



Grafting the Grape
American Grapevine
Rootstock in Missouri
& the World



Grafting the Grape American Grapevine Rootstock in Missouri & the World

Wine has long been a part of the history of the Missouri Botanical Garden, and it continues to play a role in the work the Garden does today. Grateful thanks to all of these contributors and collaborators to the Stephen and Peter Sachs Museum's exhibition and programs who shared their expertise, passion, and creativity on grapes, grapevines, and wine for this project. The Garden's Herbarium collects and preserves many *Vitis* species found around the world, and holds the legacy of the work Dr. George Engelmann started in the 19th century on the American *Vitis* species. The Garden's William T. Kemper Center for Home Gardening has partnered with Dr. Allison Miller on the *Vitis* Underground project, and planted native American vines as well as French-American grapevines for use in this research project (those grapes are on view at the Kemper Center today). The Garden's William L. Brown Center, Tower Grove House, Peter H. Raven Library, and Archives have all shared their collections in this exhibition.

Take a virtual tour of the museum:
<https://kuula.co/post/n1/collection/7kwy9>

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Artists Dornith Doherty, Lei Han, and Lorraine Walsh

Allison Miller, Saint Louis University and Danforth Plant Science Center; National Science Foundation Plant Genome Research Program 1546869.

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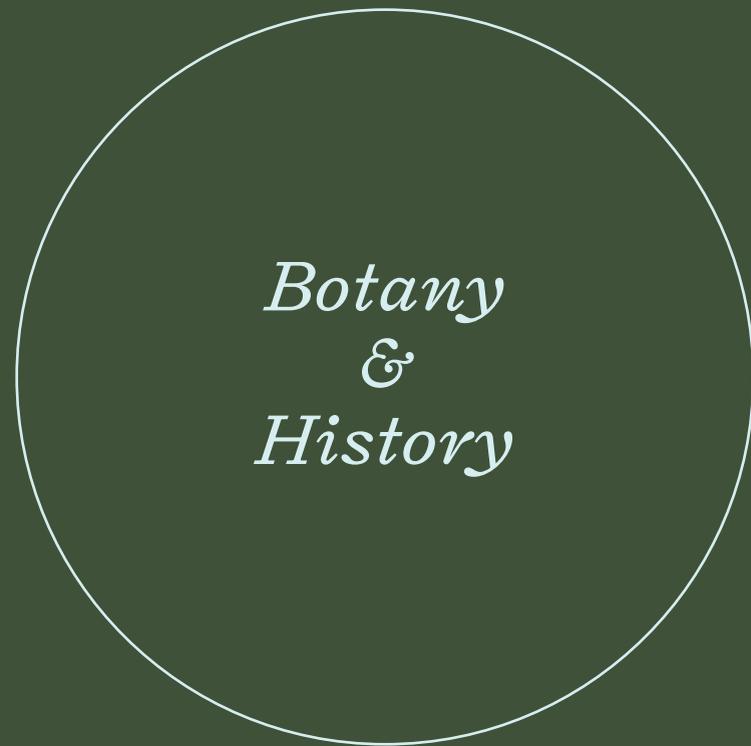
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Especial thanks to Virginia Harold for the exhibition photography, Hermannhof Winery & Vineyard for their beautiful location, and Studiopowell for the design of this publication.

*For millennia, humans have cultivated wine as a drink and for social, religious, and economic power. Drunk for social communion, held as a symbol of elite status, and offered in ritual ceremonies, wine made from the grapes of *Vitis vinifera* has been shipped and transplanted around the world, with the earliest winemaking traditions found in central Asia thousands of years ago. Today, wine enthusiasts are very familiar with the world-renowned wines that are grown in Europe, South America, South Africa, Australia, New Zealand, and the United States. Yet, drinking wine from this grape species would not be possible today without the research, identification, and development of 19th-century Missouri botanists, entomologists, and viticulturists.*

- *inside cover*
Wine harvest
Opus Ruralium Commedorum
Pietro de Crescenzi (1230-1320)
Leuven, Belgium ca. 1474
Courtesy of the Missouri Botanical
Garden Peter H. Raven Library



Grapes & the Garden

What's in a Grape

Winemaking 101

The Material Culture

Saving Wine for the World

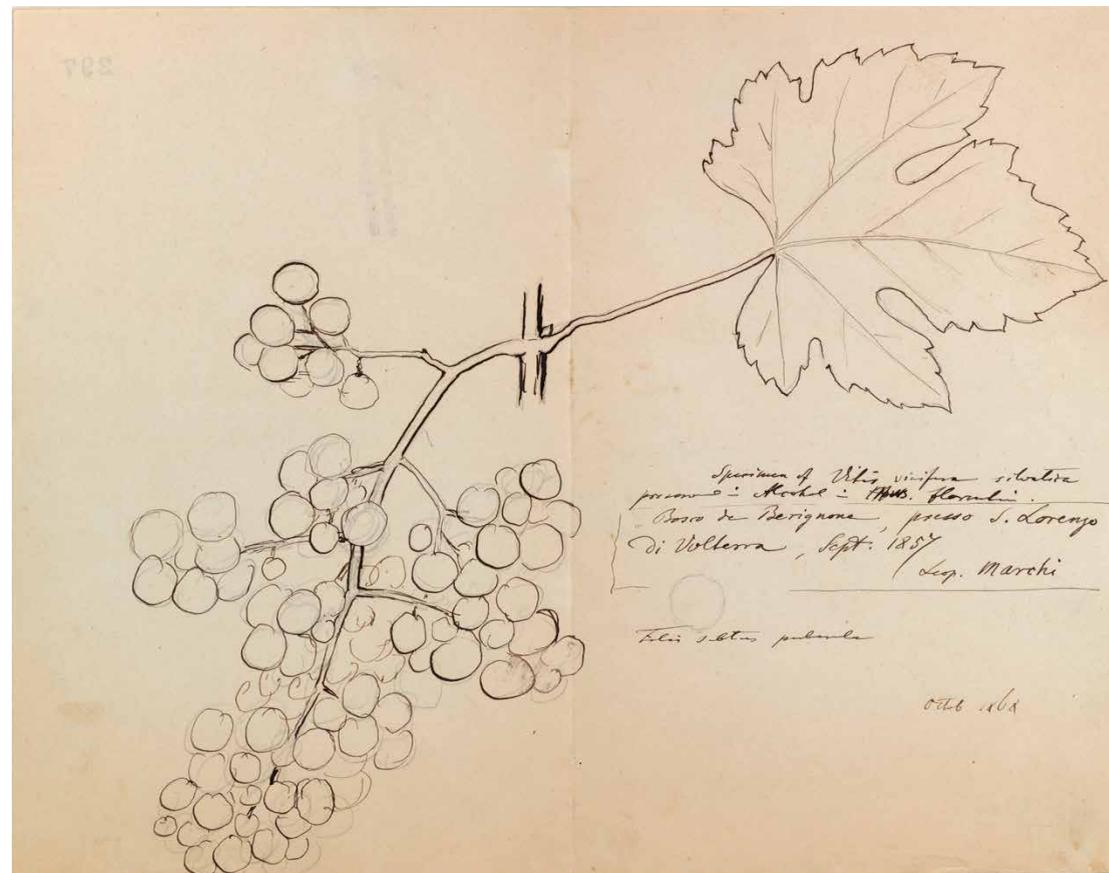
Grafting's the Thing

Vitis Underground

Missouri Winemaking

The Grafting the Grape exhibition explores the various American grape species that are most used in viticulture, grafting, and winemaking, and how they were and continue to be used by the Native peoples of Missouri. Today, these American grapevine rootstock species continue to provide research challenges as scientists study and understand how the rootstock plants affect the scion plant's berries and chemical compounds (which affect the final wine product) as well as how climate change is impacting the future of viticulture around the world. You can see a few examples of grafted and own-rooted (ungrafted) grapevines in the test plots of the Garden's William T. Kemper Center for Home Gardening (located within the purple circle on the map below).

Grapes & the Garden



Wine has long been a part of the material history of the Missouri Botanical Garden. Garden founder Henry Shaw (1800-1889) was a dedicated oenophile—a connoisseur of wines—as well as a supporter of botanical science and a successful businessman in St. Louis. The Garden's first botanical advisor, Dr. George Engelmann (1809-1884) aided Shaw in developing the Garden into a scientific research institution; he spent a significant time focusing on the identification and understanding of the American grapevine species when he came to St. Louis. Engelmann spent a great deal of time studying grapes, and specifically native American grapes, writing a number of publications on the varieties and classifications of grape species. Today, the Garden's Kemper Center for Home Gardening has a plot of several American grapevine plants and hybrids growing as part of a research project started and managed by botanist Dr. Allison Miller, professor at St. Louis University and principal investigator at the Danforth Plant Science Center.

- *top right*
Drawing of Native Missouri Grapes by
George Engelmann
- *bottom left*
Map of the Kemper Center
for Home Gardening
Missouri Botanical Garden



What's in a grape?

The grape family, Vitaceae, is mostly distributed in the pantropical areas in Asia, Africa, Australia, the neotropics, and the Pacific islands, with a few genera in temperate regions. There is strong support for Vitaceae as the earliest diverging lineage of rosids—a major group of flowering plants including apples, walnuts, and chocolate. *Vitis* is a relatively ancient clade, and its evolution has been shaped by Earth's climatic fluctuations and continental drift; a clade is a natural group of organisms that are composed of a common ancestor and all its lineal descendants.

The American *Vitis* species that the **Grafting the Grape** exhibition explores have an ancient history. These grapevines and berries were first harvested by the Indigenous peoples who first inhabited the North American continent, and who lived or traveled through the lands that are now designated as the boundaries of the state of Missouri. Throughout the period of European colonization and settlement, Indigenous Americans continued to use these species throughout the North American continent and today, these native grapes are one of many native American plants that play a role in Indigenous culture and foodways.

The country of Georgia, in the south-eastern corner of Europe, is located on an isthmus between the Black and Caspian Seas, a crossroads of diverse regional ecosystems, cultures and languages. The rugged, mountainous terrain has contributed to the region's high biocultural diversity, harboring biological and cultural systems that have co-evolved over millennia. In addition to its high levels of plant diversity, Georgia is home to an ancient agricultural practice, and the center of domestication for multiple food crops including wheat, legumes, and fruits, such as grapes, which includes one of the world's most desirable agricultural commodities, wine made from *Vitis vinifera*.

Documented in the archaeological record as the earliest region of winemaking (as early as 6000 BCE), Georgia has a long history and association with wine in its culture, including its use in Christian ritual and traditions; today Georgia is also a young winemaking country as its industry has been reborn since the Soviet era. Additionally, it remains common for Georgian families to grow their own grapes and make their own wine. One of the most identifiable tools and symbols of Georgian winemaking is the vessel used to make, store, and age the beverage, the *kvevri* or *qevri*, which is still used in modern Georgian winemaking, and can range in size from 5 to 3500 liters.

Earliest evidence of ancient winemaking in the Republic of Georgia

- *left*
Backyard Home-Garden and Rkatsiteli Vineyard Nearing/Awaiting Harvest, Ujarma, Georgia
Photograph by Aurora Prehn, ca. 2019

Winemaking 101

Wine is fermented grape juice. At its simplest, wine is made by crushing grapes and allowing the natural yeasts present on the skins to come in to contact with the natural sugars present in the juice. No other human intervention is needed: crushed and fermented like this, any grapes will make wine. Fermentation stops at an alcohol concentration of about 16%—at this point, yeast cannot tolerate the high level of alcohol, they die, and fermentation stops. There are three types of wines: table, sparkling, and fortified. If fermented to dryness, the alcohol of table wines falls within the 11-15% alcohol concentration range. Sparkling wines are the ones with bubbles—such as Champagne—which are achieved by placing wines through a second fermentation in bottles, after which the bottle is opened to eliminate excessive pressure, and then resealed; these have alcohol concentrations around 12%. In fortified wines, brandy (a distillate of wine) is added to make the alcohol content higher (16 to 23%). After fermentation and before bottling, wine is clarified by filtration and then microbially stabilized. Wine flavors can continue to change while the wine is stored in wooden barrels, stainless steel tanks, and glass bottles. Red wines are fermented with the skins. After crushing the grapes, the combination of juice and skins is known as “must.” The must is fermented, and then pressed to retain only the fermented liquid; the grapes skins are removed. White wines are fermented after the must has been pressed to extract the juice. No skins are present during the fermentation with the resulting wine considered “white.” Rosé wines are white wines made with red grapes. The must is pressed when its color is the desirable shade of rose. After pressing, the skins are removed and the fermented liquid retains the desirable shade of rose.



- *top left*
Wine Cellar at Hermmannhof Winery
Photograph by Cassidy Moody
- *bottom left*
From a wine tasting at Hermmannhof Winery
Photograph by Cassidy Moody

The material culture of wine



The making, storage, presentation, and drinking of wine offers a long historical legacy of objects created to enjoy this unique beverage. Presses, barrels, corks, and corkscrews are various tools used to make and store wine so that it can be preserved and aged to enhance the flavor and experience of tasting wine. It is the history and development of glass that has been used to great effect in the manufacture of decanters and glasses to enjoy wine through the senses of vision, scent, and taste. Decanters are formal containers for wine and spirits that allow for the color of the liquid inside to be appreciated at a glance, but also to perform the function of 'decanting' wine by aerating, or exposing the wine to oxygen; this process enhances the flavors and releases the gasses that developed during the aging, or refining, process, and can be said to let the wine 'breathe.' Wine glasses come in a wide variety of shapes and sizes as each type of wine glass shape is suited to a specific type of wine or wine-based drink. The earliest forms of wine glasses were developed by the ancient Romans, who enjoyed being able to see the color of their wine through their transparent and almost-colorless glass vessels. 15th-century Venetian glassblowers crafted the shape of the wine glass—the base, stem, and bowl—that is the standard design today. Specialized glasses were developed for drinking different wine-based drink, such as bubbly Champagne, or cordials for fortified wines (such as sherry and port), and liqueur glasses for spirits, such as brandy—a distillate of wine. The shapes of the bowls allow for the fragrance, flavors, and carbonation to be viewed and contained, so that scent and the taste of the beverage is experienced at its fullest.



top left

- A collection of wine glasses lent to the Museum exhibition
Courtesy of Dr. Peter Wyse Jackson Collection
Photograph by Virginia Harold

bottom left

- Small fruit basket press
Courtesy of Dr. Peter Wyse Jackson Collection
Photograph by Virginia Harold

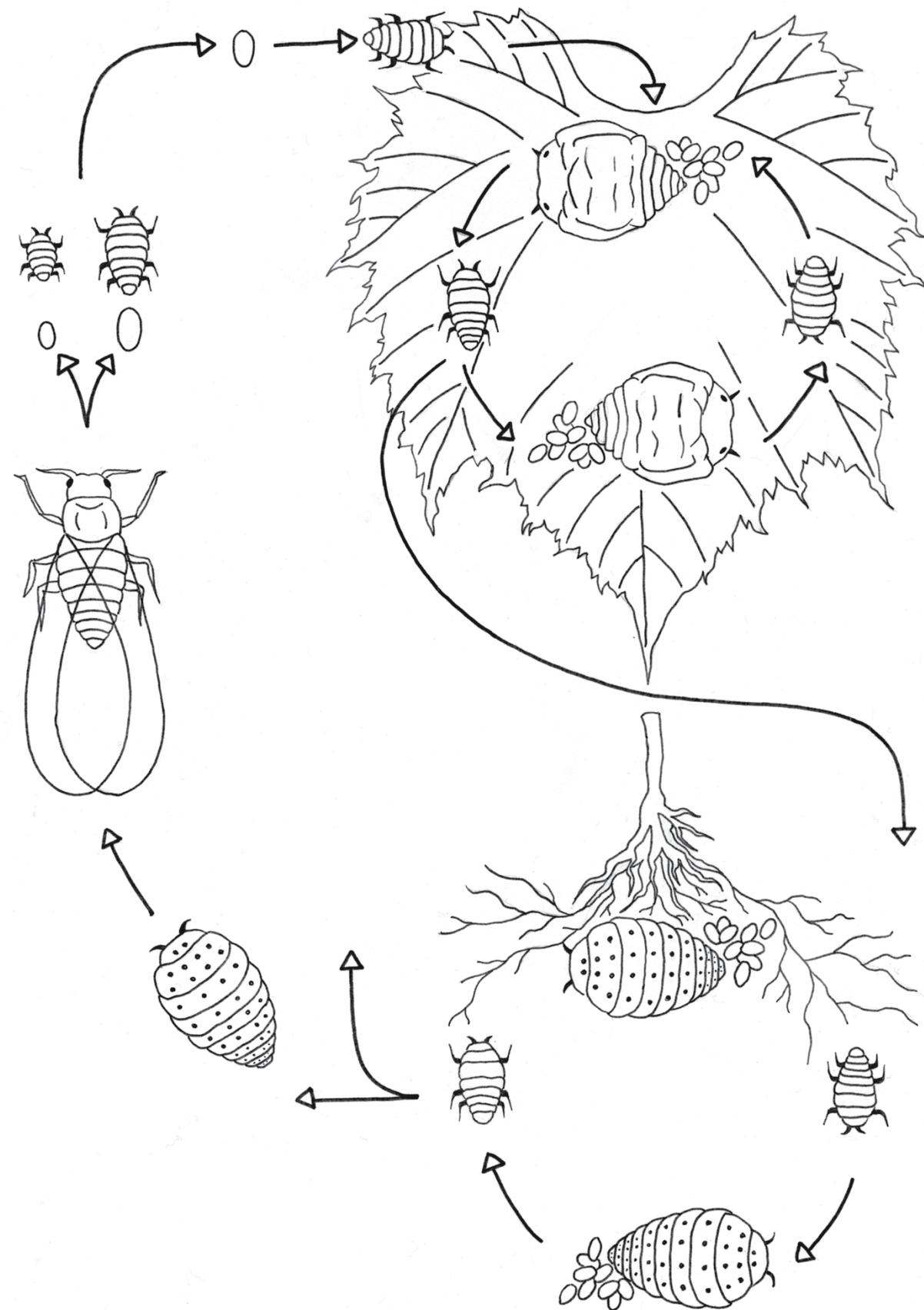
For millennia, humans have cultivated wine as a drink and for social, religious, and economic power. Drunk for social communion, held as a symbol of elite status, and offered in ritual ceremonies, wine made from the grapes of *Vitis vinifera* has been shipped and transplanted around the world, with the earliest winemaking traditions found in central Asia thousands of years ago. Today, wine enthusiasts are very familiar with the world-renowned wines that are grown in Europe, South America, South Africa, Australia, New Zealand, and the United States. Yet, drinking wine from this grape species would not be possible today without the research, identification, and development of 19th-century Missouri botanists, entomologists, and viticulturists.

A key culprit in this agricultural innovation is the result of an insect, grape phylloxera, which found its way from the American Midwest to the vineyards of Europe in the 1850s; by the 1870s had devastated the wine grape crop there, attacking and feeding on the plant's roots to the point of killing the plants completely. It was the work of the Dr. George Engelmann and the Missouri state entomologist Charles V. Riley, that identified the lifecycle of grape phylloxera (as evidenced on the native American grapevine plants and rootstock) as the cause of the devastation.

The scientific name of grape phylloxera *Daktulosphaira vitifoliae* means "fingerball of vine leaf." This insect is barely perceptible by the naked eye, yet it causes an immense impact to the grapevine plants that humans have been using to make wine for millennia. Endemic to North America, closely related to aphids, this insect belongs to the family Phylloxeridae in the order Hemiptera (true bugs) which share similar arrangements of sucking mouthparts; most phylloxerid species produce galls on dicotyledonous plants, which are seeds that have two embryonic leaves or cotyledons. The life cycle of grape phylloxera is complex, due to its four different forms, all of which can reproduce either from sexual or parthenogenetic reproduction (reproduction without ovum fertilization), and they can be found underground or on the leaves of the grapevine. Grape phylloxera's ability reproduce asexually exponentially is one reason it devastated European vineyards so quickly.

The four forms are: the wingless, root-feeding form (radicole); a winged, egg laying form (alate); a wingless, sexual form (fundatrix); and a wingless, leaf-galling form (gallicole). Due to its minute size, the presence of the gallicole, or wingless female is almost imperceptible if not for the distinctive galls that they form on leaves. Grape phylloxera galls are wrinkly pouch-like growths on the bottom of the leaf that also have very fine translucent hairs. The galls are approximately the size of a pea and at the worst point of infestation, can completely fill the underside of a leaf. Today, grape phylloxera can be controlled as part of an integrated pest management plan or with pesticides. There are few vineyards around the world that have not been touched by this insect; namely certain sections of Australia, the country of Chile, and the Mosel region of Germany. Several factors likely play a role as natural barriers to grape phylloxera infestation, including soil composition and geographical isolation.

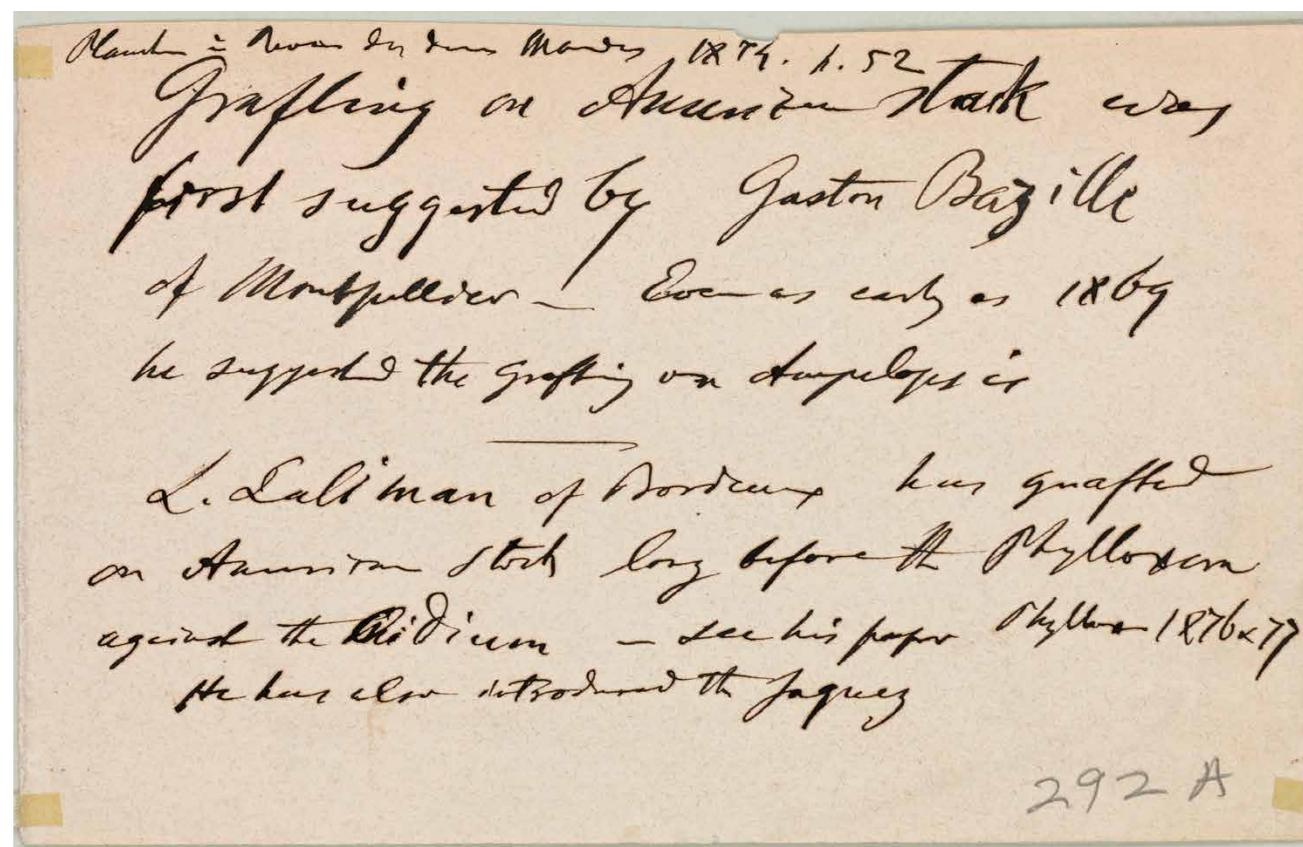
A botanist and an entomologist saved wine for the world



● *right*
Grape phylloxera life cycle
Illustration by Natalia Granquist

The technique of grafting developed thousands of years ago, with some of the earliest cultivated orchards confined to fig, olive, pomegranate, grape, and date palms propagated from cuttings or division of root stock. Grafting developed because agriculturalists realized that growing new plants from seeds of existing trees did not breed true, therefore they developed grafting so that they would control the end result of the fruit tree. In North America, grafting was widely used in apple orchards, resulting in the discovery and creation of numerous apple variations. The grafting and propagation of apple and other fruit trees became essential to many settlers moving west as they colonized the continent.

Grafting's the thing

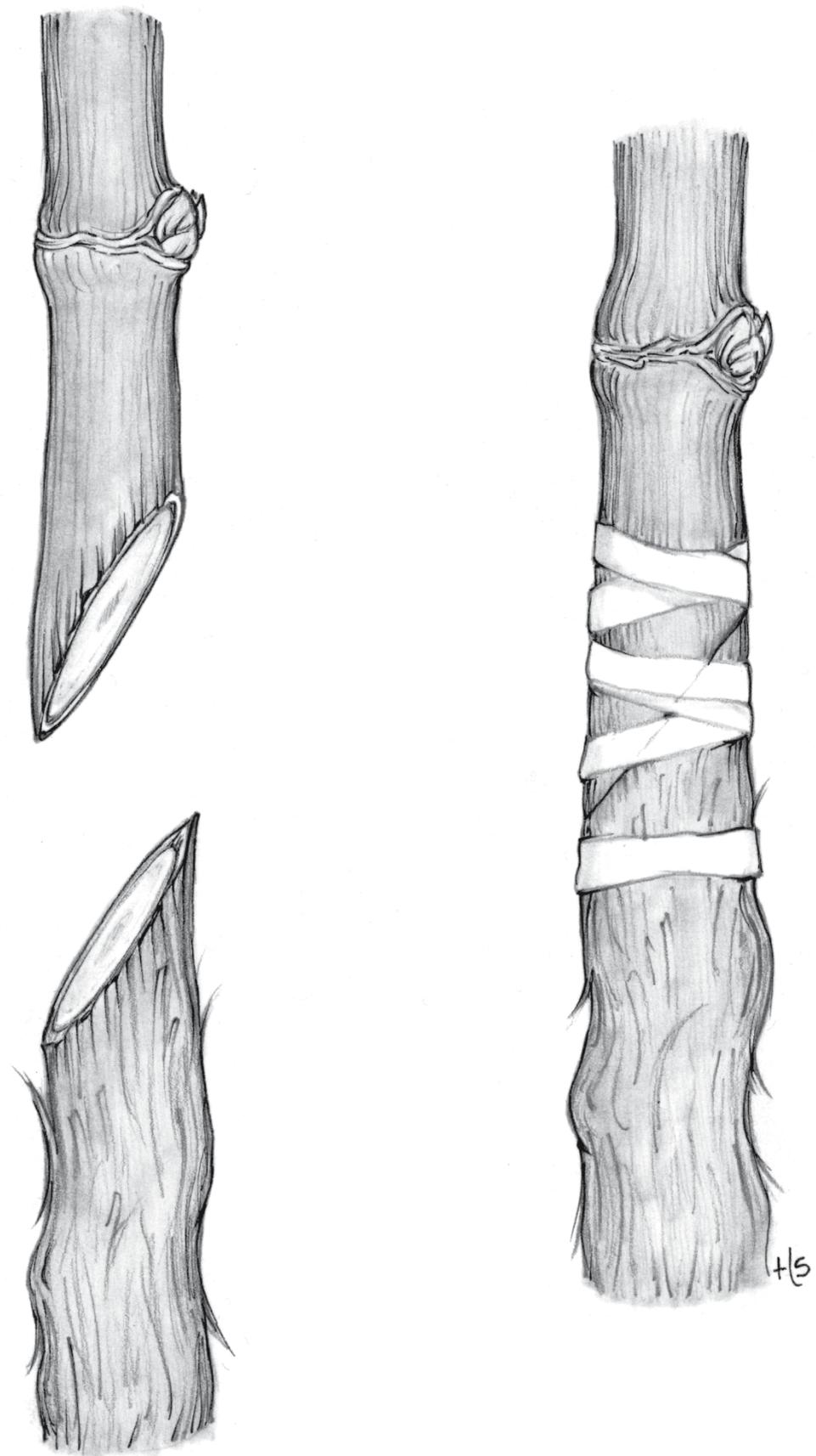


In this handwritten note (left), Engelmann credits the first idea to graft European grapevines onto American grapevine rootstock to Gaston Bazille and Leo Laliman, two French wine growers. This idea came after the idea to replace French vines with American ones, something that many rejected because of the perceived inferiority of American grapes. By grafting French vines on American rootstocks, the French would be able to utilize American resistance but keep their beloved French grapes.

- *top*
 Grape vine rootstocks prepared for imaging
 Courtesy of Allison Miller
 Photograph by Laura Klein
- *left*
 Grafting on American Stock was First Suggested by Gaston Bazille on Montpellier (n.d.)
 Courtesy of the Missouri Botanical Garden Archives, Dr. George Engelmann Papers

Grafting is the deliberate fusion of two plants into one by cutting off the upper part of one plant (called the scion), typically a shoot or bud, and inserting it into the lower part of another, closely related species plant, (called the stock) that must always include the root system. When grafting, the scion will contain multiple buds, but only a single bud is grafted at a time. The only requirement for grafting and budding is viable cambium contact. The cambium is a single layer of cells located just below the bark. This area leads to the formation of the graft union of the scion and rootstock. Increased cambial contact (the more area that touches) between scion and rootstock increases the chances of success. There are multiple types of grafts, some of the most common are bud, cleft, or whip grafts; the whip graft is one of the oldest known methods of grafting techniques and offers the largest surface area contact between scion and rootstock, thereby making the greatest chance for the graft union healing to occur.

When the grape phylloxera infestation devastated European vineyards in the late 19th century by affecting the plant roots, and Engelmann and Riley identified the insect, they also worked with French and American viticulturists to provide the solution. This solution was to graft the European grapevine on to American grapevine rootstock, since the American plants were more resistant to phylloxera (there's a chemical compound in the roots that makes it less tasty to the insect). To determine which classifications of vines were best suited, Riley sought out Engelmann, and using Engelmann's knowledge and grapevine herbarium specimens, they figured out which species were best suited and orchestrated the export of resistant seedlings and grapevines to France. Riley found even more evidence in support of his solution when visiting the Isidor Bush-Meissner nursery in St. Louis where it was clear the European vines that had these insects on their roots would wilt and die when planted. The nursery created the Bushberg Catalogue, which also referenced Engelmann's work, to offer hundreds of options to French wine growers for grafting. Thousands of vines were subsequently shipped to France from the Isidor Bush-Meissner nursery. Almost a decade later, their solution proved promising and would save the French wine industry and others as the pest spread. Now found throughout the world, the same solution to control the phylloxera pest continues to this day.



● *right*
Whip graft
 Illustration by Heather Sheppard
 Herbarium 6212675

Vitis Underground



Dr. Allison Miller and her Vitis Underground project team have found that different rootstock/scion combinations can modify traits of the overall grape plant, including changes in berry skin tissue. She also found that rootstock and irrigation affected variation in leaf shape; for example, irrigated plants had more circular leaves while water-deficient vines had deeply lobed leaves with increased serration (jagged edge). Rootstock type, along with other factors, also altered mineral concentrations, and may also affect increased grape production.

Researchers on the Vitis Underground team are collecting samples of leaf and berry tissue at 50% anthesis (halfway through a plant's flowering period) as part of the Aim 1 project to assess phenotypic variation of a common scion plant ('Chambourcin') by growing it ungrafted and grafted to three different rootstocks in an experimental vineyard at The University of Missouri Southwest Center Agricultural Experiment Station.



- *top left*
Mount Vernon, Missouri Sampling, ca. May 2017
Courtesy of Allison Miller
- *right*
Mount Vernon, Missouri Sampling, ca. May 2017
Courtesy of Allison Miller

The history of Missouri's winemaking industry



There was a strong commercial interest to start an American wine industry from the moment European colonizers arrived in North America. Unfortunately, the European grape (*Vitis vinifera*) did not perform well or successfully to create wine in many early attempts in the colonies, except for those of the Spanish in what is today California; these results were most likely because of harsh winter temperatures that damaged vines, and of grape phylloxera consuming the roots, but the colonists did not realize that at the time. In Missouri, *V. vinifera* was not able to be grown either, so immigrants to the region in the early 19th century used the native grapes they found to make wine, being able to grow a thriving industry of winemaking. However, on the whole, the wine produced by American grapes was not considered the most desirable in terms of wine connoisseurship, and it took many years before an American wine product using native grapes was developed that was taken seriously in terms of refinement in taste and palate.

Throughout the mid- to late 1800s, German farmers became known for their winegrowing, especially in Hermann, but also in Augusta (another predominantly German immigrant-settled area), most often using the Norton grape (*Vitis aestivalis*); by the 1850s there were about 60 wineries. Because of the land's climate, soil, and geography, Missouri was especially suited to growing grapes that preferred high sun exposure, rocky soil, and long, hot summers. Missouri's multitude of rivers—the Mississippi, Missouri, and Gasconade—also helped the agriculture. In the mid-1800s, when several Native American nations in the Louisiana Purchase territory were being relocated from their lands to other parts of the country, German-Missouri farmers began creating wineries on these lands. They used farming strategies to aid in growing vineyards, including lime to reduce the acidity of the soil; soil pH ranges from acid [0] to alkaline [14], with [6] being ideal for growing grapes. The wineries were largely dominated by German immigrants or their first-generation children, though Italian immigrants also came to the region in the late 1800s and also developed wineries in the St. James area in Missouri. Missouri wineries continued to develop and flourish, leading to Missouri's rank as one of the top four wine-producing states in 1904.

Despite Missouri wineries' successes, the 18th Amendment to the Constitution was passed in 1919 in the United States, prohibiting the manufacturing, selling, and transporting of intoxicating beverages, leading to the downfall of the wineries. During the Prohibition era, Missouri had only one registered winery, which remained open for religious purposes and was run by Jesuits who produced wine for the Roman Catholic Mass. Some wineries tried to produce other crops, such as mushrooms, but most closed entirely, and these closings were overseen by government agents, who destroyed the vineyards and equipment. After Prohibition ended in 1933, a few wineries began slowly reopening, numbering only 12 wineries in 1937.

● *bottom left*
Aerial View of Hermannhof Winery
Courtesy of Hermannhof Winery

During the 1980s, there was a new tax on wine which allowed for the establishment of the Missouri Wine and Grape Program. Missouri State University and local viticulturists worked to restore Missouri's wineries and set up experiments to see which grapes are best suited for Missouri's climate; they determining the Norton-Cynthiana grape was resilient, complex to cultivate, and easily used in blends. At the same time, the United States Alcohol and Tobacco Tax and Trade Bureau began to designate "American Viticultural Areas" (AVAs), regions known for their geographic features making them ideal for growing grapes for wine. The first designated AVA was Augusta, Missouri (9600 acres) in 1980 due to its long, distinguished history of beneficial soil, healthy climate, and tasty wines. In 1986, the Missouri Ozark Mountain region (3.5 million acres extending into Arkansas and Oklahoma) and in 1987 the Ozark Highlands (1,280,000 acres), the region around St. James were also designated as AVAs. Also in 1987, the Hermann area (51,200 acres) was AVA designated.

Today, Missouri contributes to the United States' wine and grape industry, and the state's economic impact includes providing over 28,000 jobs and serving almost 1 million tourists in the years just prior to the 2020 pandemic. Globally, the US is the largest wine-consuming country (in total hectoliters consumed, not per capita), consuming 2019 33 million hectoliters of wine (a hectoliter is equal to one hundred liters) in 2019. The second largest wine-consuming country is France; in 2019, they consumed about 26.5 million hectoliters of wine. In terms of production, Italy, France, and Spain reside at the top. Italy produced about 47.5 million hectoliters in 2019. The total hectoliters produced internationally equates to 260 million in 2019.



● right
 Display of wine bottles in the Exhibition
 Photograph by Virginia Harold



Vitis aestivalis Michx.

Summer Grape
Cherokee: telú'lati
Herbarium 3108330

Vitis aestivalis is often considered to be synonymous with the wine grape cultivar Norton/Cynthiana that was found in 1835 near Richmond, VA. It is believed to be the oldest American grape cultivar in commercial production. It is Missouri's state wine grape.



Vitis berlandieri Planch.

Spanish grape, Fall grape
Wichita and affiliated nations: sic'qa
Herbarium 829343

When American vines were imported to Europe as rootstocks for grafting *V. vinifera* on, in the wake of the phylloxera wine blight, it initially proved difficult to find vine species that would grow well in lime-rich soil. *Vitis berlandieri*, which had adapted to limestone hills in central Texas, provided the lime tolerance needed to solve this problem.



Vitis riparia Michx.

Riverbank grape
Omaha: házi
Herbarium 6408911

Vitis riparia is considered by many to be the most commercially viable indigenous American species for its use as grafted root stock and in hybridization with *Vitis vinifera*.



Vitis rupestris Scheele

Sand grape
Lenape: wisahkim
Herbarium 4900084

The fruit clusters are small with small black berries that have good flavor. *Vitis rupestris* is used for making hybrid wine grapes and as a pest-resistant rootstock, primarily due to its resistance to grape phylloxera.

Early 19th Century

A wave of immigrants use the native grapes they find in the area to begin making wine

Mid 19th Century

German-American farmers begin creating wineries on lands siezed from Native American Tribes following the Louisiana Purchase

Late 19th Century

Well regarded wineries are established by German and Italian immigrants in the Hermann and St. James areas of Missouri.

1904

Missouri is ranked as one of the top four wine-producing states in America.

1920

The 18th Amendment to the USA Constitution is passed. Missouri retains only one registered winery, which remains open for religious purposes, run by Jesuits who produce wine for the Roman Catholic Mass.

1980

The first AVA is designated in Augusta, Missouri. The Missouri Ozark Mountain region, Ozark Highlands, St. James, and Hermann areas would soon follow.

Missouri Wine : A Timeline



Dornith Doherty

Lei Han
Lorraine Walsh

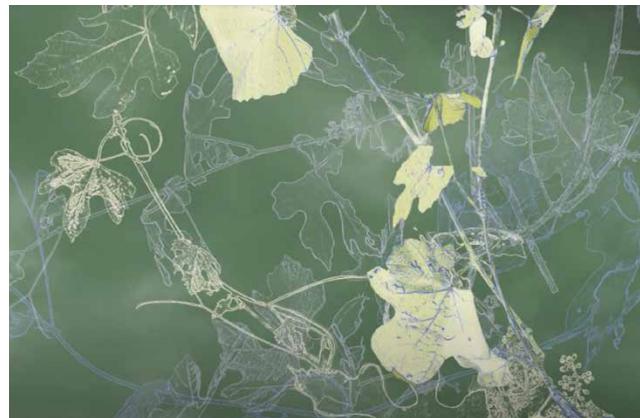
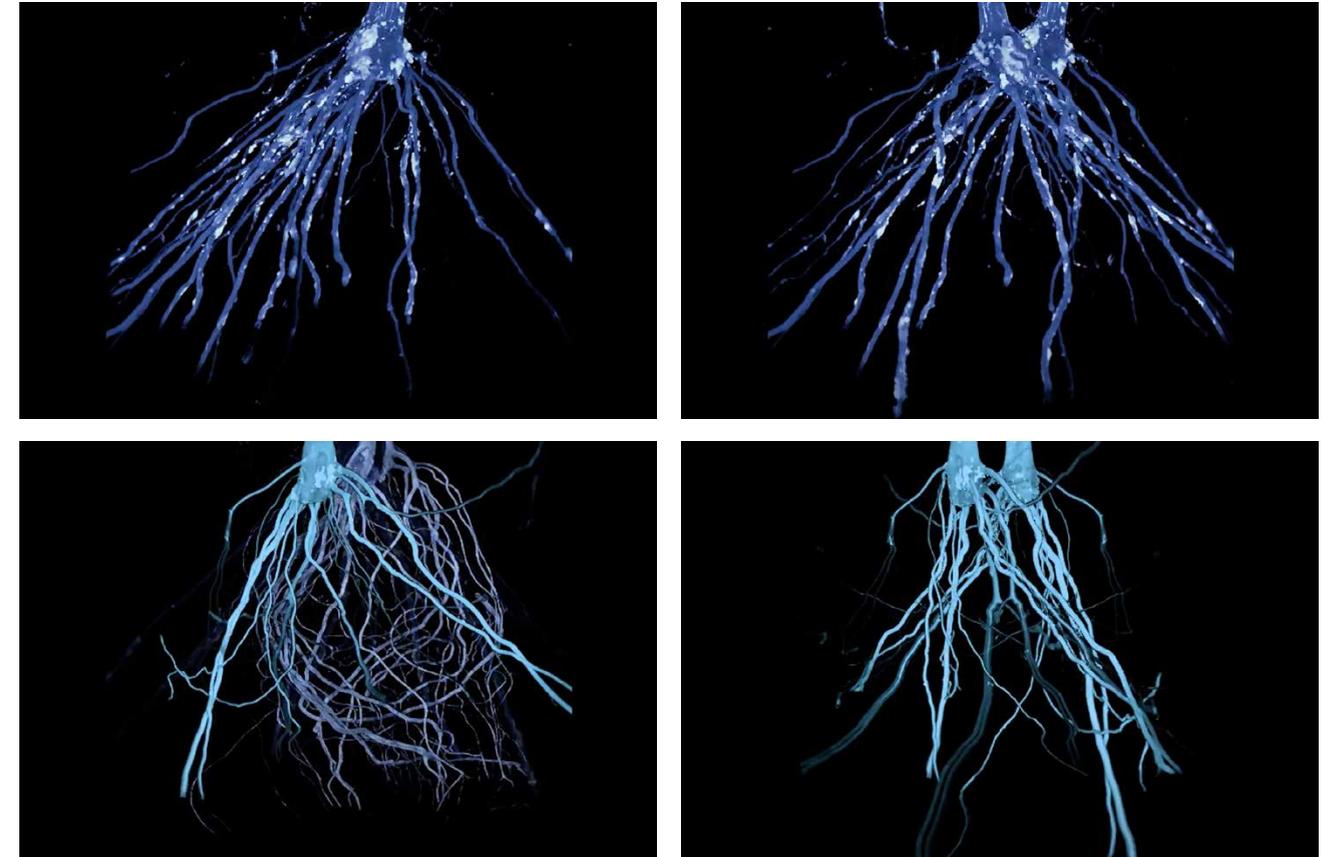
Tendrils of grapevine science in contemporary art

An important intersection to the *Grafting the Grape* exhibition is the contemporary multi-media artworks produced by three artists who were specially commissioned to create their artistic interpretations of this material, both historic and scientific, on grapevines, grafting, wine, and the Missouri Botanical Garden.

Roundabout (Circuition) is inspired by this story of human/environmental entanglement, cycles and exchange. A two-channel video projection explores the visual poetics of the bond between wild and domestic/root and scion. One video, a stop motion animation created from hundreds of digitally collaged frames of wild and domesticated grapevines, cycles through flourishing, decay and regeneration of stems and leaves. On the opposite wall, the second video presents a digital composite of three CT scans of the unseen details of diverse indigenous American grapevine roots.

Accompanying the videos are six panels that present highly magnified scanning electron microscope images of phylloxera galls. Printed on metal panels, these lustrous sepia toned photographs make reference to the mid-19th century, a time when photography was invented and the phylloxera blight occurred.

-Dornith Doherty



- *left*
Stills from *Circulation*
Dornith Doherty
Frame animation
2021
Duration 7:37, dimensions variable
Courtesy of the Artist

- *top right*
Stills from *Roundabout*
Dornith Doherty
Single Channel Video
2021
Duration 3:00, dimensions variable
Courtesy of the Artist



Arthur C. Pillsbury, an early pioneer in time-lapse botany photography, was famous for his experimental films at Yosemite National Park. In the 1920s, Pillsbury brought his then cutting-edge cameras to the Missouri Botanical Garden where he researched botanical time-lapse photography.

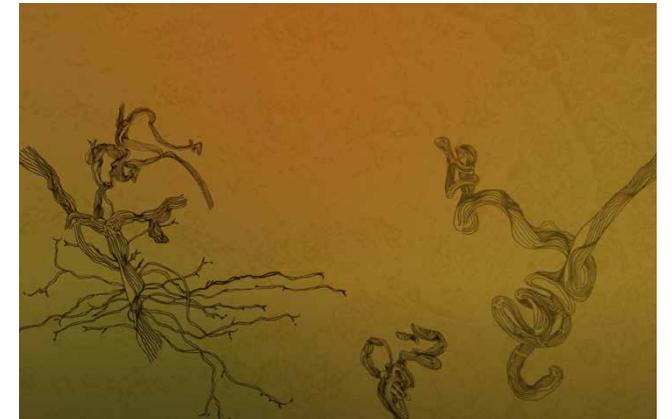
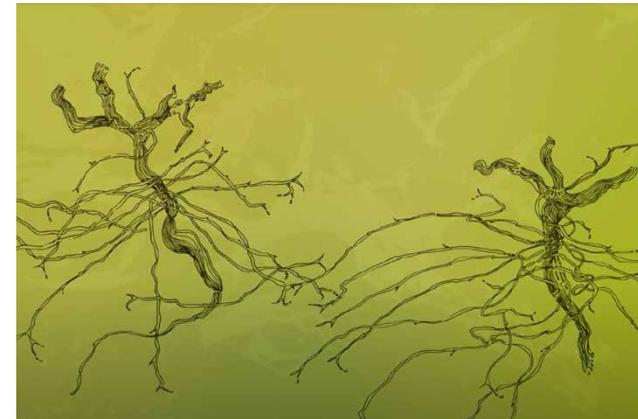
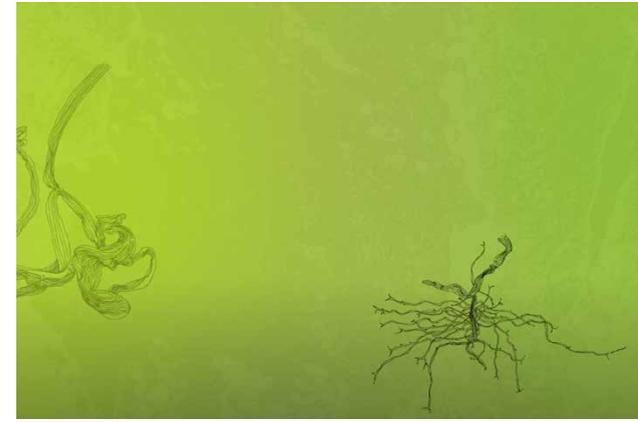
Honoring Pillsbury's legacy, the artists used time-lapse photography to capture early phenological stages of a vine plant. A dataset with over a thousand images of a grapevine plant were captured on a DSLR camera with a 100mm macro lens. These images were used to train a model through StyleGAN (a type of generative adversarial network) which has been used to generate and customize synthetic images that look real. Latent Spacewalk (the latent space is a representation of compressed data in which similar data points are closer together in space) animations were generated from that model and juxtaposed with the real time-lapse videos.

By means of a clock-work mechanism and other ingenious devices of his own invention, Mr. Pillsbury is not only able to secure records of the movement of parts of the flowers, leaves, etc., which have never before been visualized, but his success in obtaining pictures of what goes on in the cell of the plant as seen under the microscope has never been equaled.

Through the success that Mr. Pillsbury and others have had with films of this kind, it should not be long until every biological laboratory will come to regard a moving picture outfit as essential as the microscope. So far as is known the Missouri Botanical Garden is the first botanical garden to undertake this sort of an investigation. The wealth of growing material at the Garden will make it possible to obtain moving pictures of many plants not hitherto followed through their development, the budding and blooming orchids of various species affording an unusual opportunity in this direction.

A special studio, including developing and printing rooms, has been fitted up for Mr. Pillsbury, and four movie cameras are now installed, two for microscopic and two for macroscopic work. Because of the great value of such films in teaching, it is expected that later certain subjects showing the hidden activities of plants will be made available for classes in botany in schools and colleges.

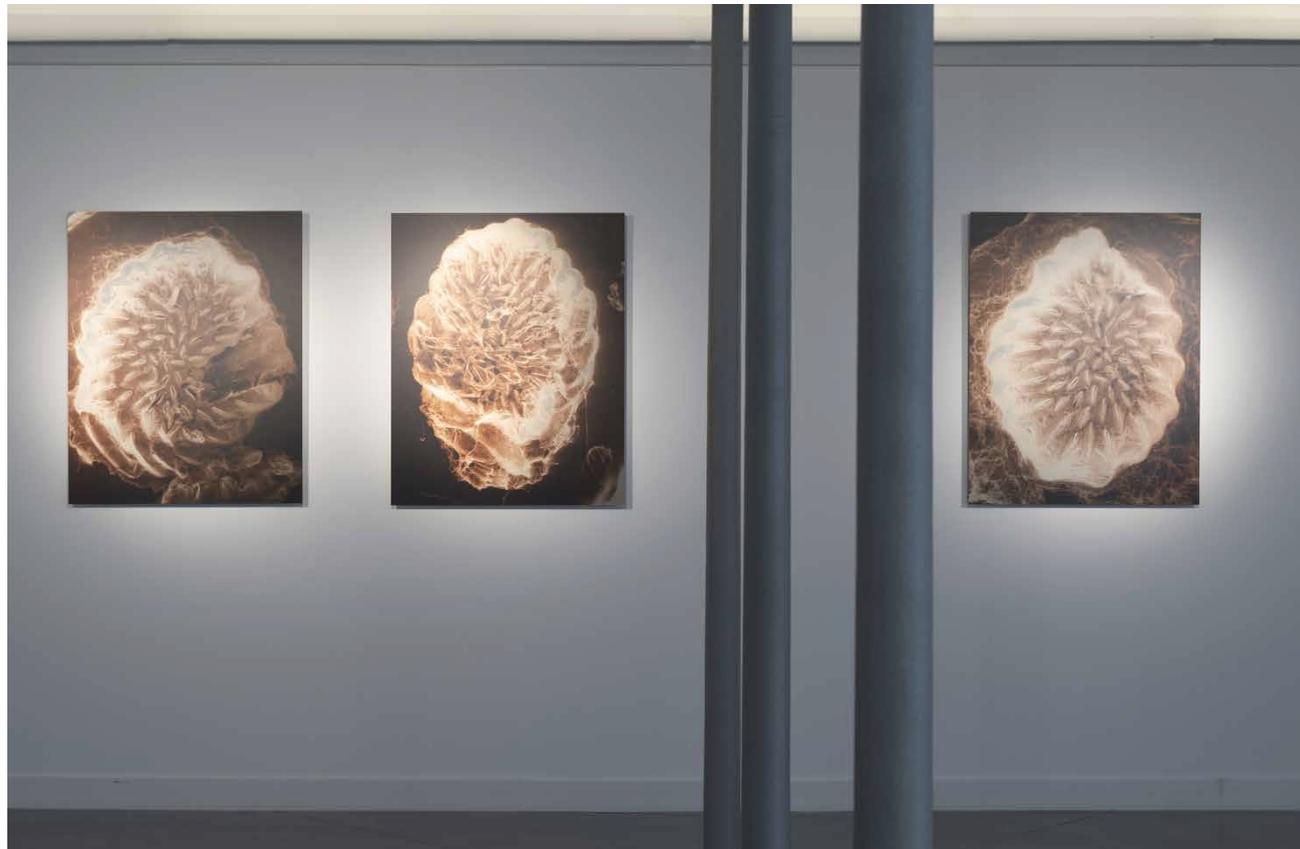
— Missouri Botanical Garden Bulletin, September 1927



This animation coalesces various elements from the artists' projects in the exhibition, depicting drawings from The In-Between set against a background of machine learned images from the NASA Earth Observatory. Shifting through a palette of colors to represent a warming climate, the video of the Earth's changing surface is generated from a model trained using StyleGAN2- a Generative Adversarial Network (GAN) effective at generating synthetic images from massive image databases such as those at NASA. GANs are not supervised. Instead they "teach" itself how to imitate or mimic any given database-in this case thousands of images-to create new, artificial content based on machine learning algorithms. This distribution, or training of data, is often called the latent space of the model, hence model trained, with algorithms.

- *top left*
Homage to Arthur Clarke Pillsbury
Lei Han & Lorraine Walsh
Time-lapse animation
2021
Duration 5:07, dimensions variable
Courtesy of the Artists

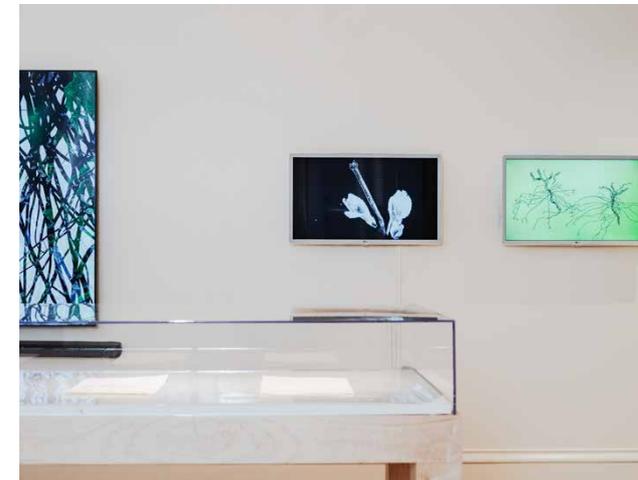
- *right*
Stills from Cycles
Lei Han & Lorraine Walsh
Animation, drawings
2021
Duration 3:16, dimensions variable
Courtesy of the Artists



Roundabout (Circuition) continues my focus on bringing to light the underlying sociocultural and environmental questions present when considering human entanglement with botanical biodiversity, and more specifically, the role of agrobiodiversity in viticulture. The history of the insect pest grape phylloxera and its destruction of the vineyards of Europe has its roots in the Columbian Exchange, when the newly formed link between the eastern and western hemispheres led to an explosive interchange of plants, animals, culture, human populations, technology, diseases, and ideas in the 15th and 16th centuries. In an effort to improve crops, agricultural plants and their wild relatives were often removed from the specific location in which they had evolved and adapted, and were transplanted into a new ecosystem. Although grapevines were part of the earliest interchanges between east and west, there is evidence to suggest that the accidental introduction of the phylloxera organism to Europe from American vines did not occur until the mid-19th Century, when the speed of travel increased with the development of steamships, allowing the insect stowaways to survive. The remedy for the infestation and the related blight was to graft domesticated European grapevines onto wild American phylloxera-resistant rootstock. These new plants (part wild/part domestic) were hybrid entities, expressing characteristics derived from both the scion and the rootstock. These plants reconstituted the French vineyards and grafting continues to be standard practice in the present era.

-Dornith Doherty

- *top*
Installation View
Phylloxera no.6
Phylloxera no.3
Phylloxera no.4
Dornith Doherty
Archival pigment on aluminum
2021
40"x32"
Courtesy of the Artist
Photograph by Virginia Harold



Our research is inspired by nature and climate change. We consider how environmental shifts are seen through the ancient practice of horticultural grafting and contemporary machine learning (a subset of Artificial Intelligence). These two methods share a paradoxical trait: grafting propagates and machine learning backpropagates. Yet they both mediate between systems for new results.

We focus on the Missouri native species *Vitis aestivalis* and the technique known as grafting. Although an ancient method, grafting was found in the mid-19th century to be the most effective solution to the vineyard pandemic occurring at the time as a result of the insect phylloxera. Grafting fuses plant parts so that vascular continuity is established between them resulting in a genetically composite single plant organism more resistant to environmental challenges. In this process, the upper part of the combined plant—the scion—is connected to the lower part called the rootstock. Simultaneously we explore new technologies for our creative expression. Specifically, we investigate the idea of grafting using machine learning (ML) through models trained with StyleGAN2—a Generative Adversarial Network (GAN) effective at generating synthetic images from massive image databases.

The projects we created for Grafting the Grape are realized in several forms. The phenology of the grapevine includes grafting in a sculpture *The In-Between*; climatic change in animations *A Degree Warmer* and *Cycles*; digital archival prints in *BudBurst 1-4* and *Vitis 1-2*; and the exploration of machine learning with synthetic artistic results in prints.

Also included is a special homage to Arthur C. Pillsbury, an early pioneer in time-lapse photography who conducted research at the Missouri Botanical Garden in the early 20th century.

— Lei Han and Lorraine Walsh



The *BudBurst* print editions capture flowering grapevines against a palette of colors that represent a warming climate. Included here are the original photographs, drawings, and some machine learned imagery from image databases of botanical illustrations utilizing the Biodiversity Heritage Library (BHL), the world's largest open access digital library for biodiversity literature and archives.

- *top left*
Installation View
Lei Han & Lorraine Walsh
Courtesy of the Artists
Photographs by Virginia Harold
- *top right*
BudBurst 1-4
Lei Han & Lorraine Walsh
Archival digital prints
2021
12.5" x 10"
Courtesy of the Artists
Photographs by Virginia Harold



The *In-Between* is inspired by grafting, which is a horticultural technique defined as the natural or deliberate fusion of plant parts so that vascular continuity is established between them and the resulting genetically composite organism functions as a single plant. In this process, the upper part of the combined plant—the scion—is connected to the lower part called the rootstock.

The drawings were laser engraved on plexiglass and suspended within a framework that references a traditional grapevine trellis. Thus the sculpture observes the time-honored tradition of cultivating grapes to be trained for upright or semi-upright growth habits. The top row are the scions which will be grafted with the roots below. The space in-between the plexiglass plates is where the grafting occurs. The ephemeral nature of this sculpture considers the balance and influence of climate change on grape cultivation and vine phenology today.

– Lei Han & Lorraine Walsh

- *left, next*
The In-Between
 Lei Han & Lorraine Walsh
 Laser engraving on plexiglass, cedar
 2021
 6' 6" x 1.5" x 8' 9"
 Courtesy of the Artists
 Photographs by Virginia Harold
- *inside back cover*
**Vitis vinifera, Stirpium historiae
 Pemptades Sex, Sive Libri XXX**
 Rembert Dodoens (1516/17-1585)
 Antwerp, Belgium ca. 1583
 Courtesy of the Missouri Botanical
 Garden Peter H. Raven Library
- *covers*
Stills from A Degree Warmer
 Lei Han & Lorraine Walsh
 Music composed by Ben Richter
 3D animation, HD video
 2021
 Duration 5:43, dimensions variable
 Courtesy of the Artists

