Chapter 4

Phytomorph and Geomorph Identification

This Chapter is based on three published works: (1) a paper by Hugh O Neall (1944) that identifies two New World plants (sunflower and chili peppers) in the Voynich manuscript; (2) a paper of Tucker and Talbert (2013) which identified 39 plants in the Voynich as indigenous to the New World; (3) a paper by Tucker and Janick (2016) which extended the list to 59 species. Although many of the illustrations of the Voynich Codex on first blush could be considered bizarre or whimsical (See Figure in Chapter 14) most contain morphological structures which permit botanical identification. Many enthusiasts have attempted to analyze the plants of the Voynich Codex, but few are knowledgeable plant taxonomists or botanists, despite their large web presence. Most of the plant identification has been predicated on the conclusion that the Voynich is a 15th century European manuscript (Friedman 1962). The principal reports in a web report by non botanists Edith and Erica Sherwood (http://www.edithsherwood.comn/coyhnich_botanical_plants) who identifies he plants as Mediterranean based on their premise that Voynich is a 15th century Italian manuscript and claims to find signature of Leonardo da Vinci in voynich drawings. We respectfully disagree with both assertions.

The first exception to the conclusion that the Voynich plants were European is a short remarkable 1944 paper in Speculum (a refereed journal of the Medieval Academy of America) by the distinguished plant taxonomist, the Rev./Dr. Hugh O’Neill (1894–1969), former Director of the Herbarium (official acronym LCU) at the Catholic University of America (CUA) in Washington, D.C. From black and white photostats provided by Father Theodore C. Petersen (1883–1966) at CUA, Rev. O’Neill identified two Mesoamerican plants in the Voynich Codex. O’Neill was qualified to make this identification, because he was familiar with the flora of Mexico and allied regions. He collected 8,000 herbarium specimens in British Honduras (Belize), Guatemala, and Nicaragua in 1936, and subsequently wrote a paper on the Cyperaceae of the Yucatan Peninsula (O'Neill, 1940). Besides acquiring numerous types of Ynes Mexia and other Mexican collectors for the LCU Herbarium, he also directed the dissertation of Brother B. Ayres in 1946 on Cyperus in Mexico (Tucker et al. 1989). Rev. O’Neill was so well regarded by his colleagues in plant taxonomy that five species were named after him: Calyptranthes oneillii Lundell, Carex ×oneillii Lepage, Eugenia oneillii Lundell, Persicaria oneillii Brenckle, and Syngonanthus oneillii Moldenke.

Despite O’Neill’s documented background in plant taxonomy, his expertise was called into question by cryptologist Elizebeth Friedman, who wrote in 1962: “Although a well-known American botanist, Dr. Hugh O’Neill, believes that he has identified two American plants in the illustration no other scholar has corroborated this, all agreeing that none of the plants depicted is indigenous in America. Sixteen plants, however, have been independently identified as European by the great Dutch botanist Holm.” Mysteriously, there was only one mid-twentieth century plant taxonomist named Holm, Herman Theodor Holm (1854–1932), but he was Danish-American and was only on the faculty of Catholic University of America from July 1932, until he died in December 1932. This Holm spent almost his entire career on plants of the Arctic and the Rocky Mountains and had no documented expertise in Mesoamerican plants.
O’Neill’s discovery had powerful implications for Voynich Codex studies. Tucker and Talbert (2013) identified a New World origin for 37 plants, seven animals, and one mineral in the Voynich Codex and concluded that it originated in 16th century Mexico. In the present paper, identifications are expanded to 59 phytomorphs of the Voynich Codex.

The Voynich Codex contains an estimated 362 plant images or phytomorphs, 132 in the “herbal” section, plus 230 in the “pharma” section. The 132 phytomorphs in the “herbal” section are often quite bizarre and whimsical style that seem to be drawn by the same hand using a pen for outlines and then rather crudely tinting the forms with a few basic mineral pigments: green, brown, blue, or red. The roots are quite stylized and strange, often in the shape of geometric forms or animals. The leaf shapes are clearly to as “grafted.” However the floral parts are often quite detailed and helpful for identification. The 230 plants in the “pharma” section are reduced, often confined to a single leaf or roots. Furthermore, these images are often associated with names in the Voynich symbolic script. A careful analysis of the images leads us to conclude that the artist was particularly concerned only with certain features significant to identification in their way of thinking.

In the text below, the botanical images of the “herbal” and “pharma” sections of the Voynich Codex are combined by botanical family and species in alphabetical sequence, incorporating the folio number in the Codex. Multiple plants occur on each folio of the “pharma” section. On each page, the plants are numbered from left to right, from top left. Some folios, e.g., fol. 101v, are a trifold, so the section of the folio number is indicated in parentheses, e.g., fol. 101v (3) is the third section.

Nomenclature below follows a concordance of the cited revisions and/or GRIN (USDA, ARS, 2015), and/or the collaboration Royal Botanic Gardens, Kew and Missouri Botanical Garden (Plant List 2013).

A. Fern: Ophioglossaceae

1. Fol. 100v #5. *Ophioglossum palmatum* (Plate 1). O’Neill (1944) identified the eusporangiate fern *Botrychium lunaria* (L.) Sw., moonwort, in the Voynich Codex on fol. 100v. However, O’Neill did not designate the phytomorph number, only the folio number, but only #5 would match with a member of the Ophioglossaceae. The fronds with both a fertile and a sterile portion, the fertile portion bladelike and palmately lobed into multiple segments (Plate 1A), suggest instead a specimen of the eusporangiate fern *Ophioglossum palmatum* L. The photograph of this species (Plate 1B) confirms the identification. This species is epiphytic in dense, wet forests at low to middle elevations from Florida to Brazil (Mickel and Smith 2004).

B. Gymnosperm: Taxodiaceae

1. Fol. 100r #15. *Taxodium sp.*, cf. *Taxodium mucronatum* (*T. huegelii, T. mexicanum*)? (Plate 2). This phytomorph (Plate 2A) is very crude but appears to be either the cones or whole plant outlines of the Mexican cypress, *Taxodium mucronatum* Ten. (*T. huegelii* hort. ex P. Lawson & C. Lawson; *T. mexicanum* Carrière). The cones and forked tree trunk of *T. mucronatum* are shown (Plate 2B & C). This species is often multi-trunked in older specimens, *e.g.*, The Tule Tree, or El
Árbol del Tule on the grounds of a church in Santa María del Tule in the Mexican state of Oaxaca, ca. 2000 years old. The Nahuatl name for *T. mucronatum* is *ahoehoetl/aueuetl/ahuehuetl, ahuehuecuahuitl*, or *ahuehuetl* (Hernández et al. 1651; Hernández 1942; Dressler 1953; Díaz 1976; Farfán and Elferink 2010).

Plate 1. *Ophioglossum palmatum*: (A) fol. 100v #5; (B) *O. palmatum* (Source: Robbin Moran, New York Botanical Garden).

Plate 2. *Taxodium* sp.: (A) Plate 100r #15; (B & C) grouped strobili (cones) and forked tree trunk of *T. mucronatum*, respectively (Source: Geoff Stein).

C. Angiosperms: Asparagaceae/Agavacea

1. Fol. 100r #4. *Agave* sp., cf. *A. atrovirens* (Plate 3). Phytomorph #4 on fol. 100 (Plate 3A) appears to be a pressed specimen of an *Agave* sp. with leaves bearing a toothed edge, quite possibly *Agave atrovirens* Karw. ex Salm-Dyck (Plate 3B) which was a source for the beverages pulque, mescal, and tequila in 16th century Colonial New Spain (Hough 1908; Dressler 1953). In Hernández (1651) and Hernández (1942), this is called *metl* (Dressler 1953) or *metl coztli/mecoztli*. In the Florentine Codex (Sahagún 1963), this is known as *macoztic metl*.

D. Apiaceae

1. Fol. 16v. *Eryngium* sp., cf. *E. heterophyllum* (Plate 4). Probably the most phantasmagoric phytomorph in the Voynich Codex. is the *Eryngium* sp. portrayed on fol. 16v (Plate 4A). 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 fol. 9v. This lack of technical attention makes identification beyond genus difficult if not impossible. However, a conjecture might be *Eryngium heterophyllum* Engelm. (Mathias and Constance 1941). This species, native to Mexico and Arizona, New Mexico, and Texas in the U.S., has similar blue inflorescences and involucral bracts (Plate 1B) and stout roots, and it also develops rosy coloring on the stems and basal leaves (Plate 4C). However, *E. heterophyllum* has pinnately compound leaves, not peltate, but leaves subtend the inflorescence and covers the stem, suggesting that the phytomorph was drawn from a dried, fragmented specimen. This lack of concern about the shape of the leaves also plagues identifications in the Codex Cruz-Badianus (Clayton et al. 2009). Today,
Wright’s eryngo or Mexican eryngo (*Eryngium heterophyllum*), is used to treat gallstones in Mexico and has been found experimentally to have a hypocholesteremic effect (Navarrete et al. 1990).

Plate 3. *Agave* sp.: (A) fol. 100r #4; (B) *Agave atrovirens* (Source: Jeno Kapitany).

Plate 4. *Eryngium* sp. (A) fol. 16v; (B) inflorescence of *E. heterophyllum* (Source: Blooms of Bressingham®); (C) leaves of *E. comosum* R. Delaroche illustrating anthocyanin accumulation (Source: Pedro Tenorio-Lezama).

**E. Apocynaceae**

1. **Fol. 100r #14. Gonolobus chloranthus (Plate 5).** Phytomorph #14 on fol. 100r (Plate 5A) appears to be the ridged fruit of an asclepiad, possibly the Mexican species *Gonolobus chloranthus* Schltdl. (Plate 5B). The *tlalayotli* in the Florentine Codex (Sahagún 1963: pl. 488a) 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 (González Stuart 2004).

**F. Araceae**

1. **Fol. 100r #2. Philodendron mexicanum (Plate 6).** Phytomorph #2 on fol. 100r (Plate 6A), appears to be a vining aroid with hastate leaves, ripped from a tree, most probably *Philodendron mexicanum* Engl. (Plate 6B & C) known as *huacalazochtli* in Nahuatl (Zepeda and White 2008). This is known as *huacalxochtli*/*huacalxōchtli* (huacal flower) in the Codex Cruz-Badianus (Emmart 1940; Cruz and Badiano 1991; Alcántara Rojas 2008; Gates, 2000; Clayton et al. 2009) or *huacalazochtli* (Zepeda and White 2008). Bown (1988) 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.”

Plate 5. Gonolobus chloranthus. (A) fol. 100r #14; (B) G. chloranthus fruit. (Source: Guadalupe Cornejo-Tenorio and Guillermo Ibarra-Manríquez, The Field Museum).

Plate 6. Philodendron mexicanum: (A) fol. 100r #14; (B & C) leaves of P. mexicanum. (Source: Dave’s Garden user tathisri and Steve and Janice Lucas, respectively).

2. Fol. 100r #7. Philodendron sp. (Plate 7). Phytomorph #7 on fol. 100r (Plate 7A) appears to be the leaf or stem of an arid, most probably a species of Philodendron, but the crudeness of the drawing belies whether this is a stem or compound leaf. If the latter, it may be a crude representation of the pedately compound leaf of the Mexican species Philodendron goeldii G. M. Barroso (Plate 7B).

G. Asteraceae

1. Fol. 53r. Ambrosia sp., cf. A. ambrosioides (Plate 8). The phytomorph has composite heads borne on a raceme (Plate 8A). Leaves are brown to green and sharply serrate. Roots are brown, segmented. This matches the variability of Ambrosia ambrosioides (Delpino) W. W. Payne, which is native from Arizona and California to Mexico (Plate 8B & C).
Plate 7. *Philodendron* sp.: (A) fol. 100r #7; (B) *P. goeldii* (Source: Steve and Janice Lucas).


2. Fol. 93r. *Helianthus annuus* (Plate 9). The phytomorph has a large single yellow asteroid head borne on a stout, thick stem (Plate 9A). Leaves are green, alternate, ovate-lanceolate, acute, and entire. Petioles are short, with lines drawn down along the stem, possibly indicating a clasping base of the petiole or ridges along the stem. Roots are multiple, primary, and unbranched. The best match is sunflower, *Helianthus annuus* L. (Plate 9B & C). This identification was first made by Hugh O’Neill (1944), plant taxonomist and Curator of the Catholic University herbarium (LCU), who confirmed the determination with six botanists.

Lincoln Taiz (Taiz and Taiz 2011), emeritus plant physiologist at University of California, Santa Cruz, confirms the resemblance, while *Helianthus* authorities Robert Bye (pers. commun. 2014), distinguished ethnobotanist at Universidad Nacional Autónoma de México (UNAM) in Mexico City, and Billie Turner (pers. commun. 2014), one of the world’s leading experts on Mexican Asteraceae and former Curator of the Herbarium (TEX) of the University of Texas at Austin, also confirm this identification. Sunflower researcher Jessica Barb (pers. commun. 2015) of Iowa State University notes that inbred lines of sunflower have very short petioles (see Plate 9C), and that leaf variation is quite high.

The preponderance of evidence points to Mexico as the center of domestication for sunflower (Harter et al. 2004; Heiser 2008; Lentz et al. 2008a,b; Rieseberg and Burke 2008; Bye et al. 2009; Blackman et al. 2011; Moody and Rieseberg 2012). In Mexico, names in period literature for *H. annuus* are *chilamacatl* (Sahagún 1963), *chimalacatl* or *chimalacaxochitl* (Hernández 1942; Sahagún 1963), and *chimalatl peruina* (Hernández et al. 1651), all Nahuatl names. Additional
Nahuatl names are *acahualli* (Ramírez and Alcocer 1902; Dressler 1953) and *chimalxochitl* (Zepeda and White 2008).

**3. Fol. 13r. Petasites sp., cf. *P. frigidus* var. *palmatus* (Plate 10).** Based on the asterid inflorescence, large cleft orbicular leaves, and relatively large root system, Plate 10A is most probably a *Petasites* sp. The closest match might be *P. frigidus* (L.) Fr. var. *palmatus* (Aiton) Cronquist, the western sweet-colt'sfoot (Plate 10B). This is native to North America from Canada to California. *Petasites* spp. are used as antiasthmatics, antispasmodics, and expectorants and in salve or poultice form (Bayer et al. 2006).

![Plate 9. Helianthus annuum: (A) fol. 93r; (B) Plate 10. Petasites sp.: (A) fol. 13r (B) *P. frigidus* var. *palmatus* (Source: Ben Legler).](image)

Plate 9. *Helianthus annuum*: (A) fol. 93r; (B) Plate 10. *Petasites* sp.: (A) fol. 13r (B) *P. frigidus* var. *palmatus* (Source: Ben Legler).

**4. Fol. 33v. Psacalium sp.? Pippenalia sp.? (Plate 11).** This phytomorph (Plate 11A) has lobed peltate leaves and fleshy, round subterranean tubers. The inflorescence is characteristic of the tribe Heliantheae, and the “achenes” or cypselae are round and naked, a rare feature in the Asteraceae family. This illustration is a conundrum. The leaves and tubers suggest *Psacalium* sp., possibly *P. peltigerum* (B.L. Rob. & Seaton) Rydb. (Plate 11B) but the large flower suggests a *Pippenalia* sp., possibly *P. delphinifolia* (Rydb.) McVaugh (Plate 11C). Is this a hybrid phytomorph, *i.e.*, did the artist paint a combined image based on two species mixed together?

**5. Fol. 40v. Smallanthus sp. (Plate 12).** This folio contains two phytomorphs of the same plant, vegetative and flowering (Plate 12A). While quite definitely a member of the Asteraceae, the genus is less obvious. With bluish petals, reddish involucre, palmately compound leaves, and tuberous roots, this seems to fit a *Smallanthus* sp. It resembles somewhat the leading *Smallanthus* species...
cultivated today, the edible yacón \textit{[S. sonchifolius (Poepp.) H. Rob.]}, which is native to western South America (Plate 12B & C).

Plate 11. \textit{Pascalium} sp.? + \textit{Pippenalia} sp.?: (A) Plate 12. \textit{Smallanthus} sp.: (A) fol. 40v; (B & C) fol. 33v; (B) herbarium sheet of \textit{Pippenalia} inflorescence and tuberous roots of \textit{S. delphinifolia} (ASU0029020) (Source: Arizona \textit{sonchifolius} (yacón), respectively (Source: State University Herbarium); (C) herbarium Rob Hille, https://upload.wikimedia.org/sheet of \textit{Psacalium peltigerum} var. \textit{hintonii} R. \textit{W. Pippen} (MICH1107637) (Source: sonchifolius.P.jpg and NusHub, University of Michigan Library Digital Collections. University of Michigan Herbarium respectively). Vascular Plant Type Collection with Specimen Images).

\textbf{H. Boraginaceae}

\textbf{1. Fol. 47v. \textit{Cynoglossum grande} (Plate 13).} This phytomorph has terminal blue flowers of six to seven petals with a raised white center, prominent cauline leaves, broadly elliptic basal leaves, and broad branched brown roots (Plate 13A). This matches the variability of \textit{Cynoglossum grande} Douglas ex Leh. except that this species has only five petals and the cauline leaves are smaller and closer to the base (Plate 13B). This species is native from British Columbia to California.

\textbf{2. Fol. 56r. \textit{Phacelia campanularia} (Plate 14).} With blue flowers in a scorpioid cyme, dentate leaves, and overlapping leaf-like basal scales (Plate 14A) the phytomorph is a good match for \textit{Phacelia campanularia} A. Gray, California bluebell (Plate 14B & C), a California native.
3. Fol. 39v. *Phacelia crenulata* (Plate 15). This has bluish flowers in a cyme with deeply pinnately lobed green leaves on broad, brown, branched roots (Plate 15A). This closely matches *Phacelia crenulata* Torr. (Plate 15B) native from Colorado to Mexico.

4. Fol. 51v. *Phacelia integrifolia* (Plate 16). The phytomorph has blue flowers on a scorioid cyme and narrowly elliptic crenate leaves that curl (Plate 16A). The roots are brown and branched. This matches fairly well the variability of *Phacelia integrifolia* Torr. (Plate 16B & C) which is native from Utah and Kansas, and south to Mexico.

5. Fol. 26r. *Wigandia urens* (Plate 17). This bears what can be interpreted as bluish flowers on a scorpiod cyme with leaves that are green, crenate, and obtuse (Plate 17A). This matches *Wigandia urens* (Ruís & Pav.) Kunth very well (Plate 17B), a shrub found from Mexico and south to Peru. This is called *chichicaztle* (Díaz, 1976) and also matches *patlāhu–ctzīzticāztli* (wide/broad nettle) on fol. 47r in the Codex Cruz-Badianus (Emmart 1940; Díaz 1976; Cruz and Badiano 1991; Gates, 2000; Clayton et al. 2009; de Ávila Blomberg 2012).

I. Brassicaceae

1. Fol. 90v. *Caulanthus heterophyllus* (Plate 18). This phytomorph might be *Caulanthus heterophyllus* (Nutt.) Payson, San Diego wild cabbage or San Diego jewelflower (Plate 18A). The flowers of *C. heterophyllus* are four-petaled, white with a purple streak down the center, with four protruding dark purple anthers (Plate 18B). Leaves vary from dentate to lobed but are typically clasping, not petiolate (Plate 18C). This annual species is native to California and Baja California (Al-Shehbaz 2012).


J. Cactaceae

1. Fol. 100r #8. *Opuntia* sp., cf. *O. ficus-indica* (Plate 19). Phytomorph #8 on fol. 100r has the shape of a prickly pear cactus pad or fruit with areoles bearing leaf primordia and tiny fruits on the top edge, i.e., *Opuntia* sp., quite possibly *Opuntia ficus-indica* (L.) Mill., *O. megacantha* Salm-Dyck, or *O. streptacantha* Lem. (Dressler 1953). This is called *nochtli* and *tlatoc nochti/tla-tōc-nōchtli* in the Codex Cruz-Badianus (Emmart 1940; Dressler 1953; Cruz and Badiano 1991; Gates 2000; Zepeda and White, 2008 Clayton 2009; de Ávila Blomberg 2012). Today, *Opuntia ficus-indica* is widely cultivated but apparently native to central Mexico. *Nopalea cochenillifera* (L.) Salm-Dyck is also widely cultivated for the insect that is the source for cochineal (Standley 1920–1926:863).

K. Caryophyllaceae

1. Fol. 24r. *Silene* cf. *S. menziesii* infected with *Microbotryum violaceum* (Plate 20). This is probably a *Silene* sp., but the crudeness of the image prevents accurate designation of a species. This phytomorph might possibly be based, in part, *Silene menziesii* Hook., Menzie’s catchfly. This variable species is native from Alaska to California and New Mexico (Morton 2005). The white flowers are a good match, even showing the typical 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, and *C. menziesii* has attenuate leaf bases. Is this another case of disparity of the leaves between reality and portrayal, or is there another species of *Silene* that is a better match to the illustration?

Plate 19. *Opuntia* sp.: (A) fol. 100 #8; (B) Plate 20. *Silene* sp.: (A) fol. 24r; (B & C) stems eladode (pad) of *O. ficus-indica* with fruits and inflorescence of *S. menziesii* (Source: (Source: Atozxyz, https://en.wikipedia.org/ Robert L. Carr, http://web.ewu.edu/ewflora/wiki/File:Prickly_pear_cactus_beed.jpg). Caryophyllaceae/Silene%20menziesii.html);
L. Convolvulaceae

1. Fol. 1v + 101v(2) #4. *Ipomoea arborescens* (Plate 21). The phytomorph show a single leafy shoot with a single terminal flower bud arising from a thick caudex (Plate 21A) The flower bud has whitish sepals and brownish petals; leaves are alternate, cordate, petiolate, green on the adaxial surface, tan on the abaxial surface; while coarse roots emanate from the basal caudex. This phytomorph is repeated on fol. 101v (2) #4 (Plate 21E) of the “pharma” section. This illustration is overwhelmingly similar in style and substance to *xiuhamolli/xiuhhamolli* (soap plant) found in fol. 9r, Plate 11 (Plate 21B) in the 1552 Mexican Codex Cruz-Badianus, which has been identified as *Ipomoea murucoides* Roem. & Schult. (Emmart 1940; Cruz and Badiano 1991; Gates 2000; Clayton et al. 2009). Reko (1947) and Bye and Linares (2013) also identify this as an *Ipomoea* sp. The flower bud of *I. murucoides* (Plate 21C) is similar.

Phytomorphs in the Codex Cruz-Badianus and in the Voynich codes have a large, broad, gray to whitish basal caudex with ridged bark. However, leaves in the Voynich Codex are cordate rather than attenuate as observed in the Cruz-Badianus Codex. The phytomorph in the Voynich Codex must then be *Ipomoea arborescens* (Humb. & Bonpl. ex Willd.) G. Don, (Plate 21D) found from northern to southern Mexico (Standley 1920–1926:1205) and commonly known in Nahuatl as *quauhtzahuatl* (Ocaranza 2011).

Additional botanical characters of both species are discussed by Standley (1920–1926) and McPherson (1981) and. Curiously, McPherson described the bases of the leaves of *I. murucoides* as truncate, while Standley described the bases as rounded or obtuse, but all herbarium sheets of this species that we have seen would be better described as cuneate. Leaves of *I. murucoides* are described by McPherson as variously pubescent, while the leaves of *I. arborescens* are usually tomentose, especially on the lower surface, rendering the abaxial surface grey-green, the adaxial surface green. The tomentose abaxial surface often turns brownish green on drying, which is similar to that of the phytomorph in the Voynich Codex. Additional names for *I. arborescens* include “‘Palo blanco’ (Sonora, Sinaloa); ‘palo del muerto,’ ‘casahuate,’ ‘quauhtzahuatl,’ ‘casahuate blanco’ (Morelos); ‘palo santo’ (Sonora); ‘palo bobo’ (Morelos, El Salvador); ‘tutumushte,’ ‘siete pellejos,’ ‘siete camisas’ (El Salvador).” (Standley 1920–1926:1205). It is known as morning glory tree in English. The ashes of the arborescent *Ipomoea* species, *I. murucoides* and *I. arborescens*, are used to prepare soap and are also used in hair and skin care (Batres et al. 2012; Standley 1920–1926:1205).

2. Fol. 57r. *Ipomoea nil* (Plate 22). The phytomorph has a terminal dark blue flower with a white edge, acute petals, and elongated calyx lobes. Leaves are lobed peltate on an herbaceous bush. Roots are brown and branched (Plate 22A). This might match the variability of *Ipomoea nil* (L.) Roth (Plate 23B). This is native from northern Mexico to Argentina. This is extremely variable, from vine to herbaceous bush, with floral colors from blue to pink to white but often with a distinctive white edge. Leaves are often hastate but vary to palmately lobed.
Plate 21. *Ipomoea arborescens*: (A) fol. 1v; (B) *Ipomoea nil*: (A) fol. 57r; (B & C) *I. murucoides* from Cruz-Badianus Codex plate 11; (C) bud of *I. murucoides* (Source: Kevin C. Exotic Seeds and ghost32writer.com); (D); flower, fruits, and leaves of *I* respectively.

*M. Dioscoreaceae*

3. Fol. 32v + fol. 101v(3) #2. *Ipomoea pubescens* (Plate 23). The blue flowers, deeply lobed leaves, and tuberous roots (Plate 23A & B) are all good fits for most probably *Ipomoea pubescens* Lam., silky morning-glory (Plate 23C). This vine is native from Arizona and New Mexico to Mexico, and also in Bolivia, Peru, and Argentina. This phytomorph is also repeated on fol. 101v(3) #2 of the Voynich Codex. Species of *Ipomoea* are known for their resin glycosides and use to counter several diseases (Pereda-Miranda et al. 2010; Batres et al. 2012; Meira et al. 2012).

1. Fol. 17v. *Dioscorea composita* (Plate 24). Most probably this phytomorph (Plate 24A) is *Dioscorea composita* Hemsl., barbasco (Plate 24B). This is native from southern Mexico to Costa Rica. The roots (Plate 24C) are quite often segmented, as shown in the Voynich Codex, and a major source of diosgenin. The flowers, yellow when fresh but rust-colored upon drying, and borne on a vine fit rather well, but the phytomorph is shown with leaves more hastate than *D. composita* normally exhibits.
Plate 23. *Ipomoea pubescens*: (A) fol 32v; (B) fol. 101v(3) #2; (C) flower, leaf and rhizome of *I. pubescens* (Source: Apostolou Starvos).

Plate 24. *Dioscorea composita*: (A) fol. 17v; (B) leaves and inflorescences of *D. composita* (Source: Abisai García Mendoza); (C) segmented roots of *D. composita* (Source: Ryan Somma, https://commons.wikimedia.org/wiki/File:Dioscorea_composita.jpg).

2. Fol. 96v. *Dioscorea mexicana* (Plate 25). The rust-colored flowers and sagittate leaves of the phytomorph (Plate 25A) fit rather well for *Dioscorea mexicana* Schweidw., Mexican yam (Plate 25B & C). This vine is native from northern to southern Mexico to Panama. This is a source of diosgenin.

3. Fol. 99r #28. *Dioscorea sp.*, cf. *D. remotiflora* (Plate 26). The 28th phytomorph on fol. 99r (Plate 26A) is most probably *Dioscorea remotiflora* Kunth (Plate 26B) which is native from northern to southern Mexico. The large, dark root is paddle- or bat-like (Plate 26C & D). The rust-colored flowers and cordate leaves on a vine also match.
Plate 25. *Dioscorea mexicana*: (A) fol. 96v; (B & C) inflorescence and rhizome of *D. mexicana*, respectively (Source: Michael (F1405679) (Source: The Field Museum); (C & Charters and The Smithsonian, D) bat- or paddle-like roots of *D. remotiflora* (Source: Ignacio Garcia Ruiz).

Plate 26. *Dioscorea remotiflora*: (A) 99r #28; (B) herbarium sheet of *D. remotiflora* (F1405679) (Source: The Field Museum); (C & D) bat- or paddle-like roots of *D. remotiflora* (Source: Ignacio Garcia Ruiz).

3/04/11/i-yam-not-a-tortoise-but-a-plant/, respectively.

N. Euphorbiaceae

1. Fol. 6v. *Cnidoscolus texanus* (Plate 27). The palmately compound leaves and trichomes on the fruit (Plate 27A) match a *Cnidoscolus* sp. Both *C. chayamansa* McVaugh and *C. aconitifolius* (Mill.) I.M. Johnst. are called chaya and widely cultivated from Mexico to Nicaragua, and the leaves are matches (Ross-Ibarra and Molina-Cruz 2002). However, these cultivated species have relatively smooth fruits, and a closer correspondence would be *C. texanus* (Müll. Arg.) Small (Plate 27B & C) with fruits that are coated with trichomes.

2. Fol. 21r. *Euphorbia thymifolia* (Plate 28). The spreading growth pattern, tiny green to reddish leaves, and reddish axillary flowers (Plate 28A) fit *Euphorbia thymifolia* L. [*Chamaesyce thymifolia* (L.) Millsp.] (Plate 28B) well. It is native to the tropics in Africa, Asia, and the Americas (Florida to Argentina). The leaves, seeds and fresh juice of the whole plant are used in worm infections, in bowel complaints, and in many more diseases therapeutically (Mali and Panchal 2013).
3. Fol. 5v. *Jatropha cathartica* (Plate 29). The appropriate identification for this phytomorph (Plate 29A) is most probably *Jatropha cathartica* Terán & Berland., *jicamilla* (Plate 29B). The palmately compound dentate leaves, red flowers, and tuberous roots are similar. It is native from Texas to northern Mexico. As the name implies, this is cathartic and poisonous. Another species which is similar is *J. podagrica* Hook., native from southern Mexico to Nicaragua but the leaflets are typically broader and not as deeply cut as *J. cathartica*.

4. Fol. 93v. *Manihot rubricaulis* (Plate 30). The stout, thickened roots, palmately compound leaves, and reddish fruits (Plate 30A) all fit the genus *Manihot*. This phytomorph is most probably *Manihot rubricaulis* I. M. Johnst. (Plate 30B) from northern Mexico. This close relative to the cassava, *M. esculenta* Crantz, has thinner, more deeply lobed leaves and also bears tuberous roots (Hancock, 2012). *Manihot rubricaulis* is perhaps illustrated in fol. 43v of the Codex Cruz-Badianus as *yamanquipatlis* (gentle or weak medicine) (Emmart 1940; Cruz and Badiano 1991; Gates 2000; Clayton et al. 2009).
O. Fabaceae

1. Fol. 88r #11. **Lupinus sp., cf. L. montanus (Plate 31).** Phytomorph #11 on fol. 88r (Plate 31A) displays stylized compound peltate leaves and callus-like, nitrogen-fixing root nodules on one side of the roots. Many members of the Fabaceae have nitrogen-fixing nodules, but none have leaves exactly as depicted. While the image is crudely rendered, it might possibly be *Lupinus montanus* Humb., Bonpl. & Kunth (Plate 31B) of Mexico and Central America. The compound peltate leaves and soft, callus-like, nitrogen-fixing root nodules on one side of the roots (Plate 31C) are all typical of this species. This lupine is noted to contain alkaloids (Dunn and Harmon 1977; Ruiz-López et al. 2010).

P. Gesneriaceae

1. Fol. 55r. **Diastema hispidum (Plate 32).** This has six petals, white and bluish, with a long corolla (Plate 32A). Leaves are green and deeply lobed. Multiple stems arise from a rhizomatous base with many brown roots. While this might possibly be a species of *Geranium*, the swollen fruits seem incongruous with this genus and a better match might be *Diastema hispidum* (DC.) Fritsch. (Plate 32B & C) which is native from Nicaragua to Peru.
Plate 31. *Lupinus* sp.; (A) fol. 88r #7; (B) *L. montanus* (Source: Harry Douwes); (C) root flower of *D. hispidum* (Source: Leslie nodules on *L. montanus* (Source: Wilderness Brothers); (C) herbarium sheet of *D. hispidum* and Backcountry Site Restoration Guide, (F1836367) showing thin rhizomatous roots USDA/US Forest Service).

Plate 32. *Diastema hispidum*: (A) fol. 55r; (B) flower of *D. hispidum* (Source: Leslie); (C) herbarium sheet of *D. hispidum* (F1836367) showing thin rhizomatous roots (Source: The Field Museum).

**Q. Grossulariaceae**

1. **Fol. 23r. *Ribes malvaceum* (Plate 33).** This phytomorph (Plate 33A) is most probably *Ribes malvaceum* Sm., chaparral currant (Plate 33B & C). This woody, stoloniferous shrub has purple-magenta flowers and palmately lobed leaves and is native from California to Baja Norte, Mexico (Standley 1920–1926:316).

**R. Lamiaceae**

1. **Fol. 45v. *Hyptis albida* (Plate 34).** The gray leaves, blue flowers, and stout root (Plate 34A) are all good fits for most probably *Hyptis albida* Kunth (Plate 34B & C). This shrub is native to Sonora and Chihuahua to San Luis Potosí, Guanajuato, and Guerrero. Standley (1920–1926:1275) 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.”

Plate 34. *Hypitis albida*: (A) fol. 45v; (B & C) inflorescence of *Hypitis albida* (Source: Benjamin T. Wilder and Jim Conrad, respectively).

2. Fol. 32r. *Ocimum campechianum* (*O. micranthum*) (Plate 35). This phytomorph (Plate 35A) is most probably *Ocimum campechianum* Mill. (*O. micranthum* Willd.) (Plate 35B). This suffrutescent annual basil is native from Florida to Argentina; in Mexico it is found from Sinaloa to Tamaulipas, Yucatán, and Colima. The terminal inflorescence, bluish flowers, and ovate leaves are both good fits (Standley 1920–1926:1272; Standley and Williams 1973:269). Standley (1920–1926:1272) relates “In El Salvador bunches of the leaves of this plant are put in the ears as a remedy for earache.”

3. Fol. 45r. *Salvia cacaliifolia* (Plate 36). The blue flowers in a tripartite inflorescence and distantly dentate deltoid-hastate leaves (Plate 36A) are quite characteristic of *Salvia cacaliifolia* Benth. (Plate 36B). This is native from Mexico (Chiapas) to Guatemala and Honduras (Standley and Williams 1973:278).
Plate 35. *Ocimum campechianum*: (A) fol. 32r; Plate 36. *Salvia cacaliifolia*: (A) fol. 45r; (B) inflorescence and leaves of *O.* inflorescence and leaves of *S. cacaliifolia campechianum* (Source: Roger L. Hammer). (Source: Ashwood Nurseries Ltd).

4. Fol. 100r #5. *Scutellaria mexicana* (Plate 37). Phytomorph #5 on fol. 100r (Plate 37A) shows three flowers of what matches to *Scutellaria mexicana* (Torr.) A.J. Paton (*Salazaria mexicana* Torr.) (Plate 37B & C). This species also seems to match the description of *tenamaznanapoloa* (carrying triplets?) of Hernández et al. (1651:129) (alias *tenamazton* or *tlalamatl*). This shrub, native from Utah to Mexico (Baja California, Chihuahua, and Coahuila), bears 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 (Standley 1920–1926:1271).

S. Malvaceae

1. Fol. 102r #11. *Chiranthodendron pentadactylon* (Plate 38). Phytomorph #11 (Plate 38A) is very curious, looking more like a very dark, blue-black flag than a possible plant part. However, this is often what the five-parted stamens of *Chiranthodendron pentadactylon* Larreaut. (*C. platanoides* Bonpl.), the hand-flower, look like when pressed and dried. When fresh, the stamens are a brilliant vermillion (Plate 38B) but they turn blue-black when improperly dried and/or aged (Plate 38C) and the five-parted, hand-like stamens can assume a flag-like figure when pressed. This species typically grows in wet areas in the mountains of Oaxaca and Guatemala but is widely planted in the Valley of Mexico (Standley 1920–1926). This is called *macpalxochi quahuitl* in Hernández et al. (1651:383, 459). Additional Nahuatl names are *mapasúchil, mapilxochitl*, and *teyacua* (Díaz 1976); *mapasúchil* is derived from the Nahuatl *macpal-xochitl*, “hand flower” (Standley 1920–1926).
Plate 37. *Scutellaria mexicana*: (A) fol. 100r #5; (B & C) inflorescence of *S. mexicana* (Source: Michael L. Charters).

Plate 38. *Chiranthodendron pentadactylon*: (A) fol. 102r #11; (B) five parted stamens of *C. pentadactylon* (Source: Jan Conayne); (C) dried shoot of *C. pentadacylon* showing leaves and flower with protruding stamens (Source: José Luis Villaseñor Ríos).

**T. Marantaceae**

1. **Fol. 42v. *Calathea sp., cf. C. loeseneri*** (Plate 39). The phytomorph inflorescence (Plate 39A) is a crude representation of a *Calathea* sp., probably allied to *C. loeseneri* J.F. Macbr., which yields a blue dye. Many species of *Calathea* were recently transferred to the genus *Goeppertia*, and a synonym of this species is now *G. loesneri* (J.F. Macbr.) Borschs. & Suárez (Borschenius et al. 2012). The crudeness of the illustration, coupled with inadequate surveys of the genus *Calathea/Goeppertia* in Mexico, prevent precise identification.

**U. Menyanthaceae**

1. **Fol. 2v. *Nymphoides aquatica*** (Plate 40). The rounded notched leaves with white flowers and thick rhizome (Plate 40A) closely resembles *Nymphoides aquatica* (J. F. Gmel.) Kuntze (Plate 40B). This aquatic plant with floating orbicular leaves and white flowers (Plate 40B) with five petals is native to North America, from New Jersey to Texas. The horizontal rhizome bears thick, unbranched adventitious roots that in young plants resemble a bunch of bananas (Richards et al. 2010), earning it the popular name the banana plant. Another possibility, because the flower petals are illustrated with a crenate margin, is *N. indica* (L.) Kuntze, which has fringed petals and is native to not only Mexico but also Asia, Africa, and Australia.
Plate 39. Calathea sp.: (A) fol. 42v; (B) inflorescence and leaves of C. loeseneri N. aquatica (Source: Center for Aquatic and Invasive plants, University of Florida, Gainsville).

Plate 40. Nymphoides aquatic a: (A) fol. 2v; (B) N. aquatic a (Source: Center for Aquatic and Invasive plants, University of Florida, Gainsville).

V. Moraceae

1. Fol. 36v. Dorstenia contrajerva (Plate 41). The inflorescence (Plate 41A), appearing like a split open fig, is quite distinct and matches most probably a Dorstenia sp., likely the very variable D. contrajerva L. (Plate 41B). Leaves for this species vary “in spirals, rosulate or spaced; lamina broadly ovate to cordiform to subhastate, pinnately to subpalmately or subpedately, variously lobed to parted with 3–8 lobes at each side or subentire” (Berg 2001). This is native from Mexico to Peru. The Nahuatl name is tozpatli or tuzpatli (Díaz 1976).

W. Nyctaginaceae

1. Fol. 33r. Allionia incarnata (Plate 42). This has many petals united into a greenish corolla, backed by a swollen whitish calyx, with sagittate, green leaves, and swollen branched brown roots (Plate 42A). This matches the wide variability of Allionia incarnata L. (Plate 42B & C), trailing four o’clock or trailing windmills, known in Spanish as hierba de la hormiga (ant herb) or hierba del golpe (wound herb). This is native from Utah to Mexico. Curiously, the ends of the two main roots in the phytomorph in the Voynich Codex have a face. The roots of Allionia incarnata do bear bumps with indentations that could be interpreted as tiny faces.
Plate 41. *Dorstenia contrajervae*: (A) fol. 36v; (B) botanical image of *D. contrajervae* by Pierre Turpin from Chaumeton (1830:131).

Plate 42. *Allionia incarnata*: (A) fol. 33r; (B) inflorescence and leaves of *A. incarnate* (Source: Campbell and Lynn Loughmiller, Lady Bird Johnson Wildflower Center); (C) herbarium specimen of *A. incarnata* (DES00067664) showing the swollen, knobby roots (Source: Desert Botanical Garden Herbarium Collection, http://intermountainbiota.org/portal/collections/individual/index.php?occid=2430103).

X. Onagraceae

1. Fol. 51r. *Fuchsia thymifolia* (Plate 43). The phytomorph has four red petals and four pale sepals backed by a corolla tube and a swollen ovary; leaves are green, deeply serrate; roots are brown, tuberous (Plate 43A). This may be *Fuchsia thymifolia* Kunth (Plate 43B), native from Mexico to Guatemala.

Y. Passifloraceae

1. Fol. 23v. *Passiflora Subgenus Decaloba*, cf. *P. morifolia* (Plate 44). From the flower alone, this is definitely a *Passiflora* sp. of subgenus *Decaloba* (Plate 44A). *Passiflora* is primarily a New World genus (a few species also occur in Australia and Southeast Asia but not Europe). The prominent corona with filaments of the genus *Passiflora* is very distinctive 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 leaves that are deeply cordate only seem to match the variability of *P. morifolia* Mast. (Killip 1938) (Plate 44B & C), although the artist has made the leaves slightly more orbicular then they normally occur in mature foliage. However, young plants, *i.e.*, root suckers, often exhibit juvenile leaves that are orbicular, entire leaves.
Plate 43. *Fuchsia thymifolia*: (A) fol. 51r; (B) leaves and flowers of *F. thymifolia* (Source: Todd Boland).

Plate 44. *Passiflora* sp.: (A) fol 23v; (B) flower of *P. morifolia* (Source: Anke and Ralf Schlosser); (C) leaf showing petiolar gland of *P. morifolia* (Source: Hans B., https://commons.wikimedia.org/wiki/File:Passiflora_morifolia3.jpg).

**Z. Penthoraceae**

1. Fol. 30v. *Penthorum sedoides* (Plate 45). The cymose inflorescence, dentate leaves (Plate 45A) and stolons match *Penthorum sedoides* L. (Plate 45B & C), quite well. This is a New World species native from Canada to Texas. The artist, though, has apparently 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.

**AA. Polemoniaceae**

1. Fol. 4v. *Cobaea* sp., cf. *C. biaurita* (Plate 46). With a basally woody stem, pinnately compound elliptic leaves, campanulate corolla, segmented calyx, and exserted style (Plate 46A) the best match would be a *Cobaea* sp., most probably *C. biaurita* Standl. (Plate 46B & C) which is closely related to the cultivated *C. scandens* Cav. This vine is native to Chiapas and Oaxaca, Mexico and has elliptic leaflets with acute to acuminate apices and flowers that emerge cream-colored but later mature to purple (Standley 1914; Prather 1999).
Plate 45. *Penthorum sedoides*: (A) fol. 30v; (B) inflorescence and leaves of *P. sedoides* (Source: Fritz Flohr Reynolds, https://commons.wikimedia.org/wiki/File:Penthorum_sedoides_-_Ditch_Stonecrop.jpg); (C) botanical painting of *P. sedoides* from Millspaugh (1892 1:t. 57).

Plate 46. *Cobaea* sp.: (A) fol 4v; (B) flower of *C. scandens* (Source: Michael Wolf, https://commons.wikimedia.org/wiki/File:Cobaea_scandens_03.jpg); (C) herbarium sheet of *C. biaurita* (F1662840) (Source: The Field Museum).

**BB. Ranunculaceae**

1. **Fol. 95r. Actaea rubra f. neglecta** *(Plate 47)*. The crenate pinnately compound leaves and noticeably white, globose fruits in a raceme (Plate 47A) fit quite definitely an *Actaea* sp., probably the white-fruited *Actaea rubra* (Aiton) Willd. f. *neglecta* (Gillman) B. L. Rob (Plate 47B). *Actaea rubra* is native to Eurasia, and North America from Canada to New Mexico, but f. *neglecta* is more common in North America (Compton et al., 1998). As the common name baneberry would indicate, this is poisonous.

2. **Fol. 52r. Anemone patens** *(Plate 48)*. This has a terminal, pubescent blue flower with many linear bracts; leaves are deeply laciniate; roots are brown, long, and tuberous (Plate 48A). This matches very nicely the variability of *Anemone patens* L., pasqueflower (Plate 48B & C), which is circumboreal, south to Texas and New Mexico.
Plate 47. Actaea rubra f. neglecta: (A) fol. 95r; (B) fruits and leaves of Actaea rubra f. neglecta (Source: Donald Cameron).

Plate 48. Anemone patens: (A) fol. 52r; (B & C) flowers and leaves of Anemone patens (Source: Tom Koerner, U.S. Fish and Wildlife Service and John Richards, respectively).

3. Fol. 29v. Anemone tuberosa (Plate 49). This has blue-green, hairy flower buds with a multi-petaled, bluish corolla; basal leaves are deeply divided; roots are tuberous (Plate 49A). This matches Anemone tuberosa Rydb., desert anemone (Plate 49B), native from Utah to Mexico.

CC. Saxifragaceae

1. Fol. 49r. Lithophragma affine (Plate 50). This has blue flowers with fringed petals and red calyces; leaves are numerous and borne tightly together on long petioles; roots are tuberous (Plate 50A). This matches the variability of Lithophragma affine A. Gray (Plate 50B & C), which is native from Oregon to Baja California and intergrades with L. parviflorum (Hook.) Torr. & A. Gray (Park and Elvander 2012).
DD. Solanaceae

1. Fol. 101r #3 & Fol. 101v (1) #2. *Capsicum annuum* (Plate 51). O’Neill (1944) identified a *Capsicum* sp. in the Voynich Codex. However, in the text he said fol. 101v, but the illustration provided was from fol. 101r. Fortunately, we agree that the shape and color of the fruits of both phytomorphs (Plate 51A & B) agree with the genus *Capsicum*. Phytomorph #3 on fol. 101r has erect green fruits with depressed stem attachments and a forked primary root. Phytomorph #2 on fol. 101v has pendant red fruits and a forked primary root. Both fall within the wide variation of *C. annuum* L. (Plate 51B & C). The common red capsicum pepper originated in Mesoamerica but was introduced to Eurasia and Africa by the early 16th century.

EE. Urticaceae

1. Fol. 25r. *Urtica* sp., cf. *U. chamaedryoides* (Plate 52). This phytomorph (Plate 52A) was first postulated by the Rev. Hugh O’Neill (1944) to be a member of the Urticaceae, or nettle family. The best match, because of the dentate, lanceolate leaves and reddish inflorescences, seems to be *Urtica chamaedryoides* Pursh, heart-leaf nettle (Plate 52B). This is native from Canada to northern Mexico. *Urtica* and the closely related genus *Urera* also occur in the Codex Cruz-Badianus (Emmart 1940; Cruz and Badiano 1991; Gates 2000; Clayton et al. 2009) and Hernández et al. (1651).

Plate 51. *Capsicum annuum*: (A) 101r #3; (B). Plate 52. *Urtica* sp.: (A) fol. 25v; (B) *U. Fol. 101v (1) #2; (C and D) green and red fruit *chamaedryoides* (Source: Steve Baskauf, of *C. annuum* (Source: Consell Comarca Baix http://bioimages.vanderbilt.edu/).
Empordà, https://commons.wikimedia.org/
FF. Valerianaceae

1. Fol. 65r. *Valeriana albonervata* (Plate 53). The palmate- or cleft-lobed leaves; inflorescence; and napiform to fusiform, often forked taproots (Plate 53A) are a good match for *Valeriana albonervata* B.L. Rob. (Plate 53B). This is native to the Sierra Madre of Mexico (Meye 1951).

GG. Verbenaceae

1. Fol. 94r. *Duranta erecta* (*D. repens*) (Plate 54). This has terminal black fruits with a white terminal knob, arranged in a corymb or umbel. Leaves are obcordate and crenate. The roots are thick and brown, branched (Plate 54A). Except for the shape of the inflorescence (Plate 54B), this matches perfectly a dried specimen of the repent form of *Duranta erecta* L. (*D. repens* L.), golden dewdrop (Plate 54C). This shrub is native from Florida and Texas, south to Argentina. The fruits are golden yellow when fresh and borne on a panicle, but when dried, they often quickly fall apart and turn black. Presumably because of the color of the fruits matching that of a dried specimen, the sample would have been fragmented when the artist prepared this illustration, and thus the artist was likely unaware of the color of the mature fruit on a living branch.

HH. Violaceae

1. Fol. 9v. *Viola bicolor* (*V. rafinesquei*) (Plate 55). This phytomorph (Plate 55A) clearly shows linear terminal stipular lobes, as in the North American native *V. bicolor* Pursh (*V. rafinesquei
Greene) (Plate 55B), not spatulate as in the Eurasian *V. tricolor* L. Also, this phytomorph matches the blue flowers of *V. bicolor*, not the tricolored ones of *V. tricolor*; *V. bicolor* flowers are uniformly cream to blue, while those of *V. tricolor* usually have two purple upper petals and three cream to yellow lower petals. *Viola bicolor* is native from New Jersey to Texas, west to Arizona, with a center of diversity in eastern Texas (Shinners 1961; Russell 1965).

The delineation of *V. bicolor* as native to North America and not introduced from elsewhere was only first fully elucidated by Shinners in 1961. Prior to 1961, *V. bicolor* was considered doubtfully native and also classified as a variety of the Eurasian *V. kitaibeliana* Schult. [var. *rafinesquii* (Greene) Fernald] and often confused with *V. tricolor* and *V. arvensis* Murray (Fernald 1938). The North American *V. bicolor*, besides being seasonally dimorphic with fertile and cleistogamous flowers, differs from the three other related species of Eurasia by “roundish, almost entire basal leaves, and by pectinate, palmately divided stipules. The petals of its open flowers are twice as long as the sepals, slightly shorter than the petals of *V. tricolor* but longer than those of *V. arvensis* and *V. kitaibeliana*.” (Clausen et al. 1964). Thus, because *V. bicolor* was only known as a North American endemic since 1961, any attempt to propose a forgery prior to 1912 (Barlow 1986) will have to explain this anomaly.

![Plate 55. Viola bicolor: (A) fol. 9v; (B) flowers and leaves of *V. bicolor* (Source: Daniel Reed).](image)

II. Boleite

1. **Folio 102r #4 Boleite (Plate 56).** This image includes a cubic (isometric) blue mineral resembling a blue bouillon cube. This can only be boleite (KPb_{26}Ag_{9}Cu_{24}Cl_{62}(OH)_{48}). Boleite crystals are cubic, typically 2–8 mm on the side, rarely up to 2 cm. Boleite is closely related to pseudopoleite and cumengeite, but the crystal structures are slightly different (isometric for boleite, tetragonal square tablets for pseudoboleite, tetragonal pyramids for cumengeite).
Boleite occurs naturally in the oxidized zone of lead-copper deposits but also in smelter slags immersed in and leached by sea water. The only sources for large crystals of this quality and quantity are three closely related mines in Baja California Sur, Mexico, principally the mine at Santa Rosale (El Boleo). Typically at El Boleo, crystals of boleite occur embedded in atacamite, the probable source of the green pigment used in the Voynich Codex (see Chapter 1). Boleite crystals also occur, more rarely, in copper mines of Chile; Broken Hill, Yancowinna Co., Australia; and St. Anthony deposit, Tiger, Arizona. It also occurs as trace deposits in other counties in Arizona, California, Montana, Nevada, and Washington. In Eurasia, boleite has been reported as trace deposits, more commonly in slag localities, in France, Germany, Greece, Iran, Italy, Russia, Spain and the United Kingdom.

http://www.mineralspecies.com/?page_id=16&num=594

Plate 56. Boleite: (A) cuber from 102r-4 (B) boleite mineral. Source: http://www.minfind.com/mineral-54337.html

SOURCES AND TECHNIQUES

Fifty-nine phytomorphs, representing 55 plant species, were identified from the “herbal” and “pharma” sections. In addition the geomorph boleite was indemnified in the “Phama section. Of the 132 phytomorphs in the “herbal” section, 123 had inflorescences or fruits, of which 44 (35.8%) were identified. In contrast to the 230 phytomorphs in the “pharma” section, only 14 showed flowers or fruits (with the great majority only roots lacking key botanical characters), and 9 (64.3%) were identified. Thus, of the 137 phytomorphs in the Voynich Codex with inflorescences or fruits, 53 (38.7%) were identified. All phytomorphs identified were from Colonial New Spain, primarily with a native range in the 21st century from Texas, west to California and south to Honduras. Asteraceae was the most common family, and at least seven more phytomorphs have been tentatively identified from this family but are not included here (folios 18r, 34r, 35r, 46r, 50r, 53v, and 54r).
No indigenous European, Asian, African, Australian or South American plants have been identified other than circumboreal species (e.g., *Actaea rubra*). Some of the plant families, such as Cactaceae, and genera, such as *Passiflora*, are primarily native to the New World. In addition, the animals and mineral identified in the Voynich Codex are primarily from Colonial New Spain (Tucker and Talbert 2013).

The plants identified include a fern and a gymnosperm, but the remainder are angiosperms, including dicotyledonous and monocotyledonous herbaceous and woody plants. Although a number of food plants, including the genera *Agave*, *Capsicum*, *Helianthus*, *Ipomoea*, *Opuntia*, and *Smallanthus*, were described, most of the plants appear to have medicinal value, indicating that the Voynich Codex is largely a medicinal herbal of the New World. This would explain the absence of maize, which was so important in Mesoamerica. The Aztec culture was rich in knowledge of medicinal plants and had many botanical gardens that pre-dated those in Europe (Nuttall, 1925; Granziera, 2001, 2005).

Many of the genera identified herein can also be found in sixteenth century Aztec herbals including the Codex Cruz-Badianus (Emmart 1940; Cruz and Badiano 1991; Gates 2000; Clayton et al. 2009), book 11 of Sahagún (1963), and the collections of Hernandez (Hernández et al. 1651; Hernández 1942). Thus, the plant identification alone is evidence that the Voynich Codex is a codex from Colonial New Spain, probably from the sixteenth century.

The accuracy of the drawing of some phytomorphs, e.g., fol. 9v (*Viola bicolor*), versus the broad strokes of others, e.g., fol. 16v (*Eryngium heterophyllum*), might suggest that more than one artist was involved or that both fresh and dried specimens were used as models. The mixed nature of some of the phytomorphs (fol. 9r, 15v, 33v), the flatness of many phytomorphs (e.g., fol. 100r #4, *Agave* sp.), and the discoloration that could result from drying (e.g., fol. 100r #11, *Chiranthodendron pentadactylon*) would point to the use of dried specimens. The *curanderos/curanderas* in Mexico today most often deal with dried herbs, not fresh ones, as this is the easiest means to preserve materials to have them available for future use.

Correct identification of the phytomorphs today is further rendered difficult by an extremely limited palette of colors. Thus, the red pigment seems to have been used for hues, shades, and tints from pink to dark red and from purple to orange. Furthermore, not only do vegetative pigments shift in color with age, but mineral pigments may also shift, and these changes are increased with humidity, heat, and light (Feller 1986; Eastaugh et al. 2008; Finlay 2014).

The Voynich Codex utilizes a number of other uncommon iconographic techniques: (1) a flat, two-dimensional representation of plants reminiscent of pressed specimens, e.g., folio 100r #4; (2) a foreshortening of large plants in which young shoots appear “grafted or inserted ” upon older bases, e.g., folios 1v, 13r, 16v, 23r, 26r, 45r; (3) anthropomorphic faces among the roots, e.g., folio 33r; (4) reptiles and amphibians among the roots and leaves, e.g., folios 25v, 49r; (5) enlarged organs out of proportion to the rest of the plant, e.g., folio 40v; and (6) a mixture of accurate botanical details vs. crude representations, e.g., folios 9v vs. 16v. These methods of plant illustration are not those of the native Nahua of pre-Conquest New Spain so what were their origins? Fray Motolinia, one of the twelve Franciscan priests who accompanied Cortés, remarked
that the Nahua were extremely talented in copying Latin and Greek manuscripts, so much so that
the original and copy were indistinguishable (Motolinía 1951). The Spanish friars routinely used
European images of Biblical figures as inspiration for Nahua artists (tlacuiloque) (Camelo
Arredondo et al. 1964; Morrill 2014). Furthermore, the library of the Colegio de Tlatelolco, the
school for the Nahua elite created after the Conquest by Fray Zumarraga, the bishop of New Spain,
had an eclectic collection of books including 51 from Lyon, 51 from Paris, 35 from Venice, 22
from Salamanca, 20 from Antwerp, 19 from Basle, 13 from Mexico, 11 from Cologne, 19 from
Aleala de Henares, and 22 from Santiago de Tlatelolco (Gravier 2011).

The illustration style of plant illustrations in the Herbal section of the Voynich Codex, such as
individual naturalistic illustrations interspersed with text, are common in ancient Dioscoridean
illustrated herbals, such as the Juliana Anica Codex of 512 (Collins 2000; Janick and Hummer
2012) and were continuously recopied for a millennium. Naturalism was reintroduced in the
herbals of the Secreta Saliterniana, an Arab-influenced school based in Salerno, which also
contain many of the iconographic features of the Voynich Codex. These Salerno-inspired herbals
range in time from the Tractatus de herbis, British Museum, Egerton 747 of the first third of the
14th century, to the many variations of the Livre des Simples Médecines of the end of the 14th to
first half of the 15 century. (Collins 2000). The Salerno school greatly impacted European herbals
prior to the Conquest of New Spain. There may have been European herbals in the well-stocked
library of the Tlatelolco Colegio that influenced the Voynich Codex as well as other herbals
executed by native tlacuiloque. However caution must be exercised until antecedent herbals can
be identified (Emmart 1940; Peterson 1988). We conclude on the basis of the identification of
these phytomorphs that the Voynich Codex is largely a 16th century herbal that was written in
Colonial New Spain. We suggest that linguists focus in the future on Mesoamerican writing
systems in relation to the Voynich Codex.

ACKNOWLEDGEMENTS
We thank Anna L. Whipkey for her invaluable assistance with the figures. We acknowledge Dr.
Kim Hummer, Dr. John Wiersema, and Dr. Susan Yost for informal reviews.

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GEOMORPH IDENTIFICATION

Folio 102r #4 (Plate 56) includes a cubic (isometric) blue mineral resembling a blue bouillon cube. This can only be boleite \((\text{KPb}_{26}\text{Ag}_{9}\text{Cu}_{24}\text{Cl}_{62}(\text{OH})_{48})\). Boleite crystals are cubic, typically 2-8 mm on the side, rarely up to 2 cm. Boleite is closely related to pseudopoleite and cumengeite, but the crystal structures are slightly different (isometric for boleite, tetragonal square tablets for pseudoboleite, tetragonal pyramids for cumengeite).

Bolleite occurs naturally in the oxidized zone of lead-copper deposits but also in smelter slags immersed in and leached by sea water. The only sources for large crystals of this quality and quantity are three closely related mines in Baja California Sur, Mexico, principally the mine at Santa Rosale (El Boleo). Typically at El Boleo, crystals of boleite occur embedded in atacamite, the probable source of the green pigment. Boleite crystals also occur, more rarely, in copper mines of Chile; Broken Hill, Yancowinna Co., Australia; and St. Anthony deposit, Tiger, Arizona. It also occurs as trace deposits in other counties in Arizona, California, Montana, Nevada, and Washington. In Eurasia, boleite has been reported as trace deposits, more commonly in slag localities, in France, Germany, Greece, Iran, Italy, Russia, Spain and the United Kingdom (Cooper and Hawthorne, 2000; Mallard, 1891; Mottana et al., 1978; Ralph and Chau, 2012). In summary, the identification of this geomorph is critical: boleite most likely came from the New World or, less likely, Australia; a Eurasian origin is unlikely.

Copper compounds have been used historically to treat pulmonary and skin diseases and parasitic infections (e.g., shistosomiasis and bilharzia) (Copper Development Association, 1972).

LITERATURE CITED


102r (20)=
4. ot eös

atlaan, atlan=in or under water (an allusion to the color?)
boleite/pseudoboleite (cubical blue crystal and associated with atacamite, source of the green pigment in the Voynich ms. according to McCrone)

http://www.mineralspecies.com/?page_id=16&num=594

http://www.minfind.com/mineral-54337.html
Pseudoboleite with Atacamite-Paratacamite

Mina Amelia, Santa Rosalía, Boleo, Baja California Sur, Mexico

85mm x 66mm x 36mm

Good sized and colored crystal of Pseudoboleite that has a very well marked twin with the typical echelon on the edges. It is on a matrix of fibrous Gypsum partially coated by Atacamite and Paratacamite, not distinguishable by eye.

From: Fabre Minerals

http://www.minfind.com/mineral-92459.html
Boleite with Atacamite-Paratacamite

Mina Amelia, Santa Rosalía, Boleo, Baja California Sur, Mexico

60mm x 49mm x 45mm

Group of cubic crystals of Boleite, with a smaller single cubic crystal of the same species, on a Gypsum matrix, with Atacamite and Paratacamite.

From: Fabre Minerals