Chapter 18
Medicinal and Aromatic Plants—Uses and Functions

Maiko Inoue and Lyle E. Craker

Abstract Medicinal and aromatic plants contain the chemical constituents first used by humans as medicines for healing, as flavoring agents for food and drink, and as mental stimulants for mystic interactions with super natural gods. These plant materials continue to play positive roles in human life, as sources of modern pharmaceuticals to treat medical problems, as herbs and spices to tempt the palate, and in a multitude of other applications. Demand and trade for these plant materials initiated globalization that spread new ideas, new diseases, and new settlements along with native resentment. This chapter presents a detailed and thorough review of plant metabolites used in modern and conventional medicine and those providing spices and condiments. The taxonomy, biochemistry and extraction are described. Truly it may be said that medicinal and aromatic plants have changed the world and undoubtedly play an important role in the future as they have in the past.

Keywords Healing · Flavoring · Pharmaceuticals · Herbs · Spices · Metabolites

Introduction: Special Plants

Medicinal and aromatic plants represent a broad group of plant materials valued primarily for their chemical constituents. Since ancient times, these plants have been used to help restore and maintain health, to preserve and flavor foods, to add color and aroma to daily life, and to serve as pathways to spiritual dreams and mystical adventures. While sometimes referred to as medicinal herbs, culinary herbs, potherbs, spices, seasonings, essential oil plants, or other terms to distinguish plant use, collectively these plants have been used for a variety of applications throughout recorded history, enhancing the quality of human life. Currently, an estimated 70,000 plant species are used in traditional medicine (Farnsworth and Soejarto 1991).

The discovery and initial uses of medicinal and aromatic plants by various groups of people are unknown, but possibly the plants were chosen for use as alternative

M. Inoue (✉) · L. E. Craker
Medical Plant Program, University of Massachusetts, Amherst, MA 01003, USA
e-mail: den8mai@yahoo.co.jp

L. E. Craker
e-mail: craker@umass.edu

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Table 18.1 Terms used with medicinal and aromatic plants. (Source: American Botanical Council (2013))

Herbal term	Description
Herb or culinary herb	Aromatic plant material from temperate regions used in minor quantities to flavor foods and beverages, but has little or no nutritional value
Spice	Aromatic plant material from tropical regions used in minor quantities to flavor foods and beverages, but has little or no nutritional value
Medicinal plant	Various plants used for treatment of disease or other body afflictions
Essential oil plant	Plants from which a volatile oil that can be extracted by distillation, solvents, or expression
Aromatic plant	Plants with an aroma that comes from the presence of an essential oil in the plant tissue
Poisonous plant	Plants containing alkaloids or other substances that can produce toxic effects when introduced into the body
Endangered plant	Plant species of which few remain, are in danger of becoming extinct, and are generally protected by law and trade restrictions

food sources and then recognized for an attractive aroma or enhanced healing when applied to cuts and scrapes. Undoubtedly, these first trials with plants were tentative and perhaps came from watching the plant materials selected and eaten by animals and earlier humanoids. From this beginning, plant trade among groups would lead to trade among near-by countries and eventually to global trade of medicinal and aromatic plants. The activities of early humans in medicinal and aromatic plants continue today with plant exploration and botanical sourcing for new medicines, new aromas, and new uses. Global trade in medicinal and aromatic plants has become a US$ 30 to US$ 60 billion business (Anon 2008).

Although the populations of many countries remain dependent on traditional uses of medicinal and aromatic plants for health care, these plants are also recognized as major contributors to modern life, pharmaceuticals for human diseases, seasonings to flavor foods and beverages, and beauty through cosmetic goods and herbal gardens. Laboratory chemists work to modify plant constituents to improve bioactivity. In contemporary societies, individualsfrequently seek to develop and protect health through self-treatment with herbal materials as foods, food additives, and dietary supplements meant to improve the normal diet and reduce medical costs. Although known by several names, medicinal and aromatic plants continue to make useful and valuable contributions to world societies (Table 18.1).

Discovery: Historical Progress

To fully understand and appreciate medicinal and aromatic plants and their uses and functions, some history on their interactions with people is necessary (Table 18.2). The anthropological residues provide clues in the search for plant materials to be used as pharmaceuticals. The discovery of medicinal and aromatic plants that could produce delightful aromas, flavor foods, enhance health, and cure illnesses was an

Table 18.2 Significant events in the history of medicinal plants and medicine. (Source: Mamedov and Craker (2012))

Timeline	Significant events	Related developments
~200,000–5,000BC	Humans with ailments	Testing of plants for medicinal activity; development of traditions and myths about medicines
~5,000–3,000 BC	Ötzi, the Iceman, is killed and frozen	Evidence that early humans used plant medicines
~3,000–500 BC	Formal training initiated for useful plant medicines and applications; Ayurvedic medicine founded in India; recognition of willow bark and *Cannabis* as medicines	Initiation of spice trade; in Asia and Middle East; development of written records on medicine; Imhotep and Papyrus Ebers in Egypt, Pen Ts'ao Shen Nung in China; Rigveda in India
~500–300 BC	*Hippocratic corpus* written by Hippocrates; *De Causis Plantarum* and *Historia Plantarum* written by Theophrastis	Formalized medicine practices in diagnosis and treatments; lists of medicinal plants and applications; medical school established in Cyrene
~300–100 BC	Formal medical education is increased; trade in medicinal herbs and spices between east and west	Sharing of medicinal recipes and medicinal plants; medical school formed in Alexandria; study of anatomy
~100 BC–100 AC	Celsus wrote *De Medicina*; Dioscorides wrote *De Materia Medica*; opium recognized as medicinal drug	Development of materia medica and pharmacopoeias
~100–200 AC	Galen made medicinal preparations	Medicinal doses calibrated; initiation of pharmacies
~200–500 AC	Mayans practiced medicine; Greek culture encouraged learning	Continued study of medicine and medicinal practices
~500–1,000 AC	Avicenna did clinical trials on medicines and developed medical books; Albucasis wrote medical encyclopedia; Hildegard of Bingen wrote about medicinal plants	Medicinal plants tested for various health problems; medical reference books available for study; Avicenna writes Book of Healing and Canon of Medicine
~1000–1500 AC	Marco Polo traveled to China; Gutenberg built printing press; medicinal books were written in European languages with descriptions of plants; Ibn al-Baitar wrote books on botany and pharmacy, pioneered veterinary medicine	Travelers and traders told of spices and medicines in Asia; need for medicines and spice trade stimulated exploration with ocean-going ships; ship-building school by Henry the Navigator in Lisbon; voyage of Columbus to America for spices
~1500–1900 AC	Vasco da Gama reached India; Withering discovered heart medicine in foxglove; Seishu Hanaoka used atropine and scopolamine	Medicinal plants and spices start being widely used as medicine throughout the world
~1,900–2,012 AC	Traditional medicine being used by 70–80% of world population; many chemically synthesized medicines based on plant extracts; revived interest in medicinal plants	Development of vaccines and antibiotics discouraged use of medicinal plants in advanced countries; recognized medicinal benefits of plants and plant extracts encourage expanded research in plants for medicine

important development during the early history of humans. Such information would be incorporated into traditional rituals, stories, and myths that could transmit the learned uses of these plants to future generations. Medicine men and women with specialized knowledge and skills in the use of plant materials for healing would become significant and honored members of societies.

With the development of mnemonic symbols and subsequent writing skills, instructions on medicinal plants and their use was recorded in several locations, including Egypt, India, China, the Middle East, and the Americas. The oldest written document on the use of medicinal plants in the preparation of a pharmaceutical is an approximately 5,000 year old Sumerian clay tablet that refers to 250 plants. Early written instructions, which were frequently a mixture of plant material and mysticism, provide historical detail on plants and plant preparations used in the treatment of medical issues. The Ebers papyrus, dated 1,550 BC, but thought to be copied from even older written sources, is the most complete of the medical papyri. A recommended treatment for urinary problems in the Ebers papyrus includes the plants, carob (*Ceratonia siliqua*), celery (*Apium graveolens*), date (*Phoenix dactylifera*), fig (*Ficus carica*), grape (*Vitis vinifera*), gum arabic (*Senegalia senegal* and *Vachellia seyal*), and wheat (*Triticum* spp.) (Carpenter et al. 1998).

In India, the traditional medicine system, Ayurveda, is based on the *Charaka Samhita* (100 BC–100 AC), the *Sushruta Samhita* (300–400 AC), and the Bower manuscript (400–600 AC). Unani, a second traditional medicine system of India, is a Greco-Arab medicinal practice imported to India from the writings of Avicenna, a Persian physician that wrote a series of treatises on medicine. Ayurvedic medicine contains over 600 plant species for use in treatments and Unani medicine approximately 40 plant species, including the Damson tree (*Terminalia* spp.), Malacca tree (*Emblica officinalis*), Ajowan (*Ptychotis ajowan*), and Senna (*Cassia angustifolia*). Both the Ayurvedic and the Unani systems of medicine had spread to other parts of Asia by 1,300 AC.

In China, the traditional medicine system originated primarily from a 2,000 year-old Chinese medical text, *Huangdi Neijing*, containing a series of chapters, which along with earlier writings and later revisions became the foundation for Traditional Chinese Medicine, a health system based on humoral balances. In the Chinese medicine system, good health requires equity among the natural forces associated with diet, lifestyle, emotions, and environment. Thus, good health requires a balance among natural forces, such as Yin-Yang (two opposites form the whole), Qi (life energy), and the Five Elements (interactions and relationships). Medicinal and aromatic plants, along with animal and other natural substances are used to bring the body into balance. The first recognized Chinese herbalist is Shennong, a legendary ruler of China of 5,000 years ago who taught the people the use of medicinal herbs (Anon 2013).

Early European medicine markets made use of spices that were undoubtedly part of the trade goods coming from Asia via routes that followed the Silk Road and via crossings at the Isthmus of Suez located between the Red Sea and the Mediterranean Sea. Although limited western trade with India and China occurred as early as 1,600

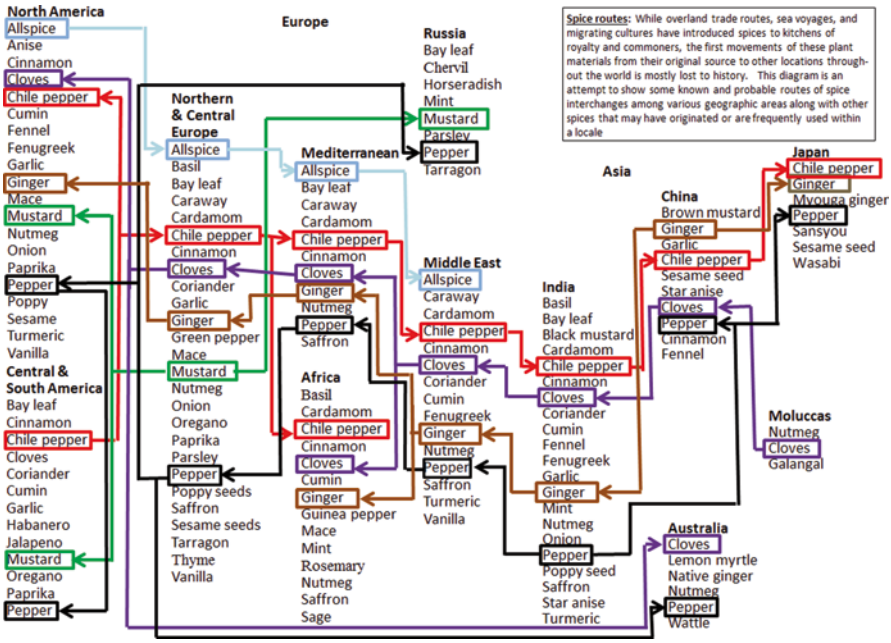

Fig. 18.1 Some early trade routes of spices along with spices frequently used in various regions. (Sources: Czarra (2009); Food University (2013); Keay (2007); Kew Gardens (2013); Spices & Herbs (2013))

BCE, the conquests of Alexander the Great into Northern India by 325 BCE probably introduced other European countries to spices as flavorings and medicines.

A book by Marco Polo, *The Travels of Marco Polo* (Polo and Rossabi 2012), which detailed the riches in Asia he observed during travel (1271–1291) with his father and uncle, became popular reading in Europe, bringing an awareness of other civilizations and spices. Large demands for Asian spices occurred during the fourteenth to seventeenth centuries as possible preventatives or cures for the plagues that swept through Europe during this time period. The limited quantities of spices available via the overland Asian-European trade routes, especially after the Ottoman victory at Constantinople in 1453, promoted the search for a sea route to Asia. An ocean-going ship building and learning facility built in southern Portugal by Prince Henry the Navigator in 1418, trained sailors in ship building, navigation, and other trades necessary for an ocean voyage into unknown waters.

Sailing East for Portugal, as agreed upon in the Treaty of Tordesillas in 1494, Vasco da Gamma reached Calicut, India, opening a new trade route to Asian spices in 1498. Sailing West for Spain, Columbus reached America, a continent unknown to Europe, in 1492, but instead of the pepper (*Piper nigrum*) of Asia, he returned to Europe with samples of allspice (*Pimenta dioica*), and red pepper (*Capsicum* spp.) (Fig. 18.1).

Constituency: Chemical Extracts

Medicinal and aromatic plants are valued for their chemical constituents known as secondary metabolites. These secondary metabolites, which include essential oils, are organic compounds with no known necessity for the normal growth, development, or reproductive activity of an organism, but are bioactive, interacting with tissues and provide the aromas, tastes, and medicinal activity associated with such plants. For example, in sensing the aroma of aromatic plants, the volatile chemical constituents from the plants interact with sensory neurons within the olfactory epithelium system to produce nerve impulses that communicate the aroma signal along the olfactory nerve to the brain. Anticancer activity exhibited by the American Mayapple (*Podophyllum peltatum*), for example, contains constituents that interfere with DNA replication, thus stopping the rapid cell division associated with cancer (Chaurasia et al. 2012).

Positive effects from secondary metabolites are associated with pharmacological action beneficial to the consuming organism, while negative effects are associated with toxicity that harms those consuming the plant tissue. As with other drugs, the bioactivity exerted by secondary metabolites is directly related to absorption, distribution, metabolism, and excretion (ADME) of the metabolite. Beneficial effects from a secondary metabolite may, however, become toxic if too much is consumed.

While secondary metabolites may not be essential for bodily functions, they can enhance life through improvement in health, spirit, and aesthetics. The exact reason why some plants contain essential oils and other secondary metabolites is unknown, but the presumptions are that these chemical constituents could attract or repel insects and other life forms that benefit or stress the plant, respectively, or could act as storage centers for metabolic waste products. Secondary metabolites are used by humans to improve life through use in disease prevention and healing, food flavorings and preservation, beauty products and aesthetics, and recreational drugs and mysticism.

Secondary metabolites are extracted from plant tissue by distillation, expression, or solvents, depending on the constituents and plant material (Table 18.3; Fig. 18.2). Extracts (Table 18.4) are frequently grouped according to the extraction method, application, physical properties, chemical structure, or synthesis pathway of the extract (Figs. 18.3 and 18.4). Grouping of medicinal and aromatic plants by chemical properties would include alkaloids, anthraquinones, flavonoids, glycosides, lipids, phenylpropanoids, resins, saponins, and terpenoids (Figs. 18.5, 18.6, and 18.7). Variations in chemical structures are numerous, differing in chemical constituency, isomerism, and substituents.

Although a number of plants have been tested with some becoming new pharmaceuticals or innovative commercial products, many more plants have not yet been fully evaluated for bioactive properties. Thus, continued exploration, but not exploitation, of plants with health or other benefits is necessary. Over collection and habitat destruction of wild medicinal and aromatic plants used in commercial trade can lead to shortages and possible extinction of species. An estimated 400 species are currently at risk. These at risk species and other species that become endangered

Table 18.3 Methods for extracting essential oil from plant tissues. (Source: Soysal and Öztekin (2007); Esoteric Oils (2013))

Distillation—The conversion of volatile liquids (essential oils) into vapor and then back to liquid by cooling
Water distillation—plant tissue covered in water and brought to boil so that essential oil vaporizes
Steam distillation—steam moved up through plant tissue to vaporize essential oil
Hydro diffusion—steam moved down through plant tissue to vaporize essential oil
Expression—the plant is cold pressed to squeeze essential oil from the tissue; used primarily for citrus oil extractions
Sponge expression—tissue macerated and essential oil squeezed on top of collection sponge
Écuelle à piquer—tissue punched by a machine with spikes to release oil
Machine abrasion—tissue subjected to abrasion to remove oil cells and then centrifuged for oil collection
Solvent—the plant material is placed in a solvent system to extract essential oil from tissue
Solvent—plant material placed in a selected organic solvent to leach essential oil from tissue
Enfleurage—plant tissue pressed into bowl of fat to extract essential oil; used primarily with flower petals
CO_2 extraction—plant material placed in sealed container with hypercritical carbon dioxide

Fig. 18.2 Preparing for distillation of essential oil in Nepal. (Source: Photo courtesy of Han Saran Karki)

must be cultivated to ensure survival of the species and that an adequate supply of the plant is available for commercial use. Some future supplies of medicinal and aromatic plant bioactives may come from production of the chemical constituents in bioreactors (McCoy and O'Connor 2008), and modifications to plant genomes to produce variations in constituents (Runguphan and O'Connor 2009).

The World Health Organization has published quality control methods for plant materials (Anon 2003b) to help ensure public safety and conservation and protection of plants collected in the wild (Table 18.5). In the European Union herbal medicines are regulated under the European Directive on Traditional Herbal Medicinal Products and in the United States dietary supplements and herbal remedies are controlled by the Food and Drug Administration. These agencies, along with the processing and manufacturing companies are responsible for maintaining safe

Table 18.4 Medicinal and aromatic plant extracts. (Source: Leung and Foster (1996))

Extracts	Description
Absolute	Pure essence, the pure odoriferous extract of flowers for use in perfumes
Balsams	Resinous mixtures that contain large proportions of benzoic acid and/or cinnamic acid
Concréte	Water insoluble fraction of a plant remaining in retort after distillation
Decoction	A water based plant extract made by boiling plant material in water
Essential oil	Plant extract obtained from plant tissue by distillation, solvents, or expression
Fixed oil	Plant extract that contains glycerol esters of fatty acids
Infusion	A water based plant extract made by steeping or soaking plants in hot water
Oleoresins	Homogeneous mixtures of resins and volatile oils
Plant extract	Substance or chemical removed from a plant, usually the essential oil
Resins	Solid or semisolid amorphous plant product of a complex chemical nature
Stimulant/tonic	A plant or plant extract that energizes the body and/or mind
Tincture	Pharmacologically, an alcoholic solution of a nonvolatile medicine

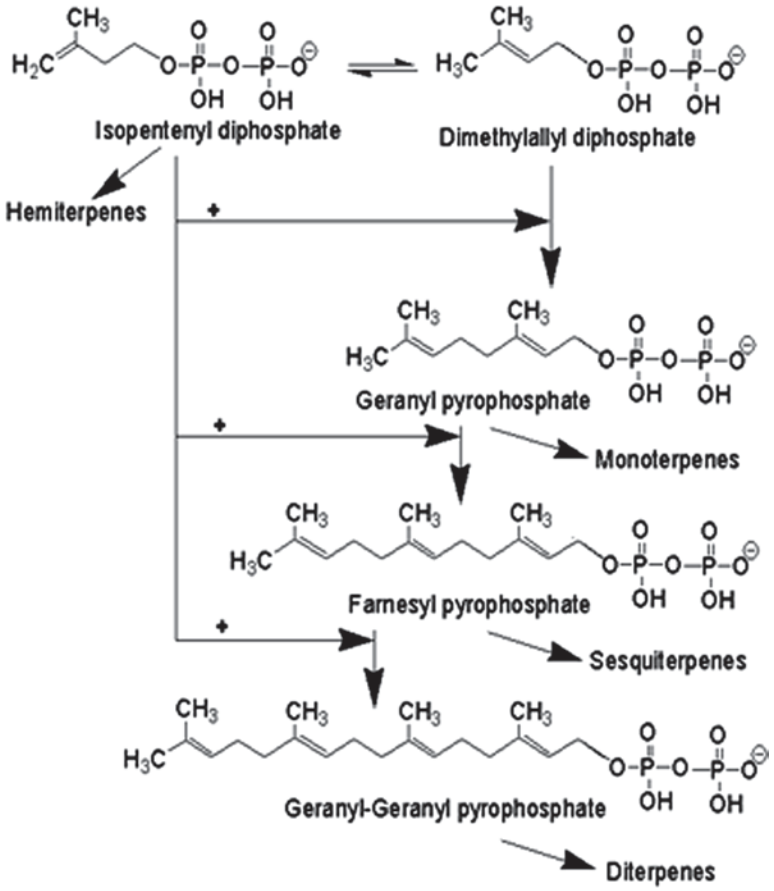

Fig. 18.3 The mevalonic acid synthesis pathway. (Source: Samuelsson (1992))

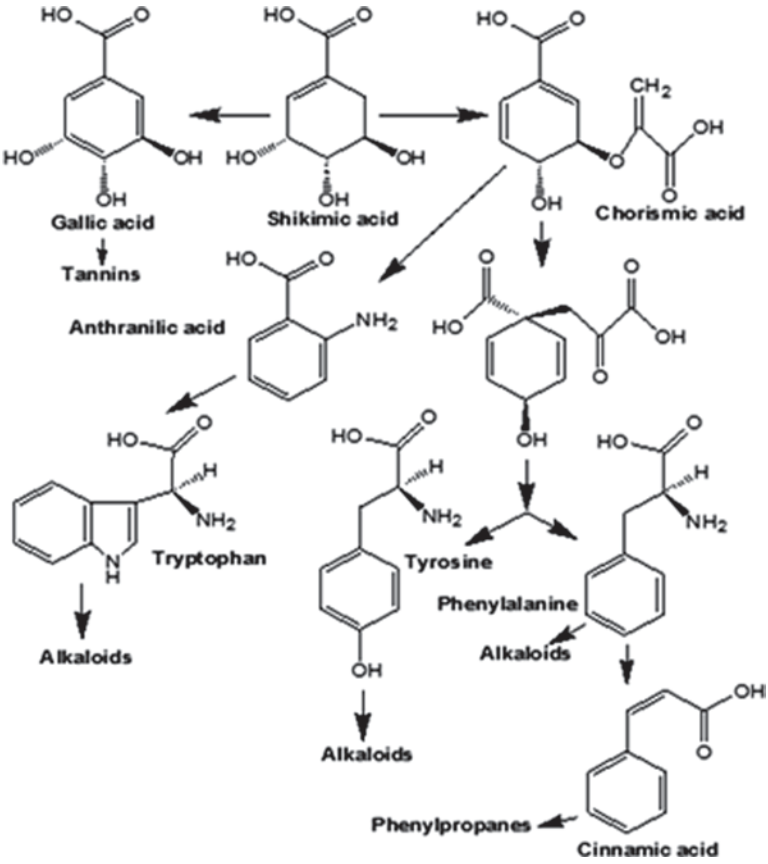

Fig. 18.4 The shikimic acid synthesis pathway. (Source: Samuelsson (1992))

marketable medicinal and aromatic products. Plants and plant extracts go through a series of steps to determine the safety and biological activity of the chemical constituents (Fig. 18.8).

Applications: Pharmaceutical

The use of medicinal and aromatic plants in medicine obviously began when humans first discovered that plants or parts of plants could be used to make ill people feel better. From this beginning of pharmacognosy (the study of medicines derived from natural sources), plant medicines have moved from crude preparations to an important source of pharmaceuticals in the treatment of several diseases. Today, the exploration of plant materials to develop new and effective medicines involves

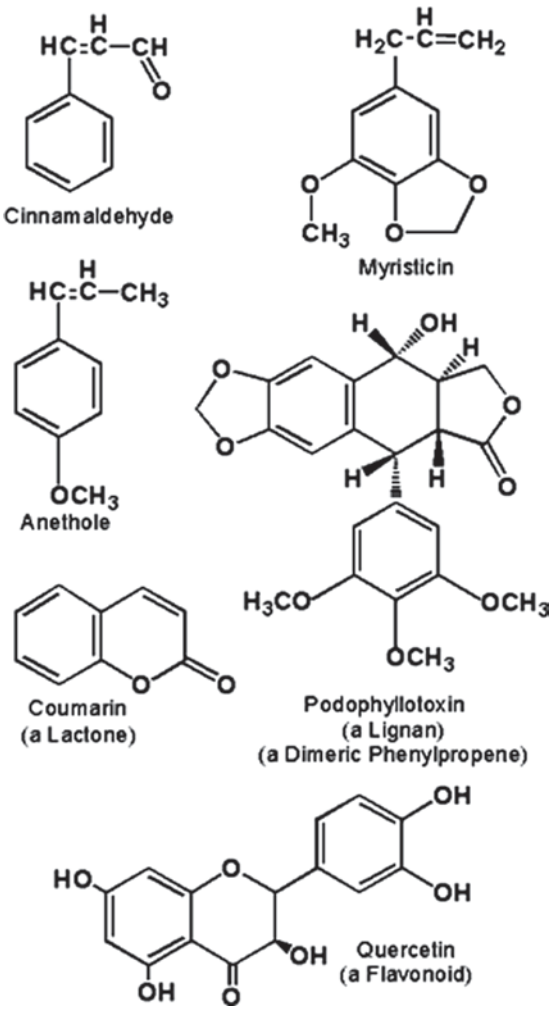

Fig. 18.5 Phenylpropanes. (Source: Jiangsu New Medical College (1978); Samuelsson (1992))

partnerships among plant explorers, ethnobotanists, physicians, medical chemists, and many others interested in developing better medicines.

Phytotherapy, the medical practice of using medicinal and aromatic plants and extracts to promote health, has been criticized by Western medicine due to the unregulated variations within alternative medicines that contrast with the standardized drugs and treatments of conventional medical therapies. The use of extracted constituents that have pharmacological benefits has led to an accepted status for natural product medications in most countries. A number of medications have originated with plants, but may be currently synthesized in chemical laboratories or modified to improve drug standardization, administration, and/or bioactivity (Table 18.6). Use of plants as a source of medicine is approached in different ways, depending on the society (traditional to modern) (Table 18.7).

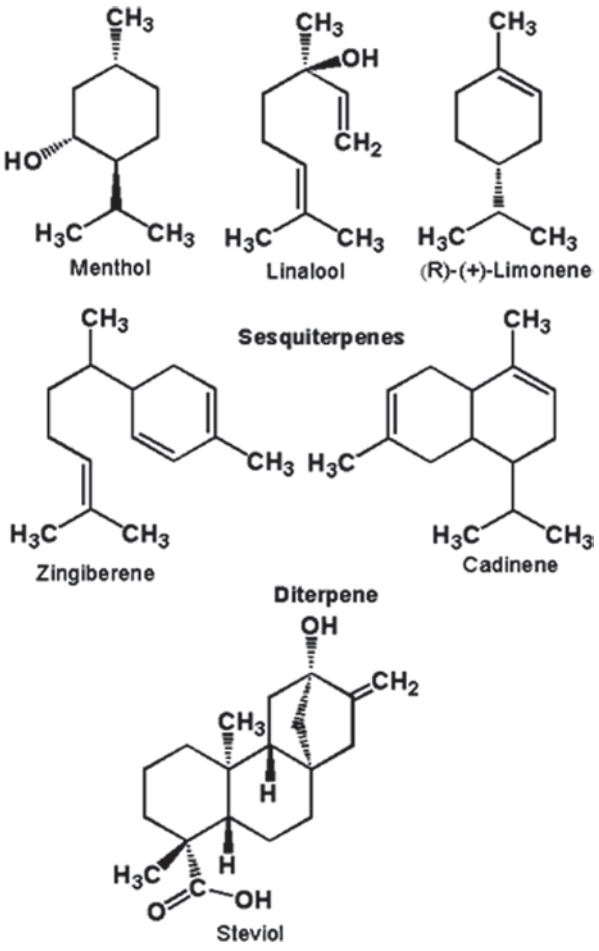

Fig. 18.6 Terpenoids. (Source: Jiangsu New Medical College (1978); Samuelsson (1992))

The World Health Organization indicates plants are used as the primary healthcare for 80% of the world's population (Anon 2008). Most plant based healthcare systems occur in areas lacking modern facilities and pharmaceuticals or in locations that have established a traditional healthcare system based on herbal products (Table 18.8). As both traditional and modern health care become more available, the trend is for people to choose that medicine that will best return them to good health.

The types of plant materials used in traditional medical systems throughout the world reflect the available plant material and the experience of generations of people that have tested various plant materials when ill. Traditional healers generally learn their trade by apprenticeships to established practitioners, by following healing practices used within a family group, or by personal experience from being a patient. Supernatural spirit powers are frequently invoked during the treatment process.

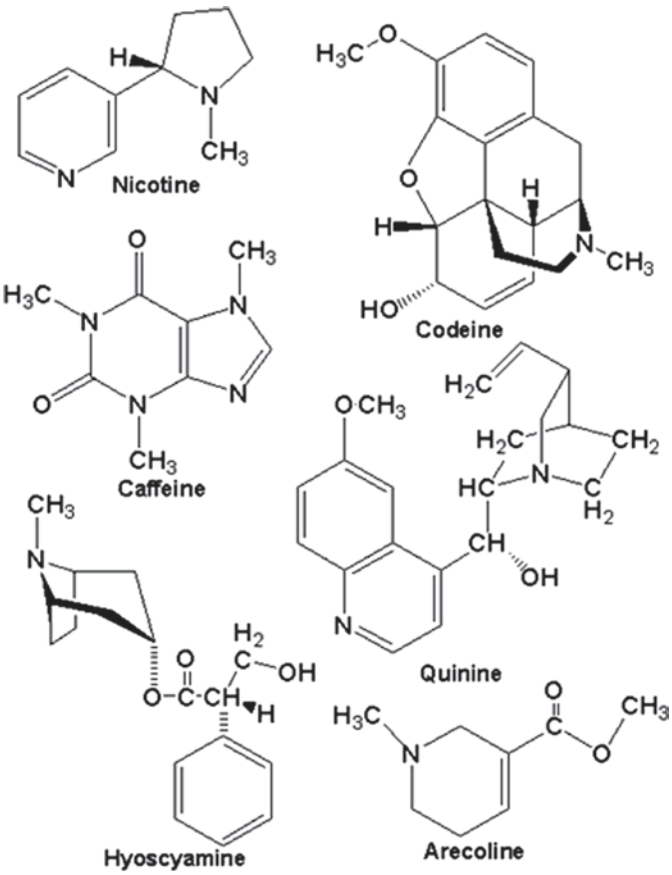

Fig. 18.7 Alkaloids. (Source: Jiangsu New Medical College (1978); Samuelsson (1992))

Table 18.5 World Health Organization guidelines for good practices in production, collection, and manufacturing of medicinal and aromatic plants

Practices	Title	Listing website
Agricultural production and collection	Good Agricultural and Collection Practices (GACP) for medicinal plants	Anon (2003a)
Manufacturing	WHO guidelines on good manufacturing practices (GMP) for herbal medicines	Anon (2007)

Although recognizing that traditional herbal medicines may sometimes be effective, conventional medicine practitioners generally reject the use of traditional medicines, primarily due to the lack of cleanliness and hygiene associated with the practitioner and plant materials, the lack of defined dosages, the lack of practitioner education, the mystification of the medicine and medical treatment, and the reluctance to share information on treatments except to those initiated into a code

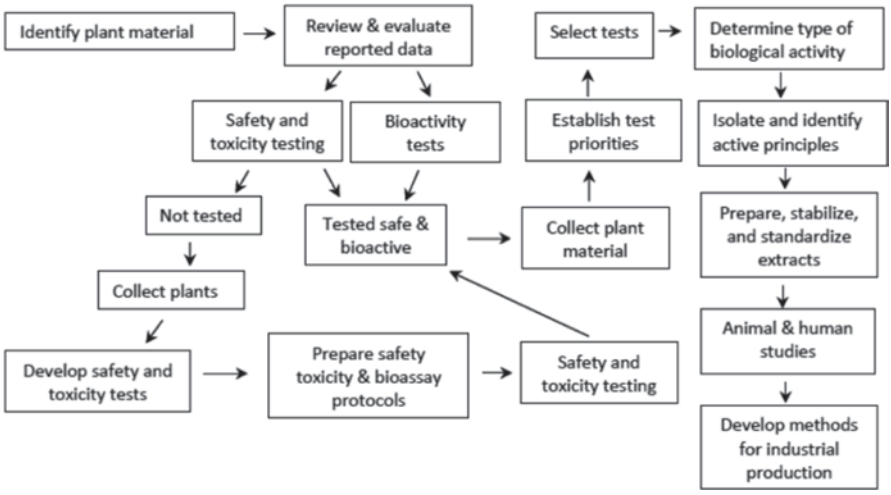

Fig. 18.8 Procedures to determine bioactivity and safety of chemical constituents in plants. (Modified from Fabricant and Farnsworth (2001))

Table 18.6 Some modern medicines originating from plants. (Source: MMS Gardens (2012))

Medicine	Plant material	Medicinal actions
Aspirin	Willow (*Salix alba*)	Antipyretic, analgesic, anti-inflammatory
Cardiac glycosides	Foxglove (*Digitalis purpurea* and *Digitalis lanata*)	Congestive heart failure, edema, atrial fibrillation
Morphine	Poppy (*Papaver somniferum*)	Analgesic
Paclitaxel	Pacific yew tree (*Taxus brevifolia* and endophytic fungi in bark)	Cancer treatment for lung, ovarian, breast, head, neck, Kaposi's sarcoma
Vincristine and Vinblastine	Madagascar periwinkle (*Catharanthus roseus*)	Cancer treatment for lymphomas, leukemia, Wilms' tumor, and other cancers

Table 18.7 Approaches for use of medicinal plants. (Source: Modified from Hirani (2012))

Approach	Application
Magical	Used in traditional societies; the practitioner (shaman) uses herbs to affect the spirit of the patient
Energetic	Used in Chinese, Ayurveda, and Unani medical practices; the practitioner uses herbs to balance energy within patient
Functional	Used by physiomedical practices; the practitioner uses natural products with action thought linked to a physiological function
Chemical	Used by modern phytotherapists: the practitioner prescribes treatments according to known constituents in plant tissues

Table 18.8 Some traditional medicinal plants of Africa and Asia. (Source: Ayensu (1978); Kokwaro (2009); Simon et al. (2007); van Wyk et al. (2011); Wiart (2001, 2012))

Plant material	Applications
Africa	
Aframomum melegueta	Leprosy, aphrodisiac, dysentery, toothache, migraine, rheumatism, fever, diarrhea, antifeedant, control lactation, postpartum hemorrhage
Aspalathus linearis	Colic, antispasmodic, block the nose, emetic, insomnia, headaches, hepatoprotective, suppresses skin tumor formation
Asystasia gangetica	Asthma
Cinnamomum camphora	Coughs, fevers, pneumonia, diarrhea
Cryptolepis sanguinolenta	Blood pressure, fevers
Harpagophytum procumbens	Fever, indigestion, malaria, allergies, rheumatism, arthritis, diabetes, senility, anti-inflammatory, low back pain
Hoodia spp.	Indigestion, blood pressure, diabetes, stomach aches
Mondia whitei	Stomach pain, indigestion, pain, post-partum bleeding
Prunus africana	Fever, improve appetite, chest and stomach pain, gonorrhea, inflammation, kidney disease, urinary tract complaints, prostate hypertrophy
Securidaca longepedunculata	Laxative, nerve disorders, treat wounds and sores, coughs, venereal diseases, snakebites, schistosomiasis, headaches
Voacanga africana	Leprosy, diarrhea, edema, convulsion, madness, carious teeth, cardiac spasms, asthma, anti-ulcer
Asia	
Astragalus propinquus	Treat hepatitis strengthen immune system
Azadirachta indica	Worms, malaria, rheumatism, skin infections
Ephedra sinica	Respiratory ailments, weight loss, low energy and athletic performance
Euphorbia hirta	Bronchial asthma, laryngeal spasms
Panax ginseng	Aphrodisiac, stimulant, type II diabetes
Piper methysticum	Soporific, asthma, urinary tract infection
Saraca indica	Gynecological disorders, edema, swelling
Zingiber officinale	Stimulant, carminative, dyspepsia, gastroparesis, constipation, colic

of secrecy. Plant materials used in treatments are frequently exposed to “unclean” environments (Fig. 18.9). Production, collection, and processing of medicinal and aromatic plants should be done under clean and sanitary conditions (Fig. 18.10).

By contrast, conventional medicines used in “modern” nations requires trained medical doctors and an associated professional staff, diagnostic equipment, and laboratory tests to confirm a patient’s health status, and uses manufactured pharmaceuticals in the form of pills, lotions, capsules, liquids, or injections to bring the body and/or mind to a “normal,” healthy state. These pharmaceuticals, chemical substances used for treatment, curing, or preventing a disease, are sometimes synthesized in a chemistry laboratory, but due to difficulty in chemical synthesis could also be extracted from medicinal plants. According to Taylor (2004), at least 120 current pharmaceuticals are sourced from plant materials (Table 18.10). Such

Fig. 18.9 Supply of plant material for use in traditional medicine-herbal market in Nigeria. (Source: Herbal market in Nigeria. Photo courtesy of Dr. Ade-Ademilua, University of Lagos)

plant based pharmaceutical drugs are used to treat a variety of medical problems, exemplifying the range of medicines extracted from plant tissues.

A cultural divide separates the traditional herbal healing (in which the medical practitioner brings the body into balance using natural products to modify the factors that caused the imbalance) to conventional healthcare (in which the medical practitioner determines the biological cause and treats the ailment with clinically approved, but expensive medicines). In the United States, an increasing number of healthcare consumers are beginning to seek natural herbal remedies along with a healthy approach to diet and lifestyle as an alternative to the high costs and side effects of chemically-based medicines (Dickinson et al. 2012). In the United Kingdom, 25 % of the population regularly uses herbal medicine (Behrens 2004). Herbal medicine, sometimes referred to as traditional medicine or complementary/alternative medicine (CAM), uses herbal materials, preparations, and finished herbal products that contain bioactive ingredients. Drug terms indicate the plant parts being used in herbal medicinal preparations (Table 18.9).

Pharmaceuticals originating from plants arise from literature reports or with a study of plant materials used in traditional medicines by plant explorers. These medicine hunters visit native villages to observe plant use, identify the plant material, and source plant samples for analyses in chemical laboratories. Plant constituents are subsequently bio-assayed and those with positive indications are tested in clinical trials. The plant constituent to be used as a pharmaceutical may be modified to increase solubility, selectivity, and effectiveness (Lipinski 2004). If the chemical cannot be synthesized in the laboratory, an adequate supply of the plant material must be sourced through collection or cultivation.

Natural products remain an important source for developing medicines in the foreseeable future. Of the 877 new medicines developed during 1981–2002, 52 were from natural products, 237 were derivatives of natural products, and 140 were synthetics modeled after a natural product (Newman et al. 2003). Of the drugs considered essential by the World Health Organisation (Anon 2011), at least 10 % are

Fig. 18.10 Medicinal plant cultivation, harvesting, processing, and wild collection. (Source: All photographs courtesy of the authors, Maca photograph courtesy of Christopher S. Kilham, Medicine Hunter Incorporated)

Table 18.9 Drug terms used with traditional natural product medicines. (Source: Samuelsson (1992))

Drug term	Plant part
Aetheroleum	Essential or volatile oil
Balsamum	Balsam, solution of resin in volatile oil
Bulbus	Underground stem with leaves
Cortex	Bark, all tissue outside of cambium, can be roots, stems, or branches
Flos	Flower, single flowers or entire inflorescences
Folium	Leaf, generally middle leaves of plant
Fructus	Fruit
Herba	Herb, aerial parts of the plant, stem, leaves, flowers, and fruit
Lignum	Wood, from plants with secondary thickening; woody parts of xylem (sometimes thin bark)
Oleum	Oil, fixed oil prepared from plant by expression
Pericarpium	Fruit peel
Pyroleum	Tar, prepared by dry distillation of plant material
Radix	Root, could include rhizome
Resina	Resin obtained from secretory structures or residue after distillation of balsam
Rhizoma	Rhizome
Tuber	Root or rhizome
Semen	Seed or part of seed

Table 18.10 Examples of current pharmaceuticals extracted from plants. (Source: Li and Adair (1994); Rajwar et al. (2011); Taylor (2004))

Pharmaceutical	Plant source
Antitussives	
Bergenin	Marlberry (*Ardisia japonica*)
Glaucine	Yellow hornpoppy (*Glaucium flavum*)
Noscapine	Poppy (*Papaver somniferum*)
Rorifone	Indian Field Cress (*Rorippa indica*)
Antihypertensives and tranquilizers	
Deserpidine	Rauwolscine (*Rauvolfia canescens*)
Reserpine	Snakeroot (*Rauvolfia serpentina*))
Rhomitoxin	Rhododendron (*Rhododendron molle*)
Tetrandrine	Han Fang (*Stephania tetrandra*)
Cancer and tumor treatments	
Betulinic acid	Birch (*Betula alba*)
Camptothecin	Tenuous leaf happytree (*Camptotheca acuminata*)
Colchicine	Autumn crocus (*Colchicum autumnale*)
Demecolcine	Autumn crocus (*Colchicum autumnale*)
Etoposide	Mayapple (*Podophyllum peltatum*)
Irinotecan	Happytree (*Camptotheca acuminata*)
Lapachol	Trumpet tree (*Tabebuia* spp.)
Monocrotaline	Crotalaria (*Crotalaria sessiliflora*)
Podophyllotoxin	Mayapple (*Podophyllum peltatum*)
Taxol	Pacific yew (*Taxus brevifolia*)
Teniposide	Mayapple (*Podophyllum peltatum*)
Topotecan	Happytree (*Camptotheca acuminata*)
Vinblastine	Madagascar periwinkle (*Catharanthus roseus*)
Vincristine	Madagascar periwinkle (*Catharanthus roseus*)
Cardiotonics	
Acetyldigoxin	Grecian foxglove (*Digitalis lanata*)
Adoniside	Pheasant's eye (*Adonis vernalis*)
Deslanoside	Grecian foxglove (*Digitalis lanata*)
Digitalin	Purple foxglove (*Digitalis purpurea*)
Digitoxin	Purple foxglove (*Digitalis purpurea*)
Gitalin	Purple foxglove (*Digitalis purpurea*)
Lanatosides A, B, C	Grecian foxglove (*Digitalis lanata)*
Ouabain	Ouabain tree (*Strophanthus gratus*)
Scillaren A	Jimson weed (*Datura* spp.)

exclusively from plant material. In the United States, interest in natural products decreased with the development of vaccinations and antibiotics and many in the American medical establishment instructed patients that natural products were ineffective for healing (Craker and Gardner 2006). This negative attitude by American medical personnel began to change after the Dietary Supplement Health and Education Act of 1994 was passed, and the medical doctors began to understand natural product supplements could help individuals remain healthy.

In addition to personal use of traditional medicines, farmers and others are using natural products to treat livestock and other domestic animals (Table 18.11).

Table 18.11 Plant materials used in veterinary practice. (Source: Day (2012))

Veterinary medicine	Plant material
Analgesic	Bergamot (*Citrus aurantium*)
Anesthetic	Clove (*Syzygium aromaticum*)
Antibacterial	Oregano (*Origanum vulgare*)
Astringent	Myrrh (*Commiphora myrrha*)
Carminative	Lavender (*Lavandula* spp.)
Digestive	Basil (*Ocimum basilicum*)
Disinfectant	Garlic (*Allium sativum*)
	Tea tree (*Melaleuca bracteata*)
Expectorant	Eucalyptus (*Eucalyptus* spp.)
Galactagogue	Fennel (*Foeniculum vulgare*)
Insect repellent	Cedar (*Cedrus libani*)
	Lemongrass (*Cymbopogon citratus*)
Nervine	Chamomile (*Matricaria recutita*)
Stimulant	Camphor (*Cinnamomum camphora*)
	Rosemary (*Rosmarinus officinalis*)
Tonic	Frankincense (*Boswellia carteri*)

These ethnoveterinary practices frequently include holistic approaches (physical exercise and touch therapy) along with the use of medicinal plants. In Nigeria, 92 plant species are reportedly used in the treatment of animals (Nwude and Ibrahim 1980), and many plants are used for animal care in Asia, Africa, Central Europe and South America. As with using plants for personal healthcare, availability, low cost, effectiveness, cultural appropriateness, and ease preparation make ethnoveterinary practices attractive to farmers and to animal owners interested in a natural approach to animal health.

Applications: Herbs and Spices

Herbs and spices are terms used to distinguish two types of aromatic plants based on their use and preparation. The herbs are generally fresh, but sometimes dry, leafy tissues are used in small portions as a flavoring for foods and as a garnish. The spices are dried flowers, seeds, roots, or bark used in small portions for flavoring, coloring, and preserving food. The separation of aromatic plants into herbs and spices, however, is not clearly defined and some plants, such as dill (*Anethum graveolens*) fit into both categories as dill weed (a herb) and dill seed (a spice).

The herbs and spices used in various cuisines are territorial, a taste and aroma gained as a child when introduced to foods in the home. As individuals and groups migrate from their home country to another, they generally favor the taste and aroma of food from the area in which they came. Thus, these migrations bring new foods and flavors to areas to which they immigrate and introduce these foods and flavors to others, making these new tastes and aromas available as alternatives to the usual

Table 18.12 Some herbs and spices used in Asian dishes. (Sources: Kingsely (2009); Miyano and Miyano (2011))

Spice	Plant source	Cuisines
Asafoetida	*Ferula assa-foetida*	Indian and other Asian
Black cardamom	*Amomum subulatum*	Nepalese, Indian, Chinese, Vietnamese
Chinese cassia	*Cinnamomum cassia*	Southern and Eastern Asian
Cloves	*Syzygium aromaticum*	Asian
Indian bay leaf	Cinnamomum tamala	Indian, Pakistani
Indonesian bay leaf	Syzygium polyanthum	Indonesian, Southeast Asian
Green cardamom	*Elettaria cardamomum*	Indian, Malay, Australian, Asian
Kaffir lime leaf	*Citrus hystrix*	Lao, Thai, Cambodian, Indonesian
Kalonji	*Nigella sativa*	Pakistani
Laksa leaves	*Persicaria odorata*	Vietnamese, Cambodian, Thai, Lao
Lemongrass	*Cymbopogon* spp.	Eastern and Southern Asian
Mace	*Myristica fragrans*	Malay, Indian, Indonesian
Mitsuba	*Cryptotaeniajaponica*	Japanese
Pippali	*Piper longum*	Indian,Malaysian, Indonesian
Rice paddy herb	*Limnophila aromatica*	Vietnamese, Thai
Radhuni	*Trachyspermum roxburghianum*	South Asian
Saffron	*Crocus sativus*	Central Asian and Indian
Sesame leaf	*Perilla frutescens* var. *frutescens*	Korean
Shiso	*Perilla frutescens* var. *crispa*	Japanese
Star anise	*Illicium verum*	Chinese, Asian
Szechuan pepper	*Zanthoxylum simulans* *Zanthoxylum bungeanum*	East Asian, Tibetan, and Chinese
Thai basil	*Ocimum basilicum* cv. *Horapha*	Thai, Taiwanese, Vietnamese
Thai holy basil	*Ocimum tenuiflorum*	Asian
Tia to	*Perilla frutescens*	Vietnamese, Japanese
Turmeric	*Curcuma domestica*	Indian, Vietnamese, Asian

cuisine. This observation is particularly apparent in countries, such as the United States, to which a number of immigrants have arrived from several countries.

Immigrants to the United States from Mexico have brought traditional foods flavored with chili peppers, oregano, cumin, Mexican oregano, and epazote. Immigrants to the United States from China have brought traditional foods flavored with ginger, star anise, fennel seed, Szechuan pepper, cassia, and cloves. Immigrants to the United States from Mediterranean countries have brought traditional foods flavored with basil, bay leaves, caraway seeds, cardamom, chervil, cilantro, parsley, rosemary, saffron, tarragon, and other herbs and spices. The popularity and use of various herbs and spices are associated with familiar foods and culture and generally defined by location (Table 18.12).

Whether used by the pinch or by the bunch, herbs and spices can be used to infuse a meat or vegetable dish with unparalleled aroma and flavor (Fig. 18.11). In heated dishes, the aromatic oils within the herbs and spices diffuse from the plant tissue into the liquid in the cooking dish, flavoring the goods being prepared. In salads and other cool dishes, herbs and spices are usually added using a salad dressing

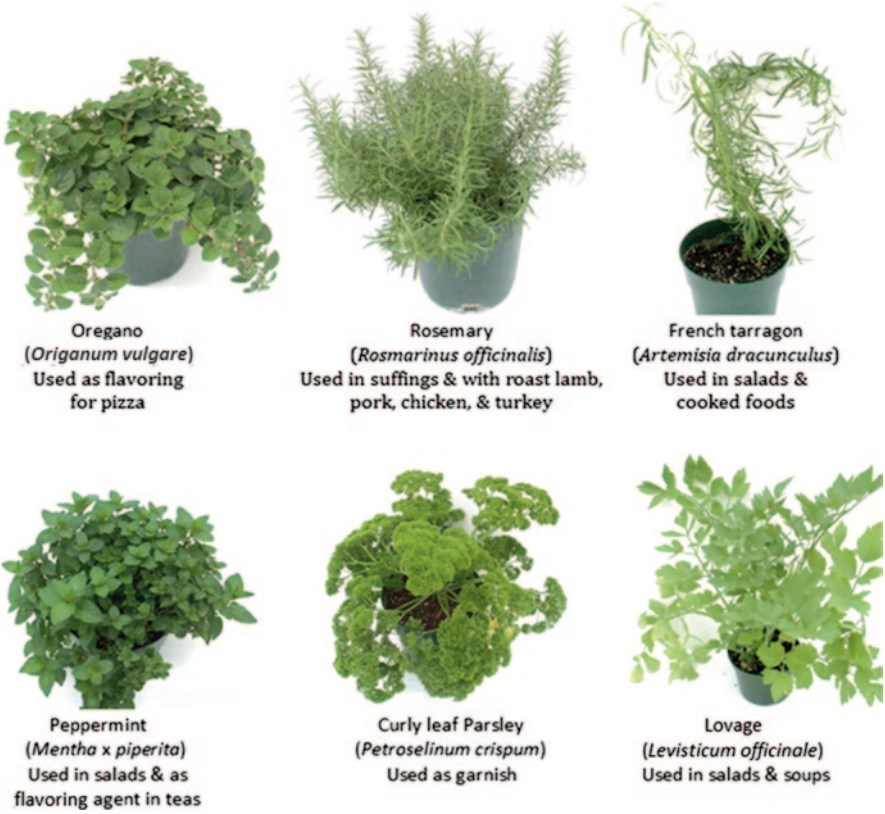

Fig. 18.11 Some culinary herbs and their uses. (Source: Authors)

or vinegar containing extracts of these plants. Recipes for using herbs and spices exist in several languages in numerous cookbooks for preparation of local dishes.

Herbs and spices are a large global business with a complex market chain utilizing established brokers, importers, exporters, processors, and marketers (Fig. 18.12). As the largest herb and spice consumer in the world (Buzzanell et al. 1995), the United States imports over 40 separate spices from over 50 countries (Table 18.13). The end uses for these herbs and spices vary with about 40% going to retail outlets and most of the rest being used in industrial food preparation and food service. Most herbs and spices are cultivated, as opposed to being collected in the wild because of the large quantities needed for world markets that could not be supplied by wild collection and by the need to provide authenticated, clean plant material to the market. Consumer demand is moving towards organically produced herbs and spices under fair trade conditions. A number of herb gardens have been established to familiarize the public with medicinal and aromatic plants (Fig. 18.13) (Table 18.14).

Fig. 18.12 Some spices of the modern world. (Source: Upper row photographs by the authors, bottom row photos courtesy of Ákos Mathe, West Hungarian University)

Conclusions

The market for medicinal and aromatic plants can be expected to continue into the future, serving as the primary medicine for most people in the world and as an alternative medicine for those individuals accustomed to more conventional medicine. The continued exploration for new medicines among the numerous plant species will most likely discover new chemical constituents that can be used to treat human and animal diseases. The challenge will be to protect and conserve medicinal and aromatic plants and plant habitats from poachers and land developers.

The exact level of the global market for medicinal and aromatic plants is difficult to discern due to the large number of plants, the multitude of countries importing and exporting, and the increasing number of sales outlets, including sales to mass markets via the internet. Over the past 20 years, consumers previously unfamiliar with medicinal and aromatic plants have become more aware of the many contributions these plants make to medicine, food products, cosmetics, and other goods used daily. The acceptance of natural medicines by the conventional medicine system in the United States has encouraged many previously cautious people into trying

Table 18.13 The production and use of some spices. (Sources: Kingsely (2009); Miyano and Miyano (2011))

Common name	Scientific name	Plant part used	World production (metric tons)	Some common uses
Allspice	*Pimenta dioica*	Dried unripe fruit	40,000–50,000	Used in Caribbean cuisine, jerked meats, sausage preparations, and curry powders
Anise	*Pimpinella anisum*	Seed oil	8–10	Used in various foods, drinks, and candies
Cinnamon	*Cinnamomum* spp.	Inner bark	150,000–155,000	Used in baked goods and candies
Cloves	*Syzygium aromaticum*	Flower buds	90,000–105,000	Used in meats, curries, and sweet dishes
Ginger	*Zingiber officinale*	Rhizomes	1,610,000–1,640,000	Used in Asian dishes and sweet foods
Nutmeg	*Myristica fragrans*	Seeds and aril	15,000–20,000	Used in Indian cuisine, potato dishes, and processed meat products
Pepper	*Piper nigrum*	Dried fruit	450,000–460,000	Used in meats, soups, pickling, and curry powders
Turmeric	*Curcuma longa*	Rhizomes	200,000–210,000	Used in Asian and other dishes and used as coloring agent
Vanilla	*Vanilla planifolia*	Beans	9,000–10,000	Used in flavoring ice cream, custard chocolate, coffee and other dishes

Fig. 18.13 Herb gardens. (Source: Authors)

medicinal plants. The immigration of individuals and families from other countries and the expansion of global travel have introduced several people to new cuisines.

The value of medicinal plant extracts has encouraged scientists and businesses to invest time and money into developing alternative methods for producing these extracts. Chemists are beginning to synthesize constituents in some plant extracts

Table 18.14 Some plant materials used in perfumes. (Sources: Bukisa (2013); Ellena (2011); Kole et al. (2005))

Common name	Scientific name	Common name	Scientific name	Common name	Scientific name
Aloe	*Aloe vera*	Fennel	*Foeniculum vulgare*	Myrrh	*Commiphora myrrha*
Basil	*Ocimum basilicum*	Fir	*Abies balsamea*	Nutmeg	*Myristica fragrans*
Bergamot	*Citrus aurantium*	Frankincense	*Boswellia carteri*	Patchouli	*Pogostemon cablin*
Calendula	*Calendula officinalis*	Rose geranium	*Pelargonium capitatum*	Rose	*Rosa species*
Camphor wood	*Cinnamomum camphora*	Jasmine	*Jasminum sambac*	Rosemary	*Rosmarinus officinalis*
Cardamom	*Elettaria cardamomum*	Jojoba	*Simmondsia chinensis*	Rosewood	*Pterocarpus indicus*
Cedarwood	*Cedrus libani*	Juniper berry	*Juniperus communis*	Sage	*Salvia officinalis*
Chamomile	*Matricaria recutita*	Lavender	*Lavandula species*	Sweet violets	*Viola odorata*
Cinnamon	*Cinnamomum verum*	Lemon grass	*Cymbopogon citratus*	Thyme	*Thymus vulgaris*
Clove	*Syzygium aromaticum*	Mignonette	*Reseda odorata*	Vanilla	*Vanilla planifolia*
Cucumber	*Cucumis sativus*	Mimosa	*Acacia dealbata*	Vetiver	*Vetiveria zizanioides*
Dill	*Anethum graveolens*	Mint	*Mentha species*	Ylang-ylang	*Cananga odorata*

that can perhaps replace the need for limited plant materials or can make changes in a constituent that will enhance bioactivity. Plant scientists and bioengineers are attempting to produce extracts via cell and microorganism cultures. In the future, geneticists may make modifications in a plant genome to enhance extract production or enable other plants to produce bioactive constituents. The success of these alternative production methods may limit the need for cultivation and wild harvesting of some plant materials.

Medicinal and aromatic plants have not cured all the diseases, but the interest in new medicines has led to the development of standardized screening processes for bioactivity and has advanced the use and science of medicinal and aromatic plant materials and their extracts. Scientific investigations on medicinal and aromatic plants are conducted in many countries with results presented at professional conferences and published in professional journals available to the public. Numerous books, websites, and blogs publicize the benefits of natural products. Medicinal and aromatic plant material can be observed in private and public display gardens.

Progress in good practices associated with crop production, wild plant collecting, and processing practices provide businesses and consumers with quality plant materials. Various conservation practices, laws, and trade restrictions help protect

endangered species and ecosystems, although the destruction of plant habitats remains a serious issue for survival for some species. Medicinal and aromatic plants have played an important role in human life and will undoubted continue to be important for the foreseeable future.

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