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Identification of Phytomorphs in the Voynich Codex

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ABSTRACT

The Voynich Codex, one of the most fascinating and bizarrely illustrated manuscripts in the world, is preserved in the Beinecke Rare Book and Manuscript Library of Yale University. The descriptive text seems to be an undeciphered writing system. The manuscript has been divided into sections by Voynich commentators, with the major portion of the manuscript depicting plant, animal, and geological images. About 362 phytomorphs, 20 zoomorphs, and 1geomorph are included. In 1944, Hugh O'Neill, a distinguished taxonomic botanist at the Herbarium of the Catholic University of America in Washington, DC, identified two Mesoamerican plants, indicating the possibility that this manuscript is post-Columbian. These identifications were expanded by Tucker and Talbert (2013) to include 37 plants of Colonial New Spain. This paper extends these identifications to 59 phytomorphs, encompassing 55 plant species. Phytomorphs were analyzed by comparing the morphology of the botanical illustrations with herbarium specimens, photographs, and contemporary sources of live plants. The 55 plant species, identified with various levels of certainty, are either circumboreal or indigenous to Colonial New Spain. Most appear to have medicinal uses to improve human health. No European, Asian, or South American plants have been identified other than circumboreal species. This study is consistent with the determination that the Voynich Codex is a herbal written in Colonial New Spain in the 16th century.

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KEYWORDS: Aztec; botany; Colonial New Spain; herbal; Mexico; plant taxonomy; Voynich Manuscript

I. INTRODUCTION AND HISTORICAL CONTEXT

In 1912, the book collector Wilfred M. Voynich discovered a curiously illustrated manuscript written in an unknown symbolic text. Since then, the manuscript has elicited enormous interest resulting in a proliferation of books and web pages with no confirmed resolution concerning the origin or meaning of the text. The U.S. National Security Agency (NSA) has taken cryptological interest (D'Imperio 1978), and Ph.D. theses have been awarded on attempts to decipher the language of the Voynich manuscript (Casanova 1999). Despite claims of the text as a nonsensical hoax (Rugg 2004), the "distribution of words … is compatible with those found in real language sequences" (Montemurro and Zanette 2013) and represents "one single text or as a conglomerate of cryptograms endowed with six separate alphabets" (Casanova 1999). The history of the Voynich manuscript can be easily found elsewhere and need not be repeated here (Brumbaugh 1978; D'Imperio 1978; Kennedy and Churchill 2006; Kircher and Becker 2012). High quality scans of the pages are available, courtesy of the Beinecke Rare Book and Manuscript Library, Yale University (Anon n.d.).

The Voynich Manuscript is numbered with Arabic numerals in a different ink and penmanship from the text. The pages are in pairs ("folios"), with a number on the facing page on the right as *recto*, the reverse unnumbered on the left as *verso* (thus fol. 1r, 1v, 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: "herbal pages" or a "botanical section" (pages with one exception a single type of plant and text); a "pharmaceutical or pharma section" (pages with multiple plant parts and what appears to be apothecary jars or maiolica; "astrological pages" (circular volvelles with nymphs, fol. 70v2–73v that represent the zodiac); "balneological or biological section" (bathing nude nymphs with plumbing fol. 75r–84v), various "magic circle often containing astronomical symbols" (fol. 57v, 67r–69v, 86v), various pages of continuous text that may be recipes or poems (103r–117r), and a last page incomplete (fol. 116v) with some illustrations and text in a different script.

Experts disagree whether this is parchment or vellum. Yale's Beinecke Library terms it parchment, but the report submitted to them by McCrone Associates (2009) calls it vellum. Regardless, while it can be called a manuscript, it is more accurately a codex. A similar shift has been made from the appellation of the Badianus Ms. to the more accurate Codex Cruz-Badianus (Clayton et al. 2009). Henceforth, we will

thus refer to this under the more accurate designation of the Voynich Codex.

II. PHYTOMORPH IDENTIFICATION

Although many of the illustrations could be considered bizarre or whimsical, most contain morphological structures which permit botanical identification. Many enthusiasts have attempted to analyze the plants of the Voynich Codex, but only a few are knowledgeable plant taxonomists, 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 exception to this *zeitgeist* 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, DC. 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 8000 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-20th 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, 9 animals, and at least 1 mineral in the Voynich Codex and concluded that it originated in the 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 seems 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 exaggerated. The stems often seem to be inserted onto other stems and have been erroneously referred 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, for example, fol. 101v, are a trifold, so the section of the folio number is indicated in parentheses, for example, 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* (Fig. 1.1). O'Neill (1944) identified the eusporangiate fern *Botrychium lunaria* (L.) Sw.,

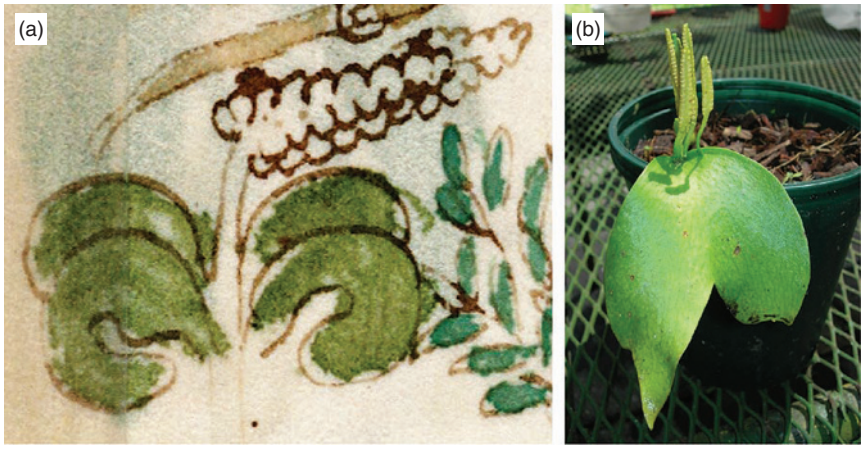

Fig. 1.1. *Ophioglossum palmatum*: (a) fol. 100v #5; (b) *O. palmatum* (Courtesy of Robbin Moran, New York Botanical Garden).

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 (Fig. 1.1a), suggest instead a specimen of the eusporangiate fern *Ophioglossum palmatum* L. The photograph of this species (Fig. 1.1b) 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. *T. mucronatum* (*T. huegelii*, *T. mexicanum*)? (Fig. 1.2). This phytomorph (Fig. 1.2a) 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 (Figs. 1.2b and 1.2c). This species is often multi-trunked in older specimens, for example, 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 *ahuehuete/ahuehuetl* (Hernández et al. 1651; Hernández 1942; Dressler 1953; Díaz 1976; Farfán and Elferink 2010).

Fig. 1.2. *Taxodium* sp.: (a) Fig. 100r #15); (b and c) grouped strobili (cones) and forked tree trunk of *T. mucronatum*, respectively (Courtesy of Geoff Stein).

C. Angiosperms: Asparagaceae/Agavaceae

1. Fol. 100r #4. *Agave* sp., cf. *A. atrovirens* (Fig. 1.3). Phytomorph #4 on fol. 100 (Fig. 1.3a) appears to be a pressed specimen of an *Agave* sp. with leaves bearing a toothed edge, quite possibly *Agave atrovirens* Karw. ex Salm-Dyck (Fig. 1.3b) which was a source for the beverages pulque, mescal, and tequila in the 16th century Colonial New Spain (Hough 1908; Dressler 1953). In Hernández et al. (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* (Fig. 1.4). Probably the most phantasmagoric phytomorph in the Voynich Codex is the *Eryngium* sp. portrayed on fol. 16v (Fig. 1.4a). 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

Fig. 1.3. *Agave* sp.: (a) fol. 100r #4; (b) *Agave atrovirens* (Courtesy of Jeno Kapitany).

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 United States, has similar blue inflorescences and involucral bracts (Fig. 1.4b) and stout roots, and it also develops rosy coloring on the stems and basal leaves (Fig. 1.4c). 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 (*E. heterophyllum*), is used to treat gallstones in Mexico and has been found experimentally to have a hypocholesteremic effect (Navarrete et al. 1990).

E. Apocynaceae

1. Fol. 100r #14. *Gonolobus chloranthus* (Fig. 1.5). Phytomorph #14 on fol. 100r (Fig. 1.5a) appears to be the ridged fruit of an asclepiad,

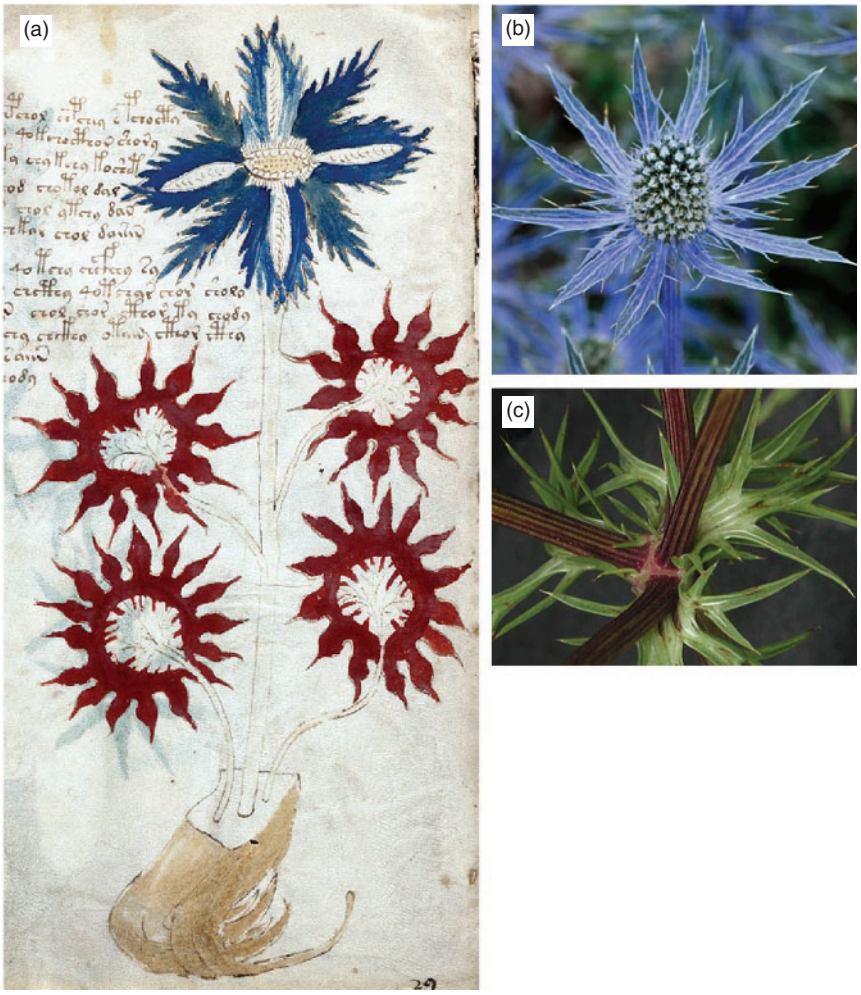

Fig. 1.4. *Eryngium* sp.: (a) fol. 16v; (b) inflorescence of *E. heterophyllum* (Courtesy of Blooms of Bressingham®); (c) leaves of *E. comosum* R. Delaroche illustrating anthocyanin accumulation (Courtesy of Pedro Tenorio-Lezama).

possibly the Mexican species *Gonolobus chloranthus* Schltdl. (Fig. 1.5b). 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).

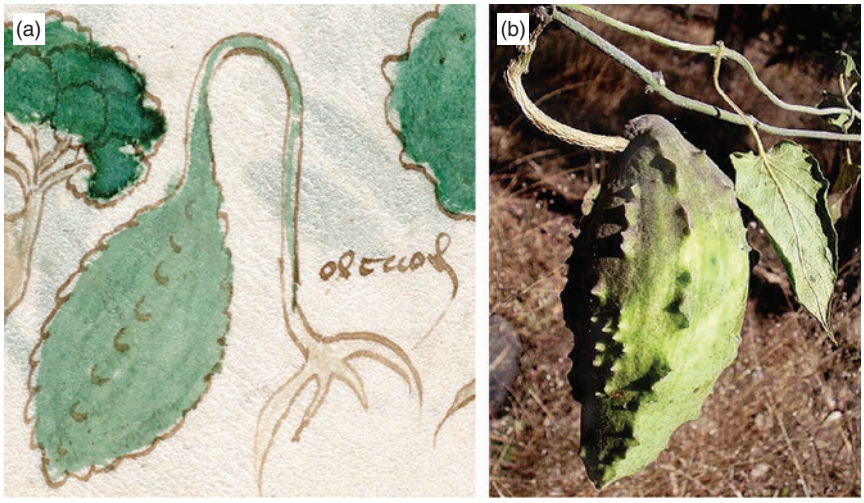

Fig. 1.5. *Gonolobus chloranthus*: (a) fol. 100r #14; (b) *G. chloranthus* fruit (Courtesy of Guadalupe Cornejo-Tenorio and Guillermo Ibarra-Manríquez, The Field Museum).

F. Araceae

1. Fol. 100r #2. *Philodendron mexicanum* (Fig. 1.6). Phytomorph #2 on fol. 100r (Fig. 1.6a), appears to be a vining aroid with hastate leaves, ripped from a tree, most probably *Philodendron mexicanum* Engl. (Figs. 1.6b and 1.6c) known as *huacalazochitl* in Nahuatl (Zepeda and White 2008). This is known as *huacalxochitl/huacalxōchitl* (huacal flower) in the Codex Cruz-Badianus (Emmart 1940; Cruz and Badiano 1991; Gates 2000; Alcántara Rojas 2008; Clayton et al. 2009) or *huacalazochitl* (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."

2. Fol. 100r #7. *Philodendron* sp. (Fig. 1.7). Phytomorph #7 on fol. 100r (Fig. 1.7a) appears to be the leaf or stem of an aroid, 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 (Fig. 1.7b).

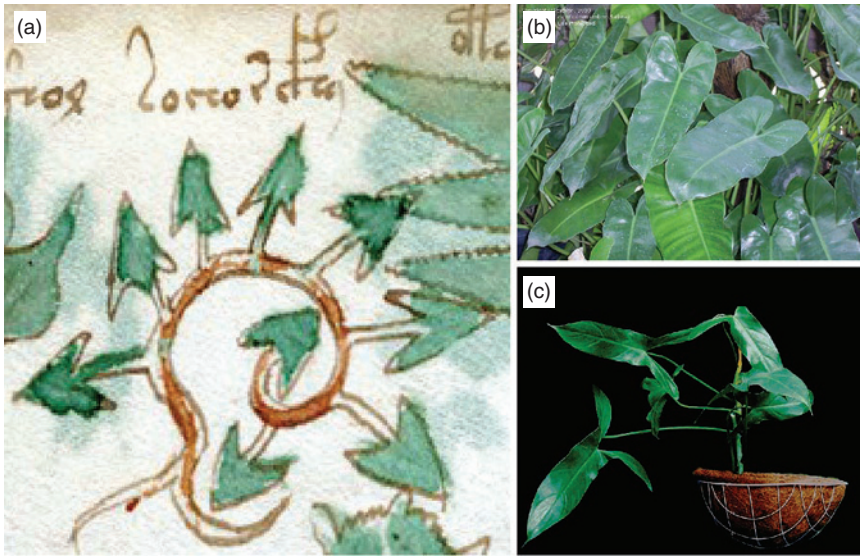

Fig. 1.6. *Philodendron mexicanum*: (a) fol. 100r #2; (b and c) leaves of *P. mexicanum* (*Source:* Dave's Garden user tathisri and Steve and Janice Lucas, respectively).

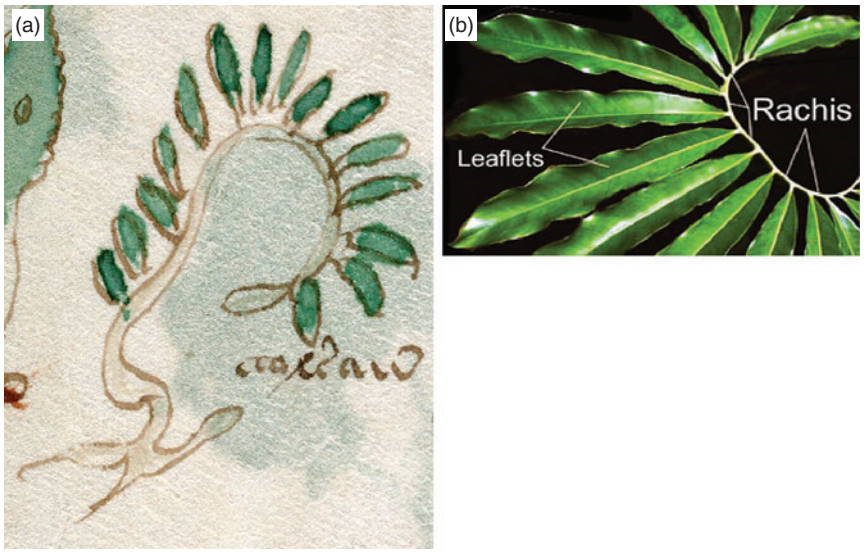

Fig. 1.7. *Philodendron* sp.: (a) fol. 100r #7; (b) *P. goeldii* (Courtesy of Steve and Janice Lucas).

G. Asteraceae

1. Fol. 53r. *Ambrosia* sp., cf. *A. ambrosioides* (Fig. 1.8). The phytomorph has composite heads borne on a raceme (Fig. 1.8a). Leaves are brown to green and sharply serrate. Roots are brown, and segmented. This matches the variability of *Ambrosia ambrosioides* (Delpino)

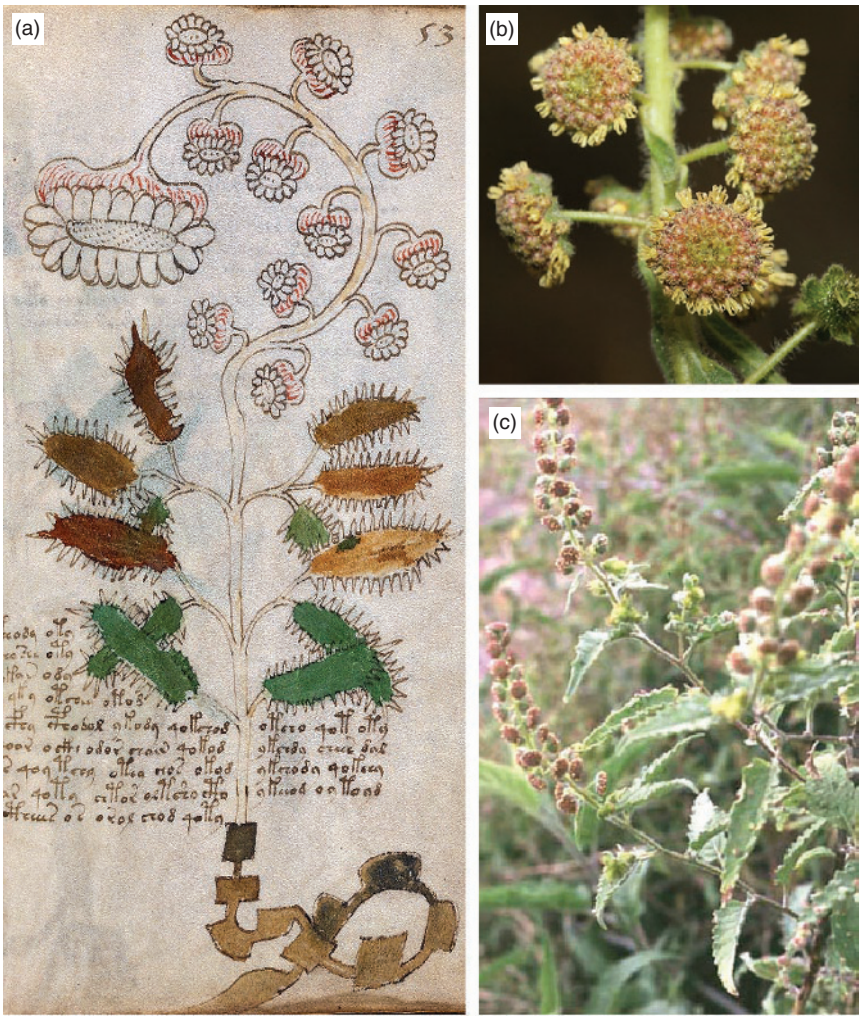

Fig. 1.8. *Ambrosia* sp.: (a) fol. 53r; (b and c) flowers, inflorescences, and leaves of *A. ambrosioides* (*Source:* T. Beth Kinsey and Cabeza Prieta, http://cabezaprieta.org/plant_page.php?id=1196, respectively).

W. W. Payne, which is native from Arizona and California to Mexico (Figs. 1.8b and 1.8c).

2. Fol. 93r. *Helianthus annuus* (Fig. 1.9). The phytomorph has a large single yellow asteroid head borne on a stout, thick stem (Fig. 1.9a). Leaves are green, alternate, ovate-lanceolate, acute, and entire. Petioles are short, with lines drawn down along the stem, possibly indicating a

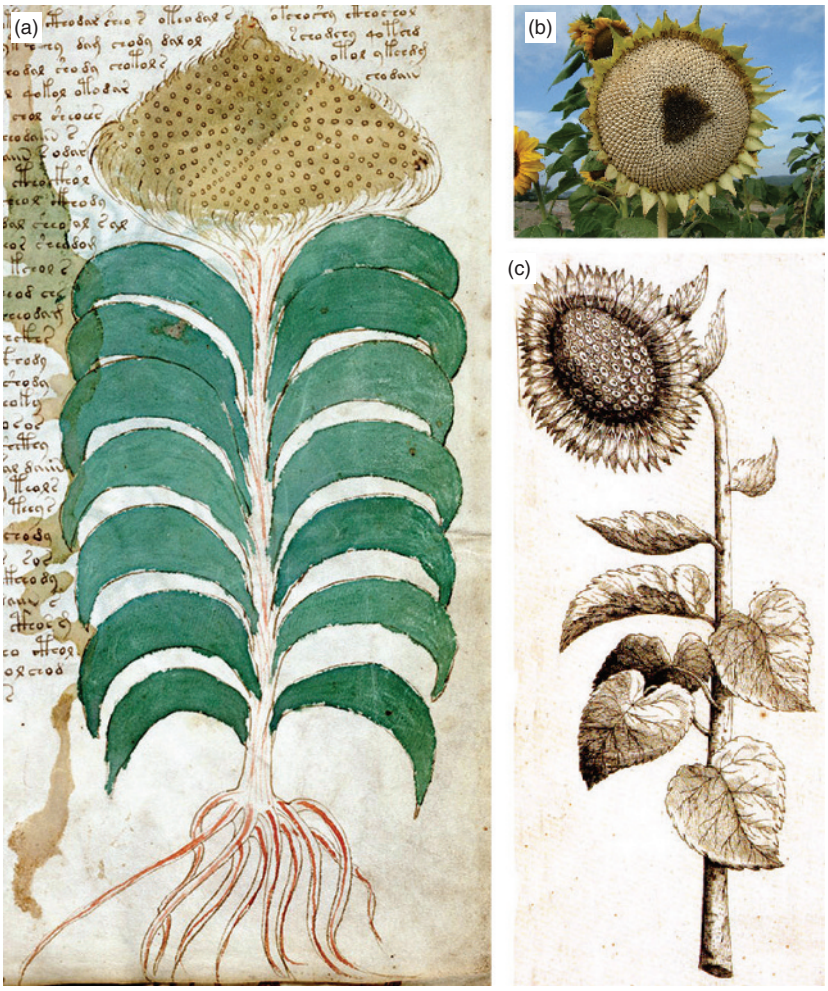

Fig. 1.9. *Helianthus annuum*: (a) fol. 93r; (b) seedhead of *H. annuum* (Courtesy of Dave Fenwick www.aphotoflora.com); (c) *Solis flor Peruuinus* of Emanuel Sweerts of 1612 (Bleiler 1976), showing short petioles towards the apex.

clasping base of the petiole or ridges along the stem. Roots are multiple, primary, and unbranched. The best match is sunflower, *Helianthus annuus* L. (Figs. 1.9b and 1.9c). 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 (personal communication, 2014), distinguished ethnobotanist at Universidad Nacional Autónoma de México (UNAM) in Mexico City, and Billie Turner (personal communication, 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 (personal communication, 2015) of Iowa State University notes that inbred lines of sunflower have very short petioles (see Fig. 1.9c), 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, 2008b; 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* (Fig. 1.10). Based on the asterid inflorescence, large cleft orbicular leaves, and relatively large root system, Fig. 1.10a is most probably a *Petasites* sp. The closest match might be *P. frigidus* (L.) Fr. var. *palmatus* (Aiton) Cronquist, the western sweet-coltsfoot (Fig. 1.10b). This is native to North America from Canada to California. *Petasites* spp. are used as antiasthmatics, antispasmodics, expectorants, and in salve or poultice form (Bayer et al. 2006).

4. Fol. 33v. *Psacalium* sp.? *Pippenalia* sp.? (Fig. 1.11). This phytomorph (Fig. 1.11a) 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.

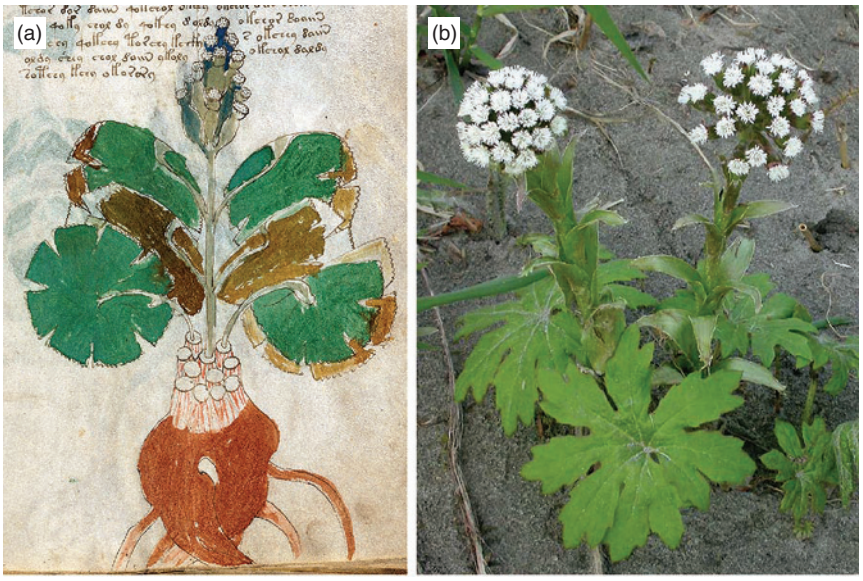

Fig. 1.10. *Petasites* sp.: (a) fol. 13r; (b) *P. frigidus* var. *palmatus* (Courtesy of Ben Legler).

Rob. & Seaton) Rydb. (Fig. 1.11b) but the large flower suggests a *Pippenalia* sp., possibly *P. delphinifolia* (Rydb.) McVaugh (Fig. 1.11c). Is this a hybrid phytomorph, that is, did the artist paint a combined image based on two species mixed together?

5. Fol. 40v. *Smallanthus* sp. (Fig. 1.12). This folio contains two phytomorphs of the same plant, vegetative and flowering (Fig. 1.12a). 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 (*S. sonchifolius* (Poepp.) H. Rob.), which is native to western South America (Figs. 1.12b and 1.12c).

H. Boraginaceae

1. Fol. 47v. *Cynoglossum grande* (Fig. 1.13). 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 (Fig. 1.13a). This matches the variability of *Cynoglossum grande* Douglas ex Lehm. except that this species has only

Fig. 1.11. *Pscalium* sp.? + *Pippenalia* sp.?: (a) fol. 33v; (b) herbarium sheet of *Pippenalia delphinifolia* (ASU0029020) (Courtesy of Arizona State University Herbarium); (c) herbarium sheet of *Psacalium peltigerum* var. *hintonii* R. W. Pippen (MICH1107637) (*Source*: University of Michigan Library Digital Collections. University of Michigan Herbarium Vascular Plant Type Collection with Specimen Images).

five petals and the cauline leaves are smaller and closer to the base (Fig. 1.13b). This species is native from British Columbia to California.

2. Fol. 56r. *Phacelia campanularia* (Fig. 1.14). With blue flowers in a scorpioid cyme, dentate leaves, and overlapping leaf-like basal scales (Fig. 1.14a) the phytomorph is a good match for *Phacelia campanularia* A. Gray, California bluebell (Figs. 1.14b and 1.14c), a California native.

3. Fol. 39v. *Phacelia crenulata* (Fig. 1.15). This has bluish flowers in a cyme with deeply pinnately lobed green leaves on broad, brown, and

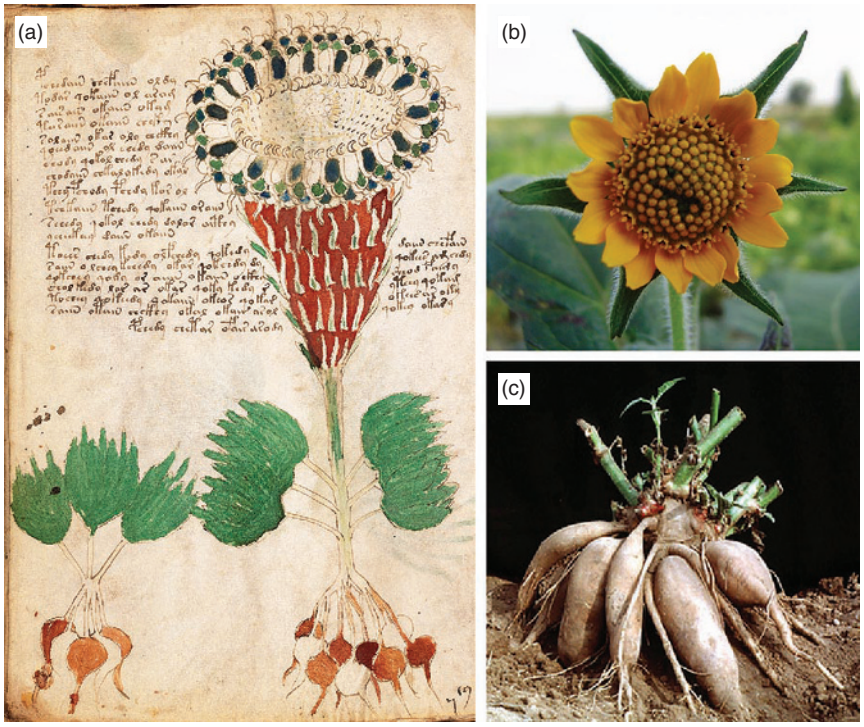

Fig. 1.12. *Smallanthus* sp.: (a) fol. 40v; (b and c) inflorescence and tuberous roots of *S. sonchifollius* (yacón), respectively (Public domain and courtesy of and NusHub, http://www.cropsforthefuture.org/, respectively). (b) Courtesy of Rob Hille.

branched roots (Fig. 1.15a). This closely matches *Phacelia crenulata* Torr. (Fig. 1.15b) native from Colorado to Mexico.

4. Fol. 51v. *Phacelia integrifolia* (Fig. 1.16). The phytomorph has blue flowers on a scorpioid cyme and narrowly elliptic crenate leaves that curl (Fig. 1.16a). The roots are brown and branched. This matches fairly well with the variability of *Phacelia integrifolia* Torr. (Figs. 1.16b and 1.16c) which is native from Utah and Kansas, and south to Mexico.

5. Fol. 26r. *Wigandia urens* (Fig. 1.17). This bears what can be interpreted as bluish flowers on a scorpioid cyme with leaves that are green, crenate, and obtuse (Fig. 1.17). This matches *Wigandia urens* (Ruis & Pav.) Kunth very well (Fig. 1.17b), a shrub found from Mexico and south to Peru. This is called *chichicaztle* (Díaz 1976) and also matches

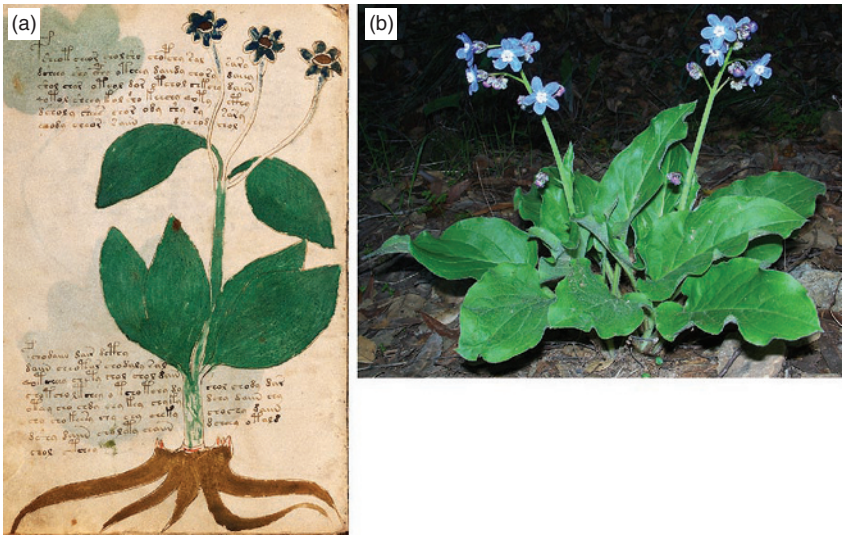

Fig. 1.13. *Cynoglossum grande*: (a) fol. 47v; (b) *C. grande* (*Source*: Eugene Zelenko, https://commons.wikimedia.org/wiki/File:Cynoglossum_grande-1.jpg, used under CC-BY-SA 2.0, https://creativecommons.org/licenses/by-sa/2.0/deed.en).

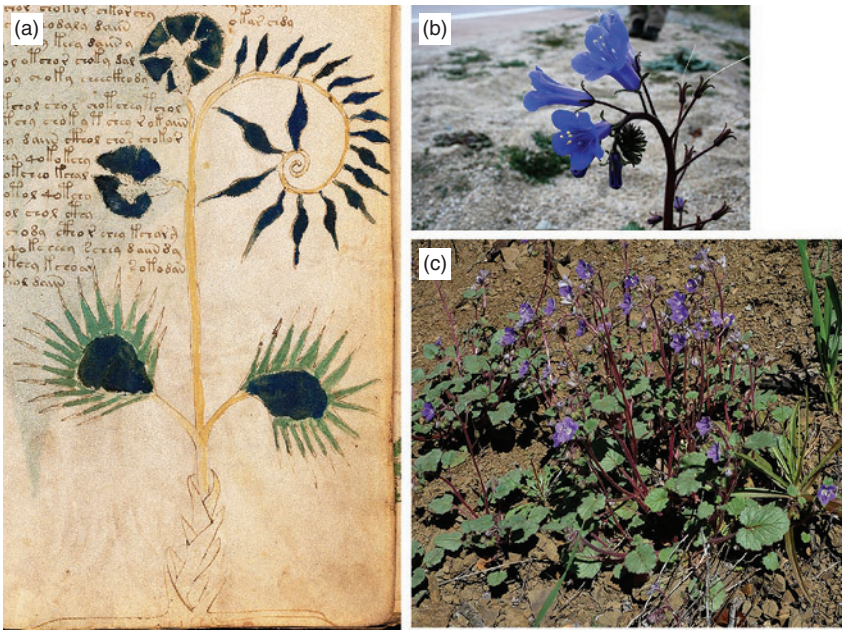

Fig. 1.14. *Phacelia campanularia*: (a) fol. 56r; (b and c) inflorescence and plant of *P. campanularia*, respectively (Courtesy of Chez Brungraber and George Williams, respectively).

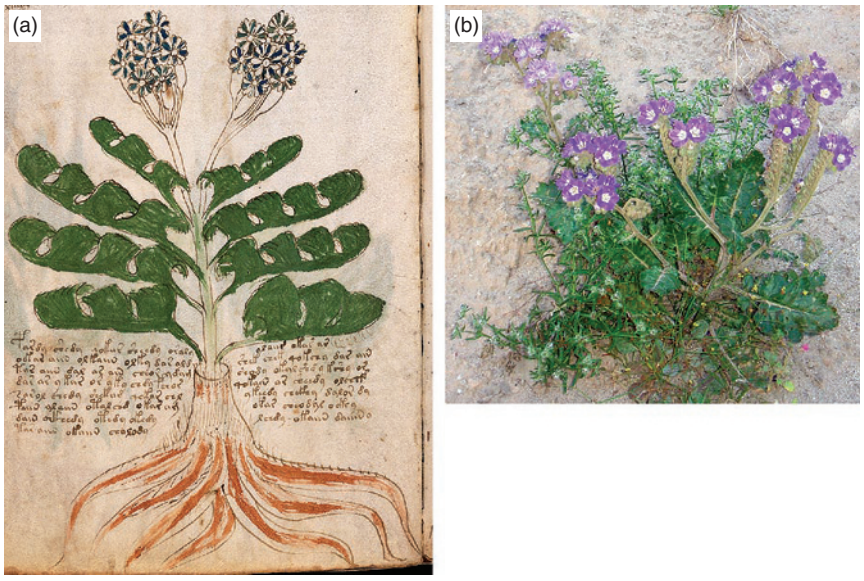

Fig. 1.15. *Phacelia crenulata*: (a) fol. 39v; (b) *P. crenulata* (Courtesy of Tom Chester, http://tchester.org/sd/plants/floras/borrego_mtn.html).

patlāhua-ctzītzicāztli (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* (Fig. 1.18). This phytomorph might be *Caulanthus heterophyllus* (Nutt.) Payson, San Diego wild cabbage or San Diego jewelflower (Fig. 1.18a). The flowers of *C. heterophyllus* are four-petaled, white with a purple streak down the center, with four protruding dark purple anthers (Fig. 1.18b). Leaves vary from dentate to lobed but are typically clasping, not petiolate (Fig. 1.18c). 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* (Fig. 1.19). 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, that

Fig. 1.16. *Phacelia integrifolia*: (a) fol. 51v; (b) inflorescence (*Source*: Nieland and Finley, 2009. Reproduced with permission of Texas Tech University Press); and (c) shoot of *P. integrifolia*, respectively (Courtesy of Russell Kleinman).

is, *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 nochtli/tla-tōc-nōchtli* in the Codex Cruz-Badianus (Emmart 1940; Dressler 1953; Cruz and Badiano 1991; Gates 2000; Zepeda and White 2008; Clayton et al. 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).

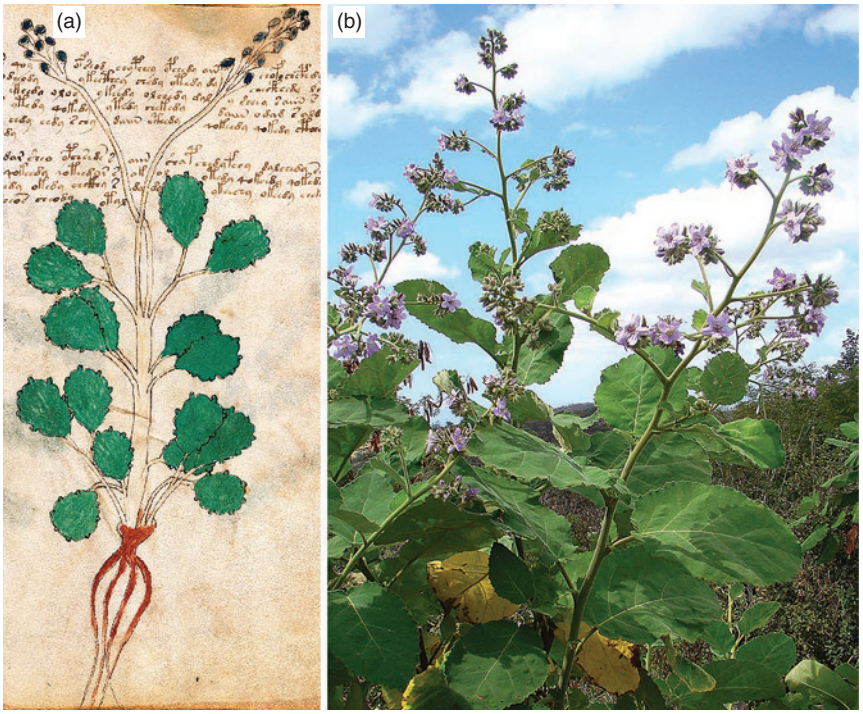

Fig. 1.17. *Wigandia urens*: (a) fol. 26r; (b) *W. urens* (*Source*: Dick Culbert, https://commons.wikimedia.org/wiki/File:Wigandia_caracasana_(9361123018).jpg, used under CC-BY 2.0, https://creativecommons.org/licenses/by/2.0/deed.en).

K. Caryophyllaceae

1. Fol. 24r. *Silene* sp., cf. *S. menziesii* Infected with *Microbotryum violaceum* (Fig. 1.20). 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?

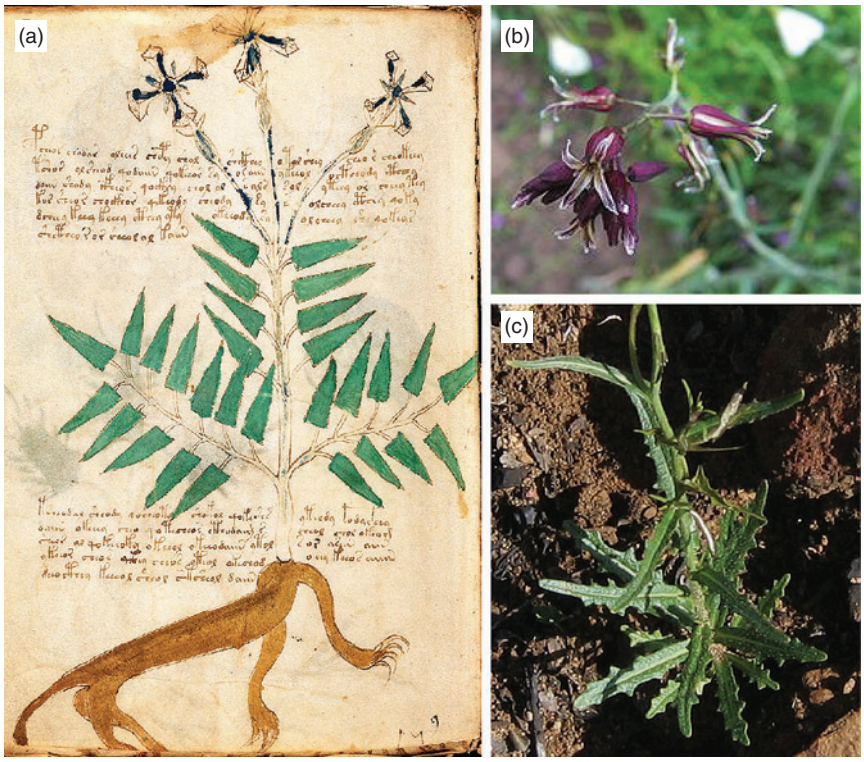

Fig. 1.18. *Caulanthus heterophyllus*: (a) fol. 90v; (b and c) inflorescence and shoots of *C. heterophyllus*, respectively (*Source*: National Park Service, public domain and Anthony J. Valois, respectively).

L. Convolvulaceae

1. Fol. 1v + 101v(2) #4. *Ipomoea arborescens* (Fig. 1.21). The phytomorph shows a single leafy shoot with a single terminal flower bud arising from a thick caudex (Fig. 1.21a) The flower bud has whitish sepals and brownish petals; leaves are alternate, cordate, petiolate, and 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 (Fig. 1.21e) of the "pharma" section. This illustration is overwhelmingly similar in style and substance to *xiuhamolli*/*xiuhhamolli* (soap plant) found in fol. 9r, Fig. 1.11 (Fig. 1.21b) in the 1552 Mexican Codex Cruz-Badianus, which has been identified as *Ipomoea murucoides* Roem. & Schult. (Emmart 1940; Cruz and Badiano 1991;

Fig. 1.19. *Opuntia* sp.: (a) fol. 100 #8; (b) cladode (pad) of *O. ficus-indica* with fruits (*Source*: Public domain).

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* (Fig. 1.21c) 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, (Fig. 1.21d) 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

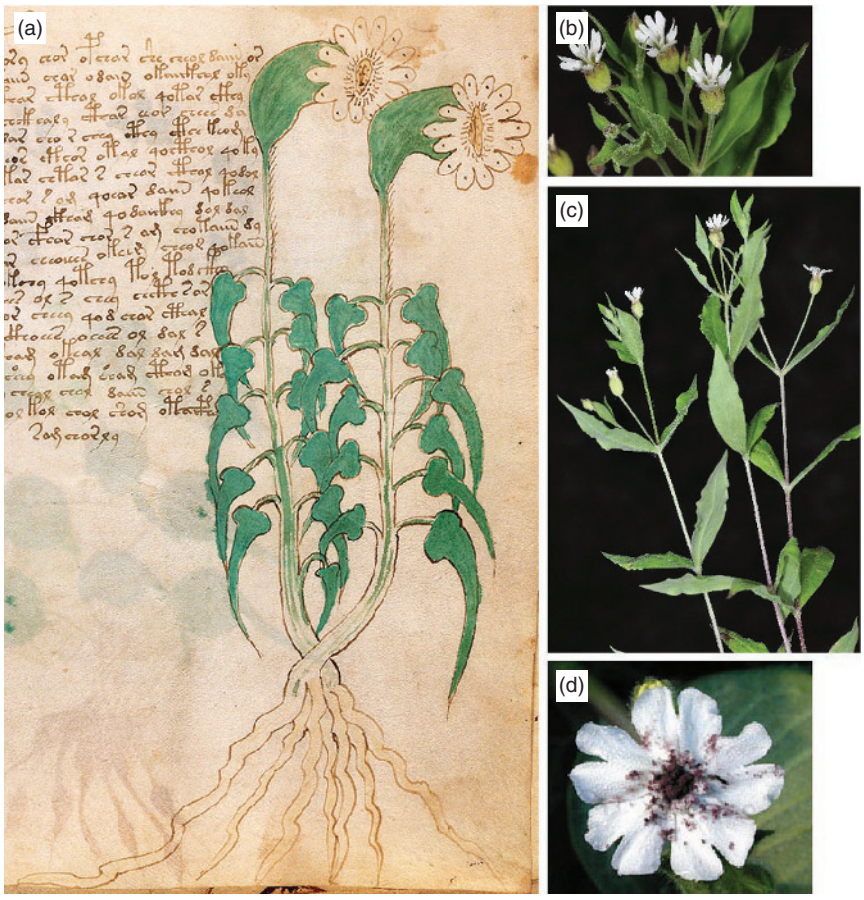

Fig. 1.20. *Silene* sp.: (a) fol. 24r; (b and c) stems and inflorescence of *S. menziesii* (Courtesy of Robert L. Carr, http://web.ewu.edu/ewflora/Caryophyllaceae/Silene%20menziesii.html); (d) flower infected with *Microbotryum violaceum* (Courtesy of Michael Hood).

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 gray-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*

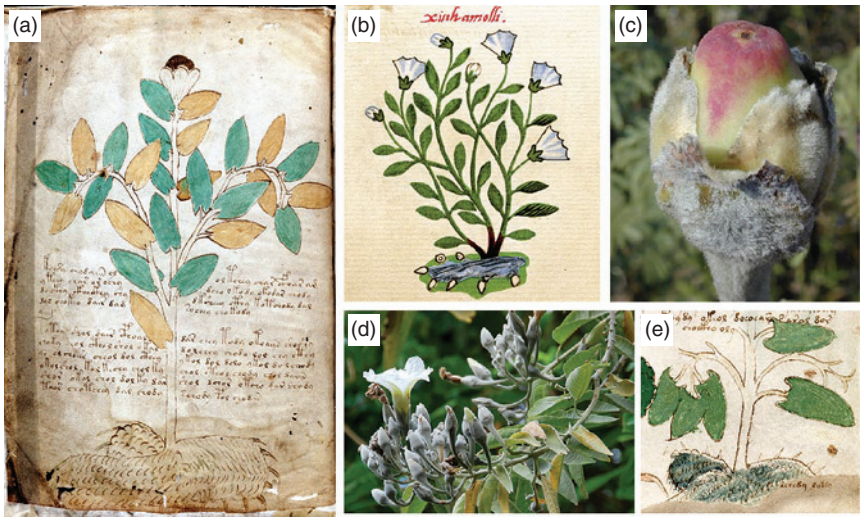

Fig. 1.21. *Ipomoea arborescens*: (a) fol. 1v; (b) *I. murucoides* from Cruz-Badianus Codex plate 11; (c) bud of *I. murucoides* (Courtesy of Kevin C. Nixon); (d); flower, fruits, and leaves of *I. arborescens* (*Source*: Tony Rodd, https://www.flickr.com/photos/tony_rodd/532873040); (e) 101v(2) #4.

include "'Palo blanco' (Sonora, Sinaloa); 'palo del muerto,' 'casahuate,' 'quauhzahuatl,' '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* (Fig. 1.22). The phytomorph has a terminal dark blue flower with a white edge, acute petals, and elongated calyx lobes. Leaves are lobed peltate on a herbaceous bush. Roots are brown and branched (Fig. 1.22a). This might match the variability of *Ipomoea nil* (L.) Roth (Fig. 1.23b). 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.

3. Fol. 32v + fol. 101v(3) #2 fol. 101v(3) #2. *Ipomoea pubescens* (Fig. 1.23). The blue flowers, deeply lobed leaves, and tuberous roots

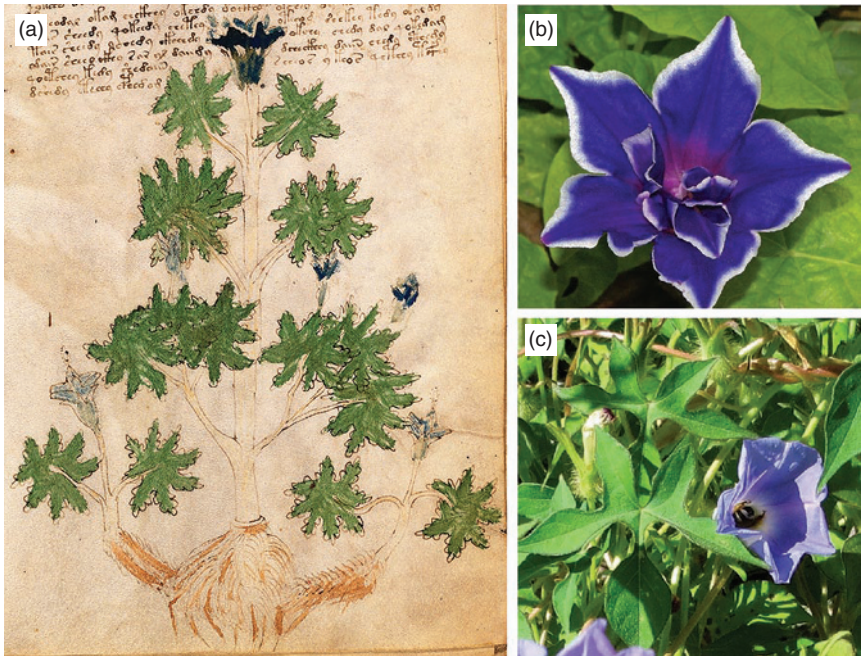

Fig. 1.22. *Ipomoea nil*: (a) fol. 57r; (b and c) flowers and leaves of *I. nil* (Courtesy of Rare and Exotic Seeds and ghost32writer.com, respectively).

(Figs. 1.23a and 1.23b) are all good fits for most probably *Ipomoea pubescens* Lam., silky morning-glory (Fig. 1.23c). 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).

M. Dioscoreaceae

1. Fol. 17v. *Dioscorea composita* (Fig. 1.24). Most probably this phytomorph (Fig. 1.24a) is *Dioscorea composita* Hemsl., barbasco (Fig. 1.24b). This is native from southern Mexico to Costa Rica. The roots (Fig. 1.24c) 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.

Fig. 1.23. *Ipomoea pubescens*: (a) fol. 32v; (b) fol. 101v(3) #2; (c) flower, leaf and rhizome of *I. pubescens* (Courtesy of Apostolou Starvos).

2. Fol. 96v. *Dioscorea mexicana* (Fig. 1.25). The rust-colored flowers and sagittate leaves of the phytomorph (Fig. 1.25a) fit rather well for *Dioscorea mexicana* Schweidw., Mexican yam (Figs. 1.25b and 1.25c). 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* (Fig. 1.26). The 28th phytomorph on fol. 99r (Fig. 1.26a) is most probably *Dioscorea remotiflora* Kunth (Fig. 1.26b) which is native from northern to southern

Fig. 1.24. *Dioscorea composita*: (a) fol. 17v; (b) leaves and inflorescences of *D. composite* (*Source*: Abisaí García Mendoza); (c) segmented roots of *D. composite* (*Source*: Ryan Somma, https://commons.wikimedia.org/wiki/File:Dioscorea_composita.jpg, used under CC-BY-SA 2.0, https://creativecommons.org/licenses/by-sa/2.0/deed.en).

Mexico. The large, dark root is paddle- or bat-like (Figs. 1.26c and 1.26d). The rust-colored flowers and cordate leaves on a vine also match.

N. Euphorbiaceae

1. Fol. 6v. *Cnidoscolus texanus* (Fig. 1.27). The palmately compound leaves and trichomes on the fruit (Fig. 1.27a) 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

Fig. 1.25. *Dioscorea mexicana*: (a) fol. 96v; (b and c) inflorescence and rhizome of *D. mexicana*, respectively (Courtesy of Michael Charters and The Smithsonian, https://smithsoniangardens.wordpress.com/2013/04/11/i-yam-not-a-tortoise-but-a-plant/, respectively).

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 (Figs. 1.27b and 1.27c) with fruits that are coated with trichomes.

2. Fol. 21r. *Euphorbia thymifolia* (Fig. 1.28). The spreading growth pattern, tiny green to reddish leaves, and reddish axillary flowers

Fig. 1.26. *Dioscorea remotiflora*: (a) 99r #28; (b) herbarium sheet of *D. remotiflora* (F1405679) (*Source*: Neotropical Herbarium Specimen Scans, The Field Museum, Chicago); (c and d) bat- or paddle-like roots of *D. remotiflora* (*Source*: Ignacio Garcia Ruiz).

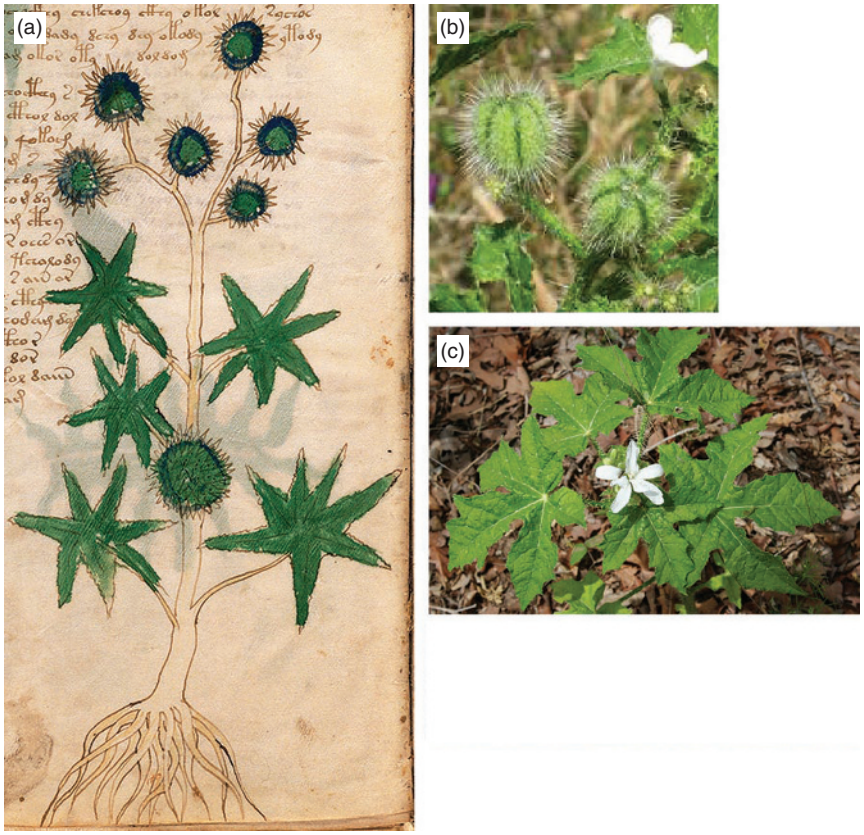

Fig. 1.27. *Cnidoscolus* sp.: (a) fol. 6v; (b) fruits of *C. texanus* with trichomes (Courtesy of Carl Fabre, Lady Bird Johnson Wildflower Center); (c) leaves and flower of *C. texanus* (Courtesy of Tiana Rehman).

(Fig. 1.28a) fit *Euphorbia thymifolia* L. [*Chamaesyce thymifolia* (L.) Millsp.] (Fig. 1.28b) 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* (Fig. 1.29). The appropriate identification for this phytomorph (Fig. 1.29a) is most probably *Jatropha cathartica* Terán & Berland., *jicamilla* (Fig. 1.29b). 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

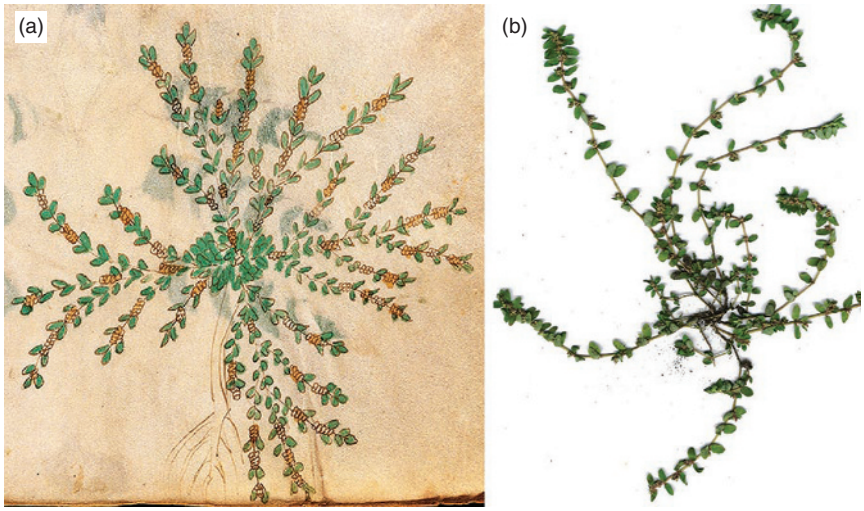

Fig. 1.28. *Euphorbia thymifolia*: (a) fol. 21r; (b) *E. thymifolia* (Courtesy of Forest and Kim Starr).

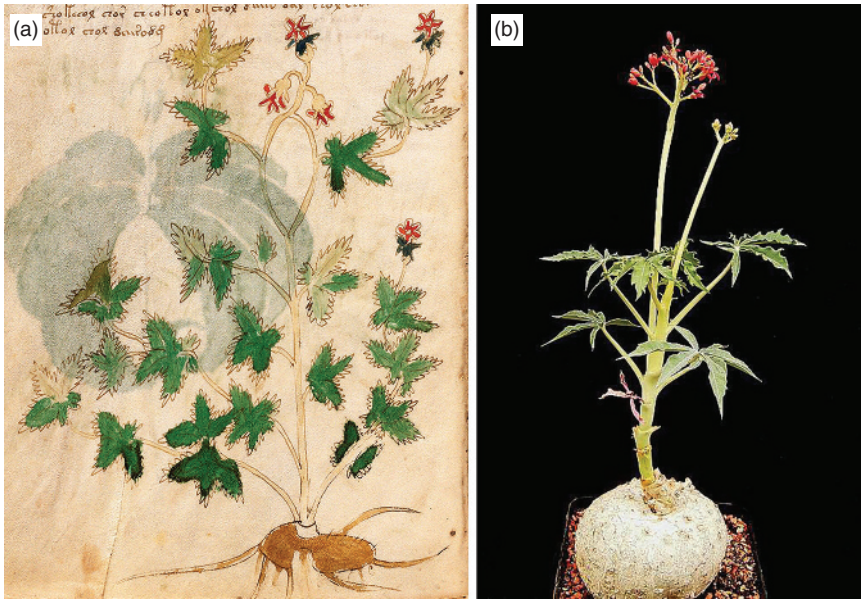

Fig. 1.29. *Jatropha cathartica*: (a) fol. 5v; (b) *J. cathartica* (*Source*: Frank Vincentz, https://en.wikipedia.org/wiki/Jatropha_cathartica#/media/File:Jatropha_cathartica1_ies.jpg, used under CC-BY-SA 3.0).

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* (Fig. 1.30). The stout, thickened roots, palmately compound leaves, and reddish fruits (Fig. 1.30a) all fit the genus *Manihot*. This phytomorph is most probably *Manihot rubricaulis* I. M. Johnst. (Fig. 1.30b) 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

Fig. 1.30. *Manihot rubricaulis*: (a) fol. 93v; (b) leaf of *M. rubricaulis* (*Source*: Sky Jacobs, wildsonora.com); (c) tubers of *M. esculenta* (*Source*: David Monniaux, https://en.wikipedia.org/wiki/Cassava#/media/File:Manihot_esculenta_dsc07325.jpg, used under CC-BY-SA 3.0, http://creativecommons.org/licenses/by-sa/3.0/).

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* (Fig. 1.31). Phytomorph #11 on fol. 88r (Fig. 1.31a) 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 (Fig. 1.31b) of Mexico and Central America. The compound peltate leaves and soft, callus-like, nitrogen-fixing root nodules on one side of the roots (Fig. 1.31c) are all typical of this species. This lupine is noted to contain alkaloids (Dunn and Harmon 1977; Ruiz-López et al. 2010).

Fig. 1.31. *Lupinus* sp.: (a) fol. 88r #7; (b) *L. montanus* (Courtesy of Harry Douwes); (c) root nodules on *L. montanus* (*Source*: Wilderness and Backcountry Site Restoration Guide, USDA/US Forest Service).

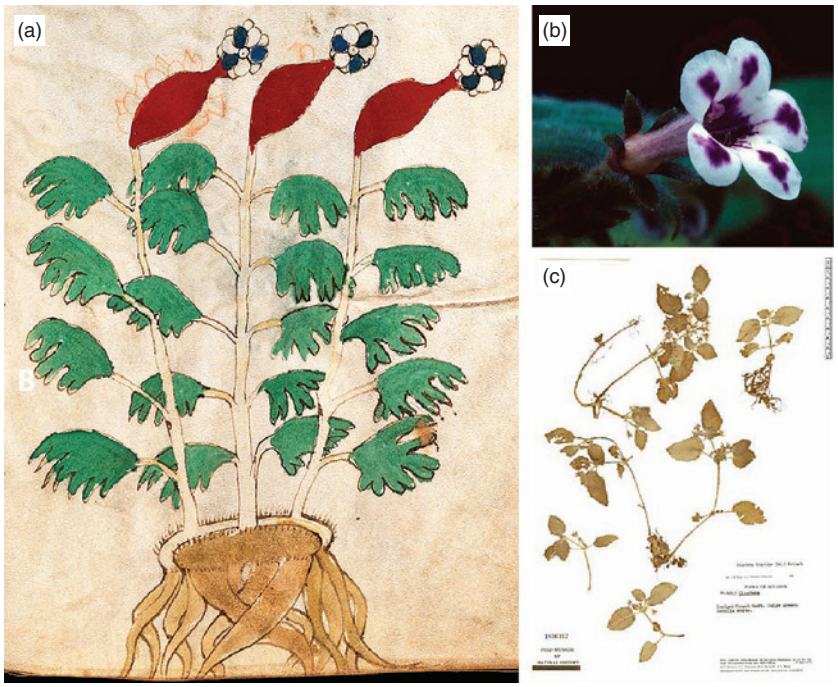

Fig. 1.32. *Diastema hispidum*: (a) fol. 55r; (b) flower of *D. hispidum* (*Source*: Leslie Brothers); (c) herbarium sheet of *D. hispidum* (F1836367) showing thin rhizomatous roots (*Source*: Neotropical Herbarium Specimen Scans, The Field Museum, Chicago).

P. Gesneriaceae

1. Fol. 55r. *Diastema hispidum* (Fig. 1.32). This has six petals, white and bluish, with a long corolla (Fig. 1.32a). 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. (Figs. 1.32b and 1.32c) which is native from Nicaragua to Peru.

Q. Grossulariaceae

1. Fol. 23r. *Ribes malvaceum* (Fig. 1.33). This phytomorph (Fig. 1.33a) is most probably *Ribes malvaceum* Sm., chaparral currant (Figs. 1.33b and 1.33c). 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).

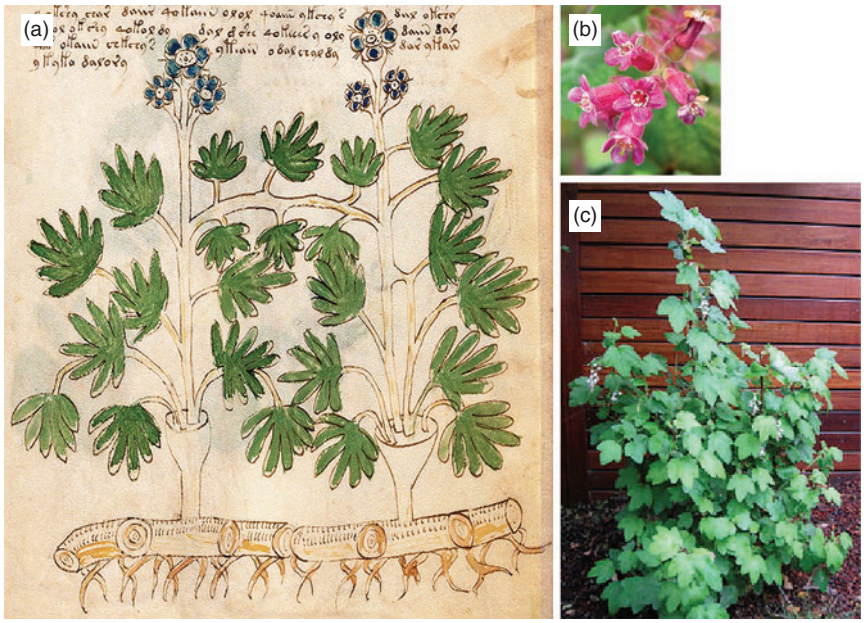

Fig. 1.33. *Ribes malvaceum*: (a) fol. 23r; (b and c) flower and shoots of *R. malvaceum*, respectively (*Source*: Stan Shebs, https://commons.wikimedia.org/wiki/File:Ribes_malvaceum_var_veridifolium_2.jpg and Toedrifter, https://commons.wikimedia.org/wiki/File:Ribesmalvaceum12-2.jpg, respectively. Used under CC-BY-SA 3.0, https://creativecommons.org/licenses/by-sa/3.0/deed.en).

R. Lamiaceae

1. Fol. 45v. *Hyptis albida* (Fig. 1.34). The gray leaves, blue flowers, and stout root (Fig. 1.34a) are all good fits for most probably *Hyptis albida* Kunth (Figs. 1.34b and 1.34c). 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."

2. Fol. 32r. *Ocimum campechianum* (*O. micranthum*) (Fig. 1.35). This phytomorph (Fig. 1.35a) is most probably *Ocimum campechianum* Mill. (*O. micranthum* Willd.) (Fig. 1.35b). This suffrutescent annual basil is native from Florida to Argentina; in Mexico, it is found from Sinaloa to Tamaulipas, Yucatán, and Colima. The terminal

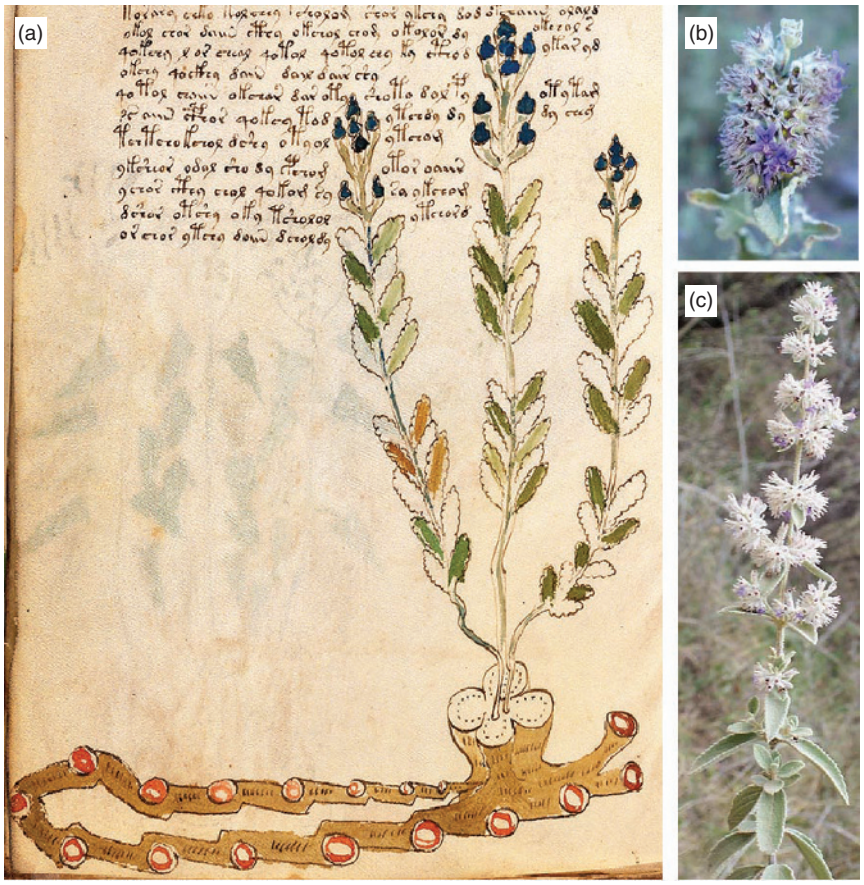

Fig. 1.34. *Hyptis albida*: (a) fol. 45v; (b and c) inflorescence of *H. albida* (Courtesy of Benjamin T. Wilder and Jim Conrad, respectively).

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* (Fig. 1.36). The blue flowers in a tripartite inflorescence and distantly dentate deltoid-hastate leaves (Fig. 1.36a) are quite characteristic of *Salvia cacaliifolia* Benth. (Fig. 1.36b). This is native from Mexico (Chiapas) to Guatemala and Honduras (Standley and Williams 1973:278).

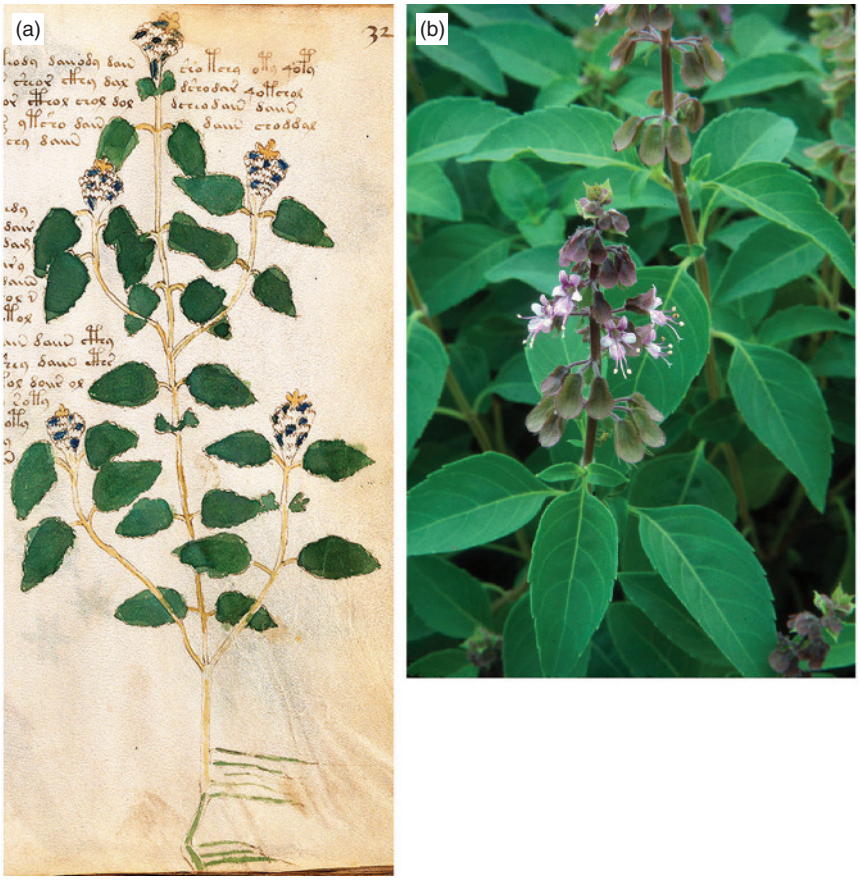

Fig. 1.35. *Ocimum campechianum*: (a) fol. 32r; (b) inflorescence and leaves of *O. campechianum* (Courtesy of Roger L. Hammer).

4. Fol. 100r #5. *Scutellaria mexicana* (Fig. 1.37). Phytomorph #5 on fol. 100r (Fig. 1.37a) shows three flowers of what matches to *Scutellaria mexicana* (Torr.) A.J. Paton (*Salazaria mexicana* Torr.) (Figs. 1.37b and 1.37c). 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).

Fig. 1.36. *Salvia cacaliifolia*: (a) fol. 45r; (b) inflorescence and leaves of *S. cacaliifolia* (Courtesy of Ashwood Nurseries Ltd.).

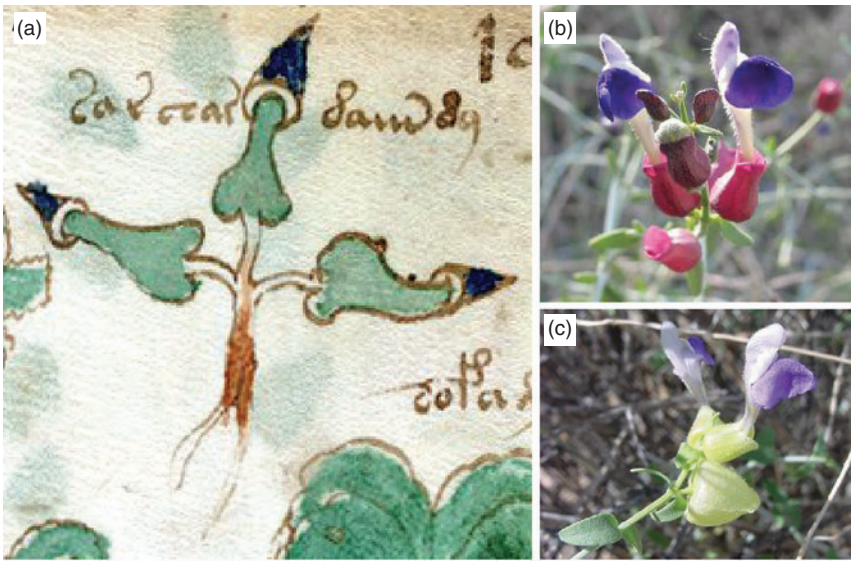

Fig. 1.37. *Scutellaria mexicana*: (a) fol. 100r #5; (b and c) inflorescence of *S. mexicana* (Courtesy of Michael L. Charters).

S. Malvaceae

1. Fol. 102r #11. *Chiranthodendron pentadactylon* (Fig. 1.38). Phytomorph #11 (Fig. 1.38a) 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* Larreat. (*C. platanoides* Bonpl.), the hand flower, look like when pressed and dried. When fresh, the stamens are a brilliant vermillion (Fig. 1.38b) but they turn blue-black when improperly dried and/or aged (Fig. 1.38c) 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).

Fig. 1.38. *Chiranthodendron pentadactylon*: (a) fol. 102r #11; (b) five-parted stamens of *C. pentadactylon* (Courtesy of Jan Conayne); (c) dried shoot of *C. pentadactylon* showing leaves and flower with protruding stamens (Courtesy of José Luis Villaseñor Ríos).

T. Marantaceae

1. Fol. 42v. *Calathea* sp., cf. *C. loeseneri* (Fig. 1.39). The phytomorph inflorescence (Fig. 1.39a) 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.

Fig. 1.39. *Calathea* sp.: (a) fol. 42v; (b) inflorescence and leaves of *C. loeseneri* (Courtesy of Milan Kořínek).

U. Menyanthaceae

1. Fol. 2v. *Nymphoides aquatica* (Fig. 1.40). The rounded notched leaves with white flowers and thick rhizome (Fig. 1.40a) closely resembles *Nymphoides aquatica* (J. F. Gmel.) Kuntze (Fig. 1.40b). This aquatic plant with floating orbicular leaves and white flowers (Fig. 1.40b) 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.

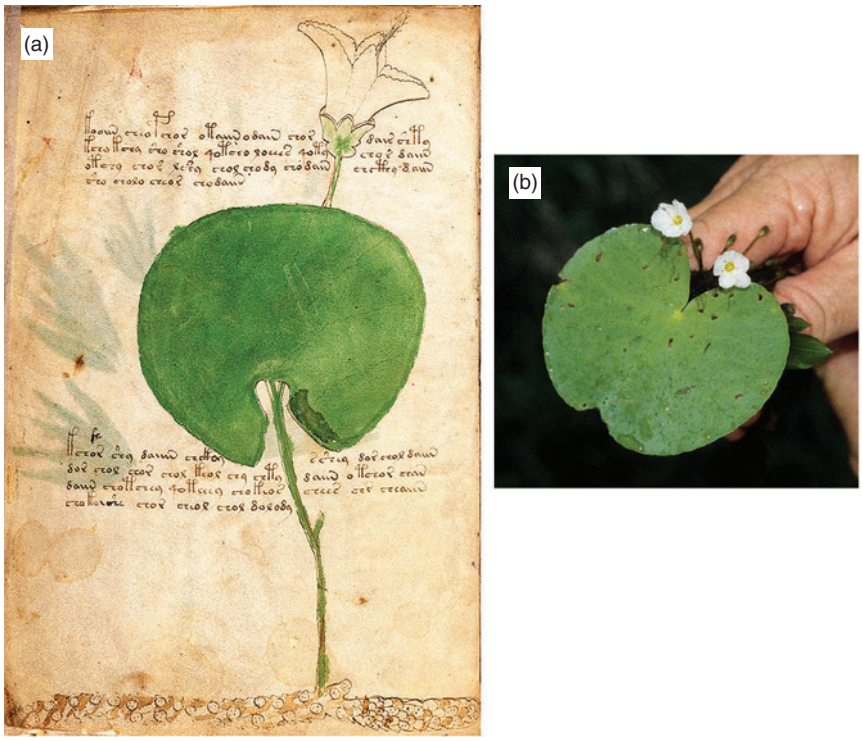

Fig. 1.40. *Nymphoides aquatica*: (a) fol. 2v; (b) *N. aquatica* (*Source*: Center for Aquatic and Invasive plants, University of Florida).

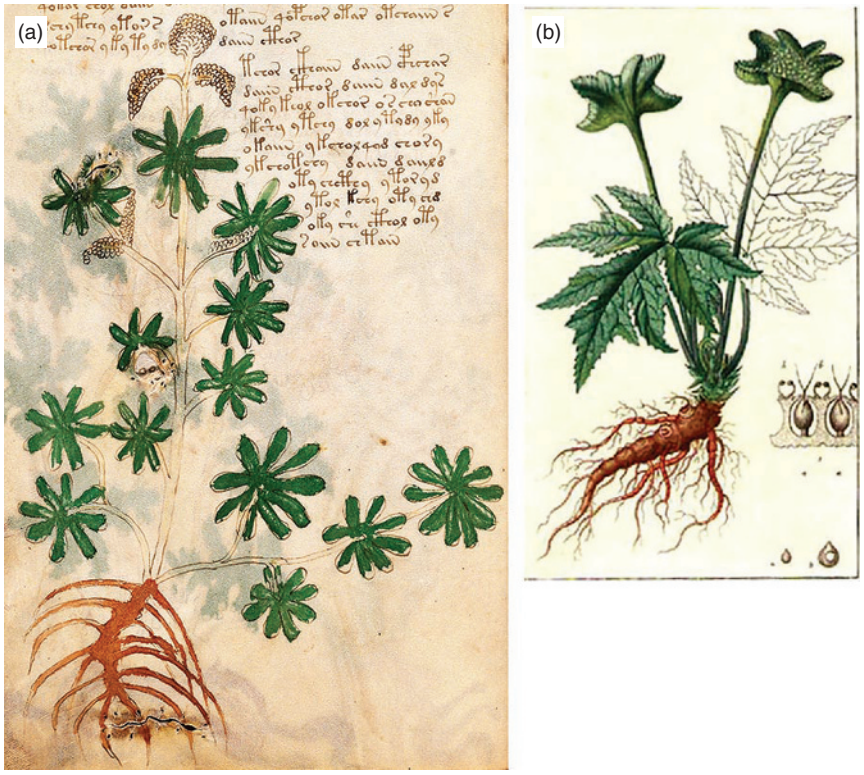

Fig. 1.41. *Dorstenia contrajerva*: (a) fol. 36v; (b) botanical image of *D. contrajerva* by Pierre Turpin from Chaumeton (1830:131).

V. Moraceae

1. Fol. 36v. *Dorstenia contrajerva* (Fig. 1.41). The inflorescence (Fig. 1.41a), appearing like a split open fig, is quite distinct and matches most probably a *Dorstenia* sp., likely the very variable *D. contrajerva* L. (Fig. 1.41b). 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* (Fig. 1.42). This has many petals united into a greenish corolla, backed by a swollen whitish calyx, with

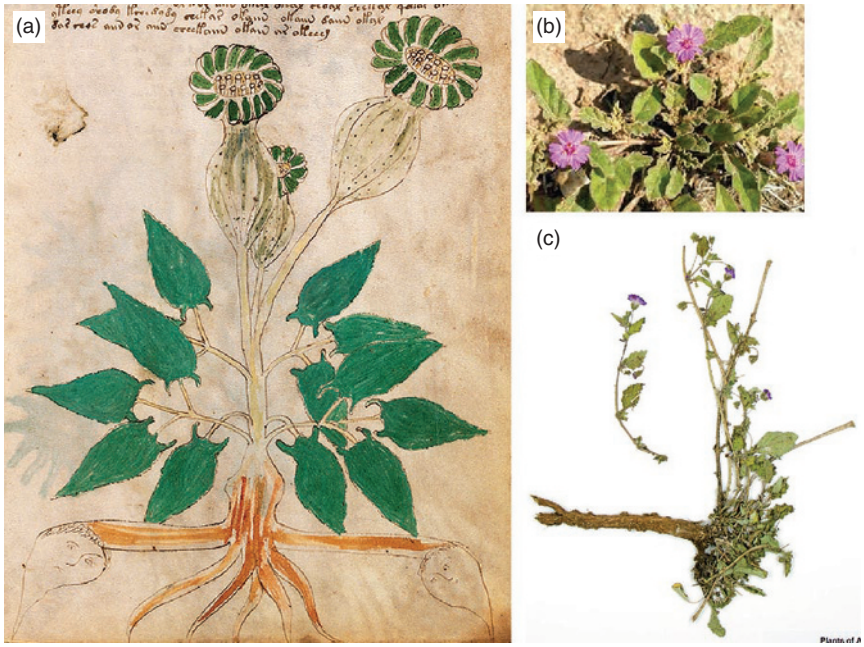

Fig. 1.42. *Allionia incarnata*: (a) fol. 33r; (b) inflorescence and leaves of *A. incarnata* (*Source*: Campbell and Lynn Loughmiller, Lady Bird Johnson Wildflower Center); (c) herbarium specimen of *A. incarnata* (DES00067664) showing the swollen, knobby roots (*Source*: Desert Botanical Garden Herbarium Collection, http://intermountainbiota.org/portal/collections/individual/index.php?occid=2430103).

sagittate, green leaves, and swollen branched brown roots (Fig. 1.42a). This matches the wide variability of *Allionia incarnata* L. (Figs. 1.42b and 1.42c), 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.

X. Onagraceae

1. Fol. 51r. *Fuchsia thymifolia* (Fig. 1.43). 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 (Fig. 1.43a). This may be *Fuchsia thymifolia* Kunth (Fig. 1.43b), native from Mexico to Guatemala.

Fig. 1.43. *Fuchsia thymifolia*: (a) fol. 51r; (b) leaves and flowers of *F. thymifolia* (Courtesy of Todd Boland).

Y. Passifloraceae

1. Fol. 23v. *Passiflora* Subgenus *Decaloba*, cf. *P. morifolia* (Fig. 1.44). From the flower alone, this is definitely a *Passiflora* sp. of subgenus *Decaloba* (Fig. 1.44a). *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) (Figs. 1.44b and 1.44c), although the artist has made the leaves slightly more orbicular than they normally occur in mature foliage. However, young plants, that is, root suckers, often exhibit juvenile leaves that are orbicular, entire leaves.

Fig. 1.44. *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, used under CC-BY-SA 3.0, https://creativecommons.org/licenses/by-sa/3.0/deed.en).

Z. Penthoraceae

1. Fol. 30v. *Penthorum sedoides* (Fig. 1.45). The cymose inflorescence, dentate leaves (Fig. 1.45a), and stolons match *Penthorum sedoides* L. (Figs. 1.45b and 1.45c), 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* (Fig. 1.46). With a basally woody stem, pinnately compound elliptic leaves, campanulate corolla,

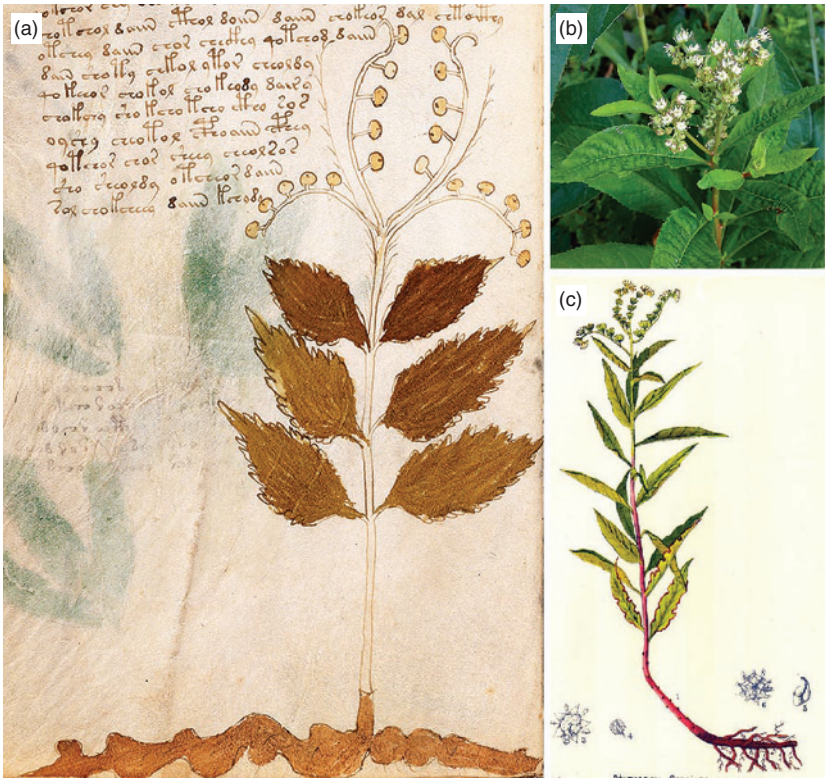

Fig. 1.45. *Penthorum sedoides*: (a) fol. 30v; (b) inflorescence and leaves of *P. sedoides* (*Source*: Fritz Flohr Reynolds, https://commons.wikimedia.org/wiki/File:Penthorum_sedoides_-_Ditch_Stonecrop.jpg, used under CC BY-SA 3.0, https://creativecommons.org/licenses/by-sa/3.0/deed.en); (c) botanical painting of *P. sedoides* from Millspaugh (1892 1:t. 57).

segmented calyx, and exserted style (Fig. 1.46a) the best match would be a *Cobaea* sp., most probably *C. biaurita* Standl. (Figs. 1.46b and 1.46c) 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).

BB. Ranunculaceae

1. Fol. 95r. *Actaea rubra* f. *neglecta* (Fig. 1.47). The crenate pinnately compound leaves and noticeably white, globose fruits in a raceme (Fig. 1.47a) fit quite definitely an *Actaea* sp., probably the white-fruited

Fig. 1.46. *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*: Neotropical Herbarium Specimen Scans, The Field Museum, Chicago).

Actaea rubra (Aiton) Willd. f. *neglecta* (Gillman) B. L. Rob (Fig. 1.47b). *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* (Fig. 1.48). This has a terminal, pubescent blue flower with many linear bracts; leaves are deeply laciniate; roots

Fig. 1.47. *Actaea rubra* f. *neglecta*: (a) fol. 95r; (b) fruits and leaves of *Actaea rubra* f. *neglecta* (Courtesy of Donald Cameron).

Fig. 1.48. *Anemone patens*: (a) fol. 52r; (b and c) flowers and leaves of *Anemone patens* (Courtesy of Tom Koerner, U.S. Fish and Wildlife Service and John Richards, respectively).

Fig. 1.49. *Anemone tuberosa*: (a) fol. 29v; (b) *A. tuberosa* (Courtesy of 7Song).

are brown, long, and tuberous (Fig. 1.48a). This matches very nicely the variability of *Anemone patens* L., pasqueflower (Figs. 1.48b and 1.48c), which is circumboreal, south to Texas and New Mexico.

3. Fol. 29v. *Anemone tuberosa* (Fig. 1.49). This has blue-green, hairy flower buds with a multi-petaled, bluish corolla; basal leaves are deeply divided; roots are tuberous (Fig. 1.49a). This matches *Anemone tuberosa* Rydb., desert anemone (Fig. 1.49b), native from Utah to Mexico.

CC. Saxifragaceae

1. Fol. 49r. *Lithophragma affine* (Fig. 1.50). This has blue flowers with fringed petals and red calyces; leaves are numerous and borne tightly together on long petioles; roots are tuberous (Fig. 1.50a). This matches the variability of *Lithophragma affine* A. Gray (Figs. 1.50b and 1.50c), which is native from Oregon to Baja California and intergrades with *L. parviflorum* (Hook.) Torr. & A. Gray (Park and Elvander 2012).

Fig. 1.50. *Lithophragma affine*: (a) fol. 49r; (b and c) inflorescence and leaves of *L. affine*, respectively (Courtesy of Doug Zimmerman, dazimmerman.com and Rebecca Snyder, www.fallbrooksource.com, respectively).

DD. Solanaceae

1. Fol. 101r #3 & Fol. 101v (1) #2. *Capsicum annuum* (Fig. 1.51). 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 (Figs. 1.51a and 1.51b) 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. (Figs. 1.51b and 1.51c). 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* (Fig. 1.52). This phytomorph (Fig. 1.52a) was first postulated by Rev. Hugh O'Neill (1944) to be a member of the Urticaceae, or nettle family. The best match, because

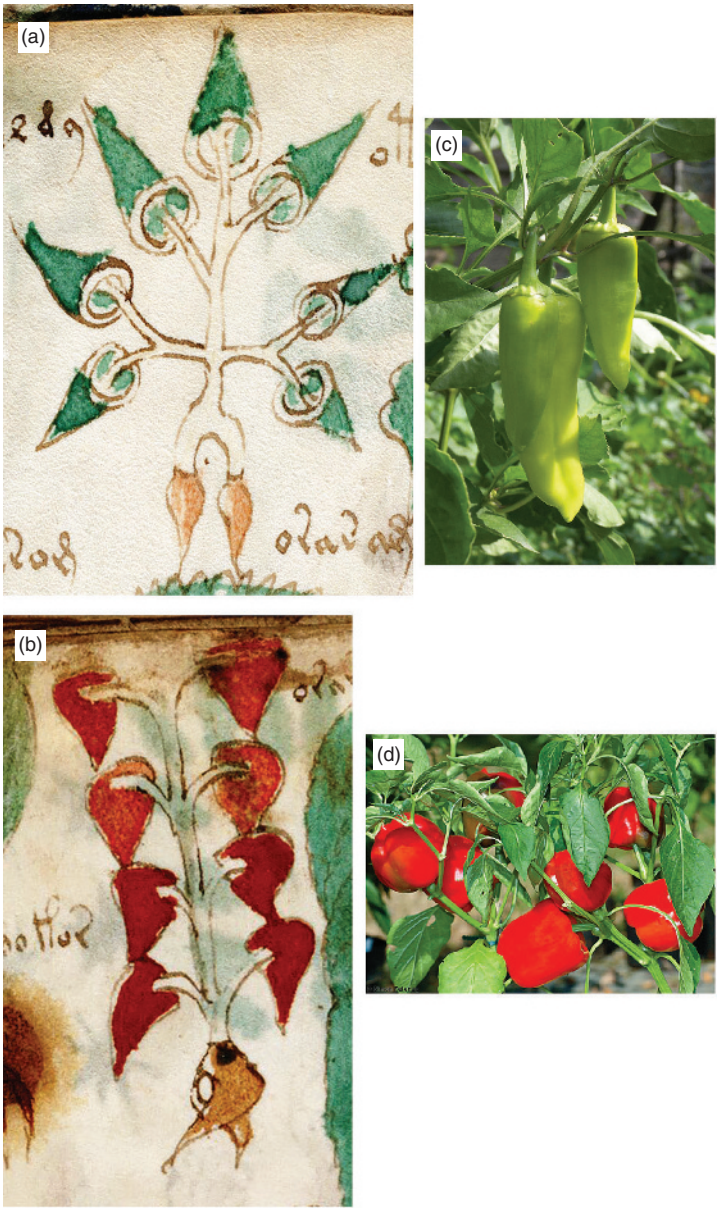

Fig. 1.51. *Capsicum annuum*: (a) 101r #3; (b) fol. 101v (1) #2; (c and d) green and red fruit of *C. annuum* (*Source*: Consell Comarca Baix Empordà, https://commons.wikimedia.org/wiki/File:Bitxos_de_girona.jpg, used under CC-BY-SA 2.0, https://creativecommons.org/licenses/by-sa/2.0/deed.en and Simon Feiertag, respectively).

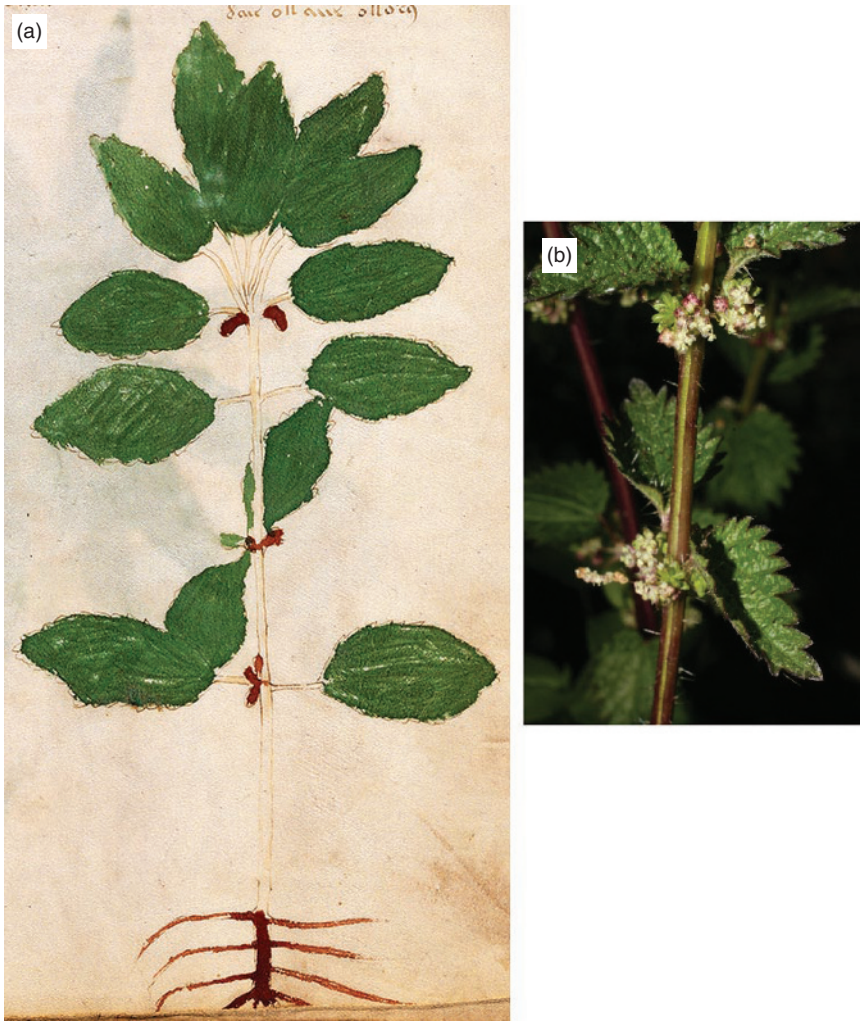

Fig. 1.52. *Urtica* sp.: (a) fol. 25v; (b) *U. chamaedryoides* (Courtesy of Steve Baskauf).

of the dentate, lanceolate leaves, and reddish inflorescences, seems to be *Urtica chamaedryoides* Pursh, heart-leaf nettle (Fig. 1.52b). 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).

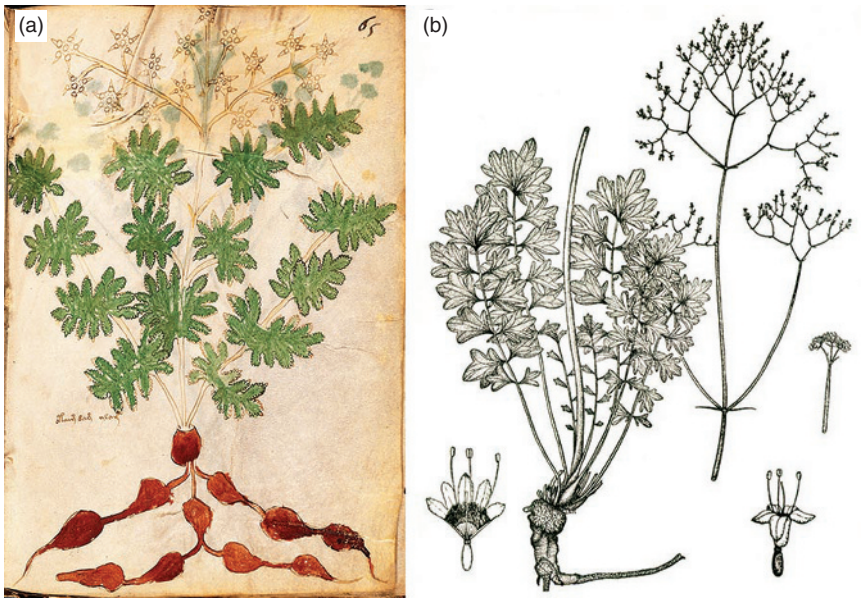

Fig. 1.53. *Valeriana albonervata*: (a) fol. 65r; (b) botanical drawing of *V. albonervata* from Meyer (1951).

FF. Valerianaceae

1. Fol. 65r. *Valeriana albonervata* (Fig. 1.53). The palmate- or cleft-lobed leaves; inflorescence; and napiform to fusiform, often forked taproots (Fig. 1.53a) are a good match for *Valeriana albonervata* B.L. Rob. (Fig. 1.53b). This is native to the Sierra Madre of Mexico (Meyer 1951).

GG. Verbenaceae

1. Fol. 94r. *Duranta erecta* (*D. repens*) (Fig. 1.54). 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 (Fig. 1.54a). Except for the shape of the inflorescence (Fig. 1.54b), this matches perfectly a dried specimen of the repent form of *Duranta erecta* L. (*D. repens* L.), golden dewdrop (Fig. 1.54c). 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

Fig. 1.54. *Duranta erecta*: (a) fol. 94r; (b) fruit cluster of *D. erecta* (*Source*: Hari Krishnan, https://commons.wikimedia.org/wiki/File:Duranta_erecta_fruits.jpg, used under CC-BY-SA 3.0, https://creativecommons.org/licenses/by-sa/3.0/deed.en); (c) herbarium sheet of *D. erecta* (F1721033) (*Source*: Neotropical Herbarium Specimen Scans, The Field Museum, Chicago).

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*) (Fig. 1.55). This phytomorph (Fig. 1.55a) clearly shows linear terminal stipular lobes, as in the North American native *V. bicolor* Pursh (*V. rafinesquei* Greene) (Fig. 1.55b), 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

Fig. 1.55. Viola bicolor: (a) fol. 9v; (b) flowers and leaves of V. bicolor (Courtesy of Daniel Reed).

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.

III. SOURCES AND TECHNIQUES

Fifty-nine phytomorphs, representing 55 plant species, were identified from the "herbal" and "pharma" sections. 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 (fol. 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 the 16th 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 1942; Hernández et al. 1651). Thus, the plant identification alone is evidence that the Voynich Codex is a codex from Colonial New Spain, probably from the 16th century.

The accuracy of the drawing of some phytomorphs, for example, fol. 9v (*Viola bicolor*), versus the broad strokes of others, for example, 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, for example, fol. 100r #4); (2) a foreshortening of large plants in which young shoots appear "grafted or inserted" upon older bases, for example, fol. 1v, 13r, 16v, 23r, 26r, 45r; (3) anthropomorphic faces among the roots, for example, fol. 33r; (4) reptiles and amphibians among the roots and leaves, for example, fol. 25v, 49r; (5) enlarged organs out of proportion to the rest of the plant, for example, fol. 40v; and (6) a mixture of accurate botanical details versus crude representations, for example, fol. 9v versus 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, 1 of the 12 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 (Motolinia 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 (Blunt and Raphael 1979; 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 15th 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.

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