Plant Trivia TimeLine

A Chronology of Plants and People

The TimeLine presents world history from a botanical viewpoint. It includes brief stories of plant discovery and use that describe the roles of plants and plant science in human civilization. The TimeLine also provides you as an individual the opportunity to reflect on how the history of human interaction with the plant world has shaped and impacted your own life and heritage.

Information included comes from secondary sources and compilations, which are cited. The author continues to chart events for the TimeLine and appreciates your critique of the many entries as well as suggestions for additions and improvements to the topics covered. Send comments to planted[at]huntington.org

BP

5-15 Billion+ 6 December. Carbon (the basis of organic life), oxygen, and other elements were created from hydrogen and helium in the fury of burning supernovae. Having arisen when the stars were formed, the elements of which life is built, and thus we ourselves, might be thought of as stardust. (Dauber & Muller, 1996)

3.75 Billion. Mixed deposits of ferrous and ferric oxide suggest the presence of free atmospheric oxygen. This could be construed as evidence for photosynthetic activity. (de Duve, 1995)

3.5 Billion. Formation of the oldest dated stromatolites. These layered geological formations are built by successive generations of blue green algae (cyanobacteria.) (de Duve, 1995) Lower Precambrian rocks in South Africa contain what is possibly the earliest known evidence of cellular organisms, resembling blue green algae. (Bold, Alexopoulos, & Delevoryas, 1980)

2 Billion. Data suggest that by this time in the history of the Earth molecular oxygen began to make a significant difference in the nature of the atmosphere. (de Duve, 1995)

1.6 Billion. Strong evidence indicates that filamentous and unicellular blue green algae existed by this period in the history of the Earth. (Bold, Alexopoulos, & Delevoryas, 1980)

900 Million. Late Precambrian deposits at Bitter Springs, Australia, hold numerous kinds of blue-green and green algae. (Bold, Alexopoulos, & Delevoryas, 1980)

570 Million. Dawning of the Paleozoic era

395 Million. The lower Devonian Period. The Scottish Rhynie chert deposit from this period is famous for its excellent representation of *Rhynia*, one of the earliest vascular plants in the fossil record. By 350 million years BP land plants at last became significant. By the upper Devonian, *Calamites* (the giant horsetail) achieved abundance (as represented in strata of that age.) We know now that seed bearing plants (*Archaeosperma* and *Spermolithus*) are represented in upper Devonian deposits. (Bold, Alexopoulos, & Delevoryas, 1980)

345 Million. This time marks the beginning of the Mississippian period. Together with the Pennsylvanian which followed (through to 225 million years BP), the two periods constitute the age of coal - often called the Carboniferous.

136 Million. With deposits from the Cretaceous period we see the first evidence of flowering plants. (Bold, Alexopoulos, & Delevoryas, 1980)

49 Million. The Azolla Event (AE). Hypothetically, Earth experienced a melting of Arctic ice and consequent formation of a layered freshwater ocean which supported massive proliferation of the fern *Azolla*. That vegetation sequestered significant atmospheric carbon dioxide, as successive generations of the fern sank and created oil and gas reserves in the Arctic, while depletion of carbon dioxide from the atmosphere impacted global climate. (see Wikipedia)

BC

50,000 Wild date seed were left in the Shanidar Cave of Northern Iraq. Also discovered at that site was evidence that cave dwellers consumed chestnuts, walnuts, pine nuts, and acorns. (Root, 1980)

30,000 In 2009, Archaeologist Eliso Kvavadze and colleagues discovered linen fiber, even twisted linen threads, left in the Dzudzuana Cave, in Georgia - constituting the earliest documented evidence of human use of fiber..
https://www.thoughtco.com/dzudzuana-cave-early-upper-paleolithic-cave-170735

17,000+ Excavations at Wadi Kubbaniya, Nile Valley (Egypt) reveal charred remains of 25 different plants, including wild nutsedge tubers, acacia seed, cattail rhizomes, and palm fruit. (Levetin & McMahon, 1996)

8000+ The cultivation of grains had an essential role in the development of civilization. By this time period, wheat and barley were Near Eastern food crops. In ancient cultures, barley was the everyday food of the poor. Archeologists have learned that by this time people used flint sickles and grinding stones.

7000 Flax was known in Syria and Turkey, and is apparently the earliest plant source for fiber (used to make linen) as well as an important source of oil (pressed from the seed). By 5000 B.C. we know that various species of flax (*Linum*) were cultivated/harvested. Evi-

dence shows that flax seed size increased over time, suggesting that humans were selecting for larger seed.

6800 A "large hoard of carbonized lentils," over 1,000,000 seed, was abandoned in B Yiftah'el, north Israel. The size of this hoard indicates the lentils were under cultivation. (Zohary & Hops, 1994)

6500 Faba bean was known in Israel. Lentil, pea, chickpea, and faba bean constituted the principal pulses for ancient Old World agriculture.

6500 Inhabitants of Abu Hureya, Syria relied on 8 domesticated crops for plant-based sustenance. This appears to represent a steady increase in crop cultivation and abandonment of other found sources, in that excavations of older middens (as early as 11,050 BP/9,050 BC) suggest the community regularly consumed as many as 118 species of seed and hard fruit. (Fry, 2016)

6000 Chili pepper and beans of this date have been discovered in a Peruvian highland valley. Lima beans (*Phaseolus lunatus*) and regular beans (*Phaseolus vulgaris*) are known archaeologically from Peru. (Heiser, 1981)

5500 Researchers have discovered evidence of gourds, squashes, beans, and chili peppers in midden levels dating from 5500 to 7000 B.C. in Tamaulipas, Mexico.

5000 Corn (*Zea mays*) was cultivated in Meso-America. This important grain would be introduced to Europe by Columbus. [See 1550, China]

5000 Domesticated rice (*Oryza sativa*) is reported from the Ho-mu-tu site in Chekiang Prov., China. Cabbage seed from this period were discovered in earthen jars in Shensi Province (today cabbages make up 1/4 of all expenditures for vegetables among Chinese families).

4000 Cotton seed dating from this time period have been found in Pakistan.

4000 Grape (*Vitis vinifera*) is thought to have been cultivated in the area from Afghanistan to the Black Sea.

c3050 In this year, the oldest-known living Bristlecone Pine germinated. (Wikipedia, 2017)

3000 Sorghum was known in sub-Saharan Africa. [See 1100 B.C., China].

2850 Two un-inscribed rolls of papyrus paper were entombed with Hemaka, who was the chancellor and royal seal-bearer to Pharaoh Den. These rolls were escavated by Walter Emery in 1936, and are said to be the oldest known examples of paper made from papyrus culms. Papyrus was the major writing surface for the ancient Western world until more than 2,000 years later when parchments (stretched skin) and then "laid" paper (made of rag linen) became common. (Gaudet, 2014)

c2830 A Bristlecone Pine seedling germinated, giving rise to Methuselah, one of the oldest surviving Bristlecone Pines, and one of the most ancient living organisms on Earth. (McKibben, 2008)

2800 The Fah Sh n-Chih Shu details five sacred crops of China: soybeans, rice, wheat, barley, and millet. (Root, 1980)

2750 A coffin from the Egyptian Saqqara Pyramid was made of six layers of wood veneers, sandwiched and glued together like plywood. Cypress (*Cupressus*), juniper (*Juniperus*), and cedar of Lebanon (*Cedrus*) were used. (Connor, 1994)

2737 Tradition credits Chinese Emperor Shen Nung with the first brewing of tea as a beverage. (Levetin & McMahon, 1996)

2732 Shen Nung, the second of China's mythical emperors is said to have encountered the tea plant and to have discovered the use of tea. (Hohenegger, 2007)

2000 Pearl millet was cultivated in sub-Saharan Africa.

2000 Since the Bronze Age, olive has figured into the wealth of many Mediterranean populations.

2000 Peach (*Prunus persica*) and apricot (*Prunus armeniaca*) were mentioned in Chinese literature before 2000 B.C., where they are considered to be native. It is supposed that apricots were introduced to Greece by Alexander the Great. Certainly the Greeks knew peaches by 332 B.C. Virgil noted the Persian fruit in Rome, circa 50 B.C. By 1571 the Spanish had introduced three kinds of peaches to Mexico. [See 1663; 1977]

1550 A 65ft long medical scroll from Egypt (discovered in 1884 by Georg Ebers and named the Ebers Papyrus) lists about 800 medicinal drugs, including many herbs and spices, among them anise, caraway, cassia, coriander, fennel, cardamon, onions, garlic, thyme, mustard, sesame, fenugreek, saffron, and poppy seed. (Rosengarten, 1969)

1485 Hapshepsut, Queen of Egypt, had 31 myrrh trees imported to Egypt for planting at Thebes as homage to the god Amon. (Rosengarten, 1969)

1370 Chemical tests of red fabrics from Tell el ‘Amara, Egypt show the presence of alizarin, a pigment extracted from madder (*Rubia tinctorum*.) (Zohary & Hopf, 1994)

1325 Many seed and other plant products were deposited in the Tutankhamen tomb, including watermelon, safflower, emmer wheat, barley, lentils, chickpeas, flax, fenugreek, olive (both leaves and oil), almond, date palm, garlic, cumin, and coriander. (Zohary & Hopf, 1994)

1100 Soybean (*Glycine max*) long had been domesticated in China. It is thought that by 300 B.C. soybeans became one of two major food crops for northern China. By A.D.100 soybean was common throughout China and Korea. Lotus also was known to have been a crop by this time.

1000 Archaeological evidence shows peanuts were cultivated at this time in Peru, demonstrating that the peanut is truly native to South America.

1000 By this time it is certain that oats were cultivated, most probably originating as weeds in wheat and barley fields. (Zohary & Hopf, 1994)

780 Lu Yu, the Tea Sage, authored *Ch’a-ching* (*The Classic of Tea*), thought to be the first significant treatment on tea. Born in 733, Hupeh Province, China, Lu Yu is said to have grown up in the Dragon Cloud Monastery. (Hohenegger, 2007)

c694 Trees bearing wool (cotton) were introduced to Assyria by Sennacherib.

520 Bodhidarma, a Buddhist priest from India, is said to have visited the Emperor of China. Credited as China’s patriarch of Buddhism, Bodhidarma’s life is clad with legend, particularly related to long periods of meditation. Portrayed without eyelids, he is said to have cut them out and cast them to the ground, at which point a tea bush appeared. The story commemorates the importance of tea in wakefulness, and images of an unblinking Bodhidarma tie tea and zen together. (Hohenegger, 2007)

c500 The Susruta-Samhita, an Indian herbal, described 700 different plants of value. This time period in India also provides the earliest known record of banana.

c500 The oldest known Chinese herbal, the Classical Pharmacopeia of Tzu-I was written. Although no version of this book survives, its existence is documented by Shen Nung, the writer of the extant Classical Herbal (which was produced as early as 100 BC.)

c500 It is supposed that the radish was introduced to China from Europe.

450 Roman law, memorialized on twelve metal tablets, prescribed ownership and responsibility. Table VII, on Real Property, states *“If a tree from a neighbor's farm has been felled by the wind over one's farm, ... one rightfully can take legal action for that tree to be removed.”* and *“It shall be lawful to gather fruit falling upon another's farm.”* https://avalon.law.yale.edu/ancient/twelve_tables.asp

c400 Hippocrates wrote numerous treatises on medicinal plants, discussing plants such as saffron, cinnamon, thyme, coriander, mint, and marjoram. (Rosengarten, 1969)

c399 Condemned to death, Socrates was allowed to administer his own sentence by drinking a potion of poison hemlock, the celery-relative *Conium maculatum*. (Levetin & McMahon, 1996.)

c300 Theophrastus (ca. 372-287 B.C.), the Father of Greek Botany, taught about plants from his own working knowledge of them, experience reflected in the "Inquiry" (*Historia Plantarum*) and "Causes" (*De Causis Plantarum*). Text covers 550 kinds of plants, including strawberry tree (*Arbutus unedo*), date palm, figs, and water lilies. His avoidance of more mystical notions about plants made a seemingly auspicious beginning for botanical study. During the middle ages, however, the Theophrastan works were generally unavailable, and second-hand versions were corrupted with misinformation - thus the level of botanical knowledge available in writing actually declined. The rediscovery and printing of his works beginning in 1483 replaced muddled interpretations of plants and helped rekindle an interest in botany. (HNT)

c300 Plants known to the ancient Chinese were discussed by Erh Ya. Other treatments from the period mention cultivated crops such as yam (*Dioscorea esculenta*) and taro (*Colocasia*).

250 By this time the Maya are known to have cultivated cacao intensively in Belize.

241 Annual tribute demanded after the conquest of Sicily allowed Rome to provide wheat cheaply to its citizens. War in general brought benefits through the capture of productive

acreage, the opening of markets for Roman plantation-produced wine, and the taking of slaves. (Gras, 1946)

216 The south China province of Kweilin (a word that means Cassia Forest) was founded. The Kwei River could be translated as the Cassia River. (Rosengarten, 1969) Cassia refers to the Chinese form of cinnamon, the pungent *Cinnamomum cassia*.

203 Tribute to Rome from Carthage included 500,000 bushels of wheat and 300,000 bushels of barley. (Root, 1980)

c50 Varro described Roman agriculture, including cultivation of grain (wheat, spelt, & barley - but not rye or oats), legumes, olive, and grapes. By this time Romans had well-developed systems of legume rotation (the use of legumes as a fertilizer crop to return nitrogen to the soil.) (Gras, 1946)

c50 Columnella wrote a treatise on Roman Agriculture, covering many subjects, including the various benefits and difficulties of managing slaves versus tenants on large properties. (Gras, 1946)

c50 Virgil, though not a botanist, gave descriptions and information concerning 164 different plants known to the Greeks in his *Georgica*. (HNT, 1492 edition) Advice included laying fields fallow and allowing a crop of vetch and lupine (legumes) to mature before sowing wheat. Virgil recommends the scattering of manure as well as ashes. (Gras, 1946)

43 Cicero (Marcus Tullius Cicero, *De natura deorum academica,* in translation by H. Rackham, 1933, Loeb Classical Library, London: William Heinemann) : "*We enjoy the fruits of the plains and of the mountains, the rivers and the lakes are ours, we sow corn, we plant trees, we fertilize the soil by irrigation, we confine rivers and straighten or divert their courses. In fine, by means of our hands we essay* ***to create*** *as it were* ***a second world within the world of nature.***" (Williams, 2006)

24 Aelius Gallus, the Egyptian prefect for Augustus' Roman Empire, led an ill-fated campaign to conquer the South Arabian spice kingdoms. (Rosengarten, 1969)

AD

c32 The extreme value of spikenard, a fragrant emollient made from *Nardostachys jatamansi*, is highlighted in a Biblical episode in Mark 14:3-6. A believer is chastised by other supporters for anointing Christ with the expensive spikenard, which could have been sold for charity. By the time of Pliny [See c70] the increase in direct Roman trade with India [See c40] lowered the cost of spikenard to one-third of the value it held before Roman fleets began to sail with the monsoons. (Rosengarten, 1969)

c32 Biblical account of Palm Sunday. The date palm has long been considered the tree of life in deserts of the Old World. With 70% sugar content the fruit serve humans and other animals. Moreover, the date palm is associated with fertility and fecundity.

C40 The Greek merchant Hippalus is said to have been the first to realize that the winds from seasonal monsoons could power sailing vessels between Egypt and the pepper-producing Malabar coast of India. This led to extensive development of Roman fleets, which captured the Indian spice trade from overland routes controlled by Arab traders. An account of this trade is recorded in T*he Periplus...*, a treatise known from about 90 A.D. (Rosengarten, 1969)

c47 The approximate, presumed year in which Aulus Cornelius Celsus compiled *De Medicina*, a famous medical treatise constituting extant elements of Celsus's much larger encyclopedic work (now lost) covering all aspects of Roman knowledge and technologies. As with other ancient, classical texts, no original survives; what we have is transmitted and augmented cultural history that was passed on in manuscript until publication was feasible. *De Medicina* was first printed in Florence, 1478, as one of the earliest medicinal incunables. Celsus's text is core to European medicine, considered the foundation of later scientific/medical Latin. Scotsman James Grieve's translation was published in 1756, the first English version of an ancient medical text. A legendary concoction described in *De Medicina* is mithridate, a complex potion named for its supposed-inventor Mithridates IV, who lived a century prior to Celsus. Fearing he was being poisoned (like his father), Mithridates is claimed to have fortified himself against future attacks through ingesting low levels of known poisons in a complex draught. Celsus is credited with having compiled the earliest Mithridate recipe, consisting of nearly 40 ingredients (and even more in other formulations). The translation given in Wikipedia (2019) includes: costmary (*Tanacetum balsamita*), sweet flag (*Acorus calamus*), hypericum, natural gum, sagapenum (*Ferula*), acacia juice, Illyrian iris (probably *Iris germanica*), cardamom, anise, Gallic nard (*Valeriana italica*), gentian root, dried rose leaves, poppy-tears (*Papaver rhoeas*, a wild poppy with low opiate content), parsley, casia (*Cinnamomum cassia*), saxifrage, darnel (the poisonous grass *Lolium temulentum*), long pepper, storax (resin from the bark of *Liquidambar orienta-*

lis), castoreum, frankincense, hypocistis juice (from the parasitic flowering plant *Cytinus*), myrrh, opopanax (probably resin from *Commiphora*), malabathrum leaves, flower of round rush, turpentine-resin, galbanum (perhaps *Cinnamomum tamala*), Cretan carrot seeds, nard (*Nardostachys jatamansi*), opobalsam (perhaps the same as opopanax), shepherd's purse, rhubarb root (*Rheum*), saffron, ginger, and cinnamon. This is, of course, preposterous. There is no way Celsus (if he really existed) would have known of these materials. Castoreum, for example, is a fragrant compound extracted from the anal glands of beavers, which are not native to the Mediterranean. Or perhaps it should have been translated as Castor Oil, which (in pure form) will contain ricin, a very toxic lectin. Regardless, recipes for Mithridate are embellished frauds, highly vaunted among mysteries and secrets that dominated cures before the 19th century. In this particular instance, it is almost impossible to imagine that a Roman writer in 37 AD had knowledge of, or access to, the range of ingredients in the translated formula. The list, by itself, suggests to me that the manuscript was not truly original to Celsus, rather it was created/embellished in the Middle Ages. (Link to Wikipedia: https://en.wikipedia.org/wiki/Mithridate In Greek-based texts, the universal antidote is often termed Theriac (sugary treacles were the English substitute). https://en.wikipedia.org/wiki/Theriac

c50 Dioscorides (the Father of Medical Botany) authored his *Materia Medica* (HNT), a compilation of descriptions and medicinal uses for plants, including about 650 different species. As the most widely known western botanical text during the middle ages, Dioscorides' work became the basis for most early herbals. With an expanding awareness of the natural world in the 16th-century, herbalists began to make their own descriptions of plants, and at last Dioscorides's influence waned. In quoting Ludwig Choulant on Dioscoride's influence (1841, *Handbuch der Bücherkunde für die ältere Medicin*): *"He was the most important writer of all of antiquity on the subject of materia medica. to the later Greek physicians, to the Arabs and Arabicists as well, he was an infallible oracle. Even to the time of the sixteenth century, the habit could not be broken of believing that in pharmacology and in botany there could be anything beyond the teachings of Dioscorides."* (Stannard, 1999, IX, 16)

c70 Pliny (Caius Plinius Secundus, A.D. 23-79), in his compilation called a Natural History (HNT), discussed about 1000 different plants. Well known throughout the middle ages, Pliny's book constituted a major source of information on plants. Primarily an historian and storyteller, Pliny related accounts uncritically, even fancifully. Once original, rarer source documents were discovered and printed, errors in Pliny's account became more obvious. Still the work remains valuable; it is through Pliny that we know the exact costs of many products, and that farmers alternated crops, such as beans and spelt. Recognized in his comments was the growing trend of farm land consolidation into slave-maintained plantations. (Gras, 1946) On teaching: "Yes indeed, those who have gained a little knowledge keep it in a grudging spirit secret to themselves, and to teach nobody else increase the prestige of their learning." (transl. Eamon, 1994)

79 On 24 August, Pompeii was buried by the volcanic eruption of Mt. Vesuvius. Walnuts were left at a table, uneaten by priests whose meal was terminally interrupted. (Root, 1980)

c90 John predicted the fall of Rome (disguised as Babylon,) describing how the merchants of that city would mourn the loss of their cinnamon and frankincense. (Rosengarten, 1969)

105 In this year, according to tradition, the first paper was made. Paper maker, Ts'ai Lun (also written Cai Lun), used the inner bark of paper mulberry (*Broussonetia papyrifera*), as well as other material, such as fish nets. (Levetin & McMahon, 1996; Kurlansky, 2016)

c170 A wreath of delicate flowers was placed in a tomb. Among the flowers were roses, which having been unearthed, are considered among the oldest extant specimens. These came from excavations of a cemetery in Hawara, Egypt (Fayum Province), led by William Flinders Petrie, and when moistened in 1888 by George Schweinfurth revealed detail preserved in lovely perfection. Samples were delivered to rosarian Pierre-Charlesl-Marie Cochet in 1908. See page 10 in Phillips & Rix (1993) for interesting transcriptions of correspondence between people involved in that discovery. (Phillips & Rix, 1993)

280 Roman Emperor Probus rescinded the edict of Domitian, which had prohibited planting grape vineyards in outlying provinces. (Johnson, 1989)

290 A Peruvian Moche warrior priest was interred/entombed with gold and silver jewelry shaped like peanuts. (Levetin & McMahon, 1996)

c310 Several of over 150 "bog people" that had been discovered and examined from peat bogs of Northern Europe were examined by Danish archaeologist Peter Vilhelm Glob. In the person he calls Grauballe Man (excavated south of the Danish village of Grauballe), stomach contents included remains of 63 different "grains" - domesticated and wild plant seed of all sorts. Wheat, barley, rye, and oats were included in the inventory, reminding us these grasses were all in cultivation and widely available at that time Glob's studies were recorded in his popular book *The Bog People: Iron-Age Man Preserved* (published in Danish, 1965, referencing the English translation 1969, Barnes and Noble Books)

332 Constantine issued an edict that bound tenants to country parcels, ensuring continued cultivation of land that might otherwise be abandoned. (Gras, 1946)

335 Cloves were delivered to Constantine - the first record of this spice in the West. The source of cloves, flower buds of *Syzygium aromaticum*, had been known in China for centuries. Etiquette in the Han Court demanded that a person received by the emperor hold a clove in his mouth to sweeten the breath. (Root, 1980)

c350 During the middle ages popular herbals of very little scientific content appeared. They contained no observations beyond those taken from Dioscorides. The various versions of Apuleius' herbals were unfortunate simplifications both in text and in accuracy of plant illustrations. The Huntington has a printed edition of Apuleius (1483), considered to be the first printed herbal.

400 Haric (Alaric) the Goth demanded 3000 lbs of black pepper as part of the ransom for the city of Rome. His assaults on the city continued, and Rome fell on 24 August 410 after the third siege. (Rosengarten, 1969)

500 Coffee, apparently native to the mountains of Ethiopia, was known as a beverage in Arabia. It was first thought to have been roasted in the 1450's, with drinking of brewed coffee spreading to Egypt by 1510, to Constantinople in 1550, to Venice in 1616, to England in 1650, and to Holland in 1690. By 1600, coffee was grown in India, Ceylon, and the East Indies. Cultivation moved to the West Indies and Brasil via propagation from a single tree that was grown in Amsterdam. [See 1706]

548 Cosmas Indicopleustes wrote his *Topographia Christiana*, describing the harvesting and processing of black pepper (*Piper nigrum*.) (Rosengarten, 1969)

593 Tea is said to have been taken to Japan, where it assumed a major role in Buddhist ritual. (Simpson, 1989)

c600 Mohammed was partial owner of a shop in Mecca, trading in plant products such as myrrh, frankincense, and spices. (Rosengarten, 1969)

610 Papermaking is said to have been first introduced from China to Japan. (Levetin & McMahon, 1996)

632 Mohammed's death. His injunction against consumption of alcohol had immediate impact, such that within ten years of his demise, drinking was already banned in Arabia and much of the new Islamic empire (Egypt, Libya, Palestine, Syria, Mesopotamia, and Armenia.) (Johnson, 1989)

674 China's governmental authorities required paper manufactured for official documents be impregnated with natural toxins to reduce damage caused by insects. (Kurlansky, 2016) The original source for this citation is not given, but the name of the plant thought to be the source of the poison (philodendron) cannot be correct. Perhaps the source was berries was the Chinese *Phellodendron*, a member of the citrus family.

725 Wynfrith of Crediton (Boniface) felled the Donar oak at Geismar (near Hesse, Germany), a tree held as a sacred pillar (an Irminsul) by pagan Germanic tribes. The wood was said to have been used later to construct a chapel lectern. (Stannard, 1999)

746 The Dutch and Germans began adding hops to beer. The British would not use hops until after 1524. (Simpson, 1989) Hops adds its own unique flavor to beer, and is said to retard spoilage.

764 The Benedictine monastery of Lorsch was established. In an overt attempt to colonize the area, Charlemagne assigned control of royal forest in the Odenwald area to the Lorsch and Amorbach abbeys. By 900, Odenwald's Unter-Flockenbach community was developing along the Waldhufendorf pattern, which came to characterize German forest-clearing settlements into the 13th century. (Williams, 2006; See also: Jan Horák & Tomáš Klír , 2017. https://www.researchgate.net/publication/318790071_Pedogenesis_Pedochemistry_and_the_Functional_Structure_of_the_Waldhufendorf_Field_System_of_the_Deserted_Medieval_Village_Spindelbach_the_Czech_Republic)

775 Charlemagne gave the upper slopes of the hill of Corton to the Abbey of Saulieu, where vineyards have a great history. Wine from this zone is still called Corton-Charlemagne. (Johnson, 1989)

812 Charlemagne ordered imperial farms in Germany to grow anise, fennel, fenugreek, and flax. (Rosengarten, 1969)

857 Several thousand people perished in the Rhine Valley, victims of St. Anthony's fire. Today we know this condition to be a type of poisoning resulting from a toxic fungal infection (ergot) of rye. The fungal pathogen discolors the grain but gives limited hints otherwise as to spoilage. Epidemics were most serious during times of famine when people consumed grain that might otherwise have been discarded. Outbreaks occurred from time to

time until 1816. The active ingredient is ergotamine. One study suggests that the Salem, MA witch trials resulted from hallucinations of important community members who were exposed to contaminated rye. (Root, 1980)

867 King Charles the Bald granted land on the Loire at Chablis to the Chapter of St. Martin at Tours for a vineyard. Because the Loire connects to the Seine, this wine became well known in Paris. (Johnson, 1989)

900 People in Flanders and Zeeland began systems of dikes to exclude the sea from low-land areas to create land for agriculture. In response to rising population, the same treatment began in Holland some 300 years later. (Ponting, 1991)

903 Ibn al-Faqih published *Mukhtasar Kitab al-Buldan*, which is interpreted to describe sorghum and cowpeas as food staples for Ghana. R. L. Hall in Viola & Margolis, 1991)

1000 Many plants, including spinach and olive, arrived in Spain with the Moors.

1150 Paper was first produced in Europe - introduced to Spain by the Moors. (Levetin & McMahon, 1996)

1057 Chinese Emperor Jen Tsung ordered a new national pharmacopeia be written. More than 1000 drawings were received in Hangchow and the treatment covered over 1000 plants.

1070 Mythical (and impossible to specify chronologically) in this year of the Shire-reckoning, Tobold Hornblower of Longbottom first cultivated the real pipe-weed (or "leaf", presumably a Nicotiana, though tobacco is native to the New World) at his gardens in the Southfarthing. (Tolkien, J.R.R. The Lord of the Rings Part One: The Fellowship of the Ring, 1st ed. 1954, 18th Ballantine Books ed, 1991)

1180 A consortium of pepper wholesale merchants, a pepperers' guild, was founded in London. Later this organization merged with a spicers' guild. In 1429 the spicers' guild became The Grocers' Company (the word "grocer" from *vendre en gros*, French for wholesale.) By charter, this organization managed trade in spices, drugs, and dyestuffs; guild members held exclusive right to "garble" - which meant to select and process spices and medicinal products. (Rosengarten, 1969)

c1200 Opium poppy, *Papaver somniferum*, was introduced to China.

1236 The Statute of Merton gave English manor lords the right to enclose parts of the common woods, waste, and pasture. By 1485 the Tudor move toward increased enclosure further exacerbated problems with tenants, contributing to an uprising called Ket's rebellion in 1549. (Gras, 1946)

1250 Having settled in New Zealand by 950 AD, Maori populations had grown to approximately 10,000 inhabitants. Utilizing fire as a clearing and game management tool, researchers estimate the Maoris had burned 8,000,000 acres of forest. (Williams, 2006)

1256 Albertus Magnus produced *De Vegetabilibus*, based on ancient herbals with some added observations and descriptions.

1300 Villanova detailed Poems for Health, recommending nut oils for cooking. (Root, 1980)

1315 From 1315 through the year 1317, medieval Europe had a significant famine. Following less than half normal crop production in 1315, people began consuming the seed supply for the next year. Wheat prices soared. Over 50% of livestock died, the poor starved. By 1318 bodies in Ireland were disinterred for food. (Ponting, 1991)

1324 William of Ockham established a philosophical viewpoint that avoids complicated explanations: "What can be accounted for by fewer assumptions is explained in vain by more." Called Ockham's Razor, this approach admonishes scientists to search for the most "parsimonious" solutions to their questions. (HNT, first publication in 1495)

1358 The Jacquerie, an early, notable European peasant revolt, endured for 2 months. Brigands had so plundered the region (destroying unprotected villages and isolated homesteads, taking loot and food and leaving in their wake death, carnage, ruined homes, destroyed stores, trampled fields, and uprooted vines) that peasant farmers failed to replant for fear of further loss. In desperation peasant countrymen came together, at first in rebellion against deplorable conditions, eventually in retaliation. Though this and other movements were quelled, similar revolts (stemming from brigandry, manorialism, and feudalism) occurred throughout Europe (most notably in England in 1381 and Germany in 1525) for centuries. These revolts would continue to expand in scope and shift in epicenter, presaging the French Revolution of 1779 and the 1918 Russian Revolution. (Gras, 1946)

1358 Merchants were held to strict standards in Germany. In this year, Nuremberg instituted standards for Saffron - a law called *Safranschau*. Alexander Blythe (1882) reports records of severe punishment for adulterating products, such that in 1444 a very unfortu-

nate vender named Jobst Fendeker and his false saffron were burned to death. (Blythe, 1882)

1450 Nicolaus of Cusa wrote De *Staticus Experimentis*, in which he proposed a plant physiology experiment similar to the van Helmont work of 1648. (David Hersey, *Misconceptions about Helmont's Willow Experiment*, 2003, in Plant Science Bulletin on line, 48(3): 78.)

1455 Gutenberg printed a Bible, the first produced utilizing moveable type. His innovation proved of immediate significance. Ancient texts, available previously only in hand scribed versions, would now be printed. Publication of new herbals and simples advanced quickly. [See Theophrastus, c300 BC]

1471 The *Opus Ruralium Commodorum* was published, based on a manuscript written a century earlier by Peitro Crescenzi of Bologna. Compiled from works of Varro, Columnella, and Cato, with an admixture of Crescenzi's own thoughts, this book was translated into various languages and read extensively. It could be considered the foundation of modern western gardening. (Camp, Boswell, & Magness, 1957)

1478 Publication of the first incunable edition of Aulus Cornelius Celsus's *De Medicina*, in Florence, based on text published by the German, Niccolò di Lorenzo, but said to be compiled by Niccolò Fonzio and edited by his brother Bartholomeo. The two earliest and most significant examples of *De Medicina* are the Florentine and Vatican codices, each incomplete and informing the other. [See TimeLine entry AD c47] Additional Note regarding Bartholomeo Fonzio: *"Fonzio was a fraud, the worst kind of humanist huckster, as lick-spittle as a Chihuahua and as derivative as a dictionary. His works don't deserve to survive in a world bereft of the Botticellis his bonfire-friendly hero incinerated. Alessandro Daneloni has created... the definitive English-language edition of the "Letters to Friends," and readers owe him thanks for that. But they don't owe Fonzio anything, least of all an afternoon's reading-time."* Stephen Donoghue, in his 19 Sept 2011 Book Review of Martin Davies English translation of Daneloni's *Bartholomeo Fonzio Letters to Friends*.

1480 The dry garden at the monastery of Ryoan, in Kyoto, was built during this decade, apparently reaching completion by 1490.

1485 *Gart der Gersundheit*, in translation, the concluding words of Preface: *"Now fare forth into all lands, thou noble and beautiful garden, thou delight of the healthy, thou comfort and life of the sick. There is no man living who can fully declare thy use and thy fruit. I thank thee, O Creator of heaven and earth, Who has given power to the plants...contained in this book that thou has granted me the grace to reveal this treasure, which until now has lain buried and hid from the sight of common men."* (Agnes Arber, 1953; Stannard, 1999, II: 220)

1487 Diaz worked his way around Africa in search of spice & trade for the Portuguese.

1492 Columbus left Spain, sailing west to search for new routes and sources for importing spices from the East. He returned with corn (*Zea mays*) and other crop plants. Over a decade, he led four several voyages, returning to Spain with cargo and information documenting many plants utilized by natives of the new land for food & flavoring, medicine, dyes, fiber, etc. Convincing themselves of proximity to Asia, the explorers were perplexed by the diversity of unfamiliar plants: *"There are trees of a thousand types, all with their various fruits and all scented. I am the saddest man in the world because I do not recognize them, for I am sure they are of great value in Spain for dyes and as medicinal spices. I am bringing specimens of them to Your Highness."* Regardless, the explorers were determined to interpret plants encountered as presumed representatives of valuable sources of exotic medicines, spices, and materials. Columbus returned from his first voyage with a load of Agaves he thought were Aloes, *Bursera* exudate he was convinced to be mastic (from *Pistacia*), *Moringa*, a small tree thought to be Rhubarb, and *Canella* believed to be a form of Cinnamon. Columbus is the first European to report on tobacco use (though it sounds as though there could have been other psychotropic additives): *"Men and women were crossing to their villages, the men with half-burned wood in their hands and certain herbs in order to take their smokes, which are dry herbs put in a certain leaf, also dry, in the manner of a musket made of paper; and having lighted one part of it, by the other they suck the smoke inside with the breathe by which they become benumbed and almost drunk."* George B. Griffenhagen, 1992. "The Materia Medica of Christopher Columbus", Pharmacy in History 34(3): 131-145, American Institute of the History of Pharmacy - Stable URL: https://www.jstor.org/stable/41111458

1493 Sugar cane was introduced to Santo Domingo during Columbus' second voyage. The crop was soon established and a settler named Aguilón is reported to have harvested cane juice by 1505 (Thomas, 1999). By 1516 the first processed sugar was shipped from Santo Domingo to Spain. Soon afterward, Portugal began importing sugar from Brasil. (Sugar cane would become a driving force for the slave trade.) On this voyage, Columbus also carried seed of lemon, lime, and the sweet orange to Hispaniola. He returned to Europe with pineapple. (Viola & Margolis, 1991)

1493-94 Peter Martyr wrote that Columbus brought "pepper more pungent than that from the Caucasus." These capsicum peppers were first introduced in Spain, but were known in England by 1548, and grown in Central Europe as early as 1585.

1494 Columbus introduced cucumbers and other vegetables from Europe to Haiti.

1494 The Papal Treaty of Tordesillas (formalized by the 1529 Treaty of Zaragosa) established a line 370 leagues west of the Cape Verde Islands, granting Spain exploration and trade to the west (including the Philippines) and Portugal the eastern half - which included the routes around Africa to Asia and the Spice Islands. (Andrews in Foster & Cordell, 1996)

1497 Vasco de Gama opened Portuguese trade around the Cape of Good Hope. Having left Lisbon on 8 July 1497, under orders from the King of Portugal, he followed the route (discovered by Diaz 11 years before) around the Cape of Good Hope. On 20 May 1498 he arrived at Calicut, on the west coast of India, marking the first voyage to that region from Europe. This trip and the subsequent voyage of Cabral broke the Venetian monopoly on the sugar and the spice trade established across the Arabian Peninsula. (Rosengarten, 1969; Root, 1980) See 1572 for reference to "Os Lusíadas", an epic poem written by Luís Vaz de Camões.

1499 In his *Hypnerotomachia Poliphili*, Francesco Colonna described dream-like scenes (some illustrated) of mansion, forest, and garden that influenced writers, artists, architects, and designers well into the 17th century. (Thacker, 1979)

c1500 Bean and lima bean, crops native to America, became known to Europeans. By the late 1700's the lima bean was grown in Africa, Europe, India, and the Philippines. By this year also, the sweet potato (also native to South America) had been taken to Spain, where it was in cultivation at mid-century. This root was soon cultivated in China, India, and Malaya. [See 1526; 1648]

1500 The native population of Brasil numbered about 2.5 million before European settlement. At the close of the 20th century, that population base was less than 200,000. (Ponting, 1991)

1502 Death of Murata Shuko (b 1423), who shaped the Japanese tea ceremony as essentially Buddhist, as the way of tea (chado). With this evolution, Japanese ceremonial tea moved to simple surroundings and the use of more rustic objects. (Hohenegger, 2007)

1502 The island of St. Helena was encountered by J. de Nova, and soon became a garden site for cultivating fresh provisions to break the several month voyage between Portugal and Mozambique. At the end of the century, James Lancaster would take with him bottled lemon juice and *"by this means the Generall cured many of his men, and preserved the rest."* (Tolkowsky, 1938)

1502 During Columbus's 4th voyage (as written in an account by his son, Ferdinand), the explorers encountered and captured a Mayan trading canoe on 15 August. Among the goods carried by the Mayans were seed of cacao (which Ferdinand called almonds) that seemed to hold great value: "For their provisions they had such roots and grains as are eaten in Hispaniola [these would have been maize and manioc], and a sort of wine made out of maize which resembled English beer; and many of those almonds which in New Spain [Mexico] are used for money. They seemed to hold these almonds at a great price; for when they were brought on board ship together with their goods, I observed that when any of these almonds fell, they all stooped to pick it up, as if an eye had fallen."

1505 Enslaved Africans were first brought to the New World. Trade in slaves would steadily rise, driven at first by gold mining, the harvest of natural resources, and increasing agricultural demand. In the end, at least 9.5 million African slaves were brought to the New World, fully 2.5 million of whom were deployed in the Caribbean where they worked substantially in the sugar industry. For 360 years slavery was the key labor source for New World sugar production. (Mintz *in* Viola & Margolis, 1991) By another breakdown, approximately 13,000,000 slaves were exported from Africa between 1440 and 1870. Of those people, about 6,000,000 were deployed initially to work in sugar plantations, 2,000,000 to coffee, 1,000,000 to mining, 1,000,000 for domestic labor, 500,000 for cotton fields, 250,000 for cacao walks, and 250,000 for construction. (Thomas, 1999)

1505 The Portuguese settled Ceylon. Their exploitation of the cinnamon forests led to a system of slavery and a monopoly on trade in this spice. (Rosengarten, 1969)

1506 A Suzhou author described Chinese potted landscapes (pinjing, or pan jing) in the following manner: *"The people of Tiger Hill are excellent at planting strange flowers and rare blossoms in a dish. A dish with pine or antique flowering plum, when placed on a table, is pure, elegant and delightful."* (Clunas, 1996)

1511 Western explorers discovered the Molucca Islands (the Spice Islands) to be the source of cloves. See Root (1980) for detail of intrigue that followed. Eventually [see 1773] one

tree planted by Pierre Poivre parented orchards in Madagascar and Zanzibar. These countries nearly provide the world supply today.

1511 Having won battles over Muslim forces, the Portuguese advanced their control over spice producing areas of India, Ceylon, Java, Sumatra - and by 1514, the Spice Islands. For nearly 100 years great Portuguese wealth would flow from control of the spice trade. [See 1605] (Rosengarten, 1969)

1513 Afonso de Albuquerque communicated with the Portuguese monarch: *"If your Highness would believe me I would order poppies...to be sown in all the fields of Portugal and command opium to be made...and the laborers would gain much also, and people of Indi are lost without it, if they do not eat it."* Musgrave & Musgrave, 2002.

1513 Gabriel Alonso de Herrera published his *Obra de Agricultura compilada de diuersos auctores...*, a book in vernacular Spanish of agricultural practice. The *Obra* remained current for more than three centuries, in Spain and as well as its many colonies. (Pinney, 2017; Ciencia Y Humanismo: La Obra de Agricultura de Gabriel Alonso de Herrer (1513, CRITICÓN, 46, 1989, PP 95-1098, ecopy, WWW,)
https://cvc.cervantes.es/literatura/criticon/PDF/046/046_097.pdf

1514 Alvarez commanded the first European vessel to reach China by sea. In the region of Canton the Portuguese crew encountered oranges superior in sweetness and fragrance even to those brought from India and Ceylon. (Tolkowsky, 1938)

1515 “The Malay merchants say that God made Timur for Sandalwood and Banda for mace, and the Moluccas for cloves, and that this merchandise is not known anywhere else in the world except in these places; and I asked and enquired very diligently whether they had this merchandise anywhere else and everyone said not” - the introductory quotation in The Spice Route, taken from a translation of The Suma Oriental by Tomé Pires. Keay, 2007

1516 The banana was introduced to the New World from Africa. (Heiser, 1981)[See 1804]

1518 Duarte Barbosa, in *An Account of the Countries bordering on the Indian Ocean and their Inhabitants* described sweet oranges in Ceylon. A later book by Garcia da Orta, 1562, one of the earliest European books printed in India, commented that the oranges of Ceylon "are the best of the whole world in regard to sweetness and abundance of juice." Prior to the discovery that Asia harbored sweet oranges, Europeans considered citrus more valuable for fragrant oils. (Tolkowsky, 1938) [See 1550]

1519 Magellan began his circumnavigation of South America, exploring new trade routes. Nearly 3 years later, on 8 September 1522, the journey ended when 18 of the original 250 crewmen (lacking Magellan, who died on the isle of Mactan in April, 1521) returned to Seville, with 1 of the 5 ships that started (only the Victoria made the entire voyage). Even given such great losses, the cloves (26 tons), sacks of nutmeg, mace, and cinnamon, and load of sandalwood returned to Spain from the very last legs of the voyage covered the entire expedition cost. The returning captain, Sebastian del Cana, was given a pension and awarded a coat of arms that displays two cinnamon sticks, three nutmegs, and 12 cloves. A journal detailing exploits of this voyage was maintained by Antonio Pigafetta, gentleman-adventurer, and published subsequently as *Primo Viaggio Intorno al Mondo*. (Rosengarten, 1969; Boorstin, 1983) [See 1522]

1521 Hernando Cortés conquered Mexico. While on reconnaissance in southeastern Mexico, his soldiers were the first Europeans to discover the delights of the Aztecan spice, vanilla. (Rosengarten, 1969) Among the people in Cortés’ party was a free, black African, Juan Garrido. At his farm in Coyoacán, Garrido later would become the first European to plant wheat in Mexico. (Thomas, 1999)

1522 Pigafetta, following three years on the Magellan voyage to the Moluccas, wrote that *"in all the islands of the Moluccas there are to be found cloves, ginger, sago which is wood-bread, rice, ...pomegranates, both sweet and sour oranges, lemons..."* He also wrote that: *"the betel-nut is a fruit which they keep chewing together with flowers of jasmine and orange,"* and *" the cannibals of the islands...eat no other part of the human body but the heart, uncooked but seasoned with the juice of oranges and lemons."* (Tolkowsky, 1938)

1524 Representatives of Spain and Portugal met to review maps and charts in an attempt to agree over ownership of the Spice Islands (first controlled by Portuguese in 1511); five years later Portugal paid 350,000 gold ducats to Spain for relinquishment of claims. (Milton, 1999)

1525 Rycharde Banckes published his English Herbal with the introductory phrase: *"Here begynneth a newe mater, the whiche sheweth and treateth of ye vertues and proprytes of herbes, the whiche is called an Herball"* (Sanecki, 1992)

1526 Peter Treveris published *The Grete Herbal*, an English translation of a popular French herbal. The book appears to be the first illustrated herbal published in English. (Sanecki, 1992)

1526 Oviedo reported having often transported sweet potato (batata or camote in Spanish) from the Caribbean to Castile. During the 16th century, Portuguese traders carried the crop to all of their shipping ports, and the sweet potato was quickly adopted from Africa to India and Java. To this day, confusion exists between the sweet potato (*Ipomea*) and the true yam (*Dioscorea*). Confusion began with the first Western encounter of the plant during Colombus' voyages, when sweet potato was introduced to the Spanish court as similar to the yam (i.e. *Dioscorea*, which is native to West Africa and already familiar to Europeans.) (Sauer, 1993) A member of the morning glory family, sweet potato originated from South America and the Caribbean.

1530 Brunfels published *Herbarium Vivae Eicones*, the first newly written and printed botanical book/herbal. The "German fathers" were working with the North European cultivated and natural flora, which presented regional challenges for traditional Dioscoridean texts that continued as the basis for both *materia medica* and floristic plant studies.

1530 Poet and Physician Girolamo Fracastoro published his discursive poem on the French Disease, introducing the term Syphilis (which seems already to have been in use in his region). Some of his verse extols the tree itself: *"Hail great tree sown from a sacred seed by the hand of the Gods, with beautiful tresses, esteemed for your new virtues: hope of mankind, pride and new glory from a foreign world; most happy tree, if only the holy powers had wished you to have been born under our heaven and to grow amid this race of men belonging to the Gods, sacred with everlasting wood. Yet you yourself shall be known even in these parts and you will also be sung under our heavens, wherever through our song the Muses can make you travel by the lips of men."* (copied from Piechocki, 2016)

Other verses relate the transfer of wood for extracts of Guaiacum as treatment:

But not forgetfull of their Country's good,
They fraight their largest Ships with this rich Wood, To try if in our climate it would be
Of equal use, for the same Malady:
The years mild Season seconds their desire,
And western Winds their willing Sails inspire, Iberian Coasts you first were happy made
With this rich Plant, and wonder'd at its Aid; Known now to France and neighbouring Germany Cold Scythian Coasts and temp'rate Italy,
To Europe's Bounds all bless the vital Tree.

That English version comes from another curious book, *Poetical History of the French Disease,* which is the English translation of Fracastoro's poem, published by Nahum Tate in 1685 in London. (Robert S. Munger, 1949. "Guaiacum, the Holy Wood from the New World" *Journal of the History of Medicine and Allied Sciences*, Volume IV, Issue 2, Spring 1949, Pages 196–22. More information on Frascotoro's poem is presented in Katarina Piechocki's article Syphilologies: Fracastoro's Cure and the Creation of Immunopoetics, 2016, *Comparative Literature* 68(1). Duke Univ. Press. https://www.academia.edu/22888104/Syphilologies_Fracastoros_Cure_and_the_Creation_of_Immunopoetics

1531 A decree issued in Castile under the Spanish Crown established good terms for loans to allow purchase of slaves by settlers for establishment of sugar mills. (Thomas, 1999)

1532 Francisco Pizarro conquered Peru.

1533 A professorship in botany, created at the university in Padua, established plant study as a discipline separate from medicine. That position was filled by Francesco Bonafede. The following year Luca Ghini became a lecturer in botany at Bologna. (Morton, 1971) [See 1543; 1545]

1533 Wen Zhengming authored an album including a lengthy written Record as well as numerous paintings and poems documenting the Garden of the Unsuccessful Politician in China's garden city of Suzhou. Codifying the history of one of the world's most famous built landscapes, his concluding descriptive statement gave a panoramic view of the site: *"In all there is one hall, one tower, six pavilions and twenty-three studios, balustrades, ponds, terraces, banks and torrents, making a total of thirty-one, by name the Garden of the Unsuccessful Politician."* (Clunas, 1996)

1536 Spaniards completed the conquest of Peru, soon utilizing potatoes as cheap food for sailors. The earliest English publication describing potatoes was Gerard's 1597 herbal. By 1700 potatoes were important in Germany, and by 1800, important in Russia.

1538 The word "carnation" first appeared as a royal reminder (coronation) of this plant's ancient Greek name Diosanthos, which translates as "the flowers of Zeus." The scientific name for these plants, Dianthus caryophyllus, yields yet more etymological charm. We are reminded of its clove-scented flowers through the specific epithet (*caryophyllus*). The term for clove spice comes to us from the Arabic (*quaranful*) to the Greek (*karyophillon*) to the Latin (*caryophyllus*). (Grimshaw, 1998)

1541 Jacques Cartier introduced cabbage to Canada on his third voyage. The first written record of cabbage in the US is 1669.

1541 A book to promote cooking with sugar was available in Venice. Later Nostradamus wrote the first French book on this topic. (Root, 1980)

1541 Thomas Elyot, in his book *The Castel of Helth* summarizes growing realization that Classical herbs might not apply to plants and cures in more northerly Europe with his observation that ancient texts bring "*no little profyte concernynge myne owne helthe."* (Stannard, 1999)

1542 Fuchs published *De Historia Stirpium Commentarii*. By 1543 he had published the German version, *New Kreüterbuch*. Illustrations for his herbals were based on studies of living plants, rather than on the simplified images that had become common in various scribed editions of the Apuleius herbal. [See c. 350] The text, however, was taken essentially from Dioscorides. (HNT) Much later, the plant genus Fuchsia was named in his honor.

1543 One of the earliest botanical gardens, a garden of "simples," was established by Luca Ghini at the University in Pisa - on a site different from that of the present garden.

1545 A botanical garden was established at Padua, Italy.

1545 A Nahuatl document of commodity prices in Tlaxcala estimated values based on cacao beans: *"one good turkey hen is worth 100 full cacao beans, or 120 shrunken cacao beans; a turkey egg is worth 3 cacao beans; a small rabbit is worth 30; an avocado newly picked is worth 3 cacao beans; one large tomato will be equivalent to a cacao bean; a tamale is exchanged for a cacao bean."* (Coe and Coe, 1996)

1550 Introduced to China by 1550, corn (maize) grew so quickly in importance that the crop became a significant factor in the 18th century increase in the Chinese population, particularly in inland areas where rice was not prolific. (By the end of the 20th century, China was the world's second largest producer of corn.)

1550 By this year, tomatoes (introduced from the New World) were regularly consumed in Italy. [See 1554] (Morton, 1981)

1550 Damiao de Goes described orange exports from Portugal to Spain. The mention was made shortly after J. de Castro's return from India, a voyage from which he is said to have brought a sweet orange tree that he planted at his country home of Penh Verde. His tree is thought to be the original source of Portuguese sweet oranges. (Tolkowsky, 1938)

1551 Jerome Bock published his *Kreüterbuch*, one of the first herbals to include the author's own plant descriptions from first-hand observations - rather than copying the work of Dioscorides. (HNT)

1554 Rembert Dodoens published his herbal, *Cruydeboeck*, complete with 714 plates. The book was very well-received throughout temperate Europe, and soon translated to other vernacular languages - into French by Charles de L'Ecluse in 1557 and English (from the French) by Henry Lyte in 1578, and into Latin in 1583. The Latin translation was called *Stirpium historiae pemptades sex*, which explains the many simple references to this work - as Cruydeboedk, Pemptades, and Stirpium..... Claims are that in its time Dodoens' work was a most translated book, second only to the Bible, and remained in use for two centuries. (Wikipedia, 2015)

1554 First written record of the tomato. Italians grew the plant by about 1550. Thomas Jefferson was the first American to grow tomatoes, in 1781. Tomatoes were eaten in New Orleans by 1812. George W. Carver dedicated himself to promoting the tomato, in addition to his work on peanuts.

1554 Though the first description in Europe of kohlrabi was in this year, it was not grown commercially (that was accomplished in Ireland) until 1734. Records of this vegetable in the US date from 1806.

1556 Tobacco cultivation began in Europe with an importation of seed by André Thevet. (Simpson, 1989) Introduction to Europe is reported as 1559 by De Wolf. (Punch, 1992)

1558 An illustration published by Thevet documented the harvesting and processing of cashew by natives in Brasil. (Other contemporary writers also had discussed the value of this native American tree.) Within a decade, Portuguese traders had introduced cashew cultivation to India, where this remains an important crop. Its value lies not simply in the cashew nut, but also in the juicy peduncle (the stem, called *marañon* in Latin America) on which the nut-bearing fruit forms. That fleshy peduncle, resembling a quince or apple, provides astringent, watery refreshment. Moreover, once fermented it yields cashew wine and brandy. North Americans, very aware of the asymmetric roasted cashew seed, are often unfamiliar with the juicy, fruit-like peduncle. (Sauer, 1993) Never make the mistake of eating raw cashew nuts taken from a fresh marañon. The shell (the real fruit) surrounding the seed is invested with toxic compounds that are dispelled with roasting. The cashew tree is related to the mango (*Mangifera indica*), which is native to the hills of Assam. Many people are allergic to the foliage of the mango, though they may not be affected by the fruit.

1559 Perhaps the first mention of tea is made in western literature, by Giambattista Ramusio, in Navigazioni et viaggi. (Hohenegger, 2007)

1559 In this year Conrad Gesner recorded the earliest known instance of a tulip flowering in cultivation in Europe, in the garden of Johann Heinrich Herwart of Augsburg (Pavord, 1999.) Gesner is said to have received these bulbs himself from Ogier Ghiselin de Busbecq, ambassador from Holy Roman Emperor Ferdinand I to the Ottoman court of Suleiman the Magnificent. Busbecq reported to Gesner that the highly colored flowers were called tulipam by their Turkish admirers, though the native word for these plants is *lalé*. Confusion as to the name could have had something to do with the turban (dulban) shape of the bulbs and flowers. (Grimshaw, 1998)

1559 A wonderful blog by Hannah Marcus reminds us of the church and the 1559 listings of prohibited books. Included was Fuch's publications, though they were expurged, rather than burned. Search for the Blog cited below, where you will see excellent library examples of this kind of censorship. From Books, Health, and History, The New York Academy of Medicine: *"Pope Paul IV published the papacy's first Index of Prohibited Books. The list banned more than 500 authors and proclaimed that Catholic readers could no longer own or read books written by heretics. Leonhart Fuchs (1501-1566) was one of many Protestant authors whose works were banned by the Index of Prohibited Books. And yet, Fuchs was no theologian and his published works were not about religion. Leonhart Fuchs was one of the great botanists and doctors of the 16th century."* On expurging: *"Expurgation was meant to correct a book and remove what was harmful, not to destroy the whole object. In a way then, expurgation made it possible for these books to avoid the inquisitors' bonfires and find their way eventually to the corner of East 103rd Street and Fifth Avenue, bearing on their pages the scars of their histories in Counter-Reformation Europe."* (Blog: "Censoring Leonhart Fuchs: Examples from the New York Academy of Medicine", by Hannah Marcus; Posted on February 20, 2015 by The New York Academy of Medicine - https://nyamcenterforhistory.org/2015/02/20/censoring-leonhart-fuchs-examples-from-the-new-york-academy-of-medicine/

1560 Spanish settlers planted three olive saplings in Lima, Peru. An olive from this original introduction was later taken to Chile. This simple introduction formed the basis of today's South American olive industry. (Root, 1980)

1561 The posthumously published work of Valerius Cordus established wholly new standards for systematic plant description. His was the first work to uniformly address all aspects of a plant, in standard sequence and parallel treatment. (Morton, 1981)

1564 The European grape vine was imported to California via Mexico, brought by priests.

1565 According to popular history, John Hawkins introduced the potato to Ireland.

1568 The *New Herball* of William Turner was published in completed form (in Cologne), including all three parts. Part 1 had been published in 1551 (in Antwerp), part 2 in Cologne in 1561. (Sanecki, 1992) Though woodcuts were copied from Fuchs, Turner added observations from his own working knowledge of herbs. Turner's book is often described as the first herbal in the English vernacular, though earlier titles seem to hold this distinction [See 1525, 1526]. (Wikipedia, 2015)

1569 *Historia medicinal de las cosas que se traen de nuestras Indias Occidentales*, was published by Nicolas Monardes in Seville in many editions (between 1569 and 1574), including an English translation by John Frampton (1577) with the great title: *Joyfull News out of the Newfounde Worlde*. Many new plants are discussed in this book, including tobacco and sunflower (the first mention). Among plants described, 47 were considered to have medicinal value, such as Guaiac, the resin from Holy Wood (Lignum vitae). Monardes cites early reports: *"A Spanyarde that did suffer greate paines of the Poxe, whiche he had by the companie of an Indian woman, but his servaunte beyng one of the Phisitions of that countrie [Santo Domingo], gave unto hym the water of Guaiacan, wherewith not onely his greevous paines were taken awaie that he did suffer: but healed verie well of the evill, with the whiche many other Spanyardes, that were infected with the same evill were healed, the whiche was communicated immediatly, with them that came from thence, hethcr to Sevill, and from thence it was divulged throughout all Spaine, and from thence through all the worlde. . . ."* (extracted from Munger, along with the following note: Antonio Herrara, in his Historia general [Madrid, 1723-32], places the date of the romantic episode as 1503, but does not furnish further details.- Robert S. Munger, 1949. "Guaiacum, the Holy Wood from the New World" *Journal of the History of Medicine and Allied Sciences*, Volume IV(2): 196–22)

Joyfull News... seems also to be the first mention in Europe of the American native tree sassafras. [See 1586] Monardes' plants became prominent, but most went through epochs of popularity. In 1596 John Gerard celebrated the sunflower, which he had grown in his own garden. By 1665 John Ray commented that the flower's popularity had subsided. See the following citation, in which the author suggests that Monardes's publication truly constituted the first widespread discussion of the medicinal value of plants from the Western Hemisphere: J. Worth Estes, 1995. "The European Reception of the First Drugs from the

New World Author(s)" Pharmacy in History, 37(1):3-23 Published by American Institute of the History of Pharmacy Stable URL: https://www.jstor.org/stable/41111660

1569 Pius V determined that chocolate, though nourishing, would be classified as a beverage. Thus chocolate could be taken during periods of fasting. In 1662, Cardinal Francesco Maria Brancaccio determined that though nourishing, beverages, including wine and chocolate, are not to be considered foods. (Bailleux, et al, 1996)

1572 Hernández's work on the natural history of the New World [in Mexico from 1572-1577, see publication in 1651] led to his description of recipes utilized by the Aztecs for chocolate (*cacahuatl*). The beverages they made with cacao were highly spiced, the three principal flavorings being hueinacaztli (a petal from the Annonaceous tree *Cymbopetalum penduliflorum*), tlilxochitl (the processed "bean" of the orchid, *Vanilla planifolia*), and mecaxochitl (the inflorescence of *Piper sanctum*, a relative of black pepper.) In line with contemporary European concern over the humor and the nature of medicines and foods, Hernandez classified cacao as "temperate in nature," but somewhat "cold and humid." (Coe and Coe, 1996)

1572 Luís Vaz de Camões. published his epic poem "Os Lusíadas" - celebrating Vasco de Gama's discovery of a sea route around Africa's cape to India. The following stanzas describe encounters with orchards of sweet oranges (native to China and introduced to India).

> A thousand trees are seen towards heaven rising,
>
> With beautiful and sweetly-scented apples;
>
> The orange, wearing on its lovely fruit
>
> The colour Daphne carried in her hair;
>
> Bent low, nay almost fallen to the ground,
>
> The citron, heavy with is yellow load;
>
> And, last, the graceful lemon with its fruit
>
> Of pleasant smell and shaped like virgins' breasts. (Tolkowsky, 1938)

1573 The peanut is known to have been cultivated in Chekiang Province, China, probably arriving from Brasil through Portuguese traders.

1573 Clusius became court gardener to Maximilian II in Vienna, remaining in that position until 1587. He later became a professor at the University of Leiden in Holland, where he introduced and popularized the tulip.

1575 Milanese voyager and writer Girolamo Benzoni noted in his History of the New World (in reference to chocolate): *"It seemed more a drink for pigs, than a drink for humanity. I was in this country for more than a year, and never wanted to taste it, and whenever I passed a settlement, some Indian would offer me a drink of it, and would be amazed when I would not accept, going away laughing. But then, as there was a shortage of wine, so as not to be always drinking water, I did like the others. The taste is somewhat bitter, it satisfies and refreshes the body, but does not inebriate, and it is the best and most expensive merchandise, according to the Indians of that country."*

1578 Henry Lyte (sometimes awkwardly listed as John Lite or John Lyte) published *A niewe herball* or *Historie of Plantes*..., as the English translation of Charles de L'Ecluse's *Histoire des Plantes* (1557), which was the French translation of *Cruydeboeck* (1554) by Rembert Dodoens. Though published nearly two decades prior to Gerard's *Herball*, and even though both are essentially translations of Dodoens, Lyte's version of *Histoire* never became as widespread or well-known. (Wikipedia, 2015 - note dates for both L'Cluse and Dodoens in the Wikipedia treatment of Lyte were incorrect.) In the *Herball*, Lyte introduced the word "arborist" to English, based on the Latin *arborator*. (Campana, 1999)

1578 Bernal Díaz del Castillo observed the devastation of native peoples in New Spain: *"Let us turn to the province of Soconusco which lies between Guatemala and Oaxaca. I say that in the year 25 [1525] I was traveling through it for 8 or 10 days, and it used to be peopled by more than 15,000 inhabitants [households], and they had their houses and very good orchards of cacao trees, and the whole province was a garden of Cacao trees and was very pleasant , and now in the year 578 [1578] it is so desolate and abandoned that there are no more than twelve hundred inhabitants in it."* (Coe and Coe, 1996)

1581 In a series of letters sent from Portugal (1581-1583) Phillip II of Spain wrote to his two daughters about the love of plants and gardening: *"The other day I was given what is contained in this box, being told that it was a sweet lime; and, although I do not believe that it is anything else than a lemon, I longed to send it to you because, should it be a sweet lime then I never saw one so big...I also send you roses and some orange blossoms, that you may see there are some here."* It is likely that the Phillip's sweet lime was what we today would call an orange, for the Portuguese called the Indian sweet orange the *limon doce*. (Tolkowsky, 1938)

1581 Just a few years prior to the battle of the Spanish Armada, the English Parliament banned use of logwood dye (extracted from the tropical American tree *Haematoxylon campechianum*, and traded through Spanish sources), which had recently come into use for its capacity to yield black cloth. In 1673, with direct access to sources in Central America assured, the bans were repealed. A memory of logwood harvesting was recorded by William Dampier (later to become a prominent English Admiral), who at the age of 22 spent several months in a work camp. The dye comes from heartwood of the trees, some of which were so great in diameter that the workers *"therefore are forced to blow them up."* (Finlay, 2002)

1582 Rikyu consolidated the way of tea with construction of the Taian hut for Japan's ruler, Toyotomi Hideyoshi. (Hohenegger, 2007)

1583 *De Plantis libri* by Andrea Cesalpino became the greatest botanical book of the 16th century and the first general plant science text to supersede ancient writings. In the preceding 2000 years, little had been added to our knowledge about plants. Like his predecessors, Cesalpino accepted anecdotal information, but he advanced plant study in many areas, particularly in his grouping of plants by their physical characteristics (morphology) rather than by their supposed medicinal properties. (HNT) Cesalpino was a student of Luca Ghini [See 1533; 1543.] The bean genus *Caesalpinia* was named for him.

1583 Clusius is said to have taken the yellow-flowered *Rosa foetida* to Holland from Vienna, where it became known as the Austrian Briar (the orange-red cultivar 'Bicolor' is still known as 'Austrian Copper'.) (Grimshaw, 1998) [See 1900]

1584 Richard Hakluyt, friend of Walter Raleigh and ardent supporter of the potential of North America, published *A Discourse of Western Planting*, which promoted establishment of plantations through settlement. Though he lobbied Elizabeth I for support, such a project would not be advanced until 1606, when James I issued the First Charter of Virginia. Hakluyt participated in that charter as part of the London Company, which managed the Virginia Company (a separate group formed the Plymouth Company.) At his death, in 1616, Hakluyt's son inherited his two shares of the Virginia Company, valued at 21 pounds. Hakluyt had predicted remarkable exports of raw materials from North America, with great emphasis on wood and forest products. At his time, construction of a large warship required about 2,000 oak trees, clearing approximately 50 acres of forest. In final analysis, lumber was not a major export, but he was on target in regard to naval stores. By 1609, 80 ship masts had been shipped to England. This trade would continue, eventually engendering a new charter governing management of trees for use in shipbuilding. [See 1691] The newly established regulations would mean English shipbuilders became dependent on this source for masts until 31 July 1775, when the final shipment of white pines was delivered, In the intervening period, England received over 4500 masts from the colonies. (Rutkow, 2012)

1585 The first commercial shipment of cacao seed arrived in Spain, having been sent from Veracruz. (Bailleux, et al, 1996)

1586 Francis Drake, on landing at Roanoke Island, North Carolina (Rupp states it was Roanoke, VA) heard tales from colonists who had survived on soup made from sassafras. He returned to England with what may have been the first shipment of this plant. As early as 1602 Bartholomew Gosnold (who named Cape Cod and Martha's Vineyard) had shipped material of *Sassafras* to England, and by 1607 *Sassafras* was in great demand, sold in English coffeehouses and even on the street. The tea was said to cure a wide range of diseases; the wood, thought to repel insect attack. Today we know that oil of sassafras (out of use since the early 1960s) is substantially the chemical safrole, once used to flavor root beer, but now considered carcinogenic. The most significant commercial use for sassafras today is the manufacture of filé, which is a powder made from young, dried leaves and an important ingredient to gumbo recipes. (Rupp, 1990) [For more on colonists who survived on "a pottage of sassafras leaves" - visit the National Park Service Heritage Education website on Roanoke Revisited.]

1587 In early October, Rikyu hosted the great Kitano tea meeting (Kitano dai chakai) through patronage of Hideyoshi. Followers of tea converged in the Kitano pine grove, where they constructed hundreds of tea huts for temporary use. In succeeding years, Rikyu's heirs would come to establish three main schools of tea (Urasenke, Omotesenke, and Mushanokojisenke), each based on principles of *wa* (harmony), *kei* (reverence), sei (purity), and *jaku* (tranquility). (Hohenegger, 2007)

1587 First written description of Brussels sprouts, a form of cabbage. Common in Belgium, this vegetable crop was known in the US by 1800.

1587 Joseph du Chesne published *Great Mirror of the World* (five parts,, later expanded to six), a massive poem expounding on Paracelsan ideas of alchemy. In the fifth part, he discusses earth, air, fire, and water, and the three principles (mercury, sulfur, salt), which he describes as drawn from distilling oak powder.

1590 José de Acosta noted, in his Natural and Moral History, that: *"The main benefit of this cacao is a beverage which they make called Chocolate, which is a crazy thing valued in that country. It disgusts those who are not used to it, for it has a foam on top, or a scum-*

like bubbling. ...It is a valued drink which the Indians offer to the lords who come or pass through their land. And the Spanish men - and even more the Spanish women - are addicted to the black chocolate." Acosta also tells of a time in the port of Guatulco (Mexico) when the English burned more than 100,000 loads of cacao (a load contained 24,000 beans). (Coe and Coe, 1996)

1590 Adriaen Collaert published his *Florilegium*, a book for flower illustrations and seemingly the first to utilize the term 'florilegium.

1591 On 28 February, at age 70, Sen no Rikyu, the tea master said to have established the character of today's Japanese tea ceremony, committed ritual suicide at the behest of Hideyoshi. (Hohenegger Beatrice, 2007)

1593 Carolus Clusius, having relocated to Leiden, established the *Hortus Academicus*, said to be the first botanical garden dedicated to ornamental plants. The valuable collection of tulips he cultivated there provided much of the material for the growing Dutch tulip industry - apparently through theft as much as sale or gift. (Grimshaw, 1998)

1594 Through 1597 a great famine struck Europe, caused by four bad harvests. (Ponting, 1991)

1595 Bakers in Montpellier, France were forced to use bushes to fire their ovens because there remained no forest in the area to supply firewood. Europe would continue to face energy shortages based on dwindling forest reserves. Eventually reliance would move to coal, then to petroleum (remember, even these fossil fuels are based on plant life), which would mark a major shift in the history of civilization, from renewable to non-renewable energy sources. (Ponting, 1991)

1595 John Davies penned his Epigramme 36," Of Tobacco" (from *The Complete Poems of Sir John Davies,* ed. Rev. Alexander B. Grosart, 1876)

"Homer, of Moly and Nepenthe sings:
Moly, the gods' most souveraigne hearb divine,
Nepenthe, Heaven's (Helen's) drinke, most gladnesse brings,
Heart's griefe expells, and doth the wits refine.
But this our age another world hath found,
From whence an herb of heavenly power is brought;
Moly is not so sovereign for a wound,
Nor hath Nepenthe so great wonders wrought:
It is Tobacco, whose sweet substantiall (subtle) fume,
The hellish torment of the teeth doth ease,
By drawing down, and drying up the rheume,
The mother and the nurse of each disease:
It is Tobacco which doth cold expell,
And clears the obstruction of the arteries,
And surfeits threatning death, digesteth well,
Decocting all the stomach's crudities:
It is Tobacco, which hath the power to clarifie
The cloudy mists before dimme eyes appearing:
It is Tobacco, which hath the power to rarifie
The thick grosse humour which doth stop the hearing;
The wasting hectick, and the quartaine fever,
Which doth of Physick make a mockery;
The gout it cures, and helps ill breaths for ever,
Whether the cause in teeth or stomack be;
And though ill breaths were by it but confounded,
Yet that vile medicine it doth farre excell,
Which by Sir Thomas Moore hath beene propounded:
For this is thought a gentleman-like smell.
O, that I were one of those Mountebankes,
Which praise their oyles and powders which they sell!
My customers would give me coyne with thanks;
I for this ware, for sooth a tale would tell:
Yet would I use none of these tearmes before;
I would but say, that it the Pox will cure:
This were enough, without discoursing more,
All our brave gallants in the towne t'allure,"

Also, see a more contemporary translation by Christopher Marlowe, https://classic-literature.co.uk/epigrams-by-john-davies-translated-by-christopher-marlowe/

1596 L. Shih Chen published Pen Ts'ao Kang Mu, the most well-known and praised of Chinese herbals. (Rosengarten, 1969)

1596 Gerard included in a catalog of plants in his Holborn garden what may be the first mention of the garden Nasturtium (probably *Trapaeolum majus*). A much later publication, Aiton's Hortus Kewensis, notes that Lumley Lloyd introduced this plant to horticulture, in 1686. (Halliwell, 1987)

1597 Gerard published the first edition of his *Herball*, followed eventually by a second edition in 1633, which was edited and expanded by Thomas Johnston. Titled *The Herball* or *General Historie of Plants*, the text relied heavily on an English translation of Dodoens' Stirpium. (Sanecki, 1992). See Jackson, 1876 in this TimeLine, for more information. Jackson describes the Herball as an English translation of Dodoen's *Stirpium Pemptades* (the Latin translation of *Cruydeboeck*) that Gerard reorganized along the lines of L'Obel's work.

1597 The Polish alchemist Michael Sendivogius (Michał Sędziwój) insisted: *"Therefore when there is Rain made, it receives from the Air that power of life, and joyns it with the Salt-nitre of the Earth..., and by how much more abundantly the Beams of the Sun beat upon it, the greater the quantity of saltnitre is made, and by consequence the greater plenty of Corn grows."* (Leigh, 2004) What is this telling us? The era of alchemy has much to do with the work of Paracelsus, and his intention to discover the chemistry of medicinal cures (iatrochemistry). Embedded in alchemical thought is the observation that air is necessary for fire, and for life. A truly important mineral, saltpeter (potassium nitrate), was used to manufacture gunpowder, but was also known to improve soil fertility. There must have been, by this reasoning, an aerial form of nitrate (nitre) that could be fixed into solid form through rain and sun. Sendivogius is sometimes called the Father of Oxygen, because his many studies presage the existence of a flammable component in the atmosphere.

1598 In Ben Jonson's play "Every Man in His Humour", Captain Babodil extols tobacco, claiming: *"I could say what I know of the virtue of it, for the expulsion of rheums, raw humours, crudities, obstructions, with a thousand of this kind; but I profess myself no quacksalver. Only this much: by Hercules I do hold it and will affirm it before any prince in Europe to be the most sovereign and precious weed that ever the earth tendered to the use of man."*

1599 Thomas Nashe, known for his bawdy writings, commented on the vaunted use of guaiacum in treatment of syphilis: *"Physicians deafen our ears with the* honorificabilitudinitatibus *of their heavenly panacea, their sovereign* guiacum*, their clysters, their treacles, their mithridates, compacted of forty several poisons, their bitter rhubarb, and torturing stibium."* Nashe's guiacum is resin from Lignum vitae, the wood of small trees in the genus *Guaiacum,* which had been highlighted as a powerful medicinal in Monardes descriptions of useful plants from the New World (1569-1575). The fragrant resin is also harvested from the similar, related *Bulnesia sarmientoi.* Syphilis, an infection caused by the bacterium *Treponema pallidum*, became recognized as a scourge in Europe following Columbus' first voyage. Having been diagnosed in Naples around 1494, it was initially referred to as the "French disease," assuming France to be the source. That association was memorialized in 1530, when Girolamo Fracastoro penned the name Syphilis in his epic poem *"Syphilis sive morbus gallicus"* (Syphilis or The French Disease), creating a myth about the generation of the disease and the roles of *fomes* (infectious agent). Fracastoro's poem notes mercury and guaiacum for treatment. One general assumption today gives the true origin of *T. pallidum* as the New World. NOTES: [Source of the Nashe quote: "Praise of the Red Herring" (Nashe's Lenten Stuff - Containing the Description and the First Procreation and Increase of the Town of Great Yarmouth, in Norfolk: with a new play, never played before of the PRAISE OF THE RED HERRING - Fit for all clerks of the noblemen's kitchen to be read; and not unnecessary by all Serving-men who have short Board-wages and to be remembered... *faman peto per undas."*] https://archive.org/details/acw5721.0001.001.umich.edu) If you are loaded with cash, you can pay $45 to Oxford University for 24-hour access to an article published in 1949, Robert S. Munger, "Guaiacum, the Holy Wood from the New World" *Journal of the History of Medicine and Allied Sciences*, Volume IV, Issue 2, Spring 1949, Pages 196–229, https://doi.org/10.1093/jhmas/IV.2.196 A good, accessible article is: J. Worth Estes, 1995. "The European Reception of the First Drugs from the New World" *Pharmacy in History* 37(1): 3-23 American Institute of the History of Pharmacy Stable URL: https://www.jstor.org/stable/41111660 PS: also Search honorificabilitudinitatibus in Wikipedia, the longest English word, even once-used by Shakespeare,: https://en.wikipedia.org/wiki/Honorificabilitudinitatibus

1600 Britain's East India Company was founded. (Rosengarten, 1969)

1601 Jean Robin published a catalog for his medicinal herb garden.

1602 Shareholders formed The United (Dutch) East India Company, with bad consequences for Portuguese traders. [See 1605, 1799] (Rosengarten, 1969)

1603 Spigelius published instructions on making dried herbarium specimens (in his *Isagoges in Rem Herbarium*) - a technique that had only come into practice during the previous 50 years. The collecting, exchange, archiving, and study of pressed, dried plants that are mounted to sheets of paper engendered a quiet revolution in taxonomy, floristics, and systematics. (Morton, 1981)

1603 At the age of 18, Federico Cesi (meeting with three friends in his Umbrian home) founded the Academy of Linceans (the Academy of the Lynx-eyed), the four members devoting themselves to "the keen exploration of the minutiae of nature." Each member assumed a specialty; Cesi was devoted to botany. By 1610, Giovaanni Battista Della Porta had become the 5th member, and in 1611, Galileo Galilei was enrolled. For a span of time, "astronomy and botany went hand in hand," with such additions to the membership as botanists Nicol Antonio Stelliola and Fabio Colonna. (Freedberg, 2002) [See 1624]

1604 *"Man was created of the Earth, and lives by virtue of the air; for there is in the air a secret food of life...whose invisible congealed spirit is better than the whole Earth - without which no mortal can live, and without which nothing grows or is generated in the world."* These words are taken from the works of Polish alchemist Michael Sendivogius, and (according to Lane) constitute an early reference to the relationship between the "ether" and life - presaging discovery of the substance known today as oxygen - (Lane, 2002)

1605 James I issued letters of incorporation to London's Worshipful Company of Gardeners.

1605 The Dutch began seizing control of Portuguese-held trade with the Spice Islands (historically called the Moluccas, today the three widespread groups of islands that make up the Indonesian province of Maluku), gaining full control by 1621. By 1681 a plan to eliminate trees in most areas of the Moluccas and to concentrate cultivation of nutmeg and cloves on only two islands had the desirable effect of raising prices and tightening management of supply. (Rosengarten, 1969)[See 1770; 1860; 1886]

1606 A million black mulberry trees were imported to England, another step in an effort to start a silk industry. Production of silk in England was never successful. (Lewington, 1990)

1607 Joseph du Chesne (also called Quercetan, see Digby, 1661) *Diaeteticon Polyhistoricon, Opus* .... rails against sugar: *"Under its whiteness, sugar hides a great blackness and under its softness an extremely large acrimony which equals that of strong water. So much so that it could dissolve and liquefy the sun itself."* (Oddy, Atkins & Amilien, 2009. *The Rise of Obesity in Europe: A Twentieth Century Food History*)

1608 Jean Robin and Pierre Valet published the first European florilegium, J*ardin du Roy tres Chrestien Henri IV*. It was followed closely by *Florilegium Novum* (1611-1614) and *Florilegium Renovatum* (1641) by Jean Theodore de Bry, Besler's Hortus Eystettensis (1613), Emanuel Sweert's *Florilegium* (1612), and *Hortus Floridus* by Crispin de Passe (1614). These books covered extensive numbers of horticultural floral forms. For example, Besler's work included 660 species and more than 400 variants (doubles, variegates, etc); 400 of his plants had medicinal value, 180 were used in cooking, and 250 were grown principally for ornament. Besler's book included numerous forms of lilies, campanulas, delphiniums, hollyhocks, scabiosas, iris, tulips, narcissus, roses, hyacinths, and anemones.

1609 Jamestown colonists planted cucumbers and carrots in their gardens.

1610 First apparent importation of tea to Europe. (Hohenegger, 2007)

1610 The practice of drinking tea was first introduced to Europe, and to England in 1644.

1610 By this year, huge sugar plantations in the province of Bahia, Brasil were run by 2,000 white settlers, 4,000 black slaves, and 7,000 Indian slaves.

1610 Tea was imported to Europe (apparently the first time) through the Dutch East India Company. It was not until September 1658 that an advertisement appeared in England for this commodity. (Coe & Coe, 1996)

1611 John Tradescant, gardener at Hatfield House, submitted a bill for various plants purchased in Holland, including 80 shillings paid for 800 tulip bulbs. At that price, the bulbs represented a gardener's salary for about six months. (Pavord, 1999)

1612 In his *De Orbe Nove*, Peter Matyr commented concerning chocolate (cacao): *"But it is very needfull to heare what happie money they use, for they have monye, which I call happy, because for the greedie desire and gaping to attaine the same, the bowelles of the earth are not rent a sunder, nor through the ravening greediness of covetous men, nor terrour of warres assayling, it returneth to the dennes and caves of the mother earth, as golden, or silver money doth. For this groweth upon trees."* (Coe and Coe, 1996)

1612 The 225 square mile, 13 foot deep Lake Beemster in Holland was drained to create 17,000 acres of fertile land. The draining required 43 windmills. In the hundred years from 1550 to 1650, nearly 400,000 acres of Dutch land were reclaimed for agriculture. (Ponting, 1991)

1612 John Rolfe is said to have introduced the Orinoco strain of tobacco from Venezuela, giving Virginia colonists their first commercially successful agricultural export crop. (The tobacco native to Virginia was not popular in Europe). The value of tobacco was so great that Virginia governor Thomas Dale was forced to require that each farmer plant 2 acres of corn also. About 500,000 pounds of tobacco were produced in 1627; and 35 million pounds by 1700. The eventual demands of tobacco as a crop resulted in institution of slave labor in about 1674. (Schlebecker, 1975)

1613 Basilus Besler published *Hortus Eystettensis*, a highly illustrated codex documenting plants in the garden (hortus) of Johann Konrad von Gemmingen, the Bisho of Eichstätt. Organized based on the four seasons, Besler's team of artists and writers worked over 16 years to produce and publish the hundreds of engravings.

1619 The Virginia Company of London (having been founded through a land grant in Virginia in 1606) instituted the headright system, a means of granting land (in 50 acre parcels) to farmers. The original working arrangement had been a seven-year indenture period for settlers, with the expectation farmers would continue as share-cropping tenants. The headright system of land disposal established a precedent for other colonies in eastern North America. (Schlebecker, 1975)

1620 Although some advances in the study of natural phenomena had been made in the previous century, Francis Bacon's call for method in scientific inquiry in his *Novum organum* (HNT) prompted a new spirit of investigation. His method rejected "the dogma and deduction" of ancient philosophers who ignored the value of observation.

1621 A thanksgiving feast was held in mid-October by Plymouth Colony Pilgrims in appreciation of assistance from members of the Massasoit tribe and celebration of the first harvest. (Milestones, Pen, 1974) The gift of corn in 1620 proved critical to the survival of half of the 102 Pilgrims who had arrived on the Mayflower. A brass plaque at Truro (Corn Hill) quotes Governor Bradford: *"And sure it was God's good providence that we found this corne for we know not how else we should have done.*" - and reveals the Western hubris of superiority. Several thousand years of native New World agricultural talent produced the corn those colonists enjoyed. Galinat in Foster & Cordell, 1996)

1622 Native Americans killed a third of the Virginia population of European settlers in apparent retaliation for the encroachment of these immigrants on Indian cornfields. (Root, 1980)

1623 Gaspard Bauhin produced the *Pinax*, a monumental compilation that pulled together uncoordinated plant names and descriptions that had appeared in Theophrastus and Dioscorides, as well as in later herbals and other plant records. By accepting Bauhin's compilation, Linnaeus was able to avoid many of the complications of the ancient literature. (HNT)

1623 Carrying through with the barbarous cruelty of Dutch Governor General Jan Pieterszoon Coen in establishing control over spice producing islands, Dutch representatives committed a brutal massacre of the British and Japanese working on Amboyna. (Milton, 1999)

1624 Galileo sent an occhialino (an early term for microscope) to Cesi, with the conclusion: *"But your Excellency will have a huge field in which to observe many thousands of specimens. I beg you to notify me of the most interesting things you observe. In sum, it gives us the possibility of infinitely contemplating the grandeur of nature, how subtly she works, and with what indescribable diligence."* By 1625, Colonna had called the instrument an enghiscope, while another Lincean, Johannes Faber, termed it the microscope. (Freedberg, 2002) [See 1603]

1624 John Smith's incredible recounting of English colonization in the midst of the extant native culture (of what we call Virginia today) is worth reading. Here he describes a typical native village: *"Their houses are in the midst of their fields or gardens, which are small plots of ground. Some 20 acres, some 40. some 100. some 200. some more, some lesse. In some places from 2 to 50 of those houses together, or but a little separated by groues of trees. Neare their habitations is little small wood or old trees on the ground by reason of their burning of them for fire."* - Source: THE GENERALL HISTORIE OF Virginia, New-England, and the Summer Isles... (See https://docsouth.unc.edu/southlit/smith/smith.html Also, see: http://www.virtualjamestown.org/exist/cocoon/jamestown/fha-js/SmiWorks1)

1625 Francis Bacon published his essay 'Of Gardens,' in which he imagined an ideal garden, a princely 30-acre Eden.

1627 Thomas Morton (in his book *The New England Canaan of Thomas Morton*) reported on use of fire to clear forests: *""The Salvages are accustomed to set fire of the Country in all places where they come, and to burne it twize in the yeare, viz; as the Spring and the fall of the leaf. The reason that mooves them so to doe so, is because it would other wise be so overgrowne with underweedes that it would be all coppice wood, and the people would*

not be able in any wise to passe through the Country out of a beaten path." (for this and further info, see Williams, 2006)

1629 John Parkinson published *Paradisi in Sole Paradisus Terrestris*.

1632 Natural Philosopher (and literary executor for the estate of playwright Ben Jonson), Kenelm Digby is credited with manufacturing and later patenting (1662) the first prototypes of the modern glass wine bottle - narrow-necked and fired under elevated temperatures, the "English" bottles could be stoppered with corks, laid down, stored, and shipped more effectively than earlier types. (Taber, 2007) Digby, an alchemist by nature, also published a book on plants, see 1661 - *Discourse Concerning the Vegetation of Plants*.

1633 Jesuit Father Antonio de la Calaucha reported antimalarial properties of extracts from a Peruvian tree. The use of the extract, quinine, spread quickly in Europe, where malaria (called ague) had always been a major source of sickness and death. Availability of quinine during a 1655 papal conclave was likely the reason none of the cardinals attending died - the first time this had happened. Because of the way the dried extract was introduced to Europe, it became known as Jesuit's powder. Other stories about quinine refer to the miraculous cure of Francisca Henriques de Rivera, wife of the Count of Cinchón, the Spanish viceroy to Peru. From this event, people began to refer to the fever tree as Cinchona. Europeans did not know the true source of the bark until 1735, when Joseph de Jussieu collected samples of the tree. (Le Couteur & Burresson, 2003) Linnaeus named the tree *Cinchona officinalis* in his 1753 *Species plantarum*.

1633 In the same year of Galileo's famous Inquisitional trial and conviction, Giovanni Battista Ferrari (of Sienna) published De Florum Cultura, an early book dedicdated to ornamental flowers and horticulture. Among the illustrations by Dutch artist Cornelis Bloemaert were examples of the double-flowered Chinese Hibiscus. Of significance, Ferrari and the artist decided to include illustrations of the seed, as examined through a microscope and labelled: "*Idem semen triplici ad microscopium aspectu repraesentatum*." This appears to constitute the first published plant illustration that takes advantage of microscopy (32 years prior to Hooke's *Micrographia*.) The use of microscopes in Italy had been popularized by Galileo (a member of the Lincean society) as: "*that kind of lens in a tube which makes very small bodies look very large, and can show each part distinctly.*"(Freedberg, 2002)

1634 Until 1637 the zeal of collectors inflated values of tulip cultivars. This Tulipomania eventually fell victim to a market collapse that affected the entire Dutch economy.

1634 William Wood published the first account of New England ecology, highlighted by the following poem (Rutkow, 2012):

Trees both in hills and plaines, in plenty be,
The long liv'd Oake and mournefull Cypris tree,
Skie towring pines, and Chesnuts coated rough,
The lasting Cedar, with the Walnut tough;
The rozin dropping Firre for masts in use,
The boatmen seeke for Oares light, neate growne Sprewse,
The brittle Ash, the ever trembling Aspes,
The broad-spread Elme, whose concave harbours waspes…
The Diars Shumach, with more trees there be,
That are both good to use, and rare to see.

1635 The Jardin des Plantes was established in Paris through monarchal edict.

1635 Two decades of hostility between the Portuguese and the English East India Company along the east coast of India ceased. By 1639 the East India Company had established factories for production of cotton cloth at Madras, and by 1651 in Bengal. In 1661 England acquired Bombay and the Company established factories there. Over 150 years would pass before industrial processes yielded cotton fabrics of the delicacy produced in India by hand. (Musgrave & Musgrave, 2002)

1636 The Portuguese were expelled from Deshima, their Japanese trade island; the Dutch were allowed on-going contact with Japanese traders, through Hirado and eventually Deshima in 1641.

1636 The Dutch occupied Ceylon, forcing villagers to supply quotas of cinnamon, as had the Portuguese previously. (Rosengarten, 1969)

1636 John Shawe was rewarded patent #95 for *'Diverse Wayes and Meanes for the Better Manuring and Improveing of Grounds of all Sort nor formerly Found Out nor Practiced by Any."* It is left up to future researchers to determine what Shawe was claiming as his discovery. (Leigh, 2004)

1637 Tradescant *f.* (the son, *filius*, of elder Tradescant) made his first trip to Virginia, returning to England with living material of bald cypress and American sycamore. Tradescant *f.* made his second trip to Virginia in 1642. John Tradescant introduced *Mimosa pudica*, the South American sensitive plant, to cultivation in England. (Grimshaw, 1998)

1640 John Parkinson published his *Theatrum Botanicum* in which plants are classified according to 17 classes or tribes; i.e. 1. Sweet smelling Plants; 2. Purging Plants; 3. Venemous Sleepy and Hurtfull plants and their Counter Poysons; 4. Saxifrages; 5. Vulnerary or Wound Herbs; 6. Cooling and Succory Herbs; 7. Hot and Sharpe Biting Plants; 8. Umbelliferous Plants; 9. Thistles and Thorny Plants; 10. Fearnes and Capillary Herbes; 11. Pulses; 12. Cornes; 13. Grasses; 14. Marsh Water and Sea Plants and Mosses and Mushroomes; 15. The Unordered Tribe; 16. Trees and Shrubbes; 17. Strange and Outlandish Plants. (Sanecki, 1992)

1642 Samedo Alvaro recounted stories to Europeans about the Chinese healing root called jin-chen, or ginseng. (Emboden, 1974)

1643 Expressing belief in alchemy and the concept of palingenesis, Thomas Browne wrote in his *Religio Medici* that: *"A plant or vegetable consumed to ashes, to a contemplative and school Philosopher seems utterly destroyed, and the form to have taken his leave for ever: But to a sensible Artist the forms are not perished, but withdrawn into their incombustible part, where they lie secure from the action of that devouring element. This is made good by experience, which can from the ashes of a plant revive the plant, and from its cinders recall it into its stalk and leaves again."* See also Jorge Luis Borges and his short story The Rose of Paracelsus. (Wikipedia)

1644 A recipe for preparation of chocolate in Spain was published by Antonio Colmenero de Ledesma. The mixture included: 100 cacao beans, 2 chilis, a handful of anise, ear flower, 2 mecasuchiles, 1 vanilla, 2 oz cinnamon, 12 almonds and as many hazelnuts, 1\2 lb sugar, achiote to taste. This was beaten into hot water, to a froth. (Coe and Coe, 1996)

1646 Giovani Battista Ferrari published his 500-page compendium of all known information on citriculture, *Hesperides, sive De Malorum aureorum Cultura et Usus Libri Quator* (Hesperides, or Four Books on the Culture and Use of the Golden Apples). He relates a fable of citrus in which the three daughters of Hesperus, the Hesperides, fled to Italy from Africa. Aegle took her citrons to the country near Lake Garda, Arethusa bore her lemons to Liguria, and Hesperthusa sowed seed of oranges in the Campania Felix. Among his many woodcut illustrations is figured the navel orange, a form we tend to think of as modern. (Tolkowsky, 1938)

1647 Rice was introduced into cultivation in the Carolinas. Today California, Arkansas, Louisiana, & Texas are the main rice producing states. (Heiser, 1981)

1647 Correspondence from the Caribbean to Gov. Winthrop of Massachusetts confirmed that workers at sugar plantations would require food provisions from the outside, because the production of sugar was more profitable than the production of other provisions. The most important export for Massachusetts was salt cod sold to feed slaves in West Indian plantations. Returning ships brought quantities of sugar and molasses sufficient to spur the New England rum industry. (Root, 1980)

1647 Garancières: *"It is clear that sugar is not a food, but an evil spell; that it is not a preservative but a destruction, and that we should send it back to India, for before its discovery the consumption of the lungs was not known but was brought to us with the fruit of our labor."* (Oddy, Atkins & Amilien, 2009. *The Rise of Obesity in Europe: A Twentieth Century Food History*)

1648 French doctor Guy Patin was critical of a thesis on tea, stating: *"One of our doctors who is more celebrated than able, named Morissot, wanting to bestow favor upon that impertinent novelty of the century… has had presented here a thesis on tea. Everyone disapproved, some of our doctors burned it…."* (Hohenegger, 2007)

1648 Sweet potatoes were in cultivation in Virginia.

1648 Jean Baptiste van Helmont reported on his experiment in plant physiology and nutrition. A five pound willow tree was planted in 200 pounds of dry soil. It was watered and allowed to grow for five years. At the end of this period, the total gain in weight was one hundred and sixty-nine pounds and three ounces, while the soil had lost only two ounces. As an alchemist,Van Helmont assumed that water is a complex substance which is changed into plant material. Van Helmont did not mention publication of the idea for such an experiment two centuries earlier by Nicolus of Cusa [see 1450; also see John Woodward, 1699], or make associations between plant growth and gas exchange. David Hersey, Misconceptions about Helmont's Willow Experiment, 2003, in Plant Science Bulletin on line, 48(3): 78.

1649 Nicholas Culpeper published his herball, T*he English Physician* or an *Astrologophysical Discourse of the Vulgar Herbs of this Nation Being a Compleat Method of Physic*

Whereby a man may preserve his body in health or cure himself being sick for thee pence charge with such things onely as grow in England, they being most fit for English Bodies. The English Physician dealt considerably with astrology and the signatures of plants. (Sanecki, 1992)

1650 By this year coffee had arrived in England. In 1675 one could take the beverage in over 3,000 coffee houses in that country. (Simpson, 1989)

1650 From this time until the 20th Century the Caribbean was the world center for growing sugar cane.

1651 *Rerum medicarum Novae Hispaniae*... (HNT) was published, 80 years late. This work resulted from one of the earliest explorations of the natural history of the New World, made in 1570 by Francisco Hernández, private physician to Philip II of Spain. He was sent to assess natural resources and reported on more than 1000 plants that were considered medicinally important by the natives of Mexico. Some of the plants he described and preserved as botanical specimens are now extinct.

1651 Britain's Navigation Act required that all imports from the colonies be received on British ships.

1652 Pasqua Rosée, a Greek who settled in England, opened his London coffeehouse with a printing of *"The Vertue of the COFFEE Drink"* summarized as: *"a simple innocent thing; composed into a Drink, by being dryed in an Oven, and ground to Powder, and boiled up with Spring water, and about half a pint of it to be drunk, lasting an hour before, and not Eating an hour after, and to be taken as hot as possibly can be endured."* (Pendergrast, 1999)

1652 The first New England pine trees were felled for British ship masts. Before the end of the century, British warships were built in North America. By 1775 easy sources of wood for masts had been stripped from Eastern North America. (Ponting, 1991) The pine tree was used as one of the symbols on the first American-made coins, issued in Boston. [See 1652; 1761]

1652 John Hull of Boston, Massachusetts was selected to establish a New England mint. His first coins bore inscription only, but his second set was ornamented with a willow, his third with an oak, and his fourth (the largest issue) with a pine. These Boston shillings are sometimes called the tree coins. John Hull grew wealthy through this process and became the subject of an apocryphal tale, which claims that the marriage of his daughter to Mr. Samuel Sewell was settled with a dowry of 30,000 shillings, the amount determined as equivalent to her weight. (Connor, 1994)

1652 Capetown was founded. The Dutch sent two ships to Table Bay, near Cape Town, South Africa to establish a garden to provide fresh foods and fruits for sailors on their voyages by the Cape of Good Hope. By 1679 the garden included ornamental plants from upcountry regions of Africa, as well as edible and decorative plants from China, Java, Zanzibar, etc. By 1700 plants native to Table Bay had become common in Holland. Among those plants were the calla (*Zantedeschia aethiopica*), bird of paradise (*Strelitzia reginae*, named in honor of Queen Charlotte Sophia, wife of George III), and impatiens (*Impatiens holsti*). [See 1772]

1653 In his *Anatomical Exercitations,* William Harvey reminds us of the importance of hands-on study: "For although it be a more new and difficult way, to find out the nature of things, by the things themselves; then by reading of Books, to take our knowledge upon trust from the opinions of Philosophers: yet must it needs be confessed, that the former is much more open, and lesse fraudulent, especially in the Secrets relating to Natural Philosophy."

1654 Tradescant f. made his third trip to Virginia. On earlier voyages he had introduced tulip poplar and red maple to England.

1658 Oliver Cromwell died of malaria, refusing to take the only known treatment (quinine from cinchona), because it was introduced by Jesuits. As a result, Amsterdam *"was lighted up as for a great deliverance and children ran along the canals, shouting for joy that the Devil was dead."* (Durant) [See 1633, 1820] By 1681 cinchona was universally accepted as antimalarial. (Simpson, 1989)

1658 First English translation of Giambattista della Porta's *Natural Magick*, a century following the first Latin edition (1558). You can follow the link below to gain access to the English and Latin versions. The text is amusing, but repetitive and mostly irrational. There is absolutely no way any human ever tested the great bulk of ideas presented, so one is left with the steady assumption that this is a vanity press book meant for purchase but not use. It would certainly be considered malarky by members of the Royal Society, which was founded just two years later.
http://www.faculty.umb.edu/gary_zabel/Courses/Phil%20281b/Philosophy%20of%20Magic/Natural_Magic/jportat5.html

1659 France's first chocolate maker, David Chaliou, obtained a patent letter from the French king (signed in 1666) for *"the exclusive privilege of making, selling and serving a certain composition known as chocolate"* in the form of chocolate liquor, pastille, and other ways. Another Frenchman had opened the first chocolate house in London two years earlier. (Bailleux, et al, 1996) (Coe and Coe, 1996)

1660 On 25 September, Diarist Samuel Pepys recorded his first taste of tea, which he had ordered at one of the many coffeehouses of London where tea was initially served to the English. Coffeehouses were still new, the first one having just opened ten years prior, and served coffee, tea, and chocolate. (Hohenegger, 2007)

1660 Under Charles II, England established an excise tax of 8 pence on each gallon of tea that was sold. The tax would eventually be levied on tea leaf, as it was too easy for merchants to manipulate the numbers. (Hohenegger, 2007) This year also marks the Restoration, when Charles II returned. His birthday, 29 May, is celebrated each year as Oak Apple Day, or Royal Oak Day, an association tied to his having hidden in an Oak tree to escape capture, and his having been greeted (on return) by people brandishing clusters of Oak leaves. The Stuart reign was marked with Oak leaves as an emblem. (Stafford, 2016/2017)

1660 Cacao saplings were transported to the Philippines to begin plantations for production of raw chocolate. (Bailleux, et al, 1996)

1661 Robert Boyle carefully experimented with increase in plant biomass (as had van Helmont). In an effort to determine what had happened to the water taken up by plants, he actually boiled the liquid away from the plant tissue and found a coal-like residue. On pages 192-195, Boyle specifically describes spirits isolated (methanol, orwood alcohol) isolated through distilling *Buxus*.(*The sceptical chymiste...*, HNT) It was not until 1834 that "methylene" was named.

1661 Kenelm Digby, a natural philosopher and member of the Royal Society, published his *Discourse Concerning the Vegetation of Plants* (which was translated to French in 1667.) Digby's book was of great concern to other members of the Royal Society, and never made in-roads, though the philosopher touched on several subjects that one could say hinted at future topics, such as respiration and photosynthesis. In reality, the *Discourse* is a remarkable example of how alchemists thought about plants and life, and is an excellent example of the state of understanding (in 1661) as to how plants grow and metabolize. In his text, Digby recounts a resurrection fable related to the corporeal essence of a plant residual in the ash (once water was driven off), which related to his ideas of palingenesis: *"Let us come back to our Plant, and enquire if it be not possible to render it perpetuall, or rather to convert it into a permanent substance and state, no longer subject to the Vicissitudes of time; and outward Agents, that destroy all things: So to bring it to a kind of glorifyed body, such as we hope ours will be after the Resurrection. Quercetanus the famous Physician of King Henry the fourth telleth us a wonderfull story of a Polonian Doctor that shewed him a dozen glasses Hermetically Sealed, in each of which was a different Plant; for example, a Rose in one, a Tulip in another, a Clove-Gilly-flower in a third; also of the rest. When he offered these Glasses to your first view, you saw nothing in them but a heap of Ashes in the bottom. As soon as he held some gentle heate under any of them, presently there arose out of the Ashes, the Idaea of a Flower; the Flower and the Stalk belonging to those Ashes; and it would shoot up and spread abroad to the due height and just dimensions of such a Flower; and had perfect Colour, Shape, Magnitude, and all other accidents, as if it were really that very Flower. But when ever you drew the heate from it, as the Glasse and the enclosed Aire and matter within it grew to cool by degrees, so would this Flower sink down by little and little, till at length it would bury itself in its bed of Ashes. And thus it would doe as often as you exposed it to moderate heate, or withdrew it from it. I confesse it would be no small delight to me to see this experiment, with all the circumstances that Quercetan* (Joseph du Chesne) *setteth down. Athanasius Kircherus* (Athanasius Kircher) *at Rome assured me he had done it; and gave me the processe of it. But no industry of mine could effect it."* (Taber, 2007; William Lynch, Chapter 9, "A Society of Baconians?: The Collective Development of Bacon's Method in the Royal Society of London", in Solomon and Martin, 2016, *Francis Bacon and the Refiguring of Early Modern Thought...*)

1662 Notes from lectures by Joachim Jung appear as *De Plantis Doxoscopiae Physicae Minores* and *Isagoge Phytoscopica* (which was not formally published until 1679). These publications express an increasingly modern approach to the study of plant morphology, including a strikingly contemporary definition of plant: *"A plant is a living, non-sentient body, attached to a particular place or habitat, where it is able to feed, to grow in size, and finally to propagate itself."* Jung's thoughts appear to have had great influence in later works, such as those of Ray, and eventually the publications of Linnaeus. (Morton, 1981)

1664 John Evelyn published *Sylva: Or a Discourse on Forest-Trees and the Propagation of Timber in His Majestie's Domain*. Evelyn's *Sylva* was the first book published by London's Royal Society (founded in 1660.) Sylva remained the dominant English treatise on forestry for over a century. [See on-line: Gabriel Hemery, *Nature* 507, 166–167 (13 March 2014) doi:10.1038/507166a, Published online 12 March 2014] (Campana, 1999)

1665 Simon Paulli, a German physician, claimed: "*As to the virtues they attribute to it (tea), it may be admitted that it does possess them in the Orient, but it loses them in our climate, where it becomes, on the contrary, very dangerous to use. It hastens the death of those who use it…"* (Hohenegger, 2007)

1665 In his *Micrographia*, Robert Hooke detailed the structure of cork and described "cells" as studied through a microscope that had been constructed for him. This is recognized as the first time the word cell was applied to what we now understand is the basic unit of life, though the cork Hooke studied was composed of dead cells, and he had no idea as to the contents and organization future research would reveal.

1666 Isaac Newton selected Indigo as one of seven colors he distinguished in the spectrum, thus indigo became a color of the rainbow, the midnight blue between blue and violet. (Finlay, 2002)

1666 The Great Fire of London is said to have originated in the King's Bakery on Pudding Lane. (see the History of Wheat, at allaboutwheat.com)

1666 Work began on The Great Garden (the *Großer Garten*) at Herrenhausen. The 50 hectare garden grew impressively and reached its current aesthetic under the patronage of Sophie of Hanover, between 1696 and 1714. In addition to this Großer Garten, the Royal Gardens today include the *Berggarten*, the *Georgengarten* and the *Welfengarten*. (Herrenhausen Garden website, 2017)

1667 The English East India Company, having begun importing tea in 1664, gained a monopoly when the English government declared Dutch imports illegal. (Hohenegger, 2007)

1667 John Ray was admitted as a Fellow to London's Royal Society.

1667 The Treaty of Breda provided for cessation of hostilities between Holland and England, with each country retaining all foreign properties controlled at the time, regardless as to how recently or shamelessly those lands were conquered. England retained control over New Holland, i.e. New York; a primary gain for Holland was final recognition of their control over Run, the one island in the spice-yielding Banda archipelago with English credentials dating back to 1603. (Milton, 1999) As part of this bargain, the Dutch gained control of sugar plantations in Surinam. (Tannahill, 1988)

1668 Friedrich Jacob Merck acquired Angel Pharmacy (*Engel-Apotheke*) in Darmstadt, Germany. By 1827, his descendent Emanuel Merck had expanded the business through experimenting with various alkaloids (notably morphine, which was first extracted by 1805). The Merck business grew, giving rise to an American branch that was seized during WWII. Through steady acquisitions, by the late 20th Century, the American Merck had grown larger than the original Merck, thogh both remained pharmaceutical heavy hitters. (Wikipedia, 2017)

1669 Robert Morison was named Professor of Botany at Magdalen College, apparently the earliest recognition of botany as an academic discipline in England. Morison (a Scotsman) was not popular with John Ray, having criticized Ray's plant table created for (Bishop) John Wilkins' *Essay towards a Real Character and Philosophical Language* (published by the Royal Society in 1668). This was spelled out in Ray's 1669 letter to Martin Lister: re: Morison *"Nevertheless I despise that particular writer with good cause. Although he is so ill-equipped that he cannot even write decent Latin, he flatters himself in such bad taste and is so impenetrably conceited that he scorns men a thousand times more learned than himself and thinks himself unfairly treated because he has not been promoted long ago to a professorial chair. But as long as he sneers so fatuously at the Royal Society, he makes himself ridiculous to all sane and decent-minded people."* (C. Raven, 2009)

1670 Thomas Garaway opened a shop where tea was served until its closing two hundred years later. Garaway had actively advertised and promoted tea for a decade, stating *"that the Vertues and Excellencies of this Leaf and Drink are many and great is evident and manifest by the high esteem and use of it … among the Physitians and knowing men in France, Italy, Holland and other parts of Christendom."* (Hohenegger, 2007)

1671 Nehemiah Grew published T*he Anatomy of Plants Begun* and Marcello Malpighi published *Anatome Plantarum Idea*. These independent studies are the first important descriptions and statements on the subject of plant internal structure (Anatomy). Both researchers continued to work in this field for several more years, resulting in new editions by Malpighi and, in 1682, Grew's *Anatomy of Plants*. The studies of Malpighi and Grew proved of such quality that little was added for over 100 years. These men explained the structure of buds, the organization of wood, the character of flowers and their separate parts, the generation of seed and embryo, and many other topics that had never been explored before. (HNT) (Morton, 1981) [See 1682]

1672 Robert Morison published the first scientific study of a single plant group (the carrot family) [the first monograph.] (HNT)

1673 Property for what would become the Chelsea Physic Garden was leased by the Worshipful Society of Apothecaries of London. Hans Sloane purchased the adjacent manor, Chelsea, in 1712, and by 1722 the garden was on the Chelsea property, with Sloane heavily involved in its activities,, including the appointment of Philip Miller as the garden supervisor. (Sanecki, 1992)

1674 The institution of the London coffeehouse was all-male, generating considerable distaste among women for the practice and the society it engendered. The Womens Petition Against Coffee commented: "We find of late a very sensible Decay of the true Old English Vigour...Never did Men wear greater Breeches, or carry less in them of an Mettle whatsoever." It is blamed on: *"the Excessive use of that Newfangled, Abominable, Heathenish Liquor called Coffee, which...has so Eunucht our Husbands, and Crippled our more kind gallants....They come from it with nothing moist but their snotty Noses, nothing stiffe but their Joints, nor standing but their Ears."* (Pendergrast, 1999) Pendergrast reports encountering a response, that coffee *"makes the erection more Vigorous, the Ejaculation more full, adds a spiritualescency to the Sperme."*

c1675 Slave traders brought cowpeas to Jamaica. A native of India, this pea has many varieties important in the southeastern US, particularly the black-eye and the crowders.

1676 Jimsonweed gained its common name (originally Jamestown weed) when British soldiers in Virginia mistook *Datura* for an edible plant and "turn'd fool" with hallucinations that endured for eleven days. (Levetin & McMahon, 1996)

1676 Antoni van Leeuwenhoek, a resident of Delft, reported to the Royal Society in London that through the use of his microscope he had discovered multitudinous tiny animals in pepper-water. Leeuwenhoek had been examining a range of materials. In examining black pepper, he had hoped to *"discover the cause of the pungency of pepper upon our tongue."* Black pepper was an imported spice of considerable economic importance. Leeuwenhoek believed microscopic examination of pepper might demonstrate a physical cause, such as corpuscles, that would cause the sharp taste. (Jardine, 1999)

1678 John Banister arrived in Virginia as a missionary. Through connections with Henry Compton (Lord Bishop of London), John Ray, the Botany Club, and (in Virginia) with William Byrd, he received financing to support an interest in natural history. Collections by Banister that arrived in England included *Magnolia virginiana* and *Rhododendron viscosum*. He was one of the founders of William and Mary College. In May, 1692, while on a collecting trip, hunched over a wildflower, Banister, was mistakenly killed by a member of the expedition with which he traveled. (Petersen, 2001)

1679 Leeuwenhoek published a scientific letter estimating the carrying capacity of Earth to be 13.385 billion people. His figure was based on total land area as compared to the number of people (120) supported per square kilometer in Holland. (Cohen, 1995)

1680 By this time, the year of his death, Wang Shimin (China) had written in his autobiography concerning his ruinous love of gardens: *"Having been amply provided for by my forefathers, I am ignorant of anything to do with a livelihood: I do not even know how to use a scale or handle an abacus. Yet I was fatally addicted to gardens. Wherever I lived I set up rock arrangements and planted trees so as to express my sentiments and amuse my eyes. During the prime of my life I was bent on constructing and planting in heroic proportions. Once I gave in to my extravagant fancy I no longer thought about the consequences."* (Clunas, 1996)

1681 Thomas Burnet published *A Sacred Theory of the Earth*. On the surface, Burnet insists the antediluvial world was more regular and perfect, seemingly regarding the post-Noah world as scarred and ruined. But writing from a fresh background of travel in the Alps, Burnet expressed awe at nature's sublime beauty (though he seems to have rejected applying the word beauty). A change in philosophical perception of the Creation begins with the sublime, and creates fertile ground for the later development of transcendentalism. (Lothian, 2017)

1682 In his new edition of *Anatomy of Plants*, Nehemiah Grew reported a conversation between himself and Thomas Millington at a meeting of the Royal Society in which both men agreed that flower pollen represents the male element. (Morton, 1981)

1682 John Ray completed and published his *Methodus*. From his preface, as translated in C. Raven: *"The number and variety of plants inevitably produce a sense of confusion in the mind of the student: but nothing is more helpful to clear understanding, prompt recognition and sound memory than a well-ordered arrangement into classes, primary and subordinate. A Method seemed to me useful to botanists, especially beginners; I promised long ago to produce and publish one and have now done so at the request of some friends..."* (C. Raven, 2009)

1683 William Penn wrote in a letter dated 16 August, from Philadelphia, that all native American plantations included peaches of good quality. (Root, 1980 - Root cites the date as 1663) In his 1682 Carolina, or a Description of the Present State of that Country, Thomas

Ashe stated "the Peach Tree in incredible numbers grows wild." (De Wolf in Punch 1992) This demonstrates how quickly a valuable plant (such as the peach, which is native to Persia) can be distributed and accepted.

1683 Dutchman, Cornelius Decker (aka Dr. Bontekoe) commented: *"It must be a considerable and obstinate fever that cannot be cured by drinking every day forty to fifty cups of tea.."* (Hohenegger, 2007)

1685 Guy de Tachard and colleagues, on a missionary voyage to China, were outfitted by the French Académie to collect climatic data, make astronomical observations, determine latitude and longitude, and issue reports on natural history and native science. In their voyage, the group was well-received by Simon van der Stel, the Dutch Commissioner of the Cape of Good Hope. Van der Stel made provisions for the group to set up a temporary observatory with the objective of recalculating the longitude of the Cape, and Tachard was allocated a pavilion, "a great Pile of Building" at the entrance to the botanical garden. (Jardine, 1999) [See 1652]

1686 John Ray, in his *Historia plantarum* (published in volumes through 1704) arrived at an early natural grouping of plants through looking at their many different characteristics. His study dealt with plants worldwide, establishing standards and giving currency to much of our modern botanical terminology and summarizing the current state of botanical knowledge. Ray, unaware of the work by Rudolf J. Camerer, concluded in his discussion on fertility in date palm, willow, and other plants that: *"in our opinion the pollen is equivalent to the sperm of animals."* His definition of species was quite modern: "each produces only its own kind; one must distinguish between essential, accidental, and environmental characters." Ray's summary of plant physiology was so thorough that he could be considered the founder of that field. (HNT) (Isely, 1994; Morton, 1981)

1689 Abraham Cowley's *Of Plants* (The Third Park of the WORKS of Mr. Abraham Cowley... BEING His Six Books of Plants, Never before Printed in English) was published by Charles Harper, London. Buried in Westminster Abbey, his epitaph begins: "Here under lies ABRAHAM COLWEY, The Pindar, Horace, and the Virgil of the English Nation", Cowley was a poet and playwright of note - one whose reputation faded over the generations. Among Cowley's productions were poems, in Latin, about plants, published in six small books. Following his death in 1667, Cowley's *Plantarum Liber* volumes were translated and republished. http://cowley.lib.virginia.edu/works/frontm.htm

1690 John Locke's *Essay concerning Human Understanding* was first published, giving renewed philosophical basis to scientific investigation. Asserting that knowledge would be improved by experience, Locke encapsulated the working bias of descriptive botany when he wrote "the way to improve our knowledge...is to get and fix in our minds, clear, distinct, and complete ideas, as far as they are to be had, and annex to them proper and constant names." Locke also presaged evolutionary groupings of plants in his suggestion that one class of relations between species of things might depend on *"the circumstances of their origin or beginning, and not afterwards to be altered."* (Morton, 1981)

1691 William III of England granted a charter for the Massachusetts Bay Colony, which established royal ownership of trees over 24 inches in diameter. Trees suitable as masts for shipbuilding were marked with an incision in the shape of an arrow. (Rutkow, 2012)

1693 The first record of the grapefruit in the West Indies was made by Hans Sloane in a catalog of Jamaican plants. It is assumed the grapefruit originated there from chance hybrids between other cultivated citrus. This plant was not introduced to Florida until nearly 1850.

1693 Famine struck northern Europe. By 1694 fully 10% of the population of northern France had perished as a result.

1694 Rudolf Jacob Camerer (in Latin, Joachim Camerarius) wrote a scientific letter (later published by Valentini in his *Polychresta exotica*, 1700, HNT) that made the first clear case (with solid experimental evidence) for the nature of sex in plants and the actual role of pollen and ovule in this process. The publication documented years of work with plants such as the dioecious *Morus* (mulberry), *Mercurialis*, and *Spinacia* (spinach), as well as *Ricinus* (castor bean) and *Zea* (corn), which are both monoecious. In all cases, removal of staminate plants or flowers either greatly reduced or completely eliminated fertility. In his experiments with *Cannabis* (hemp), removal of staminate plants from a field did not completely deter production of fertile seed, a result *"at which I must admit I was quite upset"* Camerer reported. (Morton, 1981) [See 1718]

1697 Father Francisco Cupani published the first scientific description of *Lathyrus odoratus*, a plant from Sicily and the parent stock of today's sweet pea. Seed that he sent in 1699 to Robert Uvedale, headmaster of Enfield Grammar School near London, resulted in cultivated forms, and by 1731, a famous selection called 'Painted Lady' - the exact origins of which are not known. (Grimshaw, 1998)

1699 Dr. Uvedale of Enfield received a shipment of *Lathyrus odoratus* (Sweet Pea) form Father Cupani in Sicily. Due to their form, color, and fragrance these plants became popular and their cultivation spread. A century later many variants were recognized, including the 'Painted Lady' which remains in cultivation today. (Fletcher, 1969)

1699 John Woodward reported "Some thoughts and experiments concerning vegetation" in *Philosophical Transactions of the Royal Society*. He had replicated van Helmont's experiment with willow weight gain, but used much more precise and measured methods, and was not able to replicate Helmont's results [see 1648, van Helmont) David Hersey, Misconceptions about Helmont's Willow Experiment, 2003, in Plant Science Bulletin on line, 48(3): 78. (see also, King, 2011)

1699 A decade after his first visit to northwest Australia, William Dampier returned as Captain of the English ship Roebuck. Landing in Shark Bay, in western Australia, the expedition collected what seem to be the first herbarium specimens of Australian plants - 23 of which are extant. Otherwise rather ill-fated, the ship and expedition would be abandoned, the crew rescued, and Dampier would publish the story in 1701 as his second book *A Voyage to New Holland*. John Ray cited Dampier's specimens in *Historia Plantarum* (1704) and (in 1810, more than a century later) Robert Brown studied the specimens, on which he based description of the new genus *Dampiera* (Goodeniaceae). (Webb, 2003)

1700, 1721 In the second half of the 17th century, England began importing quantities of inexpensive calico and chintz fabrics. This caused serious issues for domestic wool and linen producers, who demanded protection from the cheap imports.. Thus, Britain instituted the Calico Acts, which banned imported cotton textiles. At that time, cotton cloth production was completely manual, and the major exporter was India. With growing industrialization, the acts were repealed in 1774. (Wikipedia, 2018)

1700 Irish Poet Nahum Tate, appointed England's Poet Laureate in 1692 (though heavily criticized by Alexander Pope, and though his father had been a supporter of Oliver Cromwell), published his *Panacea, a Poem on Tea in Two Cantos* (HNT 18503; Wikipedia, 2019). His preface tells us: "*The Tale in the First Canto of this Poem, was taken {as (Romantic as it may seem) from the Chinese History, and, with Very modest Fiction, accommodated to my Subject ; to make the Discovery and production of the TEA- TREE more wonderful and surprizing. Which, being in it self of most admirable Virtues, and certainly One of the greatest Blessings of Nature, 1 may as well suppose it to have been Miraculously Produc'd,as Fracastorius his West-Indian Tree, which his Poem tells us was* Deûm manibus Sata, Semine Sacro," In the final elements of this preface, Nahum claims the Tea Tree is as marvelous as Fracastoro's Guaiacum, which is discussed in the TimeLine entry for 1530) Nahum's verse moves ahead to claim:

Tip Tea sustains, Tea only can inspire

The Poet's Flame, that feeds the Hero's Fire.

The two cantos are followed by a shorter poem, "The Tea-Table", which begins:

Hail Queen of Plants, Pride of Elysian Bow'rs !

How shall we speak thy complicated Pow'rs ?

Thou Wond'rous Panacea*, to asswage*

The Calentures of Youth's fermenting Rage,

And Animate the freezing Veins of Age.

1701 Jethro Tull introduced his horse-drawn seed drill, a mechanism he devised while working on the family farm (named *Prosperous*) that he had inherited. Tull later wrote *Horse-hoe Husbandry,* relating his invention of a mechanized hoe. His work began an agricultural movement called New Husbandry that assumed all plant needs were provided by soil, thus hoeing or working of the soil was requisite for good production. A main thought was that working soil would eliminate need for application of manures and fallowing. (Wikipedia, 2015)

1704 Michel Sarrazin transported roots of American ginseng to Paris. A paper he presented on this topic was published in the Memoirs of the French Academy in 1714, the same year in which a missionary to China, Father Jartoux, published an article on Asian ginseng in a London journal. (Emboden, 1974) (Note: Wikipedia, 2019, states Sarrazin introduced Ginseng to the Jardin du Roi in 1701) PS: Sarrazin was the earliest collector of American pitcher plants, and Linnaeus named the genus *Sarracenia* in his honor.

1706 Coffee trees were sent to the botanical garden in Amsterdam from Sri Lanka (where the Dutch had only recently managed to establish plantations, breaking an ancient Arab monopoly). A single tree survived, which was the parent of a tree at the conservatory in Paris. In 1723, de Cliey carried a single offspring from the Paris tree to Martinique, which yielded thousands of trees there by 1777. The Martinique plantations became the source of

the first plants to be taken to the various coffee-growing regions of South America. (Simpson, 1989)

1708 Michel Sarrazin's collections, shipped from Canada to the Jardin du Roi in Paris, were described by Sebastien Vaillant in *Histoires des Plantes de Canada*, the first French book on North American plants.

1709 Famine struck Europe, affecting Prussia on a great scale. (Ponting,1991)

1709 At his death, Godfrey Copley (2nd Baronet) left a bequest of £100 "in trust for the Royal Society of London for improving natural knowledge." The Society responded through establishing its Copley Medal, the oldest prestigious international award for scientific achievement. The first award was made in 1731to Stephen Gray for his studies of electricity. Many subsequent awards went to scientists who contributed to botany as part of their broad studies, includingWilliam Watson, Stephen Hales, Joseph Priestley, and Charles Darwin.

1709 Anthony Ashley Cooper, in *The Moralists*, expressed the growing appreciation of the natural landscape, as contrasted with formal order in a garden. His character, Philocles, converts to a love of the "primitive state," of "the horrid Graces of the Wilderness," and "the Genius of the Place." (Thacker, 1979)

1711 Louis Crommelin, a Huguenot and linen weaver fled France in 1865, relocating to Ulster, in Ireland. His success in weaving fine linen there improved the local industry, with the result that the Board of Trustees of the Linen Manufacturers nurtured and controlled the Irish Linen Industry, leading to the reputation of Irish linen.

1712 Engelbert Kaempfer published *Amoenitates Exoticae*, the first western description of the Japanese flora (as well as other information). Kaempfer was a physician with the Dutch East India Company at Deshima from 1690 to 1692. Other Kaempfer notes, published by Hans Sloane as History of Japan, include the first western description of ginkgo.

1712 Mark Catesby made his first trip to America, traveling first to Virginia. He returned to England in 1719, but his time in the New World included travels to Jamaica in 1714. (Meyers & Pritchard, 1998)[See 1729]

1712 Captain Frezier introduced the Chilean strawberry, *Fragaria chiloensis*, to France. It arrived in Britain a few years later. This plant, along with the North American species taken to France by Jean Robin in 1624, is in the ancestry of today's commercial strawberries.

1715 At the age of 71, Stradivari created a beautiful violin, today called Il Cremonese, using a single piece of strikingly patterned maple for the back. (Finlay, 2002)

1716 The first certain report of plant hybridization was provided in a letter written by Cotton Mather, discussing the "infection" of Indian corn planted alongside yellow corn. The following year a British hybrid dianthus was described [See 1717]. In 1721 a hybrid cabbage was reported. By 1750 the controversy of sex in plants was in the news. By 1760 plant hybridization was a professional occupation. The study, hybridization, and selection of corn continued. By 1969 scientists understood more about corn genetics than the genetics of any other flowering plant. (Zirkle in Ewan, 1969) [See 1761]

1717 Nurseryman Thomas Fairchild (of Hoxton, England) produced a hybrid pink (called 'Fairchild's Mule') through crossing a sweet william and a carnation. This may be considered the first purposefully-created artificial hybrid. At his death, Fairchild bequeathed £25 to the Hoxton parish to provide annual support (of £1) for a sermon on "the wonderful works of God in the Creation" - a series delivered on Whit Tuesday (the Tuesday of the first week of Pentecost) and now called the "vegetable sermons."(Thompson, 2010)

1717 Having opened Tom's Coffee house in 1706, Thomas Twining followed that success in opening the Golden Lyon, the first real English tea shop. Women were welcome at Golden Lyon, and by 1725 Quaker Mary Tuke became the first woman licensed to merchandize tea. (Hohenegger, 2007)

1718 Sébastian Vaillant was one of the earliest supporters of Camerarius's ideas concerning the sexual nature of plants. He contributed to the development of terminology necessary to discuss flower structure and function (some of which shocked his contemporaries, such as his comparing stamens to animal testicles and penis). Originally Vaillant delivered his information in a talk at the Jardin du Roi in Paris. By 1718 he had published the remarks as *Discours sur la structure des fleurs...* (HNT) (Morton, 1981) [See 1694]

1718 The initial shipment of American ginseng (sent from Canada) arrived in China (Canton). In 1773 shipment began from Boston, with a load of 55 tons on the Hingham. That shipment is said to have earned nearly three dollars a pound, which would have made for substantially profitable cargo. The potential of monetary gain created a strong supply network of North American "seng diggers." Philadelphia records from 1788 indicate that Daniel Boone sold 15 tons of ginseng root to merchants there. Given such levels of harvesting, the American ginseng (*Panax quinqefolium*) became rare in nature. By 1885 George Stanton had founded his 150-acre Ginseng Farm in New York. (Emboden, 1974)

1720 In reference to production of cacao, Jean-Baptiste Labat (a Jesuit priest) noted: *"Several experiments have convinced me that twenty Negroes can tend and cultivate fifty thousand cacao trees...These fifty thousand well-tended trees will yield a hundred thousand pounds of almonds (seed) which, selling at seven sols and six deniers per pound...will earn thirty-seven thousand francs, a sum which is all the more appreciable because of the fact that almost all of it goes directly into the owner's pocket, due to the low cost of keeping the slaves who tend the trees. They constitute the one and only obligatory expense. ...A cacao plantation is a veritable gold mine."* (Bailleux, et al, 1996)

1722 Mark Catesby journeyed to America, leaving England in February, arriving in South Carolina on 23 May. Prior to his return to England in 1726, Catesby traveled to the Bahamas. (Meyers & Pritchard, 1998) [See 1729]

1722 Philip Miller began management of the Chelsea Physic Garden.

1725 The first in a series of laws was passed in England, with the goal of prohibiting adulteration of tea. High cost and limitations on import meant that countless materials were explored in order to bulk up or illicitly replace the product sold as tea. Overarching control came with he 1875 Food and Drug Act. (Hohenegger, 2007)

1727 Stephen Hales' work in his *Vegetable Staticks* represented the first significant publication in plant physiology. He explained some aspects of water uptake by roots, movement of liquid through plants, and evaporation of water from leaves. His work advanced the prospect that air provides food for plants (that plants are "probably drawing through their leaves some part of their nourishment from the air", and even suggested that light might be involved. Hales was one of the first to use the equipment and methods of the physical sciences to study plants. (Morton, 1981) (HNT)

1729 China banned opium. That ban on importation would be seriously compromised by the British East India Company until 1839.

1729 Mark Catesby published the first of ten parts of his *Natural History of Carolina, Florida, and the Bahama Islands*. He completed the work in 1747. Second and third editions followed in 1554 and 1771 respectively. One of Catesby's significant patrons was Quaker Peter Collinson; another was the influential Hans Sloane, doctor to George II and founding donor of the botanical garden at the Society of Apothecaries in Chelsea. (Meyers & Pritchard, 1998)

c1730 By this time *Ginkgo biloba* was in cultivation in the botanical garden at Utrecht. [See Kaempfer, 1712]

1730. This year is loosely associated with widespread adoption of what is often called Norfolk Four-Course Rotation. British farming methods had a certain prescription about them, with two years dedicated to different grains (wheat or rye one year, followed by barley or oats, and then a fallow third year). With origins in Holland, a more intensive system became associated with Norfolk, and most particularly with Charles Townshend, owner of Norfolk's Raynham Hall. The four-course crop rotation system ran in sequence from clover to wheat to turnips through barley, with no "fallow" period (though we might think of clover as being a fallow crop.) Implications and fallout of the 4-rotation system seem broad. Provision of turnips (which had been growing in popularity since the previous century) to feed livestock over winter was changing behavior, moderating the annual, autumnal culling of livestock. According to Shah, the change in year-round density of livestock in the landscape contributed to another impact. Because livestock do not harbor the malaria *Plasmodium*, livestock density dissipates spread of malaria in the immediate human population (mosquitos prefer biting cows, sheep, and pigs). Changes in livestock to human ratios in England are given credit as contributing to decreases in human infection rates. (Shah, 2010) From Shah: "Years later, when malariologists realized what had happened, some took to calling for "a pig under every bed" as an effective substitute for a mosquito net."

1732 By 1732 the black slave population of South Carolina numbered about 32,000 as compared to approximately 14,000 whites. Slavery at this time in South Carolina was driven by rice cultivation. Rice seed imported from Madagascar was grown and harvested by black slaves from rice growing zones of Africa. Thus the early success in rice production in North America was possible due to a skilled, slave labor force. (Thomas, 1999)

1732 J. S. Bach completed his Coffee Cantata. He stages a daughter making the humorous request: *"Dear father, do not be so strict! If I can't have my little demi-tasse of coffee three times a day, I'm just like a dried up piece of roast goat! Ah! How sweet coffee tastes! Lovelier than a thousand kisses, sweeter far than muscatel wine! I must have my coffee, and if anyone wishes to please me, let him present me with - coffee!"* By this time coffee had been available in Germany for six decades, showing increasing popularity. By 1777 Frederick the Great began a campaign to control the beverage. (Pendergrast, 1999)

1733 In Lyons, Jesuit Father Sarrabat set plant roots in the red juice from *Phytolacca* fruit and observed the colored liquid rising to leaf tips, and even stamen filaments. He noted the

root cortex was red. This is considered the first example of vital staining. (Clark & Kasten, 1983)

1733 John Bartram of Philadelphia began correspondence with Collinson, Miller, and others. Their exchange is the likely source of pawpaw, sourwood, and other American plants introduced to cultivation in Europe. (Spongberg, 1990)

1733 James Oglethorpe established the Trustees Garden in Savannah. The ten acre plot was dedicated to botanical and agricultural studies, mainly involving experimental plantings of potential crop plants, such as tea, coconut, and cotton. (L.P. Neely in Slosson, 1951) Initially, land was dedicated to mulberries, which were to feed silkworms in order to establish a silk industry. Olive plants were soon sent, as were capers and grapes. In anticipation of the garden, funds from investors were used in 1732 to send two botanists to gather suitable esculent, drug, fibre, dye and ornamental' plants for trial. One botanist died during the search, while the other was seemingly unsuccessful. Few plants were ever delivered. (Hedrick, 1950)

1733 John Kay patented the fly-shuttle, which quickened the weaving of cloth, thus mechanizing weaving - while the generation of thread through spinning remained a cottage industry. In 1764, James Hargreaves's spinning jenny made the thread generating process more efficient. Further improvements in bleaching and dyeing as well as the steam-powering of looms would change the British textile industry - with production soaring from 2.5 million pounds in 1760 to 22 million pounds in the 1780s. (Milestones, Twilight, 1974)

1735 Linnaeus arrived in Holland (for a 3-year stay), visiting the Amsterdam Hortus botanicus on his first day. In Holland Linnaeus would gain the respect and support of three important botanists: Herman Boerhaave, Jan Frederik Gronovius, and Johannes Burman. Through Burman he gained the acquaintance and support of George Clifford, wealthy banker and owner of de Hartecamp. Since purchasing that estate in 1709, Clifford had transformed it into a botanist's paradise of exotic plants. During his three years in Holland, Linnaeus published 14 books, laying the groundwork for his entire career. (Stafleu, 1971)

1737 Linnaeus authored *Hortus Cliffortianus*, with illustrations by Ehret. This record of plants cultivated by George Clifford in his garden at Hartekamp (Holland) is the forerunner of *Species Plantarum*. The illustrations demonstrate Linnaeus' belief that botanical drawings should be of superb detail and must result from close collaboration between botanist and artist. In his introduction, Linnaeus waxed "I gazed at Your garden in the very center of Holland bright with flowers, between Haarlem and Leiden, a charming spot between two thoroughfares, where boats, where carts pass by; my eyes were captivated by so many masterpieces of nature..." (Stafleu, 1971) (HNT)

1737 The magnificent Southern magnolia, *Magnolia grandiflora* (introduced from Southeastern North America to Europe by 1730) flowered in August at the London home of Charles Wagner, First Lord of the Admiralty. Georg Ehret immortalized this event with a sumptuous and justifiably famous illustration. Ehret, an apprentice gardener, had learned his artistic skills from his father during his youth in Heidelberg, Germany. (Grimshaw, 1998)

1737 Johannes Burman published *Thesaurus zeylanicus*, using plant specimens from Ceylon that were collected by Paulus Hermann and Jan Hertog. In the following two years Burman published *Rariorum africanum plantarum decades I-X* based on drawings made at the Cape of Good Hope by Hendrik Claudius. (Stafleu, 1971)

1737 Elizabeth Blackwell began publication of her *Curious Herbal*, a portfolio of approximately 500 botanical illustrations serialized over 125 weeks, and published in two volumes, in 1737 and 1739. (Madge, B., 2001, "Elizabeth Blackwell—the forgotten herbalist?". *Health Information & Libraries Journal*, 18: 144-152. doi:10.1046/j.1471-1842.2001.00330.x) The accompanying text seems to have been paraphrased from Joseph Miller's 1722 *Botanicum Officinale*.

1737 John Belchier received the Copley Medal, recognizing his novel introduction of madder (a red stain derived from *Rubia tinctorum)* to animal diets as a successful method toacolor bone as an aid to study of skeletal development. (Wikipedia, 2019)

1738 J. A. Külbel began his work on soil quality, stimulated by the offer of a prize on this subject by the Royal Academy of Bordeaux. One of his conclusions (that was cited in the work of Linnaeus) was that humus content is important to soil fertility. (Morton, 1981)

1738 John Bartram discovered populations of American Ginseng *(Panax quinquefolia)* growing near the Susquehanna River. The discovery added to the 1704 collections by Sarrazin and 1714 exportation of Canadian ginseng. It was sufficiently important to be announced by Bartram's friend Benjamin Franklin in the 27 July edition of *Pennsylvania Gazette*. (Johnson, 2018) *"We have the Pleasure of acquainting the World that the famous Chinese or Tartarian Plant, called Ginseng, is now discovered in this Province [colony], near Sasquehannah, from whence several whole Plants with a Quantity of the Root have been lately sent to Town, and it appears to agree most exactly with the Description given of it in Chambers's Dictionary, and Père du Halde's Account of China. The Virtues ascrib'd to*

this Plant are wonderful." (extracted from website, National Humanities Center Resource Toolbox Becoming American: The British Atlantic Colonies, 1690-1763)

1738 Dr. Thomas Bond (of Maryland, with a practice in Philadelphia) travelled to Paris to study with Jussieu at the Jardin du Roi. The Jardin's living collection of North American plants was rich in American plants, such that Bond wrote to John Bartram: *"My friend Jussieu tells me that I shall feel myself at home, by being amongst so many of my native plants, as brought from America by himself, in quest whereof he was sent by the King."* (Gilbert Chinard, 1957. "André and François-André Michaux and Their Predecessors. An Essay on Early Botanical Exchanges between America and France", Proceedings of the American Philosophical Society, 101(4): 344-361)

1739 Gronovius published the first part of *Flora virginica* (the second part came in 1743). His work was based on collections made by John Clayton, an amateur botanist who moved to America in 1705 and served as Clerk of Gloucester County, Virginia. *Flora virginica* appears to be the earliest work by an author other than Linnaeus that followed the sexual system. Gronovius died in 1762; sixteen years later his herbarium was sold at public auction. (Stafleu, 1971)

1739 Eliza Lucas (later Eliza L. Pinckney), at the age of 16 and having moved to Charlestown, SC from Antigua only a year before, received a packet of indigo seed from Antigua, sent by her father. Persisting through a fascinating four seasons of disappointment because of crop failure and processing setbacks, Eliza produced South Carolina's first commercial indigo in 1744. Within six years, the Carolinas were a significant source of indigo for English dyers. (Finlay, 2002)

1739 Buffon (Georges Louis Leclerc, comte de Buffon), at age 32, was appointed to oversee the Jardin du Roi, which was under the direction of Antoine de Jussieu. By this year the Jardin was in deplorable financial condition, Jussieu was forced to spend his own income to purchase and ship plants. Given his stature and goals, Buffon would lead the transformation of this garden and the creation of the Cabinet du Roi, all destined to become elements of the Muséum d'Histoire Naturelle. During redevelopment of the grounds, Jussieu began his famous rearrangement of plantings to reflect the natural order of the vegetable kingdom. (Duval, transl. 1982)

1739 An historical cultural tract was published by "Joseph Fume" entitled *A Paper: - of Tobacco; Treating of the Rise, Progress, Pleasures, and Advantages of Smoking. With Anecdotes of Distinguished Smokers, Mems. on Pipes and Tobacco-boxes, and a Tritical Essay on Snuff.* Dedicated to " The Candid and Benevolent Smoker" the book proposes: "*Though much has been written both for and against the use of tobacco, yet in no treatise on the subject that I am acquainted with, have the rise and progress of smoking been distinctly traced, or the real pleasures and advantages of the custom sufficiently set forth. To supply this defect is the object of the present paper ; which, though it also contains a few tritical observations on Snuff, is yet chiefly intended for the use and entertainment of smokers."*
https://play.google.com/books/reader?id=NwoXAAAAYAAJ&hl=en&pg=GBS.PP11

1739 About 500,000 people died in Ireland due, by one account, to widespread crop failure of potatoes. (Ponting, 1991) A more thorough account contends that the 1740-41 famine resulted from failure of the oat crop, accompanied by extremely cold weather during which stored potatoes were lost because they froze in outdoor storage pits. Ten years previously, the 1729 oat famine had engendered Jonathan Swift's famous pamphlet entitled "A Modest Proposal." The potato dry rot, cause of great famine a century later, did not appear in Ireland until after 1830. (Zuckerman, 1998) [See 1845]

1741 The President of the First Continental Congress, Henry Middleton, began creating his gardens at Middleton Place, South Carolina. (McGuire in Punch 1992)

1742 From Rio de Janeiro, the mango was introduced to the Barbados. (Sauer, 1993)

1742 From 1742-1745 Pehr Kalm explored North America, collecting plants for introduction to Sweden. His work resulted in a three volume publication, *En Resa till Norra America,* issued 1753-1761. (Stafleu, 1971)

1744 Rules were established for the game of cricket. Although several kinds of wood have been utilized to manufacture bats for this game, a variety of white willow (*Salix alba* var. *caerulea*) has proven to provide the best wood. Trees of this cricket bat willow are about 15 years old and around 20 meters tall when harvested. (Lewington, 1990)

1745 Pierre Poivre, recovering in Batavia from the loss of his right arm as result of injuries received when English seamen captured the French vessel on which he sailed from China, first conceived his plan to create a French spice trade. The plan involved cultivating stock plants of valuable tropical crops on two islands controlled by France, Mauritius and Reunion (which was called Bourbon Island), from whence they could be used to supply material around the world. His idea was supported in France, leading to establishment of the Jardin des Pamplemousses (the Grapefruit Garden) on Mauritius, at the former site of the Jardin de Montplaisir. By 1749 Poivre had begun sending material to the garden, everything from

sweet peas to cacao. Under perilous circumstances, he eventually obtained his most important material, nutmeg from Manilla and clove trees from Timor. Poivre returned to France in 1757. (Duval, 1982) [See 1767]

1745 J. T. Needham observed that pollen grains burst open when placed in water. Seeing similar exploded grains on the stigmas of flowers he was examining, Needham concluded that the globular substance emitted by the pollen fertilized the ovules. Botanists had observed that the style is often filled with tissue, suggesting that a liquid, analogous to animal semen, would be necessary for fertilization from stigma to the ovules buried inside the pistil. Needham's conclusions were accepted and promoted by Linnaeus. (Morton, 1981)

1746 John and Helen Mitchell boarded a ship for England, leaving their Virginia home, where John had become an important collector and expert in the North American flora. Their ship was raided *en route* and John's extensive plant specimen collection was stolen and lost. Though discouraged, Mitchell remained active and productive in many realms. His 1755 map of British and French Dominions in North America was utilized as a primary source in negotiating the Treaty of Paris. Linnaeus named the Rubiaceous genus *Mitchella* in his honor. (Reveal, 1992; Wikipedia)

1747 Bernard de Jussieu received seed of *Sophora japonica* from d'Incarville in Beijing, via Moscow. This shipment probably also included *Koelreuteria paniculata*.

1747 A process to extract sugar from beet roots was developed by Andreas Margraff. It was not until 1877 that a highly productive process would be devised. At the end of the 19th century, sugar beet production expanded greatly in the US. Through selection by specialists, the sugar content of beets increased from just 2% in the 19th century to over 20%. (Simpson, 1989)

1747 Dr. James Lind experimented with 12 sailors who had scurvy and discovered that consuming lemons and oranges for 6 days effected great improvement. Nearly 50 years passed before the British admiralty required that sailors receive daily lemon or lime juice. Scurvy is understood now to be a nutritional disease caused by lack of adequate Vitamin C (ascorbic acid). Fresh fruits and vegetables are excellent sources of this vitamin. (Levetin & McMahon, 1996) [See 1937]

1747 In *The Natural History of Carolina, Florida and the Bahama Islands*, Mark Catesby records the prevalence of fire as a management tool by native Americans: *"In February and March the inhabitants have the custom of burning the woods, which causes such a continual smoke, that not knowing the cause it might be imagined to proceed from fog, or a natural thickness of the air."* (Williamson, 2006)

1748 Michel Adanson, a student of Bernard de Jussieu, arrived in Africa to collect until 1754.

1749 A near century old female specimen of the Mediterranean fan palm, *Chamaerops humilis*, had flowered for years in Berlin without fruiting. By 1751 Gleditsch reported that in 1749 he had applied pollen from a male plant grown in Leipzig to the flowers that remained fresh on one branch of the female plant. The seed produced proved viable, thus further confirming the male role of pollen. (Morton, 1981)

1750 Slaves from Africa were traded for gold and rum. At the African source, one hundred gallons of rum would purchase a male slave, 85 gallons an adult woman, and 65 gallons a child. At the same time, the average selling price for a slave delivered to the West Indies was £20 sterling. (Schlebecker, 1975)

1751 Given as the publication date for his *Philosophia Botanica*, this year marked the coming together of various lines of thought that Linnaeus had outlined in numerous earlier publications, beginning with *Fundamenta Botanica* and *Bibliotheca botanica* in 1736. The first chapter dealt with the development of botany as a study, denoting various sorts of people who had contributed to the science. Categories included every kind, from phytologists (authors) and botanophili (amateurs) to adonides (professors), ichniographi (illustrators), commentators, describers, monographers, methodici (systematists), institutores (textbook authors), sexualists (himself, alone), and eristici (the controversial ones). The fifth chapter explained his understanding of sex as an essential basis for understanding plant life. Fundamental opinions of his were expressed in such statements as: "We hold that in the beginning there were created a single sexual pair of every species of living beings" and "Omne vivum ex ovo" (all life springs from eggs). At one point Linnaeus compares the floral calyx to a nuptial bed, the corolla to its curtains, but also, "the calyx might be regarded as the labia majora or the foreskin; one could regard the corolla as the labia minora." (Stafleu, 1971)

1751 Philip Miller (of the Chelsea Physic Garden) planted tree of heaven (*Ailanthus altissima*) seed received from French Jesuit Father, Pierre Nicholas le Cheron d'Incarville, stationed at the mission in Beijing. Once introduced to North America (the first time by William Hamilton in 1784), this tree would escape and become quite common - even invasive.

In popular culture, it is the "tree that grew in Brooklyn." (Spongberg, 1990) [For Hamilton, see 1770]

1751 Pehr Kalm, a Linnean student and botanical explorer, noted that Native Americans treated eye diseases with a concoction of water in which witch hazel (*Hamamelis virginiana*) had been boiled. The common name for this plant, however, did not arise from that connection. In England, an elm (*Ulmus glabra*) is called the witch hazel tree because its branches are used for dowsing, also called witching. The wood of that tree also serves for the manufacture of bows. Once settlers learned that the American Indians used *Hamamelis* for making bows, they began to call it by the same common name as the English elm. Transferred along with the name were the associated traditions, so that the American plant called witch hazel is today the popular choice for dowsers in this country. (Connor, 1994) [See 1866]

1751 First printed record of Chinese cabbage and Chinese mustard in England.

1752 Joseph G. Kölreuter (a medical student in Tübingen) published his survey of studies of sex in plants that had been reported since Camerarius first suggested plant sexuality in his *Epistola*. Kölreuter had almost certainly been a student of S. G. Gmelin (a professor at Tübingen), who had republished Camerarius's work and appended his own lectures calling for increased dedication to experimental work on this subject. (Morton, 1981) [See 1760; 1761]

1753 Linnaeus' *Species Plantarum* established a new standard for plant classification as well as nomenclature. This treatise eventually became recognized as the beginning point for today's binomial nomenclature. (HNT)

1754 To protect wheat crops from rust, the Province of Massachusetts enacted anti-barberry legislation: "to prevent damage to English grain arising from barberry bushes in the vicinity of grain fields." This could be the earliest American legislation established to control plant diseases. (Hedrick, 1950)

1755 Henrietta Saint-John Knight issued a magnificent rebuke to poet William Shenstone concerning his failure to visit her and her garden: *"The elms are green in vain: in vain the cucumbers are large, and as vainly the Shrubbery shoots out, and the Coppice has a carpet of primrose, cowslips, &c. Let them reproach you."* Their communication, over a period of several years, details developments in the landscape at his garden, The Leasowes, and in hers at Barrels. Shenstone is given credit for coining the terms "landscape garden" and "shrubbery," the latter appearing frequently in correspondence relative to Knight's garden. (Laird, 1999)

1756 The British government purchased the right to export 600,000 Russian trees each year to supply the Royal Navy. (Ponting, 1991)

1757 Elizabeth Blackwell's *Curious Herbal* (1735-1737) was republished. One of the plates (and accompanying description) detailed a ginger, *Amomum verum*, which Joseph Miller held in his apothecary and had included in his 1722 publication, *Botanicum offinale*. Because 1753 (publication of Linnaeus's *Species Plantarum*) is the starting point for botanical nomenclature, the first valid publication of *A. verum* was with Blackwell's 1757 reprint. Description of *A. verum*, therefore, appears to constitute the earliest valid publication of a plant scientific name by a woman author.

1758 John Bartram wrote to Philip Miller, appending a list he had composed of pernicious weeds that had been introduced: "A brief account of those Plants that are most troublesome in our pastures and fields in Pennsylvania, most of which were brought from Europe." It begins: *"The most mischievous of these is, first, the stinking yellow Linaria. It is the most hurtful plant to our pastures that can grow in our northern climate. Neither the spade, plough, nor hoe, can eradicate it, when it is spread in a pasture. Every little fibre that is left, will soon increase prodigiously; nay, some people have rolled great heaps of logs upon it, and burnt them to ashes, whereby the earth was burnt half a foot deep, yet it put up again, as fresh as ever, covering the ground so close as not to let any grass grow amongst it; and the cattle can't abide it."* Also: *"The common English Hypericum (H. perforatum, L.) is a very pernicious weed. It spreads over whole fields, and spoils their pasturage, not only by choking the grass, but infecting our horses and sheep with scabbed noses and feet, especially those that have white hair on their face and legs."* And: *"The Scotch Thistle (Cirsium horridulum) is a very trouble-some weed, along our sea-coast. The people say, a Scotch minister brought with him a bed stuffed with thistledown, in which was contained some seed. The inhabitants, having plenty of feathers, soon turned out the down, and filled the bed with feathers. The seed coming up, filled that part of the country with Thistles."*

In this same note, one could also qualify Bartram with early observation and documentation of ecology and dispersal. Read the following account: *"We have another weed, called Cotton Groundsel (Erechtites hieracifolia, Raf.), which grows with us six or seven feet high, and the stalk at bottom, near as thick as my wrist, in our new cleared land after the first ploughing, in the spring, or in our marshes, the year after they are drained and*

cleared. It grows there all over, so close that there is no passing along without breaking it down, to walk or ride through it ; but in old fields, or meadows, there is not one stalk to be seen. Now, if we put the question, how comes this to grow so prodigiously on the new land ploughed ground, and perhaps not one root growing within several miles, the answer is very ready : it is natural to new land and not to old. But our philosophers say, that every plant is produced from the seed of the same species but how came the small seed of this plant there, in such quantities as to fill a field or meadow of one hundred acres as full of plants as they can stand?

One day when the sun shone bright, a little after its meridian, my Billy was looking up at it, when he discovered an innumerable quantity of downy motes floating in the air, between him and the sun. He immediately called me out of my study, to see what they were. They rose higher and lower, as they were wafted to and fro in the air, some very high and progressive with a fine breeze, some lowered, and fell into my garden, where we observed every particular detachment of down, spread in four or five rays, with a seed of the Groundsel in its centre.carried by that breeze, can't be known ; but I think they must have come near two miles, from a meadow, to reach my garden. As these are annual plants, they do but little harm in the country." (William Darlington, 1849. *Memorials of John Bartram and Humphrey Marshall, with Notices of their Botanical Contemporaries,* Philadelphia)

1759 The Royal Botanic Gardens, Kew, was established on the property belonging to the Dowager Princess of Wales. This institution was to remain a private activity of the royal family for 82 years.

1760 In the decade following 1760, over 20,000 Irish workers emigrated from seaports at Ulster. Most of these people moved to North America, voyaging on the same ships that had brought flax from the new world to linen mills in Ulster. Many of the emigrants were skilled linen weavers. A sharp decline in the linen market in 1770 exacerbated the situation, and led to emigration of over 30,000 more Irish in the next few years. (Zuckerman, 1998)

1760 Kew received one of its first tropical orchids *Epidendrum rigidum*; Kew received Vanilla sp. by 1765

1760 Governor Arthur Dobbs discovered Venus Fly-trap in North Carolina and sent a description to Collinson, in England. (Ewan, 1969) [See 1768]

1760 Joseph Kölreuter began his numerous experiments in hybridization, using *Nicotiana paniculata* and *Nicotiana rustica*. His thorough and detailed studies using many different plant groups created the basis for much of our modern understanding of plant biology, from phenomena of pollination to the nature of inheritance. (Morton, 1981)

1760 Daniel Carl Solander, a student of Linnaeus, arrived in England to work in the British Museum, later to serve as librarian to Joseph Banks. Solander attended Banks on Cook's first voyage in the Endeavor. (Stafleu, 1971)

1761 Kölreuter reported his work on the role of insects in pollination. His detailed descriptions of insect activity and floral structure instructed botanists on the mechanisms and significance of insect pollination, and led directly to the work of Sprengel. (Morton, 1981) (HNT)[See 1716 & 1877]

1761 John Hill established an association between tobacco snuff and malignant (and fatal) nose polyps. (Lewis & Elvin-Lewis, 1977)

1761 By this year British land grants in New England had long required that pine trees, most notably white pine, that were suitable as ship masts be conserved - to be cut only under license by the crown. Appointed surveyors marked trees to be protected with the "king's broad arrow," a triangular scar. This decree, among many others, greatly perturbed American colonists. The first flag used by Revolutionaries bore the image of a single white pine - representing the state of Massachusetts. [See 1652 & 1792] (Rupp, 1990)

1763 Michel Adanson's *Familles des plantes* represented the first general attempt to group plants based on their relatedness, a "natural system." The entry for each of his natural families presents a variety of characters common to the group. Much of Adanson's work provided important foundation for *Genera plantarum*, published in 1789 by his associate Antoine Laurent de Jussieu. (Morton, 1981) (HNT)

1764 The spinning jenny was invented by James Hargreaves. [See 1733]

1765 The Bartrams discovered the Franklin tree. Not until another trip, in 1773, would the younger Bartram collect seed in the only known population, near Fort Barrington, GA. In 1774, the supporter of this trip, John Fothergill, presented seedlings to Kew. Publication of William's travel accounts was completed by 1781, but awaited identification of plants from specimens he had sent to Fothergill. At Fothergill's death in 1780, his herbarium was purchased by Joseph Banks. (Spongberg, 1990)

1765 Samuel Bard (of Philadelphia) completed his thesis at The University of Edinburgh, defending his thesis: Bard's thesis, 'De viribus opii', in May. Bard's study considered

opium's effects on humans, having studied this through personal experimentation and examination of the impact of opium on his college roommate. Returning to the US, Bard became George Washington's personal physician, and later one New York's most prominent doctors. He founded the King's College (now Columbia University) school of medicine. (Johnson, 2018; Wikipedia, 2019; Our History, the University of Edinburgh website.)

1766 Joseph Banks explored Newfoundland and Labrador, charting waters and making collections.

1766 A colonial garden was established on St. Vincent, receiving mango trees as well as East Indian spice trees. (Sauer, 1993)

1766 Peonies and iris are said to have been first planted in Missouri by the Chouteau family, who brought the plants from Illinois. French settlers were the first to establish permanent settlements in Missouri (in St. Genevieve in 1755). (Edith Sinclair in Slosson, 1951)

1767 Pierre Poivre again was sent by France to Mauritius, as general intendant. The following year Poivre brought over his nephew, Pierre Sonnerat, who became a notable botanical explorer. Early in his career Sonnerat collected and transplanted the famous double coconut to the Mauritius garden from the Seychelles. Over the following two decades, Sonnerat contributed to our understanding of many tropical plants (such as dragon's blood, breadfruit, banana, and cavalam), but his greatest energies were dedicated to the study of palms. (Duval, 1982)[See 1745]

1768 John Ellis published *Dionaea muscipula*, the full scientific name and an account of the Venus Flytrap (also dubbed Tipitiwitchet) in the 1 September issue of The St. James Chronicle, a London newspaper. With its scientific name having been translated as Aphrodite's mousetrap, one might expect a larger plant that the flytrap, but this magical plant inspired great admiration, observation, and conjecture over the years. (Mabey, 2015)

1769 Sweet oranges were established at San Diego mission. In 1804 the first sizable citrus orchard in California was established at the San Gabriel mission.

1769 On 3 August, Portola's Sacred Expedition had reached the Los Angeles basin, causing Father Juan Crespi to record in his journal: *"After crossing the river we entered a large vineyard of wild grapes and an infinity of rosebushes in full bloom. All the soil is black and loamy, and is capable of producing every kind of grain and fruit which may be planted."* (Pinney, 2017) By 10 October, Portola's exploration of the California coast reached low hills forested by very tall trees that were red in color. This became the first recorded siting of the coast redwoods. [See 1784] (Rupp, 1990)

1769 An early North American newspaper, the Boston Newsletter, published encouragement for people to recycle their rags for the manufacture of paper, including the poem:

Rags are as beauties, which concealed lie,
But when in paper how it charms the eye,
Pray save your rags, new beauties to discover,
For paper, truly, everyone's a lover.
By the pen and the press such knowledge is displayed,
As wouldn't exist if paper was not made.

American paper manufacturers would rely on importation of rags until the use of wood pulp became common. Most of the rags were likely linen, since production of paper using cotton did not become a common source of paper fiber until the following century. (Connor, 1994; McCrady, 1992) [See 1840]

1769 On receiving plants of Venus Flytrap from introductions collected the same year by British botanist William Young, John Ellis sent a description to Linnaeus. The following year, Ellis published *Directions for bringing over seeds and plants, from the East Indies*, documenting his work on the Venus Flytrap, which he named *Dionaea muscipula*., providing the earliest known illustration. (Wikipedia, 2019; see also Oak Spring Garden Foundation website: From the Library, 25 August 2017, which library holds the manuscript letter from Ellis to Linnaeus)

c1770 William Hamilton built his magnificent 300 acre estate, The Woodlands, near Philadelphia. His interest in importing exotic plants made the grounds, landscaped in European style, a center for future plant introductions to US gardens.

1770 Australia was "discovered" by the British (though the Dutch had already named the area New Holland and had experienced at least 15 landings since 1606.) James Cook set out in the *Endeavor* on a scientific mission in 1768, with the young naturalists Joseph Banks and Daniel Charles Solander (a pupil of Linnaeus), as well as artists. On 29 April 1770, the ship stood into Botany Bay (an oceanic embayment 13 km south of Sydney), which Cook originally called Sting Ray Harbor - until the great collection of new plants by Banks and Solander provoked him to change the name.

1770 An entire year's supply of nutmeg and cloves was destroyed in Amsterdam with the goal of maintaining high prices. Beginning in the 17th century Dutch traders had gained control of spice production in the Moluccas (at the expense of the Portuguese). Short supply kept prices high enough to create fortunes. (Root, 1980) [See 1602; 1605]

1770 Joseph Priestly coined the name "rubber" for the natural latex of the South American tree *Hevea brasiliensis*, noting it is "a substance excellently adapted to the purpose of wiping from paper the marks of a black lead pencil." Rubber was first introduced to Europe in 1744 by Charles Marie de la Condamine. (Lewington, 1990)

1770 John Hill published *The construction of timber, from its early growth: explained by the microscope.....* Hill's work is recognized as constituting the most serious application of microscopy to plant material in the 18th century. He is said to be the first researcher to systematically use stains, and to employ clearing techniques. (Smith, 1915) Hill is also remembered for his cantankerous relationship to members of the Royal Society, which resulted in many scathing responses. One injured party, David Garrick penned: "For physics and farces, his equal there scarce is; His farces are physic, his physic a farce is." (Wikipedia, 2018)

1771 By this year the Prince Nursery on Long Island offered 42 varieties of pear.

1772 Carl Pieter Thunberg and Francis Masson arrived in South Africa independently (though they often collected together). Masson would send over 500 plant species to Kew. Thunberg's study was mainly scientific, but he sent such specialties to Sweden as the strelitzia. [See 1652]

1772 Joseph Banks was appointed scientific advisor for the royal gardens by George III.

1772 An uprising against British authority in New England, the Pine Tree Riot, resulted from the levying of fines on a New Hampshire man for cutting what were determined to be the King's pines. (Connor, 1994) [See 1772]

1773 Americans were displeased by a 3% tax imposed by the English Parliament on tea and other products. That small tax added to a 100% import duty that all English subjects already paid on tea, and led to an increase in smuggling of tea from Holland. Loss of business for the London-based John Company resulted in the Tea Act of 1773, which eliminated the 100% tax - meaning the Dutch would be undersold. Even though this change represented a savings for American tea drinkers, the monopoly granted to the John Company continued to carry a 3% tax for colonists who had no representation in Parliament. The uniting of American colonists resulted in some ships being turned away at their ports, but for others (in Boston, Greenwich, Charleston, Philadelphia, New York, Annapolis, and Edenton), boarding parties threw consignments of tea into the sea. (Pratt, 1982) On the evening of 16 December, American colonists boarded the ships Dartmouth, Eleanor, and Beaver, which were docked at the harbor in Boston, and threw 120,000 lbs of tea into the bay. (Hohenegger, 2007)

1773 French explorer Pierre Poivre's plan to take propagation material of spices (clove, nutmeg, cinnamon, and black pepper) from the Dutch controlled Molucca Islands to Mauritius and Reunion succeeded in breaking the Dutch monopoly. [See 1770] (Root, 1980) [For earlier dating, See 1745, in which Duval notes that Poivre returned to France in 1772, where he remained at La Freta (his estate) until his death in 1786]

1773 Through the following decade, Maarten Houttuyn published his 37 volume *Natuurlijke Historie of uitvoerige Beschr ving der Dieren, Planten en Mineraalen, volgens het Samenstel van der Heer Linnaeus*. Fourteen volumes (8600 pages with 125 copperplate illustrations) were dedicated to plants. The compilation was an elaboration of Linnaeus's *Systema natura*. (Stafleu, 1971)

1773 Antoine-Agustine Parmentier published *Examen chimique des pommes de terre, dans lequel on traite des parties constituantes du froment et du riz* [Chemical examination of potatoes dealing with the constituting parts of wheat and rice.) Continued interest in, and promotion of potatoes meant that Parmentier's name became synonymous with these tubers. [See 1789]

1774 Joseph Priestley reported (*Experiments and observations on different kinds of air*, HNT) that burning a candle in a closed container changes the quality of the atmosphere so the flame is extinguished. Animals placed in that environment quickly die. A living sprig of mint renews the air so a candle will once again burn. Today we know that the non-flammable air is carbon dioxide; growing a plant in such an environment replenishes the oxygen which is necessary to sustain life. On learning of his results, Benjamin Franklin, a correspondent of Priestley's, commented in a letter: *"I hope this [rehabilitation of air by plants] will give some check to the rage of destroying trees that grow near houses, which has accompanied our late improvements in gardening from an opinion of their being unwholesome."* [See 1604]

1774 In October of this year, Priestley and his employer met with Antoine Laurent Lavoisier, perhaps the most famous chemist of all time. Priestley described a new gas he had dis-

covered (through heating mercuric oxide) that supported a brighter flame than normal air. He termed this new gas dephlogisticated air. Lavoisier would soon give this new gas the name oxygen. (Cobb and Goldwhite, 1995) [See 1777] Though Priestley receives credit for describing the gas that would become known as oxygen, Polish alchemist Michael Sendivogius produced the "elixir of life" in 1604 by heating Chilean saltpeter (potassium nitrate – note there is much confusion in the internet as to whether Chilean saltpeter is potassium nitrate or sodium nitrate) – a reaction that liberates oxygen. (Schwarcz, 2005)

1774 Thomas Jefferson planted olive cuttings at Monticello - unsuccessfully. In 1791, he sent several hundred cuttings from France to South Carolina, only to be disappointed by the lack of commercialization. He was unaware that the Padres who established missions in California had planted olives there by 1769.

1774 The bleaching effect of chlorine was discovered. This replaced much more complex and less effective methods previously used to eliminate the natural color of plant fibers used for yarn and cloth. (Levetin & McMahon, 1996)

1775 Carl Pieter Thunberg arrived at Nagasaki harbor to work at Deshima with the Dutch East India Company. Thunberg received medical training in Sweden, and had been a student of Linnaeus. He was surprised to learn he had considerable freedom to collect dried specimens of plants on the Japanese mainland around Nagasaki. There he collected *Hovenia dulcis* and *Rosa rugosa*. Thunberg returned to Europe in 1776, having essentially smuggled his specimens out of Japan. He published Flora Japonica in 1784. (Spongberg, 1990)

1775 Frenchman Mathieu du Tillet studied agricultural problems as a serious avocation. In one study, he examined the wheat smut disease that caused problems for local farmers. In this year he published field experiments through which he demonstrated that the black smut (a dust) could infect new wheat plants. Once the fungus was identified, researchers described the genus as *Tilletia*. Clear proof for the fungal source of smut came in 1807 through the work of Swiss researcher Benedict Prevost. Prevost's work was rejected and ignored for forty years, partly due to the lack of understanding that plant diseases could be caused by microorganisms. (Arthur Kelman, lecture 4 in Frey, 1994)

1775 With the death of physic gardener Ephraim Potter, the family business was assumed by his son James and daughter Anne. James Potter eventually took his nephew James Moore (son to Anne Potter Moore and her husband Benjamin) into partnership, establishing the familiar firm of Potter and Moore. By the end of the 18th century Potter and Moore had 250 acres under cultivation in Surrey, England. (Sanecki, 1992)

1776 Juan Bautista de Anza (Spanish explorer) arrived at a river in the Santa Clara Valley (near Half Moon Bay), which his party named the Guadalupe River. Confirming the site as good for a mission, de Anza made his 30 March journal entry: *"To this arroyo or river we gave the name of Guadalupe [sp. Gaudalupe??]. It has abundant and good timber of cottonwood, ash, willow, and other kinds. In all directions there is a great abundance of firewood, and likewise agricultural lands for raising crops by natural humidity, or by irrigation if the river is permanent, as we conjecture, in which case it would make possible a large settlement."* (Quote from the ULISTAC Natural Area Restoration Project website, Santa Clara University Environmental Studies Institute, 04.02.29)

1777 Lavoisier published his conclusion that all acids include the purist portion of air, which he called oxygen, adapted from Greek to imply the substance makes acids. (We know today that not all acids contain oxygen.) Oxygen was the gas that Priestley had earlier isolated and studied, and named dephlogisticated air. Lavoisier would later demonstrate that phlogiston does not exist, which means that reduction (metals losing weight upon heating) does not result from the combination of metal with phlogiston, rather from the driving off of oxygen. (Cobb and Goldwhite, 1995) [See 1774]

1777 Carl Peter Thunberg, who eventually would occupy Linnaeus's chair at Uppsala, was appointed botanical demonstrator at the botanical gardens. This followed seven years of travel and collecting in Europe, South Africa, Ceylon, Japan, and the East Indies. His work in Japan, because it was with Dutch merchants who held sole access to that country, required a stay in Java to learn the Dutch language. (Stafleu, 1971)

1777 After his arrival in Paris, Benjamin Franklin contacted his friend John Bartram concerning wartime interruption in the capacity to send seed to Europe: *"My old dear Friend, The communication between Britain and North America being cut off, the French botanists cannot, in that channel be supplied as formerly with American seeds, etc. If you, or one of your sons, incline to continue that business, you may, I believe, send the same number of boxes here that you used to send to England; because England will then send here, for what it wants in that way. Inclosed is a list of the sorts wished for here. If you consign them to me, I will take care of the sale, and return, for you. There will be no difficulty in the importation, as the matter is countenanced by the Ministry, from whom I received the list. My love to Mrs. Bartram, and your children. I am ever, my dear friend, yours most affectionately. B. Franklin."* (Gilbert Chinard, 1957. "André and François-André Michaux and Their Predecessors. An Essay on Early Botanical Exchanges between America and France", Proceedings of the American Philosophical Society, 101(4): 344-361)

1778 Joseph Banks began his 42-year stint as president of the Royal Society.

1778 John Fothergill brought *Cymbidium ensifolium* and *Phaius tankervilliae* to England from China. These are the first Asiatic orchids to appear in England.

1779 Jan Ingenhousz's *Experiments upon vegetables...* (HNT) demonstrated that plants produce oxygen in sunlight and carbon dioxide in darkness. These observations added to studies by his friend Priestley, but unlike Priestley, who was interested primarily in the nature of gases, Ingenhousz was concerned with the physiology of plants.

1779 From his jail cell, in a letter dated 9 May, the marquis de Sade wrote to his wife: "I asked...for a cake with icing, but I want it to be chocolate and black inside from chocolate as the devil's ass is black from smoke. And the icing to be the same." (Coe and Coe, 1996)

1779 Opposing Austrian and Prussian armies came to a stalemate in Bohemia when both armies consumed the local potato stores to depletion. The resulting lack of food combined with cold weather forced a retreat of both sides. Today this War of Bavarian Succession is still sometimes called "The Potato War." (Levetin & McMahon, 1996)

1779 Ned Ludd is said to have destroyed a stocking frame, and by that action initiated uprisings among textile workers against machination of textile processes that were significant changes allied with the industrial revolution. The rejection of industrialization led to the term "Luddites", which was later adopted as a catch-phrase for people who are not early adopters of technologies. (Wikipedia)

1780 John Hannon, financed by Dr. James Baker, started the first chocolate factory in the US in Dorchester, Mass. (Fussell, 1986) James Baker later founded Baker's Chocolate.

1780 John Fraser traveled from England to Canada to collect plants; he entered US territory in 1785, receiving financial support from William Forsyth (Curator of the Chelsea Physic Garden), William Aiton (Head Gardener at Kew) and James Smith (President of the Linnean Society). He returned to America in 1788 and again in 1796. Fraser (and son) returned yet later as collectors for the Russian Czar and Czarina. Their work was commemorated through plant names, Fraser fir and Fraser magnolia.

1780 Thomas Minton, a potter's apprentice, originated the pattern we call Blue Willow. (Rupp, 1990)

1780 Englishman Philip Luckombe commented concerning Ireland that: *"landlords first get all that is made of the land, and the tenants, for their labor, get poverty and potatoes."* (Zuckerman, 1998)

1782 Oliver Evans contracted to build a flour mill on Red Clay Creek, north of Wilmington, Delaware. His "improvements" produced the first automated mill. One person could run an automated mill and produce 20 barrels of flour in a day. Ordinary mills required one person for ten barrels. (Storck & Teague, 1952)

1783 Lavoisier verified conclusions by Cavendish, Priestley, and Watt that water is the sole product when an inflammable air (hydrogen) is burned in oxygen. Though he failed to give full credit to other workers, Lavoisier was indeed the first to see that water is not an element, rather a combination of oxygen and another element. That second element was the inflammable air, which he named hydrogen, the producer of water. (Cobb and Goldwhite, 1995)

1783 José Celestino Mutis (a Spanish citizen who had moved to Bogota, Colombia in 1761 to serve as a physician) was successful in gaining support for a new "expedition" - an enterprise dedicated to documenting the region's flora. Over the next three decades, Mutis was employed and trained local peoples to paint several thousand spectacular and botanically-realistic paintings of local plants. The collection is held by the Real Jardín Botaníco de Madrid. (Bleichmar, 2017; Wikipedia)

1784 William Hamilton introduced ginkgo, *Acer platanoides*, and tree of heaven (*Ailanthus altissima*) to his garden near Philadelphia (the tree of heaven had first been planted in Europe by Miller at the Chelsea Physic Garden in 1751). Tree of heaven is now a major weed tree for eastern North America, and is "The Tree" that grew in Brooklyn. (Spongberg, 1990) [See 1770]

1784 David Landreth, along with his brother Cuthbert, established North America's first substantial seed house in Philadelphia. D. Landreth & Co. was the country's most important seed merchant for many years. (Hedrick, 1950)

1784 Thunberg published F*lora Japonica*. [see 1775]

1784 Junipero Serra died and was interred beneath the floor of Mission San Carlos Borrome in Carmel - in a redwood coffin. [See 1769] (Rupp, 1990)

1784 England's Commutation Act reduced duty on tea from 119% to 12.5%, effecting an immediate change in both smuggling and adulteration. Tax revenue was replaced through a new tax on the number of window panes in the owner's house. Revocation of that tax, in the next century, figured into the growth of greenhouses for exotic plants. (Hohenegger, 2007)

1784 Antoine-Agustin Parmentier sent his contribution, *Memoire sur le Maïs*, to the Academy of Sciences, Letters, and Arts of Bordeaux. Publication by the Academy (in 1785) greatly increased interest in Corn (Zea mays) cultivation in Europe.

1785 Thomas Jefferson visited the Jardin du Roi and presented seed from North America to André Thouin. The two men became lifelong correspondents. Over the next four decades Thouin sent packages of seed to Jefferson yearly. Following this visit, American authorities allowed the French botanist André Michaux to explore their newly settled country. (Duval, 1982)

1785 André Michaux arrived in Manhattan to begin his botanical journeys for the King for France. (Gilbert Chinard, 1957. "André and François-André Michaux and Their Predecessors. An Essay on Early Botanical Exchanges between America and France", Proceedings of the American Philosophical Society, 101(4): 344-361; See Also: http://www.michaux.org/michaux.htm)

1785 While in the Southeastern US, André Michaux encountered wild populations of Cherokee rose, which he believed to be native. The plant appears to have come to North America with early Spanish explorers or settlers, as it is native to China, and had been cultivated in Moslem countries. Similarly, when William Penn acquired Penn's Woods from the Indians, he found they were already cultivating the peach (another China native) in their gardens. [See 1663]

1785 Culminating four years of study and collection in Peru for the *Jardin des plantes* in Paris, Joseph Dombey began his return journey. In Cadiz his material was confiscated by the Spanish under demand that it be shared. By the time Dombey arrived in Paris, most of his collections and notes were lost. Material confiscated by Spain was incorporated into the scientific production of Ruiz and Pavon. Dombey fell victim to French revolutionary fervor. Imprisoned by counter revolutionaries upon his arrival on the remote isle of Guadeloupe, he died of maltreatment. (Duval, 1982)

1785 William Withering, an English country doctor, published *An Account of the Foxglove and Some of Its Medical Uses: With Practical Remarks on Dropsy and Other Diseases.* His study began in 1775 when asked to investigate a home remedy for dropsy. The active principals, digitoxins, in foxglove both slow heart rate and increase the strength of each heart beat. This improves circulation and therefore alleviates edema - which is the basis for dropsy. (Levetin & McMahon, 1996) Withering had learned about digitalis as a component of herbal treatments from herbalist Mother Hutton, a Shropshire resident. As a result of trial and error in treating his own patients with the different plants in the herbal tea, he deduced that Digitalis leaves provided the active ingredient. One patient, who had been referred by Physician Erasmus Darwin, improved. Darwin reported results of that treatment to the London College of Physicians in his paper "An Account of the Successful Use of Foxglove in Some Dropsies and in Pulmonary Consumption". The outcome of the collaborations proved unfortunate, with each professional accusing the other of impropriety. This was particularly awkward, since Darwin had, in 1775, been the person to recommend Withering assume his successful medical practice - and both men were among the very few members of London's Lunar Society. (Wikipedia, 2015)
http://www.historyofscience.com/articles/jmnorman-william-withering.php

1785 For powering spinning operations, the Robinsons of Papplewick, Nottinghamshire, installed the first steam engine made for a cotton mill.

1785 Dr. Edward Bancroft was awarded exclusive rights by the British Parliament to use the yellow coloring agent which he had extracted from black oak (*Quercus velutina*) and named quercitron, for the dyeing and printing of fabrics. Taken from the inner bark of the tree, this dye remained commercially available for over 200 years. (Rupp, 1990)

1785 Benjamin Franklin returned to the US after serving as ambassador to France for over nine years. Chaptal (in his 1823 book, see TL 1835) reports, perhaps apocryphally: *"The use of plaster, or gypsum, which has become common in Europe as a source of manure, is one of the most important improvements that has ever been made in agriculture. It has even been introduced to America, where it was made known by Franklin upon his return from Paris. As this celebrated philosopher wished that the effects of this manure should strike the gaze of all cultivators, he wrote in great letters, formed by the use of ground plaster, in a field of clover lying on the great road to Washington, "This has been plastered." The prodigious vegetation which was developed in the plastered portion led him to adopt this method. Volumes upon the excellences of plaster would not have produced so speedy a revolution. From that period the Americans have imported great quantities of plaster of Paris."* Whether true or not, it is a great story.

1786 On 3 November, André Michaux purchased a plot of land, 111 acres, 10 miles from Charleston, SC, to collect and grow plants. Over 8 years, Michaux would ship 60,000 plants and 90 boxes of seed to France for distribution. (Gilbert Chinard, 1957. "André and François-André Michaux and Their Predecessors. An Essay on Early Botanical Exchanges between America and France", Proceedings of the American Philosophical Society, 101(4): 344-361)

1787 Publication began for Botanical Magazine by William Curtis, the world's longest-running journal, dedicated to introducing exotic plants to an avid audience. Curtis resigned his position as Demonstrator in Botany for the Chelsea Physic Garden to produce this series.

1787 Spencer Turner established his Holloway Down Nursery in Essex, England. Among his earliest inventories was a seedling oak, an apparent hybrid he had cultivated since 1783. It isn't clear how this plant, now called *Quercus ×turneri,* was determined to be a hybrid between *Quercus robur* and *Quercus ilex* (though oaks are noted for their infidelity); but the account in The Trees of Great Britain and Ireland (Elwes and Henry, 1906-1913) describes it as a found seedling while Willis and Fry (2014) state the seedling was "bred" by "Kew nurseryman" Turner in 1783. Regardless, the Turner Oak gained notoriety when a grafted specimen was planted at Kew in 1798. In the great windstorm of 16 October 1987, the oak was lifted from the ground, after which it fell back, vertically, meaning it was not one of the 15 million trees lost during that storm - rather the experience proved curative. Following the storm the uprooted tree was mulched into place while other, more pressing cleanup moved ahead. The result was that Kew's Turner Oak, which had been in decline actually improved. Kew arborist Tony Kirkham suggests the newly-provided aeration and drainage for it root system rescued the tree from two centuries of soil compaction caused by the tens of thousands of visitors. The incident also instigated changes in how Kew's trees are planted and the forest soils maintained. (Willis and Fry, 2104; see also the website monumentaltrees.com, which documents locations for other grafted examples)

1788 Jean Senebier, in his *Expériences sur l'action de la lumi re solaire dans la végétation* (HNT) established the relationship between the presence of carbon dioxide in the atmosphere and the production of oxygen by plants. His studies built on the work of Ingenhousz. [See 1779]

1789 Captain Bligh was relieved of his authority on the Bounty shortly after water-starved sailors cast 1,000 breadfruit plants (that required fresh water to survive and were being transported from Tahiti to provide a food crop for slaves in the West Indies) into the ocean. By 1793 the Providence had accomplished delivery.

1789 Aiton's Hortus Kewensis recorded 15 exotic species of orchid at Kew. They were: *Bletia verecunda, Epidendrum fragrans, Epidendrum cochleatum, Phaius grandifolius (syn P. tankervilliae), Cypripedium spectabilis, Cypripedium acaule, Liparis liliifolia, Calopogon pulchellus, Habenaria fimbriata, Arethusa bulbosa, Satyrium carneum, Satyrium coriifolium, Bartholina pectinata, Serapias lingua*, and *Nigritella angustifolia*. *Epidendrum cochleatum* was the first epiphytic orchid known to have bloomed at Kew, in 1789. (Reinikka, 1972)

1789 Antoine Laurent de Jussieu achieved a workable system of naming and grouping plants in his *Genera plantarum*, by combining Linnaeus's nomenclature with Adanson's natural system of classification. His treatment provided the basis for the system of classifying plants we use today. The book was published in Paris - during the same year as the beginning of the French Revolution.

1789 Antoine-Augustin Parmentier published his *Traité sur la culture et les usages des Pommes de terre, de la Patate, et du Topinambour* - confirming his most active support for use of potatoes sweet potatoes, and sunchokes. In France today, his name remains associated with the culinary importance of potatoes. [See 1773]

1789 An impressive topographical map of France, 33 by 34 feet in size, was completed through work of the Paris Observatory, using astronomical methods. Its production relied on the dedicated genius of three generations of the Cassini family. (Jardine, 1999)

1789 Lavoisier published his important treatise, *Traité élémentaire de chimie*, in which 33 elements were listed and much terminology proposed. In 1794 Lavoisier was executed, one of the many phenomenal tragedies of the French Revolution. (Cobb and Goldwhite, 1995)

1789 A chewy resin, a mastic, extracted from *Pistacia lentiscus* from the Greek island of Chios off the Turkish coast, was used traditionally for varnishes, and even for chewing. But by the 1760s artists had begun to use a new formulation called megilp, which was a mastic jelly made from combining the extract with linseed oil. Joshua Reynolds, who had become an ardent supporter of the new varnishing compound used this to increase the sense of thick layering of oil paints on a painting commissioned by Noel Desenfans, a copy of his famous portrait of Sarah Siddons completed five years before. The compound was found to degrade over time, discoloring paintings on which it was used, and was soon abandoned as a varnish. (Finlay, 2002)

1789 Persistent is an appropriate word for Thaddeus (Tadeáš, Peregrinus Xaverius Haenke) Haenke. Destined to become the first Ph.D. research professional to investigate the California flora, the journey began when he missed the boat (the Malaspina Expedition) that left Cadiz, Spain on 30 July. Hoping to catch up with the expedition, he boarded another ship to Uruguay, a ship that wrecked near land. Swimming ashore, Haenke managed to preserve only his collecting equipment and copy of Linnnaeus's *Genera Plantarum*. Having again missed Malaspina, Haenke journeyed the 800 miles across Argentina and Chile, encountering Malaspina in Chile, where (along with the 1,1000 specimens he had collected in South America) he set sail with the expedition for the Arctic. On those travels, Haenke was the first person to collect herbarium samples of the Coast Redwood (which he called a Red Cypress) in 1791. Viable seed from his collections made the trip back to Spain, and a Coast Redwood recorded at the Alhambra in 1926 was validated as originating with seed from the Malaspina Expedition. On the return journey, in 1793, Haenke decided to repeat his land crossing of South America, walking from Chile to Uruguay, determined to reunite with Malaspina for the expedition departure to Spain. Missing that sailing (on 21 June 1794), Haenke remained in South America. Living in Bolivia and continuing field work until his death in 1816, Haenke made important finds, including the 1801 first scientific documentation of the Giant Water Lily, *Victoria amazonica*. (Beidleman, 2006; Aniśko, 2013)

1789 Baptist Reverend Elijah Craig of Scott County, Kentucky, is given credit for first aging Kentucky corn whiskey, thus creating America's first bourbon whiskey. (Fussell, 1992)

1789 Ginkgo was planted at Pierce Arboretum (now part of Longwood Gardens) in Kennett Square, PA. By 1968 that tree was 105 ft. tall and about 13 ft dbh. (Ewan, 1969)

1789 Thomas Jefferson, newly arrived in Philadelphia as Secretary of State, began a career of plant introduction that included vanilla, tea, and tomato.

1790 The soybean was grown at Kew, but had no crop significance at that time for Europe.

1790 Tea imports from China to England reached 20 million pounds a year, up from about 1 million pounds imported in 1730. But Chinese merchants insisted on payment in silver. (Hohenegger, 2007)

1790 Archibald Menzies journeyed as surgeon-naturalist on Captain George Vancouver's expedition to the Pacific Northwest (until 1795.) (Vancouver had sailed with James Cook on his second and third voyages of discovery.) Menzies collected some dried herbarium material.

1790 Johann Wolfgang von Goethe published his interpretation of plant structure, providing one of the earliest statements concerning the similar origins of leaves and floral parts. His book provoked numerous commentaries by botanists and served as a catalyst in the development of modern morphological theory. (HNT)

1790 Because it is present in nitrates and nitric acid, John Antony Chaptal [see 1835] suggested the word Nitrogen for the atmospheric component Lavoisier had Azote (because it does not support life, i.e. *zoe* is Greek for life).

1791 Jacques-Julien Houtton de Labillardière, appointed botanist on the journey of the vessel Recherche (with its major aim being to recover information on the disappearance of French explorer La Pérouse), began his 4-year saga. The results of his travels and studies were published in his Relation du Voyage la Recherche de La Pérouse, giving information on both breadfruit and kava. The kava (*Piper mephisticum*, a relative of black pepper) he noted could also serve as a drink, but "it was better not to see the drink prepared if one wanted to accept the invitation of these honest folk." He went on to describe how native peoples chewed the roots and spat the pellets plant tissue into a container to create tissue from which the "sharp and stimulating" infusion was prepared. (Duval, 1982)

1791 A US excise tax on whiskey (to help retire debts from the Revolutionary War) prompted the Whiskey Rebellion that peaked in 1794 near Pittsburgh. The tax was repealed 8 years later. [See 1862] (Fussell, 1992)

1791 Thomas Jefferson and James Madison, while returning from their botanical tour of New England, stopped at the Prince Nursery, in Flushing. Inspired by conversations with Benjamin Rush regarding the future potential of Maple sugar and fresh from having seen the Sugar Maple (*Acer saccharum*) tree "*in vast abundance*" in Vermont, Jefferson purchased the nursery's entire stock of saplings. (Johnson, 2018)

1791 William Cowper celebrated the Yardley Oak, which grew near the village of Olney in Buckinghamshire. The poem, complete with handsome and romantic references, is readily available on the web. The first stanza is given here:

> SURVIVOR sole, and hardly such, of al
>
> That once lived here, thy brethren, at my birth,
>
> (Since which I number threescore winters past,)
>
> A shattered veteran, hollow-trunked perhaps,

As now, and with excoriate forks deform,

Relics of ages! Could a mind, imbued

With truth from Heaven, created thing adore,

I might with reverence kneel, and worship thee.

1792 English explorer George Vancouver visited the Santa Clara Valley (CA). On seeing the large California White Oaks (*Quercus lobata*), with their massive and beautiful forms, he wondered if the valley had been planted to English Oak (*Quercus robur*). (Arno, 1973: his text gives date of Vancouver visit as 1796)

1793 Kurt Polycarp Joachim Sprengel was the first researcher to publish detailed descriptions of the manner in which different flowers are pollinated. He made the original drawings himself. Sprengel's discoveries would be ignored by botanists until Darwin. (HNT)

1793 A new edict in China made both importing opium illegal. Smoking opium had been officially banned in 1729. (Hohenegger, 2007)

1793 On his second voyage, Captain Bligh carried mango trees from Timor to British gardens in Jamaica and St. Vincent. (Sauer, 1993)

1793 On the Vancouver Expeditions, Archibald Menzies recorded presence of an iceplant (most likely *Carpobrotus chilensis*, the Sea Fig) at Point Loma, California. A native of South Africa, one notes how early exotic plants were arriving in coastal North and South America. (Beidleman, 2006)

1793 David Hosack, who would come to found one of the earliest botanical gardens (Elgin Botanical Garden) in the US, was studying medicine in Scotland. His son, in an 1861 biography, notes Hosack's growing realization of the importance of plant study....*"Having, upon one occasion (while walking in the garden of Professor Hamilton at Blandford, in the neighborhood of Edinburgh) been very much mortified by my ignorance of Botany, with which his other guests were familiarly conversant, I had resolved at that time, whenever an opportunity might offer, to acquire a knowledge of that department of science." (*Alexander Eddy Hosack, 1861, *A memoir of the late David Hosack* (available free as an ebook)*;* Johnson, 2018)

1794 Ely Whitney invented the cotton gin (a machine that pulls cottonseed apart from the hairs i.e. the cotton fibers) in 1793. (Simpson, 1989) Patented in 1794, this machine changed American life dramatically. By 1807 the US supplied 60% of Britain's cotton, becoming the world's largest producer by 1820 - with production rising from 3,000 bales in 1790 to 4.5 million bales by 1860. The plantation production of cotton and the manner in which cotton exhausts nutrients from its soil meant that between 1790 and 1860 over 800,000 slaves were moved to the new cotton growing territories of Alabama, Mississippi, Louisiana, and Texas. (Ponting, 1991) With increased production, cotton came to underwrite so completely the economy of southeastern states that sentiment against slavery slowly disappeared in the South.

1795 British colonists planted clove trees in Panang. By 1796 the English had gained control of all Dutch East Indian possessions except Java. [See 1824] (Rosengarten, 1969)

1795 In support of military needs, a prize of *ƒ*12,000 was offered by the French government for the devising of a method for preserving food. The award was made in 1809 to Nicolas Appert for preserving food in glass bottles. (Busch, et al, 1995)

1795 Clergyman Samuel Henshall was granted the first patent for a corkscrew on 24 August (he added the apron, or button, that stops the screw from further entry). Corks had been used to seal bottles of wine and other substances for over a century, and corkscrews had been around as one method of extraction. But Henshall gets credit for the first related patent. (Taber, 2007)

1797 The Rajah, out of Salem, MA, returned to New York with full cargo of bulk pepper from Sumatra. Investors made 700% profit, spawning investment by other Salem merchants. This Salem-based trade flourished until 1856, creating some of the first great fortunes in the US. (Rosengarten, 1969)

1797 In Burlington, New Jersey, Charles Newbold was awarded a patent for America's first cast-iron plow. Cast in one piece, this plow did not become remarkably successful. (Schlebecker, 1975)

1797 Membership in the Royal Society was highly prized and controlled , as explained by President Joseph Banks in response to another of William Patterson's persistent pleas for consideration: "...your chance of receiving that and other Literary honors must depend upon the benefit Science has received from your Labors while abroad, and, as the Elections into that body are carried on by Ballot, I shall have no doubt of your success, provided the Members (Numbers?) are convinced that you deserve their White Balls." (Webb, 2003)

1798 Thomas Malthus's discussion of the potential for increase in the size of a population (An essay on the principle of population..., HNT) as compared to the available resources provided important ideas for Darwin and others.

1798 Frenchman Nicholas Robert invented the first machinery to manufacture paper. (Levetin & McMahon, 1996)

1798 A Franciscan botanist native to Brasil, José Mariano de Conceição Vellozo, began publishing his 11-volume encyclopedia (*O fazendiero do Brazil*) on the natural and agricultural circumstances in Brasil. His major taxonomic work, Flora Fluminensi, was published posthumously beginning in 1825. (JSTOR: The Text of Vellozo's Flora Fluminensis and Its Effective Date of Publication, J. P. P. Carauta Taxon Vol. 22, No. 2/3 (May, 1973), pp. 281-284 Published by: International Association for Plant Taxonomy (IAPT) DOI: 10.2307/1218138 Stable URL: http://www.jstor.org/stable/1218138 Page Count: 4) According to Frodin (see his *Guide to the Standard Floras of the World*....), Martius criticized the work as duplicative and lacking citations.

1798 A chance encounter between Alexander von Humboldt and Aimé Bonpland (while both men were staying at Paris's Hôtel Boston) resulted in their amazing journey of exploration in South America [see 1799], leading to significant developments in our understanding of natural history, biodiversity, biogeography, and ecology. (Aniško, 2013)

1798 Nicholas Louis Robert patented a papermaking process that involved a loop of wire screening fabric, which allowed production of a continuous sheet of paper. The machine, a Fourdrinier, (named for London financiers Sealy and Henry Fourdrinier), has been greatly improved through variations, but remains the basic means of paper production today..

1798 Napoleon (still a General) launched the French Campaign in Egypt and Syria, a massive endeavor that included a staff of 167 scientists. Among the expedition's savants was 20-year old botanist Alire Raffeneau Delile, whose work proved valuable. Not only did Delile collect a large number of botanical specimens and describe new algae, he is credited with taking the first cast of the Rosetta stone. After being one of the French researchers stranded in Egypt, Delile returned to Paris with his specimens - having been credited with successfully persuading British forces to relinquish the material and allow him to return. Delile was assigned by Napoleon (in 1802) to the United States, where he continued his collecting and plant study. and eventually entered medical practice. Delile eventually resided and taught in Montpellier, where one of his responsibilities included managing the botanical garden. (Johnson, 2018; Wikipedia, 2019, Phycological Trailblazer No. 26, *Phycological Newsletter* 2007 43(1))

1799 John Lyon began collecting North American plants, at first for William Hamilton, and later for collectors in Europe. He followed the trails of Catesby, the Bartrams, Michaux, and the Frasiers. Lyon may have contributed to the extinction of the Franklin tree by his aggressive and successful collecting. He sent quantities of oakleaf hydrangea to England, a plant introduced by Hamilton in 1803.

1799 Agriculturists described sweet corn, long grown by Iroquois. Its value was not immediately recognized, but by 1980 sweet corn was the #1 canned "vegetable" in the United States. (Root, 1980) Botanical Note: Each grain of corn is a one-seeded fruit, the product of a single grass flower. The female corn flowers are very small organs that form along the length of the future corn cob - completely hidden by the special leaves we call husks. The only evidence of so many flowers along the cob would be the corn silks - each silk is the style and stigma from a female flower. If you trace one of these long silks to its origin, it will become obvious that every silk was formed by a different female flower and remains attached to the base of the fruit (the grain) that formed. If no pollen grain lands and grows successfully on the stigmatic surface of a corn silk, fertilization will not occur and that grain will fail to develop...

1799 The Dutch East India Company fell bankrupt. (Rosengarten, 1969)[See 1602]

1799 Marcello, a Yuman Indian convert at Santa Clara Mission (CA), worked with 200 other native Americans to plant willows and poplar trees in three rows - forming the alameda (a tree-shaded path, typically bordered with cottonwood poplars) that connected Santa Clara to San Jose. (From the ULISTAC Natural Area Restoration Project website, Santa Clara University Environmental Studies Institute, 04.02.29)

1799 The first apple orchard of record in Iowa was planted along the banks of the Mississippi River, in Lee County. The 100 seedlings were packed in on ponies and planted by French-Canadian Louis Honoré Tesson. (R.S. Herrick in Slosson, 1951)

1799 Thomas Knight published '*An Account of the Fecundation of some Vegetables.*' This included observations of his hybridization studies using peas – presaging issues of inheritance related to dominant and recessive characters that would be documented in the works of Gregor Mendel nearly a century later.

1799 Alexander von Humboldt and Aimé Bonpland began their 5-year exploration of Central and South America. Among the six thousand plant specimens Bonpland had collected, scientists named 4500 new species. (Aniśko, 2013)

1800 As science entered the 19th century, much had been accomplished. The Royal Society, in existence for nearly 140 years, had fostered the works of people such as Newton, Boyle, Hooke, Grew, Malpighi, and Ray. Descriptive botany was entering its heyday, based on the new Linnaean system of binomial nomenclature. Banks was at the height of his prestige and influence. Kew had flowered its first tropical orchid only a decade earlier, in 1789. In that same year, at the beginning of the French Revolution, Jussieu (having organized plantings at the Jardin du Roi, later termed the Jardin des plantes, in Paris to reflect his thoughts on plant relationships) published the first natural system of classification (*Genera Plantarum*). Though scientists clearly appreciated the unfolding richness of world flora, biogeography and ecology were yet to develop. Physiology was, in its infancy, a pure outgrowth of experimentation in early chemistry and physics. Priestley, whose iconoclastic religious beliefs meant he would be forced to flee England to live in Pennsylvania, had established a remarkable relationship between the effects of plants versus animals on the nature of air. But his work (*Experiments and observations on different kinds of air*, 1774) referred to phlogiston and dephlogisticated air, not to oxygen or other elements. The periodic table did not exist; indeed, oxygen was not named until 1777 and hydrogen in 1783.

1800 Per capita consumption of sugar in England reached 18 lbs, up from an approximate per person consumption of 4 pounds in 1700. Much of this rise in sugar consumption seems related to increase in tea drinking. (Hohenegger, 2007)

1800 The soybean was known in Philadelphia, but gained little widespread attention. The bean would be introduced to California agriculture in San Francisco by direct importation from Japan in 1850.

1800 The population of Philadelphia had surpassed 40,000 inhabitants, making it the most populous town in North America. Until the late 18th century, Cahokia (the population center for Mississippian people, located east of St. Louis, in the Illinois flat lands) was the largest settlement north of Mexico and Central America. (Williams, 2006; Wikipedia, 2019)

1800 See entries for 1892 and 1908, John Burroughs, referencing this often quoted stanza from *A Poet's Epitaph*, by William Wordsworth:

Physician art thou? one all eyes,

Philosopher! a fingering slave,

One that would peep and botanize

Upon his mother's grave?

1801 Elgin Botanical Garden was under development at the northern edge of New York City, largely through efforts of David Hosack, a professor at the medical school of Columbia College. Today Rockefeller Center stands on a portion of the 20 acre site once occupied by this garden. (Campana, 1999; Wikipedia page on David Hosack)

1801 The first Harvard Botanic Garden was established.

1801 The elder MIchaux published the first account of North American oaks, *Histoire des Chénes de l'Amerique*., soon followed by more complete accounts in the 1819 *North American Sylva*, by Michaux f.

1801 John Wedgwood (son of Josiah Wedgwood, uncle to Charles Darwin) wrote William Forsyth (George III's gardener) and Joseph Banks about starting the Royal Horticultural Society - which quickly came into being.

1801 The cast iron process was invented, playing eventually into systems for constructing large conservatories.

1801 The later-day owner of Alexander Pope's renowned estate was driven to removing the garden's famous willow tree in an effort to discourage tourists and lookyloos. (Rupp, 1990)

1801 In describing the new genus *Lodoicea*, J. J. H. Labillardiére commemorated an analogy made by P. Commerson (who served with Louis Bougainville on his historic voyages) between the form of the famous coco-de-mer fruit (the double coconut) and his image of the pelvis of Laodice (lovely daughter of King Priam of Troy). Previously, the plant had been included in the coconut genus, Cocos. (Emboden, 1974)

1802 Bernard M'Mahon established his nursery in Philadelphia and began his own limited publication series similar to Curtis in 1806. His seed lists are said to be the first published in the US. M'Mahon was selected to receive and germinate seed collected by the Lewis and Clark Expedition.

1802 Frederick Traugott Pursh, who had arrived in the US to work at a botanic garden in Baltimore, was hired to manage Woodlands, the noted Philadelphia estate and plant collection of William Hamilton. In 1805, Pursh left that position to collect and study plants in of Eastern North America, eventually taking a job at New York's Elgin Botanical Garden. Returning to England in 1812, Pursh completed work on his 1814 *Flora Americae Spetentrionalis*, the second flora of North America. (Hedrick, 1950)

1802 Robert Brown arrived at Sydney (Australia) on the Investigator, along with botanical artist Ferdinand Bauer. George Caley, who had already been sent to collect plants in New South Wales by Banks, was furious that a second botanist was dispatched. (In 1803 Banks received seed of 170 species from Caley.)

1802 John Champneys of Charleston, South Carolina, created 'Champneys' Pink Cluster' rose (eventual parent to the Noisette hybrids) through crossing 'Parson's Pink China' with *Rosa moschata*, a white-flowered climbing rose from Asia. His new rose, a climber producing bunches of double, pink flowers, was quickly established in American gardens. Champney had acquired his China rose from the Noisette nursery in Charleston. Philippe Noisette produced seedlings from 'Champneys' Pink Cluster' from which he selected the first Noisette, which was introduced in Europe through his brother in Paris. (Grimshaw, 1998)

1802 The first seed sold in packages in America were marketed by a Shaker community at Enfield, Connecticut. Keeping their own seed lines healthy and free of corruption was a hallmark of that community. (Connor, 1994)

1802 Franz Karl Achard, through support from Prussian King Friedrich Wilhelm III, opened what appears to be the first commercial sugar beet refinery at Gut Kunern near Steinau, Silesia. Following up on Marggraf's demonstration that sugar could be extracted from beets, Achard had begun planting them on his estate by 1789, using those crops to mass select for sugar content. (Dudley, in Frey, 1994) Achard's trailblazing efforts did not work out well for him, personally. Fires in his refineries were followed by bankruptcy in 1815, and Achard died destitute.

1802 The term biology, taken from Greek (*bios* = life) was first utilized in its modern sense by German naturalist Gottfried Reinhold. The English word was first used by Stanfield in 1813. (OED)

1803 Henry and Sealy Fourdrinier improved on Robert's paper making machine. The continuous belt of wire mesh that layers the pulp is today called a Fourdrinier Screen. (Levetin & McMahon, 1996)

1803 Benjamin Smith Barton wrote and published America's first botanical textbook, *Elements of botany, or Outlines of the natural history of vegetables*. Barton worked at the center of Philadelphia's intelligentsia, an educated and productive cadre including naturalists, collectors and professionals in many fields. He had studied medicine under Benjamin Rush, his uncle was astronomer David Rittenhouse, his son Thomas amassed a significant collection of Shakespeariana owned by the Boston Public Library today... (Wikipedia, 2018)

1803 Jane Austen completed the initial script for her first novel, *Northanger Abbey,* though the book was published postmortem, nearly 15 years later. Fortunately, her brother had repurchased the publishing rights in 1816 and Austen made final edits before her death in 1817, when the text was finally issued. The story describes heroine and viewer Catherine Morland's tour with her host General Tilney through Northanger Abbey's estate grounds and nursery: *'The number of acres contained in this garden was such as Catherine could not listen to without dismay, being more than double the extent of all Mr. Allen's, as well her father's, including church-yard and orchard. The walls seemed countless in number, endless in length; a village of hot-houses seemed to arise among them, and a whole parish to be at work within the enclosure. The General was flattered by her looks of surprise, which told him almost as plainly, as he soon forced her to tell him in words, that she had never seen any gardens at all equal to them before; -- and he then modestly owned that, "without any ambition of that sort himself -- without any solicitude about it -- he did believe them to be unrivaled in the kingdom. If he had a hobby-horse, it was that. He loved a garden. Though careless enough in most matters of eating, he loved good fruit -- or if he did not, his friends and children did. There were great vexations, however, attending such a garden as his. The utmost care could not always secure the most valuable fruits. The pinery had yielded only one hundred in the last year. Mr. Allen, he supposed, must feel these inconveniences as well as himself."'* (with modernized spelling of surprize and unrivalled.) Austen's Gothic satire refers to the "pinery" - a hothouse for cultivating pineapples. Search the web for the 1761 Dunmore Park Pineapple hothouse, an archetypal pinery. Search also: Ruth Levitt, 2014. "'A Noble Present of Fruit': A Transatlantic History of Pineapple Cultivation", *Garden History* 42:106-119.)

1803 See TimeLine 2006, entry on *Liparia villosa*.

1804 Between 1803 and 1805, German pharmacist, F.W. Sertürner, experimented with opium poppy extracts, and by December, 1804, seems to have isolated morphine from opium latex. The three extracts of opium commonly used medicinally are morphine, codeine, and papaverine. (Simpson, 1989) Sertürner elected to name the isolate morphium,

for Morpheus, the Greek god of dreams, but it would later be called morphine. Not until 1925 would the chemical structure of morphine be determined. (Le Couteur & Burresson, 2003) [See 1817]

1804 Nicholas T. de Saussure's book *Recherches chimiques sur la végétation* (HNT) marked the beginning of modern plant physiology because of its well thought-out, documented experiments and attention to good experimental methodology. Working in Geneva, de Saussure achieved advances in our knowledge of plant nutrition and demonstrated that carbon from the atmosphere is fixed into the carbon that makes up organic compounds by plants undergoing photosynthesis. Saussure answered questions concerning the role of water in plant growth. In one experiment he combined various lines of study and demonstrated that cuttings set in distilled water continued to assimilate carbon, a result that denied earlier conclusions by Senebier and should have dispelled belief in the idea that carbon enters plants in the same manner as other nutrients from the soil [See 1813, the humus theory]. (Morton, 1981)

1804 Valentin Rose, a German scientist, extracted a "peculiar substance" from roots of the daisy *Inula helenium* (made through boiling the roots in water). Today we call this substance inulin. It is a highly branched, large polysaccharide (a molecule assembled from sugars) which is not broken down by the same enzymes that dismantle regular plant starches for animal consumption. Botanists believe plants may use inulin (also called helenin, alatin, and meniantin) to help maintain osmotic balances, conditions that can impact cold-hardiness or drought resistance. As a natural product that cannot be easily broken down, inulin is used as a "dietary fiber". (Wikipedia, 2015)

1804 Lewis and Clark began their expedition. Lewis spent nine months in Philadelphia studying botany under Benjamin Smith Barton to prepare for the journey. Jefferson distributed the seed they collected to Hamilton at The Woodlands and by M'Mahon. By 1825 Oregon grape holly was widely known and was available commercially from Prince Nursery of Flushing, NY for $25. (Spongberg, 1990) [See 1823, Douglas]

1804 Christopher Gore and his wife began the construction of their home and garden in Waltham, MA. Their interest in exotic plants was shared with neighbor Theodore Lyman, who at that time was also improving his estate, The Vales. Both families imported plants from Europe and built greenhouses for tropicals.

1804 Capt. John Chester brought the first shipload of bananas to the US on the Reynard to port in New York. Bananas did not become common in this country until after 1870, when Capt. L. D. Baker began exchange of mining equipment for Jamaican bananas. (Fussell, 1986) [See 1899]

1804 American and European traders began stripping Pacific Islands for sandalwood for use in Europe and China. Sandalwood trees were wiped out on Fiji by 1809, on the Marquesas by 1814, on Hawaii by 1825. (Ponting, 1991)

1804 England's Royal Horticultural Society was formed. Present at the first meeting were John Wedgewood, William Forsyth (Gardener to King George III at Kensington and St. James, Forsythia), Joseph Banks, Charles Greville, Richard A. Salisbury, William Townsend Aiton, and James Dickson. (Fletcher, 1969)

1804 The Japanese devil lily (oniyuri) was brought into cultivation at Kew. Due to the ease of propagation from bulbils that form in the leaf axils, Kew gardeners were able to propagate and distribute over 10,000 plants within a decade. Scientific name *Lilium lancifolium* aside, the plant is known today most readily by its English common name, tiger lily. (Grimshaw, 1998)

1805 Alexander von Humboldt's personal observations of many different plant habitats resulted in his important generalizations about the relationships of plants to their native climates. He is probably best known for making ecological correlations between the different plant habitats observed with rising elevation and the changing habitats seen when traveling from the tropics to arctic regions. Publication of his *Essai sur la géographie des plantes...* may be considered the beginning of the science of ecology. (HNT)

1806 Napoleon offered 100,000 francs to anyone who could create sugar from a native plant. Russian chemist K. S. Kirchhof later discovered that sulfuric acid added to potato starch would make the conversion. (Fussell, 1992)

1806 T. A. Knight devised a wheel that rotated on a vertical plane to test the importance of gravity to plant growth. Later Julius Sachs refined this design to invent the klinostat. Knight's studies demonstrated that the gravitational field does indeed impact plant growth, and that the effects of gravity can be replaced by rotational forces. (Morton, 1981)

1806 Louis Nicolas Vauquelin and Pierre Jean Robiquet extracted and described the first known amino acid, Asparagine, from the juice of asparagus. One of 22 amino acids required by humans for building of proteins, Asparagine is considered "non-essential" because it can be synthesized through human metabolism. Plants are able to manufacture all

amino acids. (Of course, plants also make the oxygen we breathe and the sugars that power us)……. (Rupp, 2011)

1806 Walter Burling introduced cotton seed from Mexico. See: Caroll Smith, (1 March 2016, 'Your Great Granddaddy's Cotton Varieties," *Cotton Farming* Magazine, 7201 Eastern Ave., Germantown, TN, 38138 csmith@onegrower.com.) *"Mexican stock was introduced by Walter Burling at Natchez, Miss., in 1806 and was later bred as Mexican Big Boll by J.D. Hope of Sharon, S.C., in 1914. Between 1830 and 1840, H.W. Vick of Vicksburg, Miss., worked with a variety called Belle Creole from which he selected a new variety, Jethro. This variety eventually made its way to Georgia and became the parent stock of Jones Long Staple and Six-Oaks. About 1840, Vick introduced another variety called Petit Gulf.*

In 1865, a Texas settler named Supak, who lived near Austin, introduced a variety known as Bohemian, which became the parent stock of Rowden and Express. Other famous varieties from the early days include Parker, Bancroft Herlong and Peterkin. And out West, the New Mexico Agricultural Experiment Station introduced a strain of Acala in 1923 that was bred from stock that originated in California and became known as College Acala.

"The Stoneville type of cotton is descended from Lone Star 65, selected in 1916 by H.B. Brown….Lone Star 65 was thought by Brown to be a natural cross with Mississippi Station Trice," Ware says. In another section, he says, "H.B. Tisdale worked on the breeding and distribution in Alabama of the wilt-resistant varieties Dixie, Dixie-Cook and Dixie-Triumph from 1914-1920." Also see cotton varieties Belle Creole, Jethro, Parker, and Petit Gulf,red in Mississippi.

See also: Stanley Nelson, Apr 25, 2018 - "War, cotton, dolls & Walter Burling" *Concordia Sentinel*. In this newspaper article, Nelson recounts the story of Walter Burlin, and how he came to introduce cotton seed that led to a Mississippi breeding program: *"Burling was a man who became somewhat famous for his contribution to the cotton industry. He also played a minor role in two related events -- the Sabine Expedition of 1806 and the Aaron Burr Conspiracy of 1807, both important to the history of Natchez country.... While in Mexico City, Burling learned that local farmers grew a high quality cotton variety. Burling asked if he could bring some of the cottonseed back to the U.S., but learned that the Spanish government banned such an act.*

But a high-ranking Spanish official told Burling over wine one evening that there was no ban on purchasing as many Mexican dolls as he wished. Puzzled at first, Burling soon learned that the dolls were stuffed with cottonseed. These seed were later modified in Mississippi into the "Petit Gulf" and other varieties, favorites of planters for years."

1807 In *A Sketch of a Tour on the Continent,* James Edward Smith remarks on failed efforts by John Graeffer to transform an area of the formal royal gardens (Caserta) in Naples to the British landscape style. Having been recommended for that challenge by Joseph Banks and William Hamilton, Graeffer's efforts must have failed to please, as recounted by Smith: *"... unfortunately none of the Neapolitans could see any kind of beauty in his performances, and they complained of his introducing so vulgar a thing as myrtle! The queen was much disposed to be pleased, but she could not stem the tide of opinion; nor did the king approve of the expense: so the whole was given up some time after."* (Wikipedia entry on John Graeffer)

1810 Liverpool Botanic Garden received the first Cattleya known to be cultivated. The plant was sent from Sao Paulo, Brasil, by Mr. Woodforde to Mr. Shepherd at the Garden. Plants from this original introduction are said to have bloomed every subsequent year - though that was never published. (Reinikka, 1972)

1810 Goats introduced to St. Helena Island began devastation that eventually caused extinction of 22 of the 33 endemic plants. (Ponting, 1991)

1810 Fulfilling a commitment to the French government, Nicolas Appert, a confectioner, published a book describing his methods for preserving food using heat - *L'Art de conserver les substances animales et végétales* (The Art of Preserving Animal and Vegetable Substances). Appert was responding to recent works by Lazarro Spallanzani, which documented destruction of microbes through various applications of heat. Though Spallanzini's conclusions were denied by some gifted scientists (notably Joseph Louis Gay-Lussac), Appert ignored controveries and began the canning industry. (Magner, 2002)

1810 Robert Brown's *Prodromus Florae Novae Hollandiae* marked the beginning of his publications on the flora of Australia. Brown made important comparisons of plants from Australia with other floras, yielding a fresh approach to this type of study. With Brown's work, botanists began to understand that significant information can result from studying the distributions and associations of plants. We also began to realize the distinctive nature of the Australian biota.

1811 *Lehrbuch der Materia Medica*, by Johann Adam Schmidt (personal physician to Ludwig von Beethoven) was published posthumouly, introducing the term pharmacognosy.

which was formalized by 1815 with publication of *Analecta Pharmacognostica* by Antoteus Seydler. (Wikipedia)

1813 Humphrey Davy (a noted chemist) published his lectures on chemistry and agriculture as *Elements of Agricultural Chemistry*. A leading text for over three decades, this book was one important step in the development of agricultural science. At the time of this publication, agriculturists (and Davey) accepted the humus theory, which held that plants gained both carbon and nitrogen from decomposition of humus in the soil. (Morton, 1981)

1814 Frederick Pursh published his *Flora Americae Septentrionalis*. He had been engaged originally by Barton in 1805 to study the plant material collected by Lewis and Clark, and later he worked for Hosack at Elgin. In 1809 he returned to London with his own collections of plant material to study.

1814 The deadly effects of various Amazonian plant mixtures called curare were learned by early European explorers, but not until 1800 when Alexander von Humboldt gave the first Western account of how the toxin was prepared by Orinoco River natives were plant sources (often involving the vine *Strychnos*) known. In 1814, Charles Waterton, having already disposed of numerous animals through experiments with curare, injected a donkey with the mixture. The animal collapsed quickly, after which Waterton inserted bellows into its windpipe and inflated the lungs. With this intervention, the donkey recovered consciousness; however, Waterton had to pump the bellows for two hours to keep the animal alive. We later came to understand that curare immobilizes voluntary muscle tissue through blocking transmission of nerve impulses to muscles. (Lewington, 1990)

1815 Johann Friedrich Elsholz, a German, died while participating in a Russian expedition to California. Later, the German botanist, Adelbert von Chamisso, honored Elsholz through describing the new genus *Eschscholzia* for the California poppy, albeit misspelling the name of the honoree. Hardly anyone has been able to spell the scientific name of this plant, the state flower of California, ever since. (Grimshaw, 1998 - information on Chamisso in Grimshaw is incorrect - correction supplied by Ann Gardiner)

1816 John Reeves introduced *Wisteria sinensis* to European gardening from nurseries in Canton, China. The first two plants to be exported, each sent on-board a different ship, arrived in the same month of May. One of the ship Captains was Richard Rawes, famous for his involvement with introduction of the first camellias. (Grimshaw, 1998)

1816 Henry Hall is credited as the first person to cultivate cranberries.

1816 Crop failure was widespread in Europe, resulting in food riots in England, France, and Belgium. (Ponting, 1991)

1816 James Hart Stark, traveled from Kentucky to Missouri, carrying apple tree scions which were the foundation for the Stark Nursery in the town of Louisiana. (E. Sinclair in Slosson, 1951)

1816 John Claudium Loudon patented a flexible glazing-bar (for holding glass) made of wrought-iron, which made construction of large and even curvi-linear greenhouse structuse possible. (Colquhoun, 2003)

1817 The first Bourbon rose, an apparent chance hybrid between *Rosa ×damascena* 'Bifera' and 'Parson's Pink China', flowered on the French colonial Isle de Bourbon in the Indian Ocean (today the isle is called Réunion.) The 'Parson's Pink China' had only recently been introduced to the settlers' gardens. (Grimshaw, 1998)

1817 The US Congress approved *"An act to set apart and dispose of certain public lands, for encouragement and cultivation of the vine and olive."* The conditions were immediately undertaken by French exiles who had settled near Philadelphia following the Battle of Waterloo. Organized as the Vine and Olive Colony, the group moved to the Alabama Territory and settled along the Tombigbee River on 92,160 acres (purchased from the US government for $2 an acre) near the site of what is today Demopolis. Their settlement, the first effort to cultivate olive and grapes in the deep South, failed soon after. (M.B.Sulzby in Slosson, 1951)

1817 For just over a decade, French chemists had experimented with methods of defining the active principle in opium. Both Jean-Froancois Derosne and Armand Seguin independently detailed successful results. But in this year (after 12 years of work) German pharmacist Fredrich Wilhelm Adam Sertürner conducted experiments using a new procedure that precipitated crystals he named "morphium" – for Morpheus, Rome's god of dreams. J. L. Gay-Lussac coined the name "morphine." (Filan, 2011) [See 1804]

1817 Allan Cunningham joined an expedition headed by John Oxley (Surveyor-General)of the lands beyond the Blue Mountains, gathering specimens documenting about 450 species. His colorful journal is rich with information: *"On 24 June - I gathered specimens of a new and remarkable Acacia, whose long narrow leaves have induced me to propose the trivial name of stenophylla."* (published as such by George Bentham in 1842)

1817 French scientists Joseph Bienaimé Caventou and Pierre Joseph Pelletier reported and named chlorophyll. (Wikipedia)

1817 Italian scientist Sebastiani Poggioli reported his studies of plant growth in response to differing colors of light. Of particular note were his observations regarding blue light and direction of growth. After numerous researchers and directions, in 1997 researchers identified the mechanism, naming the blue-light receptors "phototropins". (Wada, et al,, 2005, Chapter 15 by Winslow Briggs)

1817 Jacob M. Bigelow published the first of his 3-volume *American Medical Botany*. *"Under the title of American Medical Botany, it is my intention to offer to the public a series of coloured engravings of those native plants, which possess properties deserving the attention of medical practitioners. The plan will likewise include vegetables of a particular utility in diet and the arts; also poisonous plants which must be known to be avoided. In making the selection, I have endeavoured to be guided by positive evidence of important qualities and not by the insufficient testimony of popular report. . . I am by no means ambitious to excite an interest in the subjects of this work, by exaggerated accounts of virtues which do not belong to them. Much harm has been done in medicine, by the partial representations of those, who, having a point to prove, have suppressed their unsuccessful experiments, and brought in to view none but favorable facts."* Plants covered represent those he believed were likely to yield medical value. The descriptions and drawings were his own. The volumes appear to represent the earliest example of a color printing process called "aquatinting." (Steven Foster, 2004. "Jacob Bigelow's American Medical Botany: Digital Reissue Illuminates Access to Rare Work" HerbalGram 63:52-61 American Botanical Council) As to his medicine, Bigelow was known, principally, as a practiced and astute physician who had earlier published important medical information decrying outdated beliefs and calling for modernization and improvements in treatment: *"Bigelow's deprications helped form a new conceptual nucleus around which medical orthodoxy could begin to redefine itself."* (Paul Starr: *Transformations in American Medicine*, per Wikipedia, 2018)

1818 The wrought iron process was industrialized, changing the way designers would create conservatory structures.

1818 The Columbian Institute petitioned the U.S. Congress for appropriation of grounds to establish a botanical garden and museum. The gardens, once established, eventually came under control of a Joint Committee of Congress on the Library, and remained as one of the forces shaping development of the Washington mall for over 100 years. Through separate interventions such as entreaties of William Darlington and direct action by the Secretary of War, Joel Poinsett, the 1836 bequest by James Smithson became involved with this developing garden as the U.S. Congress took several years to consider how best to utilize the gift. (O'Malley, in Meyers, 1998) [See 1841]

1818 Thomas Nuttall published the second volume of *The Genera of North American Plants (and a Catalogue of the Species to the year 1817)*. On page 115 he described the genus *Wisteria*, "in memory of Caspar Wistar, M.D. late professor of Anatomy in the University of Pennsylvania and for many years president of the American Philosophical Society; a philanthropist of simple manner, and modest pretensions, but an active promoter of science." Nuttall, with seeming purpose, named the genus *Wisteria*, rather than *Wistaria*; his spelling has been officially conserved by botanists. Horticulturists in England, however, continue to spell the genus *Wistaria*..... Caspar Wistar's contributions to medical science were significant, and in 1892 his great-nephew Issac Jones Wistar funded an endowment to establish The Wistar Institute of Anatomy and Biology, housing Caspar Wistar's collections and honoring his contributions. The Wistar Institute stands as America's earliest independent medical research organization. (Note: It would be easy enough to confuse Caspar Wistar with the later horticulturist John Caspar Wister, also of the Philadelphia area. Wister had a founding role in establishment of Swarthmore's Scott Arboretum during his 50-year tenure at the College.)

1819 Robert Coate began his willow business (that means he was a "withy" merchant), buying and selling twigs for products, most particularly for the manufacture of baskets. With dwindling need of willow baskets for cargo, the company found new life when Percy Coate discovered in the 1960s that willow produces excellent quality artists charcoal. (www.coatescharcoal.co.uk) (Finlay, 2002)

1819 Though potatoes would soon become more important, as of this year they were not so common in the United States. On page 179, in his *A Year's Residence in the United States of America*, William Cobbett writes: *"Nor do I say, that it is filthy to eat potatoes. I do not ridicule the using of them as sauce. What I laugh at is, the idea of the use of them being a saving; of their going further than bread; of the cultivation of them in lieu of wheat adding to the human sustenance of a country.. As food for cattle, sheep or hogs, this is the worst of all the green and root crops; but of this I have said enough before; and therefore, I now dismiss the Potatoe with the hope, that I shall never again have to write the word, or see the thing."* (Hedrick, 1950)

1820 French chemists isolated quinine (an alkaloid) from the bark of Cinchona, making possible the production of a purified chemical treatment for malaria. (Levetin & McMahon, 1996) The chemists selected the name, quinine, for the alkaloid from the native American term quinaquina (meaning bark of barks) for the cinchona. (Lewington, 1990) [See 1658, 1865]

1820 In one of the first documented timber extractions in New Zealand, the English HMS *Dromedary* and the schooner *Prince Regent* sailed to New Zealand to take on a load of kauri spars (*Agathis* wood for mast crossbeams). The required spars would be 74-84 feet long, 21-23 inches in diameter, and perfectly straight. (Pawson & Brooking, 2002)

1820 John Clare published his first poetry collection: *Poems Descrpitive of Rural Life and Scenery*. Followed in 1821 with *The Village Minstrel* and 1827 by *The Shepherd's Garden*, Clare could well be the poet Laurette of nature's seasons, as his lyrical descriptives celebrated a first-hand knowing and fondness of local flora and fauna: "*I love the lone green places where they be* ." (Mabey, 2010)

1820 In *Prometheus Unbound and Other Poems*, a posthumous publication of Percy B. Shelley's poems, his "The Sensitive Plant" explores the meaning of life through references to the bashful sensitive plant. http://plantcurator.com/shelleys-use-of-the-sensitive-plant/ also, see Itsuki Kitani, 2009, *Sensibility and Shelley's Organic System of Nature in 'The Sensitive Plant'*

1821 Fifteen thousand specimens collected by Thaddaeus Haenke as part of the Malaspina Expedition [see 1879 entry] were secured by Prague's National Museum. Haenke distinguished himself as the first Western botanist to explore the South American interior. As part of his continued explorations, Haenke had (in 1801) been the first scientist to see populations of the Giant Waterlily, V*ictoria amazonica*. (Aniśko, 2013)

1822 Europeans had cultivated pineapples in hothouses for over a century. In this year, John Claudius Loudon wrote: 'The Different Modes of Cultivating the Pine-Apple, From its First Introduction into Europe to The Late Improvements of T. A. Knight Esq, by a Member of the Horticultural Society, noting *"sixteen varieties ... most commonly grown in Britain,...: 'The Old Queen', 'Ripley's Queen', 'Welbeck Seedling', 'Pyramidal' ('Brown Sugar-loaf'), 'Prickly Striped Sugar loaf', 'Smooth Striped Sugar-loaf', 'Havannah', 'Montserrat', 'King Pine' ('Shning Green'), 'Green' ('St Vincent's Pine'), 'Black Antigua', 'Black Jamaica', 'Providence 'Blood-red', 'Silver Striped Queen' and variegated-leaved pines"*. (Ruth Levitt, 2014. "'A Noble Present of Fruit': A Transatlantic History of Pineapple Cultivation", *Garden History* 42:106-119.)

1823 Giovani Battista Amici published observations of pollen and pollen tubes: Osservazioni microscopiche sopra varie piante memoria del sig. professor Gio. Battista Amici (inserita nel tomo 19. degli Atti della Societa italiana delle Scienze residente in Modena.) One study Amici reported involved pollen, including his observation that a hair, or tube, was present, attached to a pollen grain. His description constitutes the first report of pollen tubes. (see Internet Archive for a digital version of the publication, https://archive.org/details/bub_gb_xc3ZNWlIIvUC/page/n21

1823 Philipp Franz Balthasar von Siebold arrived in Japan to live there until 1830 as surgeon major in the Dutch East Indies Army, anxious for a career as a scientific explorer. He restored order to the botanical garden at Deshima. Because he accepted the gift of a map of Japan on his trip to Edo (foreigners were not allowed access to this type of information,) Siebold was imprisoned for a year, but pardoned in 1829. Banished from Japan in 1830, he was forced to abandon his Japanese wife and their child. The deck of the vessel on which he sailed was filled with plants he used to establish a nursery in Leiden. Among his introductions were *Wisteria floribunda*, *Hydrangea paniculata*, *Hydrangea anomala*, Malus floribunda and *Rhodotypos scandens*. He returned to Japan in 1859 and by 1863 produced a sales catalog that offered 838 species native to that country. (Spongberg, 1990)

1823 David Douglas was sent by The Royal Horticultural Society to the Eastern US to procure any new varieties of fruit trees and vegetables that might have been developed there. He met Thomas Nuttall (a British native recently appointed professor of Botany at the Harvard Botanic Garden) and others who helped him. Douglas returned to England with a wide variety of fruit trees, as well as Oregon grape holly. (Spongberg, 1990) [See 1804]

1823 Charles MacIntosh found that fabrics could be made waterproof by treating with natural rubber. [See 1839, 1881] The word rubber had been coined for the ability of this resilient material to rub out pencil marks [See 1770]. (Levetin & McMahon, 1996)

1823 Robert Bruce, and later his brother Charles, negotiated the process of acquiring seed and plants of the Assam form of tea (*Camellia sinensis* var. *assamica*) from the Singpho trive of Upper Assam. Eleven years later, the East India Company recognized the value of this discovery and began establishing tea plantation in Assam, with the first tea arriving in London in 1838. The growth in this enterprise led to conscription and near-enslavement of several hundred thousand recruits from over India. Within 60 years, 340,000 acres in As-

sam were dedicated to tea plantations. With other growing areas established, Chinese tea exports plummeted from 100%, to 10% of the world market. (Hohenegger, 2007) East India Company employees Charles Alexander and Robert Bruce discovered a kind of tea previously unknown to Europeans (*Camellia sinensis* var. *assamica*) growing in Assam, a province of northern India. The first shipments of Assam tea arrived in England in 1838. Though attempts were made to cultivate China teas in India, it became clear that the native Assam tea was the better crop for that region. Today, Assam tea is grown in Africa as well as Papua New Guinea. (Lewington, 1990)

1823 While examining flowers of *Portulaca oleracea*, Giovanni B. Amici reports having observed pollen tubes, which is considered the first published observation of this phenomenon. [Amici, G. B., 1823. *Osservazioni microscopische sopra varie piante*., Atti Soc. Ital. Sci.] He elaborated further on this observation in a letter to Mirbel. (J. E. Kirkwood, 1906, *The Pollen Tube in some of the Cucurbitaceae*, Bull. Torrey Bot Club, 33(6), JSTOR)

1824 After decades of battles between the Dutch and English over control of East Indian spice trade, a formal treaty gave the Dutch control of the Malay Archipelago, minus North Borneo. The British were settled with North Borneo, the Malay mainland, India, Ceylon, and Singapore. (Rosengarten, 1969)

1824 John Harris, a US Navy Captain, imported seed of Lima beans (*Phaseolus lunatus*) and grew them on his farm in Chester, NY. By mid-century Lima beans were shipped directly from Peru to the California goldfields as comestibles. (Kaplan & Kaplan in Foster & Cordel, 1996)

1825 French chemist Henri Braconnot isolated and described pectin. Earlier, in 1811, he had isolated chitin (the first polysaccharide to be described), and (in 1819), Braconnot demonstrated the conversion of cellulosic compounds to sugar through treatment with sulfuric acid. (Wikipedia)

1825 David Douglas arrived at the mouth of the Columbia River, and returned to England in 1827. In 1829 he arrived in the Pacific Northwest again, collecting seed/plants from California to Alaska (and even Hawaii). Douglas died (1834) while collecting in Hawaii after falling into a pit trap in which a wild bull was already ensnared. C.V. Piper: *"The extent and amount of this man's collections during the three seasons he spent in the Northwest almost surpass belief."* Douglas introduced over 200 species to cultivation in Great Britain, including Douglas fir, sugar pine, noble fir, giant fir, etc. (Spongberg, 1990)

1826 Paxton left the Royal Horticultural Society garden to become head gardener to the Duke of Devonshire at Chatsworth. (Fletcher, 1969) [See 1836, 1851]

1826 John James Dufour published The American Vine Dressers Guide, describing the varieties and cultivation of grapes in Switzerland County, Indiana. Dufour's guide reflected real experience he had gained from extensive vineyards he managed on the 2,560 acres the family had purchase near Vevay since settling there in 1803. (Helen Link, Helen McNaughton in Slosson, 1951)

1826 Twigs (apparently predominately of basket willow) had long been utilized in England to record tax payments. Notches made in each twig indicated the amount of tax paid. Once split the notched twig yielded two records of payment. When the tax records went to paper transaction in 1826, the archive of twigs was abandoned. A few years later, in 1834, the government determined to eliminate the hoard of tally sticks, and a decision was made to burn them. The resulting fire escaped control and took with it the Houses of Parliament. (Rupp, 1990), see also: the Great Fire of 1834, www.parliament.uk

1826 An act of the US Congress set off the mania of planting silkworm mulberry, a short-lived industry. (Ewan, 1969)

1826 The unexploited forests of Burma gave impetus to the British conquest of that country. The first area opened (Tenasserim) "was stripped of teak within twenty years." By the end of the century about 10,000,000 acres of Burma forest were cleared. (Ponting, 1991)

1827 While studying pollen grains macerated in water through a microscope, Robert Brown observed random vibrational movement in the material. Through further investigation, he discovered the movement occurs even when there is nothing organic (or living) suspended in the water. In 1905, Einstein demonstrated that Brownian motion relates to the inherent motion of molecules present. (Krauss, 2002)

1827 The Philadelphia Society for the Promotion of Agricuulture established the Pennsylvania Horticultural Society (PSA), the earliest US horticultural society in on-going operation. (Campana, 1999)

1827 On 12 September, Thomas Coulter writes to A.P. de Condolle, with observations that describe Wilhelm Friedrich Karwinski von Karwin as a "splitter" and an: *"amateur with I think rather crude ideas on botany - a real enthusiast for species...cutting out leaves etc. I swear, Sir, that without hesitating a moment he made three species for me out of as many layers which I had made myself from a single stem of cactus. If he had as much zeal and*

success in multiplying his own species one would no longer see anything in the the world except young Karwinskis." (Nelson and Probert, 1994)

1828 C. J. van Houten developed the first modern process for making cocoa powder. Soon producers in Holland had learned that alkali could be added to neutralize various acids, making a mild, more soluble cocoa. This process is still called "dutching" today. (Simpson, 1989) By 1815, Van Houten was searching a method to remove cocoa butter better than boiling and skimming. His work resulted in a press that reduces the cocoa butter from over 50% to under 30%. This development improved the process of making chocolate beverages through providing a more soluble product. (Coe and Coe, 1996)

1828 Adolphe Brongniart published the first complete account of fossil plants, establishing himself as the founder of modern paleobotany. He was an early proponent of evolutionary theory. His interpretations of the fossil record also contributed to our understanding of historical changes in climates and plant geography. (HNT)

1828 Wenzel Bojer, an Austrian botanist, discovered Royal Poinciana, *Delonix regia*, in semi-cultivation on the eastern coast of Madagascar. It was not until1932 that native stands of this spectacular lowland tropical tree were located, on limestone cliffs in western Madagascar. The majestic, splendid orange-red display created by this tree in full bloom gives rise to its many common names, flame tree, flamboyant, and royal poinciana. (Grimshaw, 1998)

1828 Though French botanist André Michaux had (in 1785) written home that *"There are no informed people here, not even amateurs,"* Jacques Gérard Milbert (in his Picturesque Itinerary of the Hudson River and the Peripheral Parts of North America, transl. Constance Sherman, 1968) wrote: *"Truly, this is a land of botanists."* (Johnson, 2018)

1829 Kurt Polycarp Joachim Sprengel [nephew to Christian Sprengel, see 1793] published a Greek edition of Dioscorides, *Pedanii Dioscoridis anazerbei De materia medica libri quinque*. This was the first Greek edition of De materia medica to surface since 1598. (Wikipedia)

1830 The first machine for cutting lawns was introduced by Edwin Budding, an English textile-mill engineer. This machine was first imported to the USA 25 years later. (Crotz in Punch, 1992)

1830 Maple trees, taken from local forests, were planted along new streets in Norwalk, Ohio. In encouraging careful treatment for these saplings, the following notices were posted: "We, the small shade trees of Norwalk village do hereby present our humble petitions to the gentlemen of learning and leisure, their pen knives, and all the boys in town, praying you to spare us for a year or two, at least, and would plead in support of our cause that we recently have been taken by the hand of violence from a luxuriant soil and planted in your barren sand, in which, you very well know, it must be hard scratching to sustain life even if treated well. Old hickory, who so lately towered above us all in the woods, is missing here. We are only maples. We wish to grow and adorn the street, but a moment's reflection will convince you that we can never do it if our exterior must be continually punctured and lacerated by the knives of those absorbed in thought or earnest debate; or our feeble bodies loaded with as many boys as can climb us. That we may find mercy before you, and be spared to repay the planters for their toil is the earnest prayer of your petitioners, and as in feeling and duty bound, we will ever repay. Signed, Sugar and White Maples. P.S. Gentlemen from out of town are respectfully invited not to tie their horses to us, but to the posts provided on the street for that purpose." (Bessie Martin in Slosson, 1951)

1830 Robert Brown published the first account of the growth of pollen tubes from the stigma to the ovule: *"On the organs and modes of fecundation in Orchideae and Asclepiadae,"* in The Transactions of the Linnean Society of London. (HNT)

1831 Mount Auburn Cemetery was established by the Massachusetts Horticultural Society and quickly became a model for other cemeteries to be planted in a naturalistic style. The establishment of beautiful cemeteries in turn provided stimulus for increase in public parks. Botanist and physician Jacob Bigelow played a crucial role in establishment of Mount Auburn. (Hedrick, 1950)

1831 In his Story of My Botanical Studies, Goethe states: "The ever-changing display of plant forms, which I have followed for so many years, awakens increasingly within me the notion: The plant forms which surround us were not all created at some given point in time and then locked into the given form… a felicitous mobility and plasticity allows them to grow and adapt themselves to many different conditions in many different places. This understanding anticipates Darwin's Origin by three decades. (Wikipedia, 2016)

1831 Thomas Coulter had arrived at San Gabriel Mission (California), a prosperous enterprise with 1300 neophytes, over 25,000 head of cattle, and about 160,000 grape vines, but he was not in great spirits, writing to his sister (Jane Davison) in early November that: *"I have been now a month in this country and tho' there is absolutely nothing to be done in botanizing here at this time of year, I have taken a race over the country from Monterey to this place to see it a distance of about four hundred miles, and fear I shall be greatly disap-*

pointed in it when the season does come. I have not long to wait as the rains are about to begin and in March the spring commences. My intention is to work hard this next spring and if an opportunity offers leave this country about July next about which time the country will be as it is now as dry as a lime-kiln - from Monterey to this place the only beaten track in the country lies parallel to the sea coast, at a short distance from it, a ridge of low hills running in the same direction a little further inland limit the view so that I have merely seen a long narrow band of dry and barren land. What there may be inland I have yet to see but all the information I can get of it is but little encouraging. I am accordingly in as bad humour with myself and all about me as you can well imagine." Later that month, Coulter returned to Monterrey, where he encountered David Douglas on 23 November. (Nelson and Probert, 1994)

1831 David Douglas, in a 23 November letter to William Hooker, describes his encounter with Thomas Coulter: *"He is a man eminently calculated to do work - full of zeal, amiable, and I hope may do, for the benefit of the world, great good."* His note leads to the conclusion: *"I do assure from my heart it is a terrible pleasure to me to find a good man and a man who can speak of plants."* (cited in Nelson and Probert, 1994)

1832 Thomas Coulter writes to Alphonse de Condolle, regarding his spring expedition to San Gabriel, and on to the Colorado Desert: *"As this district (Monterey) has been pretty well examined last year by a Mr. Douglas I wished to examine new ground and have come south hoping to find a good harvest hereabouts and have been completely disappointed - this is really a misfortune to me, for I have lost a whole year by it. The months of April and May being the only time of year worth anything here, and these I have entirely lost. To reach this place in time I have travelled fast, and not examined any thing but the neighbourhood of my route, and consequently collected but little, and here is nothing, nothing. The is truly the kingdom of Desolation. I am at the extreme southwesterly foot of the Rocky Mountains which are totally dry and barren - to the west of them is the great sandy plain about a hundred miles broad and eight hundred miles long running [north-west] to Great Salt Lake and also totally without water except a few small salt ponds... I fear the whole flora of California alta will fall far short of a thousand species..."* He does wax a bit more positively in stating ..."*but there are amongst them a fair proportion of extraordinary and beautiful forms."* (Nelson and Probert, 1994)

1832 An English parliamentary report underscored the value of the opium trade, which had come to represent one sixth of the productivity of British India. Before opium was widely used in trade for tea, silver flowed into China. After establishing the opium trade, China was drained of silver dollars. (Hohenegger, 2007)

1832 By this year 137 different European weeds were naturalized in the New York flora. (Ponting, 1991)

1832 Advertisement for plants in a 4 January edition of The Courier newspaper in New Orleans describe the exotic material arriving at that port: *"The subscriber in addition to his already splendid collection of flowering shrubs, plants, etc. has just received from Tennessee in a short passage, a collection of fruit trees, Camelias, Japonicas, Dwarf ranges, Roses...also a number of hardy flowering plants such as Snow Balls, Syringas, Lilacs. Chinese and French Viburnums, Strawberry Tree, Sweet-scented Vitex, Blue Jasmin or Chinese Box, Thorn, Evergreen Privet, Honey Suckles, Double Dahlias - with the new and most approved varieties of the Fig tree, consisting of 10 varieties of those most cultivated in Italy and South of France."* Note these plants are arriving from Eastern North America along waterways. (Hilary Somerville Irvin in Welch & Grant, 1995)

1832 David Douglas: "I do assure from my heart it is a terrible pleasure to me to find a good man and a man who can speak of plants." (cited in Nelson and Probert, 1994)

1833 Robert Brown published the first account of a cellular nucleus (which he called the "nucleus" and the "aureole" in The Transactions of the Linnean Society of London. (HNT) Note Brown had read his paper before the Society in 1831.

1833 Colley was hired by Bateman to collect orchids in the Demerara region of British Guiana. Sixty species were returned alive from this expedition.

1833 Glass production improved, making manufacture of sheet glass up to 6ft (1.8 m) long possible. Before that time the largest size available was 4 ft (1.2m) in broad glass or 4-5 ft (1.2-1.5m) in crown glass. (A. Bonar, "Cathedrals of Glass", The Garden 115(10):526-530.)

1833 Cotton constituted over half of total US exports, with 146 million kilograms of raw product sold to Britain at a value of £8.5 million. Over 100,000 power looms were in operation and 9% of British workers (over half of whom were child laborers) were employed in the cotton industry. Their production (mainly in yarn) accounted for half of British export trade. Just over 4 decades earlier in 1771, pre-Revolutionary America supplied just over 85 thousand kilos of raw cotton to Britain - less than 10% of raw cotton imports, most of which came from Syria and the Levant. The first bale of American cotton to arrive in Liverpool ports, which would come to supply the Lancashire mills, arrived in 1784. But by 1850, Southern states were the source of 82% of cotton lint utilized by British industry. (Musgrove & Musgrove, 2002)

1833 Alcide d'Orbigny returned to Paris with thousands of specimens of plants and animals he had collected during a seven-year long expedition in South America. The results of his explorations were published in 5,000 pages over 12 years in volumes entitled *Voyage dans l'Amérique Méridionale*. Though plants were not his principal interest, d'Orbigny made many contributions to plant study, including providing accounts of populations of *Victoria*, the giant water lilies... (Aniśko, 2013)

1833 Anselyme Palen isolated and characterized diastase, the first enzyme to be studied. The term "enzyme" was first used in relationship to fermenting activity of yeast in1877, by German physiologist Wilhelm Kühne.

1833 The California mission era ended when Mexican legislation decreed secularization. Extensive vineyards that had been developed over the previous 50-60 years were increasingly abandoned, such that within 4-5 decades, no productive acreage remained. These were not, however, the only vineyards in California. Records indicate at least 22 individuals operating vineyards in the Los Angeles area by 1831. In this same year, Jean Louis Vignes, a recent arrival to the area, purchased his first vineyard acreage. Ten years later, he cultivated over 30,000 vines, the largest vineyard in California. (Pinney, 2017)

1834 When Liwwät Boke emigrated to Ohio from Germany, her packing list included seed for produce, as well as for flowers: wheat, clover, barley, rye, apples, cherries, peaches, pears, quince, plum, apricot, margaritas, snapdragon, peonies, and morning glory. (Adams, 2004)

1834 Over the next few years, and then through several editions, John Claudius Loudon published *Arboretum et Fruticetum Britannicum*, his multi-volume compendium of trees. The encyclopedic descriptions held forth as a go-to resource for tree cultivation over many decades, and remain a trove of information. Loudon incorporated references to ancient texts, scientific studies, and literature, while at the same time dishing up his own highly personal opinions as to the nature and appropriate use of trees in the landscape. From this treatment of *Laurus nobilis*, we discover: *"It was a custom in the middle ages to place wreathes of laurel, with berries on, on the heads of those poets who had particularly distinguished themselves; hence out expression, poet laureate.* '*Students who have taken their degrees at the universities are called bachelors, from the French* bachelier*, which is derived from the latin* baccalaureus*, a laurel berry. These students were not allowed to marry, lest the duties of husband and father should take them from their literary pursuits; and in time, all single men were called bachelors.'"* An amusing story comes in his treatment of Lombardy poplar. in volume III: *"These examples may serve to show how easy it is, by means of the Lombardy poplar, to destroy the harmony of its different parts. In short, the Lombardy poplar, like the weeping willow and birch, is a most dangerous tree in the hands of a planter who has not considerable knowledge and good taste in the composition of landscape."* (Taken from the Huntington copy, 2nd ed., 1854; also detailed in Christina Wood, *1994.* "'A Most dangerous Tree": The Lombardy Poplar in Landscape Gardening', *Arnoldia* 54(1): 24-30)

1834 In studying the nature of wood alcohol, Jean-Baptiste Dumas and Eugene Peligot determined it was composed of a single-carbon-hydrogen radical combined with water (the hydroxy group, -OH). They introduced the word "methylene" for this chemical group, creating the word by combining *methy* (Greek for alcoholic liquid) and *hyle* (Greek for woodland, or forest). (Wikipedia, 2019) Wood alcohol has been produced for centuries, through pyrolysis and distillation of wood chips in water. A wood alcohol fraction is generated as the wood breaks down when the mixture is maintained at 78.3 ºC.

1835 Having returned to London from nearly a decade of living, working, and collecting plants in Mexico and California, Thomas Coulter sorted through his notes and specimens. Early in this year, he loaned cones he had collected to botanist David Don. In June, Don read a paper detailing five new pine species. from Coulter's collections. Among those new species was *Pinus coulteri,* of which Don notes: "The leaves are longer and broader than those of any other Pine, and the cones which grow singly are the largest of all, being more than a foot long, half a foot in diameter, and weighing about four pounds... At the suggestion of Mr. Lambert I have applied to this remarkable tree the name of its discoverer, who is no less distinguished for his scientific acquirements than from the excellent qualities of his mind." (Nelson and Probert, 1994)

1835 Hugh Cuming commenced a 4-year trip to the Philippines. He was probably the first person to ship living orchids successfully from Manila to England. Plants he sent included *Phalaenopsis amabilis*, first grown at Chatsworth. Cuming distributed 130,000 herbarium specimens.

1835 Hugo von Mohl reported that cells in *Cladophora glomerata* divide to generate new cells.

1835 John Gibson accompanied Lord Auckland to India, via Madeira, Rio de Janeiro, and the Cape of Good Hope. He arrived in Calcutta in March 1836 with plants from Auckland destined for Calcutta Botanical Garden Director, Nathaniel Wallich. Gibson also collected in the Khasia Hills (Chirra Poongee), dispatching his plants through Wallich to England.

1835 Ludwig Clamor. Marquart published his *Die Farben der Blüthen, Eine chemischphysiologische Abhandlung*, in which introduced the term "anthocyanin" for blue, violet, and red pigments in flowers. He also created the term anthoxanthin for color in yellow flowers. (Onslow, 1925)

1835 British farmers began to import guano from the coast of Peru. Guano deposits became a significant manure/fertilizer source until after 1870. (Mingay, 1977)

1835 Hilliard, Gray, & Co., in Boston, published the first American (English) edition of John Antony Chaptal's *Chymistry Applied to Agriculture*, which was a post-mortem translation of the second French edition (the 1st edition was published in France in 1823). Chaptal gave appropriate credit to Humphrey Davy, for establishing this field of study in his 1813 publication *Elements of Agricultural Chemistry*. The publishers of Antony's lectures explain: *"The author, one of the most eminent chymists of the age, was at the same time a practical agriculturist, owning large estates, which were for a long time cultivated under his personal direction. 'In order,' he says, ' to make a useful application of the sciences to agriculture, it must be profoundly studied, not only in the closet, but abroad in the fields....The celebrated Davy has already published an Agricultural Chymistry, and I have derived from it important principles. Others will do better than we have done'"* This is a wonderful read, and worth downloading. Chaptal's first chapter (lecture) on the atmosphere is incredibly engaging, and tells us all about the state of understanding at the time. By his death in 1833, the composition of the atmosphere was well-understood, with known proportions of nitrogen (which he calls Azote), Oxygen, and Carbon Dioxide (his Carbonic acid). His explanation of gas exchange with plants is concise and lucid. *"Oxygen and azote constitute, essentially, the atmosphere, since when the two other principles* (carbon dioxide and water) *are separated from it, it still retains nearly all its characters of form, elasticity, etc. It however loses its most important powers of influencing vegetation; so that all the substances found in the atmosphere are necessary to the production and renewal of the phenomena which the three kingdoms present us."* Most interestingly, at this time scientists (remember Chaptal is a chemist) still believed the oxygen released from plants comes from carbon dioxide: *"Carbonic acid is constantly absorbed and decomposed by the leaves of plants. The carbon is appropriated by the plants to their own support, and the oxygen is thrown out into the atmosphere."* Additionally, the information on soils gives great credence to the abundance of aluminum in soils and bedrock, and its potential value to plants. We know, today, that aluminum is toxic to plants, and not incorporated into plant tissue. (from Antony, 1835, Source: Digital Archive, Babel.hathitrust.org, original from Library of Congress) [see also TL, 1785 Benjamin Franklin]

1833 Dr. Rush Nutt (Laurel Hill Plantation, Rodney, Mississippi) introduced his Petit Gulf cotton strain, as a result of his active selection techniques that quickly became core to varietal improvement. Nutt and his son became part of a widespread community of farmers engaged in cotton improvement. By 1860, cotton was actively bred and selected.

1836 Chatsworth conservatory construction was begun, to be completed in 1840. Measuring 272 x 66 ft (83 x 20m), the conservatory was designed and built by Paxton with the help of Decimus Burton (architect).

1837 Theodor Hartig was the first to characterize and name sieve tube elements. These are the living cells in phloem tissue that physically move photosynthate (sugars) from one location to another in a plant (from the site of production in a leaf to a sink such as a growing root, for example). (Wikipedia, 2015)

1837 In reference to tropical orchids, and particularly concerning *Cattleya labiata*, Gardner wrote: "The progress of cultivations (for coffee plantations, and wood for charcoal) is proceeding so rapidly for twenty miles around Rio, that many of the species which still exist will, in the course of a few years, be completely annihilated, and the botanists of future years who visit the country will look in vain for the plants collected by their predecessors." (Reinikka, 1972)

1837 Robert Schomburgk discovered *Victoria regia* in British Guiana (name later changed to *Victoria amazonica*). Early shipments of seed were not successful, until Paxton grew and flowered the plant in a heated tank of the tropical house at Chatsworth in 1849. The entire January 1847 issue of Botanical Magazine was dedicated to this waterlily.

1837 Illinois blacksmith John Deere melded a steel share to a moldboard of wrought-iron to create a plow that cut the prairie soils. Deere's plows became the prairie standard. (Fussell, 1992)

1837 *Gladiolus dalenii*, from Natal, was introduced to breeding programs for these corm producing plants in Belgium. Prior to this introduction, an early line of hybrids, the Colvilles, had developed from London Nurseryman James Colville. Subsequent to arrival of *G. dalenii*, yet other species were brought into the mix. By the end of the 19th century complex gladiolus hybrids involving several species had been created. The Grandiflora line of glads was developed largely in North America, beginning in 1891 with work of John. L. Childs. In 1904, a yellow form of *G. dalenii* (called *Gladiolus primulinus* at that time) allowed growers to expand the color range of flowers beyond orange, red, and violet. (Grimshaw, 1998)

1838 The new viceroy in Canton, China destroyed the British East India Company's illegal opium imports, a total of 2,640,000 pounds. Britain went to war with China, winning Hong Kong, trade concessions, and loot. (Lewis & Elvin-Lewis, 1977)

1838 Charles M. Hovey introduced a strawberry grown from seed produced by hybridization. This 'Hovey' strawberry is considered the first fruit variety that originated through breeding on the North American continent.

1838 John Wright Boott, Boston, MA, received the first recorded shipment of tropical orchids to the US. However, other Bostonians were known to have tropical orchids in cultivation by this year. Boott's collection went to John Lowell, eventually into the hands of Edward Rand. When Rand sold his estate, around 1865, the orchid and tropical plant collection was given to Harvard College (to Cambridge Botanic Garden.) (Reinikka, 1972)

1838 French chemist Anselme Payer isolated, described, and named cellulose.(Kurlandsky, 2016; Wikipedia , 2018). Cellulose, considered the world's most abundant macromolecule, for centuries cellulose had been critical to manufacture of papers (such as papyrus and mulberry bark). The term relates to words used for sugars (glucose, sucrose, fructose) by adopting the "ose" suffix, as appended to the basic word "cell." This is perfectly suitable since cellulose strands are made of tens of thousands of beta-1,4-linked glucose molecules. The American Chemical Society presents its annual Anselme Payer Award for work in cellulose and renewable materials.

1839 Emperor Tao-kuang sent Lin Tse-hsu to Canton to resolve the opium problem. Lin addressed a letter to Queen Victoria which included the petition: "Even though the barbarians may not necessarily intend to do us harm, yet in coveting profit to an extreme, they have no regard for injuring others. Let us ask, where is your conscience? I have heard that the smoking of opium is very strictly forbidden by your country; that is because the harm caused by opium is clearly understood. Since it is not permitted to do harm in your own country, then even less should you let it be passed on to the harm of other countries." (Filan, 2011)

1839 Nathaniel Bagshaw Ward described his Wardian Case in Gardener's Magazine. (Fletcher, 1969) This work was subsequently expanded and published as a book. [see 1842]

1839 Charles Goodyear discovered vulcanization, the heat driven process of combining sulphur with natural rubber. The cross-linking of molecular chains (isoprene units) makes rubber non-sticky, more durable, and more elastic. (Simpson, 1989) Vulcanization changed life in Brasil, causing a rubber boom, with exports rising from 31 tons in 1827 to more than 27,000 tons by 1900. Manaus became a cosmopolitan city. [See 1823, 1877, 1881] (Ponting, 1991)

1839 Salicylic acid (chemically related to salicin, the pain-relieving compound named for its source, *Salix*, i.e. willow) was isolated from yet another source, the flowerbuds of *Filipendula ulmaria* (at that time called *Spiraea ulmaria*), a European member of the rose family. In 1853 a number of synthetically prepared derivatives of this compound were prepared, one of which was acetylsalicylic acid. Years later The Bayer Company selected that chemical as a substitute for the commonly used salicylic acid, and named it "aspirin" by combining the letter "a" from acetyl and "spirin" from Spiraea. (Lewis & Elvin-Lewis, 1977) Sanecki (1992) elaborates by explaining that the original plant, called meadowsweet in English, is termed Spirinsaure in German. Sanecki dates the original isolation to 1838 and the synthesis of acetylsalicylic acid in 1899.

1839 Prickly pear was introduced to Australia for use as hedging. By 1925 over 60,000,000 acres of Australian land were infested, and prickly pear dominated the vegetation in nearly half that area. Control came eventually in the form of South American caterpillars that feed on the plant. (Ponting, 1991)

1839 Chevalier coined the word "microtome" (*l'instrument microtomique*") for the many kinds of devices used to make thin sections in microscopy. Adolf Orschatz (assistant to Jan Evangelista Purkynë) used the term for his new device in 1843. English-speaking microscopists had called these cutting engines. In 1868, Rivet introduced a wooden microtome that worked on the sliding principle still in use today. (Smith, 1915)

1840 The Opium Wars ended mandarin control of British trade with China, followed by the 1842 Treaty of Nanking. This treaty ceded Hong Kong to the British and opened numerous ports to Europeans and Americans. Under an 1858 treaty, foreigners could travel anywhere in the interior of the empire. [See 1997] (Spongberg, 1990)

1840 In the years before paper was manufactured from wood pulp, Isaiah Deck wrote that the increasing demand for paper (at that time made from cotton or linen rags) could be met through recycling Egyptian mummies - each of which provided up to 30 lbs of linen wrapping. Twenty years later I. A. Stanwood of Gardiner, Maine acted on this proposal by importing mummies for manufacturing brown wrapping paper. In Egypt mummies were being used to fuel railroad engines. (Rupp, 1990)

1840 Friedrich Keller patented a wood grinding machine that promoted the use of wood pulp for papermaking. Within 30 years, experimentation with wood pulp paper extended to

such short-lived products as coffins, horseshoes, and road surfaces. (Rupp, 1990 - which see for more detail)

1840 John Dresser (Stockbridge, Massachusetts) devised a hand powered veneer lathe. Thin sheets of wood are used for creating finished surfaces as well as in the manufacture of plywood, but they must be shaved or sawed from the original block. Dresser's lathe pointed the way to mechanization of this process, leading to the commercial manufacture of plywood. (Connor, 1994)

1840 The Gould medicinal plant business began in Maldin, Massachusetts. Run by three generations of the Gould family, their botanic garden was at one time as large as 8 acres, employing (along with the associated herb and drug factory) greater than fifty people. Products, such as catnip tea, were sold under their own label, but the Goulds also supplied botanicals to various makers of medicines, such as the Lydia Pinkham Company. (Connor, 1994)

1840 Justus von Liebig published *Organic Chemistry in Its Applications to Agriculture and Physiology*, in which he summarizes experiments in ashing (burning) plants to examine which minerals are present in what concentrations. His results showed that nitrogen, phosphorous, and potassium (present in today's commercial fertilizers as N:P:K) are important constituents of plants, helping to explain why saltpeter (sodium nitrate) and guano (deposits of bird droppings) augment agricultural production. (Schwarcz, 2005)

1840 In writing to his brother Robert, Thomas Coulter explains negotiations with Trinity College related to his collections and future: *"My arrangement with College is briefly this - I make over to them by deed my whole herbarium, a pre gift, and they make me curator of it with Fellows chambers and commons (worth abt £40 pounds a year) and £100 cash per ann. for the present, to be made £300 (per annum) on the death of Dr. Stokes. So far all right, but they would insist on another condition, which as it happens is not a disagreeable one, but which you must keep to yourself - it is that I must accept the chair of Botany when vacant if they elect me - very hard! isn't it?"* (Nelson and Probert, 1994)

1841 Orlando Jones patented a treatment for starch extraction in rice which involved treating kernels with caustic alkali. The same process was eventually applied to production of wheat and corn starches. (Personal Communication from I. Ellis, see U.S. Patent Office Website, Patent #2000, 12 March 1941)

1841 Kew Gardens was transferred to the British government. William Jackson Hooker became the first director.

1841 Physician/botanist William Darlington proposed botanic gardens as part of the Smithsonian Institution: "when nearly every crowned head in the civilized world had taken care to found such noble institutions as botanic gardens, (why) should not the classic pillars of our Republican fabric be wreathed with the chaplets of Science and festooned with the garlands of taste?...And while the Frenchman justly glories in the Jardin des Plantes - while the Briton boasts with reason, of the royal Garden at Key; and even the Russian, in his frozen clime is warmed in admiration of the Imperial Conservatory of the Czars - let American freemen, in their turn be enabled to point with patriotic pride, to a National institution of no less beauty and value, at the Metropolis of their own favored land. While at colleges they teach the various branches of knowledge, here at the common center of the Republic, we should have the entire Tree, in perennial verdure, accessible to all who might desire to participate in its pleasures and benefits." (O'Malley, in Meyers, 1998) [See 1818]

1841 Secretary of War, Joel Poinsett, ordered that the collections of the Wilkes Expedition be sent to Washington, as part of his work to establish a cabinet of natural history through a National Institution for the Promotion of Science. In line with receiving benefit of the Smithson bequest, the group continued in the vein of the earlier Columbian Institute. A statement of goals seemed eerily modern: *"to collect documents and facts illustrative of the early history of our country, specimens of its geology and of its mineral and vegetable productions, and if not to preserve the animals and plants themselves, which are passith away before the progress of settlement and cultivation, at least to perpetuate their forms and the memory of their existence."* (O'Malley, in Meyers, 1998) [See 1818] Specimens from the Wilkes Expedition yielded the beautiful Christmas poinsettia, now called *Euphorbia pulcherrima*, but originally named *Poinsettia pulcherrima* in honor of Joel Poinsett.

1841 Gardener's Chronicle began publication with J. Lindley as horticultural editor.

1841 Andrew Jackson Downing published his *Treatise on the Theory and Practice of Landscape Gardening Adapted to North America* - the most influential early American treatment of this subject. Downing died in a steamboat accident in 1852. (Adams in Punch, 1992) [See 1850]

1841 Having arrived in California (still territory of Mexico) by wagon train from Pennsylvania, William Wolfskill planted a 2-acre orange grove, the first commercial grove in the area. By 1877, his son Joseph was able to ship a railcar filled with navel oranges to St. Louis, and in 1866 the Wolfskill orchards sent an entire trainload of oranges to markets in the Eastern US. A rush of investment led to the planting of thousands of acres to citrus in the Los Angeles area, all of which came to a crashing end by 1890 when land values, the

impacts of overproduction, and arrival of white scale from Australia led to abandonment of many groves, including those the Wolfskills had made so successful. (Laszlo, 2007)

1842 Nathaniel B. Ward published On the Growth of Plants in Closely Glazed Cases.

1842 Matthias J. Schleiden, and, in 1847, Theodor Schwann synthesized their own observations along with known information to reach a reasonable understanding of plant and animal cell structure. Their work established the theory that the cell is the basic unit of all life, helping to establish the fundamental concepts that underlie the general study of biology. (HNT)

1842 John Bennet Lawes and his assistant J. H. Gilbert began manufacture of superphosphate, the first chemical fertilizer, in Deptford, England. The process involved chemical treatment of coprolites, as well as fossilized organic material mined in Cambridgeshire and Hertfordshire. Eventually phosphate rock became the source material. (Mingay, 1977)

1842 After the British assault on China, the Treaty of Nanking opened China more fully to trade, required reparations, and ceded Hong Kong to the British government (until 1997, when it was returned to Chinese control). China still refused to legalize opium, and thus a second war was waged and opium was legalized in 1858. (Hohenegger, 2007)

1842 The term "vegetarian" first appeared in print, in an article published in the April issue of *The Healthian*, one of several journals (along with The New Age) that emerged from England's short-lived Alcott House Academy and the The Ham (Concordian) School. The Academy had been established by James P. Greaves and named in honor of Amos Bronson Alcott, who briefly led and transformed (even renamed) Boston's Temple School. Alcott (you have got to check out this guy), an American transcendentalist and educational reformer, also fathered Louisa May Alcott. Wikipedia

1842 John Frémont began a series of five expeditions, which led to his arrival in Alta-California in 1844. Over a period of thirteen years, Frémont would be responsible for significant plant collections leading to designation of nineteen new genera. Included were specimens of Flannelbush, collected on 27 May 1946 and used by botanist John Torrey as the basis for the genus *Fremontodendron*. (Beidleman, 2006)

1842 The Royal Agricultural College (since 2013, Royal Agricultural University) was established in Cirencester, Gloucestershire, England, as the first agricultural college in the English-speaking world. Its initial class of students entered in 1845, the year the college was granted a charter by Queen Victoria. (Wikipedia, 2017)

1842 California vintners had methods to keep birds from devouring their grapes. Captain Phelps (W.D. Phelps, *Alta California, 1840-1842*) records: *"As I passed by the vineyards, I observed that in the middle of each a scaffolding is erected on which an Indian boy is stationed in the morning and remains throughout the day with a hat full of stones and a sling, with which he keeps away the crows and blackbirds who otherwise would destroy half the crop*" (Pinney, 2017)

1842 German botanist Gustov Heynhold described the new genus *Arabidopsis* ((looks like *Arabis*), including in this genus the diminutive herb *Arabidopsis thaliana*. That plant had been first-described and named as Pilosella siliquosa by Johannes Thal, from northern Germany's Harz Mountains in 1577. It was re-christened *Arabis thaliana'* in recognition of Thal' by Linnaeus in his 1753 *Species Plantarum*. Thal did very well by himself; *A thaliana* has become the most important model plant ever utilized for botanical investigation. (Willis and Fry, 2014; Wikipedia, 2018)

1843 John Lyons published *A Practical Treatise on the Cultivation of Orchidaceous Plants* (2nd edition 1845), the first book on orchid culture.

1843 Robert Fortune made the first of four journeys to China (ending in 1860), initially for the Royal Horticultural Society, later for the East India Company (as a result he sent 23,892 young tea plants and 17,000 germinated seedlings to northern India), and finally for the US Government. Never before had so many Chinese plants gotten to England. His success was based greatly on the newly invented Wardian case. Plants he sent included balloon flower, bleeding heart, golden larch, Chinese fringe tree, cryptomeria, hardy orange, abelia, weigela, winter honeysuckle, etc. Tea plants Fortune sent to Washington did not succeed, partly because of the War Between the States. (Spongberg, 1990) [See 1846]

1843 Rothamsted Experimental Station (now Rothamsted Research) was established in Hertfordshire by John Bennet Lawes, founder of an early industrial fertilizer firm. Agricultural research continues on the property, making this one of the oldest experimental stations in the world. (Wikipedia, 2015) Between 1843 and 1856, John Bennet Lawes and Joseph Henry Gilbert began several long-term field experiments. Adjustments in sites, methods, and goals are recorded, along with understanding gained from data that have been collected, are available from the institutional website....
https://www.rothamsted.ac.uk/long-term-experiments

1843 The first shipment of Peruvian guano arrived in Baltimore, nearly 20 years after receiving wide public notice in an *American Farmer* article by John Skinner. Guano retained

popularity for only two decades. By 1849 the first US manufactured chemical fertilizers were marketed. (Rasmussen, 1960) [See 1881]

1844 John Mercer invented a treatment for cotton that involves stretching the fibers under pressure in a cold bath of caustic soda. Mercerization gives cotton increased sheen and durability, as well as promoting the uptake of dyes. (Simpson, 1989)

1845 In 1841 the Irish population was about 8 million. Estimates are that a working man ate 12-14 pounds of potatoes each day. (Langenheim & Thimann, 1982). Due to an exhausted system of landownership and attenuated tenancy (through subdivision and subletting of leases), by 1845 there are estimated to have been 65,000 Irish farms of an acre or less. On these farms the spade was the only tool and the potato the sole crop. (Zuckerman, 1998) In 1845 potato blight was imported to Europe from the Americas. By 1846 the potato crop in Ireland had totally failed. About 1,000,000 people died and another 1,000,000 emigrated. (Ponting, 1991)

1845 William Ransom, a Quaker living in Hertfordshire, England, began his career of cultivating and distilling medicinal herbs, most importantly lavender and peppermint. Eventually, his son Francis would become a partner to establish the firm of William Ransom and Son. (Sanecki, 1992)

1846 Frenchman A. Saint-Arroman chided : *"The best tea of the Celestial Empire cannot bear a comparison with Bordeaux, Burgundy and Champagne… The Englishman is naturally lymphatic, stuffed with beefsteaks and plum-pudding, he remains for two hours almost annihilated by the painful elaboration of the stomach... Tea alone can draw him from his lethargic sleep…"* (Hohenegger, 2007)

1846 German chemist Christian Schonbein discovered that a mixture of sulfuric acid and saltpeter (usually potassium nitrate) could dissolve cotton fabric, specifically his cotton apron. Moreover, he found that when his apron dried, it exploded. The new, unstable compound proved tantalizing. By 1885, Joseph Swan had tested strands of cellulose nitrate for use as elements in electric light bulbs. (Lewington, 1990) [See 1868]

1846 Hugo von Mohl was the first to apply the term "protoplasm" to cell contents surrounding the nucleus in plants, but the term had been applied to egg white in 1839 by Jan Evangelista Purkynë. von Mohl is known for his expertise in making fresh sections for microscopic study, such that his discoveries were made before botanists adopted advanced techinques, such as aniline stains, embedding, and even permanent mounting. (Smith, 1915)

1846 Robert Fortune delivered plant material (from his first of three China collecting trips) to the Horticultural Society's gardens at Chiswick. Included was *Jasminum nudiflorum* (Winter Jasmine). Though originally cultivated in the glasshouse, the plant proved to be hardy and became a popular garden shrub. (Halliwell, 1987)

1846 William Lobb collected seed of *Tropaeolum speciosum*, the Flame Creeper, in *Nothofagus* forest of the south Chilean island of Chiloe. The plant was first grown by the Veitch nursery in Exeter, which had sponsored his trip. Flame Creeper is a close relative of Canary Vine (*Tropaeolum peregrinum*) and the garden Nasturtium (*Tropaeolum majus*)[See 1596], all of which are native to the Neotropics. (Halliwell, 1987)

1847 Chocolate candy was first created. (Levetin & McMahon, 1996) Note: In this year, Fry's (Bristol, England) began marketing a bar chocolate. There is considerable evidence that chocolate confections existed in the previous century.

1847 The first ancestor of today's complex hybrid lines of tuberous begonias (today often called *Begonia ×tuberhybrida*) was imported to Europe from the Bolivian Andes of South America. Plants of this species, *Begonia boliviensis*, have a trailing habit and brilliant scarlet flowers. Within three decades hybrids were created in nurseries around Europe. By 1882 a double-flowered cultivar had been created. (Grimshaw, 1998)

1847 Organized in Macon County, Alabama on 6 March, the Chunnenuggee Horticultural Society was the first gardening club formed in Alabama, and perhaps first in the entire region. The society was a reflection of new settlement on Chunnenuggee Ridge (near the town of Union Springs, AL today) by many families from more eastern states who arrived following Creek Cession in 1832. Among settlers and active members was Norborne Berkley Powell, a physician, who built his home and garden, Old Field, on the site of the former Indian War Council Lodge. The Society maintained a public garden for truck crop sales and sponsored a May Fair and flower festival. The community and society flourished for a time (until the War Between the States); through the contacts of local residents there were honorary members from other towns in the South, and as distant as New York. (M.B. Sulzby in Slosson, 1951)

1847 Pharmacology emerged as a scientific profession with establishment of a chair for Rudolf Buchheim at the University of Dorpat (Estonia). (Wikipedia and thetimeline, a brief history of Pharmacology, by Stanley Scheindlin, mdd@acs.org)

1847 The Vegetarian Society was organized in England, as an outgrowth of the Alcott House Academy. Wikipedia [See 1842]

1848 Robert Fortune, of the Royal Horticultural Society, was sent to China to collect plants and seed, and to learn as much as possible about tea cultivation and processing. After two journeys and nearly three years of work in China, a ship sailed from Hong Kong to Calcutta in 1851. (Hohenegger, 2007)

1848 In Bangor, Maine, John Curtis produced the first commercial spruce gum - a chewing gum made of resin from spruce trees. By 1852 the Curtises had built a large chewing gum factory in Portland. As supplies of spruce gum diminished, manufacturers tried other chewables, such as paraffin, eventually turning to the latex from the chicle tree (*Manilkara zapota*.) Chicle became the basis of the American Chicle Company, and for their product, Chicklets. (Rupp, 1990)

1849 William Lobb was sent to the Pacific coast of America by Veitch & Sons to collect plants for the horticultural trade.

1849 Chauncey Enoch Goodrich raised his first crop of seedling potatoes from stock he had imported from Chile (at a cost of $200). Goodrich (a minister by profession) dedicated decades of his life to developing new potato selections for American farmers, hoping to resolve disease issues which had caused famines. The cultivars 'Garnet Chile' and 'Early Rose' came out of his program and gave rise to important selections. A set of articles (two by Goodrich, one a biography by John P. Gray, and the fourth a Report on his seedling potatoes by B. P. Johnson of the Executive Committee) are available in the 1864 *Proceedings of the Annual Meeting, Transactions of the New York Agricultural Society*. Vol 23, pages 89-143.. Available through G**gle Books)

1849 Charles Parry began his productive two years of plant collecting in San Diego, as part of the Western Boundary Survey. Parry collected and named California's Torrey Pine, which proved (at the time) to be one of the world's rarest pines. (Beidleman, 2006)

1849 Joseph Warren arrived in California. With extensive experience managing a Massachusetts nursery, he became one of the earliest nurserymen in California, and the first large grower of camellias in the state. Warren is credited with starting the Sacramento flower show, in 1852, and assisting with the San Francisco flower shows of 1853 and 1854. (H. M. Butterfield in Slosson, 1951)

1849 Studying cornflower (*Centaurea cyanus*), F. S. Morot reported his isolation of the chemical that gives blue color to the petals. The general name for the chemical became anthocyanin. Look up Cornflower in the WWW for an account of its interesting symbolism and use. (King, 2011)

1849 On 9 November, Joseph Paxton, Gardener to William Spencer Cavendish, and his staff flowered *Victoria amazonica* at Chatsworth. The seed had been delivered to Paxton by William Hooker, Director of Kew, whose staff had successfully germinated about 50 seed delivered in March. Flowering was regarded as a horticultural triumph, the first time this South American native plant had been cultivated and flowered successfully. (Aniśko, 2013)

1849 Heinrich Richard Göppert and Ferdinand Cohn, while studying *Nitella flexilis*, introduced cochineal-derived carmine staining techniques to plant microtechnique. "Of the natural dyes used by cytologist, none was more esteemed than carmine."(Clark & Kasten, 1983)

1850 The mechanization of field agriculture began. Mechanical reapers, and later the internal combustion engine (and consequently the tractor) altered the face of the world - and the growth and increasing urbanization of the world population. Between 1860 and 1920, about 1,000,000,000 acres of new land were brought under cultivation, with another 1,000,000,000 acres coming into production during the following six decades. Improvements in shipping, refrigeration, and processing further industrialized this process. In the late 20th century, an American farmer received 4% of the price of chicken in the store and 12% of the price of a can of corn. (Ponting, 1991)

1850 John Jeffrey was sent to Oregon by a consortium called the Oregon Association of Edinburgh. His plant introductions to England included incense cedar and Jeffrey pine. (Spongberg, 1990)

1850 Seed of alfalfa (*Medicago sativa*) were brought by a gold miner from Chile to California, where the plant thrived as a forage crop. (Heiser, 1981)

1850 President Millard Fillmore invited Andrew Jackson Downing to design an arboretum and pleasure ground as landscape for the Washington Mall. (Morgan in Punch, 1992; O'Malley, in Meyers, 1998) [See 1841]

1851 Hofmeister (Friederich Wilhelm Benedikt Hofmeister) described alternation of generations in higher plants in his book Comparative Researches into Growth, Development and Fruit-formation of the Higher Cryptogams (mosses, ferns, Equisetaceae, Rhizocarpae and Lycopodiaceae) and Seed-formation in Conifers. (Morton, 1981)[see: The genius of Wilhelm Hofmeister: the origin of causal-analytical research in plant development, Donald R. Kaplan and Todd J. Cooke, 19996, Am. J. Bot, 83(12): 1647-1660 JSTOR)

1851 An importation of California grapes to Europe introduced white mildew (oidium), which eventually was treated with flowers of sulphur. The subsequent introduction of California rootstocks as a possible cure brought phylloxera, a much more problematic root aphid that can devastate entire acreages.

1851 A great glass structure, the Crystal Palace, designed by Joseph Paxton as the centerpiece of the first Great Exhibition, was opened. Paxton was knighted for his efforts. (Hix, 1974.) This was the same year in which England's Window Tax was repealed, a change that followed the 1845 repeal of the Glass Excise Tax. Horticulturists had been among those who augured for this tax relief, as the use of glass enclosures boomed in response to shipping and housing of tropical plants. (see The Regency Redingote website.)

1851 Beginning around 1820 and enduring for over 80 years, the "baked 'tato man'" was common on London streets, selling hot baked potatoes from fall through early spring. By 1851 there were over 300 such vendors, selling ten tons of potatoes daily. Some accounts suggest that hot potatoes were at times purchased as hand warmers. (Zuckerman, 1998)

1851 On 28 September U.S. Army Captain Lorenzo Sitgreaves encountered petrified wood in the area near what is today's Petrified Forest National Park. Shortly after his publication of this discovery, a large deposit of wood was encountered by another Army expedition (in what is today the northern section of the park). Lt. Amiel Whipple, who led that second expedition, gave the name Lithodendron Wash to a nearby arroyo. The report of Whipple's expedition, published in 1855, included the first illustration of these fossil deposits. (Petrified Forest, The Story behind the Scenery, Sidney Ash, 1998, 10th printing; Petrified Forest Museum Association)

1851 Stephen Elliott, Jr., (an Episcopal Priest, and Senior Bishop of the Episcopal Church in the South during the Civil War) addressed the Central Agricultural Society of Georgia at Macon: *"It is astonishing that, in a state so richly blessed as Georgia with all its advantages of Nature, so little attention should have been paid to horticulture either as a science or as an art. Each portion of the state has its peculiar beauties. The genial kindness of its climate assimilated the most precious plants of other countries to itself, and exotics like the camellia, the oleander, the gardenia, the tea roses, the kalmias, the rhododendrons, the azaleas, rifled from Asia, Africa, Persia, and China, have become indigenous in the state."* (L.P. Neely in Slosson, 1951)

1851 Hugh Low discovered the giant pitcher plant, Nepenthes rajah, on Mount Kinabalu in Borneo. F. W. Burbidge later introduced this astounding plant to reluctant cultivation.

1851 J. L. Clarke (medical research) describes use of Canadian Balsam as a mounting medium for making permanent slides. Other techniques used at the time included sugar water (lasting for about a year) and calcium chloride (more permanent, but not useful for all matter). Eventually, Canadian Balsam became the preferred mounting medium for all sciences. (Smith, 1915) Wikipedia (2018) notes that human physiologist Jan Evangelista Purkynë was the first to use Canada balsam for mounting slides (and other techniques). [See TL 1839 Orschatz]

1852 The Concord grape was discovered. Of uncertain origin, Concord became an important grape for eastern states with humid climates. (Heiser, 1981) It was introduced by Ephraim Wales Bull, of Concord, MA, who selected the clone from seedling wild grapes on his property and presented it to the Massachusetts Horticultural Society in 1853. (Fussell, 1986)

1852 At his death, Charles Morgan Lemann left an estate that included his herbarium of over 50,000 specimens, documenting 30,000 plant species. Lemann bequeathed the collection to the University of Cambridge, stipulating that specimens would firt be studied by George Bentham (a Kew botanist). The 32 cases of specimens were sent to Bentham's home, where he and his assistant dedicated seven years to mounting and study. (Webb, 2003)

1852 James Drummond (along with his son) made his last significant shipment of Australian plants to England, the results of his six major collecting expedition. Drummond's botanical legacy is strong; over 100 new species were named for him (a third of which have turned out to be taxonomic synonyms.) But he was known for fragments rather than full specimens, due partially to difficult circumstances and shortage of paper. (Webb, 2003)

1853 Albert Kellogg (native of South Carolina who had studied at Kentucky's Transylvania College, and later traveled to San Francisco where he had a pharmacy) and six colleagues established the California Academy of Sciences. To one of the meetings, he brought some specimens and stories he had heard from A. T. Dowd about a giant new conifer in the Sierran foothills, southeast of Sacramento. William Lobb, who was at the meeting, left immediately for the area, collecting seed, mature cones, vegetative shoots, and two seedlings. He returned to San Francisco and quickly left for England. The two saplings were planted at the Veitch nursery in Exeter. John Lindley described the new species that December in Gardener's Chronicles as *Wellingtonia gigantea*. (Spongberg, 1990) The name eventually accepted for this tree was *Sequoiadendron giganteum*.

1853 The first flower show held in California opened in San Francisco on 7 October. Among the entries were specimens from James Warren, of Sacramento, one of the first professional nurserymen to set up business in California (1849). Warren published the state's first nursery catalog and initiated California Farmer, the state's first agricultural and horticultural publication. By 1855, several nurseries operated along Folsom Street in San Francisco, including William Walker's Golden Gate Nursery, James and William O'Donnell's United States Nursery, and the Commercial Nurseries, a subsidiary of Highland Nursery in Newburgh, NY. A nursery from Napa County was represented in the 1854 flower show. (Taylor & Butterfield, 2003)

1853 At the age of 22, German botanist Heinrich Anton de Bary published his classic study of plant rust and smut diseases, unequivocally supporting the concept that these diseases are examples of fungal growth patterns. (Arthur Kelman, Lecture 4 in Frey, 1994)

1854 Commodore Matthew C. Perry "opened" Japan's doors to the West with signing of the Treaty of Kamagawa. Exchanges between the two countries included an American agricultural exhibit managed by Dr. James Morrow, assisted by S. Wells Williams, a Protestant missionary in China. Dried specimens from this first trip went to Williams' boyhood friend, the Harvard botanist Asa Gray. These specimens were quickly followed by collections from Charles Wright, who had been working in the North Pacific as botanist on a US Surveying Expedition, and was able to go directly to Japan once the treaty was signed. (Spongberg, 1990) [See 1861]

1854 Culminating a series of attempts dating from 1832, Mexico's *Escuela Nacional de Agricultura (ENA)* was established by retrofitting the convent of San Jacinto. The college continued to face tribulations, but by 1907 had graduated 175 professionals under a curriculum heavily influenced by French science and practice. In 1964 the school was reorganized as the *Universidad Autónoma Chapingo*. The institution houses Mexico's National Museum of Agricultura and is noted for its extensive (700 sq meters) Diego Rivera mural *Tierra Fecundada*. (Wikipedia, 2017 various entries; Cotter, 2003)

1854 *Walden* was first published. In this heavily wrought set of recollections and thoughts, Henry David Thoreau captures the essence of self-participation in nature and wildness. John Updike celebrates it as such: "A century and a half after its publication, Walden has become such a totem of the back-to-nature, preservationist, anti-business, civil-disobedience mindset, and Thoreau so vivid a protester, so perfect a crank and hermit saint, that the book risks being as revered and unread as the Bible." Today Walden stands as a beginning moment for contemporary environmentalism.

1855 Rudolf Virchow, a famous pathologist who had observed and named Leukemia and advanced our understanding of cells in many ways,, published his well-known line: "*Omnis cellula e cellula*" - which states that all cells come from existing cells. Until the mid-19th century, the origins of new cells was not so clear. People wondered if, perhaps, cells crystallized from unorganized matter...., or even *de novo*, i.e. through spontaneous generation.

1855 First steps were taken toward eventual production of rayon. After 1900, technology would be developed to allow production of rayon and cellophane. Both are products derived from cellulose extracted from wood chips. (Simpson, 1989)

1855 The first Alabama State Agricultural Society Fair was held (in Montgomery), in which premiums were offered for displays of trees, plants, and fruit. (M.B. Sulzby in Slosson, 1951)

1856 William Henry Perkin, while attempting to synthesize quinine (at the age of 18) came up with a dye that became known as Perkin's Mauve. Based on this discovery (the first aniline dye), Perkins obtained a patent and established his own dyeworks in Greenford, England. By 1859 the color was named mauve (for the color of mallow flowers) and the chemical itself was termed mauveine. (Wikipedia, 2016) [See 1880] Perkin's discovery would surface in the world of plant and animal science, as well a medicinal study, as an important histological stain called Toluidine Blue, abbreviated as TBO. In simple plant study, TBO is a fast stain that works with fresh preparations....; just make a fresh mount of plant tissue, drop on some TBO solultion, cover with a slip, and view immediately. It is a gorgeous stain. "Toluidine blue is a basic thiazine metachromatic dye with high affinity for acidic tissue components, thereby staining tissues rich in DNA and RNA. It has found wide applications both as vital staining in living tissues and as a special stain owing to its metachromatic property." (quote fro: Gokul Sridharan and Akhil A Shankar "Toluidine blue: A review of its chemistry and clinical utility" J *Oral Maxillofac Pathol*. 2012 May-Aug; 16(2): 251–255. doi: 10.4103/0973-029X.99081 PMCID: PMC3424943. PMID: 22923899) (Products listed as TB may include zinc, whereas stains listed as TBO are the chloride salt. see Sigma-Aldrich T3260)

1856 The biological importance of aniline dyes (see Perkin, immediately above) as biological stains became so apparent that new dyes quickly followed: Basic Fuchsin (1856), Safranin (Williams in 1859), Methyl violet (by Lauth in 1861), Aniline Blue and Sprit Blue (by Girard and deLalpe in 1861), Eosin (by Caro in 1871), Methyl Green (by Lauth ad Boubigne in 1871), Thionin (by Lauth in 1876), Methylene Blue (by Caro in 1876), Acid Fuchsin (by Caro in 1877), Orange G (by Baum in 1878), Sudan III (by Rumf and Garasche in

1879), and Azure B (by Bernthsen in 1885). By 1900, 52 of 81 important monoazo dyes had been synthesized. (Clark & Kasten, 1983)

1856 H. Lucas, A pharmacist working in Arnstadt (near the capital of Thuringia, in Germany), isolated a white powder, an alkyloid (that he named taxine), from Yew tree foliage. Herbalists had long been interested in Yew (*Taxus*) since it was anciently known as toxic. The first purified crystals of taxine (now understood to be a complex of alkyloids) were precipitated by French chemist W. Marmé in 1876.(Wikipedia, 2018)

1856 *Calanthe ×dominii* flowered. This is the world's first planned orchid hybrid, raised by John Dominy for Veitch & Sons. Though horticulturists were enthusiastic, botanist John Lindley was quoted as remarking: "You will drive the botanists mad." (Fletcher, 1969)

1857 William Miller (in Elements of Chemistry: Theoretical and Practical, Part III) coined the term sucrose, as a combination of "sucre" and the Latin root "ose" - which relates to sugars.

1857 Prosper Alphonse Berckmans (of Arschot, Belgium) assumed management of Fruitland Nursery in Augusta, Georgia. By 1861 the nursery offered more than 100 Camellia cultivars. Berckmans' original house and grounds are now part of the Augusta National Golf Course. (L.P. Neely in Slosson, 1951)

1857 Ferdinand Mueller was appointed Director of the Botanic Gardens in Melbourne, Australia Though many people today regard this appointment as the beginning of systematic botany in Australia, a Royal Commission charged with investigating Victoria's botanic gardens was not impressed by study of native plants, using the report to recommended Mueller's removal (14 December 1871), complaining that the director failed to establish *"a place where the whole colony could study horticulture, arboriculture, floriculture, and landscape gardening in their most perfect forms... a model of careful and thorough cultivation of well planned scenic effect, of art skillfully applied to the embellishment of nature."* Lionel Gilbert (1986) writes: *"When he was ousted, the Botanic Garden by the Yarra became beautiful but intellectually void. Systematic botany in Victoria has been a long time recovering."* (Webb 2003)

1858 Charles Darwin and Alfred Wallace were hastily paired to jointly present their ideas "On the Tendency of Species to form Varieties; and on the Perpetuation of Varieties and Species by Natural Means of Selection" before the Linnean Society of London. Darwin had been slow and cautious about publishing his concepts concerning evolution. When a letter describing many of the same, independently conceived ideas arrived from Wallace to be read before the Society, arrangements were made to establish Darwin's priority - as he had been circulating drafts of future publications among friends in London.

1858 Invention of the Mason jar stimulated use of large quantities of white sugar for preserves, reducing traditional reliance on maple sugar and molasses for home cooking. Usage of white sugar in the United States doubled between 1880 (when the tariff on imported sugar was lowered) and 1915. (Root, 1980)

1858 The Royal Horticultural Society instituted its First Class Certificate of Merit (FCC). By the following year the Floral Committee was established and given management of the FCC (Fletcher, 1969) The first orchid to be awarded an FCC was *Cattleya ×dominiana*, shown by the Veitch firm. (Reinikka, 1972)

1858 Beginning with a small quantity of alfalfa seed, Minnesota farmer, Wendelin Grimm, cultivated a crop over many years, eventually selecting seed resistant to winter kill. In 1900 the Minnesota Agricultural Experiment Station produced quantities of the seed and released it as a variety. (Busch, et al, 1995)

1858 Friedrich August Kekulé published his structural theory of chemical compounds in a paper on 19 May, describing concepts concerning the tetravalent nature of carbon and its chain-forming capabilities. Archibald Scott Couper had envisioned similar ideas and also written a paper, the publication of which was forestalled, not occurring until 14 June. Perhaps this critical loss of priority in publication coupled with apparent pre-existing mental stress, as Couper became mentally unstable soon afterward. "Described as a wreck by an acquaintance, he lived out his life tending flowers." (Cobb & Goldwhite, 1995)

1858 "*Suel Foster came to Bloomington* (now Muscatine, Iowa) *in 1836. After getting married and making a trip to California he returned to Bloomington and established the Fountain Hill Nursery of over 100 acres. In 1856, as writer for the Iowa Farmer and Horticulturist he took up the subject of schooling for farmers, insisting that Iowa must have a Farmers College. Following several publication of this proposal, in January 1858 the Iowa Legislature (General Assembly) passed an act to establish an Iowa Agricultural College which was signed by Governor Ralph Lowe on March 22, and appropriated $10,000 for support. Suel Foster was appointed to the first Board of Trustees and the Charter which was developed included the requirement that horticulture be taught. A site for the college was selected in a prairie west of Ames. When the Morrill Act, the Land Grant College Act, was passed July 2, 1862 and on September 11, 1862 Iowa was the first state to accept provisions of the act and received a grant of over 294,300 acres of Government land."* (quote

from Charles Hall, History page, Iowa State University, Department of Horticulture website: hort.iastate.edu)

1859 Asa Gray published his idea that the North American and Eurasian floras had at one time been homogeneous. He proposed that Pleistocene glaciation had separated the floras and through evolution (a new concept he had learned through personal correspondence with Charles Darwin) the species had become distinct. Gray became Darwin's leading advocate in US debates.

1859 British farming observer James Caird, in his book *Prairie Farming in America*, noted that export of grain through Chicago was about 100 bushels in 1837, 2,243,000 bushels in 1847, and nearly 18 million bushels annually by 1857. (Mingay, 1977)

1859 Charles Darwin published On the origin of species by means of natural selection.... As explained by Darwin, evolution is a simple change in character of a population of either plants or animals. Circumstances governing the success of a population are not neutral, rather the environment favors certain characteristics, which creates a natural system of selection that can lead to changes in the makeup of a population. Gradual change in a population can lead to differences that qualify the population as a distinctive enough to become a new species - thus the "origin" of species. By identifying a mechanism that could lead to the diversity of life on earth, Darwin rewrote the book on relationships of plants and interpretations of plant adaptations. My favorite quotation from Origin: "We have seen that man by selection can certainly produce great results, and can adapt organic beings to his own uses, through the accumulation of slight but useful variations, given to him by the hand of nature. But Natural Selection as we shall hereafter see, is a power incessantly ready for action, and is as immeasurably superior to man's feeble efforts, as the works of Nature are to those of Art." (HNT)

1859 In *A Tale of Two Cities*, Charles Dickens ridiculed French aristocracy through description of the ritual of chocolate consumption: *"Monseigneur could swallow a great many things with ease, and was by some few sullen minds supposed to be rather rapidly swallowing France, but, his morning's chocolate could not so much as get into the throat of Monseigneur, without the aid of four strong men besides the Cook. Yes. It took four men, all four a-blaze with gorgeous decoration, and the Chief of them unable to exist with fewer than two gold watches in his pocket, emulative of the noble and chaste fashion set by Monseigneur, to conduct the happy chocolate to Monseigneur's lips. One lacquey carried the chocolate into the sacred presence; a second, milled and frothed the chocolate with a little instrument he bore for that function; a third, presented the favoured napkin; a fourth (he of the two gold watches), poured the chocolate out. It was impossible for Monseigneur to dispense with one of these attendants on the chocolate and hold his high place under the admiring heavens. Deep would have been the blot upon his escutcheon if his chocolate had been ignobly waited on by only three men; he must have died of two."*

1859 Henry Shaw's Garden (later to become the Missouri Botanical Garden) opened to the public in St. Louis. Mr. Shaw was inspired to develop his garden by an 1851 trip to England, where he viewed the Great Exhibition and the grounds of estates such as Chatsworth, (Missouri Botanical Garden website)

1860 John Gould Veitch sent 17 new species of conifer from Japan to England, as well as seed and plants of other horticulturally valuable stock. His most popular introduction from that trip, however, became Boston ivy, *Parthenocissus tricuspidata*.

1860 In this decade, coffee rust (*Hemileia vastatrix*) infested and destroyed Ceylon's coffee plantations, eliminating 250,000 acres of plantings. By 1867, James Taylor had overseen clearing of 19 acres, which he had planted to Assam tea. By 1875, over 1000 acres were converted, a coverage that grew to 305,000 acres by the end of the century. (Hohenegger, 2007)

1860 Charles G. Williams pyrolized (cooked to the point it broke into smaller components) natural rubber, and discovered it is made of units of a compound he named isoprene (C_5H_8). Eventually, isoprene was discovered to be a significant plant product that is ever-present in the atmosphere. We now understand that sterols are, essentially, sis isoprene units. Indeed, isoprene is produced at a very low level by humans, perhaps in relationship to cholesterol pathways, and is thus present in exhaled breath. (Thomas Karl, et al, 2001, *Human breath isoprene and its relation to blood cholesterol levels: new measurements and modelin*g, J Appl Physiol 91:762-770, pdf on line)

1860 An 1860 report stated that 70,000 weed seed were isolated from 2 pints of clover seed imported from England. (Ennis, in The Yearbook of Agriculture 1962)

1860 E. Douwes Dekker published his novel Max Havelaar under pseudonym. A former Dutch Colonial Officer in Java, Dekker revealed the inhumane treatment of native workers in Dutch East Indian colonies. The resulting arousal of public concern forced governmental reforms. The Dutch held control of Javan and Sumatran spice production until WWII. (Rosengarten, 1969)

1860 Joseph Hooker's *Flora Tasmaniae*, which was published between 1855 and 1860 is dedicated to Ronald Campbell Gunn and William Archer. Of Gunn, Hooker writes: "There are few Tasmanian plants that Mr. Gunn has not seen alive, noted their habits in a living state, and collected large suits of specimens with singulaf tact and judgement. These have all been transmitted to England in perfect preservation, and are accompanied with notes that display remarkable powers of observation, and a facility for seizing important characters in the physiognomy of plants, such as few experienced botanists possess." (Webb, 2003) William Archer, a native to Tasmania, was an architect and amateur botanist and botanical artist.

1861 A new treaty with Japan in 1858 [sic] led to a race by American and European plantspeople to collect and introduce plants from these islands. Field collectors included Carl Maximowicz who sent plants to Russia, Max Ernst Wichura from Germany, and Richard Oldham from the Royal Botanic Gardens at Kew (re. *Bambusa oldhamii*). George Rogers Hall, an American resident of Yokohama, sent a huge shipment in 1861 to Francis L. Lee of Chestnut Hill, MA. Lee went to war and left Francis Parkman, explorer, neighbor, and friend, to curate the growing collection. (Parkman would become Professor of Horticulture at Harvard in 1871). Thomas Hogg (son of a Scottish emigrant and nurseryman, sent to Japan by Lincoln as a US Marshal) shipped plants to his brother, James, as well as to the Parson's firm at Flushing, NY. His introductions included the Japanese stewartia, the fragrant snowbell, the sapphire berry, and the katsura tree. (Spongberg, 1990) [See 1854]

1861 Australian Charles Ledger managed to purchase seed of a Cinchona tree, the bark of which was said to be a good source of quinine. The Dutch purchased a quantity of his seed, using them to establish plantations in Java. Those trees, determined to represent the new species *Cinchona ledgeriana*, yielded bark that was indeed a very good source of quinine, making Java the world's major source of quinine in the first half of the 20th century. (Le Couteur & Burreson, 2003)

1861 Botanist and explorer Charles Parry named several Colorado mountain peaks for active and significant botanists: James Peak for geologist/botanist Edwin James, Engelmann Peak (Mount Engelmann, one of the highest summits in the Front Range of the Rockies) for St. Louis botanist George Engelmann, Grays Peak (the highest summit on North America's Continental Divide) for esteemed botanist Asa Gray, and Torreys Peak for taxonomist John Torrey (Beidleman, 2006)

1861 Louis Pasteur published the results of his trials regarding spontaneous generation (an ancient idea he did not support), in response to a challenge issued by the French Academy of Sciences. The Alhumbert Prize would go to the first person presenting clear proof to support or refute the lingering idea of spontaneous generation (note, the cell theory had already been established, and Rudolf Virchow had already stated (1855) that all cells come from cells). After review by the appointed commission (members of which were Claude Bernard, Adophe Brongniart, Victor Coste, Pierre Florrens, and Henri Milne-Edwards, Pasteur was awarded the prize in 1862. (Raynaud, 2017) NOTE: Pasteur seems to have devised his experiments for the simple purpose of driving a silver spike in the specter of spontaneous generation, which though completely discredited, haunted contemporary cytologists.

1862 Charles Darwin published the first thorough study of orchid pollination, *On the various contrivances by which British and Foreign orchids are fertilised by insects, and on the good effects of intercrossing*.

1862 Joseph Hooker reported on the discovery two years earlier in West Africa of *Welwitschia mirabilis*. He considered this find "the most wonderful, in a botanical point of view, that has been brought to light during the present century." (Desmond, 1987)

1862 George Rogers Hall returned from Japan and brought seed, plants, and Wardian [See 1842] cases of material to Flushing, NY, which he entrusted to the Parsons & Co. Nursery. Included were the kobus magnolia, the star magnolia, zelkova, Japanese maples, wisterias, raisin tree, etc. Also in this shipment was the future weed, Japanese honeysuckle, initially called Hall's honeysuckle. Some of Hall's plants in Yokohama had been obtained from Siebold. (Spongberg, 1990)[See 1823].

1862 Specimens obtained by Jean Pierre Armand David, a Basque in the Lazarist priesthood who moved to China in 1862, form the basis of *Plantae Davidianae*, in which Adrien Franchet of the Museum at the Jardin des Plantes described nearly 1500 new species.

1862 Congress passed a series of bills constituting the US Morrill Land-Grant College Act, which were signed by President Abraham Lincoln. At this same time the US Department of Agriculture was created, having been established earlier as a division of the Patent Office, with head of the division, Issac Newton, continuing as Commissioner. These events set the stage for the first State Agricultural Experiment Stations (those in California and Connecticut in 1875). Over 13,000,000 acres of federal land were given to states to support the establishment of colleges for the agricultural and mechanical arts. By 1900 there were 60 Agricultural Experiment Stations. On 20 May of the same year Lincoln signed the Homestead Act, which opened nearly half of the continental US to settlement. (Baker, in

Ewan, 1969; Rasmussen & Baker, in The Yearbook of Agriculture 1962) In this same year, the Homestead Act (the first of several) was signed into law, This law opened western territories to settlement through granting homesteads of 160 acres to new settlers, who then had five years in which to purchase the land at an incredibly modest price. Over the next seven decades, 1.6 million homesteads would be granted, conferring 10% of the US land area to small farms. (Wikipedia, 2018) Introduction of barbed wire in the following decade enclosed western lands and became part of the short-lived, tragic epoch of open range and trail drives. (Christopher Knowlton, 2018)

1862 Partially to deal with Civil War debt, Congress established a Commissioner of Internal Revenue. One tax collected was on whiskey, beginning at $.20 per gallon in 1863, the tax rose to $2 per gallon by 1865. (Fussell, 1992) [TL 1791, Whiskey Rebellion]

1862 In Portland, Maine, Nathan and Isaac Winslow introduced a method of canning sweet corn, which was a great success for their Winslow Packing Company. The popularity of canned corn would spur further developments, including John Winters' 1884 continuous corn cooker, an improved corn cutter developed by Welcome Sprague in 1888, and steam cooking by John Jennings in 1903. Canning companies moved closer to the Midwest sources of corn, and Hoopeston, Illinois became "the Sweet Corn Capital of tthe World."(Clampitt, 2015)

1863 Wilhelm von Waldeyer is credited with having introduced Hematoxylin (also Haematoxylin) as a biological stain for microtomy, though biologists used "campeche" beforehand. Today, Haematoxylin is used as a nuclear counter-stain in combination with the synthetic dye Eosine Y, a common treatment simply called H & E, which yields nicely-differentiated nuclei and differential staining of tissues (animal). The compound, extracted from wood of the Central American shrubby legume, *Haematoxylum campechianum* (also called logwood or bloodwood) was used by indigenous peoples and had been known and used as a commercial dye in Europe since its introduction in the 16th century. .(I can't afford the level of access, but if you want to pay $44 for a 24-hour rental, go for John J. Gurecki, 1984. "The History of Hematoxylin" Laboratory Medicine, Volume 15, Issue 6, 1 June 1984, Pages 423–425, https://doi.org/10.1093/labmed/15.6.423

1864 Jabez Burns, an English immigrant to the US introduced his self-emptying roaster, designed to evenly roast and then eject coffee beans. With coffee, freshness of the roasted beans was so critical that grocers and individuals acquired raw beans for local roasting. Burns's roaster became popular quickly and offered the capability to standardize this process, leading to the branding and marketing of coffees. (Pendergrast, 1999) Vacuum packaging, which was introduced in the mid-20th century, has mitigated this concern.

1864 George Perkins Marsh published *Man and Nature: Or, Physical Geography as Modified by Human Action*. Having lived in the Mediterranean Basin (as a US diplomat appointed by President Zachary Taylor in 1849), Marsh compiled sufficient understanding to support his thesis, which describes how relentless deforestation gave rise to increasing aridity. Marsh is considered one of the country's earliest conservationists/environmentalists. (McKibben, 2008; Wikipedia, 2017)

1865 Joseph Dalton Hooker became Director of Kew.

1865 Since 1633 Europeans had known of the anti-malarial properties of extracts from the bark of a South American tree, the cinchona. One of many attempts to cultivate the tree yielded success through seed sent by Charles Ledger (from a plant then given the name *Cinchona ledgeriana)* to Europe. Those seed, collected in Bolivia by a native worker (Manuel Incra Mamani), were offered for sale. The British, stung by low-yielding plantations they had established in India, declined the opportunity. Dutch traders, however, purchased a pound of seed that were used to establish a plantation in Java. (It is claimed that the seed produced 12,000 trees.) As a result, the Dutch held near-total control of quinine production for a century. (Lewington, 1990) [See 1658, 1820]

1865 In correspondence published in *The Southern Cultivator*, Joseph Le Conte, owner of Woodmanston (a private botanical garden in Liberty County, Georgia) commented: "While the Northern regions are frozen and blocked with ice, in Georgia we have growing, in the open air that beautiful plant, the Camellia Japonica, and in full bloom on the third day of January, 1865, plants from five to ten feet high, with from thirty to one hundred and fifty flowers of nearly every shade of color, from snow white to dark crimson, present a sight gorgeous and imposing. The single flowered camellias bear seed, which ripen in September, nearly twelve months, therefore, after the blooms, the latter appearing from October to April of the preceding winter. From the seed endless varieties may be obtained." (L.P. Neely in Slosson, 1951)

1866 Gregor Mendel discovered and published the basic patterns of inheritance and his understanding of the hereditary nature of variation between individuals in a population. It is puzzling that Mendel's works, though highly complementary to Darwin's concepts, were not brought forth for general scientific discussion until after 1900.

1866 Eighteen year old Jack Newton Daniel established his distillery in Tennessee. (Fussell, 1992)

1866 The American Wood Paper Company was established in Philadelphia, based on development of techniques for dissolving wood fibers (using caustic soda, i.e. lye) to create the pulp needed for manufacturing paper. The original source of pulp in North America was the poplar, at first *Populus tremuloides* and *P. grandidentata*, later *P. balsamifera*. Poplar remained popular until replaced by the use of spruce. Maine became a major source for poplar, and later for spruce, eventually supporting 25 pulp mills. The pulp craze meant that paper corporations would begin purchasing timberlands from lumber companies. (Connor, 1994) [See 1769; 1840]

1866 Thomas Newton Dickinson constructed a distillery in Essex, Connecticut, to manufacture witch hazel extract. Extracts sold today are 86% distillate and 14% alcohol. The company, still in business, continues to harvest its witch hazel from southern New England. (Connor, 1994)

1867 Through the work of Oliver Kelly, the first Granges (the Patrons of Husbandry, i.e. the Grange) were organized. Kelly had been sent as an agent of the US Department of Agriculture to the South *"to proceed immediately through the States lately in hostility against the Government...the relations ...having prevented this Department from obtaining the usual statistical and other information.*" While on this venture Kelly, according to his own statement formulated *"the idea of a Secret Society of Agriculturists, as an element to restore kindly feelings among the people.*" (Rasmussen, 1960)

1867 On 2 May, Thomas Hanbury purchased La Mortola. In partnership with his botanist brother, Daniel Hanbury, the Italian estate prospered as a significant collection of exotic plants. The estate remained in the Hanbury family until 1960, when it was given to the Italian government. In 1983, La Mortola was transferred to management of the University of Genoa. (Quest-Ritson, 1992)

1867 A turpentine still blew up in Butte County, California when the distiller used pitch from Jeffrey pine (*Pinus jeffreyi*) rather than Ponderosa pine (P. ponderosa). Chemists would later determine that the resin of Jeffrey pine contains the chemical abietin - which is nearly pure heptane. Jeffrey pine resin became a primary source for heptane, which was used to assay gasolines to establish the octane rating. (Arno, 1973)

1867 Crossing of China tea roses with Hybrid Perpetuals yielded ‘La France’, the first Hybrid Tea. (Grimshaw, 1998) [See 1802, 1817]

1868 James Arnold left a portion of his estate in trust and Harvard agreed to establish the Arnold Arboretum.

1868 J. W. Hyatt was awarded a $10,000 prize for his invention of a process to manufacture plastic billiard balls, using a mixture of camphor and nitro-cellulose. (Lewington, 1990) [See 1846]

1868 German chemists Carl Graebe and Carl Liebermann, working for BASF, discovered the formula for alizarin (the red chemical in madder, *Rubia tinctoria*) and were successful in synthesizing this dye from anthracine. Production began, and by 1869 the cost of natural madder in London had dropped by 70% . (Finlay, 2002)

1868 Maria Ann Smith began harvesting fruit from a volunteer seedling apple she encountered on the family farm in Eastwood (near Sidney), Australia. The apple, which proved useful for cooking, was propagated and introduced as ‘Smith’s Seedling’, later christened ‘Granny Smith’s Seedling.‘ In 1890, twenty years after Maria’s death, the apple was introduced at the Castle Hill Agricultural and Horticultural Show. The following year, Maria’s introduction won the Castle Hill prize for cooking apples. (Wikipedia, 2017)

1868 Manuel M. Villarda and other luminaries founded the Sociedad Mexicana de Historia Natural. Disbanded in 1914, the Society was revived in 1936, initiating publication of the *Revista de la Sociedad Mexicana de Historia Natural* in 1939.

1868 *“Sometimes, again, you see them occupied for hours together in spoiling a pretty flower with pointed instruments, out of a stupid curiosity to know what the flower is made of... Is its colour any prettier or its scent any sweeter, when you know?”* Wilkie Collins, The Moonstone.

1869 Pathologist Edwin Klebs introduced paraffin as an enclosing medium for microtomy (Klebs identified the bacterium that causes Diphtheria). By 1881, researchers began to dissolve paraffin in chloroform, which ushered in the era of paraffin-imbedded material for thin-slicing, mounting, and staining. However, paraffin embedding did not become common until 1887, partly due to publications that year by S. Schönland and Jan Willem Moll. (Smith, 1915)

1869 By this year, Leopold Trouvelot appears to have imported the European gypsy moth (*Lymantria dispar*) to Massachusetts, ostensibly in order to experiment with mating that moth to Asian silkworm moths (*Bombyx mori*.) Some of his gypsy moths escaped and established populations that have caused sustained devastation to Northeastern forests. Free-

ranging populations were first observed near the Trouvelot home in Medford by 1881, followed in 1889 by an outbreak of infestations in the township. A year later, infestations were noted in thirty surrounding townships, and in Rhode Island by 1901. Biologists have tracked the spread, which (by 1930) became the most significant tree problem in the Northeast. Its range continued to spread; leading to defoliation of over 12 million acres of forest in 1981. Combating gypsy moth has driven a chain of investigations and interventions, from widespread application of lead arsenate (in the early 1940s), to annual spraying of millions of forested acres with DDT in the 1950s, to early employment of Bt (*Bacillus thuringiensis*), to release of tens of millions of parasites and other natural enemies, to the first production and employment of sex pheromones in forestry. For over a century, gypsy moth (with over 350 known host plants) has caused great devastation in North America, resulting in hundreds of millions of dollars spent on response and research. (Campana, 1999)

1869 John Wesley Powell, a noted geologist and cartographer, (and subsequently director of the US Geological Survey from 1881 to 1894) conducted the Powell Geographic Expedition of the Green River and Colorado River (published in his1878 Report on the Lands of the Arid Region of the United States). Powell's studies of western arid states led to conclusions that rainfall in was insufficient to support extensive agricultural development. His accomplishments are yet more impressive when we understand Powell had lost most of his right arm in the Civil War Battle of Shiloh. Powell's science could not thwart politics of the moment, resulting in tension that led to his 1894 resignation from the USGS. Despite his data and observations concerning western states, the US Congress passed (in 1902) An Act Appropriating the receipts from the sale and disposal of public lands in certain States and Territories to the construction of irrigation works for the reclamation of arid lands, as proposed by Nevada Representative Francis Newlands. This act underwrote establishment of the US Reclamation Service, under the US Geological Survey, within the Department of the Interior (to become the separate Bureau of Reclamation in 1907). The philosophy underlying "land reclamation" was that irrigation projects would impound sufficient water to make the desert bloom. (Wikipedia, 2016; see also: Kevin Burkman, John Wesley Powell and the Arid Empire of the American West, posted 16 May 2014, Rutgers Edward J. Bloustein School of Planning and Public Policy, MCRP Vol.1)

1869 Dmitri Ivanovich Mendeleev published his organizational groundwork explaining the pattern of relationships in the properties of elements, the logic that underlies today's periodic table. Missing from Mendeleev's arrangement were the noble (rare) gases. Beginning with the discovery of helium (named for the sun because its spectral lines was first observed emanating from the sun), the remaining noble gases were soon isolated and given equally interesting names: argon (the lazy one), krypton (hidden), neon (new), xenon (the stranger), and radon (a disintegrative product of radium). (Cobb & Goldwhite, 1965)

1869 Biogeography comes of age with first publication of Alfred Russel Wallace's compilation, *The Malay Archipeligo: The land of the orang–utan, and the bird of paradise. A narrative of travel, with sketches of man and nature*.

1870 Japanese plum (*Prunus salicina*) arrived in the US in 1870 when a Vacaville, CA grower imported it from Japan.

1870 During this decade the 'Red Delicious' apple was discovered in Iowa. The 'Golden Delicious' apple originated on a farm in West Virginia in 1910. (Levetin & McMahon, 1996)

1870 On 4 April, the City of San Francisco acquired land for Golden Gate Park. The park's initial surveyor, William Hall, oversaw the first plans and plantings for the park. His career with the park ended with an forced resignation, when an employee he had dismissed was elected to the state legislature. Later, Hall became the State Engineer. (Taylor & Butterfield, 2003)

1872 The extent of an East India Company customs line workforce in India reached its peak of 14,188 staff. Their role: to maintain and police a customs barrier, from the Indus to Madras - a distance of over 2,000 miles. Formed of plant material with thorns, spines, and prickles (such as jujube, opuntia, and carissa), the hedge ranged from 10-14 feet high and six to twelve feet thick. The formal barrier eventually included 800 miles of living hedge, augmented by hundreds of miles of dried spiny plant material. Initiated in the 1840s, the project endured for almost 50 years. (Moxham, 2002)

1872 Julius Sterling Morton initiated the first US Arbor Day, on 10 April, in Nebraska. Many states and other countries followed this example through proclamation of their own arbor days. The golden anniversary of the Nebraska Arbor Day was celebrated in 1922, with Warren Harding proclaiming 22 April as a national Arbor Day. (Campana, 1999) Today, US Arbor Day is celebrated as the last Friday in April.

1872 Edward Lear published his *Nonsense Songs, Stories, Botany, and Alphabets* in London. Included were playful, nonsense plant names (which he illustrated), such as *Queeriflora tabyöides*, *Tigerlillia terribilis*, and *Manypeeplia upsidownia.* The names and illustrations are available on the internet, through sources such as Project Gutenberg. http://plantcurator.com/edward-lear-nonsense-botany/

1873 Celebrated as the year Eliza Tibbets first planted the seedless navel orange in Riverside, CA. By 1970, the seedless form of the navel orange had been brought to Washington, D.C., from Brasil through efforts of William Saunders. As chief botanist for the USDA, Saunders had grafted plants for distribution. Riverside resident Eliza (Mrs. Luther) Tibbets received two especially successful trees from which propagation material was taken. Her plants may have proven the ultimate source for the entire citrus industry. Though this seedless navel orange had been known in other countries beforehand, the Tibbets plants were christened the Washington Navel Orange, which became the cultivar name for this selection. (Levetin & McMahon, 1996, Ewan, 1969, Farmer, 2013, for most information, see: University of California, Riverside Citrus Variety Collection, citrusvariety.ucr.edu)

1873 Sander built his first greenhouse at St. Albans, England. The Sander firm began a system of tracking orchid hybrid (grex) names that was later institutionalized by the Royal Horticultural Society.

1873 Legislation created Yellowstone, the first National Park. (Morgan in Punch, 1992)

1874 Botanists came later to the game of using biological stains than zoologists. This was especially obvious as aniline dyes made their appearance. Between 1874 and 1881, Dahlia, Eosin, Methyl Violet, Iodine Violet, Safranin, Bismarck Brown, and Methylene Blue were showing up in publications on plant anatomy. (Smith, 1915)

1875 Daniel Peter and Henri Nestlé added condensed milk to chocolate to create milk chocolate. (Levetin & McMahon, 1996)

1875 The first agricultural experiment station in the US was established in Connecticut. After directing that effort for 14 years, W. O. Atwater relocated to Washington, D.C. to become director of the USDA Office of Experiment Stations, established as a result of the Hatch Act.(A. S., in The Yearbook of Agriculture 1962) [See 1887] In 1876, the Connecticut Agricultural Experiment Station would establish the first laboratory for seed testing in the United States. (Busch, et al, 1995)

1876 Benjamin Daydon Jackson published a facsimile of A Catalogue of Plants Cultivated in the Garden of John Gerard In the Years 1596-1599. Accompanying the reprint, Jackson gives his account of Gerard, and the production of Gerard's famous *Herball*. In that account, Jackson credits Gerard with having published (in his Catalogue) one of the earliest listings that can be encountered of live plants in a cultivated garden. It was clear that Gerard was an accomplished gardener who knew and corresponded with many plant specialists. Significantly, Jackson lays waste to the first edition (1597) of Gerard's *Herball*, as rife with plagiarism (the translation of Dodoens from Latin to English having been accomplished by a Mr. Priest, who Gerard does not credit) and misapplication of names. He explains that were it not for intervention and editing by L'Obel, the original publication would have been more faulty by a thousand points. Jackson insists the 1633 edition, edited by Thomas Johnson is "greatly superior in every respect." (Internet Archive/Biodiversity Heritage Library - Source: Missouri Botanical Garden)

1876 Darwin's book *Cross and Self Fertilization in the Vegetable Kingdom* explained the concept of hybrid vigor, stimulating experiments and studies by other scientists. Though the basic concept of hybrid vigor had been discussed by various researchers during the earlier decades of this century, this was the first complete analysis and description. ©. Zirkle in Ewan, 1969)

1876 Courts in England determined that the term Worcestershire Sauce could not be trademarked, thus the Lea & Perrins Company, inventors of this widely-used brew, must always market their product as the "original" sauce. (Wikipedia, September 2017)

1876 Henry Wickham is said to have shipped 70,000 seed of *Hevea brasiliensis* (Rubber Tree) from Brasil to Kew Gardens, which distributed seed to Sr Lanka, Singapore, and Malaysia. At the time, Wickham would certainly have been considered a hero; indeed he was knighted in 1920. Times change. The current Wikipedia (2017) treatment describes Wickham as a bio-pirate who stole rubber tree seed.

1877 British traders sent seed of the rubber tree (*Hevea brasiliensis*) from Brasil to Malaya, followed three decades later by development of Dutch plantations in Sumatra. By 1930 Brasil had lost the rubber market to plantations in Malaya and elsewhere; the work of 150,000 rubber trappers slowly dried up, returning the Amazonian city of Manaus to obscurity. In the 1920s the US company Firestone turned the American near-colony of Liberia into a land of rubber, gaining a concession of 1,000,000 acres from the Liberian government. In 1943 the US dollar became Liberia's currency. (Ponting, 1991) During WWII the US government, recognizing the importance of rubber harvest to the war effort, maintained a staff of plant pathologists in Liberia to help prevent importation of a leaf blight disease from South America. [See 1823, 1839, 1877, 1881]

1877 Frederick William Burbidge was sent to Borneo by James Veitch & Sons to collect orchids and other exotic plants. He met with Peter C. M. Veitch and they went to Kina Balu, Borneo's Sugar Loaf Mountain, returning to England in 1879. The account of this trip was recorded in The Gardens of the Sun.

1877 W. J. Beal, working at Michigan State University (then Michigan Agricultural College) made the first controlled crosses of corn in an effort to increase yield. Later workers would experiment with inbred varieties, devising a system of "double crossing" to produce large quantities of hybrid seed. In 1935 only one percent of US corn came from hybrid seed. Today virtually all corn grown in the US is hybrid, giving increased yields with reduced manpower. (Heiser, 1981) [See 1716, 1761]

1877 Following up on Louis Pasteur's studies of yeast fermentation, German physiologist Wilhelm Kühne applied the word "enzyme" to the chemical agent of fermentation. In 1897, Eduard Buchner demonstrated that the extracts from yeast cells would support fermentation. Buchner determined this was due to an enzyme that breaks down sucrose, which he named zymase. (Wikipedia, 2018)

1877 Zeiss manufactured the first production oil immersion lens, which allowed cytologists to explore detail at the very limits of normal light microscopy. The maker specified Canadian balsam diluted with alcohol as the immersion fluid. Author Jim Solladay (https://www.smecc.org/history_of_oil_immersion_lenses.htm) provides a comprehensive history of different kinds of immersion lenses (including water immersion), tracing the concepts back to 1678, when noted: "'...that if you would have a microscope with one single refraction, and consequently capable of the greatest clearness and brightness, spread a little of the fluid to be examined on a glass plate, bring this under one of the globules (lenses), and then move it gently upward till the fluid touches and adheres to the globule".

1877 Working as a professor at the University of Basel (Switzerland), Wilhelm Pfeffer published *Osmotische Untersuchungen: Studien Zur Zellmechanik* (Osmotic Investigations: Studies on Cell Mechanics) demonstrates aspects of cellular osmotic process that explain internal cell pressure. The book introduces his device, the "Pfeffer Cell" (a terracotta urn coated with an artificial internal membrane), which was based on Moritz Traube's creation of artificial membranes using copper ferrocyanide. Using his devise, Pfeffer could calculate that height of water in a column that would counteract movement of water into a his "cell" when it was filled with a concentrated solution. The water column translates into an understanding of water (i.e. osmotic) pressure. (Wayne, 2009) & (Sara Parker, 2017. Osmotic Investigations: Studies on Cell Mechanics (1877) by Wilhelm Pfeffer," The Embryo Project Encyclopedia, Search Keyword: Pfeffer Cell. https://embryo.asu.edu/pages/osmotic-investigations-studies-cell-mechanics-1877-wilhelm-pfeffer)

1878 Charles Curtis was sent by James Veitch & Sons to Mauritius and Madagascar to collect plants. He sent back *Angraecum sesquipedale*. (Reinikka, 1972)

1878 Luther Burbank relocated from Massachusetts to Santa Rosa, CA to continue his plant breeding program. (Ewan, 1969)

1878 Of weeping tree forms, Vick's Monthly Magazine commented: "Drooping trees we do not admire. An occasional specimen as a curiosity, is well, but a lawn abounding in Weeping Trees would be a sorry place." (Adams, 2004)

1878 Based on a new Hungarian mechanical process, the Washburn experimental flour mill in Minneapolis marked the beginning of modern milling in the US.

1878 John Wesley Powell completed the *Report on the Lands of the Arid Region of the United States* for the US Department of the Interior. The report predicts widespread irrigation in stating "all the waters of the arid lands will eventually be taken from their natural channels." The report suggested establishing political boundaries based on watersheds. (McKibben, 2008)

1879 Rudolphe Lindt devised conching, a method of improving smoothness and flavor in chocolate. (Coe and Coe, 1996)

1879 Capitalizing on Henri Nestlé's invention of powdered milk, Daniel Peter fabricated the first milk chocolate candy bars. (Coe and Coe, 1996)

1879 Through the effort of E. F. Babcock, the Mississippi Valley Horticulture Society was formed. One of the first achievements of that organization was a national meeting of fruit-growers, held in St. Louis in 1880. Convergence of these kinds of associations eventually led to founding of The American Horticulture Society. (Mirian Hardin in Slosson, 19510

1879 The chestnut tree in Cambridge, Massachusetts, under which Longfellow's village smithy stood, was felled to widen Brattle Street. A chair made from the wood was given to the poet on his 72nd birthday. Subsequent analysis of that chair indicated the tree was really a horse chestnut (a native to Europe,) not at all closely related to the American chestnut most readers would have imagined. (Rupp, 1990)

1879 Eduard Tangle was the first person to describe and report the presence of intercelluar connections now called plasmodesmata. He made the discovery while studying cotyledons

and other embryonic tissue of the tropical vine *Strychnos nux-vomica*. (Morton, 1981, plus WWW sources)

1879 William James Beal initiated the longest running trial in plant science (at Michigan State University), storing 50 seed each of 21 different plant species in bottles of sand, which were buried. Initially one bottle was exhumed (from which the seed were sown) every five years, but the remaining few bottles are on a 20 year cycle. The most recent recovery and planting was in 2000, and the next will be in 2020, leaving four cohorts to carry the trial to the year 2100. (Wikipedia)

1879 Because maize (and pollenta) had become such an important component of certain regional Italian diets (mainly Venice and Lombardy), pellagra became a serious nutritional disease, though the relationship of niacin-deficiency and maize was not clear untion 1937). People suffering from the symptoms were, in Italian, called "pellagrosi." In response to this worsening situation, on 1 September, Italian agricultural authorities initiated a program to: ""study the pellagrosi and the condition of the farming classes" (Monica Ginnaio, 2011. "Pellagra in Late Nineteenth Century Italy: Effects of a Deficiency Disease", in *Population*, 2011/3, Vol. 66)

1880 Farmers began to cure tobacco using clean hot air rather than the smoky air of charcoal fires, thus producing a milder, more popular form of tobacco. (Simpson, 1989)

1880 In this decade over 25% of sailors in the Japanese Navy developed beriberi - the nutritional disease resulting from insufficient quantities of the vitamin thiamine. An expanded diet corrected the disorder, but not until several years later did C. Eijkman, a Dutch physician working in the East Indies, demonstrate that a diet of brown rice - as opposed to white rice - prevented the disease. Beriberi had become more common because of the introduction of improved polishing techniques that removed the brown outer layers of the rice grain in which thiamine occurs. (Levetin & McMahon, 1996)[See 1886]

1880 For decades, German importers gained increasing control of markets in natural dye sources. BASF (the Baden Dye and Soda Company) had achieved control of indigo, a dye produced principally in India. By 1880, after much work, Adolf von Baeyer and his laboratory successfully synthesized indigo. The strength of this industry quickly galvanized, and in 1890 German exports of dyes accounted for 90% of the world's supply. In 1914 German companies formed a color cartel, known as I. G. Farben (interessen Gemeinschaft Farben) that soon expanded into the production of fine chemicals and pharmaceuticals. (Cobb & Goldwhite, 1995) [See 1856]

1880 *Pharmacographica* - A history of the principal drugs of vegetable origin, met with in Great Britain and British India - was published by Friedrich Flückiger and Daniel Hanbury, Their work marks the end of purely natural sources (plant materia medica) for medicines, as the emergence of synthetic organic chemistry increasingly led to synthetic compounds (having essentially begun with synthesis of urea from inorganic materials by Friedrich Wohler, in 1828).

1880 Rev. W. Wilks, of Shirley parish in Surrey, England, marked a poppy in his garden with white edging on the petals. By selecting from among generations of seedlings derived from that original plant, Wilks produced the Shirley strain of poppies, whose orange, pink, and white flowers lack the red and black coloration characteristic of the corn poppy (*Papaver rhoeas)* from which they were derived. (Grimshaw, 1998)

1880 Lincoln School of Agriculture (Canterbury College, University of New Zealand) opened, establishing itself as the first school of agriculture in Australasia. (Brooking & Pawson, 2011)

1881 H.F.C. Sander established his new 4-acre orchid nursery near St. Albans, England. By 1886 records show that 340 cases of Cattleya were received from South America in February and March alone. *"Sander did more to popularize orchids than nearly any other grower of the time, bringing them within financial reach of persons of modest means."* (Reinikka, 1972)

1881 The loganberry was introduced to commerce by James Logan from his garden in Santa Cruz County, CA. (Ewan, 1969)

1881 As early as 1858 Asa Gray had commented on the problem of differing colored grains of corn, the coloration due to pigments in the endosperm. In 1881, prior to scientific understanding of double fertilization, Focke applied the term "xenia" to the obvious effects of pollen on the endosperm. (Zirkle in Ewan, 1969)[See 1899]

1881 John Boyd Dunlop acquired the patent for a hollow tire made of rubber and cloth. From this point, tires became the major use of natural rubber. (Lewington, 1990) [See 1823, 1839, 1877]

1881 Famed bacteriologist and pathologist Robert Koch introduced his "plating" technique for culturing bacterial colonies on nutrient media gelatinized with agar agar. We continue to benefit enormously from this technique, but Koch's association was lost over the years. The curator of his Hygiene Institute, Richard Julis Petri, however fared much better in

name recognition through near-universal adoption of the bivalve culture vessel he championed, the Petri dish. (Magner, 2002)

1882 Bordeaux University professor Millardet noticed that the copper sulfate spray applied to grapes (to discourage children from eating the fruit from the orchards) deterred downy mildew. By adding lime, which caused the copper to precipitate and stick to the leaves, he invented Bordeaux mixture - one salvation of the French wine industry and an important early fungicide. (Langenheim & Thimann, 1982)

1882 Adalbert Emil Walter Redliffe le Tanneux von St. Paul-Ilaire (known as Baron Walter), Governor of the Usambara District of German East Africa, collected seed and plants of a small herb which were sent to his botanically-inclined father, who forwarded them to Hermann Wendland, Director of the Berlin Royal Botanic Garden. Wendland cultivated the plants and recognized them as representing a new species in a new genus, i.e. *Saintpaulia ionantha*. In the generic name. Saintpaulia he recognized the father and son; the specific name he assigned means violet (Gr. *ion*) flower (Gr. *anthos*). In Germany these plants still bear the common name Usambara veilchen, in English they are called African violets. In their native Usambara cloudforests, the plants are threatened with extinction. (Grimshaw, 1998) [See 1925]

1882 Gottlieb Haberlandt first used the term “kranz” to describe the anatomy of bundle sheaths in leaves of *Cyperus longus*. (Haberlandt G.. 1882. Vergleichende Anatomie des assimilatorischen Gewebesystems der Pflanzen. In N. Pringsheim [ed.], *Jahrbücher für Wissenschaftliche Botanik*, vol. 13 121-124 Wilhelm Engelmann, Leipzig, Germany.) Note: In Wikipedia, the date is given as 1904, based on Haberlandt, G. 1904. *Physiologische Pflanzanatomie*. Engelmann, Leipzig, in studies of Sugarcane, as cited in the Wikipedia entry on Photosynthesis.

1882 Regarding New Zealand’ “being transformed into Britain’s farm” (*Seeds of Empire*, Chapter 2, The Contours of Transformation, and Chapter 8, Flows of Agricultural Information): “The signal event was the first shipment of refrigerated meat, butter, and cheese to London in 1882.” By 1911, over 20,000 farmers specialized in “fat lamb farming.” The growth of grazing livestock led New Zealand’s conversion of forest, bush, and swamp to pasture. (Brooking & Pawson, 2011)

1883 Viscount Itsujin Fukuba built the first greenhouse (9 x 36 ft) in Japan and imported a collection of tropical orchids from England and France. (Reinikka, 1972)

1883 Addis Ababa became the Ethiopian capital. Within twenty years, the surrounding zone, 100 miles in radius, was stripped of trees for charcoal production. (Ponting, 1991)

1883 A. F. W. Schimper coined the term chloroplastids (chloroplastiden), which was contracted the following year by Eduard Strasburger as chloroplasts. The first person to describe them, von Mohl had called these *chlorophyllkörnen*, i.e. grains of chlorophyll.

1884 As the fallout of a series of conflicts to control coastal areas and the Chincha Islands (where huge deposits of guano could be harvested for sale to Europe for use in agricultural fertilizers), Chile was ceded control of coastal areas in a truce with Bolivia. Hostilities had been initiated by Spain in 1864, generating the shifting accords and alliances that left Bolivia landlocked. (Ponting, 1991). Saltpeter (sodium nitrate) was extracted from guano and used in various industrial chemical processes, from creating fertilizers, to formulating sulfuric and nitric acids, to manufacturing gunpowder. Final sovereignty over the coastal areas was codified in the 1904 Treaty of Peace and Friendship.[See 1843]

1884 An assistant to Sigmund Freud touched purified cocaine to his tongue and discovered a numbing sensation that led to its use as a local anesthetic. Later, a similar chemical compound was produced synthetically, procaine (commonly called by its trade name Novocain), which has replaced cocaine for anesthesis. (Simpson, 1989)

1884 Kate Greenaway, author of children’s books, published her Language of Flowers, one of the more popular dictionaries on this topic.

1884 The new edition of Miller’s Dictionary (OED) included *Aeschynomene*, the pith hat plant of India. By that time, the pith of this leguminous tree had been used for nearly two decades to construct hats, which were then covered with white cotton cloth and lined with green cloth. Lightweight and durable, the pith helmet achieved icon status. (Lewington, 1990)

1885 Sponsored by the Royal Horticulture Society, the first Orchid Conference was held in England. (Reinikka, 1972)

1885 By 1901, Ludwig Karl Martin Leonhard Albrecht Kossel had isolated, described, and named the five nucleobases in nucleic acids - adenine, cytosine, guanine, thymine, and uracil.

1886 John S. Pemberton created Coca-Cola, a beverage using water (later carbonated water), caramel, kola nut, sugar, vanilla, cinnamon, lime, and coca leaf extractions. By 1903

the makers began purging the coca leaf extract of its cocaine component before adding it to the syrup. (Levetin & McMahon, 1996)

1886 The Dutch government began a study of beri-beri, a disease that was devastating the native Indonesian population. Christian Eijkman was assigned the task of studying the "germ" thought responsible. When his laboratory chickens developed symptoms, Eijkman observed that a temporary diet of pure white rice coincided with the disease. Studies led to the culprit - the truncated cone rice mill - which so thoroughly polished the bran from rice as to remove some vital quality [See 1880, 1912], later determined by R. Williams to be thiamine, vitamin B_1. (Visser, 1986)

1887 The Hatch Act established a yearly grant to support an agricultural experiment station in each state. (Rasmussen, 1960) Within ten years stations across the country were engaged in basic research. The experiment station system became the basis for the US Agricultural Extension service. [See 1862, 1875, 1906]

1887 John McLaren began his career as Director of Golden Gate Park. When asked one year what he wished for his birthday, it is reported he said: "100,000 pounds of barnyard manure." Over his career, McLaren not only composted a lot of manure, he also introduced thousands of exotic plants to the landscape and oversaw the real development of this famous landscape. McLaren headed the park for fifty-six years. (Taylor & Butterfield, 2003)

1888 Eduard Strasburger showed that reductive division occurs in both pollen mother cells and embryo sac production. This significant observation was one highlight of more than two decades of productive cellular study, resulting in descriptions of the mitotic process, cell wall formation, and constancy of chromosome number, and led to his conclusion that haploid and diploid phases accompany the morphological changes Hofmeister had described in alternation of generations. (Morton, 1981)

1888 USDA entomologist Charles Valentine Riley guided introduction of the Australian Vedalia Beetle (*Rodolia cardinalis*) to control a pest threatening California citrus. Earlier, Riley had been instrumental in sending predaceous mites to France for control of grape infestations. For his work, Riley is sometimes called the Father of Biological Control. (USDA ARS Timeline; Wikipedia, 2015)

1888 Louis Carpenter was appointed as professor at Colorado Agricultural College (Colorado State University today), where he organized the first US program in irrigation engineering, the same program in which it is reported Elwood Meade developed and taught the first such class. Carpenter's papers constitute a special collection in the Colorado State University Library. (Wikipedia, 2016)

1888 Working with extracts from *Ricinis communis* (Castor Bean), Peter Hermann Stillmark isolated ricin, a very toxic hemagglutin. Soon after, abrin (another hemagglutin) was isolated from *Abrus precatorius* (Jequirity Bean) Because these proteins were originally extracted from plants, they are also called "phytoagglutinins." (Sharon Nathan and Halina Lis, 2004. "History of lectins: from hemagglutinins to biological recognition molecules" *Glycobiology*, 14 (11) 53–62.) [See TL 1954]

1889 Heinrich Gustav Reichenbach died (b. 3 January 1823) in Leipzig, Germany, leaving his orchid herbarium to the Vienna museum with instructions that it should remain closed for 25 years. Because the British had expected his collection to go to either Kew or the British Museum, this action, clearly designed to thwart upcoming British orchid taxonomists, caused an uproar.

1889 *Amorphophallus titanum*, a gigantic aroid from Sumatra, flowered for the first time in cultivation at Kew.

1889 The Pajaro Valley Evaporation Company of Watsonville, California, began small-scale production of dehydrated onions. In 1950 tins of their product, still usable, were discovered in Skagway, Alaska. (Rosengarten, 1969)

1889 The US Department of Agriculture was elevated to cabinet status. The now Secretary of Agriculture had 488 employees and a $1.1 million budget. By 1912 this Department had 13,858 employees and a $20.4 million budget. (This included reallocation of other departments, such as the weather service, to the new cabinet.) (Rasmussen & Baker, in The Yearbook of Agriculture 1962)

1889 Richard Altmann was the first to use the term "nucleic acid" instead of the earlier term nuclein. (Wikipedia)

1890 Thomas Lipton, while on a journey to Australia, ended his trip in Ceylon, where he purchased four failed coffee plantations (5,500 acres) and began his own tea business, with the slogan: "Direct from the garden to the teapot." (Hohenegger, 2007)

1890 A St. Louis physician formulated peanut butter as a food for invalids. In 1893 J. H. Kellogg (health food faddist famous for breakfast cereals) made peanut butter for patients with poor teeth. (Heiser, 1981)

1890 Rui Barbosa ordered the burning of Brasilian governmental papers relevant to the slave trade and slavery. This act followed the abolition of slavery in 1888. During over three centuries, approximately 4,000,000 black African slaves were imported to Brasil. By 1870 there were 1,500,000 slaves in that country. (Thomas, 1999)

1890 British military officer Hamilton Bower acquired birchbark manuscripts (related to ayurvedic medicine) taken from the ruins of an ancient Buddhist monastery near the border of Kyrgyzstan and China. The original collection was sold to Oxford's Bodleian Library. Translations cover many topics, including prohibition against eating garlic as well as methods to skirt the rules: "When a cow has been kept waiting for three nights with almost no grass, one should give her a preparation made of two parts grass to one part garlic stalks. A Brahmin can then partake of her milk, curds, ghee, or even buttermilk, and banish various diseases while maintaining propriety" (Block, 2010 - copied from Dominik Wujastyk, The Roots of Ayurveda - Selections from Sanskrit Writing)

1890 Hugo de Vries began examining a population of *Oenothera lamarckiana* near Hilverson. He planted an extensive cohort of Oenothera seed from the wild, which he maintained in cultivation over several generations. Among the progeny, he noted several hundred variants, which botanists would normally call sports. In his publications (1901-1903) describing the variation observed, de Vries noted many curious variants. Darwin would have called them sports, but de Vries decided to apply the term mutants, a Latin term for change. (Mukherjee, 2106)

1890 In his book, *Die Elementarorganismen*, Richard Altmann described bioblasts, cell components we know today as mitochondria. He understood they existed somewhat independently, even reproducing on their own. Unfortunately, that observation was denied by the next generation of researchers, and decades would pass before their self-sustaining nature became clear. (*Die Elementarorganismen und ihre Beziehungen zu den Zellen.Veit*, Leipzig) Many authors cite his description of bioblasts from earlier publications, as early as 1886.

1891 Eduard Strasburger (Germany) felled an oak that was 22 m tall, after which he soaked the cut trunk base in picric acid. The acid permeated the entire tree, killing all cells in the trunk, branches, and leaves. Following that treatment, Strasburger filled the vat with water and red dye (eosin) and documented that the red dye still made its way from the base into leaves - even though the tree was completely dead. Results demonstrated the continuity of water in a tree, and the importance of purely-physical structure in movement of water from the base to the top of trees. (King, 2011)

1891 A US forest reserve law established the basis for the National Forest System. The basis for this act was built through professionals (such as Bernard Fernow) who were hired into the new forestry division in the US Department of Agriculture. (Campana, 1999)

1891 Lead arsenate was introduced as an insecticide in the battle against Gypsy Moth (Campana, 1999)

1891 Ravenstein estimated Earth's carrying capacity at 5.994 billion people based on 73.2 million square kilometers in fertile lands (supporting 80 people per square kilometer), 36 million square kilometers of grasslands (supporting 3.9 people per square kilometer), and 10.9 million square kilometers in desert (supporting 0.4 people per square kilometer.) (Cohen, 1995)

1891 US Department of Agriculture scientist Newton B. Pierce arrived in Anaheim, CA, with the mission to investigate a mysterious disease afflicting wine grapes. The disease was first noticed in 1885, impacting area vineyards (which had been established through formation, in 1857, of the Los Angeles Vineyard Society, a consortium that guaranteed each investor a given acreage planted to grapes.) Damage spread quickly, such that 25,000 acres of vineyards in Southern California had been destroyed by the time Pierce arrived. His conclusions were published the following year as: *The California Vine Disease: A Preliminary Report of Investigations*, recognizing the disease but providing no conclusions as to the cause. By 1935, the still-mysterious infection was named Pierce's Disease, but only in 1974 was it determined Pierce's disease was caused by the bacterium *Xylella fastidiosa*, which is transmitted by leafhoppers. (Penny, 2017)

1892 Charles Sprague Sargent traveled to Japan to open the Arnold Arboretum's first Asian mission.

1892 On 28 September, the first Corn Palace in Mitchell, SD opened to the public. Conceived as successor to the series of palaces that had been built in Sioux City, IA (beginning in 1887) the Mitchell building was made permanent in 1921 and is the only extant example of a "palace of the product of the soil." (Fussell, 1992)

1892 Farmers first became aware that the boll weevil had crossed the Rio Grande River into Texas cotton fields, within a decade threatening destruction of the US cotton industry. USDA investigations were begun in 1894 and a culturally based approach to the problem was proposed by 1897. [See 1906] (Rasmussen, 1960)

1892 The first gasoline powered "tractor" was built by John Froelich of Froelich, Iowa. [See 1903] (Rasmussen, 1960) Froelich built his device by mounting a gasoline engine to a wood and steel frame (of a steam traction engine). Weighing about 9,000 pounds, his 30 horsepower gasoline traction engine still weighed much less than an equivalent steam device. (Schlebecker, 1975) The following year the Waterloo Gasoline Traction Engine Co. was founded, based on Froelich's work. The company did not move directly into production of equipment, but worked for many years on gasoline engines as the Waterloo Gasoline Engine Company. Waterloo eventually returned to the manufacture of working tractors, but by that time Hart and Parr [See 1902] had introduced the first commercial, gasoline powered tractor. Waterloo was purchased by Deere and Co. in the 1920's. (Williams, 1987)

1892 John Burroughs wrote to a Nature Club in Indianapolis, IN:

My Dear Young Friends:

.....Do not forget Wordsworth's lines in his Poet's Epitaph on "a fingering slave, one that would peep and botanize upon his mother's grave." I speak in this way because i fear that when you grow older, and the cares of life begin to press upon you, you will feel that you have exhausted nature and that you will give no time to the fields and woods. Keep your love fresh and eager, and remember that to love nature is better than to know her; in other words, your knowledge must first of all have a background of love. Name the birds and flowers, but do not think they are all there in your dead specimen. ...Hoping your love for nature will never grow dim, I am, John Burroughs" (from Charity Dye, 1903, *Letters and Letter Writing as Means to the Study and Practice of English,* cited from Google Books)

1892 New Zealand created its Department of Agriculture, which became the Ministry of Agriculture in the 1970s. (Wikipedia, 2017)

1892 John Garton (along with his brother Robert, having formed the firm of J. & R. Garton) introduced a selection of oats named 'Abundance' - which we may consider the first large scale introduction of a hybrid crop plant. (Wikipedia, 2018)

1893 Milton Hershey (who manufactured caramel candies) attended the World's Columbian Exposition in Chicago, where he encountered Lehmann and Co. chocolate machinery in operation. He purchased the demonstration equipment and began manufacturing his own chocolate to coat the caramels. Later Hershey sold the caramel business, purchased a farm in Derry Township, PA, and began his famous chocolate empire. (Coe and Coe, 1996) The characteristic flavor of Hershey chocolates originated with a tendency to caramalize the included milk products.

1893 At the same Chicago World Exposition, Charles Cretor introduced his steam-powered cooker (peanuts, chestnuts, coffee, and popcorn) for purchase, laying the foundation for decades of modifications and improvements that established a commercial market for popped corn. (see company history at https://www.cretors.com/).

1893 Charles Reid Barnes introduced the term "photosynthesis." (Wikipedia: see Howard Gest, 2002, History of the word photosynthesis and evolution of its definition, Photosynthesis Research, 73(1): 7-10.)

1893 Initial presentation of the Glass Flowers to Harvard University (created under the guidance of Harvard Professor Ware by artists Leopold Blaschka and his son, Rudolph). The glass flowers provided full scale models for teaching about the diversity of plants, but also included examples of important diseases as well as replicas of internal anatomy. (Ewan, 1969)

1893 Reid's Yellow Dent Corn gained the grand prize as "the world's most beautiful corn" at the World's Columbian Exposition in Chicago. Reid's corn became a major force in Midwestern agriculture and an important parent to modern hybrids. (Fussell, 1992)

1893 A Supreme Court decision, written by Justice Horace Gray, declared the tomato to be a vegetable, based on common usage of the word "vegetable" as opposed to the word "fruit." Thus tomato importer, John Nix, was required to pay a 10% vegetable tariff on a shipment of tomato fruit (now honorary vegetables) from the West Indies. (Levetin & McMahon, 1996; see quote from decision on page 88) Botanical Note: A tomato originates as the ovary, in the pistil of a tomato flower. Following pollination and fertilization, the ovary matures into a fruit. One can grow seedless tomatoes by treating the flowers with hormones that promote fruit development without pollination. But whether seedless or not, to a botanist, the tomato is a fruit. Perhaps any part of a plant could be called "vegetable" - but botanists define vegetation as leafy, non-sexually reproductive parts of plants.

1894 New Zealand's Tongariro National Park Act designated land surrounding and including the three volcanic peaks of the the North Island as the country's first real national park. Leader of the Ngāti Tūwharetoa people, Te Heuheu Tukino IV, had deeded the peaks to the government for that purpose in 1887. (Pawson & Brooking, 2002) The original gift (the first by indigenous peoples) included 2,640 hectares, establishing the world's fourth na-

tional park. Today, the park includes 7,596 hectares. (New Zealand Department of Conservation website, 2017)

1895 Danish scientist Johannes 'Eugen' Warming published his *Oecology of Plants* (*Plantesamfund*.) Basing his ecological system on water use and plant growth form, he essentially founded the modern methods of descriptive plant ecology. The terms xerophyte, mesophyte, hydrophyte, monocarpic, and polycarpic date from his usage. (Isely, 1994)

1895 Using light microscopy, Garnier first observed intracellular membranous material he called ergastoplasm. In 1953 [TL], Porter's studies using electron micrographs detailed membranes as components of the ergastoplasm, which he named endoplasmic reticulum. That study was a follow-up of 1945 observations of a "lacelike reticulum... , possibly the homologue of kinoplasm." [See TL 1953, Porter...]

1896 Hirase and Ikeno published their discovery of motile sperm in Ginkgo and Cycas. (Bold, Alexopoulos, & Delevoryas, 1980)

1896 The New York Botanical Garden was established, following legislation drafted in 1891.

1896 The standard impatiens (*Impatiens walleriana*) was introduced from East Africa. Because the plant came from the territory of the Sultan of Zanzibar, it also received the name *Impatiens sultani*, which is now considered synonymous to *I. walleriana*. (Grimshaw, 1998) For decades these plants were known by the common names of busy lizzies in some areas and sultanas in others. In North America today they are simply called impatiens. (Grimshaw, 1998)

1897 The US Government passed the Tea Importation Act, which was the first law to regulate food products. (USDA Website, Agricultural Service Timeline)

1897 The USDA section on Seed and Plant Introduction was formed, with David Fairchild as the "Explorer in Charge." (Camp, Boswell, & Magness, 1957)

1897 Having discovered major improprieties in bourbon production, the U. S. Congress passed the Bottled-in-Bond Act, controlling bourbon production at the source and setting standards for proof and aging. (Fussell, 1992)

1897 As an agricultural explorer out of the Department of Horticulture at South Dakota State College, Niels Ebbesen Hansen collected plants in Russia. In later recollections he noted: *"...the camels and other livestock seemed well nourished. The reason was this native grass called 'Gibniak' by the native settlers. I brought the first samples to America; in fact, I collected it in many other places including west Siberia. In America it is called crested wheat grass. Some believe this grass will ere long cover hundreds of millions of acres of dry prairie regions, in western states from eastern Oregon and Washington eastward through the western half of the Dakotas and south into Kansas."* (M.H. Davidson in Slosson, 1951)

1897 Wilhelm Pfeffer established the term "photosynthesis" - replacing the previously applied phrase "carbon assimilation". (Krishnamurthy, 2002)

1897 The mail order catalog for Sears Roebuck offered a hypodermic syringe kit, which included two doses of cocaine or morphine at a price of $1.50. (Filan, 2011)

1898 Wheat rust is said to have cost the US $67,000,000. By 1904 significant research programs were established to determine control measures. German scientist H. de Bary had detailed the life cycle of wheat rust, but it was not until 1917 that sufficient study existed to support a barberry eradication program, which was first legalized in North Dakota. (Ewan, 1969)

1898 Gifford Pinchot, Yale graduate and forest manager at Biltmore, was appointed head of the U.S. Division of Forestry. This agency was moved to the Department of Agriculture as the Forest Service in 1905. Pinchot was dismissed by President Taft during a controversy with the Secretary of the Interior over leasing of mineral rights and other issues. Pinchot later became governor of Pennsylvania and subsequently a professor of Forestry at Yale. (A. S. in The Yearbook of Agriculture, 1962)

1898 - George Schenck, a German Forester, was hired by George Vanderbilt to replace Gifford Pinchot. With Vanderbilt's support, by 1 September of that year he had established the Biltmore School of Forestry, the first forestry school in the US. By 1909, Schenck had left his job at Biltmore and the school was dismantled. Much of the forest lands of the extensive Biltmore estate are part of Pisgah National Forest today, where some of the original school structures remain as part of the "cradle" of American forestry. Cornell University's New York School of Forestry opened just a few weeks later this same year, thus giving that program the distinction as the first professional school of forestry in the US. Unfortunately, New York's Governor defunded the school in 1903 due to controversies over state forestry practices. A new school of forestry was established through legislative action in 1911, with a conservation mandate. (Wikipedia, 2016)

1898 The Bayer Company introduced heroin as a substitute for morphine and codeine. By 1917 this drug was found to be greatly addictive and its use in over-the-counter cough syrups was discontinued. (Levetin & McMahon, 1996) The logic for developing this drug, chemically known as diacetylmorphine, came from the earlier Bayer success at converting salicylic acid to aspirin - which involved replacing hydroxyl groups (-OH) with acetyl groups (CH_3CO). Making two such substitutions on morphine yielded a more active/effective compound, thought to be more useful medicinally, and thus termed heroic. (Le Couteur & Burreson, 2003)

1898 Russian botanist, S. G. Navashin, discovered and described triple fusion, a phenomenon common to flowering plants in which the second generative nucleus of the pollen fuses with the polar nucleus (nuclei) of the embryo sac. (Morton, 1981)

1898 Carl Benda named mitochondria in Arch. Anal. Physiol 393-398 (Lars Ernster and Gottfried Schatz, 1981. "Mitochondria: a historical review" *J Cell Biol.*: 91(3): 227–255. PMCID: PMC2112799; PMID: 7033239 (http://doi.org/10.1083/jcb.91.3.227s

1898 This appears to be the year in which Theodore Hudnut and his son Benjamin first produced and sold corn oil as a commercial product called Mazoil. The mazoil was pressed in mills they modified (for corn) and operated at their Hudnut Hominy Company in Terre Haute, Indiana.

1899 The holdings of Minor Cooper Keith (the American builder of an 1871 Costa Rican railroad and subsequent planter of bananas) were merged with the Boston Fruit Company to form the United Fruit Company. By 1981, half of all world banana exports came to the US. (Heiser, 1981)[see 1804]

1899 At his Centerville Plantation (South Carolina) cotton farmer E. L. Rivers successfully isolated a strain of Sea Island cotton that resisted Cotton Wilt and produced quality lint (cotton "fibers") Working with USDA agent W. A. Orton, Rivers created a seed supply purchased and distributed (as the Rivers strain) by USDA in 1903. Rivers and Orton also developed a second strain called Centerville. (J. O. Ware, Plant Breeding and the Cotton Industry, USDA https://naldc.nal.usda.gov/download/IND43893529/PDF)

1899 Founding of the American Society of Landscape Architects. Beatrice Farrand (wife of the first Director of the Huntington, Max Farrand) was a founding member. (Adams in Punch, 1992)

1899 William Orton was sent to the South Carolina coastal islands by the US Department of Agriculture to investigate cotton wilt, a fungal disease. Orton learned that local grower Elias Rivers had cotton plants resistant to the disease, and had been saving the seed. By 1900 Orton had published the earliest report on the value of selective breeding for crop resistance. (Rasmussen, 1960)

1899 The USDA, State Land Grant Colleges, and other agencies cooperated to begin a national Soil Survey. (Kellogg, in The Yearbook of Agriculture 1962)

1899 Navaschin described double fertilization, explaining the problem of xenia as well as establishing yet another distinction between flowering plants and gymnosperms. ©. Zirkle in Ewan, 1969) [See 1881]

1899 In his book *El porvenir de las nations Hispano-Americanas* (The Future of the Hispanic-American Nations), Francisco Bulnes represented humankind in three groups, the people of maize , the people of wheat, and the people of rice, promoting the conclusion that *"the race of wheat is the only truly progressive one,"* and *"maize has been the eternal pacifier of America's indigenous races and the foundation of their refusal to become civilized."* This opinion supported contemporary ideas that devalued the level of Indigenous American peoples. In recent times, Bulnes is regarded as a racist, in the words of historian Daniel Cosio Villegas, *"one of the most evasive, designing, and deceitful writers that Mexico has ever produced."* (Cotter, 2003; Wikipedia, 2017 entry on Bulnes)

1900 At the brink of the 20th century, world population had reached nearly 1.6 billion. Slavery in the United States, an institution born of cotton, rice, coffee, and sugar production, had been abolished for less than forty years. Women could not yet vote. The continents were conceptually fixed, in static perfection achieved at the creation several thousand years before. Light microscopy was the limit of our ability to resolve cellular structure. Scientists recognized simply two kingdoms of living beings and about 100,000 species of plants. We could list 10 essential plant elements, and remained convinced that oxygen produced during photosynthesis was derived from CO_2. American chestnut dominated the mixed mesophytic empire. There were 5 daylily cultivars. And the entire realm of genetics and genomics was about to explode.

1900 In a short period, three scientists, individually, Hugo de Vries, Carl Correns, and Erich von Tschermach published papers that recognized the work of Gregor Mendel [1866]. The significance of Mendel's observations quickly folded into many lines of research, allowing new connections and synthesis.

1900 Botanist Mikhail Tsvet, while studying plant pigments, developed chromatography, utilizing columns of calcium carbonate run with an eluent of petroleum ether and ethanol. (Wikipedia, 2018)

1900 The British owned Pacific Islands Company purchased rights to all minerals on 3-mile- long Ocean Island for £50 a year. Within 80 years 20,000,000 tons of phosphate for agricultural fertilizer (shipped to Australia and New Zealand for crops exported mainly to Britain) were extracted from the island, obliterating the original tropical vegetation and destroying the homeland of the 2,000 native islanders. The same fate befell neighboring Nauru (8.5 sq. miles.) and its original 1,400 inhabitants. (Ponting, 1991)

1900 Joseph Pernet-Ducher (of Lyon) introduced what is thought to be the first yellow hybrid rose, 'Soleil d'Or'. Making thousands of fruitless crosses, his persistence was rewarded with a single plant that provided the genetic source for yellow coloration in Hybrid Teas and Floribundas. (Grimshaw, 1998) [See 1583]

1901 Mendel's paper on inheritance in peas was re-published in the RHS journal. [See 1866]

1901 Satori Kato, a Japanese chemist filed a patent for instant coffee. His patent was issued in 1903 - #735777 Coffee Concentrate and Process of Making Same. New Zealander, David Strang, gets credit for inventing instant coffee years earlier, introducing his soluble powder in 1889, followed by a patent application in 1890. (Wikipedia, 2016)

1901 Japanese biologist Shigetane Ishiwatari isolated a bacterium involved in death of silkworms, which he named *Bacillus sotto*. In 1911, Ernst Berliner encountered the bacterium again (while studying death in Mediterranean flour moths), naming it *Bacillus thuringiensis* (after the German town Thuringia, where the moth was collected). Ishiwatari's binomial was rejected, while Beliner's stuck, giving rise to the abbreviation *Bt.* The bacterium was in use as a pesticide in France a decade later. (Ronald & Adamchak, 2018, http://www.bt.ucsd.edu/bt_history.html

1901 Iowans Charles Hatt and Charles Parr built the first gasoline powered tractor. (Fussell, 1992)

1901 John Davey published *The Tree Doctor*, considered the first serious book covering tree treatment and surgery in the US. By 1909, Davey had established Davey Tree Expert Company, which included a training academy named the Davey School of Practical Forestry. (Campana, 1999)

1901 As a student in St. Petersburg, Russia, Dimitry Neljubow demonstrated that unusual growth reactions of peas under laboratory circumstances was related to ethylene from coal-gals lights. (Hodson & Bryant, 2012)

1901 In *Journal des Voyages*, naturalist and sensationalist travel writer Louis Henri Boussenard reported a particularly exciting encounter with a colony of *Victoria amazonica*;

"*Unhappily, the base of the corolla is full of insects, contact with whom disgusts me and whose stings I fear... Very calmly the Indian, who doesn't partake of my aversion...plunges his arm slowly, up to his shoulder, into the preserved corolla. And almost as swiftly he retracts it, with a quickness that astonishes me in view of his customary apathy. A cry of terror escapes me, and I find myself tremble to the marrow of my bones. Around his wrist and forming a moving bracelet, a small snake twists and unrolls itself with rage... Vivid red with black bands, it bites furiously the thumb of the Indian. Its fangs are deeply implanted in the flesh and its ferocious little eyes sparkle like diamonds. I recognize the terrible élaps, or coral snake, whose bite kills the most vigorous of men in less than an hour...My pallor, my agitation, my offers of help make the Indian shrug his shoulders. With his admirable calm, he seizes with his left hand, between the thumb and index finger, the snake by the base of its head, with a strong grip, he makes it release its bite, smashes it against the wood of the pirogue, and says in his raspy voice. 'Give me some rum.'"* The next day, the Indian awoke: "*fresh as a daisy, without the shadow of an ill effect."* (related as a translation by John Luttrell, *in* Aniśko, 2013)

1902 Gottlieb Haberlandt described plant totipotency (which he termed totipotentiality). Haberlandt, G. (1902) Kulturversuche mit isolierten Pflanzenzellen. Sitzungsber. Akad. Wiss. Wien. Math.-Naturwiss. Kl., Abt. J. 111, 69–92.

1902 In March, the first cases of a creeping pellagra epidemic (spreading through the Southeastern US) were diagnosed. This poverty-related disease, described in Spain in the 17th century, first appears as rashes and changes in coloration of skin. Years of work by public health professional Joseph Goldberger demonstrated the condition resulted from dietary over-reliance on corn (maize) - most particularly corn that has not been treated with alkali (search the terms nixtamalization or pellagra). Curiously, in 1912 (the very year Frederik Hopkins demonstrated the importance of vitamins) a commission concluded pellagra was infectious and not diet-related. Only in 1937 was it demonstrated by Conrad Elvehjem that niacin-deficiency causes this disease. (Boutard, 2012) [See Timeline 1937]

1903 Wilson, collecting for Veitch, successfully reintroduced the blue poppy, *Meconopsis*, to Europe, though his greatest triumph was the introduction of the regal lily, Lilium regale.

1903 H. E. Huntington purchased San Marino Ranch, where he began to create his estate, complete with museum collections and botanical gardens.

1903 Based on their model constructed in 1901, C. W. Hart and C. H. Parr of Iowa City, Iowa, established the first company dedicated exclusively to manufacturing gasoline powered tractors. In 1906 they began calling their machines tractors. By 1950 there were more tractors than horses on American farms. [See 1892] (Rasmussen, 1960)

1903 M. S. Tswett, a Russian botanist, separated chlorophylls a and b as well as carotene and xanthophyll from petroleum ether extract chromatographically, using powdered chalk as the substrate. Chromatography did not become a common technique until the 1930's. (Morton, 1981)

1903 Having written extensively about her "woman's acre" (based on her own 40+ years of gardening experience at her farm in Quebec) Annie Jack published *The Canadian Garden - A Pocket Help for the Amateur*, regarded as the first book on Canadian horticulture. (Wikipedia: Annie Jack, 2017)

1903 Gustaf Komppa resolved and published "total synthesis" of camphor, moving ahead quickly into production. His work is regarded as the first commercialization of a complex organic chemical produced from readily available ingredients. In his time, Camphor (extracted most commonly from the Asian tree *Cinnamomum camphora*) was an important ingredient in many products, from medicines (such as paregoric) to cooking, pest deterrence, embalming fluids, and even formulation of smokeless gunpowder. (Wikipedia: Camphor, 2017)

1903 New Zealand's Scenery Preservation Act was passed into law. This Act created the basis for establishing New Zealand's system of national parks. (Pawson & Brooking, 2002)

1904 Iced tea is said to have been first served at the St. Louis World's Fair by an enterprising British salesman who realized that fair goers were not attracted to hot tea in summer weather. (Simpson, 1989)

1904 Chestnut blight from Japan was detected in the New York City area, with the first reported case at the Bronx Zoological Park. It is thought the fungal pathogen, *Cryphonectria parasitica*, arrived with importation of Asian chestnut trees in 1890. This disease quickly advanced to destroy nearly the entire native population of American Chestnut, until that time the largest of eastern trees and one of the most significant forest dominants in the Eastern mixed mesophytic association. (Levetin & McMahon, 1996) Rupp (1990) indicates that the pathogen arrived in 1895 amid a shipment of Chinese chestnut trees that would eventually be planted at the newly founded New York Botanical Garden. Rupp also calculated the loss in lumber alone at $400 billion.

1904 Friedrich Meves (*"Über das Vorkommen von Mitochondrien bzw Chondromiten en Pflanzenzellen," Ber Deutsch. Bot. Ges*, 22: 284-286) was the first to report plant mitochondria, while studying tapetal cells of *Nymphaea alba* anthers. (see W. C. Twiss, 1919. "A Study of Plastids and Mitochondria in Pressia and Corn" American Journal of Botany, 6(6) 217-234; Earl H. Newcomer, "Mitochondria in Plants," 1940. *Botanical Review* 6(3):85-147 Though observed before 1850, mitochondria were not described as cell organelles until 1894, when Richard Altmann named them bioblasts. In 1898, Carl Benda suggested the term mitochondria. Philip Siekevitz came up with the description of mitochondria as the powerhouse of the cell in 1957. (Wikipedia)

1905 Frederick F. Blackman proposed his concept of "limiting factors" - now called Blackman's Law of Limiting Factors, which holds that under any combination of circumstances, the rate of photosynthesis will be governed by the slowest step. This resulted from his work in measuring rates of photosynthesis while varying external factors, such as light, temperature, water availability, and gas exchange. (McDonald, 2003)

1905 Prior to general adoption of the term "gene" for a unit of inheritance, Bateson applied the word "genetics" (Gk. genno - to give birth) to the evolving study of heredity and variation. His decision avoided problems that had become associated with the term pangene, (Mukherjee, 2016)

1905 Following years of research (and a well-known public argument with German pathologist Alfred Fischer), Erwin Frink Smith began publication of a series of treatises on bacterial diseases of plants. From Campbell: "Erwin F. Smith had a keen analytical mind and ability to synthesize and evaluate this knowledge, which encompassed the entire field of bacterial plant pathology. His comparative consideration of bacterial plant pathogens culmi nated in his exhaustive three-volume treatise (16, 17, 18) published in 1905, 1911, and 1914. A portion of the material for a fourth volume was in manu script form at the time of his death, but has not been published. Some of the essential points to have been covered in the fourth volume are included in Smith's textbook, Bacterial Diseases ofPlants (20) pub-

lished in 1920. Smith dealt with over 100 bacterial diseases of plants in the treatise. “ (C. Lee Campbell, 1983. Erwin Frink Smith - Pioneer Plant Pathologist, *Annual Rev. Phytopathol*. 21:21-27.)

1906 William Bateson introduced the word “genetics” in a presentation at the 3rd International Conference on Plant Hybridization, in London. He had used the term in private letters the previous year. (Wikipedia)

1906 Pierre du Pont purchased the Pierce house and arboretum, property he would develop as Longwood Gardens. (Griswold & Weller, 1991)

1906 The first county agent, W. C. Stallings began work in Smith County, Texas. Employed to work with farmers to combat the ravages of the boll weevil on the cotton crop, this model was quickly adopted in other Southern states. By 1914 the Smith-Lever Act for cooperative extension had been passed. (Rasmussen, 1960)

1906 In the July issue of Good Housekeeping a Shaker community member recounted the growing of flowers (which for its own sake was proscribed) for economy and industry. One paragraph concerned opium: "We always had extensive poppy beds and early in the morning, before the sun had risen, the white-capped sisters could be seen stooping among the scarlet blossoms to slit those pods from which the petals had just fallen. Again after sundown they came out with little knives to scrape off the dried juice. This crude opium was sold at a large price and its production was one of the most lucrative as well as the most picturesque of our industries." (Hedrick, 1950)

1906 Kakuzo Okakura published The Book of Tea, noting that “Teaism is Taoism in disguise” (Hohenegger, 2007)

1906 The US Congress approved the Pure Food and Drug Act, partially in response to news published the previous year by reporter Samuel Hopkins Adams. The law required companies to detail ingredients in medicines. (Filan, 2011)

1907 Joel Cheek began building his Nashville, TN-based coffee roasting empire based on his own blend, one he promoted through Nashville’s Maxwell House (a fine hotel) in 1892. Within a few years a second roasting facility had been opened in Houston, TX. By the time Theodore Roosevelt visited Nashville in 1907, the Maxwell House brand had established strong presence in the Southeast. On draining a cup of this coffee, Roosevelt is reported as saying: "Good. Good to the last drop." (Pendergrast, 1999)

1908 New York tea importer Thomas Sullivan introduced the tea bag as a means of marketing samples. (Pratt, 1982) By 1934, 8 million yards of gauze were used annually to be sewn as tea bags. (Simpson, 1989)

1908 Avocados were planted at San Marino Ranch (today, the Huntington Botanical Gardens), constituting what was apparently the first commercial avocado grove in California.

1908 The United States Department of Agriculture, agencies of numerous states, and Canadian governmental agencies formed the Associations of Official Seed Analysts of North America, with the goal of setting standards for seed testing and instituting laws that would guarantee such standards. (Busch, et al, 1995) [See 1912]

1908 John Burroughs writes of Wordsworth’s *A Poet’s Epitaph* [see 1800]: *“By a close observer, I do not mean a minute, coldblooded specialist - but a man who looks closely at nature, and notes the individual features of tree and rock and field, and allows no subtle flavor of the night or day, of the place and the season, to escape him.”* In this same essay, Burroughs observes: *“There is nothing in which people differ more than in their powers of observation. Some are only half alive to what is going on around them. Others, again, are keenly alive: their intelligence, their powers of recognition, are in full force in eye and ear at all times.”* (Burroughs, 1908, ‘The Art of Seeing Things’, in *Leaf and Tendril*) (McKibben, 2008)

1908 Frank N. Meyer, an agricultural explorer for the USDA, encountered an especially fruitful, sweet lemon in Fengtai, near Beijing, China. The plant was one of about 2500 selections that Meyer sent back to the US from Asia. Today, the Meyer Lemon is well-known, and a great benefit. (Chris Shott, 5 March 2018. “A Man a Plan, a Lemon, China. The Ballad of Frank Meyer”, in Taste.)

1909 Danish botanist, Wilhelm Johannsen coined the terms “phenotype” and “genotype” in a 1903 publication of his studies of beans and in his 1905 book Arvelighedslaerens Elementer. (Wikipedia) In his 1909 publication, *Elemente der exakten Erblichkeitslehre*, Johannsen applied the word “gene” to the unit of inheritance. (Mukherjee, 2016) Gene was preferred as opposed to use of the term “pangene” that originated from Darwin’s ideas of pangenesis. From Mukherjee: “…neither (William) Bateson nor Johannsen had any understanding of what a gene was. They could not fathom its material form, its physical or chemical structure, its location within the body or inside the cell, or even its mechanism of action. The word was created to mark a function; it was an abstraction. … defined by what a gene does… a carrier of hereditary information” Also from Mukherjee, a transla-

tion from Johannsen: "It is desirable to create new terminology in all cases where new and revised conceptions are being developed. Therefore, I have proposed the word 'gene' … a very applicable little word. It may be useful as an expression for the unit factors…demonstrated by modern Mendelian researchers."

1909 Dr. Colville and Ms. White begin making crosses to produce the first 18 cultivars of modern blueberries from native stock.

1909 Erwin Baur reported that *Pelargonium* demonstrates both maternal and paternal chloroplast inheritance and defies laws of Mendelian inheritance. In this same year, Baur presented evidence of lethal genes in *Antirrhinum* (snapdragon). Baur's work was cited by Muller in his studies of induced mutation. Based on his observations in Pelargonium, he also is credited for early understanding of extra-nuclear inheritance. He is also considered a Father of Plant Virology. [See An everlasting pioneer: the story of *Antirrhinum* research, Zsuzsanna Schwarz-Sommer, Brendan Davies and Andrew Hudson], in Nature Reviews, Genetics] https://www.era.lib.ed.ac.uk/bitstream/id/1670/Hudson_A.pdf/

1909 Fritz Haber produced ammonia from atmospheric nitrogen. The German chemical company BASF purchased rights to his process and assigned Carl Bosch to create an industrial-scale application. Both Haber (in 1918) and Bosch (in 1931) were awarded Nobel prizes for this work. Commercial production of synthetic ammonia became immediately important when, during WW I, Germany lost access to deposits of sodium nitrate that had become crucial sources of crop fertilizers. (Wikipedia)

1910 The Corn Products Refining Company (subsequently Corn Products Company International) began refining corn oil for cooking, trademarking their product as Mazola. (Fussell, 1992)

1910 The USDA purchased 475 acres of farmland near Beltsville, MD to establish its Agricultural Research Center. Supplementing the 400 acre Arlington Farm which had been established in 1910 (and eventually became the site for the Pentagon), Beltsville grew to over 10,500 acres by 1962. (Hedge, in The Yearbook of Agriculture 1962)

1910 In a total US labor force of 38,167,000, the agricultural labor force constituted 32.5%, or 12,388,000 people. In 1970, the US labor force had risen to 83,049,000 while the portion reportable to agriculture had dropped to 3.4%, or 2,750,000. This change is accountable to introduction of labor-saving devices, such as the tractor. (Williams, 1987)

1910 Commissioned by the Carnegie Foundation (at the behest of an educational committee of the American Medical Association), the Flexner Report examined the state of medical training and treatment in the US. The Report suggested a new level of quality as well as a focus on more centralized training and science-based approaches. Numerous schools closed, especially those promoting alternative treatments, such as electrotherapy and homeopathy. Many private medical schools closed, Chicago, for example, had boasted 14 medical schools, which the Report assessed as "a disgrace to the State whose laws permit its existence... indescribably foul... the plague spot of the nation." The standards and programming suggested defined the next century of US physician training and placement. (Wikipedia, 2018)

1911 Mikhail Tsett noted red autofluorescence of chlorophyll *in situ* (in the chloroplasts, using a microscope). (Clark & Kasten, 1983)

1910 Konstantin Mereschkowski published (in Russian) *The Theory of Two Plasms as the Basis of Symbiogenesis, a New study on the the Origins of Organisms*. (Wikipedia, 2015)

1911 A two year famine began in Russia. While people starved and died, the country continued exporting a fifth of its annual grain production (which constituted about 25% of world trade). (Ponting, 1991)

1911 Kudzu was brought to the US from Japan for soil improvement, erosion control, and livestock forage. (Shetler in Viola & Margolis, 1991)

1911 - In this year of his death, Franklin King's *Farmers of Forty Centuries, or Permanent Agriculture in China, Korea, and Japan* was published. After a long career in University research, King had been hired (in 1902) by the USDA to head the Division of Soil Management. When it became obvious that his ideas regarding soil nutrients and chemistry were at odds with standard dogma, King was pressured to resign This book recounts King's observations during a 1909 tour of Asia, and documents his thoughts as to sustainable agriculture. (King is also noted as the originator of the cylindrical silo.) (Wikipedia, 2016)

1911 Emiliano Zapata led his Mexican revolution based on the *Plan de Ayala*, in which he demanded return of land control to working people, taken ownership and management from large landowners and governmental intelligentsia (*cientificos*).

1911 Jantina Tammes was awarded an honorary doctorate, in recognition of her significant contributions to plant variability, evolution, and genetics. (Wikipedia, 2018)

1911 Hans Stübel is credited with reporting the first useful application of fluorescence microscopy. Austrian Pharmacognosist R. Wasicky reported observations of distinctive fluorescent propertics in pulverized cocoa bean chicory roots and ergot-infected flour. He predicted this technique would become useful for localizing certain compounds in cells. S. von Provazek introduced use of fluorescent dyes in 1914. By the early 1930s, much better equipment and techniques were available. (Clark and Kasten, 1983)

1912 Ballod calculated that a US standard of life would support 2.333 billion people on Earth, a German standard would allow 5.6 billion, and a Japanese standard could underwrite 22.4 billion people. (Cohen, 1995)

1912 The GooGoo Cluster, a chocolate, caramel, & peanut candy, was created in Nashville, TN. (Levetin & McMahon, 1996)

1912 Tokyo gave cherry trees to be planted in Washington, DC. (Camp, Boswell, & Magness, 1957)

1912 Frederick Hopkins showed that there were chemical substances (additional to fats, carbohydrates, and minerals) obtained from food that are essential to human growth and maintenance. Casimir Funk termed these substances "vitamines." (Visser, 1986)

1912 The United States Seed Importation Act established legal standards for seed in the marketplace. The law also controlled noxious weeds and varietal seed mixes. (Busch, et al, 1995) [See 1908]

1913 With three wheels attached integrally to the engine housing, the Wallace Cub became the first frameless tractor. (Schlebecker, 1975)

1913 Joyce Kilmer published his short poem “Trees” in the August edition of *Poetry: A Magazine of Verse*. The poem appeared in 1914 in collection titled *Trees and Other Poems*. The poem became widely-known as anthem to a growing movement to plant and preserve shade trees.

1913 In her small book, *Rustic Speech and Folk-lore,* Elizabeth Wright first documents use of the phrase: “An apple a day keeps the doctor away.”

1913 In order to control production and pricing of Quinine, the Kina Bureau was established in the Netherlands. Though native to South America, Cinchona seed had been collected and introduced to tropical colonies around the world. The most productive regions were in Dutch-controlled Dutch East Indies, which allowed the Kina Bureau to gain control of world production by 1918. In an effort to break this control, the US Government prosecuted the Kina Bureau in 1927, but no real impact came of this action and the Bureau retained control of Cinchona. (Shah, 2010)

1913 Gottlieb Haberlandt is credited with first describing factors extracted from plant phloem that promote cell division (later understood to be the cytokinins). (History of Cytokinins, website of the International Plant Growth Substances Association, 2018))

1914 Aimed primarily at opiates, the US Congress approved the Harrison Act, which required manufactures and providers to maintain records of narcotics prescribed and dispensed. The first US law to control opiates had been set as a San Francisco ordinance in 1875. (Falin, 2011) [See Pure Food and Drug Act, 1906; Prohibition, 1919]

1914 George Harrison Shull introduced the term “heterosis” to denote the hybrid vigor he began to document in his1908 publication “The Composition of a Field of Maize”. (James F. Crow, 1998. *90 Years Ago: The Beginning of Hybrid Maize*, GENETICS March 1, 1998 vol. 148(3) 923-928 - available on the WWW)

1914 On the eve of Prohibition, many towns in California had passed ordinances outlawing alcohol (Pasadena was the first in the state, in 1876, even before incorporation as a city). Pomona was tardy in this regard, but did get there. From the January, 1914, *Pacific Wine and Spirit Review*, we have this amusing report: *“The prohibitionists of Pomona are still in a quandary over the interpretation of their ordinance which provides that alcoholic liquors shall be used for scientific purposes only. One of the effects of the ordinance is the replenishment of the the scientific chests of many families of Pomona. While clubs and similar organizations are not allowed to keep alcoholic liquors for scientific purposes, families are free to make demonstrations of the scientific value of alcohol by inviting guests to make bibulous analyses of the contents of brown, black and green bottles. The prohibitionists are now thinking of prohibiting science in Pomona.”* (Pinney, 2017)

1915 Charles Bessey formalized his Dicta in the article *The Phylogenetic Taxonomy of Flowering Plants*, Annals of the Missouri Botanical Garden, 2:109-164. [see Reader for text and description]

1915 Richard Martin Willstätter was awarded the Nobel Prize for his work with plant pigments, particularly chlorophyll. After WWI, Willstätter continued his work in biological chemistry, investigating the synthesis of cocaine and the nature of enzymes. By WWII, Willstätter suffered the isolation and persecution of so many other Jewish German scien-

tists and eventually emigrated to Switzerland. At one point during the war, gestapo agents were sent to Willstätter's home to arrest him: "He was in his garden at the time, however, and the gestapo did not think to look for him there." (Cobb & Goldwhite, 1995)

1916 Corn borer arrived in the US. Note that in Stephen Vincent Benet's *The Devil and Daniel Webster*, Jabez Stone lost his corn crop to corn borers, even though Daniel Webster had died in 1852, 64 years before the arrival of corn borer. (Root, 1980)

1916 Youth Farm Clubs, established during World War I, concentrated on the tomato as a crop, helping to popularize this fruit. (Root, 1980)

1916 The US Government established The National Park Service. It's mission (2017): *The National Park Service preserves unimpaired the natural and cultural resources and values of the National Park System for the enjoyment, education, and inspiration of this and future generations. The Park Service cooperates with partners to extend the benefits of natural and cultural resource conservation and outdoor recreation throughout this country and the world.* (The NPS website)

1916 A publication by Lennart von Post is recognized as the beginning of palynology as a field of study. (Kevin J. Edwards, Pollen, women, war and other things: reflections on the history of palynology, 2017, Veget Hist Archaeobo (PDF Download Available from: https://www.researchgate.net/publication/318989563_Pollen_women_war_and_other_things_reflections_on_the_history_of_palynology

1917 Nikolai Vavilov assumed leadership of seed and crop development resources for the Soviet Union (in the same year as the Bolshevik revolution.) Vavilov led a massive enterprise dedicated to collecting and storing landraces of important crop plants. His work and philosophy fell victim to politically expedient theories advanced by Trofim Lysenko, such that Vavilov was arrested in 1940 (the beginning of the Stalinist era) and charged with conspiring against communist social order. Convicted to a death sentence (later commuted to life in prison), Vavilov died in prison in 1943. (Thompson, 2010)

1917 Knibbs calculated that (exclusive of the Arctic and Antarctic) with a land area of 33 billion acres, Earth could yield 752.4 trillion bushels of corn, which could support a population of 132 billion. (Cohen, 1995)

1917 Ford's Fordson tractor was introduced at price of $397. (Fussell, 1992)

1918 Through studying a special tobacco plant with tardy flowering habits, W. W. Garner and H. A. Allard opened the field of daylength studies - a phenomenon they named "photoperiodism.' (Borthwick, in The Yearbook of Agriculture 1962)

1918 With pathologists having identified Barberry as the alternate host in the Wheat Rust lifecycle, serious crop loss due to spread of the disease, and the US in the heady days of WWI, a Barberry Eradication Campaign was launched. From Peterson: *"Worse than merely worthless as an ornamental, the barberry had become a dangerous foreign enemy. War-time propaganda posters in 1918 proclaimed "the common barberry the Kaiser's Kin and Ally." The failure to get behind compulsory eradication was branded as anti-American. A press release issued in South Dakota in April, 1918, described the bush as "pro-German," and warned that "it is decidedly disloyal to allow the common barberry bush to live − it must be treated as a dangerous enemy alien." Eradication officials also linked the bush to other contemporary causes of national anxiety, like the Russian Revolution of 1917 and the Red Scare that followed in the US. Playing on the nation-wide anti-radical hysteria, eradication officials branded the common barberry as a "red-handed anarchist of the grain field".* (WWW, search: "The Barberry or Bread": The Public Campaign to Eradicate Common Barberry in the United States in the Early 20th Century, by P. D. Peterson, APS Historian, 2013)

1919 The 18th Amendment to the US Constitution initiated a period of alcohol prohibition. The nearly 14-year period of prohibition caused great hardship for US vineyards and other growers and producers in the large beer, wine, and liquor industry. The language: *"The manufacture, sale, or transportation of intoxicating liquors within, the importation thereof into, or the exportation thereof from the United States and all territory subject to the jurisdiction thereof for beverage purposes is hereby prohibited."* Terms under which the amendment would be interpreted and enforced were dictated by the Volstead Act. These new circumstances ushered in a period of home winemaking. By 1933, California bonded wineries numbered 177, as compared to 694 that were in operation in 1922. (Pinney, 2017)

1919 The publication of *Inbreeding and Outbreeding* by E. M. East and D. F. Jones gave scientific underpinnings to corn breeding and introduced Jones's system of double crossing through the use of four inbred lines. This work, fostered by the US Experiment Station system, was one of the most significant early accomplishments of modern agricultural science. (Rasmussen, 1960)

1919 Working at Cornell, James B. Sumner extracted and isolated the protein concanavalin A from *Canavalia ensiformis* (Jackbean). Concanavalin A has the capacity to cause red

blood cells to stick together (agglutinate). (History of lectins: from hemagglutinins to biological recognition molecules (Sharon Nathan and Halina Lis, 2004. "History of lectins: from hemagglutinins to biological recognition molecules" *Glycobiology*, 14 (11) 53–62.)

1919 England, Australia, and New Zealand acquired control of Nauru Island, a phosphate-rich guano island. Access to abundant phosphate fertilizer made development of Aerial Topdressing possible. [see TimeLine, New Zealand, 1949] Guano mining created great wealth, but has left 80% of Nauru Island unusable. (Wikipedia: Aerial Topdressing, 2017)

1920 The American Orchid Society began, its first organizational meeting held on 25 March at Horticultural Hall, Boston, Massachusetts. (Reinikka, 1972)

1920 USDA researchers Wightman Garner and Harry Allard published *Effect of the relative length of day and night and other factors of the environment on growth and reproduction in plants*. Studies reported in this paper gave birth to the incredibly significant study and ongoing explanation of photoperiodism (a word suggested by O. F. Cook and introduced by Garner) - altering our fundamental understanding of plant response and impacting agriculture and horticulture in significant ways. (Sage, 1992)

1920 Francis Alonzo Bartlett consolidated smaller companies and founded F. A. Bartlett Tree expert Company. As with the Davey Tree Expert Company, Bartlett's new firm included its own school, which Bartlett had established in 1913. (Campana, 1999)

1920 French chemists Pierre Joseph Pelletier and Joseph Bienaimé Caventou isolated the terpenoid Quinine, naming it based on the indigenous Incan term *quina* for this bark and distinguishing the compound from cholchicine (epiquinine). (Wikipedia, 2017)

1920 D. H. Lawrence published *Women in Love*, teaching some botany while delving into sexual innuendo. "For Lawrence, this life force manifests most powerfully in botanical reproduction, the invisibly persistent generation of flowers, nuts, and leaves." Anna Deters (http://plantcurator.com/knowledge-and-catkins/) From *Women in Love*:

> *'Do you know the little red ovary flowers, that produce the nuts? Have you ever noticed them?'* he asked her. And he came close and pointed them out to her, on the sprig she held.
>
> 'No,' she replied. 'What are they?'
>
> 'Those are the little seed-producing flowers, and the long catkins, they only produce pollen, to fertilise them.'
>
> '*Do they, do they!*' repeated Hermione, looking closely.
>
> 'From those little red bits, the nuts come; if they receive pollen from the long danglers.'
>
> *'Little red flames, little red flames,'* murmured Hermione to herself. And she remained for some moments looking only at the small buds out of which the red flickers of the stigma issued.
>
> '*Aren't they beautiful? I think they're so beautiful,'* she said, moving close to Birkin, and pointing to the red filaments with her long, white finger.
>
> *'Had you never noticed them before?'* he asked.
>
> '*No, never before,'* she replied.
>
> *'And now you will always see them,'* he said

1921 George Washington Carver appeared before the US Congressional Ways and Means Committee, promoting a protective tariff on peanuts. He demonstrated the many potential products/uses of peanuts and came away from the meeting with national fame. Due to his promotional efforts, the peanut is a major crop in the Southeastern coastal plain today - and peanut butter has become an American classic. (Isely, 1994) [see 1890]

1921 Graduate student Maria Beatrice Schwarz isolated the Ascomycete *Ophostoma (Graphium) ulmi* as the causative fungal agent of Dutch Elm Disease. Her work was confirmed by Christine Buisman in 1929, a study followed two years later by work of J. J. Franzen proving the vector was the European elm bark beetle. (Campana 1999)

1921 Quoting George W. Gurney, of Yankton, SD: "Sometime when you have nothing else to do, plant a tree. It will be growing while you sleep." (Adams, 2004)

1922 W. J. Robbins initiated plant tissue culture studies. ©. Zirkle in Ewan, 1969)

1922 Knudson published his asymbiotic method of seed germination; "Nonsymbiotic Germination of Orchid Seeds" in *Botanical Gazette*. This technique revolutionized the propagation of orchids, both sexually and vegetatively. It led to techniques of mericloning and meristemming that are used widely for production of many horticultural crops today.

1922 Seven US states agreed to the Colorado River Compact, allocating water rights for the Upper Division (Colorado, Wyoming, Utah, New Mexico) and the Lower Division (Nevada, California, Arizona) of the Colorado River drainage basin. Assuming an average flow of 16.4 million acre-feet of water, each Division assumed availability of 7.5 million

acre-feet of water to be shared among the parties. The Compact also assumes 1.5 million acre-feet of water would remain for use by Mexico. The total 16.5 million acre-feet leaves no flow to enter the Pacific Ocean. A 2012 Amendment (MInute 319) addresses the failure of water flows to reach expectations, and basis allocations to Mexico on water levels at Lake Meade. (Wikipedia, 2018)

1923 Otto Warburg (working successively with many associates) published one of many important works on photosynthesis in the alga *Chlorella*, work he apparently began in 1919. In these early studies, Warburg observed that photosynthesis could be inhibited by high oxygen concentrations - called the Warburg Effect. (McDonald, 2003). His work with *Chlorella* would continue over several decades, but merely as punctuation in other much more critically-acclaimed research in human physiology and oncology. A brilliant researcher, Warburg's life and works should be more commonly known among the community of scientists.

1923 Accompanied by a microscope demonstration, Robert Feulgen reported his "nucleal reaction" and "nucleal staining" to the 8th German Physiology Congress, which met in Türbingen. Feulgen had successfully used staining procedures to localize differing components of nucleic acids - aldehyde groups and pentose components. Now termed the Feulgen Reaction, a vibrant red-violet stain for DNA. The Feulgen reaction is considered the first "end-point type reaction" - which would brand Robert Feulgen as "the first modern histochemist." Beyond introducing an important staining technique, this demonstration eliminated previously-existing ideas that plant DNA differed from animal DNA. From a 1956 presentation by Kurt Felix (who had attended the 1923 presentation): "In all preparations the nuclei were stained red-violet. The exciting finding for us was the reaction of not only the nuclei of animal cells, but rather also those of plant cells. With this demonstration, the difference between plant and animal nucleic acids ceased to exist. All cells contained in their nuclei the same kind of nucleic acid which we refer to today as deoxyribonucleic acid or DNA." (Clark & Kasten, 1983)

1923 Publication of *Botanical Pen-portraits*, by Jan Willem Moll and Hindrik Haijo Janssonius.

1924 International Harvester Company introduced their gasoline powered tractor, the Farmall, which was fitted with removable attachments. (Fussell, 1992)

1924 Frank Kingdon-Ward, tracing routes of plantsmen through southern Tibet, collected seed of the famous blue poppy, *Mecanopsis betonicifolia*. He described the flowers to be "as dazzling as sapphires." The plant became a sensation with its first cultivated flowering in London and Glasgow parks in 1927. (Grimshaw, 1998)

1924 Through a series of lectures on the future of agriculture, Rudolf Steiner established the concept of biodynamic farming. Author, spiritualist, philosopher and co-founder of the Anthroposophical Society, Steiner was heavily influenced by Goethe's phenomenological approach to science (through having worked with the Goethe archive as a young man). (Wikipedia, 2016)

1924 With William E. Britton and Francis A. Bartlett as significant players, The Shade Tree Conference (STC) met in Stanford Connecticut, at the invitation of the Connecticut Tree Protective Association. By 1928, activity in the STC led to the 1928 formation of the National Shade Tree Conference. In 1975 the Conference reinvented itself as the International Society of Arboriculture (ISA). (Campana, 1999)

1924 "At Whitsun, Rudolf Steiner held lectures entitled "Spiritual foundations for the renewal of Agriculture" at Koberwitz, Silesia. The Experimental Circle of Anthroposophical Farmers immediately tested Steiner's indications in daily farming practice. "(Demeter International Website) (Bizarre Stuff) From Wikipedia, Rudolf Steiner, 2018: *"A central aspect of biodynamics is that the farm as a whole is seen as an organism, and therefore should be a largely self-sustaining system, producing its own manure and animal feed. Plant or animal disease is seen as a symptom of problems in the whole organism. Steiner also suggested timing such agricultural activities as sowing, weeding, and harvesting to utilize the influences on plant growth of the moon and planets; and the application of natural materials prepared in specific ways to the soil, compost, and crops, with the intention of engaging non-physical beings and elemental forces. He encouraged his listeners to verify his suggestions empirically, as he had not yet done."* And, at the Demeter International website, (2018) you will find this interesting statement: *"Biodynamic farming is a holistic approach to agriculture in which vitality has the highest priority. Its origin lies in the agricultural course held by Rudolf Steiner in 1924. Biodynamic farmers return more to the soil than they remove in the process of cultivating crops and animals; the farm is considered as an organism in which plants, animals and human beings are integrated together. The significant difference is that the Biodynamic method attempts to work with the dynamic energies in nature and not solely with its material needs. One aspect of this is the use of cosmic rhythms, for instance cultivation, sowing and harvesting are scheduled if possible on favourable days. "*

1924 "Life Is Bottled Sunshine" (Wynwood Reade, *Martyrdom of Man*)

1925 The Los Angeles-based Armacost and Royston nursery acquired seed of *Saintpaulia* (African violets) from Europe. From a thousand seedlings, a very few were selected. One of their introductions, 'Blue Boy' became an important parent for future development of African violet cultivars, giving red and pink seedlings, and even yielding a sport with double flowers. (Grimshaw, 1998) [See 1882]

1925 New Zealand's Director of Forests, Leon McIntosh Ellis, announced an afforestation target for planting 300,000 acres in non-native trees, principally *Pinus radiata* (Monterey Pine). Pawson & Brooking, Ch 12, 2002) According to Wikipedia (2017), Monterey Pine was first introduced to New Zealand in 1959, and 2017, 89% of New Zealand's plantation forest were of this species.

1926 Scientists began to formulate genetic solutions to long-known plant problems. In this year East and Manglesdorf resolved the issue of self-sterility in *Nicotiana*. Filzer and Lehmann conducted similar studies of *Veronica*. ©. (Zirkle in Ewan, 1969)

1926 Working in Germany, Adreas Stihl developed what seems to have been the first portable chainsaw. The 140 pound device required two people for operation, but it proved incredibly successful. Over 40,000 were sold within 7 years. (Campana, 1999)

1926 John Belling published "The iron-acetocarmine method of fixing and staining chromosomes" in *Biol. Bulletin* 50:1160-162. Studying chromosomes in a range of plants (*Canna*, *Cypripedium*, *Hemerocallis*, and many other monocots), Belling improved aceto-carmine staining by adding iron (even simply using a rusty probe will work), which resulted strong differentiation between chromosomes and cytoplasm. (George Clark and Frederick Kasten, 1983)

1926 James Sumner extracted, purified, and crystallized urease, the first enzyme to be purified and characterized. Sumner's work demonstrated that enzymes are proteins. (Sekeres & Zarsky, *in* Sahi and Baluska, 2018)

1927 H. J. Muller (whose main work was with fruit flies) exposed plant seed to X-rays in order to induce mutations. Muller had stated as early as 1916 the ability to induce mutations was the key to managing the process of evolution (through creating greater genetic variation in populations). Because he was using lethal doses of radiation, Muller called this new science necromancy. (Sackman, 2005) Of course, necromancy historically describes activities (such as witchcraft and magic) that claim to communicate with the dead. The term does not seem to remained in currency for the use of x-rays in creating mutations.

1927 A Congressional bill directed the Secretary of Agriculture "to establish and maintain a national arboretum for purposes of research and education concerning tree and plant life." (Skinner, in The Yearbook of Agriculture 1962)

1927 The first patent for a Scanning Electron Microscope (SEM) was filed in Germany, but decades would pass before workable instruments were commercially available (Cambridge Scientific Instrument Company, 1965). Those instruments gave magnifications of 10 to 200,000 times life size with magnificent depth of field, 500 times that of light microscopy. The earliest botanical observations using SEM were published between 1965 and 1970, with large numbers of applications and publications appearing over the next decade. Initially, the technique proved most useful for surface structure, but anatomists quickly worked this into their research.. Margaret Y. Stant , 1973. "The Role of the Scanning Electron Microscope in Plant Anatomy" *Kew Bulletin*, Vol. 28, No. 1 (1973), pp. 105-115, Source JSTOR Kew Stable URL: http://www.jstor.org/stable/4117068

1927 Using light microscopy, C. Zirkle demonstrated that chloroplasts develop from clear proplastids. (L. Andrew Staehelin, 2005. "Chloroplast structure: from chlorophyll granules to supra-molecular architecture of thylakoid membranes", pp 717-728 in *Discoveries in Photosynthesis*

1928 H. V. Harlan (Harry Vaugh Harlan) established a "de-domestication" trial for barley at UC Davis, using hybrids between seed of 28 high-yielding barley strains available at that time. The trial (called CC II) was still running at Davis in 1992. [see also J. R. Harlan, *One man's life with barley, the memories and observations of Harry V. Harlan*, 1957; J. R. Harlan *in* Chapman, 1992, *Grass Evolution and Domestication*, page 164]

1928 Following similar work with *Drosophila*, Stadler used X-rays to produce mutations in corn (*Zea mays*). ©.(Zirkle in Ewan, 1969)

1928 Asplundh Tree Expert Company was established by brothers Carl, Griffith, and Lester Asplundh. Specializing initially in work related to power lines, Asplundh, the company established its own training school and developed technical improvements that led to a dominant position in the arboriculture industry. (Campana, 1999)

1929 Geographer Joseph Russell Smith published *Tree Crops: A Permanent Agriculture.* His book suggested systems of agriculture that might use understory cropping of long-lived forests. His book inspired the life and works of humanitarian Toyohiko Kagawa.

1929 The Cactus and Succulent Society of America was founded in Southern California, with N. L. Britton as Honorary President, A. D. Houghton as President, and Scott Haselton as Editor. The society published its first journal issue in July as "A monthly magazine devoted exclusively to Cacti and Succulents for the dissemination of knowledge and the recording of hitherto unpublished data in order that the culture and the study of these particular plants may attain the popularity which is justly theirs." (J. CSSA, 1929:1(1)

1930 US Census data suggested that of 12 food groups, consumption of dry beans was the only practice that increased at inverse proportion to income (i.e. wealthier people rely less on dried beans for sustenance). In other food groups, consumption either remained the same or increased with family income. (Kaplan & Kaplan in Foster & Cordell, 1996)

1930 The Sanforizer Company introduced an ammonia-based process, devised by Sanford Cluett, that causes cotton fibers to swell, preventing shrinkage when washed. (OED)

1930 Vita Sackville-West and her husband, Harold Nicolson, purchased Sissinghurst Castle and the surrounding 10 acres. Together they began creating their famous garden of rooms. Most noted and imitated among the many plantings has been the white garden. (Grimshaw, 1998)

1930 The Plant Patent Act became part of US law, codifying the concept that people could "stake claims to living matter." Within ten years, at least 350 plant patents had been granted. (Sackman, 2005)

1930 Dutch Elm Disease (DED), which had reaped major damage in Europe over the previous decade, was first detected on the native *Ulmus americana* in Cleveland, Ohio, by arborist Charles Irish.. Now considered “the most serious tree disease in the history of North American arboriculture,” researchers eventually determined the disease arrived in European-sourced logs of the *Ulmus procera* burl form (called Carpathian elm), which are highly prized for furniture manufacture. This source was confirmed in 1933 by interception of additional log shipments in Norfolk, Baltimore, and New Orleans. (Campana, 1999)

1930 With refinement in their preferred strain of perennial ryegrass, Bruce Levy and William Davies initiated New Zealand’s ryegrass certification. Levy, a “grasslands evangelist” wrote extensively and spoke convincingly about pasture, winning over New Zealand farmers, and helping to initiate the country’s “grasslands revolution.” (Brooking and Pawson, 2011)

1930 Clarence Birdseye was granted a patent for his methods of flash freezing, leading to development of boxed, frozen vegetables. By 1944, Birdseye was shipping frozen food nation-wide. (Clampitt, 2015)

1930 Jerome Irving Rodale established Rodale Press, later establishing his Pennsylvania organic farm.

1931 A. F. Blakeslee delved into differing human sensitivities to plant fragrances and taste. From his obituary by Edmund Sinnot, nsaonline.org: *“Blakeslee's interests were so wide that he was continually exploring other problems. Notable among these was the genetics of taste. In 1917 he had noticed that a pink-flowering Verbena plant which had a pleasant odor to him was without odor to his assistant, and that a red one which was odorless to him was fragrant to his assistant. He began to watch for differences in olfactory acuteness and then in taste. In 1931 he discovered that there were sharp differences among people in their ability to taste various chemical substances, notably phenyl-thio-carbamide (P T C) To some this was tasteless but to many others very bitter, and individual sensory thresholds to concentrations of it were markedly different. Furthermore, the ability to taste it seemed to be inherited. This interested Blakeslee intensely, not only from a genetic viewpoint but also because of its bearing on fundamental human differences in reaction to the outside world. At several meetings of scientific associations he set up a little booth where hundreds of people were tested for their PTC reactions, and gathered some very interesting data.”* Sinnot adds: *“In a very readable paper, "Teachers Talk too Much," he described a chapel talk he gave at Smith on the function of a college education. At its conclusion he distributed slips of paper impregnated with PTC and asked each student to taste one. This created a mild sensation, for the young ladies found that a substance violently bitter to some had no taste at all to others. This did more to convince the girls of the existence of genetic variability in the human species than any amount of talking. Few students—or faculty members—remembered long what he had said in his talk, but they never forgot the taste test.”*

1932 Following the Great Hunger of 1921, the Soviet Union nationalized food production in kolkhozes (collective farms). To control inadequate resources during protracted food rationing, the Soviet Union Central Executive Committee and Council of People’s Commissars enacted a law prohibiting harvesting (theft) from fields at all levels, including gleaning of residue. Having been finalized on 7 August, the law was sometimes called the Seven-Eight law, or alternatively the Law of Three Spikelets. (Tatiana Voronina, Chapter 3 “From Soviet Cuisine to Kremlin Diet: Changes in Consumption and Lifestyle in Twentieth-Century Russia” in Oddy, Atkins, & Amilien, 2016, *The Rise of Obesity in Europe - A Twentieth Century Food History,* Routledge, London, electronic book; also Wikipedia, 2019)

1932 Allis-Chalmers introduced rubber, pneumatic tires for their tractors, offering by 1934 a tractor designed specifically for those tires. By 1939, 90% of the tractors manufactured had pneumatic tires. (Williams, 1987)

1932 On a mid-July day in San Antonio, Tx, Charles Elmer Doolin responded to an offer by Gustavo Olguin to acquire a recipe and rights to a process for making and marketing fried corn chips. By September, Doolin established the Frito Company and began manufacturing and distributing his Fritos chips. He developed and patented better processes, and worked with specialists to bred a proprietary strain of corn used to make Fritos. (Wikipedia, 2018)

1933 The US National Recovery Act and Emergency Relief Act (the WPA, Works Progress Administration) led to employment of 18 million workers in a range of national projects, including many environmental investments such as tree planting and development of national parks. (Campana, 1999)

1933 Investigators identified 677 trees stricken with Dutch Elm Disease in the New York area. Twelve years later, over 6 million diseased trees had been discovered and destroyed. Eradication efforts through 1940 seemed to control spread, but federal funding for those efforts was dropped during WW II, which allowed the disease to spread throughout the native and planted range of American elm. Because American elm had been the most commonly planted street tree in North America, the near complete loss of elms due to disease destroyed urban forests throughout the continent. (Campana, 1999)

1934 Data from Los Angeles show that nearly a third (1,500) of the Japanese American working population in the city (5,125 people) were gardeners. At this time, over 50% of workers in the West Coast Japanese American population were involved in the green industry (gardening, nurseries, orchards, truck farming, agriculture, supporting businesses). (Helphand, 2006)

1934 A major windstorm in the plains states removed 350 million tons of topsoil, scattering it over the eastern US and out into the Atlantic. It is estimated that 12 million tons fell on Chicago. The storms continued and by 1938 the top five inches of soil had been removed from 10,000,000 acres of land. In that year 850 million tons of soil were lost. By 1938 3.5 million people had abandoned farms on the great plains. One fifth of Oklahoma's population moved to other states. (Ponting, 1991)

1934 NewZealand passed The Native Plant Protection Act, by which taking protected native plants from public property and private lands constitutes an offence. According to Nicola Wheen, that cover most native plants, but enforcement is uneven and inconsequential. (Pawson & Brooking, 2002) If people should increasingly reject exotic plants and move to greater use of native plants, one wonders if controls such as these mean the general use of plants will be prohibited.

1935 Analysis by botanist A. Koehler demonstrated that a homemade wooden ladder used during the abduction (resulting in murder) of the son of Charles and Anne Morrow Lindbergh was made from the same wooden planks that floored Bruno Hauptmann's attic. Hauptmann was convicted of this crime. (Levetin & McMahon, 1996)

1935 William Ukers published All About Tea, a comprehensive study that remains a landmark. (Hohenegger, 2007)

1935 The Rural Electrification Administration (REA) was created through executive order by President F. D. Roosevelt, receiving Congressional authority the following year through passage of the Rural Electrification Act. REA offered loans to cooperatives and power districts in order to finance distribution, transmission, and generation of power to rural areas. In 1935 approximately one in ten US farms received electricity; by 1962 electricity was supplied to more than 97% of US farms. (Kelly, in The Yearbook of Agriculture 1962)

1935 News media proclaimed 14 April a "Black Sunday" - a particularly bleak day in a series of duststorms that impacted the Western US (most particularly Oklahoma and the Texas Panhandle) as result of drought and overgrazing. That Sunday storm led to reporter Robert L. Geiger's famous labelling of the region as the Dust Bowl. Within two weeks of the storm, the US Congress responded through creating the USDA Soil Conservation Service (expanding the Soil Erosion Service, which had been established in 1933). (McKibben, 2008; Wikipedia, 2017)

1936 USDA entomologists Hurd-Karrer and Poos discovered that selenium applied to roots of wheat plants could kill aphids feeding on the leaves. By 1945 selenium was used commercially (applied with fertilizer) to control spider mites in carnations and chrysanthemums. (Reed, Bushland, & Eddy, in The Yearbook of Agriculture 1962)

1936 From Punch, a verse on the sweets of science references research on the biochemistry of dye plants:

"Modern painters in their fervour

Seek to startle the observer

By reliance on their peacock hued appeals

But I find more consolation

In the dusty rubrication

Which the background of the galaxies reveals

And though rare sweets and ices

Compounded at high prices

A transitory rapture may impart

The glycosides of madder

Make me infinitely gladder

And rejoice the inmost cockles of my heart."(O. Morton, 2008)

1936 Walter Emery excavated the tomb of Hemaka, who is said to have been the chancellor and seal-bearer to Pharaoh Den (the First Dynasty, 2850 BC). In the tomb were two unused papyrus scrolls, which are said to be there earliest known samples of paper made from papyrus. [see 2850 BC] (Gaudet, 2014)

1936 Mikhail Chailakhyan proposed the hormone florigen as a factor he believed was manufactured in leaves and migrated to stem tips to promote flowering. The concept developed based on observations that stems could be induced to flower by grafting them to stems that had already been exposed to inducing conditions. (Hodson & Bryant, 2012) Over several decades, no solid evidence has surfaced to support the existence or character of such a hormone. Work in *Arabidopsis* now suggests the FT protein (Floral Locus T protein) represents the inducing factor Chailakhyan termed florigen. Wikipedia (2018), incorrectly, indicates the year to be 1937.

1937 The Nobel Prize was awarded to Albert Szent-Gyögyi, the first person to isolate vitamin C. He extracted it from paprika. [See 1747] (Levetin & McMahon, 1996)

1937 Conrad Elvehjem isolated Niacin (nicotinic acid) and proved that niacin-deficiency causes pellagra (Wikipedia) [See 1902]

1937 The Bankhead-Jones Farm Tenant Act provided loans for US farm workers to purchase their own lands. It also created a land conservation program that supported the retirement/purchase of marginal farmland, some acreage of which was added to the national forest system. (A. S., in The Yearbook of Agriculture 1962)

1937 George Russell of York, England, exhibited his lupines (spelled "lupins" in England), the product of years of hybridizing and selection. When Russell began his work in 1911, lupines had been known to horticulture for over a century, beginning with introduction of plants from the North American collection efforts of David Douglas (who sent seed of 23 species of *Lupinus* to his employers at London's Royal Horticulture Society in 1825). (Grimshaw, 1998)

1937 Robin Hill conclusively demonstrated that oxygen generated during photosynthesis (now called the Hill Reaction) does not require the presence of carbon dioxide. Hill's studies furthered work by T. W. Englemann, who in 1883 had demonstrated that chloroplasts of the alga *Spirogya* generate oxygen most actively when exposed to red and blue light. By 1941, C.B. van Niel, Samuel Ruben, and co-workers had demonstrated that oxygen liberated during photosynthesis comes from the splitting of water. (McDonald, 2003)

1937 American botanist Albert Francis Blakeslee described the use of colchicine in doubling chromosome numbers of plants through impacting chromosomal separation during meiosis. This technique has had significant impact on plant studies and plant breeding. ("Redoublement du nombre de chromosomes chez les plantes par traitement chimque." *Comptes-rendu, Académie des Sciences*, Paris 204: 476-479; see also: Blakeslee and Avery, "Colchicine and Double Diploids", *Journal of Heredity*, 28(12): 411–412, https://doi.org/10.1093/oxfordjournals.jhered.a104295 1 December 1937 - and reference to misleading publicity concerning Colchicine by the Hearst Newspapers....

1938 Szent-Gyögyi withdrew his suggestion that "citrin" (now known to be various flavonoids), which was present along with vitamin C in citrus peels, could help maintain small blood vessels. These bioflavonoids were termed Vitamin P, and became the subject of much discussion. The U.S. Food and Drug Administration has proclaimed that bioflavonoids are neither vitamins nor of nutritional value (Visser, 1986)

1938 Ehrenfried Pfeiffer published his *Bio-Dynamic Farming and Gardening*. Having begun work with Rudolf Steiner, Pfeiffer came to manage Loverendale farm, an experimental biodynamic project in Domburg, Netherlands. This work was coordinated through the Goetheanum (the world center for the Anthroposophical movement in Dornach, Switzerland), a center named for Goethe, with a building designed by Rudolf Steiner. Later in life, Pfeiffer immigrated to the US to work at Hahnemann Medical College (based on his research in blood testing). Once in the US, he remained involved in biodynamic farming through the Kimberton Farm School (near Philadelphia). Pfeiffer knew and collaborated with J. I. Rodale, founder of the US organic gardening movement. He combined both science and emo-

tion, consulting with Rachel Carson based on his studies of DDT on one hand, while promoting experimental methods to document the etheric body (or aura) that underlies Theosophical concepts of human existence. (Wikipedia, 2016)

1938 DDT, a chlorinated hydrocarbon formulated by Othman Zeidler in 1873, was reintroduced as an insecticide by Paul Mueller, a chemist working for J. R. Geigy in Switzerland. The chemical was used to combat Colorado potato beetle, and gained significant use during World War (as a treatment for the body louse, which transmits typhus). (Campana, 1999)

1939 Swiss chemist Paul Müller discovered the insecticidal qualities of DDT, a compound first synthesized by German chemist Othmar Zeidler in 1874. [See 1972] (Busbey, in The Yearbook of Agriculture 1962)

1939 The first commercial Transmission Electron Microscope (TEM) was available. Work on this concept began a decade earlier with efforts of Ernst Ruska and Max Knoll. Ruska was awarded the Nobel Prize in 1986 for his role in TEM.

1940 Steroids discovered in yam (*Dioscorea*) proved useful for the manufacture of cortisone and sexual hormones. Consequently, the cost of hormones dropped from $80 to $2 per gram. [See 1956] (Heiser, 1981) This was amplified through the work of Russell Marker, who while assigned to study steroids during a research fellowship at Pennsylvania State University discovered he could manufacture progesterone from steroids in the yam. Unable to receive support to further this work, he moved to Mexico City and formed a joint venture named Syntex. Though Marker abandoned his research, Syntex continued work with other chemists. Eventually Syntex manufactured testosterone and 19-norprogesterone, an analog of progesterone that was even more effective at inhibiting ovulation. Administered in an oral version, this became "The Pill." (Cobb & Goldwhite, 1995) [See 1956]

1940 *Look to the Land* was published. Written by Walter Ernest Christopher James (who coined the term Organic Gardening), the book advances ecosystem-based ideas for farming. James had long been involved with the biodynamic farming movement through association with Ehrenfried Pfeiffer, and had hosted the Betteshanger Summer School and Conference at his farm. (Wikipedia, 2016)

1940 Albert Howard published *An Agricultural Testament*, based on extensive study and experience with traditional Indore techniques (based on studies at the Indian government research farm in Indore). Sometimes called the Father of Composting, Howard is a strong advocate for using organic amendments and creating “healthy” soils, quoted as stating: “the health of soil, plant, animal, and man is one and indivisible”. In the preface to his Testament, Howard distances “organic” gardening from “biodynamic” methods: “Some attention has also been paid to the Bio-Dynamic methods of agriculture in Holland and in Great Britain, but I remain unconvinced that the disciples of Rudolf Steiner can offer any real explanation of natural laws or have yet provided any practical examples which demonstrate the value of their theories.” (Wikipedia, 2016)

1940 J. I. Rodale established the Rodale Organic Experimental Farm in Emmaus, Pennsylvania - an outgrowth of Rodale, Inc, which he had founded in 1930, leading to Rodale Press in 1942. (Wikipedia, 2016)

1942 Even in the darkness and horror of war and genocide, gardens in forced ghettos yielded food and sustained hope. Mary Berg’s diary from a Warsaw ghetto comments of a spring day: "last night sixty more persons were executed." - followed in the next paragraph with: "In our garden everything is green. The young onions are shooting up. We have eaten our first radishes. The tomato plants spread proudly in the sun. The weather is magnificent." (Helphand, 2006)

1942 Botanists William C. Steere and F. Raymond Fosberg were sent to South America on the Cinchona Mission by the US Board of Economic Warfare. Their goal was to locate and collect high quality cinchona bark for extraction of quinine to treat soldiers with malaria. The mission, eventually, involved over 30 botanists. More than 12 million pounds of bark were collected, but the mission never succeeded in locating truly high-yielding trees, or in establishing locally-managed plantations of Cinchona. (on line: Vassiliki Betty Smocovitis, May, 2003, *Desperately seeking quinine: The malaria threat drove the Allies WWII “Cinchona Mission”* The American Chemical Society, *Modern Drug Discovery*, pp 57-58) [see TimeLine 1913, Kina Bureau]

1942 The Opium Poppy Control Act Of 1942 (US) was passed and signed: From the UNODC (United Nations Office on Drugs and Crime) website: “How The Cultivation Began And Ended

“The poppy cultivated in many parts of the world, and especially in Europe, for its edible and oil-bearing seeds, is the very same species- Papaver somniferum-as the poppy cultivated for opium in many other parts of the world. In fact, the same poppy plant can be used to obtain both opium and edible seeds. In the United States there has never been much commercial cultivation of this plant. Poppy-seed for food has been imported from Europe, 3,000 tons or more a year; in 1938 nearly 4,400 metric tons, chiefly shipped from the Neth-

erlands, Poland and Danzig. This importation was almost entirely cut off by the war, and the price of poppy-seed soared from 7 cents a pound to 50 cents a pound and even more. Many farmers saw the possibility of enormous profit, and plantings of the poppy rapidly increased, especially in California. Although there was no immediate question of opium production, the occasional abusive use of the capsules had already attracted attention, and in any case the Narcotics Bureau of the United States was quite unwilling to see the cultivation of the opium poppy extended far and wide over the country, with the potentiality of narcotic evils in its wake. In response, Congress passed the Opium Poppy Control Act of 1942, making it unlawful for any person to produce the opium poppy except under licence, and licences were to be issued only if necessary to supply the medical and scientific needs of the United States for opium or opium products. The California growers, on the plea that their crop had been planted in the early winter of 1942, just before the law was passed, were allowed to harvest their crop of poppy-seed in the summer of 1943. The understanding of the Narcotics Bureau was, of course, that this concession would never be repeated nor even asked for again. But some of the growers did not stop. Under California law any person of good moral character could obtain a state permit to cultivate the opium poppy. With tremendous profits envisaged and their state permits as at least a talking-point, some of the growers again planted poppy-fields in the fall of 1943. In the following spring, the authorities of the Narcotics Bureau first attempted by persuasion to have the poppies ploughed up, and finally moved to have the remaining crops seized and destroyed. The growers, who were still resisting, then brought the case to Federal Court, alleging that the Opium Poppy Control Act was unconstitutional, that control over a food plant rested solely with the state. The case was heard by a statutory emergency court composed of a Circuit Judge and two District Judges. The Narcotics Bureau and the District Attorney based their argument for constitutionality of the law squarely upon the treaty-making power of the Federal Government; in particular, the right of Congress to legislate, even contrary to state laws, in furtherance of the International Opium Convention of 1912. On 28 August 1944 the three judges handed down a unanimous decision holding the Opium Poppy Control Act constitutional. Soon after, the growers decided not to appeal to the Supreme Court of the United States. Thus ended the California "Poppy Rebellion".”

1943 About 3,000,000 people died from famine-based starvation in Bengal. (Ponting, 1991)

1943 Henry Wallace (owner of Pioneer Hi-Bred and US Vice-President) and Marte Gomez (Mexico’s Minister of Agriculture) coordinated with Raymond Fosdick and the Rockefeller Foundation to establish programs to improve corn and wheat production. The Mexican government established an Office of Special Studies (OSS). In 1941, anticipating this program, Richard Bradfield (Cornell, soil science), Paul Mangelsdorf (Harvard, botany), and Elvin Stakman (Minnesota) constituted the review committee endorsing creation of the Rockefeller-financed Mexican Agricultural program (MAP). Jacob Harrar and Norman Borlaug were among the founding scientists. MAP was the precursor to CIMMYT (*Centro Internacional de Mejoramiento de Maíz y Trigo*), the International Maize and Wheat Improvement Center. (Dworkin, 2009; Cotter, 2003; Christensen, 1984; CIMMYT website, 2017)

1943 On 26 January, Nikolai Vavilov died in prison in Saratov, Russia, the town in which he had founded an important agricultural research institute. Vavilov, despite having been one of the world’s most significant influential researchers regarding domestic crops, was condemned as “betraying the revolution” because he rejected the *“crackpot theories of “Trofim Denisovich Lysenko.”* Lysenko’s star had risen quickly in the Soviet Union. In denying the absolute nature of genetic inheritance he promoted the idea that a farmer could improve succeeding generations of a crop by providing especially favorable conditions for the current generation. His methods aligned with Stalinism in suggesting that ideal circumstances would engender immediately improved generations. This optimistic approach to plant husbandry, branded as Lysenkoism, basically rejected Mendelian genetics and the important work of Vavilov. Lysenko’s hypotheses reigned into mid-century Russia, destroying five year plans by leading to failed harvests. Vavilov, today, has been restored to a position of honor, and his disgraceful mistreatment seems forgotten. (Dworkin, 2009)

1944 Oswald Avery had directed his research to examine Frederick Griffith’s remarkable work. Griffith had demonstrated that some physical essence in killed bacteria could be taken in by other bacteria and result in genetic change, an alteration Griffith called transformation. In a series of experiments that involved careful purifications of various fractions, Avery determined that the material effecting the change was De-oxyribose nucleic acid (DNA). His work confirmed that genetic information was somehow stored in DNA. (Mukherjee, 2016)

1944 Chinese botanists reported discovery of living specimens of dawn redwood (*Metasequoia glyptostroboides*.) The tree hitherto had been known only from fossil material that was at least 20 million years old. (Rupp, 1990)

1945 White doves were released in Pasadena, California with the following statement: "We are persuaded that this greatest new rose of our time should be named for the world’s greatest desire, PEACE." Selected in 1935 after its first flowering, the rose had originally been named for the Meilland family matriarch, ‘Mme. A. Meilland’. Stock for the rose had been

sent by the Meilland family nursery (located near Lyon) on the last commercial flight to leave France for the United States during World War II. Stock also was sent to Germany (where it received the name 'Gloria Dei') and to Italy (where it was named 'Gioia'). At the first meeting of the United Nations (in San Francisco) each delegate received a flower of 'Peace' annotated: "This is the rose 'Peace' which received its name on the day Berlin fell. May it help to move all men of goodwill to strive for Peace on earth for all mankind." (Grimshaw, 1998)

1945 Through their work with limiting factors in growth of bread mold, *Neurospora crassa*, George Beadle and Edward Tatum. Noting the impact of mutations that meant individual enzymes were not functional, Beadle and Tatum were able to confirm that a gene provides instructions for a particular protein. This advanced understanding of genetics through explaining how, specifically, genetic information was translated into form and function in a cell. (Mukherjee, 2016)

1945 Erna Reinholz completed her PhD thesis on *Arabidopsis* mutants generated through exposure to X-rays. Her major professor Friedrich Laiback (who had first reported the plant's chromosome number in 1907) was convinced the plant would serve as an important model organism and continued emphasis on variability, eventually amassing a living collection of 750 different accessions. (Maarten Koornneef and David Meinke, 2010. Arabidopsis: A Rich Harvest 10 Years after Completion of the Genome Sequence: The development of *Arabidopsis* as a model plant" *The Plant Journal* (2010) 61: 909–921 doi: 10.1111/j.1365-313X.2009.04086.x; Elliot M. Meyerowitz, 2001. "Prehistory and History of *Arabidopsis* Research" *Plant Physiology*, Published January 2001. DOI: https://doi.org/10.1104/pp.125.1.15

1946 Marion Parker, Sterling Hendricks, Harry Borthwick, and Fritz Went published Spectral sensitivities for leaf and stem growth of etiolated pea seedlings and their similarity to action spectra for photoperiodism (*American Journal of Botany*, 35:194-204), explaining that Red light impacts plant growth, inciting new lines of investigation and causing researchers in photoperiodism to refurbish their labs with green filters. Previously, labs had followed protocols similar to those of black and white photography, using red "safe light" to illuminate workspaces. (Sage, 1992)

1947 Thor Heyerdahl sailed a raft made of balsa logs, the Kon Tiki, from South America far into the Pacific Ocean, to support his contention that prehistoric people could have made such journeys. Heyerdahl would use the presence in the Easter Islands of a plant called totara (*Scirpus*) that is native to coastal South America as suggesting ancient travel. A closely related plant, also called totara, is used extensively by inhabitants of the area around Lake Titicaca - for thatching, for construction of mats, even for building boats. (Heiser, 1985)

1947 Developed during WW II, the herbicide 2,4-D was introduced for weed control. (Fussell, 1992)

1947 Rice is an important food crop in Trinidad. We learn form a note by Benson and Murray that in this year a field of rice in Trinidad failed to flower by its normal season. The mystery and pending disaster were avoided when these government scientists noted a nearby stack pipe had been constructed near the paddy, from which natural gas was burned off. Because rice flowering is initiated based on daylength (an observation reported as early as 1923, by S. Mihara), light from the flame eliminated the necessary environmental cues. The challenge was solved by eliminating the flame, (Sage, 1992) [See: E.G. Benson and D.B. Murray, 1948. A Note of the Continuous Effect of Flowering of Padi, Tropical Agriculture - Trinidad, 25:3; See also available on the WWW: The Flowering Response of the Rice Plant to Photoperiod, by B.S. Vergara and T.T. Chang, 4th Edition, IRRI]

1947 Albert Francis Blakeslee, a noted botanist and member of the National Academy of Sciences, was famed for his research of Jimson Weed (*Datura*). In his obituary, the Academy recounts an incident from 1947: *"Datura justified the choice of it as a research plant. It was easy to grow. Though naturally rank, it remained small if not given too much nitrogen, and could be made to flower and fruit early in pots or in the field. It had all the vigor and vitality of a true weed. Its disadvantages were an unpleasant odor and the possession of a powerful alkaloid, stramonium, in its sap, which sometimes produced unpleasant effects. Blakeslee became attached to this coarse, weedy plant with its beautiful flowers and once rose vigorously to its defense. Edna St. Vincent Millay, in her poem "In the Grave No Flowers," had written*

Here beggar-ticks, 'tis true,
Here the rank-smelling Thorn-apple,—and who
Would plant this by his dwelling?

This aspersion on Datura was too much for Blakeslee to take without a protest. "I thought I would write you," he said in a letter to Miss Millay in 1947, "and tell you the answer to your question by saying that I would plant this by my dwelling and have done so for the last thirty years rather extensively. It turns out that this plant (Datura stramonium) is per-

*haps the very best plant with which to discover principles of heredity." He then went on to ask her about the name "thorn-apple," and said he wished that he had used it instead of Jimson weed; the name given it by soldiers sent to Jamestown, Virginia, to put down Bacon's rebellion in 1676." (nasonline.org "*Albert Francis Blakeslee, 1874—1954, A Biographical Memoir" by Edmund W. Sinnott)

1948 "Collect everything. Save everything." Jack Harlan and Osman Tosun, collecting seed samples in Turkish wheat fields, recorded one especially "miserable looking wheat" as Plant Introduction 178383. Fifteen years later, the sample proved to be an important source for genetic resistance to wheat stripe rust. (Dworkin, 2009)

1948 Botanists and editors associated with Kew Gardens began the *Flora of Tropical East Africa* project. With assumptions the flora would comprise about 7,000 species and the task would take around 15 years, the *Flora* was concluded in 2012, covering over 12,100 species involving the work of 135 botanists. Publication had included 263 volumes (1.5 meters of shelving), covering 21 countries, and involving description of approximately 1,500 new plant species. Included in the flora are the ten species of *Saintpaulia*, plants we call African Violets, which have become extremely rare in the wild. (Willis and Fry, 2014)

1949 English phycologist (a scientist who studies algae) Kathleen Drew-Baker described the complex life cycle of *Porphyra* (nori is in this genus). This new understanding allowed commercial farming of nori in Japan to flourish. A statue of Drew-Baker stands in a Tokyo park overlooking the bay.

1949 Working with Massachusetts-based Fitchburg Engineering Company, Asplundh Tree Expert Company developed the first wood chipper. This development led to many advances in processing tree, brush, and greenwaste leading to more efficient handling of woody material and growing use of mulch in the landscape. (Campana, 1999)

1949 Following trials by the New Zealand Royal Air Force in 1948, researchers settled on suitable methods for widespread application of fertilizers - termed "aerial topdressing". By 1952, 38 private firms were operating 149 aircraft in this process. Annual aerial application of superphosphates to grasslands grew to a peak of 2 million tons in 1985, a year in which year the New Zealand government discontinued subsidies. Aerial fertilization of grasslands had underpinned huge increases in sheep populations, reaching approximately 70 million sheep by the 1980s. (Pawson Brooking, 2002; Wikipedia: Aerial Topdressing, 2017)

1949 Relaxation of WW II food rationing in Britain began in 1948, but: *"Sweets and confectionery were taken off ration in April 1949 but the rush to buy them caused rationing to be reintroduced until February 1953 when its removal was politically timed to occur before the coronation of Queen Elizabeth.*" (Oddy, Chapter 5 "The Stop-Go Era: Restoring Food Choice in Britain after World War II", in Oddy, Atkins, & Amilien, 2016, *The Rise of Obesity in Europe - A Twentieth Century Food History,* Routledge, London, electronic book)

1950 The US National Science Foundation was established.

1950 The International Association for Plant Taxonomy (IAPT) was established. The IAPT "promotes an understanding of plant biodiversity, facilitates international communication of research between botanists, and oversees matters of uniformity and stability in plant names. The IAPT was founded on July 18, 1950 at the Seventh International Botanical Congress in Stockholm, Sweden." (Wikipedia, 2018)

c1950 Lysenkoism crested with Stalin's reign of power, codified in a Russian encyclopedia: '*Gene is a mythical part of living structures which in reactionary theories like Mendelism-Veysmanism-Morganism determines heredity. Soviet scientists under the leadership of Academician Lysenko have proved scientifically that genes do not exist in nature.'* (Thompson, 2010)

1951 Publication of *The Day of the Triffids,* by John Wyndham, and origin of the triffid as a cultural icon: "*a fictitious tall, mobile, prolific and highly venomous plant species."* The book's main human character, Bill Masen, postulates: *"My own belief, for what that is worth, is that they were the outcome of a series of ingenious biological meddlings—and very likely accidental, at that. Had they been evolved anywhere but in the region they were, we should doubtless have had a well−documented ancestry for them."* (Wikipeida, 2017) In England today, triffid refers to any particularly large, impressive, and perhaps threatening invasive plant, (see Mabey, 2010)

1952 From Catherine Keever's autobiography, referencing her early teaching position at Limestone College: *"I lived in a nice apartment on campus and ate in the student dining hall. My salary was thirty-eight hundred dollars a year and I never got a raise in the three years I stayed there. One year they gave a raise to the man teaching physics who had only a master's degree. When I complained, they assured me that a man with a family could not live on so low a salary. I wondered whether they were paying him to teach or to have babies."* (Keever, 1985)

1952 G. C. Palade published the first high resolution electron micrographs of mitochondria in Anat Rect 114: 427-451. (Lars Ernster and Gottfried Schatz, 1981. "Mitochondria: a historical review" *J Cell Biol.*: 91(3): 227–255.)

1952 Irene Manton and Brian Clark, studying moss, were the first to described a 9 + 2 axoneme in flagellae of *Sphagnum* spermatozoids. This was the first accurate description of the structure of flagellae in Eucaryotes. ("An electron microscope study of the spermatozoid of Sphagnum", J. Exp. Bot. 3:265-275; R. D. Preston,1988. "Irene Manton. 17 April 1904-13 May 1988" Biographical Memoirs of Fellows of the Royal Society, 35: 248-261

1953 James Watson and Francis Crick published "Molecular Structure of Nucleic Acids: A Structure for Deoxyribose Nucleic Acid." This paper explained the double helix nature of DNA molecules, explaining how linear arrays of code could be integrated in compact molecules. There was no explanation as to how this code could be translated into cellular proteins, but the difficult task of determining how so much information could be stored in linear chromosomes was tackled. (Mukherjee, 2016)

1953 Kevin Porter reported the presence of a cytoplasmic network which he named endoplasmic reticulum (ER). This work was follow-up to a 1945 report of transmission electron microscopy by authors Keith Porter, Albert Claude, and Ernest Fullam, in which they noted observations of a "lacelike reticulum... , possibly the homologue of kinoplasm." Because the 1945 article focused on techniques for TEM study of tissue culture cells, concern was expressed that the reticulum could be an artifact of specimen preparation. In his 1953 follow-up study, Porter confirmed this network and applied the name. ("A Study of Tissue Culture Cells by Electron Microscopy - Methods and Preliminary Observations," J Exp Med. 1945 Mar 1; 81(3): 233–246. PMCID: PMC2135493; PMID: 19871454) (Kevin Porter, 1953. "Observations on a submicroscopic basophilic component of cytoplasm." *J Exp Med*. 97(5):727-50. [Also See: TL 1895, Garnier]

1953 Jean Giorno's classic book, *The Man Who Planted Trees*, was rejected for publication by The Reader's Digest as improbable, but hugely received the following year when printed in Vogue magazine. (Nabhan, 2013)

1953 The first service was held at Whipsnade Tree Cathedral. Originally conceived by Edmond Blyth in 1930, the tree plantings cover nearly 10 acres of a 26-acre site. Owned by the National Trust, the garden (near Bedfordshire, England), was established as a memorial to those who fought in WW I. The concept of an open-air cathedral came to Blyth while visiting Liverpool's cathedral, which was under construction at the time. Creation was delayed by WWII. It provides a site for various kinds of services in "faith, hope, and reconciliation." Accepted by the National Trust in 1960, the site is operated by the Whipsnade Tree Cathedral Fund. (Stafford, 2016; WWW)

1953 Alan Bloom (developer of over 170 cultivars of perennial garden plants) began developing the gardens at Bressingham Hall (in Norfolk, England). His work there led to creation of Bressingham Steam and Gardens by 1961/62, and eventual creation of the Steam Museum as a charitable trust. As of 2017, the Bloom family continued to expand and operate the adjacent home and gardens as a business. (Bressingham Garden website, Steam Museum website, Wikipedia, 2017)

1954 Brown (combined in 1957 with Bonner and Weir) estimated that if humans were willing to sustain themselves through algae farms and yeast factories, 50 billion people could be supported on Earth. (Cohen, 1995)

1954 Harvard University consolidated Gray Herbarium and Arnold Arboretum research collections (library and herbaria), permanently relocating resources from the Arboretum (at Jamaica Plain) to the main campus in Cambridge. This move was challenged by various groups, but the University prevailed in a 1966 Massachusetts Supreme Court decision (see WWW arboretum.harvard.edu I B EDM archives.) Duplicate books were sold and many supporters became annoyed and alienated. Elmer Merrill willed his archives to New York Botanic Garden. Beatrix Farrand (who had been an Arboretum board member and supporter) gave her archive to UC Berkeley.

1954 On a trip to Russia, triticale breeder Stan Nalepa recalled hearing *"a scientists at the Mironovsk Station in Ukraine assert that he could turn spring wheat into winter wheat by spraying the spring wheat with a solution of water and 5 percent sugar before frost. The sugar, he said seriously to his dumbfounded audience, would give strength to the spring wheat, and when it emerged in the spring, poof! Its very nature would be changed! It would have developed a winter habit, which it would then pass on to its progeny."* Nalepa said those results, though tried in Hungary, Poland, and other locations could not be repeated. (Dworkin, 2009) Thus the problem with Lysenkoism and other politically-selfish attempts (such as with the 2017 US leadership) to commandeer science through stifling objective research.

1954 Harry Borthwick, Sterling Hendricks, Eben Toole, and Vivian Toole published "Action of Light on Lettuce-Seed Germination" in *Botanical Gazette* (115:205-225).

1954 W. C. Boyd, and E. Shapleigh introduced the term “lectin” as a group name for related hemagglutinating proteins. Because practitioners had discovered these chemicals can distinguish between the different blood types, Boyd and Shapleigh elected “lectin” - which comes from the Latin *legere* for “to select” (Boyd and Shapleigh, 1954. “Specific precipitation activity of plant agglutinins (lectins”. Science 119,:419.)

1955 From the autobiography of Catherine Keever: *“...I got a letter from Millersville State College offering me a job as full professor at fifty-five hundred dollars a year. It was a teacher’s college, they wanted someone with a Ph.D. in botany, and did not object to a woman.”* (Keever, 1985)

1955 Carlos Miller and colleagues described a plant hormone (derived from herring sperm) they named kinetin, which is involved in promotion of cell division (cytokinesis). In 1961, Miller described zeatin, the first naturally-occurring plant cytokinin. This work grew from earlier studies on plant callus formation and cell-division by Folke Skoog and J. R. Jablonski. Before their work, Johannes van Overbeek had studied the impact of coconut milk on cell division in culture media. (University of Indiana website; Wikipedia, 2018; History of Cytokinins, website of the International Plant Growth Substances Association, 2018) [See 1913, 1961]

1955 The arrival of cellular molecular biology became evident when Heinz L. Fraenkel-Conrat and Robley C. Williams reported the purification of protein and RNA components of Tobacco Mosaic Virus (which are not infective when separated) and their reconstitution as infectious agents. (“Reconstitution of active tobacco mosaic virus from its inactive protein and nucleic acid components. Proc Natl Acad Sci”)

1956 G. Pincus disclosed that a drug derived from the yam, *Dioscorea*, could stop ovulation, therefore preventing conception - allowing production of a birth control "pill" to replace the previous need for an injection. (Heiser, 1981) [See 1940]

1957 Extracts from the common periwinkle were found effective in the treatment of childhood leukemia. (Simpson, 1989)

1958 The protein that would be named phytochrome (in 1959) was characterized. (See Tripping the Light Switch Fantastic in the USDA ARS Timeline for a complete discussion; also see: *Isolation of Phytochrome, National Historic Chemical Landmark*, at www.American Chemical Society/Education/Explore Chemistry/Chemical Landmarks).

1958 The US established its main seed bank, the National Seed Storage Laboratory, in Ft. Collins, Colorado, where hundreds of thousands of seed samples are maintained. This is one of the 19 seed-storage facilities in the US that constitute the National Plant Germplasm System. (Levetin & McMahon, 1996)

1958 Accessioned as C-58, a strain of *Agrobacterium fabrum* (nee *A. tumefaciens*), a soil-borne, pathogenic bacterium involved in crown gall formation in many dicots. This strain, isolated from a Cherry tree from the orchard at Cornell University, NY, has proven particularly useful in genetic transformation of Arabidopsis.

1958 Clark estimated that with 77 million square kilometers of temperate zone agriculturally useful land, the Earth could support 28 billion people. (Cohen, 1995)

1959 The Pajama Paper was published, a report that was given this nickname because its authors were Arthur Parde, François Jacob, and Jacques Monod, which was shortened to Pa-Ja-Mo. They investigated changes in *E. coli* physiology that allowed the cells to switch from using glucose as an energy source to using lactose. Their study indicates that genetic activity is managed, or operated, turned on and off in cells, through allied genes they christened as “operons”. This discovery provided a major clue as to how a cell can focus its own differentiation and activity, while it contains the complete genome. (Mukherjee, 2016)

1960 Peter Nowell reported that phytohemagglutinin (PHA), a lectin extracted from *Phaseolus vulgaris* (Red Kidney Bean), stimulates lymphocytes to divide (it is mytogenic.) His work altered traditional understanding that lymphocytes are incapable of dividing. Nowell’s work led to examination of conconavalin A, the lectin extracted from Jack Bean [See TL 1919]. Researchers learned that the activity of conconavalin A relates to its binding to sugar (mannose). These discoveries led to the important use of “mitogenic lectins” in study of cell activity. (Boyd and Shapleigh, 1954. “Specific precipitation activity of plant agglutinins (lectins”. Science 119,:419.)

1960 In the early years of the decade, clearing of Siberian forests near Batagai, seems to have triggered melting of permafrost, which led to formation of a megaslump, now called the Batagiaka crater. Over 1 kilometer wide, the crater continues to grow, freeing bones and carcasses of animals that died tens of thousands to hundreds of thousands of years ago. Those animals lived in a massive forest, which means scientists are able to extract all manner of specimens and data. In 2018, unearthing of a nearly intact, 40,000 year old foal was

reported. The growing crater is both a treasure for exploration and a harbinger of dread for future climate change. Search the web for on-going discovery.

1961 François Jacob and Sydney Brenner carried much of the water in explaining how Messenger RNA functions to transcribe information held by DNA molecular sequences into actionable templates from which proteins could be constructed. (Mukherjee, 2016)

1961 Kleiber made an enlightening calculation. Assuming that 0.027 percent of Earth mass is carbon, and an average adult male embodies 12 kilograms of carbon, there is sufficient carbon on the planet to allow for 1,000,000,000,000,000,000,000 people. But we also have to provide food. If people lived on potatoes alone, and 48 billion hectares were planted to potatoes (that includes all 13.3 billion hectares of land not under ice and most of Earth's ocean areas,) a population of 800 billion could be supported. (Cohen, 1995)

1961 Melvin Calvin was awarded the Nobel Prize. In association with Andrew Benson, James Bassham, and other scientists, he described the light-independent reactions (often called the dark reactions, or the Calvin cycle) of the photosynthetic system. Beginning with carbon dioxide, these reactions actually synthesize organic compounds (3-carbon phosphate sugars) that become glucose and other sugars. (Levetin & McMahon, 1996)

1961 Carlos Miller characterized zeatin, the first cytokinin isolated from plant tissue (later named zeatin). Though published later, D. Stuart (David Stuart) Letham (Auckland, NZ) isolated this hormone in the same year. Today, Miller and Letham are given joint credit for this discovery. [See 1955] (History of Cytokinins, website of the International Plant Growth Substances Association, 2018; S. S. LethmTrove, Encyclopedia of Australian Science, National Library of Australia website)

1961 University of Illinois researcher John Laughnan introduced his first strain of supersweet corn, revolutionizing the fresh corn industry. Laughman's work inspired other researchers, leading to supersweet corn strains that retain native sugar through retarding starch formation. (Clampitt, 2015).

1961 Through use of Transmission Electron Microscope imagery, botanists were able to study internal structure of chloroplasts, revealing the layered nature of the grana, which Wilhelm Menke (Max Planck Institute) named thylakoids. ("Wilhelm Menke (1910–2007): a pioneer in chloroplast structure", 2009 *Photosynthesis Research* 99 (2): 81–84

1962 Rachael Carson published *Silent Spring*, spurring an entirely new era of environmental concern and awareness. One could imagine that Silent Spring marks the beginning of an end to American belief in better living through chemistry.

1962 F. Rothschild introduced the conceptual field of biosemiotics. "In the biological realm. Biosemiotics attempts to integrate the findings of biology and semiotics and proposes a paradigmatic shift in the scientific view of life, demonstrating that semiosis (sign process, including meaning and interpretation) is one of its immanent and intrinsic features. The term biosemiotic was first used by Friedrich S. Rothschild in 1962, but Thomas Sebeok and Thure von Uexküll have implemented the term and field.[2] The field, which challenges normative views of biology, is generally divided between theoretical and applied biosemiotics." Wikipedia, 2018

1962 Paul Green explained the effect of colchicine on spindle formation in *Nitella*,

1963 Microtubules were described in plant cells by Myron C. Ledbetter and Keith R. Porter (J Cell Biol. 1963 Oct 1; 19(1): 239–250., PMCID: PMC2106853 PMID: 19866635) Using glutaraldehyde to kill and "fix" cells, the researchers described microtubules, fiber-like structures that are 25 nm in diameter and occur throughout plant cells. Ledbetter and Porter indicated these microtubules represent the same kinds of structures that constitute mitotic spindles and flagella. ("A Glorious Half-Century of Microtubules" EDITORIAL, 2013. *The Plant Journal* 75, 185–188 doi: 10.1111/tpj.12260

1963 "Maria Thun reveals to the world her comprehensive work on the cosmic influences upon plants and develops "The Star Calendar", a sowing calendar that has since been published yearly in an ever-growing number of languages." (Biodynamics, Demeter International website, History timeline) Bizarre Stuff

1964 Graduate student Donald Currey, with permission and assistance of the U.S. Forest Service, cut down a Bristlecone pine tree at Nevada's Wheeler Peak Scenic Area. On counting the rings of this tree (which had been named Promethius by conservationists) he discovered that the tree was at least 4,844 years old. This marked Promethius as 200 years older than Methuselah (a different Bristlecone pine, already documented as the oldest known living specimen). He had cut down what might have been the oldest living tree on earth. Currey's study, published the following year in the scientific journal Ecology, partially led to creation of the Great Basin National Park in 1986. (Rutkow, 2012)

1964 The Surgeon General's Report connected smoking with lung cancer, heart disease, emphysema, and other diseases. [See 1761] (Levetin & McMahon, 1996)

1964 The US Congress chartered the National Tropical Botanical Garden, which today holds 180 acres on Kauai and 120 acres on Maui. (Campana, 1999)

1965 By this year, through work of many teams of researchers, all DNA triplets had been mapped to particular amino acids, providing the code that explained how Messenger RNA could translate the information carried by DNA into proteins. Mukherjee, 2016)

1965 Yoshiyuki Takasaki and Osamu Tanabe (working at the Japanese Fermentation Institute) developed a stable process to convert glucose to fructose. The tantalizing promise of that conversion had been the holy grail of the corn syrup industry. By 1967, Clinton Corn Processing Company had licensed rights to this enzyme for the US, and their scientists worked out kinks to industrialize the process. In a complex and rapid series of moves, large companies (particularly ADM) consolidated this emerging resource, marketing and defending high fructose corn syrup, which is called HFCS in the US, and HFGS (High Fructose Glucose Syrup) in Europe. By 1984 both Coca Cola and Pepsi converted to use of the new sweetener. Already liquid, more stable in solution, easily incorporated, and subsidized by the US government, HFCS quickly rose to equal status with sucrose for industrial food production. (Folsom, Botany of Sugars in Reader)

1965 Per Scholander, H. Hammel, Edda Bradstreet, and E. Hemmingsen published their research on Sap Pressure in Vascular Plants in the journal *Science*. By introducing a new pressure chamber technique (now called Scholander's Bomb), the authors changed the course of experimental discovery regarding movement of sap through plants. (Vogel, 2012, and the PMS Instrument Company website)

1965 J. Willian Schopf published his first descriptions of prokaryotic life forms in pre-Cambrian stromatolites from Australia. He followed up on this work by examining similar sedimentary deposits from South Africa, Russia, India, and China. This was the first evidence that documents the presence of life forms on Earth 3.5 billion years ago. (Wikipedia, 2018)

1967 De Wit calculated the Earth's potential photosynthetic output. Using a human requirement of 1,000,000 kilocalories per year and allowing for city and recreation space, he calculated Earth's carrying capacity at 146 billion people. (Cohen, 1995)

1967 High-fructose corn syrup was introduced commercially by Clinton Corn Processing Co. (of Clinton, Iowa.) Manufactured using their patented enzyme Isomerose, the fructose sweetness of corn syrup was raised from 14% to 42%. With rising sugar prices, "Isosweet" became the sweetener for all major soft drinks. (Fussell, 1992)

1967 - Alan Chadwick (a student of Rudolf Steiner) established the UC Santa Cruz Student Garden, based on Biodynamic/French Intensive Gardening methods he practiced. The UCSC garden was important in establishing the organic gardening movement in California.

1968 Head of the US Foreign Aid Program, W. Gaud, coined the term "Green Revolution." [See 1970] (Levetin & McMahon, 1996)

1967 . "On the origin of mitosing cells" (*Journal of Theoretical Biology*. 14 (3): 225–274) was published by Lynn Sagan (Margulis). Her thesis re-popularized century-old ideas that cellular organelles, such as mitochondria and chloroplasts, originated as independent organisms, and are "symbiotic" components of contemporary cells. Andreas Schimper had noted the similarities between algae (Cyanobacteria) and plastids in 1883, as had Konstantin Mereschkowski in 1910. (see https://theendosymbiotichypothesis.wordpress.com/; see also Schimper, "*Über die Entwicklung der Chlorophyllkörner und Farbkörper". Bot. Zeitung.* 41: 105-...162)

1968 Studying chloroplasts of tobacco, K. K. Tewari and S. G. Wildman demonstrated the presence of plastid DNA. This followed work by H. Ris and W. Plaut in 1962 reporting DNA-like material in chloroplasts of the alga *Chlamydomonas*. (McDonald, 2003)

1969 Herbert Huber published *Die Samenmerkmale und Verwandtschaftsverhältnisse der Liliiflorae*, his morphological studies of seed in plants considered lilies. His conclusions presaged later studies that supported breaking the Asparagales apart from the broader, traditional order, the Liliales. This has meant that many plants (such as daylilies and asparagus) historically considered closely related to Lilies are now regarded as part of a separate, parallel lineage. (Wikipedia: Herbert Huber, 2017)

1969 Mary Lou Pardue and Joseph G. Gall published their article "Molecular Hybridization of Radioactive DNA to the DNA of Cytological Preparations", in *Proceedings of the National of Academy of Science*/ From the Abstract: "A method is presented for detecting the cellular location of specific DNA fractions. The technique involves the hybridization of a radioactive test DNA in solution to the stationary DNA of a cytological preparation. Sites of DNA binding are then detected by autoradiography. Experiments with DNA of the toad *Xenopus* are described." This work ldescribes use of easily-visible fluorescent markers, i.e. FISH, which led to major advances in genetic and genomic studies.

1970 Norman Borlaug was awarded the Nobel Peace Prize. As the "Father of the Green Revolution" he developed high yielding dwarf strains of wheat while working at the Rockefeller-financed CIMMYT Agricultural Station in Mexico City. Use of such seed has

allowed tropical countries to double their wheat productivity. Along with improvements in rice productivity at a similar center in the Philippines and other crops at yet more agricultural stations, the "Green Revolution" came into being. (Levetin & McMahon, 1996)

1970 Rio de Janeiro completed construction of the 4 km Copacabana beach promenade, with paving and landscape design by Roberto Burle Marx.

1971 Paclitaxel (PTX), sold as Taxol, was first isolated from the bark of Pacific yew (*Taxus brevifolia*). Between 1993 and 2005, the extracts received approvals in various countries for use in cancer treatments, as well as narrowing of arteries. Work had begun on Taxus in 1962, as a result of screening programs established by the National Cancer Institute. (Wikipedia, 2018)

1971 Theodor Seuss Geisel (i.e. Dr. Seuss) published his environmental children's book The Lorax. A Monterey Cypress, *Cupressus macrocarpa*, visible from the window of his study fell of its own accord in June, 2019. The mop-topped tree was said to have inspired his artwork for Truffula trees.

1972 DDT (dichloro-diphenyl-trichloroethane) usage was banned in the US. (Levetin & McMahon, 1996)

1972 String trimmers were introduced. (Crotz in Punch, 1992)

1973 Lieth calculated the annual net primary production for land vegetation on Earth to be 100 billion tonnes of dry matter, having a caloric content of 426 thousand trillion kilocalories. (Cohen, 1995)

1973 Peter Thompkins and Christopher Bird published their book The Secret Life of Plants. Embraced by a public that adores mysticism and lambasted by the science community. for its anthropomorphic and unsupportable claims, the book seems to have found legs in popular culture, baffling and annoying researchers and instructors whose audiences seem to latch onto sensational alchemy while remaining refractory to supportable information. (Pollan, Michael, 2013. The Intelligent Plant, The New Yorker, December 23 & 30 Issue)

1973 The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) was finalized in March. Having arisen from membership of the International Union for the Conservation of Nature (IUCN) in 1963, 80 countries came to agreement on the terms of the Convention, which came into effect 1 July 1975. (CITES website: "What is CITES?")

1974 During his lecture, when receiving the Nobel Prize, Albert Claude, stated: *"We have entered the cell, the Mansion of our birth, and started the inventory of our acquired wealth."*

1975 United Farm Workers won the concession to eliminate use of the short-handled hoe in lettuce cultivation. (Visser, 1986)

1976 Following discussion and planning in 1975 among the leadership of the National Shade Tree Conference, The International Society of Arboriculture (ISA) was established. [See 1924] (Campana, 1999)

1976 Dan Janzen and coworkers reported that lectins extracted from Black Beans (*Phaseolus vulgaris*) proved toxic to Bruchid Beetles, suggesting that lectins protect plants from insect damage. (Janzen, D.H., Juster, H.B., and Liener I.E. (1976) Insecticidal action of the phytohemagglutinin in black beans on a bruchid beetle. Science , 192, 795–796.)

1977 The perfectly preserved corpse (from the 2nd century B.C.) of the wife of the Marquis of Tai was found in Ch'ang-sha, China. In addition to melon seed discovered in her intestines, the tomb contained a bowl of peaches. Belief since the Ch'in Dynasty held that peaches "eaten in time" would preserve the body from deterioration forever. This custom survives today in the tradition of shoutao - the long life peach - a steamed roll served on birthdays. (Root, 1980)

1978 Rafael Guzman, a student at the University of Guadalajara, discovered an extant stand of perennial corn (a kind of teosinte) in the mountains near Jalisco. (Fussell, 1992)

1979 Liquid balsam produced by species of *Copaifera* (copaiba tree) was found to be so similar in composition to diesel fuel that it could be utilized (with no further processing) to power a diesel engine. (Lewington,1990)

1979 Stevie Wonder issue his album (with lyrics by Wonder and others), "Journey Through The Secret Life of Plants," to accompany Michael Braun's documentary "The Secret Life of Plants". Search Wikipedia, or http://plantcurator.com/stevie-wonders-sixth-plant-sense/ Lyrics for his song "The Secret Life of Plants":

> *I can't conceive the nucleus of all; Begins inside a tiny seed; And what we think as insignificant; Provides the purest air we breathe*

(Chorus) But who am I to doubt or question the inevitable being; For these are but a few discoveries; We find inside the Secret Life of Plants;

A species smaller than the eye can see; Or larger than most living things; And yet we take from it without consent; Our shelter, food, habilment

(Chorus)

But far too many give them in return; A stomp, cut, drown, or burn; As is they're nothing; But if you ask yourself where would you be

Without them you will find you would not; And some believe antennas are their leaves; That spans beyond our galaxy; They've been, they are and probably will be; Who are the mediocrity

(Chorus)

1980 In their ruling on *Diamond v. Chakrabarty*, the US Supreme Court determined that genetically-altered life forms could be awarded patents. From Wikipedia, 2018: *"After (Ananda Mohran) Chakrabarty had appealed his patent's initial rejection, the Court of Customs and Patent Appeals had reversed in his favor, stating that "the fact that microorganisms are alive is without legal significance to the patent law". In response, Sydney Diamond, Commissioner of Patents and Trademarks, decided to take this case to the Supreme Court. Diamond had two arguments which were not well received by the court. The first called the existence of the 1930 Plant Patent Act and the 1970 Plant Variety Act to suggest that there is a congressional understanding about the terms 'manufacture' and 'composition of matter' not referring to living things. The second was that microorganisms cannot qualify as patentable subject matter until Congress authorizes such protection since genetic technology was unforeseen when Title 35 U.S.C. 101 was first enacted."*

1980 With passage and signing of its Groundwater Management Act, Arizona became the first state to institute a system for statewide planning and managing of groundwater. Historical water use practice relate to fair use, i.e. the landowner has right to use a reasonable amount of groundwater for reasonable purpose (such as farming). But given modern capacity for deep drilling and pumping, we enter an era when industrial and urban water use far exceed the capacities of Earth's 37 major, ancient underground aquifer systems. Despite this attempt at planning and control, Arizona continues to lose ground in its struggles to stabilize exhausting ancient underground supplies. (see a Feature by Noah Gallagher Shannon, *The New York Times Magazine*, 19 July 2018: "The Water Wars of Arizona"). In 2014, California became the second state to enact a measure that encourages comprehensive management of water supplies.

1981 Hundreds of people in Spain became sick and died from consuming cheap olive oil that had been adulterated with French rapeseed oil. The rapeseed oil contained industrial aniline dyes and was manufactured only for use in steel mills. (Visser, 1986)

1982 Archaeologists working in Japan are said to have discovered Magnolia seed, still viable, from middens over 2,000 years old. I have not located the original source of this report. (Chaskey, 2014)

1982 The first genetically engineered crop was developed at Washington University in St. Louis, Missouri. By 1994 the Flavr-Savr tomato became the first such plant approved for commercial marketing. The Flavr-Savr tomato was designed for slow fruit ripening and increased shop life. (Levetin & McMahon, 1996)

1983 Kary B. Mullis devised the polymerase chain reaction, a system to replicate large quantities of DNA from a small initial sample. The ability to create a large sample of DNA for testing and study had extraordinary impact on various fields of study, from areas of paleobiology to forensic analysis. (Cobb & Goldwhite, 1995)

1983 Barbara McClintock received the Nobel Prize for her work with the complex color patterns of Indian corn, studies that revealed moveable genetic elements termed "jumping genes."

1983 *Agrobacterium fabrum* (A. tumefaceins) was successfully used for genetic transformation of plants (in tobacco) by P. Zambryskit, H. Joost, C. Genetellol, J. Leemans, M. Van Montagu and J. Schell. See their publication. "Ti plasmid vector for the introduction of DNA into plant cells without alteration of their normal regeneration capacity" *The EMBO Journal* 2(12): 2143-2150: "The vector pGV3850 makes use of the natural transfer properties of the Ti plasmid; only those genes which interfere with normal plant differentiation have been removed. Thus,the most important aspect of pGV3850-transformed cells is their capacity to regenerate into complete plants.These plants can be derived from single cells and the regeneration process itself is extremely simple, requiring only minor changes in tissue culture conditions.... evidence has been presented that the Ti vector has evolved to a point where it is ready to be used to genetically engineer whole plants; it remains for us to turn our efforts toward the isolation of particular genes whose expression we wish to study."

1985 In her 1985 autobiography, plant ecologist Catherine Keever related stories of students and other young people in the late 1960s: *"My neighbor got quite concerned when her son began wearing a beard and long hair, I tried to tell her not to worry, with no success. That Christmas I bought six cards that showed the head of Jesus with beard and long hair and sent them to six friends who were good church people and who objected to beards. I wrote on the cards, 'I have many students who look like this and they are nice too,' I heard no more complaints..."* (Keever, 1985)

1987 Richard A. Jefferson published his GUS reporter gene system, which he had already shared extensively in his effort to support open sources for techniques. Jefferson's technique has been widely adapted and utilized in plant transformation. The article, "Assaying chimeric genes in plants: The GUS gene fusion system". Plant Molecular Biology Reporter. 5 (4): 387–405, is heavily cited. *GUS* is the symbol for the gene that codes for glucuronidase.

1987 Southern England experienced its "Great Storm" on 16 October, which resulted in loss of an estimated 15 million trees. See the 1787 entry for Spencer Turner in this Time-Line for the related tale of the Turner Oak....

1987 Snowdrop lectin (GNA - *Galanthus nivalis* agglutinin) was brought to the attention of researchers through Els J.M Van Damme, Anthony.K Allen, and Willy J. Peumans, introducing a new agglutinin that might have potential medical value, but also would prove toxic to various insects, such as rice, sugarcane, papaya, potato, tomato, etc. Over the next decade, many distant relatives of *Galanthus* would be investigated, the structures and isoforms described, and genetic sequences made available for transgenic work. (Van Damme, Allen, & Peumans, 1987. "Isolation and characterization of a lectin with exclusive specificity towards mannose from snowdrop", (Galanthus nivalis) bulbs. FEBS Letters 215, 140-144: *"GNA represents apparently a new type of plant lectin with a unique carbohydrate-binding specificity. Since this lectin can easily be isolated in reasonable amounts from readily available material it can be of great potential use as a biochemical tool."* Since that publication, genetic code for Snowdrop lectin has been introduced to various crops in order to reduce insect damage.
https://febs.onlinelibrary.wiley.com/doi/epdf/10.1016/0014-5793%2887%2980129-1

1988 W. S. Merwin writes: *"On the last day of the world, I would want to plant a tree...."* Many of his poems relate the human condition to the passing beauty of plants and gardens, including most evidently the poetry in his later volume, *Garden Time*, published in 2016.

1989 Charles Jencks and his wife Maggie Keswick, began Portrack, the Garden of Cosmic Speculation, situated north of Dumfries, Scotland. The 13-hectare landscape includes numerous spaces designed around cosmic ally-inspired sculpture. As of 2017, Portrack remains a private garden which opens one day a year. Despite very restricted access, the landscape regularly appears in lists of great or most beautiful gardens in the world. (Search the web for imagery and information)

1990 Of more than 400,000 naturally occurring plant species, 90% of human nutritional needs are met by 103 species. (Prescott-Allen & Prescott-Allen, 1990)

1990 Project SEEDS was launched by NASA and The George W. Park Seed Co., allowing school students around the USA to compare growth of seed exposed to conditions of space with that of seed stored on earth. (Levetin & McMahon, 1996)

1990 The US Organic Foods Production Act authorized the USDA Agricultural Marketing Service to establish a National Organic Program (NOP) in order to standardize inputs and methods that allow use of the "Meets USDA Organic Requirements" label. (Wikipedia, 2016)

1990 Apple Day was instituted in England, promoted by a group that promotes local character. The day normally designated is 21 October. (Stafford, 2016; Wikipedia 2018)

1992 Based on heavy demand for the bark of Pacific Yew (for cancer research and treatment), The Pacific Yew Act (HR 3836) was signed into law, ensuring management of *Taxus* on Federal lands for sustainable yield of Taxol. Soon thereafter, semisynthetic methods were devised to extract the active compound from the more common *Taxus baccata.* (Source: Website of The American Presidency Project, 2018) [See TL1971]

1993 The Convention on Biological Diversity was established.

1993 As a result of the 1990 census, the US Government eliminated the annual survey of farm residents. Louv considers that abandonment as the demarcation between Frederick Jackson Turner 's second frontier (1893) and today's third frontier – which he explains as defined by five trends: 1. Lack of connection to food production; 2. Blurring of lines between humans, other animals, and machines; 3. Intellectualization of human interaction with other animals; 4. Urbanization of wild animals; 5. Creation of a new more expansive suburbia. (Louv, 2008)

1994 The US Dietary Supplement Health Education Act (DSHEA) was passed and signed. As a response to adverse fallout of the deregulation (removal of certain regulatory authority by the Food and Drug Administration), Congress modified the act with a Dietary Supplement and Nonprescription Drug Consumer Protection Act in 2007. Today, rules require manufacturers meet purity standards and report evidence of serious adverse reactions. (Block, 2010)

1994 David Nobel (a national park staff member) discovered a stand of unusual trees in Wollemi National Park within 200 kilometers of Sydney, Australia. The trees were judged to represent an entirely new genus and species, *Wollemia nobilis*, in the Araucariaceae (the monkey-puzzle tree family).

1995 Els Van Damme and his lab continued their extensive exploration of lectins in monocots. In a publication this year, the lab reports that lectins constitute the most prevalent protein in tubers of Aroids (AMA *Arum maculatum* agglutinin). This flies in the face of The Plant Paradox Diet (Gundry, 2017), which stresses consuming tropical tubers (such as taro) in order to avoid a diet heavy in plant lectins. (Van Damme EJ1, Goossens K, Smeets K, Van Leuven F, Verhaert P, Peumans WJ. , 1995. "The major tuber storage protein of Araceae species is a lectin. Characterization and molecular cloning of the lectin from *Arum maculatum* L". *Plant Physiol.* 107(4):1147-58.) You can purchase your own stock of all sorts of plant lectins from EY Labs (eylabs.com) - their motto: "Tomorrow's Reagents for Research Today"

1996 Monsanto introduced Roundup Ready soybean seed, the first genetically modified herbicide tolerant agricultural crop. By 2004, herbicide tolerant soybean, maize (corn), canola, and cotton covered 80 million hectares, constituting 80% of those crops grown world-wide. (Thomson, 2007) Monsanto began purchasing stakes in major US producers of hybrid corn seed (which had become partners in producing Bt insect-resistant corn) and by 1999 had acquired DeKalb, Holden Foundation Seeds, and Pioneer Hi-Bred. Monsanto merged with Pharmacia in 2000, and was purchased by Bayer in a transaction that closed in June, 2018.

1997 Heartless, bitter, and cynical - logger Grant Hadwin stole into the forest night on 20 January, at Haida Gwaii, in the Queen Charlotte Islands of Canada's British Columbia. His villainous goal, to destroy the famous Golden Spruce, sacred to the native Haida Peoples. Cutting well through most of the 7 foot diameter base of the 165 foot tall tree, he left it to fall two days later. (Vaillant, 2005)

1997 Control of Hong Kong was returned to China in response to treaty conditions negotiated 150 years previously, following the Opium Wars with Great Britain [See 1840]

1998 The Department of Botany at The University of Texas at Austin was decommissioned, following the 3-decade trend at major research universities to consolidate historically separate biological sciences (based on natural classification, such as botanical and zoological studies), then redistribute them based on research technique.

1999 News: John Litchfield, 11 May, "Trees that shaded Napoleon's troops face their Waterloo"... One hundred Plane Trees lining roads near Ariege, France, were taken down. Now considered hazards for automobile drivers who veer off the road, the trees are said to be part of a campaign by Napoleon to provide shade along byways through which troops marched. Over 20,000 trees in the French Dpt of Gers had been removed or were scheduled for removal at the time of the news report. The article indicates that removal of the Napoleonic trees does not seem to have impacted the rate of tragic automobile accidents. See also: 12 February 2004, *The Economist,* "The Killer Trees"; John Litchfield, 9 March 2015, *Independent*, "French campaigners up in arms over plan to chop down Napoleon's roadside trees."

2000 Ten years after the US National Science Foundation selected *Arabidopsis thaliana* as the plant study organism for studies to elucidate the entire genetic sequence, and following four years of intense research in laboratories (at a cost of over $70 million), researchers announced the project was complete. The sequence of the approximately 120 million nucleotides (about 25,000 genes) that constitute the DNA of this plant was now known. (Chamovitz, 2012)

2000 Commemorating California's sesquicentennial, the U.S. Postal Service inexplicably introduced a 33¢ stamp featuring flowering specimens of the invasive Sea Fig, *Carpobrotus chilensis*. (Beidleman, 2006)

2001 Genetically-modified (GM, i.e. transgenic) crop plants had clearly become mainstream, highlighted through reassessment this year by the US Environmental Protection Agency, reaching the conclusion that Bt cotton and Bt corn did not pose significant environmental risk for the environment or for human health. In 2001, Bt white corn was planted in South Africa for basic human subsistence (direct consumption) for the first time (previously, all GM maize had been used for animal food). By 2002, 6.8 million hectares had been planted to Bt cotton worldwide (12% of the world's production.) (Thomson, 2007) [Bt is the abbreviation for *Bacillus thuringiensis*, a soil-living bacterium. Bt produces what

compounds called crystal proteins, abbreviated as Cry proteins, that are toxic to insect larvae, and are the active compounds in Bt pesticides. Companies have modified crop plants genetically by inserting the Cry genes, which cause the engineered crop plants to produce the toxin.]

2001 Quist and Chapela published information in the journal Nature stating that transgenic DNA had appeared in native landraces of corn (maize) in Mexico. This publication engendered serious debate concerning the safety of transgenic crops. By 2002 *Nature* had retracted the article. A subsequent publication by Ortiz-Garcia, Ezcurra, Schoel, Acevedo, Soberón, and Snow (*Proceedings National Academy of Sciences*) presented results from screening of over 150,000 seed samples in which no evidence of transgenic introgression could be discovered. (Thomson, 2007) [See TimeLine, Elena Álvarez-Buylla Roces, 2017]

2001 Betty Brown Casey donated funds which led to the 2002 establishment of Casey Trees, a non-profit dedicated to restoring, enhancing, and protecting the tree canopy of Washington, D.C.. In 2008, Ms. Casey also gifted the family's 730 acre tree farm (in Berryville, Virginia) to the foundation. (Wikipedia, the Casey Trees website)

2001 Complementing the Convention on Biological Diversity, the Food and Agriculture Organization of the United Nations (FAO) completed negotiations for the International Treaty on Plant Genetic Resources for Food and Agriculture (*aka* the International Seed Treaty). Adopted by a vote of 116 to 0 (with the US and Japan abstaining), the treaty came into force in 2004. (Dworkin, 2009) Based on the 1983 International Undertaking on Plant Genetic Resources for Food and Agriculture (IU), the new Treaty reinterpreted ownership of foodplants as belonging within jurisdiction of country of origin (as contrasted with the 1983 IU claim these resources are the common heritage of humanity.) (Wikipedia, 2017)

2001 Arsonists claiming to be part of the Earth Liberation Front (ELF) destroyed Merrill Hall (University of Washington's Center for Urban Horticulture), which housed the working lab of Dr. Toby Bradshaw, who was studying genetics and gene-modification in *Populus*. (September, 2001, Briefings, Arsonists Destroy Merrill Hall in $4.1 Milion Blaze, COLUMNS - The University of Washington Alumni Magazine.

2003 Joseph Cotter's post-mortem publication, *Troubled Harvest,* details socioeconomic and political nuances of Mexican agriculture, leading to and through development of the Green Revolution. Discussion engages top-down, earnest attempts to industrialize (modernize?) agricultural practice in a political context of land ownership, and the historically near-subsistence nature of Mexico's rural life. The drama is described as flawed evolution of a technical class (the *agrónomos*) in conflict with always-struggling traditional farmers (the *campesinos*). His conclusion damns good intentions: *"With political empowerment the* campesinos*' wisdom may not be lost or stolen in a maelstrom of neoliberal-induced technological and socioeconomic change."* (Cotter, 2003)

2004 The International Treaty on Plant Genetic Resources for Food and Agriculture (IT PGRFA, sometimes called the International Seed Treaty) was signed by 135 countries. The agreement, which recognizes exotic origins of food crops important to most of the world's countries, complements the CBD (Convention for Biological Diversity). Negotiated through the Commission on Genetic Resources for Food and Agriculture (CGRFA) of the Food and Agriculture Organization of the United Nations (FAO), the Governing body has existed as a separate organization in the FAO since 2006. The Treaty replaced the 1983 International Undertaking on Plant Genetic Resources for Food and Agriculture (IU), which had considered genetic resources as the common heritage of humanity. The new Treaty was imagined as a compromise between political oversight by states, stakeholding by traditional farmers, and needs of an expanding world population. In the end, it is not clear what has been achieved of real value, outside bringing so many voices to the table that progress is hard wrought on any front.

2005 Richard Louv's acclaimed book, *Last Child in the Woods*, was first published. Citing countless supporting studies, Louv documents societal change resulting from contemporary trends in urbanization. His commentary unites observations and concerns (from fields as wide ranging as ecology, evolution, conservation, and child psychology) related to the contemporary child's lack of freedom to work and play in natural environments into a societal call to guarantee all children access to and relationship with the natural world. (Louv, 2008)

2005 Methuselah is the name given to a date palm grown by Dr. Elaine Solway, at Israel's Arava Institute for Environmental Studies. The palm grew from a seed unearthed in 2005 at the Masada archaeological site, left for nearly 2,000 years in a jar where date pits were stored following consumption.
http://www.haaretz.com/2-000-year-old-date-seed-grows-in-the-arava-1.213054

2006 Brasil's famous Inhotim, a contemporary art museum and botanical garden complex, opened to the public. Created and funded over two decades by Bernado Paz, the basic land-

scape plan was created by his friend Roberto Burle Marx. In November, 2017, Paz was convicted of money laundering and sentenced to 9 years in prison. (WWW)

2006 Sixteen seed of *Liparia villosa* (as well as one seed each of an *Acacia* and a *Leucospermum*) germinated at Kew Gardens, They were recovered from a leather wallet dating to 1803. The wallet was encountered by Dutch researcher Roelof van Gelder, while examining documents held in the UK National Archives. The papers he examined had been part of material taken in 1803 when the British Navy seized the Dutch ship *Henriette*. The wallet belonged originally to Vlissingen merchant Jan Teerlink, who had been aboard the ship en route from China to Holland. Apparently, Teerlink collected the seed in South Africa (perhaps in the Dutch East India Company garden (est. 1652) when the ship anchored there for provisions. (Fry, 2016)

2006 Xavier Metz, a French plantation manager in Madagascar, encountered a massive flowering palm in the northwestern regions of the country. Herbarium specimens of the palm, which was 18 meters tall with a 5 meter leaf span, were made by Mijoro Rakotoarinivo. Rakotoarinivo and John Dransfield determined this was not simply an undescribed species, but is sufficiently distinct so as to be recognized as a monotypic genus, thus Tahina spectabilis. (Willis and Fry, 2014)

2006 Researchers (G. A. Tuskan, *et al*) published a draft genomic sequence of a selected *Populus trichocarpa* female specimen (Nisqually-1), in Science. This was the first woody plant to be sequenced. [See also TL 2001, Arson] (Stafford, 2016; Wullschleger, et al, *Revisiting the sequencing of the first tree genome: Populus trichocarpa*, Tree Physioogy 00, 1-8, doi:10.1093/treephys/tps081)
https://www.researchgate.net/publication/232705803_Revisiting_the_sequencing_of_the_first_tree_genome_Populus_trichocarpa

2006 *"An important factor in the domestication process was defecation. The seeds of sweet corn, tomatoes, lemons, cucumbers, and many more edible plants, as well as the fruits of shrubs and trees, can pass intact through human and animal guts (their reproductive vigor may even be enhanced), to be subsequently dispersed and reproduced. In the case of humans, the peripheral latrine areas common to virtually all societies would become new gardens in time."* Excerpt From: Michael Williams, 2006. "Deforesting the Earth."

2007 Storage chambers made by a pre-historic arctic ground squirrel (*Urocitellus parryii*) were excavated in permanently frozen loess-ice deposits along the lower Kolyma River, in northeastern Siberia. The deposits included several hundred thousand seed and fruit specimens. Deep in the deposits, researchers collected seed of *Silene stenophylla*, which showed radiocarbon dates of nearly 32,000 years when examined through radiocarbon dating techniques. By 2012, Svetlana Yashina, Stanislav Gubin, Stanislav Maksimovich, Alexandra Yashina, Edith Gakhova, and David Gilichinsky reported successful germination of several seed from the trove in a *Proceedings of the National Academy of Sciences* article: "Regeneration of whole fertile plants from 30,000-y-old fruit tissue buried in Siberian permafrost." (Science News, 23 Feb 2012)

2008 A Swiss commission was established to consider ethical issues related to the dignity of plants. (Chamovitz, 2012) See The dignity of plants, Florianne Koechlin, Plant Signal Behavior, 2009, 4:78-79 and Simacha Lev-Yadun (Letter to the Editor) Bioehtics: On the road to an absurd land, Plant Signal Behavior 2008, 3:612. From Koechlin:

"Anything and everything can be done with plants today; there is no ethical consideration, no awareness of any problem. But it is slowly getting harder to justify this attitude toward plants.

Philosophers and experts on ethics, but also molecular biologists and scientists, sit in the ECNH. We have tried to work out the ethical basis for attributing dignity to plants. Many questions were controversial, but in one there was agreement: plants should not be treated in a completely arbitrary way. Plants are living beings and must be respected for their own sake. Arbitary injury or destruction of plants is not permissible. The Committee could not agree on the meaning of 'arbitrary.' For some, this was the senseless picking of roadside flowers, for others—I among them—the massive and total instrumentalisation and industrialisation of plants. In my view, the 'terminator' technology (GURT technologies) and other methods to produce sterility with the exclusive goal of making plants available for the maximizing of economic profit of humans, as well as the patenting of plants, violate their dignity."

Note: Switzerland is one of only two countries that does not follow international standards for conducting clinical trials of herbal medicines. Production of herbal medicines is a major protected industry there.

2008 Simone Moser, Thomas Müller, Marc-Olivier Ebert, Steffen Jockusch, Nicholas Turro, and Bernard Kräutler published their article *Blue Luminescence of Ripening Bananas*, explaining that breakdown of chlorophylls in banana (as the yellow color begins to show) yields fluorescent compounds (catabolites) that cause blue (or indigo) luminescence under black light. Their report raised intriguing questions as to the meaning or value of

these lingering compounds and their luminescence. Perhaps this change in color could be perceived by animals in which vision is skewed to the UV range, or perhaps these compounds might impact quality of this very moist fruit as breakdown proceeds. At a simple level, the most intriguing issue is that such a simple initial observation has not surfaced before - proof there are still mysteries that can be readily identified when someone takes a fresh look at the common. (Angewandte Chemie International Edition, 2008, 47:8954-8957)

2010 The first instance of regulation-required destruction of a GMO crop was reported, when US District Federal Judge J. S. White ordered elimination of several hundred acres of Sugar Beets grown from Monsanto's genetically-modified Round*up* Ready seed (glyphosate-resistant). Based on shortages of non-GMO seed, the USDA had allowed use of GMO seed in advance of completing an Environmental Impact Statement, leading to challenges, i.e. Center for Food Safety v. Vilsack, No. C10-04038 JSW (N.D. Cal. 2010) (Source: EarthJustice, 1 December 2010) By August, 2012, USDA-APHIS completed the study, finding Round*up* Ready (RR) Sugar Beets safe for use. (Western Farm Press, 15 August 2012)

2011 The Institute of Food Resources, in collaboration with botanists at theJHohn Innes Centre, released 'Beneforté' - a new strain of broccoli that includes parentage from *Brassica villosa*, a Silician relative of the cabbage (*B. oleracea*) with relatively high level of glucoraphanin. Production and distribution rights for the seed were licensed to Seminis, which was purchased by Monsanto, which was acquired by Bayer in 2018. (Fry, 2016; "Beneforte, Super Broccoli". Institute of Food Research, Norwich Research Park, Colney, Norwich, UK. 2014. Retrieved 29 September 2014. http://www.superbroccoli.info)

2012 On 7 February, Plantagon (a Swedish company) broke ground on a new multi-purpose building in Linköping, Sweden. This World Food Building incorporates a multi-story greenhouse as its south-facing wall. Ostensibly, the greenhouse will support urban hydroponic farming in an attempt to reduce both footprint and distance issues related to feeding a growing world. Coining the term "agritechture" highlights corporate promotion of automated agriculture integrated with modern urban life. It will be curious to see how reality and concept play out as the challenges of hydroponics (which depend greatly on chemical treatment and balance not easily coincident with organic methodologies) meet occupancy concerns of office workers and potential residents in such buildings. Completion is scheduled for 2020.(Plantagon website, for press release info: http://www.plantagon.com/about/business-concept/the-linkoping-model/)

2012 Russian biologists reported successful germination of *Silene stenophylla* seed, which had been uncovered near the xxxx River in Siberia. The cache of seed had been carbon-dated as 32,000 years old. [See 2007]

2012 Jennifer Doudna (UC Berkeley) and Emmanuela Charpentier (Max Planck Institute) proved that CRISPR technology could be targeted for gene editing. Their work represents an important breakthrough in the quickly-evolving story of CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) which were first identified in 1987 by Japanese Researcher Yoshizumi Ishino, described by Spanish researcher Francisco Mojica in 1993, and named by University of Utrecht Researcher Ruud Jansen in 2002.

2012 The Tomato Genome Consortium of researchers published the first complete genome of tomato (inbred cultivar 'Heinz 1706') in *Nature*: "The tomato genome sequence provides insights into fleshy fruit evolution", *Nature* 485: 635–641 (31 May 2012). The 12 (*n*) chromosomes included 900 million base pairs. Tomato (*Solanum lycopersicum)* evidenced an 8% difference from potato (*Solanum tuberosum*).

2013 Wen Zhi Jiang and colleagues (H. Zhou, H. Bi, M. Fromm, B. Yong, and D. P. Weeks) demonstrated success in using CRISPR gene-editing techniques (introduced the previous year by Jennifer Doudna and Emmanuelle Charpentier) in Arabidopsis, tobacco, sorghum, and rice. In 2018, the USDA ruled gene editing a safe technique for crop development. (Jiang, W. et al. Demonstration of CRISPR/Cas9/sgRNA-mediated targeted gene modification in Arabidopsis, tobacco, sorghum and rice. Nucleic Acids Res. 41, e188 (2013).) See Xuan Liu, Surui Wu, Jiao Xu, Chun Sui, Jianhe Wei, 2017. "Application of CRISPR/Cas9 in plant biology" *Acta Pharmaceutica Sinica* B 7(3), May 2017, Pages 292-302, open access https://www.sciencedirect.com/science/article/pii/S2211383516302982 See Kamburova, et al, 2017. Genome Editing in Plants: An Overview of Tools and Applications, https://www.hindawi.com/journals/ija/2017/7315351/; https://doi.org/10.1155/2017/7315351

2013 Trials of "Golden Rice" produced through genetic engineering at the International Rice Research Institute (in the Philippines) were destroyed by a small crew of criminals masquerading as farmers and paid by anti-GMO forces. Rice is made "golden" through addition of genes that enable the rice to generate beta-carotenes, which are precursors to Vitamin A in human diets. Greenpeace is among organizations that oppose Golden Rice.

2014 The Future Library was established. Katiepatterson.org: "A forest has been planted in Norway, which will supply paper for a special anthology of books to be printed in 100

years time. Between now and then, one writer every year will contribute a text, with the writings held in trust, unread and unpublished, until the year 2114. The manuscripts will be presented in a specially designed room in the new public library, Oslo. Writers to date include Margaret Atwood (2014), David Mitchell (2015), and Sjón (2016)."

2014 France's Parliament approved a new law banning cultivation of genetically-modified corn (maize). The law was meant to reinforce and extend bans already instituted by a March decree (which was ruled unenforceable by French courts in 2016) and the European Union. In early May, activists had damaged a field of corn said to have been planted with MON810 maize seed (Monsanto's insect-resistant seed, the only GMO seed approved for use in the European Union.) (Reuters, 5 May 2014)

2014 A GMO *Camelina sativa* (False Flax) was developed and introduced by Rothamsted Research (Hertfordshire) that produces Omega 3 Fatty Acids in its seed oil. The new seed were engineered to provide fish food for farmed salmon, which require dietary omega 3 fatty acids, otherwise provided through consumption of marine algae (Fry, 2016). Studies into the viability of this sourcing were conducted through the IoA (Institute of Aquaculture) based at Sterling University, Scotland. The work stretched over two decades of research by botanist Jonathan Napier and nutritionist Doublas Tocher (source: Gareth Moore, 1 August 2018, *Fish Farming Expert*)

2015 Tu Youyou became the first Chinese woman recipient of a Nobel Prize, awarded for her work in elucidating anti-malarial effectiveness of extracts from *Artemesia*. See Wikipedia and other WWW sources.

2015 Hershey Company announced a policy to discontinue use of sucrose manufactured from Sugar Beets due to public concerns over genetically-modified products. (On-Line, Tom Meersman Star Tribune, 27 December 2015) [Comment by Author: If you study the process through which sucrose is extracted and purified from Sugar Beets, you might have other, more sincere concerns.]

2016 LIFE: A ... contemporary perspective suggests... that life proceeded from a cellular "mush" (a primoridal "Planetary holobiont") in which cells promiscuously exchanged much more than mere genes. .... this primordial "golden age" was followed by differentiation of the three domains known today. Archaea and Bacteria evolved toward a prokaryote-like lifestyle of "multispecies" consortia that were metabolically specialized yet interconnected via universal protocols of extensive horizontal gene transfer and pheromone signalization. The third domain, Eukarya, arose as a result of the multiple merger capacity of early cells. As a result..., the mitochondrion [sic] is today's only easily recognizable evidence of ... early blending..." (Švorcivá, Jana, Anton Markoš, and Orabab Das, in Sahi, Vaidurya Pratap and František Baluška ed, 2016) TRANSLATION:

2017 Elena Álvarez-Buylla Roces and collaborators reported (in *Agroecology and Sustainable Food Systems*) that: "90.4 percent of the tortillas studied contained recombinant sequences of transgenic maize (corn)." (*Gaceta Digital de UNAM*, 6 November 2017)

2018 František Baluška and Sherrie Lyons propose updating Virchow's dictum "*Omnis cellula e cellula*" to "*Omnis Energide e Energide*" ("Energide-cell body as smallest unit of eukaryotic life". Ann Bot. 2018 Feb 21. doi: 10.1093/aob/mcy022. Epub ahead of print, Excerpt From: Vaidurya Pratap Sahi and František Baluška. "Concepts in Cell Biology - History and Evolution.")

"History celebrates the battlefields whereon we meet our death, but scorns to speak of the plowed fields whereby we thrive. It knows the names of the kings' bastards but cannot tell us the origin of wheat. This is the way of human folly."

J. H. Fabre

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WWW: plantexplorers.com

http://ricepedia.org/culture/history-of-rice-cultivation The Online Authority on Rice

OTHER TIMELINES:

www:allaboutwheat.com. The History of Wheat.

SECTION 1

Footsteps

WALKING THROUGH THE TIMELINE

1. Cells, as the Basis of Life
2. Making Sense out of Plant Diversity
3. Botanical History in Cultural Context

Cells, as the Basis of Life (All Life, not just Plants)

Construction of this Essay was inspired by:

Suddhartha Mukherjee's *The Gene - An Intimate History*

Randy Wayne's *Plant Cell Biology, from Astronomy to Zoology*

Henry Harris's *The Birth of the Cell*

The National Human Genome Research Institute reports that humans and bananas share 60% of their genetics.).

Though so completely different in architecture and lifestyle, humans share many characteristics with a full grown oak tree. We are both made of cells, around 30 trillion of them each. Glucose, and the mechanisms that allow us to use simple carbohydrates for building components and energy storage are owned by the oak as much as by any human. And our cells follow a similar organizational nature, with the same basic mechanisms of inheritance and control. In fact, just being alive and having nuclei demands a lot of regulation - such that, genetically, the oak and a human probably differ by less than 50%. The implications of this sharing are that somewhere, way back in your family tree, you share an ancestor with the oak.

So what is the science behind this? How did we come to such an understanding about ourselves and oaks? When did this become standard knowledge? What were the steps to progress; who made the discoveries? What does information about humans tell us about our distant relatives in the plant kingdom? How doe knowing this history help us to understand science today?

It really all started with sex. Or perhaps it was wine. Toward the end of the 17th century (1665), Robert Hooke published a significant book titled *Micrographia*, reporting his examinations of many objects. For this discussion, it is important that Hooke was the first person to use a microscope in determining that a part of a plant (a piece of cork, maybe from a wine bottle) is divided into microscopic chambers, which he called cells.

This is a bit problematic for those of us who teach biology, because we know it is normal to bring up Anton von Leeuwenhoek as the inventor of the microscope, and as the first person to reveal the microscopic world to science. But trust me, Robert Hooke scooped von Leeuwenhoek when it comes to cells. Significantly, Hooke studied cork in sufficient detail to speculate that a cubic inch would be composed of 1,200,000,000 cells. He had a beautiful desktop microscope (with magnification of about 50x) at a time that von Leeuwenhoek was mounting the special glass lenses he learned to make in little portable handheld gimbals. Sometimes its useful to have a lot of funding.

Later, Hooke wrote: *"These pores, or cells, were not very deep..I no sooner discerned these (which were indeed the first microscopical pores I ever saw, an perhaps that were ever seen, for I had not met with any writer or person that had made any mention of them before this) be me thought I had with the discovery of them presently hinted to me the true and intelligible reason of all the phenomena of cork."* (Taber, 2007. *To Cork or Not to Cork*)

Just six years after *Micrographia* appeared, it became apparent that serious studies in plant anatomy were flourishing. Nehemiah Grew published *Anatomy of Vegetables Begun* (followed a decade later by his tremendous *Anatomy of Plants*.) In the same year, Marcello Malpighi published *Anatome Plantarum Idea*. Both authors continued improving their work, which seemed sufficiently solid that a century would pass before plant cells got much additional attention. But Anatomy had peaked too soon. Though there were curious moments and discoveries worth noting, by 1800 we knew very little more of significance about cells than people had learned from Grew and Malpighi.

In other areas of investigation, things were not so complacent. Born the same year as Hooke published *Micrographia*, German botanist Rudolf Camerarius went to work at the botanical gardens in Türbingen, where his observations of plant flowering and seed set led to the 1694 publication of a scientific letter on sexual reproduction in plants (*De sexu planetarum epistola*). Camerarius probably knew little about cells as the stuff of plants. But his observations of plant reproduction kindled a great amount of interest, capturing the attention of scientists, and changing everything we understand about plants.

Camerarius‘ s ideas took off. The concept that plants

have sex, and the flower is a nuptial bed where marriages are sexually consummated, became a core theme for Linnaeus, the 18th century's premier plant Systematist. This is likely the reason Henry Baker, one of the few productive plant microscopists of the 18th century, paid so much attention to pollen (which he called farina). Both hybridization studies and pollination ecology gained their start with the detailed work of Joseph Koelreuter (also of Türbingen), who was following up on ideas developed at the gardens there. (see: Sophie C. Ducker and R. Bruce Knox, 1985. "Pollen and Pollination: A Historical Review", Taxon, Vol. 34, No. 3 (Aug., 1985), pp. 401-419 Published by: International Association for Plant Taxonomy (IAPT) Stable URL: https://www.jstor.org/stable/1221207

As late as 1800, the structure and workings of cells remained yet a mystery, partly due to simple limitations in optics. Microscopy had remained more a hobby than the core aspect of science it would soon become. The early 19th Century would become a watershed period; in 1807 Link described plant cells as functioning independently. By 1830 botanists and zoologists were beginning to explore the nature of cells, with improvements in microscopy and microtechnique emerging quickly..

And the sex thing continued to spark life in that study, particularly in pollen and pollen tube development. Robert Brown, known for his floristic work in Australia, was not in the line of great microscopists, but he was very interested in pollen. In a study of burst pollen grains, published in 1827, Brown reported observations that matter under a microscope moves (like it vibrates or jiggles), even when there is no obvious external force, an inherent movement physicists today refer to as Brownian Motion. Just a few years later, in 1831, while studying pollen and pollen germination, he described the presence of a body, an "aureole" or a "nucleus" he called it. Here we have confirmation that cells are not just hollow bubbles. They corral nuclei, and other things.

Granted, Brown had no idea as to a function for his nucleus, or that there were other kinds of bodies inside plant cells. But his simple observation was at the very cusp of a great epoch in microscopy, both plant and animal. By 1835, Hugo von Mohl (who had been appointed a Professor of Botany at Türbingen) reported that cells reproduce themselves, an observation he made through his studies of the green alga *Cladophora glomerata,*

Ideas from many labs coalesced in what we, today, call the "cell theory" - that is: "all living organisms are composed of cells." Matthias J. Schleiden (botanist), Theodor Schwann (a zoologist), and Rudolf Virchow (pathologist) gain credit for first enunciating cell theory, but further investigation reminds us Schwann and Schleiden were not always the most astute. However, they were (along with Virchow) the "Colonizers" who managed to create impact based on their own work, as well as the contributions of many less vocal researchers. Even though people argue as to who should get the credit, the new understanding highlighted in Schwann's 1839 book *Microskopische Untersuchengen über die Uebereinstimmung in*

der Struktur und dem Wachsthum der Thiere in Pflanzen, signals that botany and zoology began to merge as biology - a word that had only been around since 1802.

The cellular nature of plants and animals inspired researchers and drove development of new techniques. Microscopy became its own field; a scientific understanding of the production, structure, and activities of cells became the holy grail. As late as 1850, however, microtechnique remained somewhat primitive, and cell biology did not even exist as a field of study.

Hugo von Mohl and his cohorts were famous for using fresh hand-cut sections to make observations, but at that time, slide preparations could not be stored over the long term - they were not permanent, because microtomists used sugar solution for mounting. And even though early studies (Hooke, 1665; Hill, 1770) had made use of natural dye, it wasn't until the second half of the 19th century that botanists fully-adopted the use of stain technologies.

Moreover, life sciences were in an uproar in many regards; one most pertinent to this discussion was Charles Darwin's 1859 publication - *The Origin of Species by means of Natural Selection* ***or the Preservation of Favorite Races in the Struggle for Life***.... Darwin's work has become a tenant of faith for biologists, which has different meaning to us today, as compared to what was implied at its debut. Notice that even the book title might be something of a surprise. In contemporary discussion, we skip over the subtitle (which I made bold for emphasis).

Darwin clearly understood that circumstances could favor reproductive success of one form or variant as compared to another. Over time, that could lead to evolution of a different kind of plant or animal, a new species. But he did not have evidence as to what mechanism allowed for stable inheritance, while also creating diversity between individuals within a population. This mystery be-deviled Darwin, and challenged others.

Curiously, a missing piece to Darwin's puzzle was known as early as 1865, when Gregor Mendel had presented and then published (1866) his studies of hybridization and inheritance. Mendel even communicated with noted scientists, who seemed unwilling to give his work much credence, which meant his observations, data, and conclusions were mothballed for 35 years. While Mendel's calculations on inheritance lingered in limbo, however, the next three decades were not silent in other regards.

Considerable advances were made in understanding cell structure and biology. Studying white blood cells at the University of Türbingen, Swiss biochemist Friedrich Miescher isolated and characterized nucleic acids - compounds we would later know as DNA and RNA. By 1879, using the new aniline stains for microtomy, Walther Flemming was able to describe chromatin threads (strands of unconsolidated chromosomes), associating them with the nucleus. Furthering his studies, in

1882, Flemming's significant book, *Zellsubstanz, Kern und Zelltheilung (Cell substance, nucleus and cell division)* utilized the term "mitosis" and proved nuclei give rise to new nuclei - "*omnis nucleus e nucleo*." Following up on Flemming's work, Wilhelm von Waldeyer-Hartz observed and named chromosomes as cellular bodies made of chromatin in 1888. None of these researchers understood the structure of chromosomes, or their relationship to inheritance.

Chemically, Albrecht Kossel followed up on Miescher's discovery of nucleic acids, publishing important work beginning in 1895, in which he characterized and named the five nucleobases scientists would later understand constitute the coding imbedded in nucleic acids.

In the last decade of Mendel's exile, Darwin enthusiast, Dutch botanist Hugo de Vries, set about searching for clues to underpin Darwin's half-hearted concept of pangenesis (suggesting inheritance from everywhere, hypothesizing diffuse corpuscles that would somehow come together to launch an egg or sperm).... De Vries began numerous trials, culminating in a series of publications. His 1897 *Hereditary Monstrosities* indicated that a trait, however one defines a trait, would be managed by a discrete parcel of information. This paralleled efforts that began early in the decade, when he launched a series of trials with 50,000 seed from a population of *Oenothera lamarckiana*, dedicating 8 years to a search for variants. Additionally, he had been working on studies of plant hybrids. De Vries was in the middle of these heady labors when he was sent a copy of Mendel's paper. There it was, de Vries had been scooped 30 years before, while he was still a teenager. During his entire career, Mendel's publication had been sitting on the library shelf.

By the end of the century, de Vries work was destined to corroborate the work of others, bringing context to Mendel's research. Studies of cell biology, molecular structure, and inheritance were now linked. With growing realization that the basis of inheritance is the same for all life forms, discoveries informed each other across silos - work with plant breeding and selection proved important to people studying human disease; studies of fruit flies were foundational for plant biologists.

This became obvious early in the new century, which dawned with scientific renewal as researchers resurrected and tuned into the implications of Mendel's work. Connecting the dots between Mendel, Darwin, and what had been learned about chromosomes and cell biology quickly brought massive realization that the world of biological understanding had undergone a paradigm shift, or a sea change, or something truly significant. William Bateson the most effective proponent of Mendel's work, announced to an audience of the Royal Society in 1900: *"We are in the presence of a new principle of the highest importance... To what further conclusions it may lead us cannot yet be foretold."*

Among the first to corroborate Mendel's ideas was the young botanist at Türbingen, Carl Correns. Working with a composite called Hawkweed (*Hieracium*), Correns published his ob-

servations on inheritance of traits early in 1900, citing both Mendel and Darwin.

> Correns worked under Nägeli at Türbingen. It was Nägleli with whom Mendel had corresponded, and Nägeli who suggested Mendel work with Hawkweed. Mendel's attempts in studying Hawkweed had been frustrating, a frustration that likely correlates with Correns' conclusions about the non-Mendelian effects of linkage (assortment is not random, rather two different genes are linked due to physical proximity on chromosomes.) Of course, the most frustrating part of Correns' career must have been that Nägeli never shared with him that he knew all about Mendel's work. Coreens would encounter Mendel's publication on his own.

Theodor Boveri and William Sutton are credited with introducing the "Chromosome Theory of Inheritance" in 1902, recognizing chromosomes as the carriers of inheritance. In short order, we are told, Bateson christened this field as "genetics" in 1905 while Wilhelm Johannsen coined the term "gene" in 1909, to represent a unit of inheritance - whatever that might be. (Worth pointing out, in 1893 Charles Bessey referred to "genetic relationships" in his address to the US National Academy of Sciences. This suggests the field of study was termed "genetics" well before 1905.)

Through this first generation of researchers whose work was informed directly by the exhumation of Mendel's publication, additional realizations snowballed, some of which would quickly challenge the simplicity of Mendel's assertions.

Post-Mendelian Reality: Succeeding generations of geneticists explored territory well beyond a focus on the nature of inheritance. What are the basic sources of selection, or selective pressure? How does selection impact speciation in smaller populations, in founder populations, on islands? What does a gene do, like how does the information in a gene get translated into real activity? If every cell with a nucleus has all of an organism's genetic information, what happens to control events during growth and development. What regulates the activity of genes? How much information is there in a genome? As a physical entity, how does a gene layout in the chromatin? And, importantly, how can we goose the larder? What tools are available to humans that can be employed to change the future?

Answers to those questions continue, as new tools and techniques are aligned with ever-increasing funding to explore and conquer the very secrets of life. In this new world of cell biology, breakthroughs are compounded as discovery and realization in one area informs work in all others. Solving problems and answering questions means finding the useful organism. Historical disciplines of Botany and Zoology retain meaning, but mainly in organismal (systematics, ecology, natural history) and applied (agriculture, medical care) studies.

At a cellular and molecular level, it almost boils down to convenience. Mendel had struck gold with Peas...., while Nägeli's pressure for him to work with Hawkweed killed his momentum. The next organism to spur advances was the Fruit Fly, *Drosophila melanagaster*. Thomas Hunt Morgan, a researcher at Columbia, was interested in how an organism emerges from a single cell and had elected to pursue that line

of research through studying Fruit Flies for many reasons, most obviously their short generation times (10 days) and ease of culture.

Turning the attention of his lab to mutations that could be studied genetically, researchers in Morgan's lab were successful in many endeavors. By 1913, team member Alfred Sturtevant had published the first genetic map. In the 13 years since rediscovery of Mendel's work, researchers working synchronously had gone from the simplest realization that chromosomes carried genetic instructions to having mapped genetic control of characteristics to identifiable regions of chromosomes.

But 1914 brought the War to End All Wars, which of course led to a second World War in 1939. Research advances moved to North America as some of the world's greatest science talent and knowledge scattered or died. Integrally linked to four decades of war lull was the painful shadow of eugenics, which drew so many brilliant minds to the dangerous edge of inhumane application of genetic manipulation of human populations and society.

Somehow, with so much effort directed to the war machine, advances in certain areas of pure science continued. Most particularly, technologies improved. Imagery available from TEM (transmission electron microscopy) and SEM (scanning electron microscopy) evolved, promising much greater detail as to structural features. Molecular techniques advanced in refinement, separation, and analysis. Researchers could delve more deeply and precisely into cellular activity, teasing out new realizations, such as the role and mechanism of hormones, the complex sequences of photosynthesis, the perception and processing of environmental cues.

And people had to be fed, so agricultural research advanced, especially in the United States. This was integral with the reality that *Zea mays* (Corn in the US, Maize in the rest of the world) became a model plant for genetic study. Maize is one of the great grasses that feed the world; rice, wheat, and maize together constitute 60% of calories in the human diet. But more than that, maize has become a molecular goldmine, the source of oils and carbohydrates that power machinery, sweeten and cook foods, create plastics, etc.

Food security underwrote studies of healthy eating. Working at Stanford University and funded partially by military monies to study nutrition, George Beadle and Edward Tatum experimented with bread molds to test their one gene-one enzyme hypothesis (made in 1941), suggesting that a gene corresponds to production of a protein. At the close of WWII, in 1945, Beadle and Tatum published results supporting that concept.

Concomitantly, Oswald Avery, Colin MacLeod, and Maclyn McCarty (working at the Rockefeller Institute) provided evidence in 1944 that DNA (deoxyribonucleic acid) is the genetic material that researchers have sought. Somehow, DNA held life's blueprints.

Understanding that chromosomes housed linear arrays of genetic information, and realizing that genes somehow correlate

to proteins, the search was on for the molecular system that could provide and actualize instructions (templates) to create build and operate cells. This heralded a period of post-war advances, as lab groups across Europe were re-energized. Alfred Hershey and Martha Chase published studies in 1952 bolstering Avery-MacLeod-McCarty conclusions that genes are somehow embedded in DNA. Studies by Watson, Crick, and Franklin brought structural reality to the discussion in 1953 by explaining the double helix architecture of DNA, and the pairing of nucleobases.

By the early 1960s, the role of RNA in transcription had been explained and in 1965 the code was cracked. Researchers in various labs had competed to complete understanding as to how triads of the five "canonical" nucleobases (plus variants) generate matches for the 20 amino acids that constitute proteins. Suddenly, scientists could sequence DNA and interpret the message, which determined what protein would be transcribed from each functional gene in the DNA.

Just as suddenly, the new reality dawned. Not all sequences are created equal. There are nonsense segments, and repeated sequences. A gene might not even consist of contiguous sequences. If all genes are present in linear but non-straightforward formats, how is order achieved? What regulates developmental sequences? How are genes controlled? When is a gene activated? Who's in charge?

It turns out that the life of each cell is multi-variately integral. Earlier thoughts that cells were filled with air, or water, or slime were successively informed with greater detail. At magnifications we can only approach through electron microscopy, organelles and membranes scientists discovered in the 19th century were now seen to be integrated with complex membranes and tubules forming a cytoskeleton, like the ropes, ladders, and platforms of the world's most elaborate high wire act. Nothing really floats through fluid or void, rather components are guided and positioned with micro-precision.

The numerous elements in this structural schema and the ways in which communication and signaling occur continue to come into focus, but great strides have been made over recent decades. By 1953, through electron microscopy, many workers had detailed and Kevin Porter had named the endoplasmic reticulum, a membranous network Garnier first noted in 1897.

After several years of work, in 1961 Wilhelm Menke determined there was a regular structure to stacks of membranes in the grana of chloroplasts, which he name thylakoids. Appreciating the internal structure of chloroplasts led to work that has further explained how photosynthesis systems function. Moreover, by 1968 scientists had learned that chloroplasts (and other plastids) carry their own DNA, which became part of many stories, from evolutionary studies that depend on maternal inheritance to providing greater support for Lynn Margulis proposals (1967) regarding the origins of organelles such as chloroplasts and mitochondria.

In the 1960s researchers began to make progress on structure and function of the Golgi complex, another mysterious cell feature named for Camillo Golgi, who first described it in 1897. Today the membranous Golgi complex is viewed as a multifarious and adaptable factory for cell components, such as membranes, proteins, and carbohydrates.

Ultimately, setting aside the semi-independent organelles, components of cellular cytoplasm can be viewed both as membranous workbenches that translate nuclear instructions into physical compounds and as antennae for stimulus response. These platforms are embedded in a soft fluid and, along with organelles, are manipulated through microtubular and actin motors. Internally, the chloroplasts and mitochondria replicate this organizational logic, in yet more miniature and compact versions.

Finally, despite initial concepts that cells function independently (even though united in tissues), Tangl had observed the presence of intercellular connections by 1879, which Strasburger confirmed and named as plasmodesmata in 1901. The assumption of completely independent cells has fallen. By 1930, Münch had expressed the concept of a symplast (united cytoplasmic tissue) as contrasted with the apoplast, though further real appreciation of material movement between cells would await development of electron microscopy and advanced staining techniques. Even now there remain points of discussion regarding structure and function of intercellular connections, and the basis of our understanding of living organisms continues to emerge. (A. G. Roberts and K. J. Oparka, 2003. "Plasmodesmata and the control of symplastic transport" Free Access, Plant, Cell & Environment, 26(1): 103-124)

In the end, energy is harnessed and order is achieved. Materials are manufactured, stored, and retooled. Cells thrive or survive, and manage to recreate and reinvent themselves so that multicellular second order forms evolved. And that is life....., which *"is not found in atoms or molecules or genes or such, but in organization"* (Edwin Grant Conklin, 1940. "Cell and protoplasm concepts: Historical account," in: F. R. Moulton, ed. *The Cell and Protoplasm*. Washington, DC: The Science Press.)

Detailed Plant Cell Biology & Genetics Time-Line

1614 Galileo had adapted lenses from telescopes to study small objects (Harris, 1999)

1619 Protestant John Andreas notes: *"If you do not analyze matter through experiment, if you do not improve knowledge through better instruments, you are worthless."* (Harris, 1999)

1624 Cesi (a Lincean) described lens systems in Italy devised to investigate small objects.(Harris, 1999)

1665 In his *Micrographia*, Robert Hooke detailed the structure of cork and described "cells" as studied through a microscope that had been constructed for him. This is recognized as the first time the word cell was applied to what we now understand is the basic unit of life, though the cork Hooke studied was composed of dead cells, and he had no idea as to the contents and organization future research would reveal.

1671 Nehemiah Grew's *The Anatomy of Vegetables Begun*, was received by London's Royal Society about the same time an abstract arrived from Marcello Malpighi, which covered his studies of both plants and animals. Malpighi would send additional material to the Royal Society for publication in 1675 and 1679, informing Grew's studies significantly. In his 1999 book, *The Birth of the Cell,* Henry Harris notes that Malpighi made important observations of plants, but reminds the reader that his contributions to zoology are more fundamental, that he is, perhaps: *"the founding father of microscopic zootomy, as well as phytotomy."* It was Malpighi who first described pulmonary capillaries, explaining the connection between veins and arteries and resolving the major question surrounding Harvey's proposed model for blood circulation. Malpighi's plant studies were heavily influenced by his knowledge of animal anatomy, thus Malpighi is the author who applied the term **tracheid** to xylem vessels, implying their similarity to respiratory trachaea of insects. Malphigi's concept of cells seems different from that of Grew, in that he referred to them as utricules, or sacs, suggesting he believed they were filled with liquid. Of note, Malpighi described the formation of plant galls resulting from deposition of insect eggs, which was one early observation that argued against the ancient, pseudoscientific concept of spontaneous generation. (Harris, 1999)

1674 Antoni van Leeuwenhoek, it seems clear, came to view living matter as made of globules (cells, essentially), as he reports in *Philosophical Transactions* of the Royal Society: *"I have divers times endeavored to see and to know, what parts the Blood is composed of; and at length I have observ'd taking some blood out of my own hand, that it consists of very small globuls driven through a Crystalline humidity of water…"*, suggesting that similar globules meld to form hair. Christiaan Huygens queried Oldenburg, the editor of the Transactions: *"I should very much like to know what credence is given by your people to the observations of our Mr. Leeuwenhoek who turns everything into little balls."* (Harris, 1999)

1682 Nehemiah Grew's *The Anatomy of Plants* was published, and his text makes it clear Grew thought the cells he was studying were more like bladders (or foam), forming through inflation. That suggested to Grew that the walls he observed were somewhat skeletal, and suggests to us that he viewed plant tissue as fenestrated, which would mean the "cells" were equivalent to pores. He applied the term **parenchyma** to the tissue, suggesting this is filler material, flesh (Harris, 1999)

1733 In Lyons, Jesuit Father Sarrabat set plant roots in the red juice from *Phytolacca* fruit and observed the colored liquid rising to leaf tips, and even stamen filaments. He noted

the root cortex was red. This is considered the first example of vital staining. (Clark & Kasten, 1983)

1756 O. F. Müller described binary fission in *Vibrio (Closterium) lunula*, a microscopic green alga. (Harris, 1999)

1759 (1774 2nd ed) Kaspar Friedrich Wolff published *Theoria generationis*, explaining his concepts that the vessels (of plants) and fibers (animal cells) were secondary, beginning as cells or vesicles, something akin to Leeuwenhoek's globules. He may have envisioned them as originating through inflation, though eventually some would be filled with liquid. In studying development of a seed leaf (cotyledon), Wolff observed: *"the young leaf arising from the seed turns out to be composed entirely of vesicles, and is patently devoid of fibers, vessels or grooves of any kind... They arise from a hitherto unadulterated, homogeneous, glassy substance, without any trace of vesicles or vessels."* Almost certainly, Wolff was examining the apical meristem, or an emerging leaf primordium, which would have been composed of such minuscule meristematic cells that he could not resolve more structure in the "glassy substance." That would not have been a surprise, since he explains in reference to animal tissue: *"its constituent parts [could] escape notice on account of their very smallness."* (Harris, 1999) Wolff's ideas concerning embryology did not advance the science; he supported the *homunculus* concept (look it up) in each sperm. (Wikipedia, 2018)

1774 Bartholemew Corti published his observations of the fungus, *Tremella* (which he considered a plant), noting obvious circulation of fluid within the hyphae ....(Harris, 1999)

1792 Luigi Galvani published *De viribus Electricitatis*, famous and grim studies of the effects of electricity on living tissues (in frogs). (Harris, 1999)

1802 Kurt Sprengel published his introduction to the study of plants (*Anleitung zur Kenntnis der Gewächse*), a book Harris suggests may be the publication that first suggested new cells could arise from granules or corpuscles inside existing cells. Decades would pass before researchers came to solid agreement that cells reproduce themselves through a division process (Harris, 1999) Note, in 1793, Sprengel published the earliest study of floral form and its relationship to pollination....

1804 Discovery of Inulin: *"Valentin Rose (1762-1807) reported that the root of elecampane (*Inula helenium*) contained "a white material appearing very much like starch, but differing from it both in its principles and in its manner of action with other substances". Rose found that after boiling the roots in water and leaving the decoction stand for several hours, a white powder precipitated, which looked very much like starch but differed from it both in its principles and in its manner of action with other substances. This substance was soluble in cold water but readily soluble in boiling water producing a not quite transparent mucilagenous liquid. After some hours most of the solute re-precipitated as a compact white powder; addition of alcohol produced the*

same effect." (Jaime Wisniak, 2016. "Henri-François Gaultier de Claubry", *Revista CENIC Ciencias Químicas*, v 47(1), Versión Electrónica 2221-2442)

1805 In studying sections of *Ranunculus ficaria*, Gottfried R. Treviranus reported that living cells are separate and independent from one another: *"The origin of the organization of living material is an aggregate of vesicles (i.e. cells), which have no connection with each other. From these vesicles all living bodies are formed, and all they contain eventually undergoes dissolution"* (Harris, 1999)

1806 The Royal Society of Science of Gottingen (Konigliche Societat der Wissenschaft) organized a competition for essays on plant vessels (cells). Submissions by Link, Rudolf's and Treviranus were accepted, and Link was awarded the prize. (Harris, 1999) (PS: the German naturalist Gottfried Reinhold Treviranus and the French scientist Lamarc independently introduced the term biology in 1802)

1807 As reported in his book *Grundlehren der anatomie und physiologie der pflanzen*, Heinrich Friedrich Link established the independent nature of plant cells through various studies and manipulations. He noted coloration versus lack of color in the cells of variegated plants. He studied the movement of cell contents once they were denatured with heat. Link, like his contemporary Ludolph Christian Traviranus, did not see direct evidence as to how cells might communicate or transfer materials to each other, but he imagined there could be invisible openings. As with others in this period, Link had no answer as to how new cells originate, nor a concept of nuclei. (Harris, 1999)

1811 Ludolph Christian Traviranus reported studies from 1803, in which he observed cyclosis (protoplasmic streaming) in *Hydrodictyon utriculatum* and *Nitella flexilis*. He was not aware of a report by Conti, from 1774, ("Microscopic observations on *Tremella* and on the circulation of fluid in an aqueous plant") (Harris, 1999)

1812 Moldenhawer's *Beiträge zur Anatomie der Planzen*, summarized nearly two decades of work, demonstrating tthat plant cells an be separated through macerating tissue in water. (Harris, 1999) Moldenhawer noted that stomata were formed by paired cells, and discussed the nature of tree rings.

1814 Following the discovery of iodine in 1811 by Bernard Courtois, Jean-Jacques Colin and Henri-François Gaultier de Claubry introduced iodine staining in *Annales de chimie et de physique*. Quoted from Wisniak, their study advanced methodically: *"In the first part of their memoir they indicated they would describe their results using the three-tier classification of vegetable and animal substances suggested by Gay-Lussac and Thenard: (1) substances composed of carbon, hydrogen, and oxygen, in the ratio they are present in water plus the excess oxygen (that is, the acids); (2) substances composed of carbon, hydrogen, and oxygen, in the ratio they are present in water, that is, sugar, gums, starch, etc. (carbohydrates). This category also included animal substances containing nitrogen and hydrogen in the ratio present in ammo-*

nia (albumin, gelatin, fibrin, etc.); and (3) substances similar as those in the previous category but containing an excess of hydrogen (oils, camphors, etc.).” The second part of their work observed that: *“mixing dry starch with dry iodine led to the immediate coloring of starch from blue to black, depending on its proportion in the mixture. This phenomenon was observed with starch of several origins, for example, from potatoes, salep, and the mucilage of the roots of marshmallow. The coloration disappeared only when the mixture was heated to the temperature of decomposition of the vegetable matter: HI* (iodohydric acid) *vapors formed mixed with the product of the decomposition of the organic matter.”* (Jaime Wisniak, 2016. “Henri-François Gaultier de Claubry”, *Revista CENIC Ciencias Químicas*, v 47(1), Versión Electrónica 2221-2442)

1815 Dietrich Georg Kieser’s 1814 essay *“Mémoire sur l’organisation de plantes”* was awarded a prize offered by the Teylerian Society (Teyler’s Museum, Haarlem) for entries related to plant structure. In this same year, Kiefer published his textbook *Elemente der Phytotomie*, which provided an important summary of work to date. Kieser states that *“plants are composed in large part of cells, which form a tissue,”* with a contemporary but erroneous understanding that cells originate from globules suspended in plant sap. (Harris, 1999)

1823 Giovanni Battista Amici first observed growth of pollen tubes, in *Portulaca*. In 1846 Amici confirmed (studying orchids) that the embryo forms from an egg in the embryo sac, which is stimulated to seed production by presence of the tip of the pollen tube. This revelation had followed Brown’s suggestion the tubes were produced by the ovary, and Schleiden’s assertion that the tip of the pollen tube “becomes” the seed. (Johnson, 1915, *History of the Discovery of Sexuality in Plants*, G**gle Play)

1823, 1826 French zoologist Henri Milne-Edwards described animal cells as similar in shape and volume, in contrast to the better-known variety in size and shape of plant cells. He assumed that larger tissues were made of *“globules, which might be called elementary, are perhaps themselves formed by still smaller corpuscles that our present methods of investigation do not permit us to see.”* (Harris, 1999)

1824-1837 Henri Dutrochet (née du Trochet), commenting on the similarity of plants and animals in his 1837 *Mémoires*: *“Life is one; the differences shown by its various phenomena, in all things that are alive, are not fundamental differences; if these phenomena are tracked down to their origins, the differences are seen to disappear and an admirable uniformity of plan is revealed.”* In the words of H. Harris, Dutrochet is one of the first researchers who considered cells to be *“physiological entities ..., the basic units of metabolic exchange”*. Dutrochet developed concepts of **endosmosis** and **exosmosis** (movement of molecules out of and into cells based on a concentration gradient). In Dutrochet’s words: *“If one compares the extreme simplicity of this astonishing structure (the cell) with the extreme diversity of its innermost nature, it is clear that it constitutes the basic unit of the organized state; indeed, everything is ultimately derived from the cell.”* Keep in

mind that Robert Brown described the plant cell nucleus in 1831-1833, but animal cells were not as amenable to study (and erythrocytes, which Leeuwenhoek had described, are enucleate), thus Dutrochet and his colleagues knew about globules or cells, but were unclear as to their origins or internal structure. (Harris, 1999)

1825 Raspail (who introduced iodine to stain starch granules) insisted that starch grains are the progenitors of new cells (vesicles). In his 1825 publication (*Développement de la fécule*) Raspail states, in Latin: *"Omnis cellula e cellula"* (Every cell is derived from another cell), a proclamation normally attributed to Virchow. (Harris, 1999)

1830 German doctor Franz J. F. Meyen published his *Phytotomie*, in which he discussed the shapes of plant cells and his concept that those shapes were determined by mathematical laws. Meyen appreciated the homology of cells in algae as compared with those of flowering plants. A few years later, in 1837, Meyen published his *Neues System der Pflanzen-Physiologie*, remarking: *"In the year 1832 M. Dumortier observed the multiplication of cells by means of true cell division.... this kind of cell multiplication by means of cell division was observed by C. Morten in Closteria (a Charophyte) and by H. Kohl in Conferva (Cladophora) glomerata. Nowadays, the number of such observations has greatly increased."* Indeed, referencing liverworts, he states: *"the most striking demonstration is provided by spore formation in the genus Marchantia, where the evidence is compelling that cell multiplication does not take place in so-called mother cells, but by means of cell division as it does in other mosses and liverworts."* Though Meyer does not step away completely from other concepts of cell formation, he clearly advances the idea that cell division is significant. (Harris, 1999)

1830 Charles Moreno described binary cell division in *Crucigenia*, which he described as a new kind of microscopic plant (an alga) (Harris, 1999)

1831 Though not published until 1833, Robert Brown delivered his paper to London's Royal Society, describing the aureole, or **nucleus** as he also called it, so commonly present in plant cells. (Harris, 1999) (see also: Sophie C. Ducker and R. Bruce Knox, 1985. "Pollen and Pollination: A Historical Review" Taxon, 34 (3): 401-419, International Association for Plant Taxonomy (IAPT)https://www.jstor.org/stable/1221207

1832 Bartheley Charles Dumortier published his observations of *Conferva (Cladophora) aurea*, explaining that cell division is binary (the cell divides in two) through creation of a midline partition and extension of the cell wall. He explicitly rejected models (such as ideas of Kieser and Treviranus) that involved cells created through growth of granules or internal partitioning of existing cells. (Harris, 1999)

1833 François Vincent Raspail developed methods to freeze and section tissue, and devised a platinum spoon on which cells could be incinerated for analysis of the residue, reminding us he was truly one of the founders of cell chemistry. In Harris's translation of Raspail's research interests, they were: *"Chemical and physiological experiments designed to explain*

not only the structure and development of the leaf, the trunk and the organs that are merely transformation of them, but also the structure and development of animal tissues." Paraphrasing Laplace, Raspail wrote (in translation): *"Give me an organic vesicle endowed with life and I will give you back the whole of the organized world."* (Harris, 1999)

1833 Johannes Müller was appointed to a chair in Berlin, overseeing a lab that would turn out a series of influential students - Schwann, Henle, Remak, and Virchow. some "Discoverers" and others "Colonizers" (Harris, 1999, page 136)

1836 Valentin, an associate of Purkyně, and the first person to apply the term nucleus in relationship to animal cells, accepted a position in Bern, and thus became the first Jewish scientists appointed as a full professor at a German-speaking university. (Harris, 1999)

1837 Studying filamentous algae (*Cladophora*, *Zygnema*) as well as several seaweed, Hugo von Mohl confirmed that cells arise through binary fission. As had Dumortier, Mohl rejected earlier suggestions that new cells might originate from granules (such as plastids). Mohl's publications were well-known, and thus he is typically given credit for discovery of binary fission. (Harris, 1999)

1837 Theodor Hartig was the first to characterize and name **sieve tube elements**. These are the living cells in phloem tissue that physically move photosynthate (sugars) from one location to another in a plant (from the site of production in a leaf to a sink such as a growing root, for example). (Wikipedia, 2015)

1837 In a lecture presented at the Society of German Naturalists and Doctors, Purkyně states, in reference to animals: *"the basic cellular tissue is again clearly analogous to that of plants which, as is well known, is almost entirely compose of granules (Korner) or cells."* His presentation marks the time during which the term cell (*zellen*) was becoming the standard term for life's units. (Harris, 1999)

1837 Carl Julius Fritsche published *Ueber den Pollen*, in summarizes much of his extensive study of pollen grain structure, coining the words **intine** and **exine**. (Ducker and Knox, 1985)

1838 In summary, from *The Birth of the Cell*, Harris: *"This review of the most widely read textbooks of the day makes it clear that before 1838 the scientific community had no inkling of the ubiquity of cells in living forms. It was generally agreed that plants were largely composed of cells, and cells had indeed been seen in several animal tissues, but no one had suggested in print that plant and animal cells were homologous. Nor was there any agreed opinion about how cells were generated. Binary fission had been described, but its occurrence, when noted at all, was thought to be an exceptional mode of cell multiplication limited to certain lower forms of plant life. Nothing like binary fission had yet been observed in animal cells."* (Note that Abraham Trombley, in a

1744 letter to the Royal Society described longitudinal division in fresh water polyps). (Harris, 1999)

1839 Theodore Schwann's acclaimed book, *Microskopische Untersuchengen über die Uebereinstimmung in der Struktur und dem Wachsthum der Thiere in Pflanzen* was published in Berlin. Schwann's proposition: *"The aim of the present treatise is to establish the intimate connection between the two kingdoms of the organic wold by demonstrating the identity o the law governing the development of the elementary subunits of animals and plants."* Given credit as the beginning of current understanding of the Cell Doctrine, Schwann's monograph is an effective but flawed compilation. He accepted concepts of botanist Schleiden, which were outmoded and incorrect regarding initiation of new cells. Thus some of the very laws on which he based his understanding were incorrect. Schwann also glossed over priority and contributions of others to the consolidation of this idea, particularly regarding the work of noted cell biologist Purkyně. In Harris's words, Schwann was a Colonizer; he came from Mueller's lab, where marketing tended toward bravado. (Harris, 1999)

1843 Francois-Vincent Raspail, describing the independent activity of animal cells: *"Each cell selects from the surrounding milieu, taking only what it needs. Cells have varied means of choice, resulting in different proportions of water, carbon and bases which enter into the composition of their walls. It is easy to imagine that certain walls permit the passage of certain molecules... A cell is therefore a kind of laboratory within which all tissues organize and grow."* Note Harris's translation refers to a cell "wall", which remained the sole construct until the cell membrane was described and the cell wall was understood to be an external, non-living component of the plant cell. And, Harris states, Raspail had *"no inkling of a cell nucleus."* (Harris, 1999)

1844, 1846 Hugo von Mohl distinguished between plant sap and cellular content, which eliminated considerable confusion in the literature. In his later paper, Mohl proposed the word **protoplasma** for the fluid (or gel) that fills cells, a word use that had been introduced by Purkyně a few years earlier. Protoplasm quickly replaced earlier terminology. (Harris, 1999)

1844 Franz Unger (studying *Campelia (Tradescantia) zanonia*) confirmed binary cell division in flowering plants. (Harris, 1999)

1847 Reichard published observations (on nematode sperm development) that the nuclear envelope disappears in advance of cell division, and nuclei reappear in the daughter cells. Important and accurate, these observations still fall short of observing the consolidation of chromatin.... (Harris, 1999)

1848 Followed quickly with his 1849 monograph, Wilhelm Hofmeister illustrated and described formation of chromosomes during mitosis, first with *Tradescantia*, and subsequently in *Passiflora coerulea* and *Pinus maritima*. He also observed and accurately reported reductive division in meiosis of *Psilotum*. Hofmeister didn't use the term chromosomes [see 1888], or express any deeper significance to these observations. (Harris, 1999)

1849 Heinrich Richard Göppert and Ferdinand Cohn, while studying *Nitella flexilis*, introduced cochineal-derived carmine staining techniques to plant microtechnique. *"Of the natural dyes used by cytologist, none was more esteemed than carmine."*(Clark & Kasten, 1983)

1851 Elucidation, by Hofmeister, of alternation of generations in plants.

1856 The value of aniline dyes as biological stains became so apparent that new dyes were quickly adopted: Basic Fuchsin (1856), Safranin (Williams in 1859), Methyl violet (by Lauth in 1861), Aniline Blue and Sprit Blue (by Girard and deLalpe in 1861), Eosin (by Caro in 1871), Methyl Green (by Lauth ad Boubigne in 1871), Thionin (by Lauth in 1876), Methylene Blue (by Caro in 1876), Acid Fuchsin (by Caro in 1877), Orange G (by Baum in 1878), Sudan III (by Rumf and Garasche in 1879), and Azure B (by Bernthsen in 1885). (Clark & Kasten, 1983)

1859 Charles Darwin published *On the origin of species by means of natural selection*.... As explained by Darwin, evolution is a simple change in character of a population of either plants or animals. Circumstances governing the success of a population are not neutral, rather the environment favors certain characteristics, which creates a natural system of selection that can lead to changes in the makeup of a population. Gradual change in a population can lead to differences that qualify the population as a distinctive enough to become a new species - thus the "origin" of species. By identifying a mechanism that could lead to the diversity of life on earth, Darwin rewrote the book on relationships of plants and interpretations of plant adaptations. My favorite quotation from Origin: "We have seen that man by selection can certainly produce great results, and can adapt organic beings to his own uses, through the accumulation of slight but useful variations, given to him by the hand of nature. But Natural Selection as we shall hereafter see, is a power incessantly ready for action, and is as immeasurably superior to man's feeble efforts, as the works of Nature are to those of Art." (HNT)

1866 After nearly a decade of hybridizing peas and gathering data on patterns of inheritance, Gregor Mendel explained and published his basic understanding of the hereditary nature of variation between individuals in a population, including mathematical statements as to predictable assortment of characteristics. Mendel *"applied the terms **dominant** and **recessive** to the tall and dwarf habits respectively"* (Punnett, 1905). It is puzzling that Mendel's works, though highly complementary to Darwin's concepts, were not brought forth for general scientific discussion until 1900.

1872 Edmund Russow observed and described chromosomes (which he called rods, 'Stabchen') in sporangial development of the ferns *Polypodim vulgare* and *Aspidium felix*. (Harris, 1999)

1875 Edward Strasburger and Otto Butschli (studying nematodes, and later, chicks), working independently and yet collaboratively, confirmed the consolidation of nuclear material

as chromosomes (not yet named) and a regular choreography of events in both plants and animals. (Harris, 1999)

1879 A word for nuclear divisions, **karyokenisis**, was introduced by W. Schleicher. (Harris, 1999)

1879 The term **chromatin** was introduced by Walther Fleming to describe nuclear condensations that yield what we later learned to call chromosomes. In this year, he also introduced the term **mitosis**. (Harris, 1999; Verga and Agarwal say it was 1882)

1879 Eduard Tangl reported connections between cells (now called plasmodesmata) in seed of the tropical liana *Strychnos nux-vomica* (the source of the poison strichnine). Tangl's observations were well- received, as contemporary botanists believed some order of connectivity would be discovered. Wilhelm Pfeffer (who elucidated the nature of osmotic pressure) was especially impressed, writing: *"the continuity of the living substance is so essential (for correlative harmony in the whole plant) that it would be necessary to propose it if it were not already discovered."* (Piotr Köhler and Denis J. Carr, 2006. "Eduard Tangl (1848–1905) — discoverer of plasmodesmata" *Huntia* 12(2): 169-172)

1880 Following up on his 1879 work with Salamanders and other animals (in which he employed the term "chromatin" for the nuclear threads that take up stain), Walther Flemming investigated *Lilium croceum*, in which he also observed "longitudinal splitting" of chromosomes. This ties into his insistence on indirect nuclear division as the norm (as contrasted with faulty observations that suggest the entire nucleus simply splits in half, rather than breaking down.) Though Flemming expressed no relationship between this form of duplication and the workings of inheritance, the understanding as to how chromosomes are duplicated proved to be a critical step in moving toward understanding of mechanisms of inheritance. (Harris, 1999)

1882 Walther Fleming published *Zellsubstanz, Korn, und Zelltheilung*, in which he coined the slogan: *Omnis nucleus e nucleo* (that is, nuclei are only produced from other nuclei)... (Harris, 1999)

1883 Studying the parasitic nematode *Ascaris*, Edouard van Beneden clarified, once and for all, that nuclear material contributed through sperm and those from the egg remain discrete; they do not fuse together: *"Thus there is no fusion between the male chromatin and the female chromatin at any stage of division... The elements of male origin and those of female origin are never fused together in a cleavage nucleus, and perhaps they remain distinct in all of the nuclei derived from them."* (Harris, 1999) A few decades later, researchers would come to realize that when chromosomes pair, they can swap segments (Researchers began to appreciate crossing in Thomas Hunt Morgan's lab, see TL 1911)

1884 Terms in use today for the stages of mitosis (**prophase, metaphase, anaphase, telophase**) were introduced by Strasburger. In the same year, through studying fertilization in *Orchis latifolia*, Strasburger showed that the pollen nucleus

is forced out of the pollen tube into the egg sac, with little evidence of any accompanying cytoplasm. Observations such as this further enforced gathering realization that nuclear material is the source of heredity. (Harris, 1999)

1884 Studying the impact of various salt solutions on cell activity, Hugo de Vries confirmed that a cell membrane (internal to the cell wall) exists, which regulates the movement of water and solutes. He described earlier work and introduced the term **plasmolysis** to describe the shrinking of cell contents from the cell wall due to osmotic flow. (Harris, 1999)

1885 Carl Rabl, studying Salamanders, demonstrated that chromosomes remained consistent in number and character. (Harris, 1999)

1888 Hanreich Wilhelm Gottfried Waldeyer-Harz proposed the word **chromosome** *"to replace the previous miscellany of Stabchen, Shleifen, Faden (threads), and bayonets"*. (Harris, 1999)

1888 Theodor Boveri, studying the parasitic nematode *Ascaris univalens* (which has two chromosomes), demonstrated that the number and individual appearance of chromosomes persists through reproduction, which he expressed as the principle of 'The Continuity of Chromosomes'. (Harris, 1999)

1895- 1890. Working with *Spirogyra*, Ernest Overton solidified observations by de Vries [1884] regarding regulation of osmotic balance across a cell membrane. (Harris, 1999)

1898 Carl Benda named **mitochondria** in Arch. Anal. Physiol 393-398 (Lars Ernster and Gottfried Schatz, 1981. "Mitochondria: a historical review" *J Cell Biol.*: 91(3): 227–255. PMCID: PMC2112799; PMID: 7033239 (http://doi.org/10.1083/jcb.91.3.227s

1901 Strasburger identified connections similar to those Tangl had described in 1879, creating the term **plasmodesmata**.

1902 Boveri, working with sea urchin eggs, demonstrated that individual (distinguishably different) chromosomes consistently correlate with specific heritable traits, a second principle he called 'The Individuality of Chromosomes' (Harris, 1999)

1902 William Bateson published *Mendel's Principles of Heredity - A Defense*, in which he introduced many important terms and concepts... The words **homozygous** and **heterozygous**, **homozygote** and **heterozygote**, as well as **allelomorph** (from which we take the term **allele**) show up in this early exposition. (Original text available through **Internet Archive** = archive.org)

1902 Garrod, Archibald E. 1902. "The Incidence of Alkaptonuria: A Study in Chemical Individuality" (*Lancet*, vol. ii, pp. 1616-1620.) In a strikingly modern and predictive publication, Garrod introduces compelling evidence (which, as with Mendel's work, would be almost wholly ignored for decades) of the genetic basis for disease, based principally on his study of alkaptonuria. He states: *"It has recently been pointed out by Bateson that the law of heredity discovered by Mendel of-*

fers a reasonable account of such phenomena. It asserts that as regards two mutually exclusive characters, one of which tends to be dominant and the other recessive, cross–bred organisms will produce germinal cells (gametes) each of which, as regards the characters in question, conforms to one or other of the pure ancestral types and is therefore incapable of transmitting the opposite character. When a recessive gamete meets one of the dominant type the resulting organism (the zygote) will usually exhibit the dominant character, whereas when two recessive gametes meet the recessive character will necessarily be manifested in the zygote. In the case of a rare recessive characteristic we may easily imagine that many generations may pass before the union of two recessive gametes takes place."

1903 Wilhelm Johannsen introduced the terms **phenotype** and **genotype** as part of his discussion of pure lines in breeding. Abstract from D. Berry, "The plant breeding industry after pure line theory: Lessons from the National Institute of Agricultural Botany." *Stud Hist Philos Biol Biomed Sci.* 2014 Jun;46:25-37. doi: 10.1016/j.shpsc.2014.02.006. Epub 2014 Mar 17.

"In the early twentieth century, Wilhelm Johannsen proposed his pure line theory and the genotype/phenotype distinction, work that is prized as one of the most important founding contributions to genetics and Mendelian plant breeding. Most historians have already concluded that pure line theory did not change breeding practices directly. Instead, breeding became more orderly as a consequence of pure line theory, which structured breeding programmes and eliminated external heritable influences. This incremental change then explains how and why the large multinational seed companies that we know today were created; pure lines invited standardisation and economies of scale that the latter were designed to exploit. Rather than focus on breeding practice, this paper examines the plant varietal market itself. It focusses upon work conducted by the National Institute of Agricultural Botany (NIAB) during the interwar years, and in doing so demonstrates that, on the contrary, the pure line was actually only partially accepted by the industry. Moreover, claims that contradicted the logic of the pure line were not merely tolerated by the agricultural geneticists affiliated with NIAB, but were acknowledged and legitimised by them. The history of how and why the plant breeding industry was transformed remains to be written." (See also:Roll-Hansen, 2009. "Sources of Wilhelm Johannsen's genotype theory." *N J Hist Biol.* 2009 Fall;42(3):457-93.)

1904 Friedrich Meves (*"Über das Vorkommen von Mitochondrien bzw. Chondromiten en Pflanzenzellen," Ber Deutsch. Bot. Ges*, 22: 284-286) was the first to report plant mitochondria, while studying tapetal cells of *Nymphaea alba* anthers. (see W. C. Twiss, 1919. "A Study of Plastids and Mitochondria in Pressia and Corn" American Journal of Botany, 6(6) 217-234; Earl H. Newcomer, "Mitochondria in Plants," 1940. *Botanical Review* 6(3):85-147 Though observed before 1850, mitochondria were not described as cell organelles until 1894,

when Richard Altmann named them bioblasts. In 1898, Carl Benda suggested the term mitochondria. Philip Siekevitz came up with the description of mitochondria as the powerhouse of the cell in 1957. (Wikipedia)

1905 William Bateson, Edith Saunders, and Reginald Punnett, encountered evidence of gene linkage while repeating aspects of Mendel's work with peas. (Genetic Linkage in Wikipedia, 2018) Full-blown exposition of this non-Mendelian behavior would come shortly, through work with fruit flies in Thomas Hunt Morgan's lab at Columbia University in New York.

1905 First edition of Punnett's *Mendelism*

1906 First edition of Robert Heath Lock's *Recent Progress in the Study of Variation, Heredity, and Evolution*, which many consider the first genetics textbook. You will read that the term "Genetics" first appeared in print in William Bateson's review of Lock's book. [see A. W. F. Edwards, 2013. "Robert Heath Lock and His Textbook of Genetics, 1906." *Genetics*. 2013 Jul; 194(3): 529–537.doi: 10.1534/genetics.113.151266, PMCID: PMC3697961, PMID: 23824968], but that is not accurate in the least. For example, in 1893, Charles Bessey used the phrase "genetic relationship" in his address on "Evolution and Classification" to the American Association for the Advancement of Science, Section G (see their journal, v 42, page 238) I believe it's a fairly short and insignificant distance between talking about genetic relationships and referring to a field of study as genetics....

1908 William Weinberg (Germany) and Henry Harvey (England) independently arrived at mathematical statements regarding changes in genetic make-up of populations. The Hardy -Weinberg Principle contends that relative abundance of differing alleles (genes) in a population will remain stable unless a force selects or directs change. [See 1931, Sewell Wright.]

1908 George Shull's "The composition of a field of maize" *"marked the beginning of the exploitation of heterosis in plant breeding, surely one of genetics' greatest triumphs... In his 1908 paper, Shull reported that inbred lines of maize showed general deterioration in yield and vigor, but that hybrids between two inbreds immediately and completely recovered; in many cases their yield exceeded that of the varieties from which the inbreds were derived. Furthermore, they had a highly desirable uniformity. In a subsequent paper in 1909, he outlined the procedures that later became standard in corn-breeding programs "* James F. Crow, 1998. '90 Years Ago: The Beginning of Hybrid Maize', *Genetics* 148(3):923-928 (see also Shull, G., 1908. The composition of a field of maize" *Am. Breeders Assoc. Rep*. 4: 296–301.)

1909 Correns work with the wonderful Four O'Clock (*Mirabilis jalapa*), which produces variegated leaves, provided early evidence for cytoplasmic inheritance (that defies the Mendelian odds because chloroplasts are normally inherited from the mother-plant and carry their own genetic maternal). Today, researchers have explained more about the na-

ture of the gene *iojap,* which generated Correns' results by impacting the physiology of chloroplasts.

1909 Boveri summarized modern understanding of Chromosome biology: *"At fertilization, these two 'haploid' nuclei are added together to make a diploid nucleus that now contains 2a, 2b and so on; and by the splitting of each chromosome and the regulated karyokenetic separation of the daughter chromosomes, this double series is inherited by both of the primary blastomeres. In the resulting resting nuclei the individual chromosomes are apparently destroyed. But we have the strongest of indications that, in the stroma of the resting nucleus, every one of the chromosomes that enters the nucleus survives as a well-defined region; and as the cell prepares for its next division this region again gives rise to the same chromosome (theory of the Individuality of the Chromosomes). In this way the two sets of chromosomes brought together at fertilization are inherited by all the cells of the new individual. It is only in the germinal cells that the so-called reduction division converts the double series into a single one. Out of the diploid state, the haploid is once again generated."* (Harris translation, 1999)

1909 Frans Alfons Janssens published an article, *"La théorie de la Chiasmatypie. Nouvelle interprétation des cinèses de maturation"* presenting the idea of crossing over (which he called chiasmotypie) - a proposal that encountered long-term resistance . (Koszul R1, Meselson M, Van Doninck K, Vandenhaute J, Zickler D., 2012. "The centenary of Janssens's chiasmatype theory" *Genetics*. , 191(2):309-17. doi: 10.1534/genetics.112.139733.

1909 Wilhelm Johannsen popularized the term **gene**.

1909 Thomas Hunt Morgan and his lab team opened a major thrust in genetic research when (after nearly two years of investigation) they isolated workable mutations in populations of *Drosophila melanogaster* (fruit flies) they were studying at Columbia University. Simple to raise and easy to anesthetize, with a generation time of 10 days, these flies became the source of many great advances in our understanding of genetics and cell biology. (Harris, 1999)

1911 Punnett's third edition of *Mendelism* included full-out displays of the notoriously-useful Punnett squares, learned by every student of biology.

1911 In Thomas Hunt Morgan's lab, Alfred Sturtevant was achieving success in mapping certain fruit fly genes, explaining both linkage and crossing over. His work was first published in 1913. [Lobo, I. & K. Shaw, (2008) "Thomas Hunt Morgan, genetic recombination, and gene mapping". Nature Education 1(1):205]

1913 - Eleanor Carothers documented independent assortment of chromosomes during meiosis.

1915 - Mathematician Ronald Fisher demonstrated that a small number of genes could interact to yield a finely-tuned continuum of variation (it pencils out).

1918 Donald Jones published "The effects of inbreeding and cross-breeding upon development" (Jones, D. F., Connecticut Agric. Exp. Stn. Bull. 207), in which he proposed the "double cross" system, "a procedure that spread out the controlled hybridizing process over an extra generation and permitted tremendous increases in seed production." (Jensen, in Frey, 1994)

1919 The publication of *Inbreeding and Outbreeding* by E. M. East and D. F. Jones gave scientific underpinnings to corn breeding and introduced Jones's system of double crossing through the use of four inbred lines. This work, fostered by the US Experiment Station system, was one of the most significant early accomplishments of modern agricultural science. (Rasmussen, 1960)

1922 Göte Turreson published two significant articles in volume 3 of the journal *Hereditas*: "The species and variety as ecological units" and "The genotypical response of the plant species to the habitat." In these publications, Turreson added the term **ecotype** and others to our working vocabulary.

1922 Edgar Anderson began work in St. Louis, MO as "Geneticist to the Garden" (heading Missouri Botanical Garden's School of Gardening) and professor at Washington University. Anderson would quickly become one of the principle figures in development of biosystematics. *"His first biosystematic project was a look at the species problem in Iris. His 1928 paper took up the species problem concretely by looking at populations of two closely related yet distinct species of iris and allowed Anderson to test the relative importance of hybridization and mutations as sources of the variation on which natural selection works "* (Kim Kleinman, 2009. "Biosystematics and the Origin of Species: Edgar Anderson, W. H. Camp, and the Evolutionary Synthesis", Transactions of the American Philosophical Society, New Series, Vol. 99(1) 73-91, in *Descended from Darwin: Insights into the History of Evolutionary Studies, 1900-1970*
Stable URL: https://www.jstor.org/stable/27757425

1923 Accompanied by a microscope demonstration, Robert Feulgen reported his "nucleal reaction" and "nucleal staining" to the 8th German Physiology Congress, which met in Türbingen. Feulgen had successfully used staining procedures to localize differing components of nucleic acids - aldehyde groups and pentose components, now termed the Feulgen Reaction, a vibrant red-violet stain for DNA. The Feulgen reaction is considered the first "end-point type reaction" - which would brand Robert Feulgen as "the first modern histochemist." Beyond introducing an important staining technique, this demonstration eliminated previously-existing ideas that plant DNA differed from animal DNA. In comments from a 1956 presentation by Kurt Felix (who had attended the 1923 presentation): *"In all preparations the nuclei were stained red-violet. The exciting finding for us was the reaction of not only the nuclei of animal cells, but rather also those of plant cells. With this demonstration, the difference between plant and animal nucleic acids ceased to exist. All cells contained in their nuclei the same kind of nucleic acid which we refer to*

today as deoxyribonucleic acid or DNA." (Clark & Kasten, 1983)

1926 John Belling published "The iron-acetocarmine method of fixing and staining chromosomes" in *Biol. Bulletin* 50:1160-162, an modified version of a technique he had introduced five years earlier in *American Naturalist*. Studying chromosomes in a range of plants (*Canna*, *Cypripedium*, *Hemerocallis*, and many other monocots), Belling's new technique improved aceto-carmine staining by adding iron (even simply using a rusty probe will work), which generated stronger differentiation between chromosomes and cytoplasm. (George Clark and Frederick Kasten, 1983)

1927 The first patent for a Scanning Electron Microscope (SEM) was filed in Germany, but decades would pass before workable instruments were commercially available (Cambridge Scientific Instrument Company, 1965). Those instruments gave magnifications of 10 to 200,000 times life size with magnificent depth of field, 500 times that of light microscopy. The earliest botanical observations using SEM were published between 1965 and 1970, with large numbers of applications and publications appearing over the next decade. Initially, the technique proved most useful for surface structure, but anatomists quickly worked this into their research.. Margaret Y. Stant , 1973. "The Role of the Scanning Electron Microscope in Plant Anatomy" *Kew Bulletin*, Vol. 28, No. 1 (1973), pp. 105-115, Source JSTOR Kew Stable URL: http://www.jstor.org/stable/4117068

1927 Using light microscopy, C. Zirkle demonstrated that chloroplasts develop from clear proplastids. (L. Andrew Staehelin, 2005. "Chloroplast structure: from chlorophyll granules to supra-molecular architecture of thylakoid membranes", pp 717-728 in *Discoveries in Photosynthesis*

1928 Following similar work with *Drosophila*, Stadler used X-rays to produce mutations in corn (*Zea mays*). ©.(Zirkle in Ewan, 1969)

1928 - Frederich Griffith published proof of **transformation**, a natural process through which genetic material from one organism is inserted into the genome of another.

1930 Münch applied the terms **apoplast** and **symplast** to designate continuity of cytoplasmic content (the symplast) as opposed to the extracellular matrix (the apoplast).

1931 Sewell Wright presented the first clear concept of Genetic Drift (Wright, 1931, "Statistical Theory of Evolution", *Journal of the American Statistical Association*, 26(173, Supplement): 201–208: *"It has seemed to me that another factor should be much more important in keeping the system of gene frequencies from settling into equilibrium. This is the effect of random sampling in a breeding population of limited size. The gene frequencies of one generation may be expected to differ a little from those of the preceding merely by chance. In the course of generations this may bring about important changes, although the farther the drift from the theoretical equilibrium, the greater will be the pressure toward return."*

Direct Source: *Stanford Encyclopedia of Philosophy*, "Genetic Drift" First published Sep 15, 2016)

1937 Robin Hill conclusively demonstrated that oxygen generated during photosynthesis (now called the Hill Reaction) does not require the presence of carbon dioxide. Hill's studies furthered work by T. W. Englemann, who in 1883 had demonstrated that chloroplasts of the alga *Spirogya* generate oxygen most actively when exposed to red and blue light. By 1941, C.B. van Niel, Samuel Ruben, and co-workers had demonstrated that oxygen liberated during photosynthesis comes from the splitting of water. (McDonald, 2003)

1939 The first commercial Transmission Electron Microscope (TEM) was available. Work on this concept began a decade earlier with efforts of Ernst Ruska and Max Knoll. Ruska was awarded the Nobel Prize in 1986 for his role in TEM.

1943 Henry Wallace (owner of Pioneer Hi-Bred and US Vice-President) and Marte Gomez (Mexico's Minister of Agriculture) coordinated with Raymond Fosdick and the Rockefeller Foundation to establish programs to improve corn and wheat production. The Mexican government established an Office of Special Studies (OSS). In 1941, anticipating this program, Richard Bradfield (Cornell, soil science), Paul Mangelsdorf (Harvard, botany), and Elvin Stakman (Minnesota) constituted the review committee endorsing creation of the Rockefeller-financed Mexican Agricultural program (MAP). Jacob Harrar and Norman Borlaug were among the founding scientists. MAP was the precursor to CIMMYT (*Centro Internacional de Mejoramiento de Maíz y Trigo*), the International Maize and Wheat Improvement Center. (Dworkin, 2009; Cotter, 2003; Christensen, 1984; CIMMYT website, 2017)

1943 Building on their own work and recent reports of many scientists, Hugh Davson and James Danielli formulated the "paucimolecular membrane model," which predicts a lipid-protein-lipid trilaminate structure for membranes. By 1959, using newly available fixatives, J. David Robertson had produced electron micrographs that gave physical evidence of the trilamellar structure. This work underpins the "fluid mosaic model" proposed in 1972 by Singer and Nicholson, which resolves issues of stability. (Wayne, 2009)

1944 Oswald Avery had directed his research to examine Frederick Griffith's remarkable work, demonstrating that some physical essence in killed bacteria could be taken in by other bacteria and result in genetic change, an alteration Griffith called transformation. In a series of experiments that involved careful purifications of various fractions, Avery with his colleagues Colin MacLeod and Maclyn McCarty, determined that the material effecting the change was Deoxyribose nucleic acid (DNA). Their work partially confirmed that genetic information is somehow stored in DNA. (Mukherjee, 2016) [See Hershey and Chase, 1952]

1945 Through their studies of limiting factors in growth of bread mold, *Neurospora crassa*, George Beadle and Edward Tatum noted the impact of mutations that meant individual

enzymes were not functional. Beadle and Tatum were able to confirm that a gene provides instructions for a particular protein, advancing understanding of genetics through explaining how genetic information was translated into form and function in a cell. (Mukherjee, 2016)

1945 See Kevin Porter, 1953, Endoplasmic Reticulum

1946 Marion Parker, Sterling Hendricks, Harry Borthwick, and Fritz Went published "Spectral sensitivities for leaf and stem growth of etiolated pea seedlings and their similarity to action spectra for photoperiodism" (*American Journal of Botany*, 35:194-204), explaining that Red light impacts plant growth, inciting new lines of investigation and causing researchers in photoperiodism to refurbish their labs with green filters. Previously, labs had followed protocols similar to those of black and white photography, using red "safe light" to illuminate workspaces. (Sage, 1992)

1950 While conducting research at Brooklyn Botanic Garden, plant virus researcher Myron Kendall Brakke reported refinements in his development of density gradient centrifugation, a procedure that became basic for purifying virus samples. From the National Academy of Sciences: *"Brakke's early work ... culminated in a landmark contribution to science: the invention of density-gradient centrifugation, which he used for the first time to purify potato yellow-dwarf virus. This technique provided an unparalleled capacity to purify viruses, separate nucleic acids and proteins, and fractionate cellular organelles. In his groundbreaking paper on density-gradient centrifugation in the Journal of the American Chemical Society, Brakke reported that the basic procedure could be modified for application to many different problems involving particles and large molecules of either biological or non-biological origin." Yet, the utility of Brakke's density-gradient centrifugation invention as a "separation procedure" and "as a criterion of purity, or as a technique for measuring densities of particles or large molecules," did not become widely applied for nearly 10 years. Of course, ultimately sucrose density-gradient centrifugation became the most commonly used tool for a wide range of biological science applications and was key to the development of modern virology and molecular biology. Indeed, many advances in biology and the biomedical fields would not have been possible without this technique. By the latter half of the 20th century, density-gradient centrifugation was routinely used in nearly every biochemistry, molecular biology, cell biology, and virology laboratory in the world. Thus, Brakke's novel development provided the foundation for a more profound understanding of disease agents, and the synthesis and structure of proteins and nucleic acids."* (National Academy of Sciences, "Myron Kendall Brakke 1921–2007 , A Biographical Memoir" by Karen-Beth G. Scholthof, Andrew O. Jackson, and James L. Vanetten.

1951, 1953 Using autoradiography to study nutrient uptake by cells in the roots of beans, Alma Howard and Stephen R. Pelc defined the cell cycle ("Synthesis of nucleoprotein in bean root cells" *Nature* 167) A Quote From: Joseph G. Dubrovsky & Vic-

tor B. Ivanov, 2003. "Celebrating 50 years of the cell cycle" Nature 426 (759)*"Howard and Pelc were the first to ascribe a timeframe to cellular life and they proposed the existence of four periods in the cell cycle: a period of cell division, the pre-S-phase (called G1), the S-phase (a period of DNA synthesis) and period G2, or the pre-mitotic period. The concept of the cell cycle was born."*

1952 Working at the Carnegie Institution, through studying insertion of isotope-labelled phage DNA in bacteria, Alfred Hershey and Martha Chase provided strong evidence that DNA is the material that holds genetic information in chromosomes.

1953 - James Watson and Francis Crick published their double helix model explaining the physical structure of the DNA molecule.

1953 Kevin Porter reported the presence of a cytoplasmic network which he named **endoplasmic reticulum** (ER). This work was follow-up to a 1945 report of transmission electron microscopy by authors Keith Porter, Albert Claude, and Ernest Fullam, in which they noted observations of a *"lacelike reticulum… , possibly the homologue of kinoplasm."* Because the 1945 article focused on techniques for TEM study of tissue culture cells, concern was expressed that the reticulum could be an artifact of specimen preparation. In his 1953 follow-up study, Porter confirmed this network and applied the name. ("A Study of Tissue Culture Cells by Electron Microscopy - Methods and Preliminary Observations," J Exp Med. 1945 Mar 1; 81(3): 233–246. PMCID: PMC2135493; PMID: 19871454) (Kevin Porter, 1953. "Observations on a submicroscopic basophilic component of cytoplasm." *J Exp Med*. 97(5):727-50. [Also See: TL 1895, Garnier]

1955 Carlos Miller and colleagues described a plant hormone (derived from herring sperm) they named kinetin, which is involved in promotion of cell division (cytokinesis). In 1961, Miller described zeatin, the first named naturally-occurring plant cytokinin. This work grew from earlier studies on plant callus formation and cell-division by Folke Skoog and J. R. Jablonski. Before their work, Johannes van Overbeek had studied the impact of coconut milk on cell division in culture media. (University of Indiana website; Wikipedia, 2018; History of Cytokinins, website of the International Plant Growth Substances Association, 2018) [See TL 1913, 1961]

1958 - Francis Crick summarized what had become the Central Dogma of Molecular Biology: DNA makes RNA, RNA makes Protein, There is no going back. Protein cannot reverse-build RNA.

1959 Arthur Parde, François Jacob, and Jacques Monod, investigated changes in *E. coli* physiology that allowed the cells to switch from using glucose as an energy source to using lactose. Their study indicated that genetic activity is managed, or operated, turned on and off in cells, through allied genes the authors christened as **operons**.

1961 François Jacob and Sydney Brenner carried much of the water in explaining how Messenger RNA functions to tran-

scribe information held by DNA molecular sequences into actionable templates from which proteins could be constructed. (Mukherjee, 2016)

1961 Wilhelm Minke applied the term **thylakoid** to the stacked, sac-like membranes that constitute the grana of chloroplasts. From Friederike Koenig and George H. Schmid, 2009. "Wilhelm Menke (1910–2007): a pioneer in chloroplast structure" Photosynthesis Research 99(2) 81–84: *"Having had already seen lamellar structures in chloroplasts from Nicotiana, Spinacia and Aspidistra in the laboratory of Manfred von Ardenne in 1940 and also in Anthoceros before World War II, he finally understood the inner structure of the chloroplast as a system of stacked and unstacked flattened vesicles surrounded by a membrane made of proteins and—besides pigments—lipids, mainly galactolipids,.... He called them thylakoids, a Greek term for "sac-like" δνλαχοειδής. The original publication is in German (Menke 1961, translation in Gunning et al. 2006); however, many authors cite his review in this context, namely the 1962 article in Annual Review of Plant Physiology."*

1964 Sipra Guha (Mukherjee) and Satish Chandra Maheshwari published the first of two significant papers on their work with haploid embryos derived from *Datura* anthers. ("In vitro production of embryos from anthers of Datura", Nature 204:4977; "Cell division and differentiation of embryos in the pollen grains of Datura in vitro", Nature 212:97-98) From Wikipedia, 2018: The scientists developed *"a new high-speed culture technique for producing homozygous pure lines of haploid plants which is now in practice for crop improvement and for commercial production of horticultural and ornamental plants"*

1965 - Work in various labs resolved the "genetic code" - confirming how all combinations of the five "canonical" nucleobases correlate to amino acids.

1965 Yoshiyuki Takasaki and Osamu Tanabe (working at the Japanese Fermentation Institute) developed a stable process to convert glucose to fructose. The tantalizing promise of that conversion had been the holy grail of the corn syrup industry. By 1967, Clinton Corn Processing Company had licensed rights to this enzyme for the US, and their scientists worked out kinks to industrialize the process. (Folsom, Botany of Sugars in Reader)

1967 . "On the origin of mitosing cells" (*Journal of Theoretical Biology*. 14 (3): 225–274) was published by Lynn Sagan (Margulis). Her thesis re-popularized century-old ideas that cellular organelles, such as mitochondria and chloroplasts, originated as independent organisms, and are "symbiotic" components of contemporary cells. Andreas Schimper had noted the similarities between algae (Cyanobacteria) and plastids in 1883, as had Konstantin Mereschkowski in 1910. (see https://theendosymbiotichypothesis.wordpress.com/; see also Schimper, "*Über die Entwicklung der Chlorophyllkörner und Farbkörper". Bot. Zeitung*. 41: 105-...162)

1968 Studying chloroplasts of tobacco, K. K. Tewari and S. G. Wildman demonstrated the presence of plastid DNA. This fol-

lowed work by H. Ris and W. Plaut in 1962 reporting DNA-like material in chloroplasts of the alga *Chlamydomonas*. (McDonald, 2003)

1969 Mary Lou Pardue and Joseph G. Gall published their article "Molecular Hybridization of Radioactive DNA to the DNA of Cytological Preparations", in *Proceedings of the National of Academy of Science*/ From the Abstract: "A method is presented for detecting the cellular location of specific DNA fractions. The technique involves the hybridization of a radioactive test DNA in solution to the stationary DNA of a cytological preparation. Sites of DNA binding are then detected by autoradiography. Experiments with DNA of the toad *Xenopus* are described." This work describes use of easily-visible fluorescent markers, i.e. FISH, which led to major advances in genetic and genomic studies.

1972 Jonathan Singer (Seymour Jonathan Singer) and Garth L. Nicholson described their "Fluid Mosaic Model" for cell membrane structure, built on the evolving trilamellar concept of a lipid bilayer, with embedded proteins...., a dynamic sandwiching of lipids and proteins that allow for movement and embedding of many other kinds of ions, atoms, and molecules.

1973 - Herb Boyer and Stanley Cohen succeeded in the first successful artificial transformation (transforming the genome of an organism by inserting foreign genes). A year later, Cohen's lab announced they had transferred a frog gene into a bacterium.

1977 - Biochemist Frederick Sanger published the first sequenced genome, that of a virus.

1978 - Ed Lewis and his team, working with fruit fly mutants, demonstrated that activation of genes is managed by master-regulatory effector genes.

1980 In their ruling on *Diamond v. Chakrabarty*, the US Supreme Court determined that genetically-altered life forms could be awarded patents. From Wikipedia, 2018: *"After (Ananda Mohran) Chakrabarty had appealed his patent's initial rejection, the Court of Customs and Patent Appeals had reversed in his favor, stating that "the fact that microorganisms are alive is without legal significance to the patent law". In response, Sydney Diamond, Commissioner of Patents and Trademarks, decided to take this case to the Supreme Court. Diamond had two arguments which were not well received by the court. The first called the existence of the 1930 Plant Patent Act and the 1970 Plant Variety Act to suggest that there is a congressional understanding about the terms 'manufacture' and 'composition of matter' not referring to living things. The second was that microorganisms cannot qualify as patentable subject matter until Congress authorizes such protection since genetic technology was unforeseen when Title 35 U.S.C. 101 was first enacted."*

1982 The first genetically engineered crop was developed at Washington University in St. Louis, Missouri. By 1994 the Flavr-Savr tomato became the first such plant approved for commercial marketing. The Flavr-Savr tomato was designed

for slow fruit ripening and increased shop life. (Levetin & McMahon, 1996)

1983 Kary B. Mullis devised the **polymerase chain reaction**, a system to replicate large quantities of DNA from a small initial sample. The ability to create a large sample of DNA for testing and study had extraordinary impact on various fields of study, from areas of paleobiology to forensic analysis. (Cobb & Goldwhite, 1995)

1983 Barbara McClintock received the Nobel Prize for her work with the complex color patterns of Indian corn, studies that revealed moveable genetic elements termed "jumping genes."

1983 *Agrobacterium fabrum* (A. tumefaceins) was successfully used for genetic transformation of plants (in tobacco) by P. Zambryskit, H. Joost, C. Genetellol, J. Leemans, M. Van Montagu and J. Schell. See their publication. "Ti plasmid vector for the introduction of DNA into plant cells without alteration of their normal regeneration capacity" *The EMBO Journal* 2(12): 2143-2150: *"The vector pGV3850 makes use of the natural transfer properties of the Ti plasmid; only those genes which interfere with normal plant differentiation have been removed. Thus, the most important aspect of pGV3850-transformed cells is their capacity to regenerate into complete plants. These plants can be derived from single cells and the regeneration process itself is extremely simple, requiring only minor changes in tissue culture conditions.... evidence has been presented that the Ti vector has evolved to a point where it is ready to be used to genetically engineer whole plants; it remains for us to turn our efforts toward the isolation of particular genes whose expression we wish to study."*

1987 Richard A. Jefferson published his GUS reporter gene system, which he had already shared extensively in an effort to support open sources for techniques. Jefferson's technique has been widely adapted and utilized in plant transformation. The article, "Assaying chimeric genes in plants: The GUS gene fusion system". Plant Molecular Biology Reporter. 5 (4): 387–405, is heavily cited. *GUS* is the symbol for the gene that codes for glucuronidase.

1987 Snowdrop lectin (GNA - *Galanthus nivalis* agglutinin) was brought to the attention of researchers through Els J.M Van Damme, Anthony.K Allen, and Willy J. Peumans, introducing a new agglutinin that might have potential medical value, but also would prove toxic to various insects, such as rice, sugarcane, papaya, potato, tomato, etc. Over the next decade, many distant relatives of *Galanthus* would be investigated, the structures and isoforms described, and genetic sequences made available for transgenic work. (Van Damme, Allen, & Peumans, 1987. "Isolation and characterization of a lectin with exclusive specificity towards mannose from snowdrop", (Galanthus nivalis) bulbs. FEBS Letters 215, 140-144: *"GNA represents apparently a new type of plant lectin with a unique carbohydrate-binding specificity. Since this lectin can easily be isolated in reasonable amounts from readily available material it can be of great potential use as a bio-*

chemical tool." Since that publication, genetic code for Snowdrop lectin has been introduced to various crops in order to reduce insect damage. https://febs.onlinelibrary.wiley.com/doi/epdf/10.1016/0014-5793%2887%2980129-1

1996 Monsanto introduced Roundup Ready soybean seed, the first genetically modified herbicide tolerant agricultural crop.

2000 Ten years after the US National Science Foundation selected *Arabidopsis thaliana* as the plant study organism for studies to elucidate the entire genetic sequence, and following four years of intense research in laboratories (at a cost of over $70 million), researchers announced the project was complete. The sequence of the approximately 120 million nucleotides (about 25,000 genes) that constitute the DNA of this plant was now known, the first plant genome to be fully sequenced. (Chamovitz, 2012)

2001 Genetically-modified (GM, i.e. transgenic) crop plants had clearly become mainstream, highlighted through reassessment this year by the US Environmental Protection Agency, reaching the conclusion that Bt cotton and Bt corn did not pose significant environmental risk for the environment or for human health. In 2001, Bt white corn was planted in South Africa for basic human subsistence (direct consumption) for the first time (previously, all GM maize had been used for animal food). By 2002, 6.8 million hectares had been planted to Bt cotton worldwide (12% of the world's production.) (Thomson, 2007) [Bt is the abbreviation for *Bacillus thuringiensis*, a soil-living bacterium. Bt produces what compounds called crystal proteins, abbreviated as Cry proteins, that are toxic to insect larvae, and are the active compounds in Bt pesticides. Companies have modified crop plants genetically by inserting the Cry genes, which cause the engineered crop plants to produce the toxin.]

2006 Researchers (G. A. Tuskan, *et al*) published a draft genomic sequence of a selected *Populus trichocarpa* female specimen (Nisqually-1), in *Science*, the first woody plant to be sequenced.

2012 The Tomato Genome Consortium of researchers published the first complete genome of tomato (inbred cultivar 'Heinz 1706')

2012 Jennifer Doudna (UC Berkeley) and Emmanuela Charpentier (Max Planck Institute) proved that CRISPR technology could be targeted for gene editing.

2013 Trials of "Golden Rice" produced through genetic engineering at the International Rice Research Institute (in the Philippines) were destroyed by anti-GMO forces. Rice is made "golden" through addition of genes that enable the rice to generate beta-carotenes, which are precursors to Vitamin A in human diets.

Additional References:

Judson, Horace Freeland, 2013 (1996 Expanded) COMMEMORATIVE EDITION. *The Eighth Day of Creation: Makers of the Revolution in Biology*, Cold Spring Harbor Laboratory Press, New York, ISBN 978-0-879694-78-4 (Electronic Book). A remarkable document and must-read for those interested in the history of molecular biology, the Commemorative Edition follows the death of author Judson in 2011, and includes a forward by John Inglis, Executive Director of the Cold Spring Harbor Laboratory Press, Judson's obituary, and a Reminiscence by the author's daughter Olivia Judson.

Ducker, Sophie C. and R. Bruce Knox, 1985. "Pollen and Pollination: A Historical Review," *Taxon* 34(3): 401-419.

Frey, Kenneth J., 1994. *Historical Perspectives in Plant Science*, Iowa State University Press, Ames, ISBN 0-8138-2284-X, 205 pp.

A few resources to access:

Crow-Dove Perspectives: The Perspectives column was initiated in 1987 when Jan Drake, Editor-in-Chief of GENETICS, invited Jim Crow and William Dove to serve as coeditors of "Anecdotal, Historical, and Critical Commentaries." SEE: William F. Dove, 2016. "Weaving a Tapestry from Threads Spun by Geneticists: The Series Perspectives on Genetics, 1987–2008" Genetics 203(3): 1011-1022; https://doi.org/10.1534/genetics.116.191155

Understanding and Explaining Plant Diversity

It is natural for humans to make sense of the world around them, which causes me to wonder how we comprehended circumstances before language. I mean, how did we keep track of objects without names, and even once we had internally applied some symbolic association, how did we communicate thoughts, or decide that two different objects could merit the same symbol? Like, are a rock and a pebble the same as a stone? And how was it possible to pass down knowledge about the world around you when there was no language or taxonomy. What is the story we feel compelled to understand, and to convey? What words and symbols are needed?

But we have to discern differences and patterns, we must practice taxonomy because it's necessary to discriminate between different kinds of beings and things. Some people are born to do this, people who sort everything around them into explicit categories, screws and bolts for example. There are the ones with points, like wood screws and machine screws. And there are the ones that marry to nuts, and don't need pointed tips. But some of the bolts have faceted heads that fit a wrench, while others have rounded heads with slots that require a screwdriver. Or maybe the head is fashioned for a Phillips screwdriver, or even an Allen wrench. So those have to be separated. The same-looking screw or bolt will exist in different gauges, 1/4, 1/8, 1/16th of an inch. Or, as we have all learned over the past two decades, the entire range of fasteners can exist in metric sizes, 6mm, 7mm, 8mm etc. And there are different kinds of threads, such as tightly wound machine threads that provide more grip versus conventional threads, that are still pretty good.

Taxonomy - studying "beings" and "things" in order to give them appropriate names and organize them in a system that makes sense to the user.

Thing - an inanimate object
Being - a sentient, living object

For those of us who love to mess with gadgets, the ability to find just the right bolt or screw is highly prized. A lot of tinkerers in the Pasadena area still mourn closing of the famous Berg Hardware. You could walk up to the counter with some random mechanism, and discover the staff had the very bolt you needed. *"Yeah, we should have this. Do you want it in galvanized, or stainless? How long?"* Then they'd disappear into the ranks of shelving and come back with a small, torn box, match the fastener, and ask how many you need. Sometimes, it was just one screw, or one bolt with matching nut and washer; less than a dollar. And you didn't have to purchase a dozen, or go on-line and hope that the words you are using for the screw are the same ones deployed in some massive database. I don't know how they stayed in business, but of course, the store closed, so perhaps I know why.....

The folks at Berg Hardware were taxonomists, and they were systematists. They had names for each minorly different fastener, and they had a system by which to pigeonhole them. I wish I had begged a visit behind the counter before the store

closed, just to see how the thousands and thousands of fasteners were organized. Were the stainless ones on separate shelves, or were they interspersed with the same sized gizmos of other material? Were the nuts nearby, or over in their own area? What kind of shorthand evolved so that one staff member could most efficiently help another find their prey?

Well the world of plants is a bit, just a bit, like nuts and bolts. There are thousands of kinds (hundreds of thousands), and we even have places like Berg Hardware, herbaria with metal cabinets in which specimens of different plants are sorted, organized, and shelved. The world's larger herbaria have millions of specimens, filling cubbyholes in thousands of cabinets.

The problem with plants, what makes them so very different from nuts and bolts, is that specimens collected from different individuals are not exactly the same. The closest you'll come to a precise match would be in an herbarium that documents clones, like rose cultivars. Every 'Altissimo' basically should be fairly similar to every other 'Altissimo' sample, though each would be a unique cutting. Even if the specimens were similar cuttings, the growing conditions, stage of growth, treatment of the collection, etc. would vary, so you'd never get the perfect replicas we expect from nuts and bolts.

In naturally-occurring populations of every kind of plant, just as in a community of people, each individual differs from the other. Even though each of us is an individual, we have no problem deciding who else is a human; you just know a person when you see one. It's part of being human, knowing your kind. But we are not as competent when faced with other kinds of organisms. We do not, inherently, know the range of variation of one plant species as compared to another. We don't really even know how to define the limits of a species, when two similar-seeming plants are of the same kind, or different. The plants "know" (yes, this is pushing it), or in many cases, their pollinators, but we don't. What's worse, we do not really agree in every case how to define what separates one species from another, because different plant groups don't share the same growth and reproductive strategies.

Scientists have come to a general consensus that if two related plants, when grown within breeding distance, are not capable of interbreeding naturally, then those two plants probably represent different species. That "biological species" concept had interesting consequences when Russian botanists studying dandelions (which are notorious for apomixis, i.e. establishing clonal colonies through generating cloned seed) decided to assign a formal scientific name to each separate colony.

But almost any good idea can be taken too far.

A more contemporary thought would be that we should be able to study the genetics of plant populations, and then decide through genetic evidence what makes one species different from another. The problems with this are many. Who has the time, money, staff, and facilities to make all of those studies? How do you draw lines (based on genetic makeup) when you don't understand the way those genetics are expressed in

nature, and how they impact populational behavior? What sense can be made of differences when there may not be clear expression of that difference in any discernible characteristic? How would you use such finely tuned differences in a practical sense, how would you group plants into functional or useful categories? How would a gardener, or a field biologist, know plants of one species from those of another?

But we are getting ahead of the story. Having delved into this topic, I have made my own sense out of historical approaches to plants, and the way science has come to portray the vegetable kingdom. Simply outlined, the story I relate here identifies several epochs in this saga:

1. **Folk Traditions** describe the most ancient, regional ways differing cultures use, understood, and named the plants around them.

2. **Herbal Traditions** remind us that plants were valued as a gift of Nature to humankind, and in that anthropocentric world, the key to understanding diversity would relate to how each plant was meant to serve us.

3. **Bringing Order** reflects the dawning of discovery and globalization, when it became clear there are actually thousands of kinds of plants, and there must be a scientific basis to the differences we find.

4. **A Natural System** explains the realization of botanists that documenting and categorizing the world's plants would, in turn, provide a map to the basic plan of Nature. This was a 19th century attempt to explain the reason and relationships so evident in the world's flora.

5. **Biosystematics** relates post-Darwinian and post-Mendelian efforts to learn more about how the biology, the nature of plants, impacts speciation and diversity. Lacking direct access to the genetic code, 20th century scientists explored chromosomes, chemistry, and biologies to document the basis of variability and explain the origins or plant species.

6. **Phylogenetics** came into its own at the end of the 20th century, when sequencing of RNA and DNA began to provide direct evidence as to genetic codes. Combining morphological, chemical, ecological, biological, and genetic clues, botanists began assembling stick figures, "trees" (cladograms) that attempt to map evolutionary origins of plants we know today.

7. **Comprehension**, a new dawning, will come at some future stage, when botanists actually understand the roles genes play in the lives of plants in nature and in the garden. At that point, biologies will re-emerge as core, and we will come to understand the multivariate relationships between phenotype and genotype, nature and nurture. Almost everyone will be seen to have been right, Linnaeus, Jussieu, Darwin, Bessey, Hennig..., will have held a different part of the elephant.

Folk Traditions....

Once humans devised languages and systems of writing, the world changed, as words became symbols to record information, establish rules, name and track things, and encapsulate concepts. Names were given to plants of value, plants worth ongoing attention, because they were sources of food, flavoring, fuel, shelter, and fiber..., even medicine. Each ancient society seems to have come up with names for a few hundred plants out of the thousands that surrounded their communities. The names reflected something about culture and use, with no need to reflect much about biology.

Shreds of traditional naming systems linger throughout the world, and folk names (or "common" names) for plants survive in daily language and commerce. But of the many plant naming traditions, only one survived as the basis for a *bona fide* system for giving plants botanically-useful names. That Greco-Roman tradition led to the European system which evolved as the world of scientific nomenclature.

"Nomenclature is a system of names or terms, and the rules for forming these terms in a particular field of arts or sciences...." Wikipedia (adapted)

It's undeniable that scientific nomenclature and taxonomy are based in Greco-Roman philosophical traditions of the Mediterranean Basin (including Arabic scholarship) and northern Europe, which began with practical records, ancient compendia of information on useful plants. Some people are bothered by the Eurocentric nature of plant scientific naming conventions (animal names as well), but if it brings comfort, people should also know that norms governing plant nomenclature reflect continual oversight, review, and adjustment by an internationally-based organization of scientists native to all areas of the world. This collaboration has been on-going for decades, even during the now-forgotten Cold War, Russian, Cuban, and Chinese scientists participated in reviews and rule-making. Still, the Mediterranean roots (and social dominance of the Church) mean that science, which was derivative of Greek, Arabic, and Latin texts, clings to Latin as the lingua franca for plant and animal names.

Early botany was the province of medicine and agriculture, with Western accounts of plant identification driven through Greek and Roman discourse. Thus, many recognizable and durable plant names derive from ancient texts that retained or regained currency through nearly two millennia of cultural development, based on texts ascribed to Aristotle, Theophrastus, Pliny, Dioscorides, and a bit later, Galen.

Those texts, however, are far from singular. They were not carved in stone, and no "original" copies exist. Each has been filtered and even lost at some level, passing through Greek, Latin, and Arabic versions. Theophrastus, who is sometimes called the Father of Botany, provided information on approximately 400 different kinds of plants, information that was "rediscovered" in the Renaissance and still cited as valid knowledge by writers into the 18th century. Sources for this infor-

mation are of variable quality, but the impact remains in that some of the earliest names for plants in Western culture are tied to peripatetic sources, i.e. Aristotle, Theophrastus, and Pliny (whose *Historia* extracted liberally from Theophrastus.)

Herbal Traditions…

Dioscorides' *de Materia Medica* (around 70 AD) differs from other sources, however, in that for over 15 centuries this pharmacopoeia remained an actively utilized text, adopted and annotated through translation, transliteration, transcription, and reinterpretation by practitioners around the Mediterranean basin - eventually as far afield as Germany, France, England, and the Netherlands.

Singer (1927,) and Popa (2010) (see text box) explain some of the complex history of the Dioscorides record, differing manuscript versions showing annotations in varying languages, creating a scholarly tradition of study that was still active when printing emerged. After Gutenberg, several versions of Dioscorides were mass-produced, with Aldus's 1499 Greek edition regarded as the most authoritative. The Aldus publication gained legs when Mattioli issued his Latin translation which hit the presses in 1554.

Ioana Claudia Popa, 2010. "The Lists of Plant Synonyms in De materia medica of Dioscorides" Global Journal of Science Frontier Research, Vol. 10 Issue 3 (Ver 1.0), July 2010

Charles Singer, 1927. "The Herbal in Antiquity and Its Transmission to Later Ages" Source: The Journal of Hellenic Studies, Vol. 47, Part 1 (1927), pp. 1-52 Published by: The Society for the Promotion of Hellenic Studies
Stable URL: https://www.jstor.org/stable/625251

Invoking Dioscorides tells us more about a tradition than a person, speaking to a body of knowledge that survived and morphed through centuries as a basis of the herbal movement. There are scant records of the purported author's life, and no contemporary materials that confirm a person named Dioscorides truly lived and breathed. But we envision a famous herbalist named Dioscorides, who authored scrolls that documented a Greek pharmacopoeia, which was copied in multiple iterations in Greek, as well as translated into Arabic and Latin. Passed down through loosely connected generations of knowledgeable specialists, experiencing annotations and changes, the *Materia Medica* was core to medical plant traditions (pharmacognosy) into the early Renaissance.

Formal training in medicine demanded familiarity with important treatises, which meant Dioscorides was standard knowledge for classically-trained doctors. As printing revolutionized the impact of text, availability to Dioscorides grew and its influence was given a bit more life due significantly to Mattioli's Latin version, which became the basis for many regional herbals. That means the names and properties of plants mentioned in *de Materia Medica* stretched into the era of discovery and colonialization.

As a Mediterranean floristic document, practitioners realized the hallowed text could not fit a more northerly climate, or a world moving toward scientific revolution and empiricism. No place was this more obvious than in Germany, where many plants described in Dioscorides were irrelevant. Moreover, introduction of exotic plants from other continents provided increased challenges, as interest in pure botany and horticulture grew.

It should be no surprise, therefore, that the more recent Herbal tradition (which endured about 250 years) began in Germany, with the beginning of Western printing in Mainz. The new genre spread throughout Europe, and became an extensive, iterative, and somewhat baffling body of work, encompassing a rich mixture of original, copied, translated, and modified texts, illustrated by a growing album of prints that ranged from graphic and nearly abstract to representationally natural and accurate. The early use of woodblock prints led to resale and reuse, as well as outright copying. Quality and accuracy (as well as size) varied from one publication to another.

Histories focus on the "German Fathers of Botany." We celebrate Otto Brunfels for his early German herbals (1530-1537), but that celebrity relies more on the illustrations by artist Hans Weiditz than on the writing, which is reported to draw heavily (and un-expertly) from older texts, such as Pliny and Dioscorides. The situation shifted quickly when Hieronymus Bock published original descriptions (in German) for 700 plants in his 1539 *Kreutterbuch*. Just a few years later, in 1542, Leonhart Fuchs published *De historia stirpium*, which though reliant on text of other authors also broke new ground with fresh descriptions for native plants and for newly introduced exotics such as American corn and pumpkin. Most importantly, as with Brunfels, Fuch's *Stirpium* was gloriously illustrated by artists who were credited: plant depictions were created by Albrecht Meyer, transferred to wood by Heinrich Füllmaurer, and then carved to woodblocks and printed by Vitus Rudolph Speckle. The images made an impact, which meant they were copied and reused extensively, even by artist David Kandel who illustrated the 1546 re-issued edition of Bock's herbal.

As important as Brunfels, Fuchs, and Bock were, Rembert Dodoens 1554 herbal, *Cruydeboeck* (which included 714 plates) was the basis for a growing asset that matured in 1583 as the much expanded Latin version, *Stirpium historiae pemptades sex*. Significant botanists L'Obel and Clusius seem to have contributed to that maturing text, which in turn provided the basis for Clusius' French translation. Dodoens, we learn, was one of the most widespread and translated texts, second (perhaps) only to the *Bible*. Thus, Clusius' French translation is the basis for Lyte's *Historie*...(1678) in English, and an English translation of the Latin Dodoens provides much of the text for Gerard's *Herball* (1597), two of the most prominent English herbals in the second half of the 16th Century.

Curiously, concurrently to Dodoens' *Cruydeboeck*, Mattioli published the first edition of his translation of Dioscorides, the *Commentarii*...., making Mattioli Dioscorides' *bona fide* spokesperson. Just as Dodoens' *Cruydeboeck* gave rise to sig-

nificant translations and editions, Mattioli's *Commentarii* took on a similar remarkable a role across Europe. Most importantly, Caspar Bauhin launched his own career through compiling plant synonymies while editing the 1598 *Opera* (consolidated works) of Mattioli's publications.

Somewhere in these herbal episodes we find the inimitable alchemist Paracelsus (Theophrastus von Hohenheim, 1493-1551), the devolution of medicine as Simples, and several phytologists, such as Jakob Boëhme, Giambattista della Porta, Thomas Browne, and William Coles. These are names often tied to a Doctrine of Signatures (DOS), the idea that a plant would provide some sign or signal (such as leaf shape) to suggest value or appropriate usage, particularly as a curative. There isn't much to relate in this regard; it isn't even clear whether or not recognition of shapes drove any real trials, so I leave this episode aside, in that the Doctrine of Signatures was never a source of botanical understanding.

I mention the concept of Signatures because it appears in many texts and teachings. Moreover, some version of DOS has surfaced at many times in various cultures, with little evidence it was ever truly mainstream or marked any particular movement. The idea did not play significantly in herbals or *materia medica*, but allusions to shape and form often crop up in descriptions. One also needs to distinguish between Simples and Herbals, which overlap. Simples, however, read more like "Hints from Heloise" - compendia of suggestions and formulae for curing ills, removing stains, and cleaning house. (Bradley C. Bennett, 2007. "Doctrine of Signatures: An Explanation of Medicinal Plant Discovery or Dissemination of Knowledge?" *Economic Botany* 61(3) 246-255)

The latter flourishing of European herbals was informed by movement of plants, people, and pestilence around the planet. Despite concerns any of us have about the consequences of European voyages east (around Africa's Cape to India and Asia), and west (across the Atlantic, to the "New World") - the impacts are undeniable. European estates, gardens, farms, and cuisines changed through introduction of plants from around the world, plants Europeans had never seen or used before, and in many cases, plants of great economic potential.

Global exploitation and landed wealth led to luxury, and the herbalists were joined by other authors interested almost purely in beautiful garden plants, ushering in Europe's age of florilegia, books overladen with lavish illustrations and information on spectacular flowers, reflecting an expanding garden flora that did not require every plant represent a cure or comestible. To gain a sense of the spectacular publications these flowers inspired, check out the 1613 publication, *Hortus Eystettensis,* on the web, where you will see incredible portrayals of horticultural forms of native European plants alongside remarkable introductions, such as *Helianthus annus*, the American sunflower and *Mirabilis*, Four O'Clock, the Marvel of Peru.

Bringing Order….

In searching the many herbals, florilegia, codices, etc. that were published in the 16th and early 17th century, we quickly realize that as plant names are concerned, things were coming to a head. Imagery and avarice overloaded existing systems for naming and categorizing plants. There were no standards as to how a plant name might be formulated, and the idea of "scientific" names was not imagined. And there was no system for identifying or organizing the growing wealth of global and horticultural forms.

Because Latin crossed borders as the scholastic language, it became the language of scientific letters and books. But Latin and vernacular publications were incompatible. It was a quietly growing chaos; lacking index or concordance to correlate plants discussed by different authors.

But help was imminent, through the assiduous work of brother bibliophiles, Jean and Caspar Bauhin. The earliest and most straightforward to be published was Caspar's 1623 *Pinax Theatri Botanici*. This detailed work suggests the Bauhins had access to good resources, because Caspar was able to get his hands on scores of important books and take the time and effort to determine which plant names and descriptions were synonymous. For each entry in *Pinax*, someone had to typeset the descriptions by different authors Caspar had encountered for each different kind of plant. I can only imagine he must have acquired two sets of each book, cut them into ribbons of text, and then glued them to pages that correlated like with like. It almost seems overwhelming that someone had to handwrite and then interpret all of those crazy names and descriptions. But that is likely what happened.

Download and examine a copy of *Pinax* (there are free copies available over the internet.) It's plainly obvious that Caspar Bauhin was going in the right direction. Even though he does not consistently follow the concept of a genus as the necessary way to group similar (or related) plant species, Bauhin seems fairly clear that he is dealing with plants in groups we would readily appreciate as genera. *Pinax* came out in 1623, more than 100 years before Linnaeus, and it was sufficiently important to hold sway for that entire century.

During that next 100 years, there were gradual advances. Jean Bauhin's own take on a concordance (with more complete descriptions) was published posthumously. John Ray published descriptions and discussion that seem somewhat modern. Hans Sloane set a modern pattern, as an educated and productive gentleman scientist who began his career with personal field experience and published a flora of Jamaica in 1696. Works in English, such as Joseph Miller's *Botanicum Officinale* (1722), read as amazingly contemporary treatments, with reference to genera and species, and casual adherence to the system on nomenclature soon to be formalized by Linnaeus.

And microscopy provided incredible insights through publications by Nehemiah Grew and Marcello Malpighi (see Cells as the Basis of Life, earlier in this Section). We learn through mi-

croscopy that the course of scientific inquiry constantly changes in response to a new technology. But inquiry also responds to new ideas. Sometimes, when a fresh, important idea surfaces, it's as though blinders are removed and observations/data that have not made sense are instantly intelligible. Sex had that effect on systematics.

Joachim Camarerius (who followed Fuchs at Türbingen) made observations and conducted trials that convinced him plants reproduce sexually. Pollen is the male element (sperm) and the egg (in the ovule) is equivalent to the female. This was a slow-growing "aha" moment. One of the more entertaining interludes in botanical history was part of this story - the famous 1718 address by Sébastian Vaillant, his "Lecture on the structure of the flowers, their differences and the use of their parts ." Vaillant chose his moment, the opening day of classes for 200 medical students as well as gaggle of luminaries. Normally, the task would have fallen to Antoine de Jussieu, but he was out of the country. Thus Vaillant had the opportunity to stake his claim on the topic of sex in plants. He succeeded.

Vaillant's prose was pregnant. In translation, (for the source, see 1717 in the following TimeLine) we read his discussion of unisexual flowers, in which Vaillant describes the activity of the pollen-bearing (male) anthers: *"the tension or swelling of the male organs occurs so rapidly that the lips of the bud, giving way to such impetuous energy, open with astonishing speed. In that moment, these enthusiastic organs, which seem to think only about satisfying their violent desires, abruptly discharge in all directions, creating a tornado of dust which expands, carrying fecundity everywhere; and by a strange catastrophe they now find themselves so exhausted that at the very moment of giving life they bring upon themselves a sudden death. "*

The sensational aspects of Vaillant's *Discours* struck a chord with Carl Linnaeus, who seems to have encountered the exposé about a decade later, while he was a student at Uppsala University. The sexual nature of plants promised to be such a profound aspect of plant life that Linnaeus was able to convince himself that hard data about stamens and pistils (numbers and structure) provided inherent evidence as to how plant groups differ, most especially genera and higher groupings.

And at a functional level, he was right. Using Linnaeus's methods, counting stamens and examining pistils, often provides a quick and simple way to sort plants into categories, making identification much easier, and bringing order to the mental storage cabinet. In fact, Linnaeus's system was, basically, one spectacular key, not a typical binary key, but a functional sorting system to get to a genus of plants. That order, the beauty of it all, was short-lived, in that Antoine de Jussieu and the other people who had worked for the Jardin du Roi in Paris were already imagining a way of grouping plants they believed reflects natural affinities.

"…. we see the victory of the ingenious and simple method of classification of plants developed by Linnaeus. However, classification is not yet systematics; a key is not a monograph." (Staffleu, 1971)

Jussieu (and future generations of botanists) would remain indebted to Linnaeus however. Beginning with *Species Plantarum (1753)*, Linnaeus had rigorously applied Latinized binomials (a generic name and a specific epithet) to plants. Due to the popularity of his works and his own fame, Linnaeus nomenclature established a new international standard. Plant names have made sense ever since. Indeed, Jussieu adopted binomial nomenclature for Jardin du Roi in 1776, which likely contributed to the universal appreciation of his contribution to systematics.

A Natural System…

Jussieu's Paris system came into full expression in 1789 with publication of *Genera Plantarum*. Linnaeus's purely mechanical system of classification, in some instances, grouped plants botanists understand to be naturally related, but just as often, plants could be strangely separated from their nearest relatives. For example, some azaleas (*Rhododendron*) have five stamens, while others have ten. Otherwise these plants are incredibly similar, and clearly closely related. But in *Species Plantarum*, Linnaeus grouped *Rhododendron* as the class *Decandria* (*SP* page 392) and *Azalea* as *Pentandria* (*SP* page 150). De Jussieu's *Genera Plantarum* described *Rhododendron* and *Azalea* in the same class and order, one after the other, on *GP* page 158. For people who studied plants, this new organization recognized the inherent order in Nature.- it is a "natural system."

It's critical, however, to differentiate between Jussieu's concept of what is natural as contrasted with a post-Darwin interpretation. Jussieu, and systematists who followed in his mold (i.e., Condolle, Brown, Willdenow, Lindley, and Bentham) were, in no way, imagining that a natural system reflects evolutionary origins, or lineages. These plant experts were solidly schooled in the concept that Nature came into being fully-elaborated. All of God's creation appeared on the 3rd day, even before the stars, which shone at the end of the 4th day.

It was a matter of doctrine, now long abandoned. But do not confuse church-based acceptance with lack of technical knowledge. Those botanists were far from ignorant, and knew more about plants than most educated people in the world today. Clearly they had studied plant variation enough to understand one can describe each kind of plant based on its similarities to another distinct kind. It was evident such pairings could be discovered through the entire plant and animal kingdoms.

The idea emerged that one might imagine Nature as elaborations on themes, interpreted as a chain of possible types, a continuum. Botanists came to envision a plan for Creation in which there were logical combinations of characteristics, graduating from simple to complex structures. Along that chain, each different kind of plant was one link, varying in some salient way from the link before and the one that followed. That meant that each different species represented a successive, possible combination, one link in the chain of being. This could be seen as a continuity from simple to complex forms, and would be interpreted as evidence of Nature's

plan. We had our hands on the the core rational for all of Creation. In today's street language, someone might refer to this as part of Nature's DNA.

A recognizable segment of the chain, consisting of one to many links (one to many species), would be designated as a genus. A concatenation of genera would constitute a family. To Jussieu, this meant genera and families were convenient ways to parse out the chain. He even used the number of entities as one factor in delimiting genera and families. However, it was clear the groups reflected a kinship of similarity, based on proximity in the chain of being.

The kind of similarity Jussieu imagined, however, was somewhat mechanical, like different kinds of railcars. A box car is similar to a refrigerated box car, but fundamentally different. A passenger car is yet more distinct. And a caboose is even more specialized. Then we discover coal cars, which are similar to (yet distinguishable from) hopper cars. If you assemble a train using one of every kind of railcar, ordering those cars based on some idea of similarity in structure or function, you'll have a train of railcars analogous to Jussieu's chain of being. Someone made all of those railcars by exploring the many variations that would be both possible and functional. Those kinds of railcars were built and the train of cars was Created.

If you knew every possible variation in railcars, then you'd know all of the possible cars in the train, that is, you'd know all of the links in the chain, your collection would be complete.

To Jussieu, each new plant species described would flesh out one of the links in the chain of being. When botanists had discovered and described every link, the collection would be complete. Nature's great diversity would be explained, and our description of that arrangement would reflect the natural order of things.

Jussieu's system and philosophy quickly eclipsed Linnaeus's classes and orders. It reflected the times and made sense to people who knew enough about plants to realize that clear and intrinsic relationships were discernible in the great range of plant diversity.

Significantly, from Jussieu through Condolle, Brown, Willdenow, Lindley, and Bentham, this concept of natural relationships, though interesting, was ultimately academic. Lacking the idea of an evolutionary origin of species, these scientists could only opine as to what nature's larder, its chain of being, (whether linear or reticulate, continuous or gap-ridden) told us about the qualities of different plants, or nature's plan. But these botanists were not theologians, so there was not reverse extrapolation - knowing the plan of nature would not bring us closer to the mind of God.

Perhaps that complacency, or incapacity, explains one reason systematics went a bit quiet for several decades. Or maybe there was, simply, a new game in town, as attention and activity were drawn to the astonishing revelations of newly discovered plant species in the 19th century, a richness that propelled new fields in natural history. True, plant discovery had

been a rising tide since Linnaeus, whose many students and supporters were dedicated collectors, venturing to areas around the globe.

These botanists and others were collecting and returning plants to Europe's growing herbaria, most of which were still privately owned. Increasingly those specimens resembled Linnaeus's own collection of pressed and dried plants, mounted on individual sheets of paper rather than bound unrelentingly in unintelligible volumes.

But as Linnaeus aged and his grip faltered, botany arrived at the era of Joseph Banks, who (in 1766, at the age of 23), was elected to London's Royal Society. In 1778, Banks was selected as President of the Royal Society, a role he would occupy until his death in 1820. It would be difficult to overstate Banks' importance in imperializing science, eclipsing Linnaeus in political and economic spheres. With Banks, the attention of science was drawn from organizing to the glory of plunder. Describing and enumerating nature's larder, luxuriating in the richness and beauty of diversity proved so exhilarating that decades would pass before attention returned to order, and to the nature of creation.

And it seems Banks knew everyone on the scene. His endorsement advanced discoveries and careers of many scientists. Robert Brown was his protege, and Banks was an early supporter of his friend and correspondent, Alexander von Humboldt. George III relied on Banks' opinion regarding investment in discovery and science. Banks seemed at the center of botanical science at an apogee of discovery. With eventual waning of Banks' notoriety and influence, Joseph Hooker and a host of collectors, taxonomists, horticulturists, and sponsors kept the ball rolling. Concurrently, Alexander von Humboldt earned the role of wunderkind, collecting and compiling real data about climate and geography, establishing the basis for emerging studies in biogeography and ecology. Humboldt's methodologies and exploits in South America brought that transcendental land home for many naturalists to consider. Climate rules. Proper study of climate would explain the world's vegetation types, yielding eventually to an understanding of the biomes.

The collection, enumeration, cataloging, and mapping of plants supported an emerging sense of bioregions and growing appreciation of the great floristic regions... Realizations such as these demanded explanation. How did all of these plants originate? How did they come to colonize the world, and what is to be made of their patterns of distribution? With Bentham and Hooker listing nearly 100,000 plant species by 1883, how many more were to be discovered? What was the nature and extent of creation? What is the plan?

Realizations in floristics and ecology increasingly had confounded the idea of a linear chain, a continuity from the simplest to the most complex plant, was clearly untenable. Early in the 19th century, botanists like Willdenow had concluded there was not a single, long chain of being. The chain became regarded as a network, with branches and inter-connections. And botanists discovered sudden significant breaks, as well as

isolated segments that were not easy to tie to other linkages. Some botanists even came to explain the fossil record as documenting links that had gone extinct. Even with those realities, even knowing the chain of being was a net (a reticulum), not much very new happened.

For Systematists who had been active before 1860, Darwin's *Origin of Species* did not immediately alter course; systematics continued in a similar mold. Younger researchers, however, recognized that our basis of understanding had experienced a sea change. At the age of 48, in 1893, Charles Bessey (whose career matured after publication of the *Origin*) wrote: *"It is now a full third of a century since a great light was first turned upon all biological problems by the formulation of the doctrine of evolution by the master mind of Darwin. In its light many puzzles have been solved and many facts hitherto inexplicable have been made plain. We now know what relationship means, and we have given a fuller meaning to the natural system of classification. From the new point of view a natural classification is not merely an orderly arrangement of similar organisms It is an expression of genetic relationship. The present similarity of two organisms is not enough to determine their relationship, or place in a system. Common origin must be inferred in order that relationship shall be assumed."*

Biosystematics…

By the beginning of the 20th Century, appreciation of Darwin and then Mendel had altered the course of nearly every botanical endeavor. As Bessey predicted, a search for natural order became increasingly redirected through concern for origins, evolutionary sequence, and lineage. Lacking understanding as to the physical basis for inheritance, systematists turned their attention to karyology - the study of nuclear chromosomes (which researchers knew harbored the plant's genetic information.) It wasn't yet clear how genetic information is stored or activated, but it seemed obvious that studying the nature of a plant's chromosomes could yield understanding as to the nature of species. The era of **Cytotaxomy** had arrived.

But chromosomes and cytology were not the only new issues for taxonomists. The development of ecology, biogeography, pollination biology, and population biology challenged botanists to consider how plant biologies impact the way we should understand or delimit species.

Mapping plants and animals, relating those distribution patterns to climate and geography yielded real information that helped define species and generated new concepts about floristics, plant migration and distribution, and historical geography. Moreover, we learned that particular circumstances, such as long-isolated areas, like islands, merited special consideration and study.

Five decades earlier, observations by young Charles Darwin on his journey to the Galapagos Islands (off the west coast of

South America) led to inevitable realizations that would focus Darwin's thoughts about both naturally-occurring and domesticated populations of plants and animals. Those ideas found expression in Darwin's *Origin of Species…* (1859) in which he crystallized and documented an emerging realization that plants, animals, and other kinds of organisms are not fixed, they were not simply created in one fell swoop. Rather the myriad species on Earth emerged through a natural process that evidences success in procreation. Each organism was the most prolific fit for its current circumstances.

Species, we came to understand, have come into being over hundreds of millions, billions of years. They have evolved, through countless generations. Darwin's consolidation of many lines of thought, of much evidence, proved compelling, but left much to the imagination. If plants vary, what is the basis of inheritance; what is the source of that variation?

More perplexing, of course, was the problem with limits of variation. If plants vary, what separates one "kind" of plant from another? What are the boundaries of a species? But we can defer these questions in that scientists still debate answers. The important tack to follow at this moment actually winds from other information.

In Taraxacum: *"The genus consists of more than 60 sections worldwide). A section contains one or a few diploid sexual taxa and a number of morphologically distinct apomictic polyploids (for which more than 3000 names have been published)."* (Ľuboš Majeský,1 František Krahulec2 & Radim J. Vašut, 2017. "How apomictic taxa are treated in current taxonomy: A review" Taxon, 5 Oct 2017

In the first half of the 20th century, many important studies would inform understanding of variation within populations and the existence of regional adaptations we came to call ecotypes. Studies of plant-animal co-evolution led to a clearer understanding of isolation barriers and speciation.

Chemotaxonomy emerged as botanists began to extract and analyze various "secondary" compounds, such as flavonoids, anthocyanins, and betalains. Protein analysis and isozyme studies developed also. Under the "one gene, one protein" banner, researchers analyzed variation in proteins with the assumption we were getting closer to direct evidence of genetic variation.

These many techniques (cytotaxomy, phenotypic & population studies, and chemotaxomy) aggregated under the banner of biosystematics, suggesting the entire biology of a plant (not simply its external morphology) should be characterized in the effort to determine what distinguishes the life of one plant species as compared to another.

Though all of the kinds of studies we considered biosystematics remain important and continue to occupy graduate students around the world, the term "biosystematics" seemed to evaporate, almost overnight. The contemporary systematist now studied **Phylogenetics**, and if we must identify a year in which the the transition occurred, 2004 seems about right.

Phylogenetics, or is it Cladistics....

Willi Hennig gets credit and blame for launching the most recent era in systematics. The obvious impact of this methodology and philosophy has been at higher levels of organization. Biosystematics focused on the daily life of plant species, how they manage their business and interact. Phylogenetics, in reality, focuses on different issues - the course of evolution and the best way to determine the relationships among major plant groups.

Phylogenetics attempts to take the artifice out of constructing genera and families. All known, usable characteristics are scored and compared using different kinds of computational models. This weighting, most importantly, includes the growing addition of genetic information. The best result of analysis would be reconstruction and representation of the evolutionary lineage for all known plants. But most importantly, that representation would, somehow, imply equivalence. Equivalence suggests that family recognition is granted based on similar levels of divergence, or similar estimates of antiquity.

Hennig worked with insects, and came to his own fresh system for determining relationships.

Where has this pursuit brought systematics? What has changed about the way we view plants? If you were grounded in systematics in 1985, you would have recognized names such as Robert Thorne, Armen Takhtajan, and Arthur Cronquist, These were the last authors of artful systems, outlines that attempted to organize major plant groups to reflect a presumption of evolutionary history. What you would remember from these authors is no longer very relevant.

Studies and statements increasingly reflect phylogenetic methods, particularly guided by the Angiosperm Phylogeny Group. Regarding flowering plants, perhaps the most fundamental change has been reconsideration of the simple monocots vs. dicots breakdown. Simpson (2010) explains that having embryos with two cotyledons is “an ancestral feature for the taxa of the flowering plants and not an apomorphy for any group within. Thus, “dicots” as traditionally delimited (all angiosperm other than monocots), are paraphyletic and must be abandoned as a formal taxonomic unit” This means the evolutionary groups of flowering plants are now mapped out differently, with several more ancient groups (Amborellas, Waterlilies, Chloranthoids, Magnolids) having emerged before the Monocots and other groups. That leaves a more tightly defined group of plants with similar pollen, which is termed the Eudicots. For botanists trained earlier in the 20th Century, another major departure has been resolution of plants previously in the Lily Alliance. Major groups, such as the Agaves, the Alliums & Amaryllids, the Irids, the daylilies, and the Orchids are now placed in Asparagales with *Xanthorrhea* and *Hypoxis*. The re-interpretation segregates the lily growth-habit from garden plants with equitant leaves and fleshy stems, representing a significant change for those of us who have always thought of daylilies and tiger lilies as reasonably closely-related.

Post Script: John Wilkins' *Species: A History of the Idea* provides a very useful dialogue concerning the practical and philosophical origins of species concepts. To me, as a field biologist, much of this discussion is moot. In the field, in the garden, and in every day discussion, plant study requires a simple system of names, in order to attach information to groupings of plants you expect to closely share characteristics, to have the same biologies and chemistries, and to respond similarly to climate and stimuli.

At that hands-on level, the historical underpinnings of a plant name can be arcane. To horticulturists and field botanists, different plant groups speciate through differing processes, such that the parameters as to how you'd discriminate one "species" from another vary from orchids to cacti. Philosophically, scholars argue from a top-down perspective; a general kind has specific examples, each with its own essence. From a contemporary phylogenetic viewpoint, each plant is derivative as a branch in the continuum of evolutionary change that began hundreds of millions of years ago.

Phylogenetics traces the lineage of plants, establishes putative evolutionary relationships, and comes to some determination as to where breaks should be drawn. Reconciling that emerging, complex diagram with traditional taxonomy means a bit of a compromise, drawing lines that respect historical hierarchies, such as family, genus, and species but accepting the idea that one "species" will never be equivalent to another.

Detailed TimeLine

BCE

1500 A papyrus was created, documenting ancient information concerning plants of Egypt. The scroll describes hundreds of cures and treatments, including many ointments and extracts from plants. Purchased at Luxor (Thebes) by Georg Ebers around 1874, it is held by the library of the University of Leipzig, Germany (and thus is known as the Papyrus Ebers).

c300 Theophrastus (ca. 372-287 B.C.), the Father of Greek Botany, taught about plants from his own working knowledge of them, experience reflected in the "Inquiry" (*Historia Plantarum*) and "Causes" (*De Causis Plantarum*). Text covers 550 kinds of plants, including strawberry tree (*Arbutus unedo*), date palm, figs, and water lilies. His avoidance of more mystical notions about plants made a seemingly auspicious beginning for botanical study. During the middle ages, however, the Theophrastan works were generally unavailable, and second-hand versions were corrupted with misinformation - thus the level of botanical knowledge available in writing actually declined. The rediscovery and printing of his works beginning in 1483 replaced muddled interpretations of plants and helped rekindle an interest in botany. (HNT)

AD

c50 Dioscorides (the Father of Medical Botany) authored his *Materia Medica* (HNT), a compilation of descriptions and medicinal uses for plants, including about 650 different species.

As the most widely known western botanical text during the middle ages, Dioscorides' work became the basis for the earliest herbals. With an expanding awareness of the natural world in the 16th-century, herbalists began to make their own descriptions of plants, and at last Dioscorides's influence waned.

c70 Pliny (*Caius Plinius Secundus*, A.D. 23-79), in his compilation called a Natural History (HNT), discussed about 1000 different plants. Well known throughout the middle ages, Pliny's book constituted a major source of information on plants. Primarily an historian and storyteller, Pliny related accounts uncritically, even fancifully. Once original, rarer source documents were discovered and printed, errors in Pliny's account became more obvious. Still the work remains valuable; it is through Pliny that we know the exact costs of many products, and that farmers alternated crops, such as beans and spelt. Recognized in his comments was the growing trend of farm land consolidation into slave-maintained plantations. (Gras, 1946) On teaching: *"Yes indeed, those who have gained a little knowledge keep it in a grudging spirit secret to themselves, and to teach nobody else increase the prestige of their learning."* (transl. Eamon, 1994)

1025 Approximate date for compilation of *The Canon of Medicine*, by Persian polymath Avicenna (Ibn Sina). The *Canon* describes about 760 different kinds of plants as the sources of useful medicines.

1256 Albertus Magnus produced *De Vegetabilibus*, based on ancient treatises and herbals, with added observations and descriptions. Gilla Wöllmer explains: *"Albert the Great's botanical work De vegetabilibus libri VII is based on the little treatise De plantis, which was ascribed to Aristotle in the Middle Ages, but is in fact a work of Nicholas of Damascus... Albert the Great's treatise comprises seven books. Books 1–4 belong to the general theoretical area of botany; Books 1 and 4 have the treatise De plantis as their principal point of reference... In Books 6 and 7 he presents a special and applied botany. Beginning with the individual presentation of trees and herbs in Book 6, the account he gives of non-indigenous plants is indebted to the Canon medicinae of Avicenna, the Circa instans, and texts by other authors. Book 7 is devoted to agricultural botany..., here, he draws several times on the Opus agriculturae of Palladius. His treatise De vegetabilibus, which is the most extensive Latin commentary on De plantis, is much longer than the latter, both in terms of its sheer size and in its elaboration of the subject matter, 'but it remains indebted to this work in its title and its theme: without the De plantis and its position in the Corpus Aristotelicum, the De vegetabilibus could not have existed in this form.' "* (G. Wöllmer, 2012. "Albert the Great and His Botany," in *A Companion to Albert the Great,* Brill OnLine.) As philosophers on which he relied, Albertus Magnus grouped plants as trees, bushes, shrubs, herbs, and fungi, expressing a worry that the categories overlap, but considering trees the highest and noblest of plants. Common belief held plants as the simplest of three orders of life (vegetative, sentient, & rational). Plant form and function were interpreted as compared to human (or animal) structure. Thus the sap of a plant was central to

its life. Roots, which bring in water and nutrients, were regarded as homologous to a mouth, eating the earth for nourishment. Flowers were present to announce the coming of fruit. *Etc.*

1406 Zhu Xiao (朱橚) published *Jiuhuang Bencao* , an illustrated description of famine foods., describing and illustrating (woodblock) 414 kinds of plants.

1484, The *Latin Herbarius*, the first German herbal, was published in Mainz. An earlier natural history manuscript, *Puch der Nature* (the *Book of Nature*, ascribed to Conrad von Megenberg), was in circulation well before 1400, and then printed in 1475, but it was not a predecessor to the *Latin Herbarius*. (Locy, 1921)

1491 Jacob Meydenbach published *Ortus Sanitatis* in Mainz, which was basically the most extensive of a suite of related publications beginning with the German *Herbarius zu Teutsch* (*Gart der Gesuntheit*,) issued in 1485. The 1491 *Ortus* (in Latin) included 1066 botanical plates, that are said to be inferior to the 386 plant images provided in the earlier *Herbarius* (which is sometimes called the "smaller Ortus.") (Locy, 1921)

1493 Carolus Clusius, having relocated to Leiden, established the *Hortus Academicus*, said to be the first botanical garden dedicated to ornamental plants. The valuable collection of tulips he cultivated there provided much of the material for the growing Dutch tulip industry - apparently through theft as much as sale or gift. (Grimshaw, 1998)

1526 The accepted year for production of *The Grete Herball*, an illustrated volume in the English vernacular. Believed to have been printed by Peter Traveris, the herbal is a translation of the 1498 French volume *Le Grant Herbier*, which itself compiles and "borrows" from earlier writings. The illustrations, likewise, are taken from the French volume, which is indebted to earlier books, including the 1485 German herbal, *Herbarius zu Teutsch* (*Gart der Gesuntheit*.) (Wikipedia, 2018 & Locy, 1921)

1530 Brunfels published *Herbarium Vivae Eicones*, the first newly written and printed botanical book/herbal. The "German fathers" were working with the North European cultivated and natural flora, which presented regional challenges for traditional Dioscoridean texts that continued as the basis for both *materia medica* and floristic plant studies.

1542 Fuchs published *De Historia Stirpium Commentarii*. By 1543 he had issued the German version, *New Kreüterbuch*. Illustrations for his herbals were based on studies of living plants, rather than on the simplified images that had become common in various scribed editions of the Apuleius herbal. [See c. 350] When describing European plants, however, text was taken essentially from information ascribed to Dioscorides. (HNT) Much later, the plant genus *Fuchsia* was named in his honor. The 1543 Dutch translation of *New Kreüterbuch*

may have been generated by Dodoens, forming the basis for his *Cruydeboeck*.

1552 Created in Mexico, *Libellus de Medicinalibus Indorum Herbis* (*Little Book of Medicinal Herbs of the Indies*), was reportedly composed by native herbalist Martín Cruz in Nauhuatl (a Nauhuatl version is not extant.) The manuscript we know today was transcribed to Latin by Juan Badiano (applying Nauhuatl names to plants), and became known as the Badianus Manuscript. The manuscript, which had been transported to Spain, and then acquired by Cardinal Francesco Barberini, became property of the Vatican by 1902 ,and transferred to Mexico's National Institute of Anthropology and History by Pope John Paul II in 1990. (Wikipedia, 2018)

1554 Rembert Dodoens published his herbal, *Cruydeboeck*, complete with 714 plates. The book was very well-received throughout temperate Europe, and soon translated to other vernacular languages - into French by Charles de L'Ecluse in 1557 and English (from the French) by Henry Lyte in 1578, and Latin in 1583 (an expansion and translation called *Stirpium historiae pemptades sex*.) The cumulative growth of the Dodoens' works appeared through his productive life under various titles (culminating with the 1583 Latin *Stirpium*), an evolution that explains the many simple references to Dodoens' work - as Cruydeboedk, Pemptades, and Stirpium..... Claims are that Dodoens' growing product was one of Europe's most translated books, second only to the Bible. Various renditions remained in use for two centuries. (Wikipedia, 2015) Excerpting from A.G.M. van Asseldonk, 2001 ("Traditional and modern herbalism in the Netherlands" a Research Report presented as a short paper at the Ethnobotany Conference, Antigua, Guatemala, 14-18 sept. 2001): *"The first herbal in the Dutch language was (1554) the "Cruydeboek" (herbarium) of Rembert Dodoens (1517- 1586) (fig. 5). Dodoens was a Flemish Physician and also professor in Leiden University. He chose to call himself Dodoneus. Contributions to this herbal were also made by Dutch botanists such as Clusius and Lobelius. The work added new plants and experiences to the work of Dioscorides, which after 1500 years was still the most important in those days. It contained 1060 plant descriptions (of which 109 were original) and 715 figures (200 again original, 515 were used from the German herbal of Fuchs) 7. The book has played an important role in the past and present. So many copies were printed (last edition was the 6th in 1644) that they are still easily obtainable in the antique market and some herbal healers today still use the original antique book as a work of reference."* A Dutch website, "Plantaardigheden" (www.plantaardigheden.nl) makes two of the Latin (postmortem) versions available. See also: https://plantaardigheden.nl/dodoens/default.htm

1554 Pietro Andrea Mattioli published a Latin translation/his version of Dioscorides, having composed a very successful Italian translation ten years before (based on Ruel's Latin translation of a Greek text). Mattioli's Latin edition *"was a publishing success on all counts,"* perhaps because he added names from other sources, which made the text more widely useful, or because the book was well-illustrated. Mattioli followed

this with a 1558 edition with 133 new illustrations and expanded commentary (set in typeface so as to stand out as clear additions). By 1665, Mattioli had produced a fourth edition, which included Greek, Arabic, German and French synonyms for the Latin and Italian plant names and larger illustrations (that had been created for a translation). Over the two decades since the first Italian publication, Mattioli's many editions had spawned numerous translations, French, German, even Bohemian, as well as new drawings and woodcuts. (Stannard, 1999; XIV 71)

1557 Carolus Clusius issued his French edition of Dodoens' *Cruydeboeck*.

1559 Conrad Gessner recorded the earliest known instance of a tulip flowering in cultivation in Europe, in the garden of Johann Heinrich Herwart of Augsburg (Pavord, 1999.) Gessner is said to have received these bulbs himself from Ogier Ghiselin de Busbecq, ambassador from Holy Roman Emperor Ferdinand I to the Ottoman court of Suleiman the Magnificent. Busbecq reported to Gesner that the highly colored flowers were called tulipam by their Turkish admirers, though the native word for these plants is *lalé*. Confusion as to the name could have had something to do with the turban (dulban) shape of the bulbs and flowers, but the true origins of the word "tulip" are lost in time. (Grimshaw, 1998)

1568 The *New Herball* of William Turner was published in completed form (in Cologne), including all three parts. Part 1 had been published in 1551 (in Antwerp), part 2 in Cologne in 1561. (Sanecki, 1992) Though woodcuts were copied from Fuchs, Turner added observations from his own working knowledge of herbs. Turner's book is often described as the first herbal in the English vernacular, though earlier titles, such as the *Grete Herball*, might claim this distinction [See 1526]. (Wikipedia, 2015)

1568 Dodoens *Florum, et coronariarum odoratarumque nonnularum herbarum historia* was issued. One of the earliest European treatments of ornamental plants, the *Florum* includes garden introductions from Asia.

1569 *Joyful News*... published by Monardes from Seville between 1569 and 1574, later published by John Frampton in English, 1577, as *Joyfull News out of the Newfounde Worlde*. Many new plants are discussed in this book, including tobacco and sunflower (the first mention). In 1596 John Gerard described the sunflower, which he had grown in his own garden. By 1665 John Ray commented that the flower's popularity had subsided. *Joyfull News*... seems also to be the first mention in Europe of the American native tree sassafras [See 1586].

1570 Matthias de L'Obel published his *Stirpium adversaria nova*, a compendium of approximately 1200 kinds of plants, which he organized based on leaf characteristics. His system of organization influenced the layout of Gerard's *Herball* (1597), as well as the much later work of Linnaeus. L'Obel moved from Flanders to England in 1584, where he was appointed Physician to James I. (*Encyclopaedia Britannica*, online)

1574 Nine years following his death, Swiss naturalist Conrad Gessner's *Historia Plantarum* was published. The *Historia* included 1500 illustrations, most (or all) of which were drawn by Gessner himself.

1578 Henry Lyte, also Henry Lite (sometimes awkwardly listed as John Lite or John Lyte) published *A niewe herball* or *Historie of Plantes*..., as the English translation of Charles de L'Ecluse's *Histoire des Plantes* (1557), which was the French translation of *Cruydeboeck* (1554) by Rembert Dodoens. Though published nearly two decades prior to Gerard's *Herball*, and even though both are essentially translations of Dodoens, Lyte's version of *Histoire* never became as widespread or well-known. (Wikipedia, 2015 - note dates for both L'Cluse and Dodoens in the Wikipedia treatment of Lyte were incorrect.) In the *Herball*, Lyte introduced the word "arborist" to English, based on the Latin *arborator*. (Campana, 1999) Lyte's preface (in the 1619 edition) reads: *"TO THE FRIENDLY AND indifferent Reader... IF thou be ignorant (gentle Reader) and desirous to know, either how profitable this Historie of Plants is, or how worthy to be studied, ... **A good thing, the more common it is, the better it is**..."*

1583 *De Plantis libri* by Andrea Cesalpino became the greatest botanical book of the 16th century and the first general plant science text to supersede ancient writings. In the preceding 2000 years, little had been added to our knowledge about plants. Like his predecessors, Cesalpino accepted anecdotal information, but he advanced plant study in some regards, particularly in his grouping of plants by their physical characteristics (such as habit, i.e. tree versus herb, and fruit type) rather than by their supposed medicinal properties. As an introduction to his topic, Cesalpino classified around 1500 plants. Laurence (1951) is not so kind, i.e.: *"Cesalpino was an Aristotelian scientist in that his conclusions were based on reasoning rather then an analysis by observation. Teleology was accepted by him and treated as of major importance. He believed leaves to have been provided for the protection of buds, flowers, or fruit, denied the existence of sex in flowers, treated the pith of dicots as a homologue of the spinal column of vertebrated animals, and contended that plants had a nutritive soul."* Cesalpino was a student of Luca Ghini [See 1533; 1543.] The bean genus *Caesalpinia* was named for him.

1583 Publication of *Stirpium historiae pemptades sex*, the Latin culmination of Dodoens' studies (see 1554).

1592 Prospero Alpino published *De Plantis Aegypti liber (*which was included in Bauhin's 1623 *Pinax)*, relating plant information he garnered from having lived in Egypt. The book included citations of many tropical plants not previously mentioned in European herbals. Among his better-cited comments were observations of requisite pollination of date palms: *"the female date-trees or palms do not bear fruit unless the branches of the male and female plants are mixed together; or, as is generally done, unless the dust found in the male sheath or male flowers is sprinkled over the female flowers".*

1596 In a catalog of plants in his Holborn garden, Gerard included what may be the first mention of the garden Nasturtium (probably *Trapaeolum majus*). A much later publication, Aiton's *Hortus Kewensis*, notes that Lumley Lloyd introduced this plant to horticulture, in 1686. (Halliwell, 1987)

1597 Gerard published the first edition of his *Herball*, followed eventually by a second edition in 1633, which was edited and expanded by Thomas Johnston. Titled *The Herball* or *General Historie of Plants*. (Sanecki, 1992). Jackson (see 1876 in this TimeLine) describes the *Herball* as an English translation of Dodoen's *Stirpium Pemptades* (the Latin translation of *Cruydeboeck*) reorganized along the lines of L'Obel's work.

1598 Caspar Bauhin edited the *Opera quae extant Omnia….,* the consolidated life works of Pietro Andrea Mattioli. The importance of this publication is overlooked, but it marks the beginnings of botany as emerging separately from medicinal realms. Mattioli had, through his many studies, labors, and disagreements become the Renaissance spokesperson for ancient Dioscoridean text. His translations and commentaries (beginning in 1544) were the basis for the re-emergence of classical thought on medicinal plants throughout Europe. For the *Opera*, Bauhin authored a list of synonyms for the many plants Mattioli had covered, a list that became the basis for his 1623 Pinax. (Stannard, 1999,XIV, 73)

1603 Spigelius published instructions on making dried herbarium specimens (in his *Isagoges in Rem Herbarium*) - a technique that had only come into practice during the previous 50 years. The collecting, exchange, archiving, and study of pressed, dried plants that are mounted to sheets of paper engendered a quiet revolution in taxonomy, floristics, and systematics. (Morton, 1981)

1605 Carolus Clusius published *Exoticorum libri decem*, an important step in the documentation of his work. (On line: *The Exotic World of Carolus Clusius (1526-1609)*, Catalogue of an exhibition on the quatercentenary of Clusius' death, 4 April 2009, Ed. Kasper van Ommen, Leiden University Library: *For the first time in European history a work was dedicated to exotic nature as such, and not to its medicinal effects. Published when he had reached the ripe old age of 79, it includes an Appendix to Clusius' collected works of four years earlier (the Rariorum) which lists newer discoveries without even bothering to include page numbers. The sense of the urgency of discovery that emerges from these pages symbolizes Clusius' involvement with the exotic and his unwavering fascination with rare naturalia*.)

1608 Jean Robin and Pierre Valet published the first European florilegium, J*ardin du Roy tres Chrestien Henri IV*. It was followed closely by *Florilegium Novum* (1611-1614), *Florilegium Renovatum* (1641) by Jean Theodore de Bry, Besler's *Hortus Eystettensis* (1613), Emanuel Sweert's *Florilegium* (1612), and *Hortus Floridus* by Crispin de Passe (1614). These books covered extensive numbers of horticultural floral forms.

1613 Basilus Besler published *Hortus Eystettensis*, a highly illustrated codex documenting plants in the garden (hortus) of Johann Konrad von Gemmingen, the Bisho of Eichstätt. Organized based on the four seasons, Besler's team of artists and writers worked over 16 years to produce and publish the hundreds of engravings. Besler's work included 660 species and more than 400 variants (doubles, variegates, etc); 400 of his plants had medicinal value, 180 were used in cooking, and 250 were grown principally for ornament. The publication included numerous forms of lilies, campanulas, delphiniums, hollyhocks, scabiosas, iris, tulips, narcissus, roses, hyacinths, and anemones.

1618 The *London Pharmacopoeia* was first issued, attempting to standardize and improve medicinal preparations available in commerce. Subsequent editions issued in 1621, 1632, 1639, and 1677, were modest improvements. The 1721 edition, published through oversight of Hans Sloane, overhauled cures (eliminating many unsubstantiated formulae), included better plant names as sources, and standardized strengths of solutions. (Wikipedia, 2018)

1623 Gaspard Bauhin produced the *Pinax*, a monumental compilation that pulled together uncoordinated plant names and descriptions on 6,000 species that had appeared in Theophrastus and Dioscorides, as well as in later herbals and other plant records. *Pinax* is among the first publications to distinguish between general categories (genera) and more specific examples (today's species) of plants. Gaspard's brother, Jean Bauhin created a separate comprehensive synonymy that expanded the listing with descriptions that constitute some of the earliest examples of appropriate plant diagnoses. His compilation, *Historia plantarum universalis* was published in 1650, nearly two decades following his death. The Bauhins' publications remained core authorities for a century, and provide the basis for Linnaeus's floristic works. By accepting their compilations, Linnaeus avoided many complications of the ancient literature. Linnaeus recognized the brothers with the genus *Bauhinia*, a legume that produces bilobed leaves.

1629 John Parkinson produced *Paradisi in Sole Paradisus Terrestris*, a gardening book/florilegium that resulted in his gaining the title Botanicus Regius Primarius – Royal Botanist.

1637 Tradescant *f.* (the son, *filius*, of elder Tradescant) made his first trip to Virginia, returning to England with living material of bald cypress and American sycamore. Tradescant *f.* made his second trip to Virginia in 1642. John Tradescant introduced *Mimosa pudica*, the South American sensitive plant, to cultivation in England. (Grimshaw, 1998)

1640 John Parkinson published his *Theatrum Botanicum* in which plants are classified according to 17 classes or tribes; i.e. 1. Sweet smelling Plants; 2. Purging Plants; 3. Venemous Sleepy and Hurtfull plants and their Counter Poysons; 4. Saxifrages; 5. Vulnerary or Wound Herbs; 6. Cooling and Succory Herbs; 7. Hot and Sharpe Biting Plants; 8. Umbelliferous Plants; 9. Thistles and Thorny Plants; 10. Fearnes and Capillary Herbes; 11. Pulses; 12. Cornes; 13. Grasses; 14. Marsh Water and Sea Plants and Mosses and Mushroomes; 15. The Un-

ordered Tribe; 16. Trees and Shrubbes; 17. Strange and Outlandish Plants. (Sanecki, 1992) This is said to have been the largest English herbal produced, covering nearly 4,000 plants with more than 2,700 woodcuts.

1649 Nicholas Culpeper published his herball, T*he English Physician* or an *Astrologo-physical Discourse of the Vulgar Herbs of this Nation Being a Compleat Method of Physic Whereby a man may preserve his body in health or cure himself being sick for thee pence charge with such things onely as grow in England, they being most fit for English Bodies*. The English Physician dealt considerably with astrology and the signatures of plants. (Sanecki, 1992)

1672 Robert Morison published the first scientific study of a single plant group (the carrot family) [the first monograph.] (HNT)

1686 John Ray, in his *Historia plantarum* (published in volumes through 1704) arrived at an early natural grouping of plants through looking at their many different characteristics. His study dealt with plants worldwide, establishing standards and giving currency to much of our modern botanical terminology and summarizing the current state of botanical knowledge. Ray, unaware of the work by Rudolf J. Camerer, concluded in his discussion on fertility in date palm, willow, and other plants that: *"in our opinion the pollen is equivalent to the sperm of animals."* His definition of species was quite modern: "each produces only its own kind; one must distinguish between essential, accidental, and environmental characters." Ray's summary of plant physiology was so thorough that he could be considered the founder of that field. (HNT) (Isely, 1994; Morton, 1981)

1694 Rudolf Jacob Camerer (in Latin, Joachim Camerarius) wrote a scientific letter (later published by Valentini in his *Polychresta exotica*, 1700, HNT) that made the first clear case (with solid experimental evidence) for the nature of sex in plants and the actual role of pollen and ovule in this process. The publication documented years of work with plants such as the dioecious *Morus* (mulberry), *Mercurialis*, and *Spinacia* (spinach), as well as *Ricinus* (castor bean) and *Zea* (corn), which are both monoecious. In all cases, removal of staminate plants or flowers either greatly reduced or completely eliminated fertility. In his experiments with *Cannabis* (hemp), removal of staminate plants from a field did not completely deter production of fertile seed, a result *"at which I must admit I was quite upset"* Camerer reported. (Morton, 1981) [See 1718] Of pollen: *"In the vegetable kingdom there is accomplished no reproduction by seeds, that most perfect gift of nature, and the usual means of perpetuating the species, unless the previously appearing apices of the flower have already prepared the plant therefor. It appears reasonable to attribute to these anthers a nobler name and the office of male sexual organs."* (reproduced from Duncan Starr Johnson, 1915. *History of the Discovery of Sexuality in Plants*, Smithsonian Report for 1914, available free from G**gle Play)

1694, 1700 Joseph Pitton de Tournefort regarded flowering plants as either trees or herbs, with each divided based on flo-

ral construction and shape. He has been called “the father of the modern genus concept.” (Lawrence, 1951)

1697 Father Francisco Cupani published the first scientific description of *Lathyrus odoratus*, a plant from Sicily and the parent stock of today’s sweet pea. Seed that he sent in 1699 to Robert Uvedale, headmaster of Enfield Grammar School near London, resulted in cultivated forms, and by 1731, a famous selection called ‘Painted Lady’ - the exact origins of which are not known. (Grimshaw, 1998)

1699 Dr. Uvedale of Enfield received a shipment of *Lathyrus odoratus* (Sweet Pea) form Father Cupani in Sicily. Due to their form, color, and fragrance these plants became popular and their cultivation spread. A century later many variants were recognized, including the ‘Painted Lady’ which remains in cultivation today. (Fletcher, 1969)

1703 John Ray’s *Methodus plantarum* covered nearly 18,000 plant species, which he separated as either woody or herbaceous. Ray recognized monocots as separate from dicots, basin his classes on fruit (or cone) type, with finer segregation based on leaf and flower characters. Linnaeus substantially based his *Critica botanica* and his *Philosophia botanica* on Ray’s classification. (Lawrence, 1951)

1703 Charles Plumier published *Nova Plantarum Americanarum Genera* over a two year period. Plumier was an accomplished plant collector, and a prodigious author - leaving (at his death) 31 well-developed but unpublished manuscript volumes and 4,000 plant illustrations. Plumier described the genus *Fuchsia* from specimens collected in Hispaniola, and was himself recognized through designation of the genus *Plumeria*. (Wikipedia, 2108)

1712 Engelbert Kaempfer published *Amoenitates Exoticae*, the first western description of the Japanese flora (as well as other information). Kaempfer was a physician with the Dutch East India Company at Deshima from 1690 to 1692. Other Kaempfer notes, published by Hans Sloane as History of Japan, include the first western description of ginkgo.

1712 Mark Catesby made his first trip to America, traveling first to Virginia. He returned to England in 1719, but his time in the New World included travels to Jamaica in 1714. (Meyers & Pritchard, 1998)[See 1729]

1718 Sébastian Vaillant was one of the earliest supporters of Camerarius’s ideas concerning the sexual nature of plants. He contributed to the development of terminology necessary to discuss flower structure and function (some of which shocked his contemporaries, such as his comparing stamens to animal testicles and penis). Originally Vaillant delivered his information in a talk at the Jardin du Roi in Paris. By 1718 he had published the remarks as *Discours sur la structure des fleurs…* (HNT) (Morton, 1981) [See 1694](see also: Paul Bernasconi and Lincoln Taiz, transl. 2002. “Sebastian Vaillant’s 1717 lecture on the structure and function of flowers “Huntia 11(2) 2002.)

1722 Mark Catesby journeyed to America, leaving England in February, arriving in South Carolina on 23 May. Prior to his

return to England in 1726, Catesby traveled to the Bahamas. (Meyers & Pritchard, 1998) [See 1729]

1722 Philip Miller began management of the Chelsea Physic Garden.

1722 Joseph Miller published *Botanicum Officinale*, a substantial compilation of plants, their origins and characteristics, and their uses in medicine. Miller's treatment adopted names that had been listed in the 1721 *London Pharmacopoeia* (see 1618). Miller's text was heavily borrowed (with permission) by Elizabeth Blackwell for *A Curious Herbal* (1737-1739), suggesting that Blackwell's serialized prints constitute the illustrated version of *Botanicum Officinale*.

1729 As a student at Uppsala University, at the age of 20, Carl Linnaeus published *Praeludia Sponsaliorum Plantarum*, a discourse reflecting his understanding of the significance of the sexual nature of plants. Having been impressed by Vaillant's letter, published just a decade earlier (though he seems to have denied that influence), Linnaeus applied that important revelation to his appreciation of plant diversity. Indeed, Linnaeus realized that floral characteristics provide incredibly useful characteristics for grouping and identifying plants, an observation bolstered by the knowledge that stamens and pistils are are a flower's sexual parts.

1733 John Bartram of Philadelphia began correspondence with Collinson, Miller, and others. Their exchange is the likely source of pawpaw, sourwood, and other American plants introduced to cultivation in Europe. (Spongberg, 1990)

1735 Linnaeus arrived in Holland (for a 3-year stay), visiting the Amsterdam *Hortus botanicus* on his first day. In Holland Linnaeus gained the respect and support of three important botanists: Herman Boerhaave, Jan Frederik Gronovius, and Johannes Burman. Through Burman he gained the acquaintance and support of George Clifford, wealthy banker and owner of de Hartecamp. Since purchasing that estate in 1709, Clifford had transformed it into a botanist's paradise of exotic plants. During his three years in Holland, Linnaeus published 14 books, laying the groundwork for his entire career. (Stafleu, 1971)

1735 - 1758 Soon after arriving in the Netherlands, Linnaeus met Jan Frederik Gronovius, who was sufficiently impressed by the young naturalist so as to finance publication of the first edition of *Systema Naturae*, the manuscript for which Linnaeus carried on the journey form Sweden. Over the next 23 years, Linnaeus published 10 editions of *Systema Naturae* (with two more editions surfacing the next decade). This publication constitutes his attempt at a comprehensive accounting of Earth's plants and animals. The 10th edition (1759) included 7,700 plant species. It is documented that Linnaeus believed the world's flora would total less than 10,000 species, which means he believed *Systema Naturae* approached a comprehensive accounting of the world's plants.

1737 Linnaeus authored *Hortus Cliffortianus*, with illustrations by Ehret. This record of plants cultivated by George Clifford in his garden at Hartekamp (Holland) is the forerunner of *Species Plantarum*. The illustrations demonstrate Lin-

naeus' belief that botanical drawings should be of superb detail and must result from close collaboration between botanist and artist. In his introduction, Linnaeus waxed *"I gazed at Your garden in the very center of Holland bright with flowers, between Haarlem and Leiden, a charming spot between two thoroughfares, where boats, where carts pass by; my eyes were captivated by so many masterpieces of nature..."* (Stafleu, 1971) (HNT)

1737 The magnificent Southern magnolia, *Magnolia grandiflora* (introduced from Southeastern North America to Europe by 1730) flowered in August at the London home of Charles Wagner, First Lord of the Admiralty. Georg Ehret immortalized this event with a sumptuous and justifiably famous illustration. Ehret, an apprentice gardener, had learned his artistic skills from his father during his youth in Heidelberg, Germany. (Grimshaw, 1998)

1737 Johannes Burman published *Thesaurus zeylanicus*, using plant specimens from Ceylon that were collected by Paulus Hermann and Jan Hertog. In the following two years Burman published *Rariorum africanum plantarum decades I-X* based on drawings made at the Cape of Good Hope by Hendrik Claudius. (Stafleu, 1971)

1737 Elizabeth Blackwell began publication of 500 illustrations of plants associated with Chelsea Physick Garden, which she drew (*pinx*), engraved (*delin sculp.*), and printed. The illustrations, issued in 125 weekly serials, constituted the two-volume set named *A Curious Herbal*. Accompanying text was taken from other sources, principally Miller's *Botanicum Officinale* (see 1722). Blackwell's herbal came at the close of the Herbal era.

1742 *"Tokugawa Yoshimune decided that Dodoens' Cruijdtboeck should be examined for useful products. He ordered his personal physician Noro Genjō to study Dutch and to interview the Dutch surgeons during the court journey to Edo. These interviews took place between 1742 and 1750. Their purpose was to collect data on the medicinal properties of plants and to identify corresponding indigenous plants. The selected entries were compiled under the title Oranda Honzo-Wage. Each entry usually starts with the Dutch, Latin, Chinese and Japanese names of the plant, followed by its therapeutic properties."* Quotation from: *The Exotic World of Carolus Clusius (1526-1609)*, Catalogue of an exhibition on the quatercentenary of Clusius' death, 4 April 2009, Ed. Kasper van Ommen, Leiden University Library

1747 Bernard de Jussieu received seed of *Sophora japonica* from d'Incarville in Beijing, via Moscow. This shipment probably also included *Koelreuteria paniculata*.

1748 Michel Adanson, a student of Bernard de Jussieu, arrived in Africa to collect until 1754.

1749 A near century old female specimen of the Mediterranean fan palm, *Chamaerops humilis*, had flowered for years in Berlin without fruiting. By 1751 Gleditsch reported that in 1749 he had applied pollen from a male plant grown in Leipzig to the flowers that remained fresh on one branch of the female

plant. The seed produced proved viable, thus further confirming the male role of pollen. (Morton, 1981)

1752 Joseph G. Kölreuter (a medical student in Tübingen) published his survey of studies of sex in plants, one of the first that had been reported since Camerarius first suggested plant sexuality in his *Epistola*. Kölreuter had almost certainly been a student of S. G. Gmelin (a professor at Tübingen), who had republished Camerarius's work and appended his own lectures calling for increased dedication to experimental work on this subject. (Morton, 1981) [See 1760; 1761]

1753 Linnaeus' *Species Plantarum* established a standard for plant classification as well as nomenclature. Linnaeus included 5,940 kinds of plants in about 1,000 genera, organized in his 24 Classes. This treatise eventually became recognized as the beginning point for today's binomial nomenclature. (HNT)

1759 Bernard de Jussieu organized plantings at La Trianon, Versailles, to reflect his developing concepts as to how plants groups are naturally (evolutionarily/phylogenetically) related. He segregated plants *"on the basis of monocot vs. dicot, ovary position, presence or absence of petals, and fusion or distinctness of petals."* (Lawrence, 1951)

1759 Publication of the 10th edition of Linnaeus's *Systema Naturae* (see 1735).

1761 Kölreuter reported his work on the role of insects in pollination. His detailed descriptions of insect activity and floral structure instructed botanists on the mechanisms and significance of insect pollination, and led directly to the work of Sprengel. (Morton, 1981) (HNT)[See 1716 & 1877]

1763 Michel Adanson's *Familles des plantes* represented the first general attempt to group plants based on their relatedness, a "natural system." The entry for each of his natural families presents a variety of characters common to the group. Much of Adanson's work predicted the system outlined in *Genera plantarum*, published in 1789 by Antoine Laurent de Jussieu. Adanson's work was not widely recognized in his lifetime, perhaps because he did not use Linnaeus's binomial nomenclature, which had already established its great utility. (Morton, 1981) (HNT)

1765 The Bartrams discovered the Franklin tree. Not until another trip, in 1773, would the younger Bartram collect seed in the only known population, near Fort Barrington, GA. In 1774, the supporter of this trip, John Fothergill, presented seedlings to Kew. Publication of William's travel accounts was completed by 1781, but awaited identification of plants from specimens he had sent to Fothergill. At Fothergill's death in 1780, his herbarium was purchased by Joseph Banks. (Spongberg, 1990)

1766 Joseph Banks explored Newfoundland and Labrador, charting waters and making collections.

1766 A colonial garden was established on St. Vincent, receiving mango trees as well as East Indian spice trees. (Sauer, 1993)

1766 Peonies and iris are said to have been first planted in Missouri by the Chouteau family, who brought the plants from Illinois. French settlers were the first to establish permanent settlements in Missouri (in St. Genevieve in 1755). (Edith Sinclair in Slosson, 1951)

1767 Pierre Poivre again was sent by France to Mauritius, as general intendant. The following year Poivre brought along his nephew, Pierre Sonnerat, who became a notable botanical explorer. Early in his career Sonnerat collected and transplanted the famous double coconut to the Mauritius garden from the Seychelles. Over the following two decades, Sonnerat contributed to our understanding of many tropical plants (such as dragon's blood, breadfruit, banana, and cavalam), but his greatest energies were dedicated to the study of palms. (Duval, 1982) [See 1745]

1770 Australia was "discovered" by the British (though the Dutch had already named the area New Holland and had experienced at least 15 landings since 1606.) James Cook set out in the *Endeavor* on a scientific mission in 1768, with the young naturalists Joseph Banks and Daniel Charles Solander (a pupil of Linnaeus), as well as artists. On 29 April 1770, the ship stood into Botany Bay (an oceanic embayment 13 km south of Sydney), which Cook originally called Sting Ray Harbor - until the great collection of new plants by Banks and Solander provoked him to change the name.

1772 Joseph Banks was appointed scientific advisor for the royal gardens by George III.

1774 Antoine Laurent de Jussieu (nephew and collaborator of Bernard de Jussieu) proposed, in his *Exposition d'un nouvel ordere de plantes*, a classification of all plants as acotyledonae monocotyledoneae or dicotyledoneae. He divided the dicots into five groups, the apetalae, petalae, monopetalae, polypetalae, and diclinae. This system matured in *Genera plantarum* (1789). (Lawrence, 1951)

1774 Thomas Jefferson planted olive cuttings at Monticello - unsuccessfully. In 1791, he sent several hundred cuttings from France to South Carolina, only to be disappointed by the lack of commercialization. He was unaware that the Padres who established missions in California had planted olives there by 1769.

1775 Carl Pieter Thunberg arrived at Nagasaki harbor to work at Deshima with the Dutch East India Company. Thunberg received medical training in Sweden, and had been a student of Linnaeus. He was surprised to learn he had considerable freedom to collect dried specimens of plants on the Japanese mainland around Nagasaki. There he collected *Hovenia dulcis* and *Rosa rugosa*. Thunberg returned to Europe in 1776, having essentially smuggled his specimens out of Japan. He published Flora Japonica in 1784. (Spongberg, 1990)

1776 Antoine Laurent de Jussieu began using Linnaean binomials to identify plants at Paris' Jardin du Roi. (Stevens, 1994)

1777 Carl Peter Thunberg, who eventually would occupy Linnaeus's chair at Uppsala, was appointed botanical demonstra-

tor at the botanical gardens. This followed seven years of travel and collecting in Europe, South Africa, Ceylon, Japan, and the East Indies. His work in Japan, because it was with Dutch merchants who held sole access to that country, required a stay in Java to learn the Dutch language. (Stafleu, 1971)

1778 Joseph Banks began his 42-year stint as president of the Royal Society.

1778 Lamarck (Jean-Baptiste-Pierre-Antoine de Monet de Lamarck) published his 3-volume *Flore françoise*, a contribution that continued his relationship with Bernard de Jussieu and established his credentials with many other scientists, most notably Georges-Louis Leclerc, Comte de Buffon.

1780 John Fraser traveled from England to Canada to collect plants; he entered US territory in 1785, receiving financial support from William Forsyth (Curator of the Chelsea Physic Garden), William Aiton (Head Gardener at Kew) and James Smith (President of the Linnean Society). He returned to America in 1788 and again in 1796. Fraser and his son returned yet later as collectors for the Russian Czar and Czarina. Their work was commemorated through plant names, Fraser fir and Fraser magnolia.

1783 José Celestino Mutis (a Spanish citizen who had moved to Bogota, Colombia in 1761 to serve as a physician) was successful in gaining support for a new "expedition" - an enterprise dedicated to documenting the region's flora. Over the next three decades, Mutis employed and trained local peoples to paint several thousand spectacular and botanically-realistic paintings of local plants. The collection is held by the Real Jardín Botaníco de Madrid. (Bleichmar, 2017; Wikipedia)

1784 William Hamilton introduced ginkgo (*Ginkgo biloba*), *Acer platanoides*, and tree of heaven (*Ailanthus altissima*) to his garden near Philadelphia (the tree of heaven had first been planted in Europe by Miller at the Chelsea Physic Garden in 1751). Tree of heaven is now a major weed tree for eastern North America, and is "The Tree" that grew in Brooklyn. (Spongberg, 1990) [See 1770]

1784 David Landreth, along with his brother Cuthbert, established North America's first substantial seed house in Philadelphia. D. Landreth & Co. was the country's most important seed merchant for many years. (Hedrick, 1950)

1784 Thunberg published F*lora Japonica*. [see 1775]

1784 James Edward Smith, a botanist and associate of Joseph Banks, purchased Carl Linnaeus' herbarium (about 14,000 sheets), correspondence, library, and other natural history collections from the Linnaeus family. By Smith's death in 1828, his herbarium, totaling 27,185 specimens, became property of the Linnaean Society of London (which Smith and Samuel Goodenough had founded in 1788). The oldest collected specimen dates to 1708. (Linnaean Society website, 2018; Staffan Müller-Wille, 2006. "Linnaeus' he Antoine rbarium cabinet: a piece of furniture and its function". Endeavour Vol. 30 No. 2 June 2006;

Jean-Baptiste Saint-Lager 1886. “Histoire des Herbiers” ,Société Linnéenne de Lyon Année 1886 13 pp. 1-120)

1787 Publication began for *Botanical Magazine* by William Curtis, the world’s longest-running journal, dedicated to introducing exotic plants to an avid audience. Curtis resigned his position as Demonstrator in Botany for the Chelsea Physic Garden to produce this series.

1789 Aiton’s Hortus Kewensis recorded 15 exotic species of orchid at Kew. They were: *Bletia verecunda, Epidendrum fragrans, Epidendrum cochleatum, Phaius grandifolius (syn P. tankervilliae), Cypripedium spectabilis, Cypripedium acaule, Liparis liliifolia, Calopogon pulchellus, Habenaria fimbriata, Arethusa bulbosa, Satyrium carneum, Satyrium coriifolium, Bartholina pectinata, Serapias lingua*, and *Nigritella angustifolia*. *Epidendrum cochleatum* was the first epiphytic orchid known to have bloomed at Kew, in 1789. (Reinikka, 1972)

1789 Laurent de Jussieu achieved a workable system of naming and grouping plants in his *Genera plantarum secundum odines naturales disposita*, by combining Linnaeus’s nomenclature with a basic expectation that botanists would (eventually) discover plants that document a continuity in the forms seen in nature. This was not based on the concept that species further along the chain of life had evolved from earlier forms, rather the idea that nature would be shown to have provided examples of many different possibilities within each plant group. His treatment, by recognizing those sequences, also outlined the the manner in which those natural chains (not lineages) could be subdivided, thus establishing relatively natural groupings of major plant groups. Jussieu also had a fixation with numbers; groups could be neither too small nor too large. *Genera plantarum* grouped plants into 100 families, none of which included more than 100 genera. This caused some artificial adjustments, leading to his breaking the composites into three families. The book was published in Paris - during the same year as the beginning of the French Revolution. (Stevens, 1994)

1792 Carl Ludwig Willdenow, Grundriss der Kräuterkunde, accepted the idea that plant relationships do not form a single chain of being, that we must understand the continuity of plant life as reticulate (a network).

1798 A Franciscan botanist native to Brasil, José Mariano de Conceição Vellozo, began publishing his 11-volume encyclopedia (*O fazendiero do Brazil*) on the natural and agricultural circumstances in Brasil. His major taxonomic work, *Flora Fluminensi*, was published posthumously beginning in 1825. (JSTOR: The Text of Vellozo's Flora Fluminensis and Its Effective Date of Publication, J. P. P. Carauta Taxon Vol. 22, No. 2/3 (May, 1973), pp. 281-284 Published by: International Association for Plant Taxonomy (IAPT) DOI: 10.2307/1218138 Stable URL: http://www.jstor.org/stable/1218138 Page Count: 4) According to Frodin (see his *Guide to the Standard Floras of the World*....), Martius criticized the work as duplicative and lacking citations.

1798 A chance encounter between Alexander von Humboldt and Aimé Bonpland (while both men were staying at Paris's Hôtel Boston) resulted in an amazing journey of exploration [see 1799] that led to significant developments in our understanding of natural history, biodiversity, biogeography, and ecology. (Aniśko, 2013)

1799 John Lyon began collecting North American plants, at first for William Hamilton, and later for collectors in Europe. He followed the trails of Catesby, the Bartrams, Michaux, and the Frasiers. It has been suggested that Lyon may have contributed to the extinction of the Franklin tree by his aggressive and successful collecting, but that would also argue for the reality that the plant existed in very small numbers in a hyper-local population. Lyon sent quantities of oakleaf hydrangea to England, a plant introduced by Hamilton in 1803.

1799 Alexander von Humboldt and Aimé Bonpland began their 5-year exploration of Central and South America. Among the six thousand plant specimens Bonpland had collected, scientists named 4500 new species. (Aniśko, 2013)

1801 In describing the new genus *Lodoicea*, J. J. H. Labillardiére commemorated an analogy made by P. Commerson (who served with Louis Bougainville on his historic voyages) between the form of the famous coco-de-mer fruit (the double coconut) and his image of the pelvis of Laodice (lovely daughter of King Priam of Troy). Previously, the plant had been included in the coconut genus, *Cocos*. (Emboden, 1974)

1802 Bernard M'Mahon established his nursery in Philadelphia and began his own limited publication series (1806) similar to Curtis' *Botanical Magazine* . His seed lists are among the first published in the US. M'Mahon was selected to receive and germinate seed collected by the Lewis and Clark Expedition.

1802 Robert Brown arrived at Sydney (Australia) on the *Investigator*, along with botanical artist Ferdinand Bauer. George Caley, who had already been sent to collect plants in New South Wales by Banks, was furious that a second botanist was dispatched. (In 1803 Banks received seed of 170 species from Caley.)

1802 John Champneys of Charleston, South Carolina, created 'Champneys' Pink Cluster' rose (eventual parent to the Noisette hybrids) through crossing 'Parson's Pink China' with Rosa moschata, a white-flowered climbing rose from Asia. His new rose, a climber producing bunches of double, pink flowers, was quickly established in American gardens. Champney had acquired his China rose from the Noisette nursery in Charleston. Philippe Noisette produced seedlings from 'Champneys' Pink Cluster' from which he selected the first Noisette, which was introduced in Europe through his brother in Paris. (Grimshaw, 1998)

1802 Seed were sold in packages in America, marketed by a Shaker community at Enfield, Connecticut. Keeping their own seed lines healthy and free of corruption was important to the community. (Connor, 1994)

1804 The Japanese devil lily (oniyuri) was brought into cultivation at Kew. Due to the ease of propagation from bulbils that form in the leaf axils, Kew gardeners were able to propagate and distribute over 10,000 plants within a decade. Scientific name *Lilium lancifolium* aside, the plant is known today most readily by its English common name, tiger lily. (Grimshaw, 1998)

1805 Alexander von Humboldt's personal observations of many different plant habitats resulted in his important generalizations about the relationships of plants to their native climates. He is probably best known for making ecological correlations between the different plant habitats observed with rising elevation and the changing habitats seen when traveling from the tropics to arctic regions. Publication of his *Essai sur la géographie des plantes*... may be considered the beginning of the science of ecology. (HNT)

1810 Robert Brown's *Prodromus Florae Novae Hollandiae* marked the beginning of his publications on the flora of Australia. Brown (the "Jupiter botanicus") made important comparisons of plants from Australia with other floras, yielding a fresh approach to this type of study. With Brown's work, botanists began to understand that significant information can result from studying the distributions and associations of plants. We also began to realize the distinctive nature of the Australian biota.

1813 While a professor of botany at the University of Montpellier, Agustin Pyramus de Candolle introduced the term **taxonomy** in his *Théorie élémentaire de la botanique* (Elementary Theory of Botany), as part of his new classification scheme.

1814 Frederick Pursh published his *Flora Americae Septentrionalis*. He had been engaged originally by Barton in 1805 to study the plant material collected by Lewis and Clark, and later he worked for Hosack at Elgin. In 1809 he returned to London with his own collections of plant material to study.

1815 Johann Friedrich Elsholz, a German, died while participating in a Russian expedition to California. Later, the German botanist, Adelbert von Chamisso, honored Elsholz through describing the new genus *Eschscholzia* for the California poppy, albeit misspelling the name of the honoree. Not a huge surprise; hardly anyone has been able to spell the scientific name of this plant, the state flower of California, ever since. (Grimshaw, 1998 - information on Chamisso in Grimshaw is incorrect - correction supplied by Ann Gardiner)

1816 John Reeves introduced *Wisteria sinensis* to European gardening from nurseries in Canton, China. The first two plants to be exported, each sent aboard a different ship, arrived in the same month of May. One of the ship Captains was Richard Rawes, famous for his involvement with introduction of the first camellias. (Grimshaw, 1998)

1818 Thomas Nuttall published the second volume of *The Genera of North American Plants (and a Catalogue of the Species to the year 1817)*. On page 115 he described the genus *Wisteria*, "in memory of Caspar Wistar, M.D. late professor of Anatomy in the University of Pennsylvania and for many

years president of the American Philosophical Society; a philanthropist of simple manner, and modest pretensions, but an active promoter of science." Nuttall, with seeming purpose, named the genus *Wisteria*, rather than *Wistaria*; his spelling has been officially conserved by botanists. Horticulturists in England, however, continue to spell the genus *Wistaria*..... Caspar Wistar's contributions to medical science were significant, and in 1892 his great-nephew Issac Jones Wistar funded an endowment to establish The Wistar Institute of Anatomy and Biology, housing Caspar Wistar's collections and honoring his contributions. The Wistar Institute stands as America's earliest independent medical research organization. (Note: It would be easy enough to confuse Caspar Wistar with the later horticulturist John Caspar Wister, also of the Philadelphia area. J. C. Wister had a founding role in establishment of Swarthmore's Scott Arboretum during his 50-year tenure at the College.)

1821 Fifteen thousand specimens collected by Thaddaeus Haenke as part of the Malaspina Expedition [see 1879 entry] were secured by Prague's National Museum. Haenke distinguished himself as the first Western botanist to explore the South American interior. As part of his continued explorations, Haenke had (in 1801) been the first scientist to see populations of the Giant Waterlily, V*ictoria amazonica*. (Aniśko, 2013)

1823 Philipp Franz Balthasar von Siebold arrived in Japan to live there until 1830 as surgeon major in the Dutch East Indies Army, anxious for a career as a scientific explorer. He restored order to the botanical garden at Deshima. Because he accepted the gift of a map of Japan on his trip to Edo (foreigners were not allowed access to this type of information,) Siebold was imprisoned for a year, but pardoned in 1829. Banished from Japan in 1830, he was forced to abandon his Japanese wife and their child. The deck of the vessel on which he sailed was filled with plants he used to establish a nursery in Leiden. Among his introductions were *Wisteria floribunda*, *Hydrangea paniculata*, *Hydrangea anomala*, Malus floribunda and *Rhodotypos scandens*. He returned to Japan in 1859 and by 1863 produced a sales catalog that offered 838 species native to that country. (Spongberg, 1990)

1823 David Douglas was sent by The Royal Horticultural Society to the Eastern US to procure any new varieties of fruit trees and vegetables that might have been developed there. He met Thomas Nuttall (a British native recently appointed professor of Botany at the Harvard Botanic Garden) and others who helped him. Douglas returned to England with a wide variety of fruit trees, as well as Oregon grape holly. (Spongberg, 1990) [See 1804]

1823 Robert Bruce, and later his brother Charles, negotiated the process of acquiring seed and plants of the Assam form of tea (*Camellia sinensis* var. *assamica*) from the Singpho tribe of Upper Assam. Eleven years later, the East India Company recognized the value of this discovery and began establishing tea plantations in Assam, with the first tea arriving in London in 1838. The growth in this enterprise led to conscription and near-enslavement of several hundred thousand recruits from

over India. Within 60 years, 340,000 acres in Assam were dedicated to tea plantations. With other growing areas established, Chinese tea exports plummeted from 100%, to 10% of the world market. (Hohenegger, 2007) East India Company employees Charles Alexander and Robert Bruce discovered a kind of tea previously unknown to Europeans (*Camellia sinensis* var. *assamica*) growing in Assam, a province of northern India. The first shipments of Assam tea arrived in England in 1838. Though attempts were made to cultivate China teas in India, it became clear that the native Assam tea was the better crop for that region. Today, Assam tea is grown in Africa as well as Papua New Guinea. (Lewington, 1990)

1824 Agustus Pyramus de Condolle published the first volume of *Prodromus Systematis Naturalis Regni Vegetabilis,* Prodr. (DC.), which continued through 17 volumes (completed in 1873), the last ten published by his son, Alphonse de Candolle and other authors. Intended to cover all seed plants, the series covered dicotyledons only. Condolle is known by his variance from the core Jussieu idea of continuity, having noted that newly discovered plants did not necessarily fill in the gaps between known species.

1826 In his paper ("Character and description of Kingia") describing the Australian genus *Kingia*, Robert Brown also wanders afield and describes reproductive systems of cycads and conifers, which is recognized as constituting the first presentation of the significant differences between gymnosperms and angiosperms, particularly as relates to his concern that cycads and conifers do not appear to enclose the ovum in an ovularium (ovary).... I'm a serious advocate for Robert Brown, and when I read this paper, I'm impressed by the fabulous recitation of historical work. But Brown so steadily hedges his bets in circular discussion about the cycads and conifers as to make his point fairly obtuse. To me, it isn't a clear statement that instantly changes the field in a way other writers suggest.

1830 John Lindley, in his Introduction to the Natural System of Botany, explains: *"The principle upon which I understand the natural system of botany to be founded is, that the affinities of plants may be determined by a consideration of all the points of resemblance between their various parts, properties, and qualities; and that hence an arrangement may be deduced in which those species will be placed next each other which have the greatest degree of relationship... A genus, order, or class, is therefore called natural, not because it exists in Nature, but because it comprehends species naturally resembling each other more than they resemble anything else."* Remember, this still does not impose any idea of evolutionary origin. Lindley is simply accepting the fact that there is a natural similarity (or affinity) among certain plants, which merits recognition and study. (Stevens, 1994)

1835 Having returned to London from nearly a decade of living, working, and collecting plants in Mexico and California, Thomas Coulter sorted through his notes and specimens. Early in this year, he loaned cones he had collected to botanist David Don. In June, Don read a paper detailing five new pine species from Coulter's collections. Among those new species was *Pinus coulteri,* of which Don notes: "The leaves are longer

and broader than those of any other Pine, and the cones which grow singly are the largest of all, being more than a foot long, half a foot in diameter, and weighing about four pounds... At the suggestion of Mr. Lambert I have applied to this remarkable tree the name of its discoverer, who is no less distinguished for his scientific acquirements than from the excellent qualities of his mind." (Nelson and Probert, 1994)

1835 Hugh Cuming commenced a 4-year trip to the Philippines. He was probably the first person to ship living orchids successfully from Manila to England. Plants he sent included *Phalaenopsis amabilis*, first grown at Chatsworth. Cuming distributed 130,000 herbarium specimens.

1842 John Frémont began a series of five expeditions, which led to his arrival in Alta-California in 1844. Over a period of thirteen years, Frémont would be responsible for significant plant collections leading to designation of nineteen new genera. Included were specimens of Flannelbush, collected on 27 May 1946 and used by botanist John Torrey as the basis for the genus *Fremontodendron*. (Beidleman, 2006)

1843 Robert Fortune made the first of four journeys to China (ending in 1860), initially for the Royal Horticultural Society, later for the East India Company (as a result he sent 23,892 young tea plants and 17,000 germinated seedlings to northern India), and finally for the US Government. Never before had so many Chinese plants gotten to England. His success was based greatly on the newly invented Wardian case. Plants he sent included balloon flower, bleeding heart, golden larch, Chinese fringe tree, cryptomeria, hardy orange, abelia, weigela, winter honeysuckle, etc. Tea plants Fortune sent to Washington did not succeed, partly because of the War Between the States. (Spongberg, 1990) [See 1846]

1846 Robert Fortune delivered plant material (from his first of three China collecting trips) to the Horticultural Society's gardens at Chiswick. Included was *Jasminum nudiflorum* (Winter Jasmine). Though originally cultivated in the glasshouse, the plant proved to be hardy and became a popular garden shrub. (Halliwell, 1987)

1846 William Lobb collected seed of *Tropaeolum speciosum*, the Flame Creeper, in *Nothofagus* forest of the south Chilean island of Chiloe. The plant was first grown by the Veitch nursery in Exeter, which had sponsored his trip. Flame Creeper is a close relative of Canary Vine (*Tropaeolum peregrinum*) and the garden Nasturtium (*Tropaeolum majus*)[See 1596], all of which are native to the Neotropics. (Halliwell, 1987)

1849 On 9 November, Joseph Paxton, Gardener to William Spencer Cavendish, and his staff flowered *Victoria amazonica* at Chatsworth. The seed had been delivered to Paxton by William Hooker, Director of Kew, whose staff had successfully germinated about 50 seed delivered in March. The event was regarded as a horticultural triumph, the first time this South American native plant had been cultivated and flowered successfully. (Aniśko, 2013)

1852 James Drummond (along with his son) made his last significant shipment of Australian plants to England, the results

of his six major collecting expeditions. Drummond's botanical legacy is strong; over 100 new species were named for him (a third of which have turned out to be taxonomic synonyms.) But he was known for fragments rather than full specimens, due partially to difficult circumstances and shortage of paper. (Webb, 2003)

1853 Albert Kellogg (native of South Carolina who had studied at Kentucky's Transylvania College, and later traveled to San Francisco where he had a pharmacy) and six colleagues established the California Academy of Sciences. At one of the meetings, Kellogg relayed specimens as well as stories he had heard from A. T. Dowd about a giant new conifer in the Sierran foothills, southeast of Sacramento. William Lobb, who was at the meeting, left for the area soon afterward, collecting seed, mature cones, vegetative shoots, and two seedlings. Lobb returned to San Francisco and quickly departed for England. The two saplings were planted at the Veitch nursery in Exeter. John Lindley described the new species that December in *Gardener's Chronicles* as *Wellingtonia gigantea*. (Spongberg, 1990) The name eventually accepted for this tree was *Sequoiadendron giganteum*.

1853 The first flower show held in California opened in San Francisco on 7 October. Among the entries were specimens from James Warren, of Sacramento, one of the first professional nurserymen to set up business in California (1849). Warren published the state's first nursery catalog and initiated California Farmer, the state's first agricultural and horticultural publication. By 1855, several nurseries operated along Folsom Street in San Francisco, including William Walker's Golden Gate Nursery, James and William O'Donnell's United States Nursery, and the Commercial Nurseries, a subsidiary of Highland Nursery in Newburgh, NY. A nursery from Napa County was represented in the 1854 flower show. (Taylor & Butterfield, 2003)

1853 The herbarium at Kew was established, based on: *"the amalgamation of several formerly private collections, such as Sir William Hooker's, George Bentham's and M J. Berkeley's mycological herbarium. The collections include the personal herbaria of some of Britain's most celebrated scientists and explorers of the past. Charles Darwin, Joseph Hooker, David Livingstone, John Hanning Speke, Richard Spruce, Ernest 'Chinese' Wilson and Miles Joseph Berkeley are just a few of the famous names whose collections can still be studied in the Herbarium."* (Kew website,, 2018)

1856 *Calanthe ×dominii* flowered. This is the world's first planned orchid hybrid, raised by John Dominy for Veitch & Sons. Though horticulturists were enthusiastic, botanist John Lindley was quoted as remarking: "You will drive the botanists mad." (Fletcher, 1969)

1859 Louis Agassiz *"insisted that the ranks of the hierarchy used in the classification of life were 'instituted by the Divine intelligence as the categories of his mode of thinking.'* (Stevens, 1994)

1859 Charles Darwin published On the origin of species by means of natural selection.... As explained by Darwin, evolu-

tion is a simple change in character of a population of either plants or animals. Circumstances governing the success of a population are not neutral, rather the environment favors certain characteristics, which creates a natural system of selection that can lead to changes in the makeup of a population. Gradual change in a population can lead to differences that qualify the population as a distinctive enough to become a new species - thus the "origin" of species. By identifying a mechanism that could lead to the diversity of life on earth, Darwin rewrote the book on relationships of plants and interpretations of plant adaptations. My favorite quotation from Origin: *"We have seen that man by selection can certainly produce great results, and can adapt organic beings to his own uses, through the accumulation of slight but useful variations, given to him by the hand of nature. But Natural Selection as we shall hereafter see, is a power incessantly ready for action, and is as immeasurably superior to man's feeble efforts, as the works of Nature are to those of Art."* (HNT)

1860 Joseph Hooker's *Flora Tasmaniae*, which was published between 1855 and 1860 is dedicated to Ronald Campbell Gunn and William Archer. Of Gunn, Hooker writes: *"There are few Tasmanian plants that Mr. Gunn has not seen alive, noted their habits in a living state, and collected large suits of specimens with singular tact and judgement. These have all been transmitted to England in perfect preservation, and are accompanied with notes that display remarkable powers of observation, and a facility for seizing important characters in the physiognomy of plants, such as few experienced botanists possess."* (Webb, 2003) William Archer, a native to Tasmania, was an architect and amateur botanist and botanical artist.

1861 A new treaty with Japan in 1858 [sic] led to a race by American and European plantspeople to collect and introduce plants from these islands. Field collectors included Carl Maximowicz who sent plants to Russia, Max Ernst Wichura from Germany, and Richard Oldham from the Royal Botanic Gardens at Kew (re. *Bambusa oldhamii*). George Rogers Hall, an American resident of Yokohama, sent a huge shipment in 1861 to Francis L. Lee of Chestnut Hill, MA. Lee went to war and left Francis Parkman, explorer, neighbor, and friend, to curate the growing collection. (Parkman would become Professor of Horticulture at Harvard in 1871). Thomas Hogg (son of a Scottish emigrant and nurseryman, sent to Japan by Lincoln as a US Marshal) shipped plants to his brother, James, as well as to the Parson's firm at Flushing, NY. His introductions included the Japanese stewartia, the fragrant snowbell, the sapphire berry, and the katsura tree. (Spongberg, 1990) [See 1854]

1862 George Rogers Hall returned from Japan and brought seed, plants, and Wardian [See 1842] cases of material to Flushing, NY, which he entrusted to the Parsons & Co. Nursery. Included were the kobus magnolia, the star magnolia, zelkova, Japanese maples, wisterias, raisin tree, etc. Also in this shipment was the future weed, Japanese honeysuckle, initially called Hall's honeysuckle. Some of Hall's plants in Yoko-

hama had been obtained from Siebold. (Spongberg, 1990)[See 1823].

1862 Specimens obtained by Jean Pierre Armand David, a Basque in the Lazarist priesthood who moved to China in 1862, form the basis of *Plantae Davidianae*, in which Adrien Franchet of the Museum at the Jardin des Plantes described nearly 1500 new species.

1862 George Bentham and Joseph Dalton Hooker began presenting a new system for organizing plants with publication of *Genera plantarum ad exemplaria imprimis in herbariis kewensibus servata definita*, three volumes published between 1862 and 1883. The monumental set, simply called Bentham and Hooker by most botanists, covered seed plants and included over 97,000 species in 7,569 genera, organized in 202 families. Bentham alone dedicated 27 years to this publication, and it stands apart from other comprehensive treatments of seed plants in that descriptions of families and genera were written by the two authors, based on study of specimens. (Lawrence, 1951; Wikipedia, 2018)

1866 Ernst Haeckel published *Generelle Morphologie der Organismen: allgemeine Grundzüge der organischen Formen-Wissenschaft, mechanisch begründet durch die von Charles Darwin reformirte Descendenz-Theorie*, which is noted as the first time phylogenetic trees were used to explain phylogenetic concepts. (Note: Haeckel studied and published on embryology, and is credited with the aphorism: "*Ontogeny recapitulates phylogeny.*"

1887 Initiation of the first edition of the 23 volume *Die Natürlichen Pflanzenfamilien* by Adolf Engler and Karl Anton Prantl (completed in 1915, followed by a partial second edition). Known simply as Engler & Prantl by botanists around the world, one might say constitutes the first approach at a true world flora. Engler's schema for organizing plant families changed through many renditions, which were reflected in an 1889 guide to Breslau Botanic Garden (where Engler worked.) Paralleling his other publications, the catalog surfaced as *Syllabus der Pflanzenfamilien* in 1892, and passed through numerous editions, the 13th published in 2009. Engler's system was the standard basis for organizing many herbaria for decades, and thus held great sway over the world of systematists. Lawrence (1951) reminds us that: *"the system was not conceived to be phylogenetic in the modern sense,"* but, Lawerence does explain that Engler's groupings of flowering plants are based *"on the premises that evolutionary lines progressed from apetaly to polypetaly and gamopetaly, apocarpy to synarpy, hypogyny to epigyny, and actinomorphy to zygomorphy."* Alfred B. Rendle, Richard von Wettstein, and August A. Pulle would subsequently publish their own independent updates to the Engler and Prantl system. (Lawrence, 1951;Wikipedia, 2018)

1915 Charles E. Bessey published "The phylogenetic taxonomy of flowering plants" in Annals of *Missouri Botanical Garden*. (See The Reader, Chapter 5, Section 2 for a discussion of Bessey's Dicta.) Bessey created his own system, borrowing strongly from ideas generated by Bentham and Hooker, as

well as Engler. He thought of seed plants as polyphyletic, deriving the flowering plants (*Anthophyta*) from the cycads (*Cycadophyta*).

1922 Edgar Anderson began work in St. Louis, MO as "Geneticist to the Garden" (heading Missouri Botanical Garden's School of Gardening) and professor at Washington University. Anderson would quickly become one of the principle figures in development of biosystematics. *"His first biosystematic project was a look at the species problem in Iris. His 1928 paper took up the species problem concretely by looking at populations of two closely related yet distinct species of iris and allowed Anderson to test the relative importance of hybridization and mutations as sources of the variation on which natural selection works "* (Kim Kleinman, 2009. "Biosystematics and the Origin of Species: Edgar Anderson, W. H. Camp, and the Evolutionary Synthesis", Transactions of the American Philosophical Society, New Series, Vol. 99(1) 73-91, in *Descended from Darwin: Insights into the History of Evolutionary Studies, 1900-1970*
Stable URL: https://www.jstor.org/stable/27757425

1926-1934 John Hutchinson published *Families of Flowering Plant*s, a 2-volume classic that presented his phylogenetic system. Hutchinson separated predominantly woody groups of plants from those that are predominantly herbaceous, basing much of his thought on work of Charles Bessey.

1929 Göte Turreson explained several different and important concepts of ecological approaches to plant species, describing the Ecospecies, Agamospecies (a term he introduced in this paper), and Coenospecies. (Wilkins 2011)

1931 Walter Zimmerman published "*Arbeitsweise der botanischen Phylogenetik und anderer Cruppierungswissenschaften*", which discussed the history of plant classification schemes and promoted what would (today) be considered a cladistic approach to establishing evolutionary history as the basis for systematics.

1937 In his publication *Die Methoden der Phylogenetik*, Walter Zimmermann explained that classificadtion must reflect phylogenetic relationships. Zimmerman's ideas were important to Willi Hennig, as he developed his own statement on phylogenetics. (see Michael J. Donoghue and Joachim W. Kadereit, 1992. "Walter Zimmermann and the Growth of Phylogenetic Theory" *Systematic Biology*, Vol. 41(1): 74-85
Stable URL: https://www.jstor.org/stable/2992507

1939-1948 Jens Clausen, David D. Keck, and William M. Hiesey published a series of studies, using reciprocal plantings to document ecotypical variation across plant populations.
1939: "The concepts of species based on experimentation." American Journal of Botany 26: 103–106; 1940: *Experimental studies on the nature of species I. Effects of varied environments on western North American plants* . Washington, DC: Carnegie Institution of Washington; "Heredity of geographically and ecologically isolated races". American Naturalist 81: 114–133; 1948: *Experimental studies on the nature of species. III: Environmental responses of climatic races of Achil-*

lea. Publication 581; Washington, D.C.: Carnegie Institution of Washington.

1942 Julian Huxley published *Evolution: The Modern Synthesis*, an influential book that called for overall integration of knowledge and techniques in establishing the origins and relationships among organisms.

1942 Ernst Mayr published notes from a lecture series in his book *Systematics and the Origin of Species from the Viewpoint of a Zoologis*t. Considered a complement to Huxley's *Evolution: The Modern Synthesis*, Mayr lays out his biological species concept, which informed working assumptions of biologists in all fields.

1943 With a goal to address the *"rising tide of discontent with which the geneticist and cytologist view the systematist's concept of species,"* Wendell Holmes Camp and Charles Louis Gilly published "The Structure and Origin of Species" in *Brittonia* (vol 4: 323-385), in which they coined the term **biosystematy**, a term that morphed into the word **biosystematics**. From their text: *"The systematist has long recognized that many populations are diverse - that some species are morphologically homogeneous, while others are quite variable. Biosystematy seeks to explain the causes of these differences in the structre of species and so permit them to be arranged in a functional nomenclatural system,"* and, later in the article: *"biosystematy seeks (1) to delimit the natural biotic units and (2) to apply to these units a system of nomenclature adequate to the task of conveying precise information regard ing their defined limits, relationships, variability, and dynamic structure."* (p. 327) [For more information on both the contemporary criticdl assessments and historical significance of the Camp and Gilly publication, see also: Kim Kleinman, 2009. Biosystematics and the Origin of Species: Edgar Anderson, W. H. Camp, and the Evolutionary Synthesis" Transactions of the American Philosophical Society, New Series, Vol. 99(1), in *Descended from Darwin: Insights into the History of Evolutionary Studies, 1900-1970,* pp. 73-91.
Stable URL: https://www.jstor.org/stable/27757425

1944 Chinese botanists reported discovery of living specimens of dawn redwood (*Metasequoia glyptostroboides*.) The tree hitherto had been known only from fossil material that was at least 20 million years old. (Rupp, 1990)

1948 John Hutchinson published *British Flowering Plants*, which updated and his Families of flowering plants, which was based on 22 principles. Lawrence (1951) simplified them as:

1. *Evolution is both upwards and downwards, the former tending toward preservation... and the latter to their reduction and suppression of characters.*
2. *Evolution does not necessarily involve all organs at the same time...*
3. *Broadly speaking, trees and shrubs are more primitive than herbs in any one family or genus...*

4. *Trees and shrubs are older than climbers in any one family or genus.*

5. *Perennials are older than biennials and annuals…*

6. *Aquatic flowering plants are derived from terrestrial ancestors, and epiphytes, saprophytes, and parasites are more recent than plants of normal habit…*

7. *Dicotyledons are more primitive than monocots.*

8. *Spiral arrangement is more primitive than cyclic.*

9. *Simple leaves are usually more primitive than compound leaves.*

10. *Unisexual flowers are more advanced than bisexual; dioecious plants are more recent than monoecious.*

11. *The solitary flower is more primitive than the inflorescence…*

12. *Aestivation types are evolved from contorted to imbricate to valvate.*

13. *Apetalous flowers are derived from petaliferous flowers.*

14. *Polypetaly is more primitive than gamopetaly*

15. *Actonomorphy is ore primitive than zygomorphy.*

16. *Hypogyny is usually more primitive than perigyny, and epigyny is the most advanced.*

17. *Apocarpy is more primitive than syncarpy.*

18. *A gynoecium of many pistils preceded one of few pistils.*

19. *Seeds with endosperm and small embryo are older than seeds without endosperm and a large embryo;…*

20. *Numerous stamens, in general, indicate greater primitiveness than does an androecium of a few stamens (except Malvaceae).*

21. *Separate anthers, in general, indicate greater primitiveness than does an androecium of either fused anthers or filaments.*

22. *Aggregate fruits are more highly evolved than single fruits; as a rule the capsule precedes the berry or drupe.*

1950 Willi Hennig, an entomologist, published his book *Grundzüge einer Theorie der phylogenetischen Systematik*, which is considered foundational in phylogenetic systematics, i.e. cladistics. The total impact of Hennig's book was delayed until 1966, when the text was published in English as *Phylogenetic Systematics*. From Hoch and Raven (1995): *'The most basic principles of Hennig's theory of cladistics include: 1) relationship is clearly defined in terms of recency of common ancestry; 2) relationship is detected by means of shared derived characters (synapomorphies) in which are homologies that characterize monophyletic groups; 3) relationships and character distributions can be expressed in dichotomous branching diagram (cladograms); and 4) only natural*

groups, defined by synapomorphies to be monophyletic (i.e. descended from a common ancestor), are to be admitted into Linnaean classification schemes."

1973 Over a decade, Gottlieb and collaborators refined interpretation of isozyme information detected from enzyme electrophoroesis to establish ideas as to evolutionary timelines. *"The paper by Gottlieb* ("Genetic differentiation, sympatric speciation and the origin of a diploid species of *Stephanomeria*." Amer. J. Bot. 60: 545-553) *should be required reading for graduate students in plant systematics, because it is an excellent example of how to apply isozymic data to studies of speciation."* Quotation and Information from: Daniel J. Crawford, 2000. "Plant Macromolecular Systematics in the Past 50 Years: One View" Taxon, 49(3): 479-501 Stable URL: https://www.jstor.org/stable/1224345

1981 So what is considered a plant? Zoologist Thomas Cavalier-Smith introduced the sub-Kingdom Viridaeplantae, which might be equivalent to Plantae, or Chlorobionta. In this organizational sense, the term plant includes green algae, most especially the Charophytes.... Quotation from http://palaeos.com/Eukarya/Eukarya.html Palaeos.com, 20 December 2010: *"Prof. Cavalier-Smith of Oxford University has produced a large body of work which is well regarded. Still, he is controversial in a way that is a bit difficult to describe. The issue may be one of writing style. Cavalier-Smith has a tendency to make pronouncements where others would use declarative sentences, to use declarative sentences where others would express an opinion, and to express opinions where angels would fear to tread. In addition, he can sound arrogant, reactionary, and even perverse. On the other [hand], he has a long history of being right when everyone else was wrong. To our way of thinking, all of this is overshadowed by one incomparable virtue: the fact that he will grapple with the details. This makes for very long, very complex papers and causes all manner of dark murmuring, tearing of hair, and gnashing of teeth among those tasked with trying to explain his views of early life... Nevertheless, he deals with all of the relevant facts."*

1985 Rolf Dahlgren and K. Bremer cooperated to generate "the first computer-based analysis (using PAUP) of the angiosperms," which was published in the first volume of the new journal, *Cladistics*. The tree structure generated did not long stand, as new algorithms were quickly developed and computer technology progressively improved.

1994 David Nobel (a national park staff member) discovered a stand of unusual trees in Wollemi National Park within 200 kilometers of Sydney, Australia. The trees were judged to represent an entirely new genus and species, *Wollemia nobilis*, in the Araucariaceae (the monkey-puzzle tree family).

1998 Publication of the first paper through the: Angiosperm Phylogeny Group "An ordinal classification for the families of flowering plants", Annals of the Missouri Botanical Garden, 85 (4): 531–553, doi:10.2307/2992015, JSTOR 2992015

1998 One fallout of a meeting held at Harvard University was establishment of a committee dedicated to Phylogenetic No-

menclature, to devise a PhyloCode. Version 4c of the evolving PhyloCode, 2010, can be found on the internet, searching: https://www.ohio.edu/phylocode/PhyloCode4c.pdf

2004 In 1960, the International Organization of Biosystematics was organized at meeting of International Committee for Biosystematic Terminology, a Committee of the International Association for Plant Taxonomy (IAPT). The organization became fully independent in 1983, and following a symposium, 2004, in Valencia (Spain), reverted as an interest group of IAPT. In the same year, in Paris, the International Society for Phylogenetic Nomenclature was established at the First International Phylogenetic Nomenclature Meeting. (*Taxon*, November, 2004) Thus, 2004 has been selected as the year in which Biosystematics perished as a field of study.

2009 Publication of Pollination Biology of Basal Angiosperms (ANITA GRADE), by Leonard B. Thien, Peter Bernhardt, Margaret S. Devall, Zhi-duan Chen, Yi-bo Luo, Jian-Hua Fan, Liang-Chen Yuan, and Joseph H. Williams (American Journal of Botany 96(1): 166–182.) The paper defines characteristics of basal Angiosperms (their first three phylogenetic branches) which share similarities in pollination and chemistry: *"Floral odors, floral thermogenesis (a resource), and colored tepals attract insects in deceit-based pollination syndromes throughout the first three branches of the phylogenetic tree."*

2009 John Wilkins' *Species: A History of the Idea*

Some articles to explore:

Locy, William A. 1921. "The Earliest Printed Illustrations of Natural History," *The Scientific Monthly*, 13 (3):238-258 Available on JSTOR

Questions & Thoughts About Botanical History in Cultural Context

Exploring the TimeLine for better understanding of botanical history can be entertaining, but necessarily lacks context. Entries jump from item to item, which is what a timeline does. That format, however, necessarily teases morsels, mines jewels from an expansive cultural milieu, the greater picture in which the item of interest is likely of little import. For my own understanding, I decided to create a story that incorporates the broader circumstances in which understanding of plants emerged. This personal digging made me acutely aware that new realizations in botanical science are a product of their times; the larger world was busy with more pressing issues.

Historically, not too many people have been focused on understanding plants. In fact, most questions were not even asked until there was some reason for issues to surface. We see, in fact, that it takes a particular genius to ask questions that are not ready to be posed, persistence to pursue lines of inquiry that do not seem of particular interest to others in the field, and belief in the value of the contribution (despite the pressure of a *status quo*). Botany has benefitted from bouts of genius, but most advances have come when new technologies and fresh perspectives from related fields were diligently introduced. Advances occurred as questions emerged.

The last point is the reason lack of context is a problem for TimeLines, and for histories of plant science generally. We tend to present growth in knowledge as saltational, with developments jumping from one heroic revelation to the next. But it doesn't really happen that way. Growth in understanding oozes along, like lava. New ideas and realizations burn hot at some points, losing their calor eventually. Concepts (like Mendelian genetics) may be immortalized through occasional moments of crystallization when a new impression seems fixed. But that fresh conviction, so pure and simple, slowly melts back into the thick swirl, an important advance, but with definity no longer absolute. The embedded trail of concretion marks episodic ebbs and flows in corrugated patterns, making the very moment of gain difficult to score. Just as new realizations are seldom instantaneous, the impact of an observation is seldom as delimited as the date it was recorded or announced. Given great heat and pressure, deep below the surface, occasional dia-

Calor, dolor, rubor, and tumor: Heat, pain, redness, and swelling. The four classical signs of inflammation, per Roman encyclopedist Celsus.

monds form, and harden amid the thousands of somewhat continuous veins of development. Historians (who already know the context) mine the diamonds, following veins. And they talk about those hard points to avoid being so nebulous; it would be impossible to deliver the entire mountain of rock. It is just too much debris, and ant it is destroyed by the digging. Not claiming to be an historian, I approach this exhumation as a field geologist. My goal in this discussion is to gain a better sense of the terrain, to lay out some ruble, hoping to capture a glimpse of the mountain from which botanical ore is extracted.

The ore and rubble I've collected addresses a simple question: ***What do we know about plants?***

The tools I used were other questions, picks and pry-bars, pans and screens:

- ***When and how did simple awareness and cultural use of plants develop into the current level of scientific understanding? Who was involved and what other concerns drove their discovery?***
- ***How and why did prevailing wisdom about plants shift over time?***
- ***How certain is our understanding?***
- ***What milestones are important, and why?***

Ancient Knowledge:

There can be little doubt that early humans regarded plants as critical for food and shelter, and increasingly must have realized plants are sources of useful natural products, such as fuel, fiber, tools, medicines, stimulants, flavorings, and dyes. Though anthropologists and archaeologists will argue over timing and roles of agriculture in civilization, the importance of plants to evolving human society can't be denied.

Working Knowledge. In that history, humans have always understood plants at a profoundly functional level, as non-academic daily users. Around the globe, people knew the qualities of wood, which woods could be fashioned into tools, which would support the best fires, which might have musical qualities. They pulled and chewed on things, which becomes evident when anatomists and anthropologists study human teeth and implements to consider the nature of paleo diets,

Christian Tryon, Briana Pobiner, & Rhonda Kauffman, 2010. Archaeology and Human Evolution, in *Evo Edu Outreach* 3:377–386 (DOI 10.1007/s12052-010-0246-9), 20 July 2010, Springer Science

and it remains obvious that selection of fruit and seed (especially grains) shaped human consumption and industry over millennia. Despite realities that water might be the only liquid required for human metabolism, every society has adopted, and even become addicted to particular beverages, practically all of which are plant products. And at a near subliminal level, the mere smell, sight, and feel of plants are natu-

ral and comforting. E. O. Wilson applies the term *biophilia* to this sensibility.

Early plant knowledge is keyed therefore into development of civilization, tied into how people communicated among themselves and how they worked together to build and pass down a knowledge base. My assumption is that people treasured what was of value, which means we should expect early plant knowledge to be 'applied' - based on its usefulness.

It is abundantly clear that ancient people were not oblivious to basic plant science; that idea would paint a bleak picture of our ancestors as unknowing and lacking curiosity. So what is the story? *What can we imagine humans knew about plants during most of the last 100,000 years (500,000+ generations)?*

A lot, I believe. People knew plants are seasonal resources, recognition that led to collecting and hoarding seed, dried fruit, roots, and vegetation, as is evident from archaeological middens that document stores of plant products, troves that existed because plants were valued.

And for millennia, people practiced crop management. Clearly, humans have long-understood which seed were worth gathering or cultivating, when the time was right to harvest, and how to plant the best of those seed for future crops. Aztecs and Mayans selected and processed maize (corn) so actively that modern researchers puzzled for decades over the ancestry of modern corn. The same is true of Eurasian wheat, as well as fiber plants such as Egyptian cotton and Mesopotamian flax.

This means humans understood what was of agricultural value, as well as when and where to plant. Lessons from agricultural life transferred to culture and language.

> *"The kingdom of heaven is like to a grain of mustard seed, which a man took, and sowed in his field: Which indeed is the least of all seeds; but when it is grown, it is the greatest among herbs..."* Matthew
>
> *"If you want to know the taste of a pear, you must change the pear by eating it yourself. If you want to know the theory and methods of revolution, you must take part in revolution. All genuine knowledge originates in direct experience."* Mao

It also means people had rudimentary appreciation for reproduction and inheritance; the parallels to human biology were obvious:

A good tree brings forth good fruit; an apple never falls far from the tree... (https://bijlmakers.com/agriculture/fruit-provers-and-quotes)

People understood plants had fleshy and fibrous components, and could be sources of extracts and flavoring. Sugar was a spice, valued for its sweetness. When concentrated in dried fruit and saps, foodstuffs could be stored against spoilage. And around the world it was obvious that sweet and fleshy plants could be fermented. No textbooks detailed the chemical nature of sugar or ethanol, but early societies appreciated that fermented beverages could be warehoused for many benefits. People also knew the taste of acids, from wine vinegars

and tartaric acid precipitating on facets of vats, to sorrels and other herbs foraged directly from the wild.

North Africans were aware that pollen (dust, or farina) and fruit are produced on separate date palm trees, and a greater crop of fruit can be had by sprinkling pollen onto the flowers of productive trees. This wisdom is commonly cited in historical texts, but authors never mention the level of technical know-how required, that someone had to know enough about flowering of palms to relate the method, or have been successful in producing fruit. It isn't so simple as imagined (see: Howladar et al, *Receptivity of Female Inflorescence in Major Date Palm Cultivars of Saudi Arabia*, International Journal of Science and technology t(7): 328-330.)

Some ancient innovator realized that flax stems could be rotted (retted) to the point that the remaining clean, resilient fibers are the raw material of linen. Other techniques were applied or developed to spin those flax bast fibers into thread, which was woven to cloth, finding a recycled life as paper. Need for fibers was satisfied in other cultures through exploiting mulberry bark (Asia), agave leaves (Mesoamerica), papyrus (Egypt), banana (Manila hemp), marijuana (Indochina), etc. Lacking the basic knowledge to develop such technologies, there would have been no rope for ships, no wrapping for mummies, no paper for scrolls.

Asian farmers developed techniques for planting rice in paddies, keenly aware of germination, growth patterns, and harvest, understanding there are benefits to paddy culture without the need for lessons in nitrogen fixation. Ancient Chinese gardeners and herbalists recorded substantial understanding of plants, especially regarding selection of new forms from the wild. They knew that grafting or rooting a plant (vegetative propagation) would clone a desirable plant, while planting seed would present fresh variation from which to select new characteristics.

What was known of plants for thousands of years came through exploration of food sources, cultivation of crops, production of useful goods dependent on plants, and even selection of plants for horticultural value. Scholars call this empirical knowledge, real working understanding gained and reenforced through practical experience, and passed down as intelligence through successive generations. In China especially, substantial knowledge was committed to written text. A few records were also made of western farming. For confirmation of knowledge Roman landowners harbored on farming, read Varro's *de Re Rustica* (circa 37 BCE) available in translation by Bill Thayer:
http://penelope.uchicago.edu/Thayer/E/Roman/Texts/Varro/de_Re_Rustica/home.html

Whether written or not, knowledge was passed down and expanded. Someone in every community must have known what could be consumed raw, what benefited from being treated or cooked, and how to preserve and protect resources such as seed, fruit, leaves, stems, roots, and extracts.

The Known and Unknown….. What did people **not know** about plants? Until the close of the 17th century, no-

body had a suspicion that plants are made of cells. The first cell was described in 1665 by Robert Hooke, and it would be another century before we reached a level of microscopy and experience to appreciate that cells are the organizational basis for living beings. People knew about sexual reproduction, but even that perception was highly skewed. I mean, how did sperm (incubated in the mother) become a person? And though much terminology surrounding birth relates to plants (the seed of Abraham), nobody thought plants produced seed through a sexual process analogous to human procreation. Even Theophrastus' astonishing reports that palm pollen could be employed to increase date production treated the exercise as a sacrament, and carried no understanding this was what we now call pollination, or was related to fertilization and sexual reproduction.

People had hardly any idea as to plant chemistry. Elements, as any 3rd grade student would name them today, did not exist. Ancient ideas of elements revolved around earth, air, fire, and water, and in classical Greek culture they related to each other like a wonderful game of rocks, paper, and scissors. Earth was the solid stuff, and it all wanted to regroup - solid things fell to Earth - a perfect sphere at the center of the cosmos. Water covered earth. Air, ether, formed an outer springy but weightless sphere, and fire sought to rise. Plants were cold and wet, tied to earth. There was no thought that living plants interacted with air, or with fire (sunlight).

What was Recorded as Known? Westerners (Europeans) imagined we inhabit a given, orderly world. On Earth, humans presided, owning a godlike animation. Animals are subservient to humans, sentient but non-rational. Plants, though alive, are non-sentient, lower in the natural order. Rocks and minerals are dead last in commanding respect - neither living nor sentient. Animals, plants, and earth existed to serve humans, though it has never been quite clear why humans exist. Our only assigned tasks were to procreate, take dominion , and give names to things.

That basic Western hierarchy, supported by the elements (earth, air, fire, and water), could be described in equilibrium as a balance of humors: hot or cold, wet or dry. Humans came to be considered phlegmatic, choleric, sanguine, or melancholic based on their own native balance. Along with humans, animals and plants were corporeal, made of flesh and bodily fluids in their own particular balance:

Sanguine: Air, warm and moist
Choleric: Fire, warm and dry
Melancholic: Earth, dry and cool
Sanguine: Water, cool and moist

Living beings grew and developed, prospered and suffered, acted independently, and reproduced themselves. And all life, plants, animals, humans..., shared death - ashes to ashes, dust to dust, the body eventually abandoned to the mineral realm of Earth. Nature, when amenable, was ordered and balanced.

Classically-oriented western culture was top-down. Even logic was ruled by presiding thoughts, from which the details

could be deduced. That means Aristotle and Theophrastus, who were about the only Europeans documented as having much to say about the nature of plants for two thousand years, dealt in speculation - syllogisms that work well in math, but are not as water-tight when considering plants and animals.

Philosophically, further understanding was vain. With functional needs met through hands-on trade knowledge (even apprenticeship), additional explanation was neither useful, nor possible. Being smart, curious, and inventive were crucial practical technical skills that did not demand literacy. Lessons learned were transmitted through work, but such trade secrets might never have been recorded. These were among practical limits in exploring "why" questions.

In the East researchers continue to explore the surprisingly extensive archive of writings related to crop production and even horticultural selection and garden building. Those writings, especially the dibao (official gazettes, or bulletins), which began about 1500 years ago, give details of life in China that paint a much clearer picture of planned management based on working knowledge. And records exist that extend that timeline another 1500 years, well before the time of Aristotle and Theophrastus.

Philosophically, the Asian equivalent to western classical approaches would be works ascribed to Confucius, a record that is much more original and intact than Greek writings, and has been consistently available in Chinese culture over more than two millennia. And Confucius is not the entire story; other traditions and writings expand appreciation as to what was known. The most important issue regarding early Chinese knowledge, I believe, is to ignore claims about social and philosophical constructs we want to call Science, and consider the nature of straightforward working knowledge, much of which has been examined and is available as volume 6 of Needham's *Science and Civilization in China*. Topics are examined in six parts, published between 1985 and 2015, constituting a far greater record of knowledge than would even be possible for Western cultures. As time allows, I hope to plunder that wealth of information to provide a more balanced concept of ancient knowledge than one will encounter in typical Western-oriented histories. For an introduction, see: https://plato.stanford.edu/entries/chinese-phil-science/

Culturally, however, the "why" was unimportant in every ancient world. There was no need for greater understanding as to how or why plants make wood or generate fruit and seed (the province of plant sciences today) because society had ready answers to those more existential questions. All ancient societies (the West included) knew their worlds originated through divine means; each holding its own powerful creation story and societal traditions that hold sway even today. It might even have been considered thankless to speculate why things happen. Regardless, it is obvious early civilizations had real botanical understanding, informed through the technological gains of agriculture, industry, and medical traditions.

Modern science (what we know about nature and the physical world today, and how we know it) was born, necessarily, through departure from traditional belief systems, a break that occurred integral with globalization, imperialism, and industrialization. The forces that drove urbanization and globalism produced new concentrations of wealth, some of which were used to patronize arts and sciences. Thus, the basis for new developments in plant study (and all sciences) was seeded at the cross-roads of Mediterranean, Arabic, Asian, and Northern European culture, and germinated in the period we call the Renaissance - an arts term suggesting re-birth, or re-flowering.

Technically and scientifically, however, this was not warmed-over culture; it wasn't a re: anything. Science as we approach it today emerged as something very new. In every regard, the wisdom of ancient worlds would be swept away between 1450 and 1900, as technology formed the rocky base for today's world culture, with science as the new orthodoxy - challenging fundamentalist concepts of truth.

1450➛1550

The break - the beginning of independence of scientific knowledge from cultural lore&more - began, I believe, with wholesale availability of information through printing based on Latin-based languages with fixed, limited alphabets. Ready exchange of knowledge is the scaffold of scientific advance, and movable, easily re-usable type wrote the revolution of information technology that continues to gain momentum.

By 1500, curiosity as to the nature and inner workings of plants gained traction, and would be informed, gradually, through observation and experimentation. The emerging interest had roots in Spain and Italy, but German introduction of printing expanded the conversation, fostering:

- examination of libraries for ancient knowledge (especially *materia medica*),
- rapid growth of literacy that made "how to" publications more readily available,
- religious reformation which invited questioning of ancient wisdom,
- excitement of world discovery and realization that other lands held their own useful plants,
- growth of imperialism to scarf up natural resources, and emerging mechanics that would lead to industrialization.

Dreams and vision, possibilities, spiraled away from ancient cycles of knowledge renewal, an breakout that spawned today's world culture of science and technology.

"... establishment, during the second half of the century [15th], of scores of printshops relates to two notable feature of European, especially western European, society at the time. The first is the fairly high rate of literacy on which the market for books and pamphlets was based. The second is the quite sudden wide availability of a multitude of philosophical and other intellectual options. Together, these two features created a situation in which knowledge for many people was no longer chained to the texts of the university curriculum. This was a new situation practically without parallel." Peter Dear, 2009

Fallouts of increasing information availability between 1450 and 1550 include:

- *Printing of ancient manuscripts, such as Aristotle, Theophrastus, Cato (*de Agri Cultura*, printed 1472), Columella (*de Re Rustica*, first complete printing 1472 http://penelope.uchicago.edu/Thayer/E/Roman/Texts/Columella/de_Re_Rustica/2*.html. You might also read Varro: http://penelope.uchicago.edu/Thayer/E/Roman/Texts/Varro/de_Re_Rustica/home.html), and Dioscorides (*de Materia Medica*, 1478 and onward)*
- *Challenges to traditional doctrine through mass publication of Martin Luther's 1517* Disputation.. *heralding the Reformation.*
- *Creation of new knowledge, particularly the first German herbals, beginning with the many revisions and printings of* Ortus Sanitatus *and, by 1530 and 1544, significantly improved with the herbals of Brunfels and Fuch. By 1544, Mattioli had produced his Italian translation of Dioscorides. These kinds of works established plant recognition in various languages, initiating the first botanic gardens and study of botany as an independent discipline.*
- *Andreas Vesalius's 1543 publication of his spectacular treatise on human anatomy,* De humani corporis fabrica libri septem; in the same year *Copernicus 's* De revolutionibus orbium coelestium was printed.
- *Production of printed books of secrets, compendia of potions, elixirs, ointments, and balms said to cure almost every known ailment and rid fabrics of stains, popular publications authored by "emperics" - people who stressed they had learned their craft emperically (gained by personal observation and experience), through travel, contacts with practitioners, and personal trial and experience. Prominent among emperical authors were Alessio Piemontese and Giambattista Della Porta. Piemontese's* Secreti del reverendo donno Alessio piemontese *(1555) and Della Porta's Magi naturalis (1558) went through scores of editions and translations, retaining some prominence for two centuries.*

Compounding the capacity for greater dialogue were European voyages of discovery from 1488 to 1499. Bartolomeu Dias and crew established a sea route around the southern cape of Africa, having been the first European explorers to land at the Cape of Good Hope. Columbus completed the first of several voyages in 1493, establishing on-going contact with a world wholly new to Europeans. In 1499 de Gama returned to Portugal, completing his 2-year voyage that (in fractured stages) opened trade with India through a sea route around the Cape of Africa.

1550➛1650

Over the next century (1550 to 1650), the impacts of plant introductions from Asia and the Americas became increasing objects of imperialism, leading to establishment of trading companies and control over raw materials. Coffee, tea, chocolate, tobacco, and sugar were established as major commodities and cultural addictions. Inventories of new plants and products surpassed the traditional realm of *materia medica* and scholarly herbals were challenged to list and describe the new bounty of plant diversity. Simples would soon become outdated with professionalization of apothecaries, and chemical experiments (the pursuit of alchemy) began to yield results in characterizing materials that were not simply related to astrology, false cures, and pipe dreams (such as transforming materials to gold). Shakespeare flourished in the English vernacular, and real science was becoming untethered from Latin. But perhaps most importantly, Francis Bacon, denouncing the top-down logic of Aristotelians while embracing the value of applied experiment, crystallized his program for evidence-based, replicable approaches to science.

"This emerging sense that the world was large, and largely unknown, was not, therefore purely a matter of philosophy..

[the] considerable variety of intellectual options, closely associated with the new technology of printing, meant that Europe...was preparing itself for a battle over intellectual authority of epic proportions.

...It became harder and harder to identify an ancient orthodoxy to be restored. Ancient texts continued to be enormously important resources, but they were no longer signposts to a past golden age."

Peter Dear, 2009

Some items in the TimeLines include:

- *1569 Mercator introduced his world map and a system of map projections that improved documenting and use of trade routes.*
- *1574-1477 Monardes'* Joyfull Newes... *was published in Spanish, Latin, and then English.*
- *1581-1646 The existence and nature of magnetic fields and electricity received their first analytical attention.*
- *1583 Cesalpino published* de Plants libri*, the first statement on general botany since classical texts attributed to Theophrastus.*
- *1601-1603 The British East India Company and the Dutch East India Company were established.*
- *1602 By this date, Shakespeare had written* Hamlet*, which was published in the 1603* 1st Quarto.

- *1610 Galileo published* Sidereus Nuncius, *evidencing strong support for heliocentrism (which describes the Sun as the center of our solar system.) Galileo also provided an early microscope to his associates. His conviction of heresy in 1633 is, perhaps, the best known case tried during the Roman Inquisition.*

- *1620 Francis Bacon published* Novum Organum Scientarium *(his new method of scientific discovery and explanation), followed in 1627 by* New Atlantis*, which proposed a society that systematizes and glorifies the search for objective knowledge. Bacon's life ended ignominiously, but his ideas were sympathetic with Puritan and Interregnum ethics that changed England by mid-century.*

- *1648 van Helmont, a prominent early chemist (who introduced study of gases), reported his trials of increase in mass of a willow tree.*

1650➛1750

One could decide that Francis Bacon's *Novum Organum Scientarium* constitutes the beginning of contemporary science, due to his insistence on building a new foundation for understanding the workings of nature. Or, one could claim an actual beginning would be the founding of England's Royal Society, chartered in 1660, shortly after Restoration of England's monarchy. Following many of Bacon's goals, the Society established a process of reporting and review of experiments and discoveries. Those reports (*Philosophical Transactions…*) became a crucial record of accomplishment and priority, as well as a centralized authority establishing priority of discovery and serving much of Europe's growing scientific community. Scholars,by the end of the 17th century, abandoned any sense that God would disdain inquiry addressing the inner workings of living beings, as stated by John Ray: *"There are those who condemn the study of Experimental Philosophy as a mere inquisitiveness and denounce the passion for knowledge as a pursuit unpleasing to God, and so quench the zeal of the philosopher. As if Almighty God were jealous of the knowledge of men."* (1690, *Synopsis Britannicarum,* translated in C. Raven, 2009, pg 251)

Experiments and publications supported by the Royal Society underpin evolving understanding of cells, cell biology, and eventually molecular biology that led to our understanding that plants are alive in many of the same ways in which animals live. The first intimation of cellular structure was published by Robert Hooke, in his description (1665) of the structure of cork (the bark of *Quercus suber*) as seen through his handsome, yet primitively simple, microscope. Very shortly after Hooke's publication, botanists Marcello Malpighi (Italy) and Nehemiah Grew (England) produced descriptions of plant anatomy, descriptions that held forth for more than 100 years, and ideas that were not hugely advanced until the 19th century (see *Cells as the Basis of Life*, at the beginning of this Footsteps Section.)

The ability to see finer detail was not a lone improvement; researchers were also increasingly able to define processes more precisely through time. Following up on concepts and proto-

types developed by Galileo, Christiaan Huygens worked with clockmaker Salomon Coster to develop a pendulum clock. Minute-hands became common as mechanical clocks were developed that could keep time to an accuracy of within 15 seconds a day. Fahrenheit developed and introduced the first research-grade thermometers in 1714, followed by Celsius's centigrade scale in 1742. Steady improvement of instrumentation (technology) would come to define science as data-driven.

People involved in developments in pneumatics, fledging organic chemistry, human anatomy, and lead-up to the industrial revolution often included plants in their studies, which contributed significantly to understanding. Robert Boyle had turned his attention to botany briefly, but powerfully enough to explain that plant biomass is mostly water. Isaac Newton's *Principia* and *Opticks* represented incredible advances in understanding of physical principles that rule our world, expressing gravity in mathematical formula and deconstructing white light to colors of the rainbow. And by 1727, Stephen Hales had traced the flow of water through plants, describing transpiration and proposing that air somehow becomes part of plant tissues.

Importantly, stoked by caffeine from popularization of coffee, tea, and chocolate, Europeans were a bit more sober and alert to matters of the world, a world that had become yet more global with the first reported European landings in Australia.

The work of Caspar and Jean Bauhin had brought increased order to the growing list of plants and plant names, and John Ray treated his regional flora in a strikingly modern (non-herbal) manner. Suggestions by Nehemiah Grew that pollen was the male generative line were confirmed through experimentation by Camerarius, published in 1694. That explanation provided the rationale on which Linnaeus constructed his famous sexual system, a classification scheme developed during three years of study in Holland (beginning in 1735). His methods, which came to full expression in 1753 as *Species Plantarum*, established the foundation of plant scientific nomenclature, while his classification system became one of the great dead-ends of the era.

A few notable events:

- *1651 After decades of delay, Hernandez's* Rerum medicarum Novae Hispaniae... *was published through efforts of the Linceans (a society in which Galileo was active).*
- *1662 London's Royal Society was chartered, and began supporting research and authorship of scientific works. Notable investigators included Evelyn (trees and forestry), Boyle (pneumatics), Hooker, Grew, and Malpighi (microscopy and anatomy), and Newton (Planetary motion, Gravity, and Light).*
- *1694 Camerarius expounded on the sexual nature of plants.*
- *1727 Stephen Hales applied experimental methodologies to plants, initiating the study of plant physiology.*
- *1731 Alexander Pope opined on the genius of a place.*

- *1737 Elizabeth Blackwell's* Curious Herbal *constituted a final significant contribution to three centuries of the European herbal tradition. Linnaeus published the first edition of* Genera Plantarum*, as well as* Hortus Cliffortianus.

1750➛1850

Between 1750 and 1850, science was increasingly professionalized, with discovery growingly centered at institutions, such as universities , museums ,and botanical gardens. Imperialism and globalization reached new heights of importance and influence, with botanist Joseph Banks succeeding Hans Sloane in dominating English plant discovery and the Jussieu clan presiding in France. While Sloane had been interested in medical benefits, Banks and botany shifted emphasis to natural resources and economic value, geared to the wheels of industrial revolution. Similarly, Linnaeus's "artificial" way of classifying plants was quickly eclipsed by appreciation of more natural systemization (evolving in Paris).

Sent by Banks to Australia, geographic floristics instigated by Robert Brown gave substance to the incipient field of plant biogeography. Biodiversity, now viewed as boundless, could be cataloged, understood, and plundered. The world of plant study became broader, richer in species, and infinitely more complex. Interest in cartography and atmospherics led to the work of Alexander von Humboldt, who collected data and applied metrics (using the newly-adopted metric system) to environments, giving birth to field ecology. Consequently, climate, topography, and soils were seen to hold much greater importance than previously understood; even built landscapes assumed new connectivity to nature, as had been expressed by Alexander Pope in reference to *genius loci*.

Microscopy advanced, allowing observation of structure and generation of cells, and forcing cross-disciplinary studies as researchers came to realize plant and animal cells share components, character, and activity. Biology emerged as the unified study of life in the light of cell theory.

Plant physiology, initiated by Hales' work in 1727, acquired data-driven, laboratory-based trappings inspired by explanations of the composition of air and water, Ingenhousz's explanation that plants generate oxygen in sunlight, naming and characterization of elements fostered through Lavoisier's methods, and redefinition of elements and compounds through the work of John Dalton. Saussure had conducted studies indicating the atmosphere is the source of carbon in plants. They were all using the newly established shorthand for recently-discovered elements… C HOPKNS CaFe was possible, but not quite yet appreciated.

Applied studies in agriculture and soil nutrition, initiated in the work of Humphrey Davies, took off through concentrated studies in Justin von Liebig's laboratory. By 1850, both the humus theory (plants generate new organic matter through input of humus from the soil) and vitalism (the concept that only living beings can synthesize organic compounds) were history.

- *1756 Black generated "fixed" air, i.e. carbon dioxide.*
- *1774 Steam power, harnessed for driving machinery (the work of Watt and others,) underpinned the emerging Industrial Revolution.*
- *1776 Priestley demonstrated that plants have restorative power, converting air to a flammable (oxygenated) state*
- *1776 Adam Smith provided a philosophical mantle of moral good for the capitalism inherent with Imperialism and Industrialization.*
- *1779 In his E*xperiments upon vegetables*, Jean Ingenhousz demonstrated that plants produce oxygen in sunlight and carbon dioxide in darkness.*
- *1780 Luigi Galvani captured great public attention in demonstrating that electrical sparks cause muscle movement.*
- *1789 In Paris, the French Revolution moved forward as de Jussieu's* Genera Plantarum *was published*
- *1798 Malthus reasoned that resources imposed limits on population growth.*
- *1800 Alessandro Volta introduced his first battery.*
- *1802 Gay-Lussac explained that gas pressure rises with pressure in an closed chamber .*
- *1804 de Saussure conducted the earliest thorough experiments in plant physiology and nutrition, demonstrating that carbon from the atmosphere becomes fixed as carbon in plant sugars and other organic compounds.*
- *1804 John Dalton restructured our understanding of the atomic nature and proportions of compounds.*
- *1805 Gay-Lussac and Humboldt met with Volta while traveling to study air pressure.*
- *1811 Avogadro determined that the same volume of two gases (at equivalent pressures) should have the same number of particles.*
- *1831 Faraday demonstrated functional principles of electromagnetic induction, the basis for electric generators and motors.*
- *1837 - Having published his* Principles of Geology*, and its support of uniformitarianism, Charles Lyell commented in a letter to William Whewell:* "If I had stated... the possibility of the introduction or origination of fresh species being a natural, in contradistinction to a miraculous process, I should have raised a host of prejudices against me, which are unfortunately opposed at every step to any philosopher who attempts to address the public on these mysterious subjects"
- *1845 The Irish Potato Famine*

1854 Tennyson
"...Theirs not to reason why,
Theirs but to do and die..."
The Charge of the Light Brigade
A reading by the author was recorded in 1890 in Edison wax cylinders.

1850➛1900

Scientists (who could now be recorded in photographs) increasingly held a modern understanding of plant diversity and biogeography, as well as cell biology and physiology. It was

now evident cells are ubiquitous, indeed cells define life. With the 1830-1833 publication of Lyell's *Principles of Geology* (3 volumes), the Earth was accepted as more ancient than suggested by Biblical numerologies; geological formations were known to have grown over long periods of time. People and products were moving along railways. These changes, momentous as they were, proved of similar pace to true revolutions in how we live and view life on Earth that would occur in the second half of the 19th century. Life was swept to a new frenzy.

Telegraphic connection was established between Paris and London in 1854, and in other metropolitan areas soon thereafter. Over the next four years, Lincoln would communicate through this electronic means with his Generals during America's Civil War. Organic chemistry had become an important discipline with Perkin's synthesis of mauve (the first aniline dye) in 1857 and the 1858 explanation that carbon atoms bond to create chains and complex macromolecules. Biologically, botanically, the most significant "idea" was evolution, introduced by Charles Darwin in his 1859 *Origin of Species*.... Darwin's rational, fully-supported explanation for how nature, inexorably, evolves as a world of the most fit claimed a population of plants or animals would shift in composition and character over generations because the most successful also generate the most offspring. His proposal necessitated we accept many ideas:

- life on Earth is very very ancient,
- the fossil record documents some kinds of organisms that have gone extinct,
- species are not fixed (their nature changes over time),
- variation occurs naturally in populations of living organisms
- a mode of inheritance conveys characteristics from one generation to the next
- the origins of newly evolved kinds of plants and animals have ancient roots.

Botanists knew much of this makes sense, and understood the implication that new species have arisen from ancestral species - over great periods of time. But thoughts had been nebulous; Darwin's clearly-written concept of evolution altered the fundamental meaning of a 'chain of life', which would become interpreted as a chain of descent, all species having descended from earlier ancestors. The fallout of this reasoning is that the ancestry of all existing flowering plants might be traced to some early kind, a plant that thrived in populations hundreds of millions of years ago. The unavoidable implications for plant systematics are that:

- plant species, though recognized by distinctive physical characteristics (morphology), are better defined based on reproductive behavior and population structure than physical characteristics alone;
- hierarchical categories (Phylum, Class, Order, Family, Genus, Species) should reflect historical patterns of origin and divergence; and

- the workings of heredity, soon to emerge as molecular biology/ cell biology, would become important for a field of study that had been purely descriptive.

The Origin also placed contemporary biology in opposition to church doctrine. Just as Copernicus, Galileo, and Kepler had forced reconsideration of Biblical fundamentals concerning the centrality of Earth, Evolution challenged literal interpretations of Creation. Since writings of Augustine, 1500 years earlier, the seven days of Creation had been viewed as contracted to a single instant - the living world we know was believed to have come into being as a single thought. Adam and Eve, and their progeny, were assigned a task to name creatures, a living bounty which was there for human use. It was ingratious, even forbidden, to question this gift; our assignment was to take dominion, to manage it all. (We have not done this very well.)

Moreover, questioning Darwin's synthesis remained viable because the genetic mechanism (the source of variability and control) was unknown. The cell nucleus had only been sighted in 1830 (by Robert Brown), and chromosomes were yet to be described.

But answers would emerge soon. At the very moment the greatest debate swirled around Darwin, Gregor Mendel and his fellow Brothers at St. Thomas's Abbey (Augustinian) in Brno were eating a lot of peas. Mendel's trials in hybridizing peas and recording the results were exhaustive - thousands of crosses made and marked, scored and tallied yielding a lot of shelled peas that were never wasted. Mendel realized that the likelihood of traits (such as plant stature, the color or texture of individual peas, or flower color) showing up in a population of plants could be predicted if you understood the parentage. He learned from an early experiment, for example, that a cross between flowers of a tall and a short plant would yield seed that all grow to be tall. However, seed from the following generation (when plants of the first generation are self-pollinated) yielded some plants that revert to the short stature - in a predictable ratio of one short to three tall plants. Not only did Mendel record the data; he did the math. https://www.lcps.org/cms/lib/VA01000195/Centricity/Domain/20718/7%20Science%20Workbook%20-%20Heredity.pdf

By the end of the 19th century, the biological world was ready for a new reality, which would be the understanding of genetic control over growth and inheritance. Pure and applied sciences had advanced in this and many other profound ways. But that growth cannot be disentangled from changes in industrial technology, which led to upheavals in all areas of life and culture. Electricity would begin to power lighting and new kinds of equipment, which meant research laboratories could operate at all hours and utilize a rapidly developing battery of of support and analytical equipment.

Development of petrol-powered engines, which began a century earlier, reached the point of practicality, which meant automobiles, trucks, tanks, ships, and new types of manufacturing would emerge. Bertha Ringer Benz (Karl Benz's spouse) made a spontaneous 104 kilometer drive in a newly-

built Benz Motorwagen (on 5 August 1888) from Mannheim to Pforzheim, reporting her successful arrival to Karl by telegram.

But it was not just Bertha who was empowered or labs that were electrified. At the turn of the century, scientists could record and publish images using photography, type research papers, and communicate live through telephone. They could travel between meetings by rail. Both x-rays and radio waves had been recently described, and we would soon enough explore structure smaller than could be seen through light microscopes, as well as realize the potential of energetic rays to cause mutation.

Dmitri Mendeleev and Julius Meyer had charted the elements in periodic tables (1869 and 1870), and researchers were busy filling in blanks. Industrial research labs were dedicated to uncovering the secrets of organic chemistry, based on new realization that carbon atoms link together to form macromolecules. The stage was set for the 20th century. Greek science was history and Pandora's box was open.

1900➛1950

Botanically, scientists understood that life is cellular, that cells give rise to new cells, and cell organelles (nuclei, chloroplasts, mitochondria) replicate themselves. In 1900, Mendel's work came to light in coordination with similarly-oriented studies by several research teams. Genetic understanding crystallized as dreams of Mendelian inheritance allowed researchers to make new sense of their own observations. Within three years, chromosomes were confirmed as the location of genes in cells, and by 1913 the first genes had been mapped. Genetics emerged as the most important new field of research in biology, and Thomas Hunt Morgan's group at New York's Columbia University was in the thick of it.

Just as the world of biology was re-invented based on Darwinian and Mendelian ideas, the Newtonian revolution in physical sciences yielded to Rutherford and Einstein. An atom was no longer the smallest imaginable unit of matter, while the light year and parsec would become the units by which we gauge the cosmos.

Orville and Wilbur Wright's first recorded flights were in 1903, and in 1913, Henry Ford's newly organized assembly line turned out 300,000 Model T cars. Suddenly, it seemed, high-end technology and cutting edge science were establishing strong centers west of the Atlantic Ocean.

But the remarkable kickstart in genetics, indeed much pure biological research, turned quiet as World War I struck the European centers of research. While technology and physical sciences moved ahead rapidly, the forces of biological discovery in the first half of the 20th century were disrupted through disaster and diaspora as scientists escaped (or not) the devastation of European conflicts. Labs and institutions were diverted to war effort, or even destroyed. The great Berlin herbarium suffered huge losses through Allied bombing

campaigns.

"On the night of 1-2 March 1943, an Allied bombing raid caused a devastating fire that swept through the herbarium of the Berlin Botanical Garden, destroying all material from many plant families..." Vorontsova, M. & S. Knapp, Taxon 59(5):1585

Amazingly though, progress was made in understanding plants during this demi-century (or perhaps demonic-century). Plant physiology advanced through:

- applied studies in pathology (with significant research into fungal activity and disease),
- crop improvement led USDA scientists Allard and Garner to initiate studies in the ways daylength controls plant growth and development,
- study of plant hormones came (Auxins by Wendt, 1926),
- suggestion by Gottlieb Haberlandt of potential for plant tissue culture with his 1902 publication "*Culturversuche mit isolierten Pflanzenzellen*" - an idea finally achieved three decades later in the independent work of Gautheret, Nobécourt, and White.
- various advances in cell biology, including discovery of mitochondria.

Biosystematics was born (see Clausen, Keck, and Heisey, 1948), combining cytology, ecology, pollination ecology, population biology, chemotaxonomy, and every other ology or otomy in order to appreciate the nature of plant species. Through these biological approaches, taxonomists hoped to shed light on how species evolved and organize plants so as to reflect their natural relationships.

Realization that plants and animals share biologies led to an obvious conclusion they also share ancestries. But that simple understanding was hard wrought. It was not until 1944, with work by numerous researchers during WWII that scientists accepted the reality that deoxyribonucleic acid (now called DNA) is the molecular basis for heredity. The code that allows us to relate sequences of nucleobases in DNA to the construction of proteins was not clearly explained until 1965.

1950➢ Recent

What has happened in my lifetime (I was born in 1950)? In the year of my birth, German entomologist Willi Hennig published his intense and arcane book, *Grundzüge einer Theorie der phylogenetischen Systematik*, establishing a new, comprehensive methodology for systematics. Eventually, botanists would adopt Hennig's ideas and vocabulary, as biosystematics gave way to phylogenetic systematics. Plant Systematists in 2020 would assume their goal is to organize the plant kingdom in a cladistic system reflecting the evolutionary origins and relationships of extant species. One result has been new understanding as to the origins of flowering plants (which Darwin called "an abominable mystery." See: W. E. Friedman, 2009. The meaning of Darwin's 'abominable mystery', *Am J Bot* 96(1) 5-21.)

Access to TEM (transmission electron microscopy) and SEM (scanning electron microscopy) gave researchers access to new levels of resolution. Traditional light microscopy had allowed exploration of cellular details at 1,000×, but the new techniques and technologies allowed resolution as great as 500,000×, and meant the cell and its components were revealed as more complexly organized and structured than had been imagined. Laissez faire concepts of organelles floating in a gel-like cytoplasm are replaced by highly detailed visions of a cytoskeleton made of microfilaments and microtubules, one that orchestrates the industrial complex that is a cell. And traditional ideas of animal vs. vegetable have blurred as all living cells seem to harbor components of previously free ranging microbes. Most significantly, the "endosymbiont" concept explains why mitochondria and chloroplasts have their own genetics and multiply somewhat independently of the mother ship (the cell they inhabit).

In the same vein, early ecological ideas that certain groups of plants host soil-borne fungi in symbiotic relationships have given way to realization that symbiosis is the rule rather than the exception. Smaller yet, in 1950, Myron Brakke (working in plant pathology at Brooklyn Botanic Garden) developed a centrifugation technique that became a standard tool in purifying virus samples. This refinement became important as work with viruses moved outside concern with pathologies, as the particular capabilities of virus became a tool for transferring genetic material.

So it is not possible to disentangle successes in phylogenetic studies or advances in agriculture and cytology from the biggest stories since 1950, which relate to the unfurling of DNA and seismic gains in scientific understanding as to how plants (indeed all living organisms) control their reproduction, growth, and development. Watson and Crick published their model for the structure of DNA in 1953, which meant that in short order scientists understood how linear sequences of nucleobases provide templates for constructing proteins and perpetuate themselves. That was monumental, but one is hard pressed to explain in a few sentences the importance of discoveries in genetics and cell biology, and the impact of new understanding and techniques.

Francis Bacon was on target in this area. He could not, of course, have predicted anything about current capabilities and possibilities in the many areas that have opened. What would have seemed confirming for Bacon is the direct relationship between research in genetics and application to medicine and industry. He believed that detailed trials and analysis should be the hallmark of science, which would then advance human capacity. In plant biology, techniques and understanding developed across the range of biology further our ability to explain how plants function. Recent botany/plant biology texts explain plant structure and biology in the context of genetic control (re: *Functional Biology of Plants*, 2012, Martin Hodson and John Bryant, Wiley-Blackwell), attempting to explain the molecular biology of development and control - the myr-

iad molecular events that take place in order for a plant to grow.

This is a new world, one in which humans can understand and manipulate the mechanisms that control plant life (in fact, all life). It is the world of techno-science, in which technologies drive our both our ability and desire to know.

Having the keys to the kingdom, what can be done? Of course, anyone will be aware of the debate over GMOs (OMG!), and the drivers behind genetic modification of major crops. Today, technicians can alter plant instructions (genetics) to alter resistance to disease and insects, which could mean crops can be cultivated with less need for pesticide applications. People can directly modify plant genetics to improve shelf-life, or flavor. Plants might be introduced with their own capacity to fix nitrogen, thus eliminating the need for use of certain fertilizers. Or plants can be invested with the power to generate useful chemicals, such as vitamins or medicines that could improve health.

This does not make the miracle of life any less astonishing; in fact we become increasingly aware of the richly integrated complexity that drives cells and organisms, reminiscent of sentiments in Robert Frost's poem *(Microscopic)*, quoted early in This *Reader*.

In Summary:

What is Science?

Contemporary thought positions science as apart from arts; contemporary politics position science as that antagonist to religion. Both concepts seem wrong to me. Modern science has little to do with classical knowing, what we call science today is the child of technology - having developed based on instrumentation, industrialization, and individualism.

Science is an act of human creativity, with the simple goal of explaining and exploiting living nature and the material world. By that reckoning, science is one of the arts, interpreting and expressing the world.

What do we know about plants today?

This is, of course, a very open-ended question, one that much of the *Reader* has been dedicated to addressing. But it's worthwhile attempting a simpler response, an annotated outline fleshing out basic understanding through addressing basic questions.

1.1. We know that plants share their most ancient origin with other living beings, an origin that manifests itself in the fundamental structure and function. *1.2.* Like other life forms, plants are cellular, building themselves through the choreography of cell division. *1.3.* Instructions guiding nature and timing of cell growth and development are conserved and passed down as genetic information in long DNA double helices. Sci-

entists have learned much about how those instructions work. *1.4.* Beginning in the late 20th Century, researchers have been able to alter an organism's genetic makeup, creating new forms of life.

2.1. Though a plant is built of millions, even trillions of cells, many of those cells are dead at functional maturity. *2.2.* Only the living cells carry on life processes, which require energy captured in chemical bonds, stored in a variety of compounds, and processed through precise and elaborate mechanisms. *2.3.* Only living cells can continue growth and development, growth that occurs at the tips, from points, and peripherally, along the edges. *2.4.* By that, I mean plants grow outward from a core, always conquering new territory. Vines creep and twine, trees tower and overarch, herbs mound, grasses run, bulbs cluster.... And, of course, only living cells can propagate new individuals.

2.5. Botanists still speak of plant growth as primary and secondary. Primary growth, characteristic of all plants, produces new stem, leaves, flowers, and fruit, as well as new roots through cell division in apical meristems - tip growth. *2.6.* Secondary growth varies in format, but basically results from development of thin layers of cells, usually call lateral meristems., that can produce layers of tissue.

3.1. In simplest terms, plants make three basic kinds of structures - roots, stems, and leaves. *3.2.* Roots (like stems) grow from points; many also develop secondary growth. But roots differ internally from stems. And they tend to grow down, responding to gravity, as well as other stimuli. *3.3.* Stems follow a similar pattern, exploring new territory from tips and (in many instances) able to produce thickening tissue through secondary growth.

3.4. Stems, however, show much greater structure and organization than roots. *3.5.* The growing tip, which archetypically started with an embryo, gives rise to the stems, leaves, and their many derivative structures; it "lays down" the mature plant framework through modular architecture, employing iterative, nodular growth.

3.6. The stem growing tip also makes the leaves, which means leaves are all primary growth. *3.7.* And there are countless different kinds of plant productions that are made by the growing tip similarly to the way in which normal green leaves are made. To a botanist, therefore, bracts, spines, sepals, petals, stamens, and pistils are simply specialized leaves.

4.1. We see, in plant roots, stems, and leaves, specializations, i.e. adaptations, that make them successful components of their native habitats, allowing plants live in so many different circumstances and co-exist with other organisms in many kinds of symbiotic, mutualistic, even destructive relationships. *4.2.* That success, of course, means plants must reproduce and distribute themselves effectively.

4.3. As soil science continues to expand understanding of biotic relationships between plants and other organisms, we appreciate the web of life that makes soil a biological complex necessary for plants to take in water and nutrients.

5.1. Today we can explain the physiological nature of plants and the ways they interact with the environment, from responses to environmental stimuli to the movement of water through tissues. *5.2.* Scientists have detailed how the power of sunlight is captured, converted to chemical energy, and utilized to drive every life process.

6.1. And researchers have a reasonable grasp on Earth's plant diversity, even how that diversity has evolved over hundreds of millions of years.

7.1. We understand there are significant similarities between plants and animals. They both:

- *7.1.a.* Utilize many of the same metabolic processes, such as respiration and conversion of simple sugars to starches, fats, and amino acids.
- *7.1.b.* Operate from genetic instructions coded in DNA and transcribed to proteins.
- *7.1.c.* Are mostly water.
- *7.1.d.* Evolve through similar processes.

7.2. On the other hand, plants and animals differ considerably. Plants:

- *7.2.a.* Generate cells that are immediately distinguishable from those of animals, with basically different mechanisms for dividing and for maintaining structure.
- *7.2.b.* Make fibrous and woody tissues that allow them to take on large 3-dimensional shapes, but they do not have bones.
- *7.2.c.* Move fluids (water, sap, sugar solutions), but there is no circulatory system, and certainly nothing like a heart.
- *7.2.d.* Sense and respond to environmental cues, but they do not have nervous systems. And they do not think or feel pain.
- *7.2.e.* Respire (in a chemical sense) and exchange gases with the atmosphere, but there is no system of lungs or mechanism for active breathing.
- *7.2.f.* Reproduce themselves and colonize areas in multitudinous ways, both differently and more variously than animals.
- *7.2.g.* Produce epidermal tissue very differently from that of our skin. And plant hairs (trichomes) are are cells, while animal hair is protein extrusion.
- *7.2.h.* "Make their own food" - which is to say: Plants make glucose and other sugars through capturing the energy of sunlight and using that energy to fix atmospheric carbon dioxide into carbohydrates.
- *7.2.i.* In general, plants disperse through pollination as well as fruit and seed production, while most animals are individually mobile.

- *7.2.j.* Plants are among life forms we call producers; they generate and elaborate fixed carbon which provides sustenance for many other life forms. Plants also create habitat and materials on which other life forms depend.

8.1. Prior to 1600, most understanding of plants was based on simple and practical agricultural experience along with steadily growing wild harvest of everything from timber to medicinal herbs. Cultural demand and economic exploitation drove discovery and advances in plant taxonomies.

8.2. Though there is no evidence for planned selection of crop plants, it is evident humans have actively improved important edible plants such as corn, wheat, and other grasses, as well as flax, cotton, and other fiber crops. This means people certainly appreciated plant variation and realized (at least in a rudimentary way) that like would yield like.

8.3. For future scientists, all areas of plant study are open for further investigation. Wonders do not cease; there remains much to be discovered and brought to service. Most importantly, time to make many discoveries is quickly vanishing as the natural world is imperiled through our own activity. The only hope for preserving some of that world rests in our capacity to learn more quickly and act on the truths revealed.

TimeLine:

c1,660 BCE - A Sumerian clay tablet (Nagpur) was inscribed with reference to about 250 plants, including poppy, henbane, and mandrake. (The Largest Surviving Medical Treatise from Ancient Mesopotamia, Circa 1,600 BCE ; R. Campbell Thompson, 1923. *Assyrian Medical Texts from the Originals in the British Museum* - available free online.; R. Campbell Thompson, 1924. The Assyrian herbal, ... a monograph on the Assyrian vegetable drugs, the Royal society, March 20, 1924.

2,500 BC - Emperor Shen Nung's Pen T'Sao references 365 plants used medicinally, including Chinese rhubarb, camphor, and ginseng. willow, juniper, etc.

c1550 BC - The Luxor Papyrus was written in Thebes (Egypt), referencing about 700 plants used medicinally, including aloe, castor bean, garlic, onion, and fig. The 20 meter-long scroll is more formally called the Ebers Papyrus, based on its acquisition by Georg Ebers from Edwin Smith in 1873/74.

c800 BC - The epic tales, *The Odysseys* and *The Iliad*, include references to 63 different plants used medicinally.

c379 BC - Writings attributed to Hippocrates describe effects of about 300 different plants, such as garlic, sea onion, opium, nightshade, mandrake, parsley, haselwort, celery, asparagus, oak, and pomegranate.

c287 BC - Theophrastus, in his two works, refers to about 500 different kinds of plants with medicinal value.

c 50 AD - Celsus referenced approximately 250 plant species used medicinally, including, aloe, cardamom, cinnamon, flax, gentian, henbane, pepper, and poppy.

c77 AD - Dioscorides described 944 drugs derived from 657 plant sources. Examples include camomile, coriander, garlic, alse hellebore, ivy, marsh mallow, nettle, sage, sea onion, and willow.

c79 AD - Pliny the Elder commented on about 1,000 medicinal plants in his *Historia naturalis*.

c160 AD - Cato's *de Agri Cultura* is considered one of the oldest intact Roman prose documents.

165-180 AD - Antonine Plague

c200 AD - Galen (Saskia Klerk, 2013. Dissertation: Galen reconsidered. Studying drug properties and the foundations of medicine in the Dutch Republic ca. 1550-1700)

541-542 The Plague of Justinian

814 AD - Charles the Great established a medical school in Salerno. His *Capitularies* mandated about 100 medicinal plants to be cultivated, including sage, sea onion, iris, mint, poppy and marsh mallow.

850 AD? - Yūhannā ibn Māsawaih (in English: John Mesue) penned *Opera Medicinalia*, a trilogy of pharmaceutical texts utilized around the Mediterranean. Said to be a product of the 9th century, there remain serious issues! Many earlier texts support the idea that Mesue lived and wrote before 900 AD, while De Vos clearly indicates the Opera shows every sign of having been written in the 13th century, with no indication of an Arabic version. The earliest extant manuscript dates to 1251. Despite mysterious origins, the text was incredibly influential. A version by Jacques Dubois, entitled *De rei medica*, went through 17 editions between 1532 and 1635. (see Paula De Vos, 2013. "The "Prince of Medicine": Yūḥannā ibn Māsawayh and the Foundations of the Western Pharmaceutical Tradition" *Isis* 104(4): 667-712.)

850 AD The Nikeian pharmacological codex was written

1037 Ibn Sīnā's (Avicenna's) *Canon Medicinae (Al-Qanun fi'l-tibb; The Canon of Medicine*) Volume 2 of the 5 part Canon lists approximately 800 medical sources (plant, animal, and mineral in origin) and Volume 5 represents 650 compound preparations that remained part of pharmaceutical practice for centuries. (Jamal Moosavi, 2009. "The Place of Avicenna in the History of Medicine", Avicenna J Med Biotechnol. 1(1): 3–8. PMCID: PMC3558117 PMID: 23407771

1085 Return of Toledo (Spain) to Christian control, the "*reconquista*." Though Europeans had made noteworthy strides to learn more about Arabian intellectual life (Gerbert of Aurillac), the floodgates seem to have opened with the fall of Toledo. Extensive manuscript collections, including Arabic versions of ancient Greek texts, became available for translation to Latin and other vernacular languages. One series of manuscripts to come out of Spain was the Secretum secreto-

rum, an encyclopedic work that entered European conversation in short and long versions. The apparent restoration of this and many other works that previously had not been available to European scholars helped revitalize interest in ancient texts, most particularly Aristotelian traditions. The reconciliation of classical reasoning and approaches to science with church doctrine regarding the hubris of intellectual advancement (a legacy of Augustinian thought) would play out over the next several centuries as classical formal education and liturgical development came to reconciliation. (Eamon, 1994)

1248 *Liber Magnae Colletionis Simplicum Alimentorum Et Medicamentorum* is attributed to Ibn Baitar, describing more than 1,000 medicinal plants.

1256 - 1269 Thomas Aquinas made several writings available that resolved church doctrine with natural philosophy, a convention termed Thomism that has had a long philosophical run. Three centuries later (1567), Pope Pius V proclaimed Thomas Aquinas a Doctor of the Church; yet another three centuries afterward, in August, 1879, Pope Leo XIII issued an encyclical establishing Aquinas's theology as Catholic doctrine. For centuries, therefore, in the words of Peter Dear (2009): "*In practice if not always in principle, natural philosophy and theology had become inextricably linked.*" Many more recent scholars and researchers, notably Roger Bacon, Francis Bacon, and Charles Darwin would come to refine or refute Thomism. (Unsurprisingly, Lorenzo Valla did not buy into any resolution that incorporated Aristotelian logic into church doctrine. Having been invited in 1457 to deliver an encomium on the occasion of Aquinas' anniversary for Dominicans in Rome's Church of Santa Maria sopra Minerva, Valla instead delivered a critique. Encyclopaedia Britannica on-line)

1267 Roger Bacon, due to the brief papacy of his supporter Pope Clement IV, was given a window of time during which to submit his *Opus majus* manuscript, introducing his explanation and reasoning for bringing classical discussion and popular secrets (working techniques and formulae) into church intellectual life. Bacon's ideas were in continual conflict with Augustinian concerns about pursuit of forbidden knowledge (the knowledge that had gotten Adam and Eve in trouble).

1334 The Black Death

1455 Gutenberg printed a Bible, the first produced utilizing moveable type. His innovation proved of immediate significance. Ancient texts, available previously only in hand scribed versions, would now be printed. Publication of new herbals and simples advanced quickly.

1462 Inspired by George Gemistos (Plethon), Cosimo de' Medici (of Florence) decided to re-create Plato's Academy (in Florence). Selecting Marcilio Ficino as the leader, he provided Greek manuscript of Platonic material, which Ficino translated to Latin (published in 1484.) Those labours include additional works, such as the *Hermetica*. Ficino is considered the first writer to invoke the term *prisca theologia*, which crystallized ideas that all religions are of one. Christian scientists of the 15th-17th centuries embraced Hermetics in

support of the concept that Christianity culminates a single chain of theologies.

1488 *" Saladino Ferre D'Ascoli, chief physician to the Prince of Taranto, published his Compendium aromatarium in Bologna, Italy. Hailed as "the first modern treatise on pharmacy," the work was, in many ways, the culmination of a medieval tradition in pharmacy that had developed from a combination of Greco-Roman, European, and Arabic sources."* (Paula De Vos, 2013. "The "Prince of Medicine": Yūḥannā ibn Māsawayh and the Foundations of the Western Pharmaceutical Tradition" *Isis* 104(4): 667-712.)

1492 Colon - Christopher Columbus embarked on his first journey, returning to Spain 15 March 1493.

1492 Venetian Ermolao Barbaro published *Castigationes Plinianae*, a popular and influential editing of Pliny's *Natural History*, which featured 5,000 corrections to Pliny's text.

1497 First publication of a manuscript copy of of *Circa instans*. From the Wellcome Library Blog, 20/02/2017: "A medieval medical bestseller: the 'Circa instans', by Iolanda Ventura: *"The success of the 'Circa instans' resulted from its pragmatic, user-friendly structure, which made it especially useful to medical practitioners. The collection provides a selection of about 270 natural substances derived from plants, animals and minerals. Plants are the most consistently represented category, with everyday, readily available substances appearing more frequently than rare or exotic ones. The text is structured in alphabetical order, regardless of whether the substance is mineral, vegetal or animal in origin. This alphabetical organisation made it easier to search for a specific item within the text."*

1499 Vasco de Gama returned from his fractured 2-year journey which opened trade with India through sailing around Africa's Cape.

*c*1500 By this time, there were likely 300 distinct selected varieties of corn (*Zea mays)* grown in Mexico and Central America. George Beadle, "The Ancestry of Corn" (1980) writes: *"the development of corn by the Indians remains man's most remarkable plant-breeding achievement." (Scientific American*, 242(1): 112-119 (January 1980)

1503 The Spanish monarchy established its *Casa del Contratación* in Seville, to both gather navigational information and train pilots. This was followed in 1524 with the *Consejo de Indias* in Madrid, conceived to gather information on the geography and natural history of the Americas. (Dear, 2009)

1517 Martin Luther selected All Hallows' Eve to post his Ninety-five Theses (the *'Disputation of Martin Luther on the Power and Efficacy of Indulgences'*) at the entry to the Wittenberg All Saints' Church. Luther's statement went viral, and is said to one of the first socio-political uses of European printing. Many people celebrate Halloween as Reformation Day, reminding us that Western culture and history were considerably altered by the Reformation, the start of which is often pegged to Luther's Disputation. One could argue that botany (indeed natural history and science generally as independent

disciplines) was unlocked by the Reformation, freeing people to consider the curiosities of nature, study that had emerged as taboo since the time of Augustine of Hippo. Augustine (*City of God Against the Pagans*, c 426 AD, etc.) argued that Creation was instantaneous, and would be incomprehensible to humans. Christian doctrine evolved in Europe's Middle Ages to trivialize, even discourage study of nature. The task assigned to humans was to name things, knowledge as to the workings of nature was not the business of humans, questioning the rationale of Creation was forbidden.

1536 French botanist Jean Ruel published *De Natura Stirpium,* described as the earliest attempt to popularize and democratize plant study. Charles Plumier recognized his contributions through naming the genus *Ruellia*.

1536-1541 Dissolution of Monasteries in England, by Henry VIII, involved confiscation of about 800 monasteries, abbeys, and other communal church properties....

1543 Andreas Vesalius published *De humani corporis fabrica libri septem*, which though not his first book (nor the first published on human anatomy) was certainly a groundbreaking moment in explanation of human musculature and skeletal structure.

1569 Gerardus Mercator (Flemish) introduced his world map based on 'projections' that included rhumb lines, which show navigation courses as straight lines. (Mercator and Vesalius were contemporaneous students at the University of Leuven)

1574 In Seville, Spanish scholar Nicholás Monardes published *Primera y segunda y tercera partes de la historia medicinal de las cosas que se traen de nuestras Indias Occidentales, que sirven en medicina; Tratado de la piedra bezaar, y dela yerva escuerçonera; Dialogo de las grandezas del hierro, y de sus virtudes medicinales; Tratado de la nieve, y del beuer frio*, the complete tract of his evolving book on useful (medicinal) plants from the Americas. Translated to Latin by Charles de l'Écluse, and then to English by John Frampton in 1577, Joyfull newes (*Joyfull newes out of the newe founde worlde, wherein is declared the rare and singular vertues of diuerse and sundrie hearbes, trees, oyles, plantes, and stones, with their applications, as well for phisicke as chirurgerie*) caused quite a sensation, running through additional translations and printings. It is a charming, small volume that is freely available on-line. Monardes treats a selection of plants he believes will change the world. One is tobacco, concerning which Monardes' dedicated supporter, Juan de Cardenas, wrote: *"To seek to tell the virtues and greatness of this holy herb, the ailments which can be cured by it, and have been, the evils from which it has saved thousands would be to go on to infinity...this precious herb is so general a human need not only for the sick but for the healthy."* (J. Worth Estes , 1995. "The European Reception of the First Drugs from the New World," *Pharmacy in History*, 37(1): 3-23. American Institute of the History of Pharmacy Stable URL: https://www.jstor.org/stable/41111660 ;also, Wikipedia, 2018)

1576 Cocolitzli Epidemic - Mexico

1581 Robert Norman, in his treatise *The Newe Attractive*, described use and values of magnets (lodestones) in navigation.

1582 The Gregorian Calendar, a solar calendar, was developed and introduced.

1600 William Gilbert's *De Magnete* established the concept of Earth's magnetic field, introducing the word *electricus* ("like amber," as a term for static electricity, observed with amber), which was adopted by Thomas Browne in 1646 as the word electricity. Gilbert reflects a growing sentiment against satisfaction with classical ways of knowing: *"men are deplorably ignorant with respect to natural things, and modern philosophers, as though dreaming in the darkness, must be aroused and taught the use of things, the dealing with things; they must be made to quit the sort of learning that comes only from books, and that rests on on vain arguments from probability and upon conjectures"* (Dear, 2009)

1600 *"Science as we now know it began about 1600, when the great Italian investigator Galileo popularized the procedure of applying quantitative methods to observation, of making accurate measurements, and of abstracting generalizations that could be expressed as simple mathematical relationships."* (Isaac Asimov, 1962, *The Genetic Code*)

1601 *Philosophia epicurea, democritiana, theophrastica* was published by Nicholas Hill

1609 Kepler's *Astronomia Nova* "introduced the first two of his three laws of planetary motion: 1) that the planets orbit in ellipses with the sun at one focus, and 2) ... their radii sweep out equal areas in equal times..., that the planets do not move uniformly." (McClellan and Dorn, 2015)

1611 Commenting on the heady development of new ideas in science, John Donne penned:

"new Philosophy calls all in doubt,
The Element of fire is quite put out;
The Sun is lost, and th'earth, and no man's wit
Can well direct him where to look for it."

1620 - Publication of *Novum Organum Scientiarum* by Francis Bacon. Bacon ascribed human accomplishment to observation, experiment, and objective fact, noting that high points in human achievement included printing, gunpowder, and the magnet. *'For these three have changed the whole face and state of things throughout the world, insomuch that no empire, no sect, no star seems to have exerted greater power and influence in human affairs than these mechanical discoveries.'* In spirit and method, Bacon predicts development of modern scientific methods. arguing against Greek models of deductive (top down) reasoning, and in favor of inductive (bottom up) methods. In Bacon's world, observations and study would avoid prejudices, which he called "idols of the tribe" (preconceptions passed down through th community), "idols of the cave" (individual predilections), "idols of the market"

(decisions driven by economics), and “idols of the theater” (cultural dogma, such as classic assumptions). As stated in his first aphorism: *"Man, the servant and interpreter of nature, does and understands only as much as he has observed, by fact or mental activity, concerning the order of nature; beyond that he has neither knowledge nor power."*

1628 - At the height of his career, William Harvey introduced his book *Exercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus* (*An Anatomical Exercise on the Motion of the Heart and Blood in Living Beings*), also called *De Motu Cordis*, to a growingly professional audience. Harvey established the quantities of blood flowing through human bodies, making clear this was a matter of circulation. (Harvey was not clear as to how the large quantity of blood could pass through tissues and then return, but in 1660, Marcello Malpighi described capillaries in frogs, explaining how such quantities of blood could physically circulate.)

1636-1637 Following growing interest in horticultural flower forms, tulips became the center of financial speculation in Holland. Numerous books and articles have described the details of exploding interest in beautiful and curious variations in floral form and color patterning. Collectors and investors rushed to capitalize on the newest and most exotic selections, inflating prices for bulbs to untenable heights. An inability of traders to meet purchase debts triggered abrupt sell-off that quickly led to market collapse, resulting in a multi-year downturn for the Dutch economy.

1643 Evangelista Torricelli began experiments that demonstrate the air has weight, inventing the barometer in the process. Even Torricelli’s mentor Galileo had accepted historical assumptions that air is weightless. The new idea impacted many considerations, such as the nature of a vacuum, and character of atmosphere at various altitudes. Blaise Pascal furthered Torricelli’s work, and by 1648 Pascal’s prediction that air would weigh less at higher altitudes was confirmed when his brother-in-law, Pierre Petit ascended Puy de Dome taking measurements with a mercury barometer.

1646 - Thomas Browne introduced the word electricity. in his *Pseudodoxia Epidemica or Enquiries into very many received tenets and commonly presumed truths,* in which Browne (though a supporter of alchemy) condemns superstitions of the time. *Pseudodoxia Epidemica* evidences Browne’s support for Francis Bacon’s empirical methods. Subjects covered include the nature of errors and fallacies through to concerns of the cosmos, thus we consider him a harbinger of future science, though we also understand Browne was regarded of nearly spiritual significance by alchemists (read the curiosities concerning theft and recovery of his skull). Browne’s library (and that of his son) were acquired in 1711 by Hans Sloan, and thus incorporated with founding collections of the British Library. (Wikipedia, 2018)

1648 Jean Baptiste van Helmont reported on his experiment in plant physiology and nutrition. A five pound willow tree was planted in 200 pounds of dry soil. It was watered and allowed to grow for five years. At the end of this period, the total

gain in weight was one hundred and sixty-nine pounds and three ounces, while the soil had lost only two ounces. As an alchemist,Van Helmont assumed that water is a complex substance which is changed into plant material. Van Helmont did not mention publication of the idea for such an experiment two centuries earlier by Nicolus of Cusa [see 1450; also see John Woodward, 1699], or make associations between plant growth and gas exchange. David Hersey, *Misconceptions about Helmont's Willow Experiment*, 2003, in Plant Science Bulletin on line, 48(3): 78. Von Helmont was considered the successor to Paracelsus, and a believer in the Alkahest as the universal analyzer (solvent.)

1649 Nicholas Culpeper published his herbal, T*he English Physitian (*subtitled: *Astrologo-physical Discourse of the Vulgar Herbs of this Nation Being a Compleat Method of Physic Whereby a man may preserve his body in health or cure himself being sick for thee pence charge with such things onely as grow in England, they being most fit for English Bodies*.) The English physician dealt considerably with astrology and the signatures of plants. (Sanecki, 1992) But Culpeper was not a quack, rather he was quite the iconoclast, infuriating other physicians by offering free services and insisting that medicines should be inexpensive. His philosophy seemed to be: *"Three kinds of people mainly disease the people – priests, physicians and lawyers – priests disease matters belonging to their souls, physicians disease matters belonging to their bodies, and lawyers disease matters belonging to their estate."* Culpeper died at the age of 37, from a battle wound.

1650 John Evererard published his English translation of *The Pymander of Hermes*.

1651 *Rerum medicarum Novae Hispaniae*... (HNT) was published, 80 years late. This work resulted from one of the earliest explorations of the natural history of the New World, made in 1570 by Francisco Hernández, private physician to Philip II of Spain. He was sent to assess natural resources and reported on more than 1000 plants that were considered medicinally important by the natives of Mexico. Some of the plants he described and preserved as botanical specimens are now extinct.

1651 William Harvey's *Exercitationes de Generatione Animalium (On the Generation of Animals)* was published, in which he explains that all animals come from eggs (*ex ovo omnia*). Without the benefit of a microscope (see 1665, Hooke; 1677 Leeuwenhoek), Harvey was not able to see individual eggs or sperm; he had to deduce their presence.

1652 Capetown was founded, though Europeans had known the site since 1488. The Dutch sent two ships to Table Bay, near Cape Town, South Africa to establish a garden to provide fresh foods and fruits for sailors on their voyages by the Cape of Good Hope. By 1679 the garden included ornamental plants from upcountry regions of Africa, as well as edible and decorative plants from China, Java, Zanzibar, etc. By 1700 plants native to Table Bay had become common in Holland. Among

those plants were the calla (*Zantedeschia aethiopica*), bird of paradise (*Strelitzia reginae*, named in honor of Queen Charlotte Sophia, wife of George III), and impatiens (*Impatiens holsti*). [See 1772]

1656 Dutch physicist Christiaan Huygens is credited with inventing the pendulum clock (based on Galileo's observations of the behavior of pendulums and proposed designs for such a device), followed by his 1673 book *Horologium Oscillatorium*. Huygens contributed extensively to astronomy and physics, best known for his works on centripetal force and in probabilities and theories on the nature of light. Later in his career, 1677, Huygens collaborated in areas of microscopy with the younger Dutch mathematician and lensmaker, Nicolaas Hartsoeker, who himself is often cited for his exposition of the homunculus theory in his 1694 *Essay on dioptrics*. (Wikipedia, 2019) *Botanical Significance: For science, the pendulum clock became the most accurate method of time measurement over the next three centuries. It meant that by 1690, clocks with minute hands began to appear in the market.*

1657 Gaspar Schott, of Germany, published *Mechanica Hydraulico-Pneumatica*, which described many trials with pumps and pressure. His is the first published description of a vacuum pump devised by Otto von Guericke, in Magdeburg. Paired copper hemispheres, once evacuated through a valve, could not be separated, even when pulled by a team of horses during a demonstration in 1656. Schott's book is said to have inspired Robert Boyle in his studies of air.

1661 Robert Boyle carefully experimented with increase in plant biomass (as had van Helmont), reporting his results in his first book, *The sceptical chymiste*.... Though an alchemist, Boyle rejected many of the more fanciful conceits in that realm, i.e. *"experiments whereby vulgar Spagyrists are wont to endeavour to evince their Salt, Sulphur and Mercury to be the true Principles of Things."* In an effort to determine what had happened to the water taken up by plants, he actually boiled the liquid away from the plant tissue and found a coal-like residue. He defines elements newly: *"I now mean by Elements, as those Chymists that speak plainest do by their Principles, certain Primitive and Simple, or perfectly unmingled bodies; which not being made of any other bodies, or of one another, are the Ingredients of all those call'd perfectly mixt Bodies are immediately compounded, and into which they are ultimately resolved."*

1662 Following Restoration of the English monarchy, The Royal Society of London was created through royal charter. Formation of the Society began as early as 1660, based on an "Invisible College" of like-minded intellectuals. The initiating group, a committee of 12, included: William Ball, Robert Boyle, William Brouncker, Alexander Bruce, Jonathan Goddard, Abraham Hill, Robert Moray, Paul Neil, William Petty, Lawrence Rook, John Wilkins, and Christopher Wren. John Wilkins, having been a supporter of Oliver Cromwell, was out of favor with the monarch, but remained associated with others in the committee based on his charac-

ter, knowledge, and intellectual power. Wilkins maintained a remarkable network of correspondence, including communication with William Harvey, and friendship with Heinrich (Henry) Oldenburg, who (having early on become a member and corresponding secretary of the Royal Society) introduced the concept of peer review to scientific publication. The Ross-Wilkins Controversy forms the basis for the astronomical dialogue at the beginning of Book VIII in John Milton's *Paradise Lost*. (Grant McColley, 1992 in *John Wilkins and 17th-Century Linguistics*

1662 Notes from lectures by Joachim Jung appear as *De Plantis Doxoscopiae Physicae Minores* and *Isagoge Phytoscopica* (which was not formally published until 1679). These publications express an increasingly modern approach to the study of plant morphology, including a strikingly contemporary definition of plant: *"A plant is a living, non-sentient body, attached to a particular place or habitat, where it is able to feed, to grow in size, and finally to propagate itself."* Jung's thoughts appear to have had great influence in later works, such as those of Ray, and eventually the publications of Linnaeus. (Morton, 1981)

1664 John Evelyn published *Sylva: Or a Discourse on Forest-Trees and the Propagation of Timber in His Majestie's Domain*. Evelyn's *Sylva* was the first book published by London's Royal Society, and remained the dominant English treatise on forestry for over a century. [See on-line: Gabriel Hemery, *Nature* 507, 166–167 (13 March 2014) doi:10.1038/507166a, Published online 12 March 2014] (Campana, 1999)

1667 In his book *Physica subterranea*, German alchemist Johann Joachim Becker introduced the idea of *terra pinguis*, a flammable substance that is expended when material burns. With further work by German chemist Georg Ernst Stahl, the substance came to be known as Phlogiston (from the Greek for burning, *Phlóx* = flame.) As Johann Heinrich Pott (one of Stahl's students) elaborated, phlogiston was considered the active ingredient in all materials, the basis of colors, and the main driver of fermentation. The phlogiston paradigm was patched together over a century as the only explanation for transfer of energy during combustion and fermentation, finally extinguished by the work of Lavoisier.

1665 In his *Micrographia*, Robert Hooke detailed the structure of cork and described "cells" as studied through a microscope that had been constructed for him. This is recognized as the first time the word cell was applied to what we now understand is the basic unit of life, though the cork Hooke studied was composed of dead cells, and he had no idea as to the contents and organization future research would reveal.

1668 John Wilkins' *Essay Toward a Real Character and a Philosophical Language* was published. As a founding member of London's Royal Society and a close associate of John Ray, Robert Hooke, and others, Wilkins influenced crucial advances in scientific thought. Even though considered a failure, Hooke's *Essay* and development of a proposed language

provoked Ray to develop a plant classification schema and more developed terminologies. (Aarsleff in Subbiondo, 1992) It also generated as much engagement through engendering critiques as the original essay formulated itself. From Sidonie Clauss essay: *"...Wilkins probably intuited its failure, even from the start. But, as a scholar and teacher committed to the advancement of learning and the consolidation of Christendom, he persevered in his life-long inquiry into the nature of language; conventional, recondite, universal, scientific, philosophical. While his 'real character' never became a reality, the* Essay *did succeed in its primary objective of inspiring other attempts to improve the theory and practice of methods of obtaining, recording, and communicating knowledge."* (in Subbiondo, 1992)

1677 *"Leeuwenhoek discovered that the origin of semen was the testicles and was a committed preformationist and spermist. He reasoned that the movement of spermatozoa was evidence of animal life, which presumed a complex structure and, for human sperm, a soul."* (Wikipedia, 2019, citing David Friedman, 2001, *A Mind of its Own: The Cultural History of the Penis*, Freeman Press)

1679 French Hugenot Denis Papin, after having been employed to run experiments by Robert Boyle for three years, made a presentation to London's Royal Society, describing his "steam digester" (the earliest pressure cooker.) By 1690, Papin held an academic position in Marburg, Germany, where he introduced his concepts for a steam-powered engine. (Wikipedia, 2018)

1687 Isaac Newton's *Principia* was published, following up on earlier work on planetary motion. Highly technical and mathematical, *Principia* addressed problems of great antiquity and created mathematical models related to the motion of planets, the nature and pull of gravity, and the predictability of comets. (McClellan & Dorn, 2015)

1694 Rudolf Jacob Camerer (in Latin, Joachim Camerarius) wrote a scientific letter (later published by Valentini in his *Polychresta exotica*, 1700, HNT) that made the first clear case (with solid experimental evidence) for the nature of sex in plants and the actual role of pollen and ovule in this process.

1698 Thomas Savery introduced the first commercially-viable steam apparatus. His piston-less steam pump (the "miner's friend") was employed to pump water out of deepening coal mines in England. The pump was modified and re-invented over following decades, becoming part of the curious coming together underpinning the industrial revolution. (Wikipedia, 2018)

1704 Isaac Newton's *Opticks* was published, summarizing his work of the past four decades. Addressing diffraction of light, his *Opticks* discusses the nature of white light and its refraction into the rainbow of colors. (McClellan & Dorn, 2015)

1712 History accepts this date for introduction, by Thomas Newcomen, of his atmospheric-engine, a practical piston-run steam engine employed for the same purpose as Savery's vacuum pump - removing water that seeped and flooded into

mines. Newcomen's engine was improved and manufactured successfully over the next century. [See 1774, James Watt]

1714 Daniel Gabriel Fahrenheit, a Dutch scientist, devised the first sealed thermometer, which means it was not open to the air and thus not impacted by barometric pressure. His Fahrenheit scale was finely divided and remains in use (especially in the US). Andres Celsius proposed a metric scale in 1742, which adopted Huygen's much earlier suggestion that 100 ºC scores the boiling point of water at one atmosphere, and 0 ºC represents the freezing point (more accurately, the triple point of water). In 1848, William Thomson (later given the title Lord Kelvin) published his paper *On an Absolute Thermometric Scale*, in which he proposed a scale using zero as the lowest temperature (which he calculated as -273 ºC). That temperature was termed 0 ºK (degrees Kelvin) initially, and refined as -273.16 ºC. Today it is simply called kelvin (kelvins plural), like a kelvin (one degree Kelvin), or 5 kelvins (suggesting a change of 5 degrees Kelvin or its equivalent of 5 degrees Celsius.... (Wikipedia, 2019)

1717 Thomas Fairchild is credited with creating the first *bona fide* pre-meditated plant hybrid.

1727, 1733 - Stephen Hales, a minister and resident of Teddington, Middlesex, was elected to the Royal Society in 1718, based on his tireless and somewhat grim studies of anatomy and circulation, as well as his studies of air and other physical phenomena. Using apparatus and techniques he developed, Hales established early understanding of the movement of water through plants, and concepts underlying transpiration. Beginning in 1727, Hales published two volumes describing physical measurements (staticks), the first on plants (*Vegetable Staticks*), and the second on animals (*Haemastaticks*). With plants, Hales is the first to observe that air is somehow taken into and becomes part of the substance of plants. Though recognized for so many contributions and fine traits, Hales was also chastised for some of his experimental studies with animals. As Thomas Twining commented (in his poem *The Boat on Hales*):

Green Teddington's serene retreat
For Philosophic studies meet,
Where the good Pastor Stephen Hales
Weighed moisture in a pair of scales,
To lingering death put Mares and Dogs,
And stripped the Skins from living Frogs,
Nature, he loved, her Works intent
To search or sometimes to torment.

(Note: Hales was a founding Trustee for establishment of the Colony of Georgia, which became one of the original 13 US colonies, and in its earliest description stretched across North America to the Pacific Ocean) Reference: Eknoyan G. , 2016. "Stephen Hales: the contributions of an Enlightenment physiologist to the study of the kidney in health and disease." *G Ital Nefrol.* 2016 Feb;33 Suppl 66:33.S66.5.; Rajni Govindjee and David Krogmann, 2004. "Discoveries in oxygenic photosynthesis (1727-2003): a perspective." *Photosynth Res.*

2004;80(1-3):15-57. Hales was a friend of Alexander Pope, though Pope (a lover of dogs) is documented as having commented: *"He (Hales) commits most of these barbarities with the thought of its being of use to man. But how do we know that we have a right to kill creatures that we are so little above as dogs, for our curiosity, or even for some use to us?"*

1731 Alexander Pope, in AN EPISTLE To the Right Honourable RICHARD Earl of BURLINGTON, wrote:

Consult the genius of the place in all;
That tells the waters or to rise, or fall;
Or helps th' ambitious hill the heav'ns to scale,
Or scoops in circling theatres the vale;
Calls in the country, catches opening glades,
Joins willing woods, and varies shades from shades,
Now breaks, or now directs, th' intending lines;
Paints as you plant, and, as you work, designs.

1754 Charles Bonnet, in *Recherches sur l'usage des feuilles dans les plantes*, observed that plants submerged in water and exposed to light emit bubbles (later determined to be oxygen), and improvised a system to measure output rates of photosynthesis still in use today. Bonnet was a brilliant, wide-ranging philosopher, his earliest studies contributing considerably to understanding of insects, followed by his work on botany. In this same year, Bonnet began writing on psychology and philosophy, becoming known for his observations and arguments. In 1960 he described a condition of vivid hallucinations, now termed Charles Bonnet Syndrome.

1756 Over 3-4 years, Scottish physician and chemist Joseph Black experimented with alkaline materials, demonstrating that the gas generated when carbonates are heated is chemically distinct from the general atmosphere. He called it “fixed air” because (one presumes) it had been fixed as part of the minerals. Today we understand his fixed air is carbon dioxide, which constitutes less than 1% of the atmosphere. Curiously, Black was responsible for another discovery of occult properties, through bringing forward the earliest examples of latent heat from his heating experiments with ice, water, and steam (the beginnings of thermodynamics as a study). (Kuhn 1962/1996/2012; McClellan & Dorn, 2015; Wikipedia, 2018)

1772 Extending Joseph Black’s work with fixed air, Daniel Rutherford reported that the atmosphere created through burning a substance in an enclosed jar, once cleansed of Black’s fixed air, was noxious (deadly.) We understand, today, that he had rid the atmosphere in the bell jar of both oxygen (through combustion) and carbon dioxide (the fixed air), leaving almost pure nitrogen, a *suffocant*.

1774 Joseph Priestley reported (*Experiments and observations on different kinds of air*, HNT) that burning a candle in a closed container changes the quality of the atmosphere so the flame is extinguished. Animals placed in that environment quickly die. A living sprig of mint renews the air so a candle will once again burn. Today we know that the non-flammable

air is the mix of carbon dioxide and nitrogen; growing a plant in such an environment replenishes the oxygen which is necessary to sustain life. On learning of his results, Benjamin Franklin, a correspondent of Priestley's, commented in a letter: *"I hope this [rehabilitation of air by plants] will give some check to the rage of destroying trees that grow near houses, which has accompanied our late improvements in gardening from an opinion of their being unwholesome."* [See 1604]

1774 In October of this year, Priestley and his patron met with Antoine Laurent Lavoisier, perhaps the most famous chemist of all time. Priestley described a new gas he had discovered (through heating mercuric oxide) that supported a brighter flame than normal air. Because Priestley was trained in the concept of phlogiston as the active agent of flammability and fermentation, he loosely believed that during burning the phlogiston quality or substance was released into the atmosphere. But the new kind of gas supported flames several times brighter and the life of mice several times longer than regular atmospheres. Those observations caused Priestley to suspect the new gas was completely devoid of phlogiston, and thus he generated the term dephlogisticated air for it. Lavoisier would soon give Priestley's dephlogisticated air the name oxygen. (Cobb and Goldwhite, 1995) [See 1777] Though Priestley receives credit for describing the gas to become known as oxygen, Polish alchemist Michael Sendivogius produced the "elixir of life" in 1604 by heating Chilean saltpeter (potassium nitrate – note there is much confusion in the internet as to whether Chilean saltpeter is potassium nitrate or sodium nitrate) – a reaction that also liberates oxygen. (Schwarcz, 2005) Kuhn (1992) says it isn't really clear who made the discovery; perhaps we should say Priestly discovered oxygen, while Lavoisier invented it.

1774 - Having repaired and studied Newcomen engines, James Watt recognized inefficiencies involving the cooling/condensation of steam. After considerable trials, Watt patented his own design for a steam engine with a separate condenser. The following year, he partnered with Matthew Boulton in creating the firm Boulton & Watt (renamed James Watt & Co in 1849). Boulton & Watt, in alliance with other firms (such as the cast iron foundries of John Wilkinson) are core industries giving rise to the Industrial Revolution. (Wikipedia, 2018)

1776 Adam Smith's *An Inquiry into The Nature and Causes of the Wealth of Nations* hit the stands, introducing Economics as an area of study, while vaunting the profit motive as underlying societal good, and influencing how investors viewed the marketplace. *"In Agriculture nature too labors alongside man."*

1779 Following up on studies by Charles Bonnet (see 1754), Jan Ingenhousz's *Experiments upon vegetables* demonstrated that plants produce oxygen in sunlight and carbon dioxide in darkness. These observations added to studies by his friend Priestley, but unlike Priestley (who was interested primarily in the nature of gases) Ingenhousz was concerned with the physiology of plants. Ingenhousz was a noted physician who had

ventured from his native Dutch Republic to England, where he studied and productively employed methods of smallpox inoculation (vaccination would be devised and described by Jenner in 1798). Invited to Austria, he successfully inoculated monarch Maria Theresa, and was appointed court physician.

1780 Luigi Galvani demonstrated muscle movement elicited in dead frogs through applying electrical sparks.

1783 A first workable lighter-than-air balloon was devised and employed in Annonay, France. (McClellan & Dorn, 2015)

1784 Production of wrought iron through the "puddling" process (developed and patented by Henry Cort) made malleable iron abundant and less expensive. Functionally, the availability of iron that could worked like modern steel increased both utility and demand. Significantly, puddling meant ductile iron could be mass-produced for making rails (a process which John Birkinshaw patented in 1820), to build railroads.

1788 Living in Geneva, Calvanist pastor Jean Senebier was a noted naturalist, strongly inspired by the work of Charles Bonnet. In his *Expériences sur l'action de la lumi re solaire dans la végétation* established the relationship between the presence of carbon dioxide in the atmosphere and the production of oxygen by plants. His studies built on the work of Ingenhousz. [See 1779]

1788 John Hutton published *Theory of the Earth*, in which he introduced concepts of gradual geological change, later called Uniformitarianism. Hutton similarly suggested gradual change was part of the nature of living species.

1789 Antoine Lavoisier published his *Elemetary Treatise of Chemistry*, a landmark textbook that modernized the ways we talk about chemicals. (McClellan & Dorn, 2015)

1798 Thomas Malthus published *An Essay on the Principle of Population*, which influenced British attention to the size of population. Later editions of his book were significant inputs to evolutionary concepts developed by Charles Darwin and Alfred Russell Wallace.

1800 Following through on work describing electric currents by Luigi Galvani, Alessandro Volta introduced his pile (battery). Galvani and Volta were at odds over the source and nature of the electrical currents that caused the muscle movement in Galvani's frogs. (McClellan & Dorn, 2015)

1802 William Paley introduced the concept of God as the master designer through his Watchmaker Analogy, in *Natural Theology, or Evidences of the Existence and Attributes of the Deity Collected from the Appearances of Nature*. (see also the Bridgewater Treatises)

1802 The South American expedition of Alexander von Humboldt and Aimé Bonpland ascended Chimborazo - the top of which is said to be the furthest physical point from Earth's center. Here, as in all of their expeditions, these field scientists made extensive records of plants, animals, geology, and atmospheric conditions. Humboldt believed fervently in capturing

detailed data, a field research style that became known as Humboldtian Science. His travels, published in 1814 (in English, *Personal Narrative of Travels of the Equinocial Regions of the New Continent during Years 1799–1804*), confirm this: "Nature herself is sublimely eloquent. The stars as they sparkle in firmament fill us with delight and ecstasy, and yet they all move in orbit marked out with mathematical precision." For discussion of the Chimborazo climb, search: Caroline Schaumann, 2009. 'Who Measures the World? Alexander von Humboldt's Chimborazo Climb in the Literary Imagination', *The German Quarterly*, 82(4):447-468 https://www.jstor.org/stable/25653614?seq=1#metadata_info_tab_contents

1803 Based on simple ratios of elements involved in chemical reactions, John Dalton proposed atoms to be discrete particles, the smallest units of elements. (McClellan & Dorn, 2015)

1804 Nicolas Théodore de Saussure (whose great uncle was Charles Bonnet, and whose Grandfather was noted agriculturist Nicolas de Saussure), published his book *Recherches chimiques sur la végétation*, which marked the beginning of modern plant physiology through its well thought-out, documented experiments and attention to good experimental methodology. Working in Geneva, de Saussure achieved advances in our knowledge of plant nutrition and demonstrated that carbon from the atmosphere is fixed into the carbon that makes up organic compounds by plants undergoing photosynthesis. Saussure answered questions concerning the role of water in plant growth. In one experiment he combined various lines of study and demonstrated that cuttings set in distilled water continued to assimilate carbon, a result that denied earlier conclusions by Senebier and should have dispelled belief in the idea that carbon enters plants in the same manner as other nutrients from the soil [See 1813, the humus theory]. (Morton, 1981) Saussure's findings were not well-known until Justus von Liebig confirmed and extended his findings three decades later.

1804 John Dalton described the fact that atoms combine with each other in clear, whole-number ratios. This meant he was content in adopting the ancient word 'atom' - which derives from the concept that these are the smallest units of matter; they cannot be divided further (a = not able; tome = refers to knife, or the ability to cut). Dealing with a small number of atoms (=elements), Dalton was content to retain historic symbols for them. As the number of known elements expanded, chemists adopted the more flexible system of one- or two-letter abbreviations, introduced by Jacob Berzelius in 1813. Chemists today use the term Dalton to describe the units used in measuring the mass ("weight") of atoms. (Kroll, 2013)

1805 - In 1802, the young French chemist Joseph Louis Gay-Lussac had established the concept that pressure of a constant mass and volume of gas would increase directly in proportion to rising temperature, i.e. Gay-Lussac's Law. His observations were of great interest to Alexander von Humboldt, and when the two met in late 1804, they agreed to collaborate in a series of atmospheric studies. In January, 1805, Gay-Lussac and Humboldt discovered that water decomposes into hydrogen

and oxygen at a 2:1 ratio (not reported by Gay-Lussac until 1808). On 12 March that year, Humboldt and Gay-Lussac left on a several month journey, making numerous important observations en route and meeting Volta in Milan in September (an encounter that predicted Gay-Lussac's important later work with electric piles.) He would become a professor at the Sorbonne, and then chemist at the Jardin des Plantes. Gay-Lussac would mentor Justus von Liebig, whose contributions to plant science were substantial (see 1840).

1811 The 'mole' is born, or at least established as a concept. Amedeo Avogadro determined that equal volumes of gases (at the same pressure) must contain equal numbers of particles. Years after his death, researchers were able to draw a direct correlation. Since each atom, molecule, or compound should have the same mass (in Daltons) as another, then that number (the mass in Daltons) if assigned as a mass in grams should have the same number of particles, regardless as to what kind of atom or compound is under examination. Avogadro's number for this constant, $6.02214076 \times 10^{23}$, was determined by Jean Perrin (a French chemist) around 1909. The term 'mole' comes from the Latin *moles* and German *mol* as first used by German chemist Wilhelm Ostwalt in 1903 to indicate the gram molecular mass of a substance.

1812 A commercially-successful steam locomotive, Salamanca, began operation on the Middleton Railway in Leeds, England. The first successful public railway, the success of the Stockton and Darlington Railway, began operation in 1825.

1813 Jacob Berzelius established a system for chemical annotation that is the standard today - 1-letter and 2-letter abbreviations for elements, with subscripts for the numbers of atoms involved (though he used superscripts) in a compound. Based on his understanding of the makeup of compounds, Berzelius coined many important terms, including the words protein, polymer, isomer, and catalysis. He identified Silicon and several other elements. Berzelius was the first to distinguish organic from inorganic compounds, but very shortly ended up on the wrong side of history in his support of vitalism, a concept holding that only living beings could make organic compounds (see 1828, Wöhler)

1828 Friedrich Wöhler produced carbamide (urea), a constituent of urine, from potassium cyanate and ammonium sulfate, which constitutes the first synthesis of an organic compound from inorganic components. Wöhler's report is regarded as the end of Vitalism (the assertion that all organic compounds begin with organic precursors). It is worth noting that by current definitions, any compound involving Carbon is considered the province of organic chemistry).

1830 Publication began on Charles Lyell's *Principles of Geology: being an attempt to explain the former changes of the Earth's surface, by reference to causes now in operation*. In reviewing Lyell's work, William Whewell coined the terms Uniformitarianism (as proposed by Lyell) and Catastrophism (popular theories that supported belief in events such as Noah's flood. Lyell's ideas prevailed, creating understanding

a new foundation on which Darwin's concept of evolution would sit.

1831 Michael Faraday confirmed the process of electromagnetic induction, which meant spinning of motors could generate electricity. (McClellan & Dorn, 2015)

1835 Henry Fox Talbot devised the two-step negative-positive procedure and produced camera negatives on paper. In 1837, Louis Daguerre introduced his daguerreotypes, detailed permanent photographs on silver-plated copper sheets. (Wikipedia, 2019)

1837 Based on Faraday's explanation of electromagnetic induction, Charles Wheatstone (see Wheatstone also 1867) and associates devised an electric telegraph. A functional system was patented by Samuel Morse the same year. London and Paris were connected through telegraphy by 1854. (McClellan and Dorn, 2015)

1840 Justus Freiherr von Liebig, a young associate in the laboratory of Joseph Gay-Lussac, and friend to luminaries such as Alexander von Humboldt and Georges Cuvier, was "one of the first chemists to organize a laboratory in its present form, engaging with students in empirical research on a large scale through a combination of research and teaching." He developed many techniques and capacities, including his kaliapparat (1830), a device that simplified the process of determining oxygen, carbon, and hydrogen content of organic substances. Later in his career, Liebig turned his attention to agriculture, resulting in his influential book *Die organische Chemie in ihrer Anwendung auf Agricultur und Physiologie* (Organic Chemistry in its Application to Agriculture and Physiology), arguing that "chemistry could revolutionize agricultural practice." (Wikipedia, 2018)

1844 French scientist Lucien Vidi devised the aneroid barometer, providing a simple method of capturing atmospheric data.

1845 The Irish Potato Famine.

1847 Ignaz Philipp Semmelweis investigated high mortality rates in the maternity clinic of Vienna General Hospital (Austria). By introducing hand washing and aseptic techniques, he was successful in greatly reducing the death rate. His lessons had little impact on the community of Physicians - see Joseph Lister, 1867.

1851 The Great Exhibition, London's Crystal Palace

1851 Otto Ule employed the term 'light year' in a popular article to give some intelligible dimension to astronomical units of measure. Astronomers accept light years as a useful term for communicating with the public, but use the easily calculated parsec for their studies and discussion. The parsec was suggested as an astronomical unit of measure around 1913 by Herbert Hall Turner.

1852-1860 The 3rd Cholera Pandemic

1854 Japan was compelled to sign the Convention of Kanagawa, opening trade with the west. The subsequent Meiji Restoration, 1868, led to creation of a Ministry of Industry, signal-

ing Japan's entry to the nations promoting research and industrialization. (McClellan and Dorn, 2015)

1854 Paris and London were connected through telegraphy. IBy 1861 New York and San Francisco were connected. (McClellan and Dorn, 2015)

1855 The 3rd Plague Pandemic - China

1855 Exhibition Universelle, Paris

1858 Friedrich August Kekulé and Archibald Scott Couper. through independent research, proposed bonds between tetravalent carbon atoms would form a carbon skeleton, the organic basis for life.

1865 Louis Pasteur patented pasteurization,

1867 Based on Faraday's concept of induction, functional industrial dynamos were invented independently by Werner Siemens (Germany) and Charles Wheatstone (England). Powered by steam engines, the dynamos introduced electrical current to industry, and led to development of practical systems of lighting. (McClellan and Dorn, 2015)

1867 Joseph Lister published a series of articles in Lancet, describing success with antiseptic treatment (using carbolic acid, i.e. phenol) of serious wounds in a 7 year old boy. His observations were not universally well-received, but slowly the medical profession came to adopt some of his ideas. Regardless, Lister's reputation was solid and he served as President of London's Royal Society from 1895-1900. (Wikipedia, 2019)

1869 Dmitri Ivanovich Mendeleev published his organizational groundwork explaining the pattern of relationships in the properties of elements, the logic that underlies today's periodic table. Missing from Mendeleev's arrangement were the noble (rare) gases. Beginning with the discovery of helium (named for the sun because its spectral lines was first observed emanating from the sun), the remaining noble gases were soon isolated and given equally interesting names: argon (the lazy one), krypton (hidden), neon (new), xenon (the stranger), and radon (a disintegrative product of radium). (Cobb & Goldwhite, 1965)

1874 Germany's Friedrich Bayer Company hired its first Ph.D. chemist, establishing industrial presence in chemical research. German establishment of a uniform patent system in 1876 initiated an era of industrial research. (McClellan and Dorn, 2015)

1874 The earliest commercially-viable typewriter, the Sholes and Glidden Type-Writer (with its QWERTY keyboard), was introduced by E. Remington & Sons.

1876 Thomas Edison established his research laboratory in Menlo Park, New Jersey.

1876 Alexander Graham Bell held the documented telephone conversation, summoning Thomas Watson to his aid.

1876 Centennial Exposition, Philadelphia

1881 Werner von Siemans opened the first electric tramway in in Lichterfelde near Berlin. In 1895, Baltimore opened the first electric main line, a 4-mile stretch.

1882 Thomas Edison had patented an incandescent lamp in 1879 , and on Monday, 4 September 1882, the Edison Illuminating Company began generating power, lighting the Wall Street offices of is partner J. Pierpoint Morgan. Within a year, the company had 500+ customers supporting a system of over 10,000 electric lamps. Edison's system was DC (direct current), in direct competition with the Westinghouse AC system (alternating current). By 1917, nearly all systems in the US were AC (which is based on patents developed by Nikola Tesla). Thus began the modern world of electrification. . (McClellan and Dorn, 2015)

1885 Eduard Suess, aware of fossil deposits of Glossopteris (a fern) common in South America, Africa, and India, concluded the three continents constitute a supercontinent (Gondwanaland) that is separate through low-lying areas flooded by the oceans. (Wikipedia, 2018)

1886 Adolf Mayer conducted experiments demonstrating that foliar deformation (called mosaic) was due to a causative agent. He demonstrated the infectious agent could be deactivated by boiling in water, and concluded it must be an extremely small bacterium. related discoveries drove new areas of research. In 1892, Dimitri Ivanovsky demonstrated the agent could pass through a filter that would normally block passage of bacteria, and proposed it was some form of toxin. However, by 1898 Martinus Beijerinck had repeated Ivanovsky's filtration experiments, demonstrating the agent (for which he coined the term **virus**) could reproduce and multiply in the tobacco host cells. In 1935, Wendell Stanley reported isolation of virus crystals, which believed to be a protein. In his 1979 book on advances in molecular biology, H. F. Judson wrote: *"It was the most portentous and publicized biological discovery of the decade."* Subsequent researchers reported the material is RNA. (Arthur Kelman, in Frey, 1994)

1887 Heinrich Hertz described radio waves. In the same year, he described the photoelectric effect produced by UV light. Heinz died at a young age of serious illness, after a short but brilliant career. (McClellan and Dorn, 2015)

1889 Exhibition Universelle, Paris - the Eiffel Tower

1893 World's Columbia Exposition, Chicago

1894 With trials and development in many shops, 1894 is a reasonable date to consider as the birth of the automobile, the year in which Karl Benz and his company introduced the first production automobile, the Velo. Benz had introduced his first commercial machine (the Benz Patent Motorwagen) in 1888, following technologies he patented in the previous few years related to gas engines, ignition, gear shifting, and radiators. In 1899, Benz produced 572 units. (Wikipedia, 2019)

1895 William Roentgen demonstrated the existence of x-rays. Marie Curie would create the term "radioactivity" in 1898. (McClellan and Dorn, 2015)

1895 Auguste and Louis Lumière, French brothers, initiated *Cinématographe*, marking a beginning for the motion-picture industry.

1896 Rudolf Diesel and Maschinefabrik Augsburg completed the first functional diesel engine. By 1903, the first diesel-powered ships were launched. and the following year France launched its first diesel submarine. The machinery of war was gathering. (Wikipedia, 2019)

1897 J. J. Thomson discovered the electron.

1899 Imagining ship to shore communication, Guglielmo Marconi received a patent for radio transmission in 1896. in this year, he broadcast the first radio signal across the English Channel, followed by the first trans-Atlantic broadcast in 1901. (McClellan and Dorn, 2015)

1900 Sigmund Freud published *Interpretation of Dreams*.

1902 Telephotography ("wire photography") was introduced by Arthur Korn.

1903 The first powered flight by Orville and Wilbur Wright.

1903 Ernest Rutherford and Frederick Soddy proposed the radioactive disintegration of certain atoms to other, more stable elements. Rutherford also described gamma rays, as distinct from alpha and beta rays, which he had named earlier.

1903 Henry Ford founded the Ford Motor Company, with a mission to produce "the car for the great multitude." (Mclellan and Dorn, 2015)

1905 Albert Einstein's *annus mirabilis*, during which he produced a series of papers that proposed profound changes impacting scientific understanding in physics. Asserting that nothing can move faster than the speed of light, he altered assumptions that had been in play since writings by Isaac Newton. (McClellan and Dorn, 2015)

1906 The "Victrola" record-player, using vinyl discs, was introduced. Emile Berliner had patented the concept of records for his Gramophone in 1896. Berliner partnered with Eldridge Johnson in 1901 to establish the Victor Talking Machine Company. (Wikipedia, 2019)

1908 George Shull's "The composition of a field of maize" *"marked the beginning of the exploitation of heterosis in plant breeding, surely one of genetics' greatest triumphs... In his 1908 paper, Shull reported that inbred lines of maize showed general deterioration in yield and vigor, but that hybrids between two inbreds immediately and completely recovered; in many cases their yield exceeded that of the varieties from which the inbreds were derived. Furthermore, they had a highly desirable uniformity. In a subsequent paper in 1909, he outlined the procedures that later became standard in corn-breeding programs "* James F. Crow, 1998. '90 Years Ago: The Beginning of Hybrid Maize', *Genetics*

148(3):923-928 (see also Shull, G., 1908. The composition of a field of maize" *Am. Breeders Assoc. Rep*. 4: 296–301.)

1911 Ernest Rutherford formulated the first workable model for the structure of an atom.

1912 Alfred Wegener introduced his ideas of continental drift. As a climatologist, Wegener was positioned to bring ideas about climate-dependent formations, such as bauxite deposits, that supported other evidence (such as the shapes of continental shorelines) suggesting shifting of landmasses. Many significant geologists did not accept this idea until after mid-century.

1913 Panchromatic motion picture film (35 mm) was introduced by Kodak. (Wikipedia: Timeline of Photography Technology, 2019)

1914-1918 World War I

1915 Einstein postulated concepts introducing the concept of a 4-dimensional world that includes the space-time continuum.

1915 Panama Pacific Exposition, San Francisco

1918 The Great Flu Epidemic

1922 Rediscovery of the tomb of Egypt's King Tutankhamen.

1925 Tennessee teacher John Scopes was tried and found guilty of teaching Darwinism, which was contrary to state law.

1927 Talking pictures (movies) made their first appearance with *The Jazz Singer*, starring Al Jolson.

1929 Black Tuesday, 29 October, the New York Stock Market Crash and beginning of the Great Depression.

1930 Commercial television began.

1931 Completion of the Empire State Building

1932 The neutron was confirmed.

1932 Disney introduced *Flowers and Trees* - a Silly Symphonies animated cartoon credited as the first 3-color animated film shown. (Wikipedia Timeline of Photography History, 2019) Aldous Huxley published *Brave New World*.

1939-1945 World War II

1945 The first atomic weapon was tested, then later employed by the USA in bombing Hiroshima and Nagasaki, Japan.

1947 William Shockley, an engineer at Bell Labs, devised the first solid-state transistor. (McClellan and Dorn, 2015)

1948 Clausen, Keck, and Heisey published their recipricol transplant studies of *Achillea* ecotypes.

1951 UNIVAC, the first commercially available computer server was produced.

1953 Watson and Crick published their model for the structure of DNA.

1957 The USSR launched Sputnik 1, the first satellite to be launched by Earthlings. That team and system also launched the Yuri Gagarin into earth orbit in 1961" (McClellan and Dorn, 2015)

1962 Samuel L. Kuhn introduced the concept of the paradigm shift in his mold-breaking *The Structure of Scientific Revolutions*.

1962. Launching of Telstar inaugurated the epoch of communication satellites.

1969 The first computer network, ARPANET, was established. This was also the year of the first manned moon landing.

1973 Motorola introduced the commercial cell phone, the Dyna-Trac. By 1977, a cell system was active in Chicago, but the first commercial system was established in Tokyo in 1979. (McLellan and Dorn, 2015)

1986 The megapixel sensor was introduced by Kodak (Wikipedia Timeline of Photography History, 2019)

1990 The Hubble Telescope was launched and began operation.

1991 The WWW was activated

1991 Lectures delivered in the Plant Science Lecture Series at Iowa State University focused on "Historical Perspectives in Plant Science," featuring Robert Burris, John Dudley, Brue Griffing, Neal Jensen, Arthur Kelman, Charle Levings, ealph Riley, and G. Ledyard Stebbins. Those lectures were published in 1994 by Iowa State University Press as Historical Perspectives in Plant science, edited by Kenneth J. Frey. The book documents the state of scientific understanding of plants at that moment in time, comparing contemporary awareness to past thoughts. Stebbins, in his lecture *Biological Revolutions of Thought during the Twentieth Century*, defines four revolutions: 1. the Mendelian Revolutions: Genes on Chromosomes; 2. The Macromolecular Revolution; 3. The Transfer-of-Energy Revolution; and 4. The Second Molecular Revolution: Nucleic Acids and the Genetic Code.

2003 Completing a project initiated in 1990, the entire human genome was sequenced, cataloging 20,000 genes.

2008 The multi-national Large Hadron Collider began operation as the world's largest instrument. The LHC was used to test and confirm presence on the Higgs Boson in 2012. (McClellan and Dorn, 2015)

2019 Pete Hegseth, a news commentator and broadcast host explained to his viewers and co-hosts (10 February) that he does not wash his hands to prevent spread of disease because *'Germs are not a real thing. I can't see them, therefore they are not real.'* Hegseth's pronouncement expressed the anti-science conservative movement that rejects implications and realities of a wide range of scientific studies, from the impact of human activity on global warming to concern about GMOs and vaccinations to denial of biological evolution.

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PURGATORY

This is the storehouse for ideas and text that have been rejected ..., eventually to be altered or shredded.

ARISTOTLE....Historical accounts of pure botany, understanding of why plants do what they do (as opposed to more practical applied botany) bow to Theophrastus and Greek philosophies as early crystals in scientific thought. For two thousand years, scholars were obsessed with Greeks science, operating under some apprehension that ancient peoples had known se-

crets about the natural world that were lost, like somebody had hacked the stones and scrolls and erased significant chunks of memory.

Classical deductive logic had worked so beautifully for mathematical construction that the same thought system was applied to plants. What does survive seems to me more innocent than incisive, pretending a world of absolute givens, when biologies are better understood as probabilities.

HISTORY... Ignoring existence of incredible agricultural and applied knowledge, historical accounts tend to regard agriculture as technology, privileging pure science and medical advance as science. Thus, textbooks launch into discussion of European herbals as the beginning of botanical science as a field of natural history.

1.1. We know plants share their most ancient origin with other living beings, an origin that manifests itself in fundamental structure and function.

1.2. Like other life forms, plants are cellular, building themselves through the choreography of cell division.

1.3. Instructions guiding nature and timing of cell growth and development are conserved and passed down as genetic information in long DNA double helices. Scientists have learned much about how those instructions work.

1.4. Beginning in the late 20th Century, researchers gained the ability to alter an organism's genetic makeup and create new forms of life.

2.1. Though a plant is built of millions, even trillions of cells, many of those cells are dead at functional maturity.

2.2. Only the living cells carry on life processes, which require energy captured in chemical bonds, stored in a variety of compounds, and processed through precise and elaborate mechanisms.

2.3. Only living cells can continue growth and development, growth that occurs at the tips, from points, and peripherally, along the edges.

2.4. By that, I mean plants grow outward from a core, always conquering new territory. Vines creep and twine, trees tower and overarch, herbs mound, grasses run, bulbs cluster....

2.5. Botanists still speak of plant growth as primary and secondary. Primary growth, characteristic of all plants, produces new stem, leaves, flowers, and fruit, as well as new roots through cell division in apical meristems - tip growth.

2.6. Secondary growth varies in format, but basically results from development of thin layers of cells, usually call lateral meristems., that can produce layers of tissue.

3.1. In simplest terms, plants make three basic kinds of structures - roots, stems, and leaves.

3.2. Roots (like stems) grow from points; many also develop secondary growth. But roots differ internally from stems. And they tend to grow down, responding to gravity, as well as other stimuli.

3.3. Stems follow a similar pattern, exploring new territory from tips and (in many instances) able to produce thickening tissue through secondary growth.

3.4. Stems, however, show much greater structure and organization than roots.

3.5. The growing tip, which archetypally started with an embryo, gives rise to the stems, leaves, and their many derivative structures.; it "lays down" the mature plant framework through modular architecture, employing iterative, nodular growth.

3.6. The stem growing tip also makes the leaves, which means leaves are all primary growth.

3.7. And there are countless different kinds of plant productions that are made by the growing tip similarly to the way in which normal green leaves are made. To a botanist, therefore, bracts, spines, sepals, petals, stamens, and pistils are simply specialized leaves.

4.1. We see, in plant roots, stems, and leaves, specializations, i.e. adaptations, that make them successful components of their native habitats, allowing plants live in so many different circumstances and co-exist with other organisms in many kinds of symbiotic, mutualistic, even destructive relationships.

4.2. That success, of course, means plants must reproduce and distribute themselves effectively.

4.3. As soil science continues to expand understanding of biotic relationships between plants and other organisms, we appreciate the web of life that makes soil a biological complex necessary for plants to take in water and nutrients.

5.1. Today we can explain the physiological nature of plants and the ways they interact with the environment, from responses to environmental stimuli to the movement of water through tissues.

5.2. Scientists have detailed how the power of sunlight is captured, converted to chemical energy, and utilized to drive every life process.

6.1. And researchers have a reasonable grasp on Earth's plant diversity, even how that diversity has evolved over hundreds of millions of years.

7.1. We understand there are significant similarities between plants and animals:

- *7.1.a.* Both utilize many of the same metabolic processes, such as respiration and conversion of simple sugars to starches, fats, and amino acids.

- *7.1.b.* Both operate from genetic instructions coded in DNA and transcribed to proteins.

- *7.1.c.* Both are mostly water.

- *7.1.d.* Plants and animals evolve through similar processes.

7.2. On the other hand, at other levels, plants and animals differ considerably:

- *7.2.a.* Plants are made of cells, but plant cells are immediately distinguishable from those of animals, with basically different mechanisms for dividing and for maintaining structure.

- *7.2.b.* Plants make tissues that allow them to take on 3-dimensional shapes, but they do not have bones.

- *7.2.c.* Plants move fluids (water, sap, sugar solutions), but there is no circulatory system, and certainly nothing like a heart.

- *7.2.d.* Plants can sense and respond to environmental cues, but they do not have nervous systems. And they do not think or feel pain.

- *7.2.e.* Plants respire (in a chemical sense) and exchange gases with the atmosphere, but there is no system of lungs or mechanism for active breathing.

- *7.2.f.* Plants reproduce themselves and colonize areas in multitudinous ways, both differently and more variously than animals.

- *7.2.g.* Plants have epidermal tissue, but the cells are very different from those of our skin. And plant hairs (trichomes) are are cells, while animal hair is protein extrusion.

- *7.2.h.* Plants "make their own food" - which is to say: Plants make glucose and other sugars through capturing the energy of sunlight and using that energy to fix atmospheric carbon dioxide into carbohydrates.

- *7.2.i.* In general, plants disperse through pollination as well as fruit and seed production, while most animals are individually mobile.

- *7.2.j.* Plants are among life forms we call producers; they generate and elaborate fixed carbon which provides sustenance for many other life forms. Plants also create habitat and materials on which other life forms depend.

8.1. Prior to 1600, most understanding of plants was based on simple and practical agricultural experience and flawed, irrational assumptions about their relationship to human health. The progression in human understanding of nature of plants is a product of the past four centuries, a time during which

people have shed superstition and anthropocentric assumptions.

8.3. For future scientists, wonders do not cease; there remains much to be discovered and brought to service. Most importantly, the natural world is imperiled, through our own activity. The only hope for preserving the natural world rests in our capacity to learn more quickly and act on the truths revealed.

Of course, humans have long altered genetic makeup of plants [search using "domestication"]. Our most important crops (corn, wheat, cotton, for example) show such ancient selection for cultivation and harvest that botanists and agronomists are not fully able to decipher their origins. Even a relatively minor crop plant, saffron (*Crocus sativus*), evidences what we call "artificial selection" in being a sterile triploid clone that has been vegetatively propagated for centuries.

It isn't clear how aware ancient peoples were regarding their active selection. Certainly they did not understand the genetic bases for propagation and sexual reproduction, indeed it wasn't until around 1700 that we began to realize seed usually result from a sexual process. Thomas Fairchild gets credit for creating the first purposeful hybrid in 1717 (in Carnations), though nearly two centuries passed before people began actively creating and selecting hybrids fopr large scale improvements in crop yield [search for info on J & R. Garton's 'Abundance' oat introduction in 1892].

Hybridization, which soon matured as a highly-complex science in grains (particularly corn), is still considered a "natural" process (though Darwin called this "artificial" selection), especially as compared to the process of genetic manipulation called **transformation**. First introduced in a 1973 publication of work by Herb Boyer and Stanley Cohen, the engineered capacity to insert foreign genes into an organism's genome has changed the future and introduced people at large to the concept of GMOs (genetically modified organisms.) By 1982, the 'Flavr-Savr' tomato became the first GMO plant crop, which was introduced, unsuccessfully, to commerce in 1994. Within two decades, however, numerous major genetically-modified crops (particularly cotton, corn, and soybeans) became standard, as has public concern. As with the tale of Pandora's box, or the Humpty-Dumpty rhyme, however, there is no going back. Genetic transformation is here to stay, and today's fears/challenges will prove infinitesimal compared to what lies ahead.

Do not be deceived into thinking that modern science is the child of Greek science. Western knowledge was a swirl of Classical Greek logic, Arabic and Eastern interpretation, Christian theologies, and Eastern mysticism. While farmers tended crops based on solid, empirical knowledge, the high-minded (and literate) were trapped by their cultural mores. Modern botanical science was going nowhere. But change was coming.