines*. Unlike the roots of plants, these rhizines do not transport water and nutrients; they are only attaching the lichen to its substrate. Most foliose lichens need slightly more humidity than their crustose counterparts. In Arizona, they are typically found at higher elevation. But there is one group of species, the genus *Xanthoparmelia*, which forms large lichens that are also abundant throughout the desert.

Fruticose lichens are those that are three-dimensional. They may grow erect, with a shrubby appearance. The genus *Cladonia* forms small, erect trumpets or little stalks, but some species may cover a forest floor in large clusters — the reindeer lichens. Other fruticose lichens hang in long tresses from the trees; the genus *Usnea* is one of the best-known representatives of this growth type.

In Arizona, carpets of reindeer lichens are rare. Beyond the Arctic Circle these lichens are the main food source for reindeer. But even in Arizona, elk feed on lichens; some *Xanthoparmelia* species are vagrant, not attached to the ground and thus accessible where other food sources may be scarce.

Figure 5. Well-developed Pinnacle Soil Crusts along Hermit Trail in the Red-Rock Country near Sedona, Arizona. The conspicuous bright neon-yellow lichen is *Psora icterica*, but these crusts are not dominated by a single species. They are very species diverse, many lichen species are brown or black and thus less conspicuous, among those also grow black cyanobacteria, olive green mosses and liverworts and many other soil inhabiting lichens; one of the most complex ecosystems in drylands, frequently disturbed and highly threatened. Pinnacle Soil Crusts are unique insofar as they are common in drylands that experience regular cycles of freezing and thawing during the winter, the enormous micro-relief forming deep valleys and high pinnacles believed to be caused by these dynamics.

In Arizona, the Ponderosa pine forests are also not as conspicuously draped by beards of *Usnea* or *Bryoria* as in the fairy-tale forests of the Pacific Northwest. But even here both foliose and fruticose species can be found — from the oak and juniper forest below, through the Ponderosa pine forests, into the alpine conifer forest above.

Again, very different are the lichens growing on some of Arizona's highest mountains. Mount Agassiz (12,356 feet elevation), the second highest of the San Francisco Peaks, is off-limits to mountaineers to protect its fragile plants. Unique in the world, San Francisco Peak's Ragwort (*Packera fransiscana*) grows only here, on top of these mountains. Hikers disturbing this endemic plant when veering off the trail face a hefty fine. Less well-known is a lichen that grows here, *Lecanora subcavicola*, a species almost equally restricted, perhaps also confined only to the San Francisco Peaks, but perhaps found also on some of Nevada's highest summits (we are still investigating).

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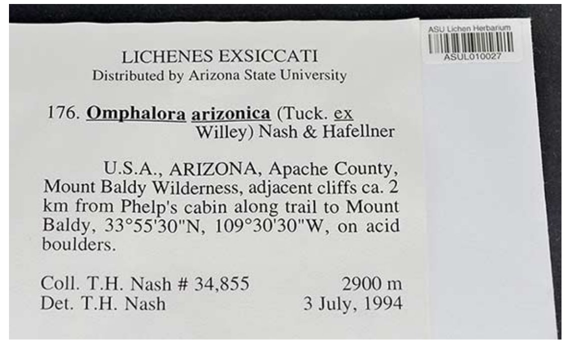


Figure 6. *Omphalora arizonica,* a specimen collected in the Mount Baldy Wilderness, Apache County, Arizona. The ASU Lichen Herbarium is one of the largest collections of lichens in the country; it is the most comprehensive collection in the Southwest, the large majority of the material from the Greater Sonoran Desert Region. Detailed specimen data are available and managed in the Consortium of North American Lichen Herbaria (**https://lichenportal.org/cnalh/**), a biodiversity data platform built on the software Symbiota, developed by Ed Gilbert and his team at Arizona State University.

# Lichens in Arizona—More than Meets the Eye! *continued*

Why then should we be bothered about the unique biodiversity of lichens in Arizona and even throughout the Sonoran region? The brightly painted cliffs, the soil crusts, the species growing on isolated peaks, surviving some of the harshest environmental conditions — why bother?

None of these organisms "fly into our face." They are hardly noticed, even though they are as colorful as the most beautiful butterfly. And they play equally important ecological roles, as important as any one of the more iconic species.

Soil crusts protect from erosion, thus resulting in fewer dust storms, less dust pollution, and better air quality. Tresses hanging from the trees, even though not as abundant as in temperate rainforests, still increase condensation, comb-out water from fog, thus replenishing groundwater. And if reindeer do not roam across Arizona, vagrant lichens are an important food source for elk. More important: at a much more minute scale, countless invertebrates depend on lichens. At a microscopic level, the web of life is just as intricately interwoven as at a macroscopic scale. And the bright "paint" of desert cliffs is not just a living skin of these rocks. This "skin" plays an important role in both protecting the surface from erosion, as well as from weathering and thus breaking down the substrate. At first glance the two processes seem contradictory. Lichen hyphae penetrate inbetween mineral grains. They chemically alter the minerology and affect mineral cohesion. But these processes are very slow and they are typically delayed by the protection that the lichen "skin" also provides against erosion. Even though lichens change their substrate, they also prevent it from further disintegrating. The weathering of rock minerals and the accumulation of organic debris, while simultaneously preventing erosion, provides a first foothold for the succession of life. Without such a "living skin," our planet would indeed be a desert, a desert entirely devoid of life.

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Figure 7. A small community of lichens growing on a twig of Ponderosa Pine (*Pinus ponderosa*). A shrubby, erect species of *Usnea*, the deep orange *Xanthomendoza montana*, broad lobes hanging down of *Ramalina sinensis*, and a small, brown *Melanelia*.

Figure 8. Species unique to the San Francisco Peaks of Arizona. Looking back towards Mt. Agassiz from the crest between Mt. Humphreys and Mt. Agassiz. San Francisco Peak's Ragwort (*Packera fransiscana*); in the world this is the only site where this plant can be found. *Lecanora subcavicola*, a lichen that is still poorly understood but is possibly also unique to these mountains.

## Lichens in Arizona—More than Meets the Eye! *continued*

In Arizona, lichens are everywhere, though too often overlooked. They are equally as diverse, equally as abundant, and equally as important as many of the more spectacular organisms of the fascinating natural landscapes in the Southwest.

**Acknowledgements**

Much of our work surveying lichens across the Sonoran Desert and in Arizona would not be possible without generous support of the Arizona Mushroom Society, and the individual support of Shirley Tucker. The US Forest Service allowed us to visit and collect lichens at Mt. Agassiz. We have also been collaborating with the US Forest Service at the Red Rock Ranger District in Sedona, where Garry Neil and Janie Agyagos are leading a species inventory of the area. Our work in the Superstitions has been facilitated by Lynne Nemeth at the Boyce Thompson Arboretum, where Paul Kinslow works on a species inventory. Research on how lichens affect their rock substrates is carried out by Guillermo Ortiz at the Boyce Thompson Arboretum, the Deer Valley Petroglyph Preserve (with support of Celeste Scott), and at V bar V (in collaboration with Arizona Archaeological Society and Spence Gustav). Images of specimens from the Galapagos Islands were taken as part of the Galapagos Lichen Inventory, supported by the Dirección del Parque Nacional Galápagos (DPNG), the Charles Darwin Foundation (CDF), and Ecuador's Instituto Nacional de Biodiversidad (INABIO).

**Selected Reference Sources about Lichens**

*—Consortium of North American Lichen Herbaria*
***https://lichenportal.org/cnalh/***

This multi-institutional platform provides occurrence records of lichens based on millions of specimens hosted in more than 100 collections from across North America and the world. The website provides international, national and regional checklist of species, a taxonomic thesaurus that helps managing lichen names (accepted names and synonyms), specimen records from the participating institutions, and detailed species profiles, like this one on the endolithic *Bagliettoa rubrocincta*: **https://lichenportal.org/cnalh/taxa/index.php?taxon=Bagliettoa+rubrocincta**.

*—General Biology of Lichens*

Nash III, T.H. (ed.). 2008. *Lichen Biology.* Second Edition. Cambridge University Press, Cambridge. 486 pp.

This textbook is still the most current account of lichen biology. Its different chapters are all written by outstanding experts in their field. The book deals with photobionts, mycobionts, morphology and anatomy, morphogenesis, reproduction, biochemistry and secondary metabolites, physicology, nutrient cycling, population and environmental ecology, lichens as ecological indicators, biogeography, and systematics. The chapters do an excellent job at summarizing current knowledge, but they are written with an academic audience in mind and are less accessible than more general books on lichens. In particular the chapter on lichen systematics has now been outpaced by more current research. Based on advances in molecular research the current understanding of lichen phylogeny has drastically changed and continues to keep evolving rapidly.

*—Lichen Biology and Species Identification*

Brodo, I.M., S.D. Sharnoff, & S. Sharnoff. 2001. *Lichens of North America.* Yale University Press, New Haven. 795 pp.

This is probably the most beautiful book on lichens with many outstanding color photographs that illustrate exceptionally well what these organisms look like. The book is

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Figure 9. A herbarium specimen of *Parmotrema internexum* from the Galapagos Islands; in the center the micro-mollusk *Pupisoma galapagorum*. As a fully grown adult this tiny snail measures only a millimeter in diameter. The lichen species occurs throughout the neotropics, but this minute snail only occurs in the Galapagos archipelago, where it lives and feeds on the lichen.

## Lichens in Arizona—More than Meets the Eye! *continued*

huge and heavy, but even it cannot possibly comprehensibly cover all North American lichens. The introduction, descriptions and keys are much more easily accessible, however, than many of the more academic books on lichens.

*—Sonoran Desert Lichens*

Nash III, T.H., B.D. Ryan, C. Gries, & F. Bungartz. (eds.). 2002. *Lichen Flora of the Greater Sonoran Desert Region.* Volume 1. Lichens Unlimited, Tempe. 532 pp.

Nash III, T.H., B.D. Ryan, P. Diederich, C. Gries, & F. Bungartz. (eds.). 2004. *Lichen Flora of the Greater Sonoran Desert Region.* Volume 2. Lichens Unlimited, Tempe. 704 pp.

Nash III, T.H., B.D. Ryan, , C. Gries, & F. Bungartz. (eds.). 2008. *Lichen Flora of the Greater Sonoran Desert Region.* Volume 3. Lichens Unlimited, Tempe. 567 pp.

When published, these three volumes were the first truly comprehensive accounts of lichen biota anywhere in the US and Mexico. Across the Southwest, a region as large as the Greater Sonoran Desert (southwestern USA: Arizona, Southern California; northwestern Mexico: Baja California, Baja California Sur, northern Sinaloa, and eastern Chihuahua). These three books still are the most reliable source for species identification. The identification keys and descriptions are not as accessible as *Lichens of North America* and require a thorough understanding of terminology being introduced in detail in the introduction to Volume 1.

*—Field Guides*

Unfortunately, no field guide to lichens of Arizona exists and the Sonoran books are too heavy to carry around. Thus, one has to rely on neighboring states:

Sharnoff, S. 2014. *California Lichens.* Yale University Press, New Haven. 405 pp.

Using many photos from *Lichens of North America* and many newer ones this is a heavy, but still portable field guide, which covers many species that also occur in Arizona, especially those bordering southern California in their distribution.

Tripp, E. 2017. *A Field Guide to the Lichens of White Rocks: (Boulder, Colorado).* University Press of Colorado, Boulder. 192 pp.

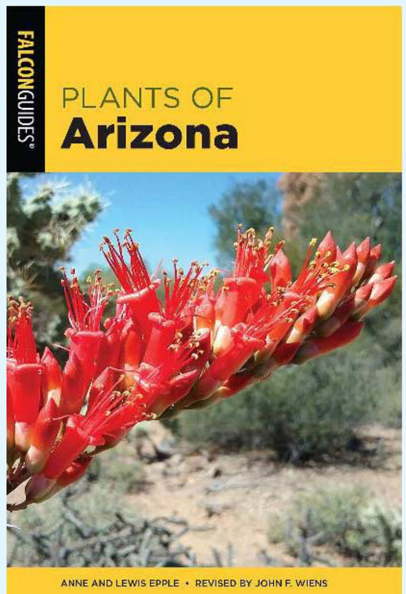
This is a nicely illustrated booklet with many of the species found at higher altitude on the Colorado plateau and thus a valuable addition to Steve Sharnoff's California guide.

BOOK REVIEW *Anita Thompson, Apache County Agricultural Extension, University of Arizona, Arizona Native Plant Society*

# Plants of Arizona, 3rd Edition by Anne and Lewis Epple, Revised by John F. Wiens, *Photos by Lewis Epple, John F. Wiens, and Julie H. Wiens.*

2021. 480 Pages. $34.95. Falcon Guides, Guilford Connecticut. Available from many independent booksellers, at local botanical gardens, through retailers supporting electronic readers, and from online retailers.

*Plants of Arizona* was originally published in 1997 by Anne and Lewis Epple. It was revised once in 2012 and most recently in 2021 by John F. Wiens. In each revision, new plants and photos were added, and common names and botanical nomenclature were updated. As someone who has a well-loved 1997 edition of this book, this new update is a nice addition to an already coveted and readily recommended field guide.




The original authors, Anne and Lewis Epple were well-known in the Arizona botanical world as they spent several years researching and photographing plants for the original edition. Anne Orth Epple has written books on other scientific topics, including fossils and amphibians. Lewis Epple, who passed away earlier this year, was the original photographer of the plants in the book. The photos remain a primary part of the book honoring his memory. John F. Wiens is a research associate at the Arizona-Sonora Desert Museum and has a significant background in the Arizona flora, and its distinct and diverse character. He has brought his extensive botanical knowledge and background as a horticulturist and researcher to this field guide which has added an expanded dimension to the already well-loved 1997 version of the guide.

One of the reasons *Plants of Arizona* is such a coveted field guide is the authors' focus on the flower as a primary identification piece. It makes the identification of both native and non-native plants found in Arizona so much easier and quicker. In addition, plants for all elevations and life zones are included in the guide. You can tuck it in your backpack for plant identification regardless of whether you are headed to the Sonoran Desert, over to the juniper woodlands, or up to Mount Baldy.

The book is divided into several sections that are very helpful to the plant identification novice, or more seasoned plant guide users that just need helpful reminders. The first section covers the Arizona life zones, everything from the deserts to the alpine zones. This is followed by plant-family descriptions, which cover most plant families. Dicots, monocots, gymnosperms, and ferns are all represented. Listed under each family is the formal nomenclature, a description of how the plants grow in Arizona (shrub, forb, etc.), and a generalized botanical description of the plants in that family by flower, leaf, and fruit.

After the main identification section, there is a helpful glossary of terms used in the book, a reference page showing the parts of the flower, a list of references, and an index with both scientific and common names of the plants. The book is laid out well and has a good flow that even the newest plant aficionado can use.

The highlight of the book is the approximately 1,100 plants featured with full-color pictures showing at a minimum the flower, and many times there are also photographs of leaves or the general structure of each plant. The angiosperms are listed first and divided into flower bloom-color classes: white to cream, yellow, orange, red, pink to purple, blue, and green to brown. Then the cacti are followed by the gymnosperms, and last are the ferns. Each plant is labelled with the primary common name in bold, followed by any other common names. Then the botanical/scientific name is listed, with the family name. Each plant then has a description by form, flower, leaves and stems, time of flower bloom, elevation, habitat, and any comments.

Identifying plants can be a challenge for even the most seasoned botanists, and a good field guide is worth its weight in gold. *Plants of Arizona* has multiple things that make it a highly desirable plant guide, from covering multiple elevations and life zones, to the clear and beautiful photographs, and my personal favorite — it can be purchased and loaded on my reading application on my phone which means I can carry the guide with me for easy access anywhere I go. Even if you prefer the book format, it's small enough to pop in your backpack or in the glove box of your car for easy reference. The book will be a great addition for both the plant novice and the seasoned botanist.

Slime molds can be grown in culture by incubating wood or other dead vegetation in a moist chamber. This *Arcyria cineria* grew within a few days of soaking a small piece of wood overnight and then incubating the wood fragment in a moist chamber at room temperature for a few days. The colorless moist "blobs" are plasmodia, and the stalked white conical structures are sporangia (fruiting bodies).

Sometimes *Arcyria cineria* grows as a single conical stalked sporangium, but other times sporangia occur in clusters. These clusters were photographed on a rotting log in Ramsey Canyon, Coronado National Forest, at 5,500 ft. in elevation, in oak forest during the summer monsoons.

# Just Add Water: The Slime Molds of Southern Arizona

*by Jillian Cowles[1] Photos courtesy the author.*

The deserts of southern Arizona may seem like an unlikely place to find delicate, moisture-loving slime molds. However, under the right conditions, slime molds are actually surprisingly abundant at all elevations, including in the low, hot desert. The key ingredient for slime molds is water — a deep, soaking rain followed by a few days of further moisture is necessary for these organisms to complete their extraordinary life cycle. Discovering these fascinating, primitive organisms in diverse habitats throughout Arizona can add a rewarding dimension to traditional forays for higher plants.

Inset: *Arcyria denudata*

The need for water is not surprising given that slime molds are actually amoebae in the Kingdom Protista. This may seem counter-intuitive, given that specimens of slime molds are traditionally kept in herbarium collections. Initially, both fungi and slime molds were thought to be plants, and even after fungi were classified as belonging to their own kingdom (separate from plants), slime molds were lumped in with fungi until relatively recently. It was not until 1969 that Lindsay Olive proposed that members of the subkingdom Gymnomycota (slime molds) be transferred to the Kingdom Protista based upon the fact that the slime molds ingest their food, rather than absorbing nutrients as fungi do. Slime molds are the predators of the detritivore world, feeding on bacteria, molds, and other slime molds.

There are three classes of amoebozoan slime molds in the Phylum Mycetozoa: Myxogastria, Dictyostelia, and Protostelia. The Myxogastria are also known as plasmodial, or acellular, slime molds. The nuclei divide and multiply in the plasmodium without corresponding cellular division, creating a multinucleate giant cell (coenocyte or syncytium). There may be many thousands of nuclei in a coenocyte. The Dictyostelia are known as the cellular or social slime molds. Individual amoeba, each consisting of only a single small cell, band together to form a motile grex (or slug) before forming a fruiting body. Some of the amoebae sacrifice themselves to form the stalk, while others form the spores of the fruiting body. The last class comprises the Protostelia. These form simple fruiting bodies that have only a few spores each.

The life cycle of the myxomycetes has been studied in some detail. The spore, which contains a single set of chromosomes, is haploid. It germinates into either a myxamoeba (amoeboid in form) or a swarm cell (with flagella). These two morphotypes

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[1]Arizona Native Plant Society, Tucson Chapter,
**jillian@mindspring.com**

*Ceratiomyxa fruticulosa* var. *arbuscula* is one of two morphotypes of this species. These are among the most commonly observed slime molds, growing on dead trees and rotten logs at all elevations. These structures are only a few millimeters in height.

*Ceratiomyxa fruticulosa* not only occurs in two varieties: (*arbuscula* and *porioides*), but also occurs in two colors: yellow and white (or colorless). *Ceratiomyxa* belongs to the Protostelia class of slime molds.

## Just Add Water: The Slime Molds of Southern Arizona *continued*

are interconvertible. Under very wet conditions, myxamoebae convert into swarm cells, which swim and feed readily. Under slightly drier conditions, swarm cells convert into myxamoebae. If conditions become too dry, these single cells can convert into microcysts, which can survive for long periods of dry conditions. The myxamoeba morphotype is able to undergo regular cell division (mitosis), and after multiple divisions, can produce large populations of cells. The swarm cell does not divide, but functions as the sex cell (gamete). If two compatible swarm cells meet, mating occurs. The two swarm cells go "head to head," their flagella thrashing as they push together. The protoplasm of the two cells fuse together (plasmogamy), followed by the fusion of the two nuclei (karygamy), resulting in a diploid cell containing the full set of chromosomes (zygote). Now the plasmodium can form. The ever-increasing number of diploid nuclei divide at the same time (synchronously) via mitosis, but the cell does not divide; thus the coenocyte may contain tens of thousands of nuclei bound together within a single cell membrane. Bits of the plasmodium can be cut off, each regenerating to form a plasmodium. Bits of the plasmodium can also directly form diploid swarm cells and diploid myxamoebae as a form of asexual reproduction. Those diploid cells can then go on to form new plasmodia. If conditions become too dry, the plasmodium can convert into a desiccation-resistant structure (sclerotium) that can be revived with moisture. Conversion back

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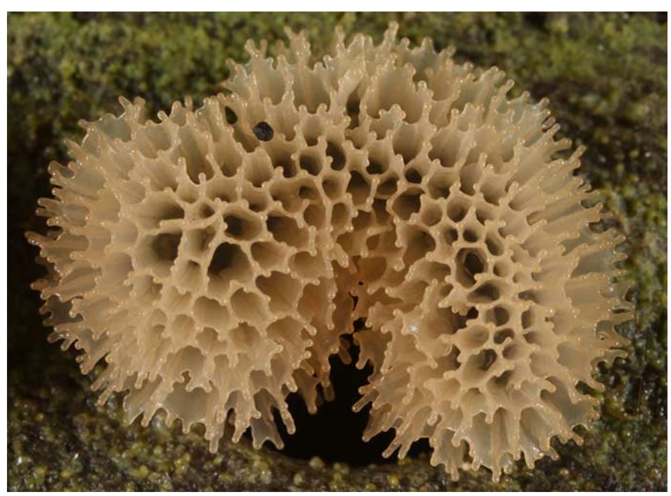
The "fuzzy" appearance of this *Ceratiomyxa fruticulosa* var. *arbuscula* is due to many hundreds of tiny sporulating stalks, each of which produces only a few spores. Simple fruiting bodies are characteristic of the Class Protestelia.



*Ceratiomyxa fruticulosa* var. *porioides* is one of two morphotypes of this species. These structures can be a centimeter or more in diameter.

*Diderma hemisphaericum* is an uncommon myxomycete in the Sonoran Desert. This specimen was found at low elevation (3,300 ft.) during the summer monsoons in a mesquite bosque among rotting leaves and twigs lying on the ground and represents the first documented occurrence of the species in Arizona.

This *Didymium nigripes* was growing on a rotting leaf lying on the ground at about 8,000 ft elevation, in mixed conifer/hardwood forest. During the summer monsoons, this is an especially rich habitat for myxomycetes.

## Just Add Water: The Slime Molds of Southern Arizona *continued*

to the plasmodium allows the completion of the life cycle with formation of new fruiting bodies. All of this can happen in as little as 12 to 24 hours.

Sporulation is a non-reversible stage of the life cycle. Some species produce haploid spores, but other species undergo incomplete meiosis during spore formation and can produce diploid or even polyploid spores. These are called *apogamic* species, meaning "without gametes." Whereas two haploid swarm cells must fuse (mate) to produce a plasmodium, diploid spores can germinate directly into diploid myxamoebae (without mating) and can then progress to a plasmodium.

The key to the success of slime molds in arid deserts lies in their extremely complicated life cycle. In the case of the myxomycetes (Myxogastria), if conditions become unfavorable, they can convert from moist, delicate organisms into dry, non-trophic microcysts or into a compact mass of hardened tissue (sclerotium), depending on their life stage at the time. The spores are also extremely resilient, remaining viable after long periods of desiccation. Another adaptation that may provide a critical advantage is the speed with which myxomycetes can complete their life cycle. One species, *Didymium eremophilum*, can complete its life cycle (from spore germination to sporulation) in as little as 3 to 7 days. In addition, if the plasmodium converts into a sclerotium, the sclerotium can recommence life as a plasmodium if conditions become wet again, shortening the time needed to progress to sporulation.

This *Didymium squamulosum* was growing at low elevation (3,300 ft.) in a mesquite bosque among rotting leaves and twigs on the ground during the summer monsoons. Mesquite bosques are an under-sampled habitat, despite the rich diversity of species of myxomycetes growing there.

Although deserts are indeed unfavorable for slime molds most of the time, a surprising number of species can be found in the Sonoran Desert after several days of rain, especially during summers with abundant monsoon rains. One study (Blackwell and Gilbertson 1980) found 52 species in the Sonoran Desert. A wider sample area including higher elevations within 145 km. of Tucson found 63 species (Evenson 1961). The presence of myxomycetes may indeed be ubiquitous in some areas of the desert. In one study, every pith sample taken from dead saguaros grew at least one species of myxomycete after incubation in a moist chamber (Blackwell and Gilbertson 1984). Dead succulents such as cacti and agaves seem to be especially conducive to slime molds; however, other habitats may be equally rich, but under-sampled at this time. Mesquite bosques in the low desert were not included in published studies of slime molds from the Sonoran Desert, and they can be incredibly rich during good summer monsoons. Some species, such as *Fuligo septica* and *Lycogala epidendrum*, are cosmopolitan, occurring from the high-elevation conifer and hardwood forests on the top

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*Fuligo septica* is a cosmopolitan species, found in many habitats on many continents. The plasmodium stage can be several centimeters across, easy to detect on a forest path or on a lawn. A common name for this myxomycete is "dog vomit slime mold."

A mature *Fuligo septica* forms a mound-shaped fruiting body called an *aethalium*. These can be over ten centimeters in length.

*Lycogala epidendrum* is a cosmopolitan species found all over the world. This myxomycete is frequently found on rotting trees, and because it may reach almost a centimeter across, it is one of the first slime molds that most people find. The spherical fruiting body seen here is called an *aethalium*.

*Metatrichia floriformis* can be found in high, cool forests in the late summer. These myxomycetes were growing on a soggy, well-rotted log in mixed conifer/hardwood forest at about 8,000 ft. in elevation. The outer covering (the peridium) of the stalked sporangium has a metallic sheen. Some myxomycetes can have brilliantly iridescent colors.

This brightly colorful *Physarum citrinum* was growing on rotten wood at 8,000 ft. in elevation in a cool, mixed conifer/hardwood forest. The summer monsoons bring out many species of myxomycetes in cool forest habitat.

This *Trichia decipiens* was growing on the charred, fallen pine tree on top of Mt. Lemmon where the Bighorn Fire had swept through the previous summer. As predators in the community of decomposers, slime molds can feed on bacteria, yeasts, fungi, and other slime molds.

This *Tubifera* species was growing in the oak zone at 5,500 ft. elevation in The Nature Conservancy's Ramsey Canyon Preserve, Cochise County. The fruiting bodies of *Tubifera* do not completely fuse together, so this composite structure is called a *pseudoaethalium*.

*continued page 35*

# A Brief History of the Vascular Plants of Arizona Project and the Journal *CANOTIA*

*by Les Landrum*[1]

In 1987, the botanists at the herbaria of Arizona State University and the University of Arizona formed an editorial committee with the intent of producing a new book — *Vascular Plants of Arizona*. Why did we think it was necessary?

The first manuals for identifying the plants of the state were *Flora of Arizona and New Mexico* by Tidestrom & Kittle (1941) and *Flowering Plants and Ferns of Arizona* by Kearney and Peebles (1942). When the latter, a government publication, was no longer available, the authors revised their book, and it was republished in 1951 by the University of California Press under the title of *Arizona Flora*, frequently known as "K & P" for the authors, Kearney and Peebles. A second edition appeared in 1960 with a supplement provided by John Thomas Howell, Elizabeth McClintock at the California Academy of Sciences, and collaborators. So, that last revised manual of Arizona plants is now 70 years old and the supplement is 60 years old. In 1987, it seemed like a good time to come out with a new and improved book on the plants of Arizona. K & P had been the botanical bible for Arizona for many years, and continues to be. But now we have the benefit of decades of botanical exploration. Glenn Rink made that clear in the last issue of *Plant Press Arizona* when he told us that *Penstemon* has grown from 38 species in 1960 to 49 or 50 now. Species new to science, heretofore overlooked species, and recent arrivals (some from far off corners of the world and other simply expanding their ranges from adjacent areas), are being added to the known flora of Arizona every year, about one per month on the average. That was a good reason to have a new book. Another reason is that K & P, as thick as it is, is a brief account of the flora. There are short family and generic descriptions, but no species descriptions. There are a few photographs, but no illustrations and no distribution maps. We have been able to add these to the Vascular Plants of Arizona (VPA) project.

The editorial committee for the VPA project included Chuck Mason, John Reeder, Don Pinkava, and Les Landrum, and together we had accumulated several acceptable manuscripts by various authors in the early 1990s. About this time the *Journal of the Arizona-Nevada Academy of Science* (JANAS) needed a new editor so Don Pinkava and I volunteered for the job with the thought of publishing VPA treatments in JANAS. We also had to handle many other articles submitted to JANAS as part of the bargain. Remember, there was no internet in those days, and part of our job was finding money for printing hundreds of copies. Once we had a few issues of VPA treatments published, Don and I went to visit the Dean of our College of Liberal Arts and Sciences to ask for money to publish another issue. The Dean was favorably impressed and decided to fund a graduate student research assistant as well! So, for a few years we had that extra help and graduate students at ASU produced several family treatments. Tina Ayers (at NAU) and I (at ASU) found that we could teach classes about "taxonomic revisions" and organize our students to write family or generic treatments. Glenn Rink and Max Licher, botanists associated with NAU, have taken on some large and difficult genera such as *Carex* and *Juncus*, and have authored treatments beautifully illustrated with drawings and photographs. Back in 1987, we thought we might have a completed project in a decade or so, in the lifetime of most of the editorial committee. Unfortunately, it has not turned out that way. So, it was a good decision to publish parts as we progressed so that they have become available for anyone to use. I no longer expect to have a book finished someday. I think the VPA project is more likely to be a continuous effort with new and/or improved versions of family treatments appearing from time to time. As you may have guessed, the VPA editorial committee is down to one person. If you think you would like to help out as a contributor or reviewer, please let me know.

In the early 2000s, I realized that a botanical journal with a few printed copies and posted online would be a lot less expensive than JANAS had been up till then. And we would not have to deal with the non-botanical manuscripts. So, in 2005 the journal CANOTIA was started, with its main purpose being a place to publish additional VPA treatments, and also accepting other related articles about plants and fungi (**https://canotia.org/**). The name comes from *Canotia holacantha*, a typical Arizona plant, nearly endemic to the state.

Ever since 2005, the Arizona Native Plant Society has supported the printing of about 40 copies of CANOTIA that are sent to major botanical institutions of the United States, Europe, and Latin America as well as local institutions in the Southwest. A few years ago, a helpful librarian obtained an ISSN number for CANOTIA and the Biodiversity Heritage Library (**https://www.biodiversitylibrary.org/**) now archives digital copies of CANOTIA.

All the VPA treatments from 1992 to 2021 are available to download as PDF files at **https://canotia.org/vpa_project.php**, a site hosted on a server at Arizona State University.

By my count, 97 family treatments have been completed and published; seven families have at least been partially published

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*continued next page*

# A Brief History *continued*

(e.g., Agavaceae, Cactaceae, Cyperaceae, Lamiaceae, and Malvaceae).

CANOTIA vol. 17 was recently published and includes four articles, all of which might be of interest to AZNPS members:

**Making Checklists with the SEINet Database/Symbiota Portals —** This paper should be useful to nearly all the users of the SEINet database. It tells you how to make simple temporary checklists as well as permanent ones, with voucher specimens, that might be part of research projects that last for years.

**NEARBY, a Computer Program for Phytogeographic Analysis Using Georeferenced Specimen Data —** The computer program described here is available on the internet and offers a new way of exploring plant distributions using the SEINet and other Symbiota databases. You can quickly find what species tend to grow together and compare their distributions in a multicolored map. You can make an illustrated list of plants that commonly grow with a chosen primary species, for example, with *Pinus ponderosa*.

**Solanaceae Part Seven: *Browallia, Calibrachoa, Capsicum, Jaltomata,* and *Salpichroa* —** This third paper completes the treatment of the family Solanaceae for the Vascular Plants of Arizona Project. Hurrah!

**The Decline and Fall of a Large Saguaro** — The last paper is a short photographic essay on the last days of a saguaro by John Alcock.

## *Fabaceae of Arizona* in press

Parallel to the VPA project has been a study of the Fabaceae of Arizona, which is expected to be published as a book (*Legumes of Arizona – an Illustrated Flora and Reference*) in mid 2022 by the Botanical Research Institute of Texas. The Fabaceae is one of the three largest families of plants in Arizona, so it is a very welcome contribution. We quote from the preface:

"Native, naturalized, and commonly cultivated legumes from Arizona are the focus of *Legumes of Arizona*. Uses and results of horticultural trials are here combined for the first time with keys, descriptions, maps, original illustrations, and photos. The aim of this project is to provide a true reference for botanists, gardeners, naturalists, and anyone who appreciates our diverse southwestern region.

"Led by the Desert Legume Program (DELEP), this project is a manifestation of the long collaboration between DELEP and the Boyce Thompson Arboretum. Additional partners include the College of Agriculture and Life Sciences at the University of Arizona, the University of Arizona Herbarium, and the Wallace Research Foundation. Most importantly, this is a product of immense volunteer contributions: 45 authors, each an expert on their groups or topics, plus 28 scientific illustrators, four photographers, one map maker, and an extraordinarily generous copy editor combined to create the contents of this volume."

# Just Add Water: The Slime Molds of Southern Arizona *continued from page 32*

of Mt. Lemmon all the way to low elevation desert habitat, while other species that require a particular substrate such as manure may be uncommon.

Rains over several consecutive days may be rare occurrences in the desert, but when they do happen, slime molds germinate and sporulate in a wide range of microhabitats. The ephemeral nature of these fascinating organisms makes them all the more exciting to discover. The photos presented here provide a guide to some of the slime molds of Arizona and indicate the types of habitats where they can typically be found.

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