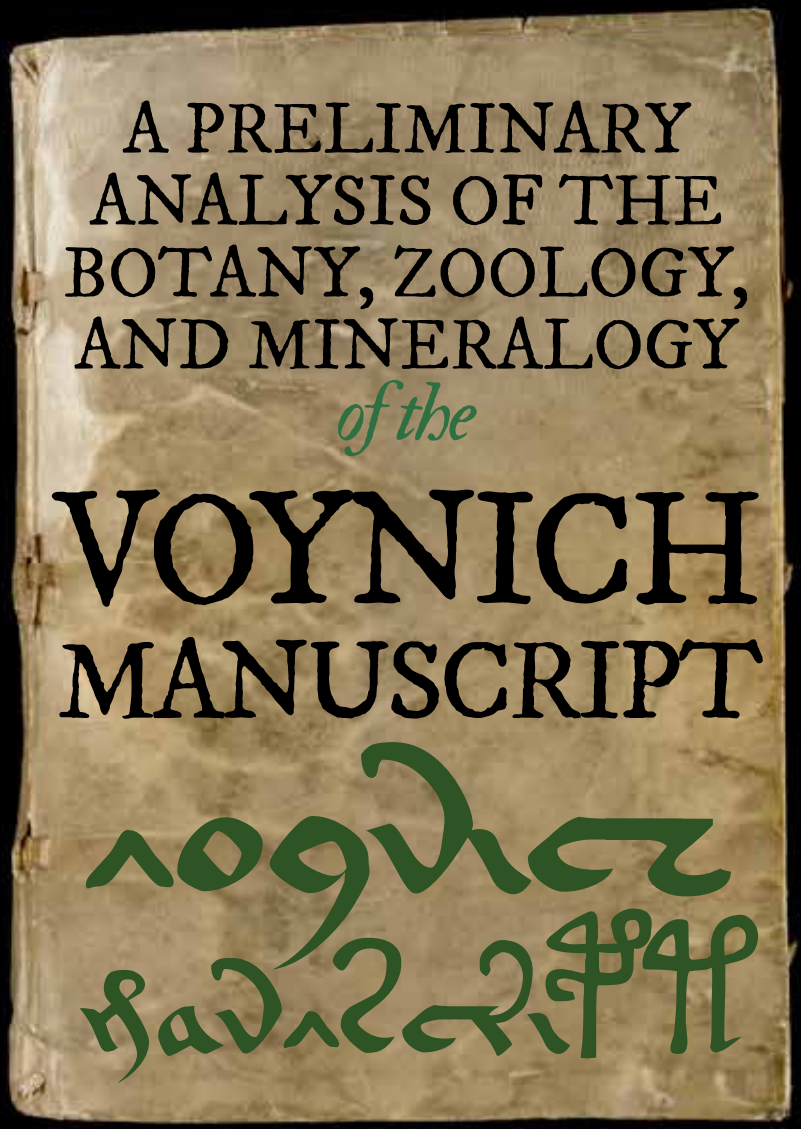


A PRELIMINARY ANALYSIS OF THE BOTANY, ZOOLOGY, AND MINERALOGY *of the* VOYNICH MANUSCRIPT

By Arthur O. Tucker, PhD, and Rexford H. Talbert

Unless otherwise noted, images courtesy of Beinecke collections: Cipher manuscript (Voynich manuscript). General Collection, Beinecke Rare Book and Manuscript Library, Yale University

Introduction

In 1912, Wilfrid M. Voynich, a Polish-born book collector living in London, discovered a curious manuscript in Italy. This manuscript, written in an obscure language or, perhaps, code, is now housed at the Beinecke Rare Book and Manuscript Library at Yale University,[1] which acquired it in 1969. Since 1912, this manuscript has elicited enormous interest, resulting in books and Internet sites with no sound resolution on the manuscript's origin. Even the US National Security Agency has taken an interest in its cryptic contents, and doctoral theses have been written on attempts to decipher the language of the Voynich Manuscript (hereinafter abbreviated Ms.). With such voluminous published information, its history can be easily found elsewhere and need not be repeated here *ad nauseum*.[1-5] However, what appears to be a reasonably reliable introduction for the novice is provided at Wikipedia.[6]

Information is continually updated on the website of René Zandbergen,[7] a long-term researcher of the Voynich Ms., and, along with Gabriel Landini, PhD, one of the developers of the European Voynich Alphabet (EVA) used to transcribe the strange alphabet or syllabary in the Voynich Ms. As Zandbergen relates, past researchers primarily have proposed — because the Voynich Ms. was discovered in Italy — that this is a European manuscript, but some also have proposed Asian and North American origins. As such, almost every language, from Welsh to Chinese, has been suspected of being hidden in the text. Of course, aliens also have been implicated in the most bizarre theories. These theories with no solid evidence have clouded the whole field of study, and many scholars consider research into the Voynich Ms. to be academic suicide. Recently, however, Marcelo Montemurro, PhD, and Damián Zanette, PhD, researchers at the University of Manchester and Centro Atómico Bariloche e Instituto Balseiro, have used information theory to prove that the Voynich Ms. is compatible with a real language sequence.[8]

The Voynich Ms. is numbered with Arabic numerals in an ink and penmanship different from the work's text portions. The pages are in pairs ("folios"), ordered with the number on the facing page on the right as *recto*, the reverse unnumbered on the left as *verso* (thus folios 1r, 1v, 2r, 2v, etc. to 116v). Fourteen folios are missing (12, 59, 60, 61, 62, 63, 64, 74, 91, 92, 97, 98, 109, and 110). By convention of Voynich researchers, the manuscript includes the following:

- "Herbal pages" or a "botanical section" (pages with a single type of plant);
- "Pharma pages" or a "pharmaceutical section" (pages with multiple plants and apothecary jars, sometimes termed "maiolica");
- "Astrological pages" (circular volvelles with nymphs, folios 70v2-73v);
- "Astronomical pages" (other circular designs, folios 67rl-70r2, etc.);
- "Balneological pages" or "biological section" (nymphs, baths, plumbing, folios 75r-84v);
- "Magic Circle page" (folio 57v);
- "Fertilization/Seed page" (folio 86v); and a
- "Michiton Olababas page" (folio 116v).

Our Introduction to the Voynich Manuscript, Backgrounds, and Pattern of Investigation

While we had known of the existence of the Voynich Ms., we, like so many others, probably dismissed it as a fantastic, elaborate hoax. Scattered, intersecting evidence may trace it back to ca. 1576-1612 to the court of Rudolf II (1552-1612) in Austria.[1-7] Any origin prior to this time is strictly conjecture, but such spurious claims have channelized scholars' thinking and have not been particularly fruitful. We had to face the facts that (so far) there was no clear, solid chain of evidence of its existence prior to ca. 1576-1612.

Thus, with our varied backgrounds and viewpoints as a botanist and as an information technologist with a background in botany and chemistry, the authors of this *HerbalGram* article decided to look at the world's plants without prejudice as to origin in order to identify the plants in the Voynich Ms. With the geographical origins of the plants in hand, we can then explore the history of each region prior to the appearance of the Voynich Ms. The authors of this article employ abductive reasoning, which consists of listing of all observations and then forming the best hypothesis. Abductive reasoning (rather than deductive reasoning normally practiced by scientists in applying the scientific method) is routinely used by physicians for patient diagnosis and by forensic scientists and jurors to determine if a crime has or has not been committed. In abductive reasoning, it is necessary to record all facts, even those that may seem irrelevant at the time. This is well illustrated by physicians who have misdiagnosed patients who were not fully forthcoming with all their symptoms because they interpreted some as trivial, unrelated, or unnecessary to share with the physician.

We were both immediately struck by the similarity of *xiuhamolli/xiuhhamolli* (soap plant) illustrated on folio 9r in the 1552 Codex Cruz-Badianus[9-12] of Mexico (sometimes known as the "Aztec Herbal") to the plant in the illustration on folio 1v of the Voynich Ms. Both depictions have a large, broad, gray-to-whitish basal woody caudices with ridged bark and a portrayal of broken coarse roots that resemble toenails. The plant in the Codex Cruz-Badianus is in both bud and flower with leaves that have a cuneate (wedge-shaped) base, while the plant in the Voynich Ms. has only one bud with leaves that have a cordate (heart-shaped) base. The illustration in the Codex Cruz-Badianus is accepted by numerous commentators[9-12] as *Ipomoea murucoides* Roem. & Schult. (Convolvulaceae); the illustration in the Voynich Ms. is most certainly the closely related species *I. arborescens* (Humb. & Bonpl. ex Willd.) G. Don. However, the portrayals of both of these Mesoamerican species are so similar that they could have been drawn by the same artist or school of artists.

This possible indication of a New World origin set us down a path that diverges from most previous Voynich researchers. If our identifications of the plants, animals, and minerals are correct as originating in Mexico and nearby areas, then our abductive reasoning should be focused upon Nueva España (New Spain) from 1521 (the date of the Conquest) to ca. 1576 (the earliest possible date that the Voynich Ms. may have appeared in Europe with any documentation). If the Voynich Ms. is, as one reviewer of this article indicated, "an invention by somebody in, let's say Hungary, who invented it based on images of early printed books," then this forger had to have intimate

The illustration of *Ipomoea murucoides* from the Codex Cruz-Badianus (fol. 9r) is in an identical style as that of *I. arborescens* in the Voynich Ms. (fol. 1v). Note the similar bud (A) and the woody caudex with rootlets (B).

Top image courtesy of Biblioteca Nacional de Antropologie e Historia, Mexico City, Mexico.

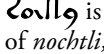
knowledge of the plants, animals, and minerals of Mexico and surrounding regions, in addition to its history, art, etc. Some of this knowledge, such as the distinction of *Viola bicolor* (Violaceae; which is not illustrated in earlier books to our knowledge) vs. *V. tricolor*, was clarified only in the 20th century. A forgery is certainly possible, but applying the principle of Occam's Razor (which says that the hypothesis with the fewest assumptions should be selected), attention should be focused upon Nueva España between 1521 and ca. 1576, not Eurasia, Africa, South America, or Australia (or alien planets).

Names

Names as keys to decipher lost languages

The most fruitful, logical approach to initially decipher ancient languages has been the identification of proper names. Thomas Young (1773-1829) and Jean-François Champollion (1790-1832) first decrypted Egyptian hieroglyphics with the names of pharaohs that were found in cartouches, coupled with a study of Coptic (the later Egyptian language that used primarily Greek script). The initial attempts by many researchers to decipher Sumerian, Babylonian, and Assyrian cuneiform were the names of kings, in conjunction with links to ancient Persian. Michael Ventris (1922-1956) and John Chadwick (1920-1998) initially deciphered Minoan Linear B as Mycenaean Greek by identifying cities on Crete and finding links of these names to ancient Greek. Heinrich Berlin (1915-1988) initially deciphered Mayan logograms by connecting "emblem glyphs" with cities and ruling dynasties or territories, which allowed the breakthroughs of Yuri Knorosov (1922-1999), coupled with a study of Mayan dialects. Michael Coe (b. 1929) and others later found the names of gods in logograms repeated in the *Popol Vuh*, the Mayan holy book.[13]

Plant, Animal, and Mineral Names in the Voynich Manuscript

None of the primary folios with plant illustrations (the so-called "herbal pages") have a name that can be teased out (yet). However, of the approximately 179 plants or plant parts or minerals illustrated in the "Pharma pages," about 152 are accompanied by names. We were initially drawn to plant No. 8 of the 16 plants on folio 100r; this is obviously a cactus pad or fruit, i.e., *Opuntia* spp., quite possibly *Opuntia ficus-indica* (L.) Mill. (Cactaceae) or a related species. Thus,  is quite easily transliterated as *nashtli*, a variant of *nochtli,* the Nahuatl (Aztec) name for the fruit of the prickly pear cactus or the cactus itself. Then we looked at plant No. 4 on folio 100r, which appears to be a pressed specimen of a young *Yucca* spp. or *Agave* spp., quite possibly *Agave atrovirens* Karw. ex Salm-Dyck (Agavaceae). Here  transliterates to *maguoey,* or *maguey.* These initial keys of proper names allowed us to uncover further names, and details are listed in the Appendix of this article.

Not many of the names beyond *nochtli* and a few others have correspondences in the nine manuscripts,[14] which include portrayals and discussions of 16th century Mesoamerican plants, particularly Codex Cruz-Badianus of 1552,[9-12] Hernández of ca. 1570-1577,[15] and Sahagún's Florentine Codex of ca. 1545-1590.[16] It should be remembered that Hernández and his associates took surveys from all over Mexico, and these works and their Nahuatl names are not monolilthic, i.e., representing only one ethnic group.[12] Thus, it is useful to distinguish the four classes of Nahuatl plant names as outlined by Clayton, Guerrini, and de Ávila in the Codex Cruz-Badianus:[12]

1. **primary 'folk-generic' names** that cannot at present be analysed [sic] but which are likely to have been known widely and to be present as cognates in the modern Nahua languages…
2. **compound 'folk-generic' names**…
3. **'folk-specific' names**, composed of a generic term plus a qualifying epithet (which may be compounded into the name), a class less likely to be widespread…
4. **descriptive phrases**, which may have been coined by Martin de la Cruz himself (see below) and which are

This illustration (fol. 100r) is obviously a cactus pad or fruit, i.e., *Opuntia* sp., quite possibly *Opuntia ficus-indica* or a related species. Thus, the name accompanying the illustration is quite easily transliterated as *nashtli*, a variant of *nochtli*, the Nahuatl (Aztec) name for the fruit of the prickly pear cactus or the cactus itself.

least likely to have been shared widely and to have been preserved in contemporary languages….

Thus the Nahuatl *nochtli* and the Spanish loan-word *maguey* fit the primary 'folk-generic' names of Number 1 above, but the use of the Nahuatl *tlacanoni* (tlacanoni) — "bat" or "paddle" — for *Dioscorea remotiflora* Kunth (Dioscoreaceae) in No. 28 on folio 99r, fits the descriptive phrase of Number 4.

Further attempts at identifying the plants and their Nahuatl names, when given, are presented in the Appendix. Many of the identifications still need refinement. Also, because we have been trained as botanists and horticulturists, not linguists, our feeble attempts at a syllabary/alphabet for the language in the Voynich Ms. must be interpreted merely as a key for future researchers, not a *fait accompli*. Much, much work remains to be done, and hypotheses will be advanced for years.

Minerals and Pigments in the Voynich Manuscript

In 2009, McCrone Associates, a consulting research laboratory hired by Yale University, filed a report on the pigments in the Voynich Ms. with analyses done by chemist Alfred Vendl, PhD. They found the following:[17]

- Black ink = iron gall ink with potassium lead oxide, potassium hydrogen phosphate, syngenite, calcium sulfate, calcium carbonate, mercury compound (traces), titanium compound, tin compound (particle), bone black, gum binder
- Green pigment = copper-organic complex, atacamite (possible to probable), calcium sulfate, calcium carbonate, tin and iron compounds, azurite and cuprite (traces), gum binder
- Blue pigment = azurite, cuprite (minor)
- Red-brown pigment = red ochre, lead oxide, potassium compounds, iron sulfide, palmierite
- White pigment = proteinaceous, carbohydrate-starch (traces).

This analysis was more thorough than the analysis done on 16th century maps from Mexico, which did not identify the chemical nature of the particles.[18] These pigments found by McCrone Associates in the Voynich Ms. differ from those of European manuscripts.[19,20] In particular, atacamite is primarily from the New World (it was named after the Atacama Desert in Chile), and the presence of this New World mineral in a European manuscript from prior to ca. 1576 would be extremely suspicious.

However, these analyses remind us that the artist for the Voynich Ms. had a very limited palette and thus one blue pigment was used for all the hues, tints, and shades of blue, i.e., colors from blue-to-purple, dark-to-light. Likewise, one red pigment was used for colors from red-to-coral, dark-to-light, etc.

Folio 102r includes a cubic (isometric) blue mineral (No. 4) resembling a blue bouillon cube. This might be boleite ($KPb_{26}Ag_9Cu_{24}Cl_{62}(OH)_{48}$); the morphology of the primitive drawing certainly matches very closely. The only sources for large crystals of this quality and quantity are three closely related mines in Baja California, Mexico, principally the mine at Santa Rosale (El Boleo).[21,22] These crystals, 2-8 mm on the side, typically occur embedded in atacamite. Copper compounds have been used historically to treat pulmonary and skin diseases and parasitic infections (e.g., shistosomiasis and bilharzia).[23]

The presence of five drop-like circles on the surface of this blue cube alludes to the Aztec logogram for water, *atl,* [9-12,16] and the name accompanying this, atlcoz, we transliterate as *atlaan*, or *atlan*, "in or under the water." Some minerals, e.g., tin (*amochitl*) and lead (*temetstli*), in the Florentine Codex[16] also are illustrated with the *atl* logogram in allusion to the color of mist and foam. The translation of the accompanying text might tell us whether this blue cube and its name are referring to a mineral, a watery color, water itself, a technique of preparation, or even a calendar date.

Artistic Style: Emphasis of Plant Parts and So-Called "Grafted" Plants

The senior author of this article taught Horticultural Plant Materials at Delaware State University (DSU) for 36 years. Students had to learn the scientific name, the common name, a field characteristic, and uses of major horticultural plants ranging from significant conifers to houseplants (within one semester!). The class involved frequent field trips to collect living specimens. The students would inevi-

This illustration (fol. 99r) is most probably *Dioscorea remotiflora*, which is native from northern to southern Mexico. The large root is paddle- or bat-like, and the name attached to this illustration is *tlacanoni*, Nahuatl (Aztec) for paddle or bat.

tably gravitate to a type of plant illustration that is depicted in the Voynich Ms. For example, when they encountered bird's nest spruce (*Picea abies* (L.) H. Karst. 'Nidiformis,' Pinaceae) in every class that was taught, one student would inevitably remark that the tips of the hooked needles of this conifer resembled Velcro®. The students would then start calling the bird's nest spruce the "Velcro plant" and illustrate it in their notebooks with a circular bird's nest outline and needles that were far out of proportion with the rest of the plant (a 0.5 inch needle was portrayed as a colossal one foot grafted onto three-foot plant). That is to say, the students omitted insignificant parts and enlarged important portions accordingly, often seemingly grafting them together. From a diversity of hundreds of students from various ages and ethnic backgrounds at DSU, this proved to be a common human pattern for notation and memorization, at least among university students in 20th century North America.

Thus, on folio 33v of the Voynich Ms., the illustration matches *Psacalium peltigerum* (B. L. Rob. & Seaton) Rydb. (Asteraceae) in botanical characters except for the size of the flowers. This may allude to the importance of the flowers, either for identification or use.

Also, following the same avenue of thought, in the case of the so-called "grafted" plants, e.g., *Manihot rubricaulis* I. M. Johnst. (Euphorbiaceae) on folio 93v, the artist may have merely left out the unimportant parts to condense the drawing to the limits of the paper size. This type of illustration also occurs in Hernández,[15] e.g., *tecpatli* (unknown, perhaps a *Smallanthus* spp., Asteraceae), *teptepehoila capitzxochitl* (unknown, probably an *Ipomoea* sp., Convolvulaceae) and *tlalmatzalin hocxotzincensi* (*Brazoria arenaria* Lundell, Lamiaceae), and uses the same sort of artistic device to compress a large plant into a small illustration. However, in Hernández, the cut portion is skillfully hidden from view, facing the back of the page. For *chimalatl peruina* (*Helianthus annuus* L., Asteraceae) in Hernandez, the top and bottom are shown side-by-side rather than attached.

Plants, Language, and Other Evidence of a Post-Conquest Central American Origin

The plants, animals, and minerals identified so far are primarily distributed from Texas, west to California, and south to Nicaragua, indicating a botanic garden somewhere in central Mexico.

Sources of Calligraphy in the Voynich Ms.

In 1821, Sequoyah (George Gist) created the Cherokee syllabary by modifying letters from Latin, Greek, and Cyrillic that he had encountered. Following this example, what was the inspiration for the calligraphy in the Voynich Ms.? Focusing upon the four most unique symbols ( ,  ,  , ) in the Voynich Ms. and perusing documents from Nueva España 1521-ca. 1576, only one document reveals some calligraphy that might have served as inspiration for the Voynich Ms.: the Codex Osuna.[24] In the Codex Osuna, there consistently is a broken version of "tl" in the Nahuatl that matches the same symbol "  " in the Voynich Ms., and on folio 12v of the Codex Osuna, there is an identical version of "" on the lower left. Throughout the Codex Osuna (e.g., folio 37v), the "s" in the Nahuatl is often written as a large, conspicuous, backward version of that from the Voynich Ms. "". On folios 13v and 14r of the Codex Osuna, the florid Spanish signatures have several inspirations for the "" in the Voynich Ms. On folio 39r of the Codex Osuna, the "z" is written in a very similar manner to the "" in the Voynich Ms.

The Codex Osuna[24] was written between 1563-1566 in Mexico City and actually consists of seven books; it is not a codex in the strict definition. According to the Biblioteca Nacional, Madrid (Control No. biam00000085605), where it is listed as *Pintura del gobernador, alcades y regidones de México,* the Codex Osuna was:

> A 16th century pictographic manuscript, written in Mexico. It contains the declarations of the accused and the eye witnesses made in New Spain by Jerónimo de Valderrama, by order of Philip II between 1563-1566, to investigate the charges presented against the Viceroy, Luis de Velasco, and the other Spanish authorities that participated in the government of said Viceroy. These people and their testimonies are represented by pictographs, followed by an explanation in the Nahuatl and Castilian languages, as the scribes translated the declarations of the Indians by means of interpreters or Nahuatlatos.

The Codex Osuna was donated in 1883 to the Biblioteca Nacional by the estate of Don Mariano Téllez-Girón y Beaufort-Spontin (1814-1882), 12th Duke of Osuna and 15th Duke of the Infantado.

The use of "tl" and "chi" endings places this dialect of Nahuatl in central or northern Mexico.[25,26] The use of Classic Nahuatl, Mixtec, and Spanish loan-words for some plant names (see Appendix) also indicates an origin in central Mexico.

Other Indications of a 16th Century Mexican Origin

A number of other features of the Voynich Ms. also point to a Mesoamerican origin. For example, a "bird glyph" (folio 1r) as a paragraph marker is not known by the authors of this paper to exist in European manuscripts but as common in Post-Conquest Mexican manuscripts, e.g., the Codex Osuna[24] and the Codex Mendoza[27] (among many others).

A volcano is pictured on the top left side of folio 86v, within the crease. Mexico has roughly 43 active or extinct volcanoes, most centered near Mexico City. The most famous in recent centuries has been Popocatepetl in Morelos, southeast of Mexico City, a World Heritage Site of 16th century monasteries.

Animals in the Voynich Ms.

The fish illustrated on folio 70r are most definitely the alligator gar [*Atractosteus spatula* (Lacepède, 1803)]. This fish is very distinctive because of its pointed snout, length/width ratio, prominent interlocking scales (ganoid scales), and the "primitive" shape and distribution of the rear fins. The alligator gar is found only in North America.[28] The Nahuatl name accompanying this illustration, otolal, transliterated to *atlacaaca,* means someone who is a fishing folk (*atlaca*, "fishing folk" + *aca*, "someone"). Curiously, there

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is an addition with this illustration of what seems to be "*Mars*" (French for March, perhaps?) in darker ink and different handwriting.

The dark-red bull illustrated on folio 71v is the Retinta breed of cattle (*Bos taurus taurus* Linnaeus, 1758), while the pale red is an Andalusian Red. Both of these types of cattle are notable for their upward curved antlers. The Spanish introduced Andalusian, Corriente, and Retinta cattle to North America as early as 1493 with Ponce de León in Florida. Cortés introduced cattle to Mexico some 30 years later. These breeds were chosen for their ability to survive the long sea voyage and later to endure grazing on just minimal "scrub lands." Descendants of these cattle in North America, albeit with later interbreeding with dairy cattle, are Texas Longhorn cattle and Florida Cracker/Scrub/Pineywoods cattle.[29] Curiously, on the illustration in the Voynich Ms., there is an addition in a darker, different ink and handwriting that seems to read "*Ma*."

The crustaceans illustrated on folio 71v match the morphology of the Mexican crayfish, *Cambarellus montezumae* (Saussure, 1857). *Acocil* (from the Nahuatl *cuitzilli*) are found in a broad section across Mexico.[28]

The cat illustrated on folio 72r is the ocelot [*Leopardus pardalis* (Linnaeus, 1758)]. The stripes across the face, the rounded ears, and the gray spotting (illustrated with the blue pigment) are all characteristic of this cat. This species ranges from Texas to Argentina.[28] Oddly, "angst" is written in a darker ink and different handwriting.

The sheep on folios 70v and 71r are bighorn sheep (*Ovis canadensis* Shaw, 1804). The hooves (two-cleft and hollow to clasp rocks) indicate that this might be the desert bighorn sheep (*O. canadensis mexicana* Merriam, 1901), which are found in deserts in southwestern North America and across Mexico.[28] What seems to be the word "*abime*" (French for chasm or abyss) is attached to this illustration in a different handwriting and a darker ink.

A black Gulf Coast jaguarundi [*Puma yagouaroundi cacomitli* (Berlandier, 1859)] is portrayed on folio 73 (with what appears to be "*noūba*," French for spree, written over the original writing with a darker, different ink). This cat, which has brown and black phases, is very distinctive in profile with a flatter face than most cats; the overall aspect of the face almost resembles a monkey. The tail is also notable, very long and particularly bushy at the base.

Additional tiny animals apparently are used as decorative elements and are difficult to identify: (1) a chameleon-like lizard (quite possibly inspired by the Texas horned lizard, *Phrynosoma cornutum* [Harlan 1825]) nibbling a leaf on folio 25v, (2) two caecilians [wormlike amphibians, probably inspired by *Dermophis mexicanus* (Duméril & Bibron, 1841)] in the roots of the plant on folio 49r, and (3) five animals at the bottom of folio 79v.

Other Evidence of Mexican Origin: The Influence of the Catholic Church

Besides Spanish loan-words, other indications of the European influence on Post-Conquest Mexico are the so-called "*maiorica*" or pharmaceutical containers in the "Pharma pages." The sharp edges, filgree, lack of painted decoration, and general design allude to inspiration by metal objects, not ceramic or glass. The immediate suggestions for inspiration were the ciboria and oil stocks of 16th century Spanish Catholic church ceremonies. The former consists of a capped chalice, often on a highly ornamented stand, which stores the Eucharist. The latter consists of a cylindrical case comprising three compartments that screw into each other and hold the holy oils. Using these holy objects as designs for pharmaceutical containers would have been a mockery of the religion forced upon the conquered natives and thus another reason for writing in code. A ciborium also appears on folio 67r of the Codex Aubin.[30]

Future Avenues for Research

The Aztec elite were highly educated and hygienic. Cortéz reported libraries, called *amoxcalli* (Nahuatl for book house), complete with librarians and scribes. The Spanish conquistadors, along with the office of the Holy Inquisition burnt them all because of their "superstitious idolatry" (translated words of Juan de Zumarraga, first Archbishop of Mexico).[14]

Axiomatically, the Spanish priests established schools for children of the Aztec elite, teaching them European writing methods, painting, and Latin. Probably one of the most famous products of these schools, the Codex Cruz-Badianus, was completed by two students educated

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at the College of Santa Cruz in Tlatelolco. It was written in Nahuatl by Martin de la Cruz — a native convert and practicing physician at the College of Santa Cruz — and translated into Latin by Juan Badiano, another native convert and student of the College. Two versions of this manuscript exist, the original Codex Cruz-Badianus, formerly in the Vatican, returned in 1990 by Pope Paul II to Mexico (now at the Biblioteca Nacional de Antropologie e Historia in Mexico City [F1219 B135 1940]), and a later copy at the Royal Library of Windsor Castle (RCIN970335).[9-12]

The Aztecs also were the first to establish comprehensive botanic gardens, which later inspired those in Europe. Gardens were in Tenochtitlan, Chapultepec, Ixtapalapa, el Peñon, and Texcoco, as well as more distant ones such as Huaztepec (Morelos). Some of these botanic gardens, such as Huaztepec, included water features for ritualistic bathing. Coupled with this was the use of the *temezcalli*, or sweatbaths.[31,32]

Besides outright destruction of the libraries by Spanish invaders, much of this accumulated indigenous knowledge also was destroyed by diseases, both imported and endemic. According to epidemiologist Rodolfo Acuña-Soto and colleagues,[33] the population collapse in 16th century Mexico — a period of one of the highest death rates in history — shows that not only were European diseases devastating, but an indigenous hemorrhagic fever also may have played a large role in the high mortality rate. On top of the smallpox epidemic of 1519-1520, when an estimated 5-8 million natives perished in Mexico, the epidemics of 1545 and 1576 were due primarily to *cocoliztli* ("pest" in Nahuatl). These latter epidemics occurred during moist years following devastating droughts, providing food for a surge of rodents, which eventually killed an additional estimated 7-17 million people in the highlands of Mexico, roughly 90% of the population.[33] This pattern is similar to the sudden, severe epidemics of other zoonoses (diseases of animal origin that can be transmitted to humans).[34] Thus, the author(s) and artist(s) (*tlacuilo,* the native painter-scribes) of the Voynich Ms. may have perished in one of these epidemics, along with the speakers of their particular dialect.

Questions in the following paragraphs are particularly pertinent to fully establish this as the work of a 16th century *ticitl* (Nahuatl for doctor or seer).[35,36]

Interpretation of the flora and languages of Mexico is a difficult task even today. Mexico is extremely diverse in both floristics and ethnic groups, with approximately 20,000 plants and at least 30 extant dialects of Nahuatl.[12] We are confident that our attempts at a preliminary syllabary for the Voynich Ms. can be refined. What are the linguistic affinities of this dialect to extant dialects of Nahuatl? Is this dialect truly extinct?

A six- to eight-pointed star, especially in the latter folios of the Voynich Ms. (103r-116r, where it often is dotted with red in the center), is used as a paragraph marker. Is this reminiscent of the eight-pointed Mexica Sun Stone or Calendar Stone? On the top center of folio 82r, the eight-pointed star is quite strikingly similar to this stone. This stone was unearthed in 1790 at El Zócalo, Mexico City, and is now at the capital's National Museum of Anthropology. One interpretation of the face in the center of this stone is Tonatiuh, the Aztec deity of the sun. Another interpretation of the face is Tlatechutli, the Mexica sun or earth monster. An identical eight-pointed star also appears on folio 60 of the Codex Aubin.[30]

What is the influence of the sibyls in the murals at the Casa del Deán (Puebla) on the portrayal of the women in the Voynich Ms.? The Casa del Deán originally belonged to Don Tomás de la Plaza Goes, who was dean of Puebla from 1553 to 1589 and second in command to the bishop. The murals were executed by native artists, *tlacuilo*, whose names are unknown. Undoubtedly, much was destroyed through the centuries, and only two restored rooms remain. In *La Sala de las Sibilias*, or Room of the Sibyls, female prophets from Greek mythology narrate the passion of Christ. The women in the murals at the Casa del Deán have short hair and European features, and the friezes include nude angels and satyrs.

How was the parchment, which may date to animals killed in the first half of the 15th century, used over a full century later for this manuscript?[37] How did putative medieval German script on folio 166v (the so-called "Michiton Olababas page") get integrated into this manuscript? Was this a case of European parchment being repurposed?

Copal resins (most commonly used for incense) were often used as binders in Mesoamerican pigments.[18,38] McCrone Associates supposedly documented the IR spectrum of the resin.[17] Is this a copal resin from a Meso-American species, such as *Protium copal* (Schltdl. & Cham.) Engl., *Hymenaea courbaril* L. (Fabaceae), or *Bursera bipinnata* (Moç. & Sessé ex DC.) Engl. (Burseraceae)?

What was the chain of evidence from post-Conquest Mexico to the court of Rudolph II? The circuitous route of the Codex Mendoza is perhaps illustrative of the fact that materials did not always flow directly from New Spain (present-day Mexico) to Spain, and European materials were quite often used for writing (rather than the native *amate* paper, *amatl* in Nahuatl). The Codex Mendoza was created in Mexico City on European paper about 20 years (ca. 1541) after the Spanish conquest of Mexico for Charles V, Holy Roman Emperor and King of Spain. It was sent by ship to Spain, but the fleet was attacked by French corsairs (privateers), and the Codex, along with the other booty, was taken to France. From there it came into possession of André Thévet, cosmographer to Henry II of France. Thévet wrote his name in five places in the Codex, twice with the date of 1553. It was later sold to Richard Hakluyt around 1587 for 20 francs (Hakluyt was in France from 1583-1588 as secretary to Sir Edward Stafford, English Member of Parliament, courtier and diplomat to France during the time of Queen Elizabeth I). Sometime near 1616 it was passed to Samuel Purchas, then to his son, and then to John Selden. The Codex Mendoza has been held at the Bodleian Library at Oxford University since 1659, five years after Selden's death.[27]

Another question is the involvement of John Dee (1527-1608/1609), if any. Dee — a Welsh mathematician, astronomer, astrologer, occultist, navigator, imperialist, and consultant to Queen Elizabeth I — purchased an Aztec obsidian "shew-stone" (mirror) in Europe between 1527-1530 (this

object was subsequently owned by Horace Walpole). Dee was in Paris in the 1550s, and a letter dated 1675 quoted Arthur Dee, son of John Dee, saying that he had seen his father spending much time over a book "all in hierolyphicks." Dee also is suspected of being the sales agent to Rudolf II, ca. 1584-1588.[2-5]

Conclusion

We note that the style of the drawings in the Voynich Ms. is similar to 16th century codices from Mexico (e.g., Codex Cruz-Badianus). With this prompt, we have identified a total of 37 of the 303 plants illustrated in the Voynich Ms. (roughly 12.5% of the total), the six principal animals, and the single illustrated mineral. The primary geographical distribution of these materials, identified so far, is from Texas, west to California, south to Nicaragua, pointing to a botanic garden in central Mexico, quite possibly Huaztepec (Morelos). A search of surviving codices and manuscripts from Nueva España in the 16th century, reveals the calligraphy of the Voynich Ms. to be similar to the Codex Osuna (1563-1566, Mexico City). Loan-words for the plant and animal names have been identified from Classical Nahuatl, Spanish, Taino, and Mixtec. The main text, however, seems to be in an extinct dialect of Nahuatl from central Mexico, possibly Morelos or Puebla.

Appendix: Plants Identified to Date

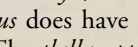
Beyond the approximately 172 plants, plant parts, and minerals in the "pharma section," the "herbal section" includes about 131 plants. In the following, we have indicated only identifications that immediately "jumped out" to us with seemingly sound identifications. We have many more putative identifications, but these still are questionable, so they have been reserved for later publication. Unless financing could be procured for a large-scale project with leading scholars in botany, linguistics, and anthropology, decades of research remain. After all, we indicate only 37 plant identifications in the following pages (and boleite mineral) from a total of roughly 303 taxa (a meager 12.5% approximation of the total). And the text, bathing practices, astrology/astronomy, chain of evidence, etc., also need explanation.

Throughout this *HerbalGram* article, nomenclature and plant distributions follow the United States Department of Agriculture's GRIN taxonomic database,[39] and/or The Plant List produced by the Missouri Botanical Garden and Royal Botanic Garden, Kew,[40] and/or the Integrated Taxonomic System (ITIS),[28] unless otherwise indicated. The plants are listed below, alphabetically by family.

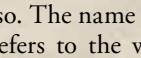
Apiaceae (Carrot Family)

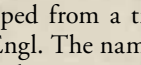
Probably the most phantasmagoric illustration in the Voynich Manuscript is the *Eryngium* species portrayed on folio 16v. The inflorescence is colored blue, the leaves red, and the rhizome ochre, but the features verge on a stylized appearance rather than the botanical accuracy of the *Viola bicolor* of folio 9v, immediately suggesting that more than one *tlacuilo* (painter, artist) was involved. This lack of technical attention makes identification beyond genus difficult, if not impossible. However, a guess might be *E. heterophyllum* Engelm.[41] This species, native to Mexico, Arizona, New Mexico, Louisiana, and Texas, has similar blue inflorescences, blue involucral bracts (whorl of leaves subtending the inflorescence), and stout roots, and it also develops rosy coloring on the stems and basal leaves. However, *E. heterophyllum* has pinnately compound leaves (leaflets arranged on each side of a common petiole), not peltate (umbrella-shaped) leaves. This lack of specificity on the shape of the leaves also plagues identifications in the Codex Cruz-Badianus.[12] Today, *E. heterophyllum,* Wright's eryngo or Mexican eryngo, is used to treat gallstones in Mexico and has been found in in vivo experiments to have a hypocholesteremic effect.[42]

Apocynaceae (Dogbane Family)

Plant No. 14 on folio 100r appears to be the fruit of an asclepiad, possibly the Mexican species *Gonolobus chloranthus* Schltdl. The name  transliterates to *acamaaya*, a variant of *acamaya*, "crab" or "crayfish," and the fruit of *G. chloranthus* does have a resemblance to knobby, ridged crab claws. The *tlallayoptli* in Hernández,[13] with a similar illustration of the fruit (but with smooth ribs), is nominally accepted as the related species *G. erianthus* Decne., or *Calabaza silvestre*. The roots of *G. niger* (Cav.) Schult. are used today in Mexico to treat gonorrhea.[43]

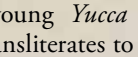
Araceae (Arum Family)

Plant No. 7 on folio 100r appears to be the leaf of an aroid, most likely the Mexican species *Philodendron goeldii* G. M. Barroso. The name  transliterates as *macanol,* which refers to the wooden sword, *macana* (a Taino word, called *macuahuitl* by some authorities for the Aztec version), studded with slices of razor-sharp obsidian.

Plant No. 2 on folio 100r also appears to be a vine of an aroid, ripped from a tree, most probably *Philodendron mexicanum* Engl. The name  transliterates as *namaepi*, which may incorporate a loan-word from Mixtec referring to soap, *nama*, which is a plant that produces soap.[44]

Author Deni Bown writes of the Araceae in general: "Most of the species of Araceae which are used internally for bronchial problems contain saponins, soap-like glycosides which increase the permeability of membranes to assist in the absorption of minerals but also irritate the mucous membranes and make it more effective to cough up phlegm and other unwanted substances in the lungs and bronchial passages."[45]

Asparagaceae (the Asparagus Family, alternatively Agavaceae, the Agave Family)

Plant No. 4 on folio 100r appears to be a pressed specimen of a young *Yucca* species or *Agave* species. Here  transliterates to *maguoey,* or *maguey*, a name that entered Spanish from the Taino in the middle of the 16th century,[46] rather than the Nahuatl *metl.* Thus, this may quite possibly be *Agave atrovirens* Karw. ex Salm-Dyck, which was a source for the beverages pulque, mescal, and tequila in 16th century Nueva España.[47,48] Mayaguil was the female goddess associated with the maguey plant as outlined in the Codex Rios of 1547-1566:[49]

Rios 15 (20v) Eighth Trecena: Mayaguil (Mayahuel)

They feign that Mayaguil was a woman with four hundred breasts, and that the gods, on account of her fruitfulness, changed her into the Maguei (Maguey plant), which is the vine of that country, from which they make wine. She presided over these thirteen signs: but whoever chanced to be born on the first sign of the Herb (Grass), it proved unlucky to him; for they say that it was applied to the Tlamatzatzguex, who were a race of demons dwelling amongst them, who according to their account wandered through the air, from whom the ministers of their temples took their denomination. When this sign arrived, parents enjoined their children not to leave the house, lest any misfortune or unlucky accident should befall them. They believed that those who were born in Two Canes (Reed), which is the second sign, would be long lived, for they say that sign was applied to Heaven. They manufacture so many things from this plant called the Maguei, and it is so very useful in that country, that the Devil took occasion to induce them to believe that it was a god, and to worship and offer sacrifices to it.

Asteraceae (Daisy Family)

In 1944, the Rev. Hugh O'Neill at Catholic University wrote that the plant illustrated on folio 93r is sunflower, *Helianthus annuus* L. He wrote that six botanists agreed with him,[50] but, in spite of this, non-botanists disagreed. This is most certainly the sunflower, called *chimalatl peruiana* in Hernández.[15] The difficulty of portraying an exceedingly tall annual is conveyed in Hernández by having cut stems side-by-side, but in the Voynich Ms. the features are deeply compressed, possibly confusing non-botanists, but perhaps more difficult is the admission that the Voynich Ms. may be post-1492 or possibly from the New World!

The plant illustrated on folio 13r is probably a *Petasites* sp. The closest match might be *P. frigidus* (L.) Fr. var. *palmatus* (Aiton) Cronquist, the western sweet-coltsfoot. This is native to North America, from Canada to California. *Petasites* spp. are used in salves or poultices as antiasthmatics, antispasmodics, and expectorants.[51]

The plant illustrated on folio 33v is likely *Psacalium peltigerum* (B. L. Rob. & Seaton) Rydb., possibly var. *latilobum* Pippen.[52,53] This is a fairly good match to this New World asterid genus as to its lobed peltate (umbrella-shaped) leaves, inflorescence, and fleshy subterranean tubers, except that the flowers are shown in larger size than reality, perhaps to emphasize the identification or use. *Psacalium peltigerum* is known from the Mexican states of Jalisco, Guadalajara, and Guerrero, but the variety *P. latilobum* is restricted to Guerrero. *Psacalium peltatum* (Kunth) Cass. is used for genito-urinary tract/reproduction treatment and for rheumatism in Mexico.[54]

Boraginaceae (Borage Family, Alternatively Hydrophyllaceae, the Waterleaf Family)

The plant illustrated folio 56r is almost certainly *Phacelia campanularia* A. Gray, the California bluebell. The blue flowers, dentate (toothed) leaves, scorpioid cyme (inflorescence coiled at the apex), and overlapping leaf-like basal scales are all good matches. This species is native to California.

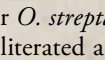
Brassicaceae (Mustard Family)

The plant illustrated on folio 90v is most probably *Caulanthus heterophyllus* (Nutt.) Payson, San Diego wild

The plant illustrated on fol. 90v is most probably *Caulanthus heterophyllus* (Nutt.) Payson, San Diego wild cabbage or San Diego jewelflower.

cabbage or San Diego jewelflower. The flowers of *C. heterophyllus* are four-petaled, white with a purple streak down the center, with four protruding, dark purple anthers. Leaves vary from dentate (toothed) to lobed. It is native to California and Baja California.

Cactaceae (Cactus Family)

Plant No. 8 on folio 100r is obviously a cactus pad or fruit, i.e., *Opuntia* spp., quite possibly *Opuntia ficus-indica* (L.) Mill. or a related species (e.g., *O. megacantha* Salm-Dyck or *O. streptacantha* Lem.).[47] Thus,  quite easily is transliterated as *nashtli*, a variant of *nochtli,* the Nahuatl name for the fruit of the prickly pear cactus or the cactus itself (the pads are called *nopalli*). *Opuntia ficus-indica* is widely cultivated but apparently native to central Mexico. *Nopalea cochenillifera* (L.) Salm-Dyck also is cultivated widely for the insect that is the source for cochineal.[55]

Caryophyllaceae (Carnation Family)

The plant illustrated on folio 24r is probably a *Silene* sp., possibly *S. menziesii* Hook., Menzie's catchfly. This grows natively from Alaska to California and New Mexico. The flowers are a good match, even showing the infection with the fungus *Microbotryum violaceum* (Pers.) G. Deml & Oberw., anther smut fungus, which turns the anthers purple. However, the leaves are shown as hastate (arrowhead-shaped), and *S. menziesii* has attenuate (gradually narrowing to the base) leaf bases. Is this another case of disparity of the leaves between reality and portrayal, or is there another *Silene* species that is closer to the illustration?

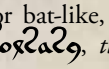
Convolvulaceae (Morning Glory Family)

As mentioned previously, the plant illustrated on folio 1v is *Ipomoea arborescens* (Humb. & Bonpl. ex Willd.) G. Don, found from northern to southern Mexico. It is overwhelmingly similar to the *xiuhamolli/xiuhhamolli* (soap plant) in the Codex Cruz-Badianus[9-12] of Mexico from 1552. Both trees have a large, broad, gray-to-whitish basal woody caudex (base) with ridged bark, portrayed here with broken coarse roots that resemble toenails. The plant in the Codex Cruz-Badianus is in both bud and flower with leaves that have a cuneate (wedge-shaped) base, while the plant in the Voynich Ms., has only one bud with leaves that have a cordate (heart-shaped) base. The illustration in the Codex Cruz-Badianus is nominally accepted as *I. murucoides* Roem. & Schult. by leading commentators.[9-12]

The plant illustrated on folio 32v is probably *I. pubescens* Lam., silky morning-glory. This vine is native to Arizona as well as New Mexico to Argentina. The blue flowers, deeply lobed leaves, and tuberous roots are all characteristic of silky morning-glory.

Species of *Ipomoea* are known for their resin glycosides and use in treating several conditions, such as diabetes, hypertension, dysentery, constipation, fatigue, arthritis, rheumatism, hydrocephaly, meningitis, kidney ailments, and inflammation.[56-58] In addition, the arborescent *Ipomoea* species, *I. murucoides* and *I. arborescens,* are used in hair and skin care, especially the ashes, which are used to prepare soap.[55,58] While the bases of both of the arborescent species are portrayed somewhat accurately, Clayton, Guerrini, and de Ávila[12] state that, "The blue patch with small, white ovate glyphs at the base of the plant is the symbol for flowing water." This may be related to the story relayed by Standley for *I. arborescens*: "In Morelos there is a popular belief that the tree causes imbecility and other cerebral affections [*sic*], and for this it is necessary only to drink the water running at the foot of the trees."[55]

Dioscoreaceae (Yam Family)

The vine illustrated as No. 28 on folio 99r is likely *Dioscorea remotiflora* Kunth, native from northern to southern Mexico. The large root is paddle- or bat-like, and the name attached to this illustration is  , *tlacanoni,* Nahuatl for paddle or bat.

The vine illustrated on folio 17v may very well be *Dioscorea composita* Hemsl., barbasco, native from northern to southern Mexico. The root quite often is segmented as shown in the Voynich Ms. and is a major source of diosgenin, a hormone precursor.

The vine illustrated on folio 96v is almost certainly *Dioscorea mexicana* Scheidw., Mexican yam. This also is native from northern to southern Mexico. This is another source of diosgenin.

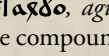
Euphorbiaceae (Spurge Family)

The plant illustrated on folio 6v is very likely a *Cnidoscolus* sp., either *C. chayamansa* McVaugh or *C. aconitifolius* (Mill.) I. M. Johnst. Both are called *chaya* and are widely cultivated from Mexico to Nicaragua. The characteristic leaves and spiny fruit are both good fits, but because of the variability in both species (especially cultivated selections), it is difficult to tell for sure from the crude illustration that is portrayed.[59]

The plant illustrated on folio 5v is most probably *Jatropha cathartica* Terán & Berland., *jicamilla.* The palmately dentate (toothed) leaves, red flowers, and tuberous roots are all good fits for the species. Its native habitats are from Texas to northern Mexico. As the scientific name implies, this is cathartic and poisonous.

The plant illustrated on folio 93v is most likely *Manihot rubricaulis* I. M. Johnst. from northern Mexico. This close relative to the cassava, *M. esculenta* Crantz, has thinner, more deeply lobed leaves. *Manihot rubricaulis* is illustrated in Hernández[15] as *chichimecapatli* or *yamanquipatlis* (gentle or weak medicine).

Fabaceae (Bean Family)

Plant No. 11 on folio 88r is almost certainly *Lupinus montanus* Humb., Bonpl., & Kunth of Mexico and Central America. This lupine is noted to contain alkaloids.[60] The name attached to this is  , *aguocacha*, which we translate as watery calluses. The compound peltate leaves and soft, callus-like, nitrogen-fixing root nodules (knobs) on one side of the roots are typical of this species.

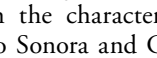
Grossulariaceae (Gooseberry Family)

The plant illustrated on folio 23r is probably *Ribes malvaceum* Sm., chaparral currant. This woody, stoloniferous shrub has purple-magenta flowers and palmately (arranged like a hand) lobed leaves and is endemic to California south to Baja Norte, Mexico.[55]

Lamiaceae (Mint Family)

The plant illustrated on folio 45v is very possibly *Hyptis albida* Kunth, *hierba del burro*. The gray leaves, blue flowers, and stout root all match the characteristics of the species. This shrub is native to Sonora and Chihuahua to San Luis Potosí, Guanajuato, and Guerrero. Standley[55] relates that "the leaves are sometimes used for flavoring food. In Sinaloa they are employed as a remedy for ear-ache, and in Guerrero a decoction of the plant is used in fomentations to relieve rheumatic pains."

The plant illustrated on folio 32r is most likely *Ocimum campechianum* Mill. (*O. micranthum* Willd.). This suffrutescent (low-shrubby) annual basil grows indigenously from Florida to Argentina; in Mexico it is found from Sinaloa to Tamaulipas, Yucatán, and Colima.[55] The inflorescence and leaves are both good matches. Standley[55] relates, "In El Salvador bunches of the leaves of this plant are put in the ears as a remedy for earache."

Plant No. 5 on folio 100r has three flowers that match *Salazaria mexicana* Torr., or bladdersage. This species also seems to match the description of *tenamaznanapoloa* (carrying triplets?) of Hernández[15] (alias *tenamazton* or *tlalamatl*). This shrub, native from Utah to Mexico (Baja California, Chihuahua, and Coahuila), exhibits inflated bladder-like calyces that vary in color, depending upon maturity, from green to white to magenta, with a dark blue-and-white corolla emerging from it.[55] We have transliterated the name accompanying these three flowers,  as *noe, moe-choll-chi*. The name *choll-chi* we translate as skull-owl (Spanish *cholla* plus Nahuatl root *chi*), and, indeed, the flowers do bear an uncanny resemblance to the white skull and black beak of the great horned owl (*Bubo virginianus* Gmelin 1788).

The plant on folio 45r most likely is *Salvia cacaliifolia* Benth., endemic to Mexico (Chiapas), Guatemala, and Honduras. The blue flowers in a tripartite inflorescence (branching in threes) with distantly dentate (toothed) deltoid-hastate (triangular-arrowhead-shaped) leaves are quite characteristic of this species.[61]

Marantaceae (Prayer Plant Family)

The plant illustrated on folio 42v is a crude representation of a *Calathea* spp., probably allied to *C. loeseneri* J.

This illustration from the Voynich Ms. (fol. 23v) is quite definitely *Passiflora* subgenus *Decaloba*. The flower (A) with prominent petals and reduced sepals and the paired petiolar glands in the upper third of the leaf (B) fit quite well. The dentate (toothed) leaves that are deeply cordate (heart-shaped) only seem to match the variability of *P. morifolia* Mast. in Mart., although the artist has made the leaves slightly more orbicular (round) than they normally occur in mature foliage (young plants, i.e., root suckers, sometimes exhibit orbicular, entire leaves in cultivation).

F. Macbr., which yields a blue dye. The crudeness of the illustration, coupled with inadequate surveys of the genus *Calathea* in Mexico, impede an easy identification at this time.

Menyanthaceae (Buckbean Family)

The obviously aquatic plant illustrated on folio 2v is undoubtedly *Nymphoides aquatica* (J. F. Gmel.) Kuntze, the so-called banana plant or banana lily. This is native to North America, from New Jersey to Texas.

Moraceae (Mulberry Family)

The plant illustrated on folio 36v is probably a *Dorstenia* sp., likely the variable *D. contrajerva* L., tusilla. The inflorescence is quite distinct and is genus-appropriate. Leaves for this species vary "in spirals, rosulate (in the form of a rosette) or spaced; lamina broadly ovate (egg-shaped) to cordiform (heart-shaped) to subhastate (tending towards arrowhead-shaped), pinnately (arranged on opposite sides of a petiole) to subpalmately (tending to be arranged as a hand) or subpedately (tending to be two-cleft), variously lobed to parted with three-to-eight lobes at each side or subentire (tending to have a smooth edge)."[62]

Passifloraceae (Passionflower Family)

The plant illustrated on folio 23v is definitely a *Passiflora* sp. of the subgenus *Decaloba*. This is primarily a New World genus (some species occur in Asia and Australia) and cannot be confused with any other genus. The paired petiolar glands in the upper third of the leaf, blue tints in the flower, and dentate (toothed) leaves that are deeply cordate (heart-shaped) seem to match only the variability of *P. morifolia* Mast. in Mart.,[63] although the artist has made the leaves slightly more orbicular (round) than they normally occur in mature foliage (young plants such as root suckers sometimes exhibit orbicular, entire leaves in cultivation).

Penthoraceae (Ditch-Stonecrop Family)

The plant illustrated on folio 30v is easily identifiable as *Penthorum sedoides* L., the ditch stonecrop, a New World species that grows indigenously from Canada to Texas. The cymose inflorescence (convex flower cluster), dentate leaves, and stolons (trailing shoots) are characteristic of the species. The artist, though, apparently has illustrated this in very early bud (or glossed over the details of the flowers) because the prominent pistils emerge later, and are very obvious in fruit, often turning rosy.

Polemoniaceae (Phlox Family)

The plant illustrated on folio 4v is quite definitely a *Cobaea* sp., a New World genus. The best match is *C. biaurita* Standl., which is closely related to the cultivated *C. scandens* Cav., the cup and saucer vine. This vine is native to Chiapas, Mexico, and possesses acute (tapering to the apex, sides straight or nearly so) to acuminate (tapering to the apex, sides more-or-less pinched) leaflets and flowers that emerge cream-colored but later mature to purple.[64,65]

Ranunculaceae (Buttercup Family)

The plant illustrated on folio 95r is quite definitely an *Actaea* sp., probably the white-fruited *Actaea rubra* (Aiton) Willd. f. *neglecta* (Gillman) B. L. Rob. *Actaea rubra* is native to Eurasia, and in North America from Canada to New Mexico.[66] As the common name baneberry indicates, this species is poisonous.

Urticaceae (Nettle Family)

As first postulated by the Rev. Hugh O'Neill, the plant on folio 25r is clearly a member of the Urticaceae, or nettle family.[50] The best match, because of the dentate, lanceolate (lance-shaped) leaves and reddish inflorescences, seems to be *Urtica chamaedryoides* Pursh, commonly known as heart-leaf nettle. This is native in North America from Canada to Mexico (Sonora). *Urtica* and the closely related genus *Urera* also occur in the Codex Cruz-Badianus[9-12] and Hernández.[15]

Valerianaceae (Valerian Family)

The plant illustrated on folio 65r is probably *Valeriana albonervata* B. L. Rob. The palmately or cleft-lobed leaves, inflorescence, and napiform (turnip-shaped) to fusiform (spindle-shaped), often forked taproots, are a good match. This is native to the Sierra Madre of Mexico.[67]

Violaceae (Violet Family)

The plant illustrated on folio 9v has been identified previously as *Viola tricolor* of Eurasia,[68] but we claim that it is not this species. If the illustration in the Voynich Ms. is correct (and the illustration is actually quite decent), the terminal stipular lobes are linear (narrow and flat with parallel sides), as characteristic of the North American native *V. bicolor* Pursh (*V. rafinesquei* Greene), not spatulate (spatula-shaped) as in *V. tricolor*. Also, the flowers of *V. bicolor* are uniformly cream to blue, while the flowers of *V. tricolor* usually have two purple upper petals, three cream-to-yellow lower petals. *Viola bicolor,* American field pansy, is native to the present-day United States from New Jersey to Texas, west to Arizona, although Russell mysteriously says "originally derived from Mexico" even though its center of diversity seems to be eastern Texas.[69,70] HG

Arthur O. Tucker, PhD, *is emeritus professor and co-director of the Claude E. Phillips Herbarium at Delaware State University in Dover, an upper-medium-sized herbarium and the only functional herbarium at an historically Black college or university, graced with a few type specimens of Mexican plants collected by Ynes Mexia, Edward Palmer, et al.[71] He has had a special interest in identifying plants from period illustrations utilizing flora and herbarium specimens, e.g., the "Blue Bird Fresco" at Knossos.[72] Because of his expertise, he was hired by CPHST/PPQ/APHIS/USDA (Center for Plant Health Science Technology/Plant Protection & Quarantine) to identify botanicals imported to the United States and to construct a Lucid key.[73] The latter research was particularly challenging because these botanicals encompass parts of everything "botanical" — from fungi (though not truly botanical), to mosses and lichens, to gymnosperms and angiosperms that had been greatly modified (bleached and/or dyed, scented, and sometimes reconstructed into new botani-*

This illustration from the Voynich Ms. (fol. 9v) is most definitely *Viola bicolor* of North America by the terminal stipular lobes (A), which are linear (narrow and flat with parallel sides), not spatulate (spaula-shaped) as in *V. tricolor* of Europe. Also, the flowers (B) are uniformly a pale blue, as in *V. bicolor*, not tricolored as in *V. tricolor*.

cals) — collected in India, China, Southeast Asia, Australia, Brazil, etc. Dr. Tucker also has published widely on the systematics and chemistry of herbs in both scientific and popular journals and is the co-author of The Encyclopedia of Herbs *(Timber Press, 2009), which attempts to summarize the latest scientific information on herbs of flavor and fragrance for the average reader.*[74]

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