PART 1

Introduction

1

Plants in medicine: the origins of pharmacognosy

The universal role of plants in the treatment of disease is exemplified by their employment in all the major systems of medicine irrespective of the underlying philosophical premise. As examples, we have Western medicine with origins in Mesopotamia and Egypt, the Unani (Islamic) and Ayurvedic (Hindu) systems centred in western Asia and the Indian subcontinent and those of the Orient (China, Japan, Tibet, etc.). How and when such medicinal plants were first used is, in many cases, lost in pre-history, indeed animals, other than man, appear to have their own materia medica. Following the oral transmission of medical information came the use of writing (e.g. the Egyptian *Papyrus Ebers c*. 1600 BC), baked clay tablets (some 660 cuneiform tablets *c*. 650 BC from Ashurbanipal's library at Nineveh, now in the British Museum, refer to drugs well-known today), parchments and manuscript herbals, printed herbals (invention of printing 1440 AD), pharmacopoeias and other works of reference (first *London Pharmacopoeia*, 1618; first *British Pharmacopoeia*, 1864), and most recently electronic storage of data. Similar records exist for Chinese medicinal plants (texts from the 4th century BC), Ayurvedic medicine (Ayurveda 2500–600 BC) and Unani medicine (*Kitab-Al-Shifa*, the Magnum Opus of Avicenna, 980–1037 AD).

In addition to the above recorded information there is a great wealth of knowledge concerning the medicinal, narcotic and other properties of plants that is still transmitted orally from generation to generation by tribal societies, particularly those of tropical Africa, North and South America and the Pacific countries. These are areas containing the world's greatest number of plant species, not found elsewhere, and with the westernization of so many of the peoples of these zones there is a pressing need to record local knowledge before it is lost forever. In addition, with the extermination of plant species progressing at an alarming rate in certain regions, even before plants have been botanically recorded, much less studied chemically and pharmacologically, the need arises for increased efforts directed towards the conservation of gene pools.

A complete understanding of medicinal plants involves a number of disciplines including commerce, botany, horticulture, chemistry, enzymology, genetics, quality control and pharmacology. Pharmacognosy is not any one of these per se but seeks to embrace them in a unified whole for the better understanding and utilization of medicinal plants. A perusal of the monographs on crude drugs in a modern pharmacopoeia at once illustrates the necessity for a multidisciplinary approach. Unlike those who laid the foundations of pharmacognosy, no one person can now expect to be an expert in all areas and, as is illustrated in the next chapter, pharmacognosy can be independently approached from a number of viewpoints.

The word 'pharmacognosy' had its debut in the early 19th century to designate the discipline related to medicinal plants; it is derived from the Greek pharmakon, 'a drug', and gignosco, 'to acquire a knowledge of' and, as recorded by Dr K. Ganzinger (*Sci. Pharm*., 1982, **50**, 351), the terms 'pharmacognosy' and 'pharmacodynamics' were probably first coined by Johann Adam Schmidt (1759–1809) in his hand-written manuscript *Lehrbuch der Materia Medica*, which was posthumously published in Vienna in 1811. Schmidt was, until his death, professor at the medico-surgical Joseph Academy in Vienna; interestingly he was also Beethoven's physician. Shortly after the above publication, 'pharmacognosy' appears again in 1815 in a small work by Chr. Aenotheus Seydler entitled *Analecta Pharmacognostica*.

Pharmacognosy is closely related to botany and plant chemistry and, indeed, both originated from the earlier scientific studies on medicinal plants. As late as the beginning of the 20th century, the subject had developed mainly on the botanical side, being concerned with the description and identification of drugs, both in the whole state and

in powder, and with their history, commerce, collection, preparation and storage. In his series *A History of British Pharmacognosy (1842–1980)*, E. J. Shellard (*Pharm. J.*, 1980, **225**, 680) wrote:

> It is a recognised fact that in the historical development of any subject the role of certain individuals is of considerable importance. This is true in pharmacognosy. The first British pharmacognosist was Jonathan Pereira (1804–1853), who as the first teacher of the subject gave it its pharmaceutical basis. He may be considered as the founder of British pharmacognosy. Daniel Hanbury (1825–1875) was the most outstanding applied pharmacognosist while the contribution made by E. M. Holmes (1843–1930) as an applied pharmacognosist stands out both in quality and quantity. H. G. Greenish (1855–1933), and T. E. Wallis (1876–1973) transformed the old academic pharmacognosy by their contribution to the elimination of adulteration from powdered drugs. Their exploitation of the microscope in pharmacognosy ensures their position as the pillars of the halcyon days (of pharmacognosy).

Such branches of pharmacognosy are still of fundamental importance, particularly for pharmacopoeial identification and quality control purposes, but rapid developments in other areas have enormously expanded the subject.

The use of modern isolation techniques and pharmacological testing procedures means that new plant drugs may find their way into medicine as purified substances rather than in the form of galenical preparations which, for various reasons, would be unsatisfactory. Preparation is usually confined to one or a few companies who process all the raw material; thus, few pharmacists have occasion to handle dried *Catharanthus roseus* although they are familiar with formulations of the isolated alkaloids vinblastine and vincristine. For these new drugs it is important that the pharmacist is cognisant of the physical, chemical and chromatographic standards applicable to the identification, purity, etc. of such products. Similar remarks apply to other anticancer drugs derived from *Taxus, Podophyllum* and *Ochrosia* spp.

When specific plants, including those used in traditional medicine, suddenly become of interest to the world at large, the local wild sources soon become exhausted. This necessitates, as in the case of *Catharanthus roseus, Coleus forskohlii, Ginkgo biloba, Arnica montana* and *Taxus brevifolia*, research into the cultivation or artificial propagation by cell culture, etc., of such species. In order to avert the type of supply crisis that arose at the clinical trial stage with the anticancer drug taxol, isolated from *T. brevifolia*, the US National Cancer Institute initiated plans for future action should a similar situation again arise (see G. M. Cragg *et al.*, *J. Nat. Prod*., 1993, **56**, 1657). However, it was reported that as a result of the original demand for the drug galanthamine (q.v.) for the treatment of Alzheimer's disease, the native source of *Leucojum aestivum* was endangered. The situation was partially resolved following the commercial synthesis of galanthamine.

The use of single pure compounds, including synthetic drugs, is not without its limitations, and in recent years there has been an immense revival in interest in the herbal and homoeopathic systems of medicine, both of which rely heavily on plant sources. At the 9th Congress of the Italian Society of Pharmacognosy (1998) it was stated that the current return of phytotherapy was clearly reflected by the increased market of such products. In 1995 the latter, for Europe, reached a figure of $6 billion, with consumption for Germany $2.5 billion, France $1.6 billion and Italy 600 million. In the US, where the use of herbal products has never been as strong as in continental Europe, the increase in recent years has also been unprecedented with the market for all herb sales reaching a peak in 1998 approaching $700 million. Again, illustrating the same trend, the editor of *Journal of Natural Products*, 1999, wrote that in response to the increasing prominence of herbal remedies, additional contributions describing scientific investigations of a rigorous nature would be welcomed, a suggestion that appears to have been fully endorsed!

Undoubtedly, the plant kingdom still holds many species of plants containing substances of medicinal value which have yet to be discovered; large numbers of plants are constantly being screened for their possible pharmacological value (particularly for their anti-inflammatory, hypotensive, hypoglycaemic, amoebicidal, antifertility, cytotoxic, antibiotic and anti-Parkinsonism properties). Pharmacognosists with a multidisciplinary background are able to make valuable contributions to these rapidly developing fields of study and pharmacists in general need to have a knowledge of, and to give professional advice on, the many herbal preparations available to the public.

2

The scope and practice of pharmacognosy

Until relatively recently pharmacognosy was regarded, almost exclusively, as a subject in the pharmaceutical curriculum focused on those natural products employed in the allopathic system of medicine. Coincident with the increasing attractiveness of alternative (complementary) therapies and the tremendous range of herbal products now generally available to the public, regulatory requirements covering medicinal herbs have been put in place by many countries in order to control the quality of these products. Monographs are now available on a large number of such drugs giving descriptions, tests for identity and purity and assays of active constituents. These monographs are being compiled by a number of bodies (see below). In this respect recognition should be given to the pioneering production of the *British Herbal Pharmacopoeia*, first produced in 1974 with the latest volume in 1996. Pharmacognosy is also important in those countries having their own systems of medicine in which plants are important components.

Many crude drugs once generally categorized as herbal remedies are now, in accordance with Continental European practice, described in the *British Pharmacopoeia* (*BP*). Chromatographic, chemical and physical tests, together with assay procedures, are given for many drugs for which previously there was no quantitative evaluation of the chemical constituents available. The importance of quality control is paramount, as the demand and the possibility of substitution has increased. The upsurge in the marketing of Chinese and Asian traditional medicines worldwide, for which there is a need for adequate control, adds a further dimension to pharmacognosy; pharmacopoeial monographs now include Liquorice for use in Chinese medicine, Chinese angelica root and Astragalus root. It is understood that further monographs on Chinese and Indian drugs for use in traditional medicine are to be included in the *BP* 2009.

Although pharmacognosy is principally concerned with plant materials, there are a small number of animal products which are traditionally encompassed within the subject; these include such items as beeswax, gelatin, woolfat, vitamins, etc. Other natural products such as the antibiotics, hormones and others may or may not be involved, depending on the teaching practice of a particular institution. Marine organisms, both plant and animal, with potent pharmacological actions are receiving increasing attention in the search for new drugs. Materials having no pharmacological action which are of interest to pharmacognosists are natural fibres, flavouring and suspending agents, colourants, disintegrants, stabilizers and filtering and support media. Other areas that have natural associations with the subject are poisonous and hallucinogenic plants, allergens, herbicides, insecticides and molluscicides.

Vegetable drugs can be arranged for study under the following headings.

1. *Alphabetical*. Either Latin or vernacular names may be used. This arrangement is employed for dictionaries, pharmacopoeias, etc. Although suitable for quick reference it gives no indication of interrelationships between drugs.
2. *Taxonomic*. On the basis of an accepted system of botanical classification (Chapter 3), the drugs are arranged according to the plants from which they are obtained, in classes, orders, families, genera and species. It allows for a precise and ordered arrangement and accommodates any drug without ambiguity. As the basic botanical knowledge of pharmacy students decreases over the years this system is becoming less popular for teaching purposes.
3. *Morphological*. The drugs are divided into groups such as the following: leaves, flowers, fruits, seeds, herbs and entire organisms, woods, barks, rhizomes and roots (known as organized drugs), and dried latices, extracts, gums, resins, oils, fats and waxes (unorganized drugs).

These groupings have some advantages for the practical study of crude drugs; the identification of powdered drugs (see Chapter 43) is often based on micro-morphological characters.

4. *Pharmacological or Therapeutic*. This classification involves the grouping of drugs according to the pharmacological action of their most important constituent or their therapeutic use. R. Pratt and H. W. Youngken Jr. were, in 1956, the first to use this approach for an English language textbook and now, with so many plant materials being screened for specific pharmacological activity, this type of listing is found increasingly in the literature. Its use is illustrated in Chapters 27–32. However, it is important to appreciate that the constituents of any one drug may fall into different pharmacological groups.
5. *Chemical or Biogenetic*. The important constituents, e.g. alkaloids, glycosides, volatile oils, etc., or their biosynthetic pathways, form the basis of classification of the drugs. This is a popular approach when the teaching of pharmacognosy is phytochemically biased. Ambiguities arise when particular drugs possess a number of active principles belonging to different phytochemical groups, as illustrated by liquorice, ginseng, valerian, etc. The scheme is employed in Chapters 19–26 for arranging the established pharmacopoeial drugs.

The following list of works, arranged in the above five groups, will serve as examples and also provide a useful list of textbooks and works of reference; those no longer in print may be found in established pharmaceutical libraries.

1. Alphabetical

Barnes J, Anderson LA, Phillipson JD 2007 Herbal medicines, 3rd edn. Pharmaceutical Press, London

Bisset NG (ed), Wichtl M 1996 Herbal drugs, a handbook for practice on a scientific basis. Medpharm Scientific Publishers, Stuttgart

Bradley PR 1992, 2006 British herbal compendium, Vols I, II. British Herbal Medicine Association, Bournemouth, UK

British Pharmacopoeia 2008 and preceding edns

British Herbal Pharmacopoeia 1996. British Herbal Medicine Association, Exeter, UK

Duke JA 2002 Handbook of medicinal herbs, 2nd edn. CRC Press, New York

Martindale: the Complete Drug Reference, 35th edn 2007. Pharmaceutical Press, London

United States Pharmacopoeia 29/National Formulary 24 and Supplement 2006

Williamson EM 2002 Potter's herbal cyclopaedia. CW Daniel Co, Saffron Walden

The national pharmacopoeias of many countries and the European Pharmacopoeia; *the relevant crude drug monographs of the latter are included in the British Pharmacopoeia*

2. Taxonomic

Paris RR, Moyse H 1965, 1967, 1971 Matière médicale. Masson, Paris, 3 vols

Thoms H 1929 Handbuch der Pharmacie. Urban and Schwarzenberg, Berlin, Band V, 2 vols, Pharmacognosy

Trease GE, Evans WC 1972 Pharmacognosy, 10th edn. Baillière Tindall and Cassell, London

3. Morphological

Berger F Handbuch der Drogenkunde. Maudrich, Vienna, Vol I, Barks and flowers, 1949; Vol II, Leaves, 1950; Vol III, Fruits and woods, 1952; Vol IV, Herbs, 1954; Vol V, Roots, 1960; Vol VI, Resins etc and seeds, 1964; Vol VII, Index, 1967

Jackson BP, Snowdon DW 1990 Atlas of microscopy of medicinal plants, culinary herbs and spices. Belhaven Press, London

Wallis TE, 1967 Textbook of pharmacognosy, 5th edn. Churchill Livingstone, London

4. Pharmacological or Therapeutic

Der Marderosian A, Liberti LE 1988 Natural product medicine. GF Stickley, Philadelphia, PA, USA

Heinrich M, Barnes J, Gibbons S, Williamson EM 2004 Pharmacognosy and phytotherapy. Churchill Livingstone, Edinburgh

Pratt R, Youngken HW, Jr 1956 Pharmacognosy, 2nd edn. Lippincott, Philadelphia, PA, USA

Ross MSF, Brain KR 1977 An introduction to phytopharmacy. Pitman Medical, Tunbridge Wells

5. Chemical

Bruneton J 1999 Pharmacognosy, phytochemistry, medicinal plants. Intercept Scientific, Medical and Technical Publications

Dewick PM 2002 Medicinal natural products, a biosynthetic approach, 2nd edn. John Wiley, Chichester

Hänsel R, Sticher O, Steinegger E 1999 Pharmakognosie-Phytopharmazie, 6th edn. Springer, Berlin (*in German*)

Robbers JE, Speedie MK, Tyler VE 1996 Pharmacognosy and pharmacobiotechnology. Williams & Wilkins, Baltimore

Tschirch A Handbuch der Pharmakognosie. Tauchnitz, Leipzig *(two editions and numerous volumes up to 1933)*

With the increase in interest in medicinal plants world-wide there are now many publications covering regional areas of the globe. Treatment of the plants in these works may be on any of the above lines. Some examples are given following the Introduction to Part VI.

As mentioned previously, a number of bodies have implemented research and published monographs on medicinal herbs. The aim has been to set standards for quality, efficacy and safety in order that the many traditional herbs meet legal requirements. The following are of note:

German Commission E monographs. These were developed for the German Federal Health Authority between 1978–1994 and involve 324 herbs used in German traditional medicine. The monographs give sources, constituents and considerable pharmacological and clinical information. They have now been translated into English and published by the American Botanical Council in 1999 as a single work followed by expanded monographs in 2000.

ESCOP monographs. ESCOP (European Scientific Cooperative for Phytotherapy) is an affiliation of European associations which has produced 60 monographs on herbal drugs, published in loose-leaf form in six fascicules, harmonizing the standards for these drugs throughout the European Union. Information is given on approved therapeutic uses, and unlike the Commission E monographs, provides references. The second edition of *ESCOP Monographs* was published in 2003, and a third edition is in the course of preparation.

AHP monographs. The *American Herbal Pharmacopoeia* (1997–2005) has monographs on a selection of traditional indigenous herbs with some overlap with the European monographs. Treatment of individual drugs can be extensive, for example, the St John's wort monograph published in *HerbalGram* 1997, No 4 extends to 32 pages with over 150 references, colour photographs and chemical formulae.

WHO monographs. The World Health Organization published Volume 1 of its *Monographs on Selected Medicinal Plants* in 1999. It contains standards for quality of drugs together with a therapeutic section; 31 plant species, the majority of which are also included in the above lists, are considered. Volume 2 was published in 2002.

USP monographs. The United States Pharmacopoeia is also producing herbal monographs. Eleven have been published, all involving drugs treated above, and twelve more were expected during 2000.

Current awareness. Students wishing to read original research will find many references in this book and should learn how to find similar ones for themselves. As no one can hope to read all the scientific

literature that is published, special journals are devoted to the publication of brief abstracts from the original papers. Such abstracts give the author's name, the subject of the research, the reference necessary to locate the paper in the original journal and usually a brief outline of the work it contains. Most pharmacy department libraries contain *Chemical Abstracts* and *Biological Abstracts*, which in the appropriate sections cover all areas of pharmacognosy. Even so, the systematic searching of the abstracts to cover a broad field of interests can itself be most time-consuming, and publications such as *Chemical Titles* and *Current Contents* can be used to give a more rapid indication of recent publications. *Phytotherapy Research* regularly includes a selected bibliography relating to plant drugs. Information storage and retrieval is now itself a science, and a glance at the shelf-space occupied by succeeding years of *Chemical Abstracts* is sufficient to indicate that before long, if not already, manual searches of the literature will become impossibly long procedures. In many libraries, hard copies of these publications and of the journals mentioned below are no longer available, but they can be accessed on-line. Inevitably it will be necessary to rely on databases for literature scanning. *Pharmacognosy Titles* is a computer abstract coverage of phytochemical research publications up to 1974 (10 vols) produced under the direction of Professor N. Farnsworth, University of Illinois. Subsequently, Farnsworth introduced NAPRALERT, a Natural Product Database which is mainly, but not entirely, post-1975 and is viewed by many as a logical and indispensable collection of pharmacognostic information. The NAPRALERT database is available on a scheduled-fee basis to scientists, industrial firms, government agencies and academic institutions. Among other useful databases having a relevance to pharmacognosy and published on the Web are MEDLINE, compiled by the US National Library of Medicine and EMBASE, produced by Excerpta Medica.

Some journals—for example, *Planta Medica, Journal of Ethnopharmacology, Phytochemistry* and *Journal of Natural Products*—periodically contain reviews on some aspect of medicinal plants. Other journals containing research papers of pharmacognostical interest are *Natural Product Research* and *Natural Product Sciences*. Periodical publications appearing in bound form and devoted to reviews on certain aspects of plant constituents are useful for updating; often the reviews cover only the advances in a particular field since the previous volume. Examples are *Natural Product Reports* (six issues per year) and *Alkaloids* (Academic Press).

A series of multi-author books *Medicinal and Aromatic Plants – Industrial Profiles* (R. Hardman, series editor, CRC Press, Boca Raton, FL) provides an in-depth coverage of major medicinal and aromatic plants for specific genera; to date (2007) forty-five volumes have been published. Individual books for appropriate drugs are cited in Part 5 under 'Further reading'. Books that are not part of a series but, like the above, multi-author and dealing with certain specialized areas (e.g. alkaloids, flavonoids, isoprenoids), continually appear and generally give up-to-date information (in so far as any book can). Symposia which cover various aspects of pharmacognosy are frequently held in various parts of the world and scientists can easily become acquainted with others having like interests. Often the informal discussions which invariably arise at such meetings can be an extremely useful means of disseminating information. In addition, the lectures presented at such meetings are often subsequently published in book form. Modern communication systems make world-wide contact between researchers much simpler.

Now available to Western scientists interested in oriental medicine is the quarterly journal *Abstracts of Chinese Medicine*, published by the Chinese University of Hong Kong. This gives abstracts in English of significant Chinese research papers from more than one hundred scientific journals not readily available outside China.

Useful dictionaries to be found in most University libraries include *Dictionary of Organic Compounds* consisting of 7 volumes and 10 supplements (to 1992), *Dictionary of Alkaloids* (2 volumes) (1989), *Dictionary of Terpenoids* (1991) and *Dictionary of Natural Products* (1994) all published by Chapman and Hall and also *Phytochemical Dictionary: A Handbook of Bioactive Compounds from Plants* (1993), published by Taylor and Francis. Some of these more expensive volumes are available on CD-ROM.

3

Plant nomenclature and taxonomy

BOTANICAL NOMENCLATURE

Before the time of Linnaeus (1707–1778) many plants were known by a double Latin title; however, it is to this great Swedish biologist that we owe the general adoption of the present binomial system, in which the first name denotes the genus, while the second (specific) name denotes the species. All specific names may be written with small initial letters although formerly capitals were used where species were named after persons. Thus the species of *Cinchona* named after Charles Ledger, who brought its seeds from Brazil in 1865, is now written *Cinchona ledgeriana* rather than *Cinchona Ledgeriana*.

The specific name is usually chosen to indicate some striking characteristic of the plant—for example, the hemlock with the spotted stem is named *Conium maculatum* (*maculatus*, *-a*, *-um*, spotted). Sometimes the reason for the name is not as obvious as in the example just mentioned, but once it is discovered it will serve as a reminder of a characteristic of the plant—for example, *Strychnos potatorum* (*potator*, *-oris*, a drinker) bears a name which is only intelligible when it is known that the seeds of this species are used in India for clearing water. A particular species can also exhibit a number of varieties; these are especially evident with cultivated plants but are also found in the wild. For a medicinal example, see *Mentha piperita* below.

The modern rules governing the terminology of plant taxonomy are laid down in the *International Code of Botanical Nomenclature*.

Unlike the names of chemical substances, which are subject to changes which conform to evolving systems of nomenclature, systematic plant names are strictly controlled by rules which give precedence to that name used by the botanist who first described the species. Nevertheless, this seemingly straightforward approach can give rise to various quirks in spelling. The following are three examples involving medicinal plants: *Rauvolfia* vis à vis *Rauwolfia*; the former name was given to this Apocynaceous genus by Plumier in 1703, honouring the botanist Leonard Rauwolf. This spelling oversight caused much contention over the years centring on whether Plumier's obvious intention should be adopted in the name *Rauwolfia*. Both spellings are commonly found but the rules dictate that *Rauvolfia* has priority. In another example the downy thornapple may be encountered as either *Datura innoxia* or *Datura inoxia*. The former, as *Datura innoxia* Miller, was used in 1768 (*Gard. Dict.*, edn. 8, *Datura* no. 5) and this spelling was invariably employed for some 200 years; however in Miller's original description, the plant was characterized as: 'Datura (*Inoxia*) pericarpiis spinosis inoxiis ovatis propendentibus foliis cordatis pubescentibus' (W. E. Safford, *J. Wash. Acad. Sci.*, 1921, **11**, 173) and taxonomists now consider *D. inoxia* Miller to have priority. Both versions are still commonly encountered. A third example concerns the genus of the coca plant which may appear as *Erythroxylum*, or in older literature as *Erythroxylon*. Uppsala Monitoring Centre (a WHO collaborating centre for International Drug Monitoring) has published 'Accepted scientific names of therapeutic plants and their synonyms'.

SUBDIVISIONS OF THE PHYLA

The branches of the genealogical tree differ so much in size that it is not easy to decide which are of equal systematic importance, and what one biologist may consider as a family another may regard as a subfamily. Similarly, the species of one botanist may be the subspecies or variety of another. The main hierarchical subdivisions of a division, arranged according to Engler's scheme, may be illustrated by the following example showing the systematic position of peppermint.

Division	Angiospermae
Class	Dicotyledoneae
Subclass	Sympetalae
Order	Tubiflorae
Suborder	Verbenineae
Family	Labiatae (Lamiaceae)
Subfamily	Stachydoideae
Tribe	Satureieae
Genus	*Mentha*
Species	*Mentha piperita* Linnaeus (Peppermint)
Varieties	*Mentha piperita* var. *officinalis* Sole (White Peppermint)
	Mentha piperita var. *vulgaris* Sole (Black Peppermint)

It will be noted that in pharmacopoeias and in research publications botanical names are followed by the names of persons or their accepted abbreviations (e.g. Linnaeus and Sole in the case of peppermint given above). These refer to the botanist who first described the species or variety. Students need not attempt to memorize these names, and in the following pages they are usually omitted except in cases where different botanical names have at different times been applied to the same plant and there is possibility of confusion. The source of cloves, for example, is now usually given as *Syzygium aromaticum* (L.) Merr. et Perry; prior to 1980 the *BP* used the name *Eugenia caryophyllus* (Spreng.) Sprague; other synonyms which may be found in the older literature are *E. caryophyllata* Thunb. and *E. aromatica* (L.) Baill. Worldwide, not all authors of research papers use the currently accepted name so caution is necessary and botanical sources should be checked.

The letters s.l. following the botanist's name refers to collective species and varieties and imply 'in the widest sense' (*sensu latiore*), e.g. *Thymus serpyllum* L.s.l.

BOTANICAL SYSTEMS OF CLASSIFICATION

Before the widespread acceptance of the principle of evolution, biologists, being convinced of the fixity of species and lacking much of the information available today, confined themselves to more or less artificial methods of classification, their systems being frequently based on one or a few characters instead of upon the organism as a whole. These earlier systems are now mainly of historic interest, but certain of their features—for example, the large division of seed plants into monocotyledons and dicotyledons as used by John Ray (1628–1705)—survive today. Linnaeus' *Species Plantarum* of 1753 is the starting point for the modern nomenclature of plants, although his actual system of classification is entirely artificial and of little significance today. The *Prodromus*, started by A. P. de Candolle (1778–1841) and completed under the editorship of his son Alphonse (1806–93), was a massive work of 17 volumes which professed to be an account of every flowering plant then known. The system of classification employed was a modification and extension of that introduced earlier by De Jussieu (1748–1836) and further demonstrated the inadequacies of the Linnaean system which were then becoming apparent. Bentham and Hooker's *Genera Plantarum* (1862–1883) was patterned on the de Candolles' work, each genus being redescribed from herbarium specimens and not consisting of a restatement of earlier literature. Although largely artificial, it was convenient to retain this system as a basis for collections such as the herbaria of Kew and the British Museum, with continuous revision based on molecular systematics.

During the last 100 years a considerable number of phylogenetic systems of classification have been propounded; these systems arrange taxa (any groups used for classification such as orders, families, genera, etc.) to indicate the possible relationship of one taxon to another. Such systems are clearly susceptible to change with increasing knowledge, and no final system acceptable to all taxonomists is in sight; indeed, for some practical purposes a stable, workable phenetic system is often preferable. A close examination of the phylogenetic systems reveals that certain taxa form precise groups, others have less well-defined boundaries and other groups are difficult to accommodate phylogenetically. The work of Engler (1844–1930) in association with other German systematists is still adhered to in this connection. Engler's scheme of classification largely embodied the fundamental concepts of Eichler (1839–87) and was exemplified in the 20-volume work (1887–89) *Die natürlichen Pflanzenfamilien*, by Engler and Prantl. Subsequent to this, there appeared many editions of Engler's *Syllabus der Pflanzenfamilien*, the eleventh by Engler and Diels in 1936. The last version of the *Syllabus*, produced by Melchoir as two volumes, was published in 1964; the plant families in Chapter 5 of this textbook are arranged in this order. The immediate popularity of Engler's works was due to their applicability to plants of the whole world; they afforded a means of identifying all known genera.

Obviously, large works such as the above are not easily compiled and many taxonomists have produced phylogenetic schemes directed at various levels of classification without the complete systematics of the Engler series. Of the schemes, those of Cronquist (1981) and Takhtajan (1959) are generally similar whereas that of Hutchinson (1992) differs in that the dicotyledons are divided into two large groups—those characteristically and primitively woody (Lignosae) and those characteristically and primitively herbaceous (Herbaceae). These schemes incorporate data often not accessible to the earlier taxonomists; thus Cronquist, while emphasizing classical morphological characters and following the strobilar theory of Angiosperm evolution also takes account of micromorphological data (e.g. embryology and pollen structure), chemical data (e.g. secondary metabolites and serology) and the fossil record.

Dahlgren's proposals (1983), which involve a taxonomic method termed cladistics, demonstrate the distribution of characters and his cladograms of the orders of Angiosperms can be conveniently used for illustrating the occurrence of secondary metabolites throughout the higher plants. In this method (cladistics), clade is a group of plants at any level sharing a common ancestor and formed by a splitting to give two new species, which themselves in the course of time may split again. Clades may be very large or small, with clades within clades; as they comprise hypothetical relationships, they are subject to change as new knowledge becomes available. Evolutionary changes as envisaged in cladistics are sudden and widespread vis à vis the continuous gradual evolution taking place by small changes over a long period of time, as postulated by Darwin. Cladistics are now widely employed by modern taxonomists.

A modern replacement for Engler's classical work, now in the course of compilation, is *The families and genera of vascular plants* [K. Kubitzki *et al*. (eds)]. So far (2007), nine volumes have been published.

TAXONOMIC CHARACTERS

All plants possess hundreds of characters of a morphological, histological, embryological, serological, chemical and genetic nature which are potentially available for building up a classification of the plant kingdom. In the artificial schemes the characters employed were those that experience had shown could be used to produce suitable groups or taxa. The eventual scheme, into which could be inserted new plants

as they were discovered or in which any plant could easily be traced, resembled a catalogue with a 'telephone directory' arrangement of plants in which the groups of individuals listed together did not necessarily have any phylogenetic relationship, but merely possessed certain common features.

Phylogenetic classifications, which endeavour to indicate the relationship of one taxon to another, imply the use of characters that are capable of showing such relationships. Because some groups of plants are more primitive than others on the evolutionary scale, certain characters will also be primitive, whereas other characters will have evolved from them. Thus, woody plants are generally regarded as more primitive than herbaceous ones and flowers with few parts more advanced than those with many parts.

The difficulties facing the taxonomist are appreciable. The appearance of a particular character in certain plants does not necessarily imply a relationship between these plants, because at some time in the past, under favourable conditions, whole groups of unrelated plants could have undergone this change (e.g. the development of fused corollas from polypetalous flowers; this is known as *convergence*). Alternatively, related plants may, in some point of time, have started to diverge in their characteristics so that the modern phenotypes appear very dissimilar—this is *divergence. Parallelism* refers to the similar evolution of characters in related plants or related groups of plants. Having decided which characters are of value and how many can be used, the taxonomist then has to consider whether each character should be given equal value or whether a 'weighting' system should be employed. Computers have an obvious role in dealing with large numbers of characters applied to thousands of plants, not only from the aspect of storage and retrieval of information, but also for the science of *numerical taxonomy*, which will probably play an increasing role in the development of systematics. For a fuller discussion of this subject the reader is referred to Heywood's *Plant Taxonomy*.

CHEMICAL PLANT TAXONOMY

This subject has recently attracted much attention and has, after many years, brought the plant chemist back to systematic botany. The concept that plants can be classified on the basis of their chemical constituents is not new; for example, early workers classified the algae into green, brown and red forms, but it is only during the last 40 years that modern techniques of isolation and characterization have led to the chemical screening of many thousands of plant samples. Compared with morphological characters, chemical constituents are often more precisely definable and can be of more fundamental significance for classification purposes. Plant taxonomists, in general, hold the view that chemical characters are yet another type of character to be considered alongside those used traditionally, but it does not necessarily follow that taxa constructed on a purely chemical basis, if such were possible on the data at present available, would necessarily coincide with those arrived at by classical methods.

The characters employed in chemical taxonomy need to be those of intermediate distribution in the plant kingdom. The presence of such ubiquitous compounds as the essential amino acids and common sugars is of little diagnostic value and, at the other extreme, the occurrence of coniine in the single species *Conium maculatum* of the large family Umbelliferae is also of little taxonomic significance. Characters most studied in this connection are therefore secondary metabolites (alkaloids, isoprenoids, flavonoids, characteristic glycosides, etc.), many of which are of established pharmaceutical interest.

However, as discussed later, secondary metabolites may be subject to considerable variation in the living plant, depending on environmental and ontogenetic factors, and more stable chemical characteristics are offered by those closely associated with DNA composition of the species. Increasingly, it is becoming possible to use DNA hybridization, serotaxonomy and amino acid sequencing techniques for taxonomic purposes. One pharmacognostical application (Y. Mino *et al.*, *Phytochemistry*, 1993, **33**, 601) has been the determination of the complete amino acid sequence of one of the iron sulphur ferredoxins present in varieties of *Datura stramonium*. The results support the view that the white and purple forms are varieties of a single species and that the tree daturas (e.g. *D. arborea*) are best regarded as constituting one section of the genus *Datura* and not a separate genus (*Idem.*, *ibid.*, 1994, **37**, 429; 1995, **43**, 1186); work with *D. quercifolia* and *D. fastuosa* also suggests that the amino acid sequence depends not on the species, but on the section. Similar studies were subsequently applied to *Physalis* (Y. Mino and K. Yasuda *Phytochemistry*, 1998, **49**, 1631).

A second example (H. Mizukami *et al.*, *Biol. Pharm. Bull.*, 1993, **16**, 388) shows that restriction fragment length polymorphisms (RFLPs) can be used as a simple and efficient method for distinguishing between *Duboisia leichhardtii, D. myoporoides* and the hybrid of the two species (RFLPs are produced by digestion of DNA with restriction endonucleases and vary in number and size according to genus, species etc.) However, the same group found (*ibid.*, 1993, **16**, 611) that the technique did not distinguish between the various geographical strains of the traditional Chinese drug *Glehnia littoralis* (Umbelliferae) containing different furanocoumarin compositions but did so with *Bupleurum falcatum* (*ibid.*, p. 279).

The differentiation between samples of *Panax ginseng* (Oriental ginseng), *P. quinquefolium* (American ginseng) and adulterants can be difficult by conventional means and F. Ngan *et al*. (*Phytochemistry*, 1999, **50**, 787) have reported on the authentication and differentiation, one from another, of six species of *Panax* and also their adulterants, using RFLPs involving the DNA sequences in a selected ribosomal region; see also J. Wang *et al.*, *Planta Medica*, 2001, **67**, 781 and Z. Zhao *et al*., *Planta Medica*, 2006, **72**, 865 for the authentication of Chinese herbal medicines. *Salvia divinorum*, which contains the hallucinogenic diterpenoid salvinorin A not present in other species of *Salvia* (e.g. the sage plant), can be identified unequivocally by the combined use of analytical chemistry (HPLC-MS) and molecular DNA fingerprinting (C. M. Bertea *et al.*, *Phytochemistry*, 2006, **67**, 371).

Random amplified polymorphic DNA analysis has been used to distinguish between the various subspecies of *Melissa officinalis* common on the pharmaceutical market and now included in the *BP*/*EP*. Previously, samples have been classified according to the distribution pattern of compounds present in the lemon balm oil (H.-T. Wolf *et al.*, *Planta Medica*, 1999, **65**, 83).

Recent examples of the correspondence of genetic profiles and chemical constituents for the delineation of closely related plant species and chemotypes is illustrated by research on *Withania somnifera* (R. S. Dhar *et al*., *Phytochemistry*, 2006, **67**, 2269), *Zingiber officinalis* and related species (H. L. Jiang *et al.*, *Phytochemistry*, 2006, **67**, 1673), and *Hypericum* spp. (A. Smelcerovic *et al.*, *Phytochemistry*, 2006, **67**, 171).

Serotaxonomic studies of *Acacia* gum exudates have demonstrated the value of such immunological tests in the chemotaxonomic analyses of these economically important products (T. C. Baldwin *et al.*, *Phytochemistry*, 1990, **50**, 599).

A standard work on chemotaxonomy (in German) is that of Hegnauer (see 'Further reading'); it comprises 11 volumes published over nearly 40 years. A four-volume work in English is that of Darnley Gibbs, published in 1974; unfortunately, it does not appear to have been updated.

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PART 2

The plant and animal kingdoms as sources of drugs

4

Biological and geographical sources of drugs

Current estimates of the number of species of flowering plants range between 200 000 and 250 000 in some 300 families and 10 500 genera. Despite a rapidly expanding literature on phytochemistry, only a small percentage of the total species has been examined chemically, and there is a large field for future research.

However, man did not require the modern methods of investigation to collect for himself a materia medica of plants which he often used in conjunction with magical and other ritual practices. Such folk medicines naturally varied according to the plants available in a particular climatic area and can be studied today in those more or less undisturbed primitive societies which still exist. It is interesting to reflect that such collections of herbal medicines compiled over centuries by trial and error, and presumably using the patient as the experimental animal throughout, must surely contain some material worthy of further investigation and should not be too readily discarded. Is it not also possible that those materials producing adverse reactions, one of the principal problems in the introduction of new drugs, might also have been eliminated by such a system of development?

In the current search for new drugs having, for example, antitumour or hypotensive activity the plants involved, unlike many of the more traditional medicaments, very often show no immediate indications of pharmacological activity. Investigators are thus faced with the problem of making a systematic investigation from among the thousands of species still unexamined. One obvious line of approach is to start with folk medicines of the world on the assumption that these materials have already been subjected to some human screening, however crude, and found acceptable to those cultures that use them. For many areas of the world, the plants used in folklore have been adequately recorded; but for other regions—for example, in South America, with its vast flora of potentially useful plants—the art of folk medicine in aboriginal societies is in rapid decline owing to a changing mode of life of the people. Ethnobotanists are currently fighting a battle against time to record such information before, within a generation or so, it is lost and with it a possible short cut to some medicinally useful plant. However, the urgency is well-recognized and as described in Chapter 8, the biological and geographical sources of many traditional plant remedies are being actively researched and documented. Often, successful research on a particular drug prompts the investigation of related species indigenous elsewhere, as evidenced with *Hypericum* and *Taxus*; the same is now happening with the bee product propolis. Much recorded information still requires sifting. An example of the employment of a combination of literature surveys and data from other sources in the search for new drugs is the US National Cancer Institute's screening of thousands of plant extracts for antineoplastic and cytotoxic activity. This undertaking involves the team-work of botanists, phytochemists, pharmacologists and clinicians. In the absence of such sophisticated collaboration, much useful research by one discipline fails to be followed through to a utilitarian conclusion.

An inspection of the plant or plant-derived drugs included in western pharmacopoeias shows them to be composed of those which have survived from Greek and Roman eras, including some spices, those more characteristic of our own flora (e.g. digitalis) and introduced at a later date, other pharmacologically active drugs (e.g. cinchona—quinine—and ipecacuanha) added as a result of increased travel and colonial expansion, drugs (e.g. rauwolfia—reserpine) long used in other systems of medicine but of more recent introduction into Western medicine, and finally, recently discovered plant constituents of therapeutic value (e.g. vinblastine and vincristine from *Catharanthus roseus*) and those semisynthetic products (e.g. steroidal hormones) which depend on plant sources for starting material.

A perusal of the current literature soon reveals that, with the general availability of sophisticated methods of phytochemical analysis and pharmacological screening, together with the establishment of research centres, many traditional remedies not previously considered by Western scientists are being investigated in their countries of origin.

An examination of the list of drugs derived from natural sources, as included in any pharmacopoeia, indicates that the majority are derived from the Spermatophyta—the dominant seedbearing plants of the land. Within the Spermatophyta the number of species and the number of useful medicinal plants is divided unevenly between the phyla Gymnospermae, which yields some useful oils, resins and the alkaloid ephedrine, and the Angiospermae, which is divided into Monocotyledons and Dicotyledons (both of these provide many useful drugs but especially the Dicotyledons). Of the other divisions of the plant kingdom, the fungi provide a number of useful drugs, especially antibiotics, and are important in pharmacy in a number of other ways. The algae are a source of a limited number of drugs (e.g. agar and alginic acid), but the full pharmacological importance of this large group of aquatic plants has still to be realized. At the moment, lichens and mosses contribute little to medicine and the Pteridophytes are pharmaceutically best-known for the taenicidal ferns and lycopodium. Land animals provide such traditional pharmaceutical materials as gelatin, wool fat, beeswax and cochineal, and are a source of hormones, vitamins and sera. Among the many important pharmaceutical aspects of the Bacteriophyta are the production of antibiotics, their use in effecting various chemical conversions of added substrates and their employment in genetic engineering as, for example, in the production of human insulin and the transformation of higher plant cells by incorporation of part of the DNA of a bacterial plastid into the plant genome.

Researchers in the US have genetically engineered microbes to produce a precursor of the antimalarial artemisinin, which is then chemically manipulated to give the bioequivalent drug. It is hoped to have the product available for distribution by 2010 (report by K. Purcell, *HerbalGram*, 2006, **69**, 24). This would alleviate the shortage, and high cost, of natural artemesinin, which is currently derived from the Chinese *Artemisia annua* (Chenopodiaceae).

GEOGRAPHICAL SOURCES

Two factors which determine the commercial geographical sources of a drug are the suitability of the plant to a particular environment and the economic factors associated with the production of a drug in a particular area.

Many plants grow equally well in numerous localities having similar climates; and as economic conditions change in one area, so the collection or cultivation of a drug plant may move in accordance. Developing countries may also start the cultivation of medicinal plants, and in this respect South America, India and S.E. Asian countries have been particularly active. Cinnamon, traditionally produced in Sri Lanka, has been introduced to the Seychelles as a commercial crop, with so much success that the plant has now become a weed! Cinnamon also grows well in West Africa but is not commercially utilized there. It must be remembered, however, that a plant may grow well in different situations but fail to produce the same constituents (e.g. cinchonas growing at altitude and in the plains). The commercial cultivation of belladonna, stramonium, hyoscyamus and valerian in England has long been uneconomic and material is now imported from Eastern Europe, largely via Germany. Similarly, the USA, which at one time utilized domestic supplies of the solanaceous drugs, now obtains such raw materials from Eastern Europe; the production of labiate oils has been largely transferred to China. During and after World War II, agar production was initiated around New Zealand, Australia and South Africa, but with the re-emergence of the Japanese industry these sources became less important. Scarcity of acacia from the Sudan prompted the exploitation of the Nigerian gum. Pharmacopoeial ginger once came exclusively from Jamaica; a decline in production in Jamaica and a vast improvement in the quality of some African gingers has led to the use of these and Chinese ginger on a large scale. Official storax was once derived only from the Turkish *Liquidambar orientalis* (e.g. *USP* from 1851) but limited supplies led to the admission into many pharmacopoeias of American storax, *L. styraciflua* (e.g. *USP* from 1936). Similarly, a lasting shortage of Rio (Brazilian) ipecacuanha root has led to the widespread use of the Cartagena, Nicaragua and Panama varieties, which are obtainable from a much wider area of South and Central America. With the exception of India, attempts to cultivate the drug in other areas (e.g. Malaya) met with only limited success. In contrast, the cinchonas, indigenous to the Andes of South America, were most successfully introduced to Indonesia (particularly Java) and India. These became the principal geographical sources for the bark and its alkaloids. Java fell to the Japanese in 1942 and, as India normally consumes most of its own quinine production, there was a great shortage of this vital alkaloid at a time when large armies were fighting in malarial areas. Expeditions searched the original South American habitats and wild trees supplied useful but inadequate quantities. Fortunately, very successful synthetic antimalarials were discovered at this time and put into large-scale production. However, 50 years on the malarial parasite became extremely resistant to these drugs and the use of quinine was again invoked. There is also a steady demand for other cinchona alkaloids, and Zaire and other African states, together with Guatemala, produce most of the world's bark.

China has now emerged as a major producer of a number of quality medicinal plant products including coumarin, menthol and oils of eucalyptus, peppermint, spearmint, sassafras and valerian in addition to its established listings. Other changes evident from market reports include the acceptance by the European market of expensive high-quality Australian coriander, Guatemala as the principal producer of cardamons and *Podophyllum emodi* from China.

Many countries produce limited quantities of medicinal plants and spices for domestic consumption and these are not listed on the international market.

Governmental policies on the export of raw materials may affect geographical sources, as when the Indian government limited the export of crude rauwolfia root, selling only the more highly priced extract. Supplies of the root were subsequently obtained from Thailand. Changes in the legal cultivation of medicinal opium in Turkey must eventually affect the geographical source of the drug; thus, the opium poppy has been cultivated in Tasmania on a large scale in recent years but political factors are militating against the continuation of this source. Political considerations have also led to changes in the starting materials for corticosteroids. Up to 1970 the sole intermediate source material for the manufacture of contraceptive steroids was diosgenin derived from the Mexican yam. Then the Mexican government nationalized diosgenin production and increased prices to above those for total synthesis; as a result, in subsequent years manufacturers have turned to other starting materials such as hecogenin (from sisal), solasodine (from *Solanum* spp.), microbiological products from cholesterol, stigmasterol, sitosterol and squalene, and petroleum products. The more recent emergence of China as a producer of high-quality, low-priced diosgenin has again changed the situation.

National and international restrictions on the collection of wild plants have also affected the sources of some drugs; the Washington Convention on International Trade in Endangered Species (CITES) placed all species of *Aloe* except *A. vera* on the protected list without warning; this caused problems in the marketing of aloes produced from the usual species. Other medicinal plants which have recently been given CITES listing include *Hydrastis canadensis* (1997) and *Prunus africana* (1998).

A number of the above factors have given added impetus to research on the application of cloning techniques in cultivation and to the artificial culture of plant cells and organs (see Chapter 13).

Further reading

Journal of Ethnopharmacology, special issue 1996 51(1–3). Intellectual property rights, naturally-derived bioactive compounds and resource conservation

5

A taxonomic approach to the study of medicinal plants and animal-derived drugs

For classification purposes the plant and animal kingdoms are each divided into a number of phyla and in addition to the phyla, the classification includes groupings of gradually diminishing size, namely divisions, classes, orders, suborders and families. According to the system used, these groupings may, or may not, indicate phylogenetic relationships.

In this chapter the principal plant families of pharmaceutical interest are arranged according to the botanical scheme of Engler (q.v.). The chapter is divided into six parts: Thallophytes; Bryophytes and Pteridophytes; Gymnosperms; Angiosperms (Dicotyledons); Angiosperms (Monocotyledons); Animal Products. At the beginning of each large taxon of plants a table is given to clarify the orders and families involved. Following the listed genera for each family, notes on the uses and constituents of specific plants not included in Part 5 are given. According to the botanical system of classification considered, schemes vary, as do the numbers of families, genera and species cited within an order.

THALLOPHYTES

The old term 'thallophyte' includes those plants which are not differentiated into root, stem and leaves. Engler divides them into 13 phyla. They include bacteria, algae, fungi and lichens. The positions of the main families of pharmaceutical interest are indicated below.

Phyla	Orders	Families
Bacteriophyta	Eubacteriales	Rhizobiaceae, Micrococcaceae
Chrysophyta (Diatomeae)	Discales Pennatales	Actinodiscaceae Fragilariaceae, Naviculariaceae
Phaeophyta (Brown Algae)	Laminariales Fucales	Laminariaceae Fucaceae, Sargassaceae
Rhodophyta (Red Algae)	Gelidiales Gigartinales	Gelidiaceae Gracilariaceae, Gigartinaceae

BACTERIA AND ALGAE

BACTERIOPHYTA

The bacteria are unicellular organisms, the great majority of which range in size from 0.75 to 8 μm. They reproduce by binary fission. Most species of bacteria contain no chlorophyll, although there is one group whose members contain a chlorophyll-like pigment and photosynthesize. Recent research has revealed much more of the details of cellular structure and it has been possible to distinguish in certain species, in no small detail, the various components of the cell. For example, in *Escherichia coli* the cell wall consists of a four-layer structure, the inner one being rigid, the three outer ones non-rigid. Within the three-layer wall structure lies a protoplast membrane enclosing the cytoplasm. The protoplast membrane acts as a permeability barrier to all but very large molecules and contains enzymes concerned with respiration and the active transport of metabolities.

Bacteria exist in a number of characteristic shapes, namely:

1. Rod-shaped or bacillary forms (e.g. *Clostridium welchii*, *Escherichia coli* and *Bacillus subtilis*).

2. Spherical or coccal forms, which can occur singly but are usually found in characteristic aggregates—i.e. in chains (streptococci), in groups of two (diplococci), four (tetracocci) or eight (sarcinae). Aggregates of irregular pattern are said to be of staphylococcal form.
3. Twisted or spirillar forms which, if having a single twist, belong to the genus *Vibrio*, while those with more than one twist belong to the genus *Spirillum*.
4. Branched forms which sometimes occur in the genus *Mycobacterium.*

Other important morphological features which are of value in classifying bacteria are: (1) The possession of flagella, thread-like processes whose number and position are often of diagnostic importance. (2) The formation of capsules consisting of polysaccharide material which is of great importance in relation to the immunological properties of the organism. (3) The possession of endospores, which are highly refractive bodies formed by certain species under what appear to be adverse environmental conditions. The position of the spore in relation to the rest of the cell is of diagnostic importance. (4) Pigmentation; many bacteria are capable of elaborating complex colouring matters.

Bacteria are able to carry out a very wide range of chemical reactions, some of which are used for identification and differentiation, in addition to forming the basis of many important industrial processes. Bacterial action is used, for example, in the production of vinegar, acetone, butyl alcohol, lactic acid and L-sorbose. Notable examples of reactions which are useful for characterizing bacteria are the ability to ferment carbohydrates with the formation of acidic and gaseous products; the ability to digest protein, as shown by gelatin liquefaction; the production of hydrogen sulphide from organic sulphur compounds.

Bacteria are most important in medicine and pharmacy in the following respects: as disease-producing organisms (about 10% of bacteria are probably pathogenic); for producing antibiotics (Chapter 30); for effecting biochemical conversions; as agents in the deterioration of crude drugs and medicaments (Chapter 15); the production of transformed root cultures and transgenic medicinal plants by *Agrobacterium* spp. (Chapters 11 and 12); in genetic engineering involving recombinant DNA (e.g. the production of human insulin). Bacteria also play a vital role in nature—for example, in the nitrogen cycle atmospheric nitrogen is fixed by *Azotobacter* or, symbiotically, by various species of *Rhizobium. Nitrosomonas* is able to oxidize ammonia to nitrite, while *Nitrobacter* can oxidize nitrite to nitrate. Bacteria are important in sewage purification, in the retting of fibres such as jute and flax, and in the ripening of cheese.

CHRYSOPHYTA: DISCALES

Actinodiscaceae

The Chrysophyta has three classes, one of which is the Bacillariophyceae (Diatomeae), containing some 10 000 species of diatom. They are unicellular algae, have a silica skeleton, and show infinite variety in shape and in the sculpturing of the cell wall. There are two main types: the subclass Centricae (in which Discales is one of the orders) and subclass Pennatae (which includes the order Pennatales). The Centricae are centric or discoid in shape and generally marine, while the Pennatae are pennate or naviculoid and more often occur in fresh water.

An example of the family Actinodiscaceae is *Arachnoidiscus*, found in Japanese agar (q.v.) and other genera are found in the fossil deposits of diatomite or kieselguhr (q.v.).

CHRYSOPHYTA: PENNATALES

Fragilariaceae and Naviculariaceae

Species of these two families occur in diatomite and are illustrated in Fig. 34.1.

PHAEOPHYTA: LAMINARIALES

Laminariaceae

The brown algae are mainly marine and vary from microscopic branched filaments to leathery frond-like forms up to 60 m in length. They owe their brown colour to the carotenoid pigment fucoxanthin, which masks the other pigments.

Many of the 30 species of *Laminaria* are used in coastal districts for agricultural purposes. They are used for the manufacture of alginic acid (q.v.), mannitol and iodine.

PHAEOPHYTA: FUCALES

Fucaceae and Sargassaceae

Examples of the Fucaceae are *Fucus* (about 30 spp.) and *Pelvetia*; and of the Sargassaceae about 250 species of *Sargassum*. These are collected on a large scale in many parts of the world for the production of alginic acid and its derivatives. The species have been much investigated for biologically active properties; *F. vesiculosus*, for example, gives water-soluble extracts that inhibit the activity of the HIV reverse-transcriptase enzyme.

RHODOPHYTA: GELIDIALES

Gelidiaceae

The red algae are divided into 11 orders. The 3000 species are mainly marine and are particularly abundant in the tropics and subtropics. Most are relatively small. Their plastids contain chlorophyll, the red pigment phycoerythrin (usually in sufficient quantity to mask the other pigments), and sometimes the blue pigment phycocyanin.

Important genera of the Gelidiaceae are *Gelidium* (about 40 spp.) and *Pterocladia* (5 spp.). Many of these are used in the preparation of agars (q.v.).

RHODOPHYTA: GIGARTINALES

Gracilariaceae and Gigartinaceae

Gracilaria (100 spp.) is a source of agar, particularly *G. lichenoides*, found in the Indian Ocean. In the Gigartinaceae *Chondrus crispus* yields carageen or Irish moss (q.v.); *Gigartina stellata* has been investigated as a source of British agar.

FUNGI

The fungi are saprophytic or parasitic members of the Thallophyta, entirely devoid of chlorophyll. The plant body is made up of filaments or hyphae, which together constitute the mycelium. The hyphae may be aseptate and coenocytic, but are often septate, the individual segments being uni-, bi- or multinucleate. In the formation of fruiting bodies the hyphae may become woven into dense masses of pseudoparenchyma (e.g. the sclerotium of ergot).

The protoplast of fungal cells consists of granular or reticulate cytoplasm, which in older cells is often vacuolated. The nucleus may show a delicate reticulum and one or more nucleoli or its contents may be condensed into a chromatin body. The cell wall in many Archimycetes

and some Phycomycetes (Oomycetes) and in the yeasts consists mainly of cellulose, but in other fungi cellulose is replaced by the nitrogenous substance chitin.

Sexual and asexual reproduction occur. The characteristic spores of the sporophyte generation are known as oospores (produced endogenously) or basidiospores (produced exogenously). In the Fungi Imperfecti the sporophyte generation is missing. The fungi also produce spores having no significance in the alternation of the generations; they are borne on the gametophyte (Phycomycetes and Ascomycetes) or on the sporophyte (rusts and some Autobasidiomycetes). These accessory spores often take the form of conidia, non-motile spores, borne externally on conidiophores.

The Archimycetes are the simplest fungi, in which the mycelium is absent or rudimentary. A member of this group causes wart disease in potatoes. The following groups and families are of pharmaceutical interest.

Class	Order	Families
Phycomycetes	Mucorales	Mucoraceae
Ascomycetes	Protoascales	Saccharomycetaceae
	Plectascales	Aspergillaceae
	Sphaeriales	Hypocreaceae
	Clavicipitales	Clavicipitaceae
Basidiomycetes	Polyporinales	Polyporaceae
	Agaricales	Tricholometaceae
		Amanitaceae
		Agaricaceae
	Phallinales	Phallinaceae
Fungi Imperfecti	Moniliales	Dematiaceae

PHYCOMYCETES: MUCORALES

Mucoraceae

These fungi have an aseptate mycelium; members include *Phytophthora infestans*, which causes potato blight. In the Mucoraceae we have *Mucor* (40 spp.) and *Rhizopus* (8 spp.), which are among the moulds associated with badly stored food products. Some *Rhizopus* species are used industrially for the saccharification of starchy material and for producing D-lactic acid from glucose; they are important in the microbiological conversions of steroids (q.v.).

ASCOMYCETES: PROTOASCALES

Saccharomycetaceae

This group includes the yeasts, some 30 species of *Saccharomyces*. Dried yeast (q.v.) is prepared from a strain of *S. cerevisiae*. A member of the related family Cryptococcaceae is *Candida utilis*, which produces torula yeast, a rich source of proteins and vitamins.

PLECTASCALES

Aspergillaceae

In this order the conidial stage is more prominent than the ascal stage. *Penicillium* (over 100 spp.) yields important antibiotics (q.v.) such as penicillin and griseofulvin; also the immunosuppressant mycophenolic acid. *P. islandicum* forms emodin. Among the 60 species of *Aspergillus* may be noted *A. oryzae*, used in the manufacture of soya sauce; *A. fumigatus*, producing the antibiotic fumagillin; and *A. flavus* producing aflatoxin in poorly stored feeding materials.

SPHAERIALES

Hypocreaceae

Gibberella (10 spp.) produces the plant growth regulators known as gibberellins, first isolated from *G. fugikuroi*, see Chapter 12.

CLAVICIPITALES

Clavicipitaceae

Like other Ascomycetes, the ascospores are produced in a sac or ascus. *Claviceps* (10 spp.) includes ergot, the sclerotium of *C. purpurea*; *Cordyceps* (100 spp.) includes *C. sinensis*, one of the most valued species in Chinese traditional medicine but limited in use by a shortage of supply. *C. militaris* has similar properties and efforts are devoted to its artificial culture; R. Yu *et al.*, have purified and identified four polysaccharides from cultured material (*Fitoterapia*, 2004, **75**, 662).

BASIDIOMYCETES: POLYPORINALES

The Basidiomycetes produce basidiospores, borne externally on the spore mothercell or basidium. They have septate mycelia which produce elaborate fruiting bodies (e.g. mushrooms). Some members are edible, others poisonous.

Polyporaceae

The Polyporaceae includes *Polyporus*, *Polystichus*, *Fomes*, *Ganoderma* and *Boletus* (200 spp.). *Polyporus officinalis* (white agaric) and *P. fomentarius* were formerly used in medicine. *Ganoderma lucida* has long been used in Chinese medicine and its biologically active triterpenoids have attracted attention. *Boletus edulis* is edible.

AGARICALES

An order of several families.

Tricholometaceae

The Tricholometaceae contains *Clitocybe* (80 spp.), species of which produce muscarine (q.v.). Other families of the order contain *Stropharia*, *Psilocybe* and *Conocybe*, which produce hallucinogenic substances (q.v.) such as psilosin and psilocybin.

Amanitaceae

The family includes *Amanita* (50–60 spp.) and *Pluteus*; *Amanita muscaria* (fly agaric) and *A. pantherina* contain muscarine (q.v.).

Agaricaceae

This family includes the common mushroom, *Agaricus campestris*. The genus *Agaricus* (*Psalliota*) contains about 30 species.

PHALLINALES

The order contains two families.

Phallinaceae

The Phallinaceae takes its name from *Phallus* (10 spp.). *Phallus impudicus* is the stinkhorn.

FUNGI IMPERFECTI: MONILIALES

The Fungi Imperfecti is a group in which sexual spores have not been demonstrated. Some members may be Ascomycetes which have completely lost the ascus stage.

Dematiaceae

The family Dematiaceae contains *Helminthosporium* (150–200 spp.), a species of which, *H. graminium*, produces helminthosporin (q.v.). Another family of the group, the Tuberculariaceae, contains *Fusarium* (65 spp.). *Fusarium lini* will transform digitoxigenin into digoxigenin.

Fungal spores are a common source of allergens.

LICHENS

A lichen is a symbiotic association of an alga and a fungal partner. Some, particularly in arctic regions, are used as food. The desert species *Lecanora esculenta* is regarded as the biblical manna. The 'oak moss' used as a fixative in perfumery is the lichen *Evernia prunastri*. Many lichens contain derivatives of orcinol, orcellic acid and lecanoric acid; these compounds are termed depsides and are phenolic acids formed by the interaction of the carboxyl group of one molecule with the hydroxyl group of another. A class of these acids termed depsidones (e.g. norstictic and psoromic acids) complex with metals and are probably responsible for the ability of lichens to flourish on mineral-rich soils including mine tailings and to accumulate large quantities of metals, such as copper, zinc etc.

Lichen dyes were formerly much used in the textile industry. Litmus, produced from certain lichens (e.g. *Lecanora*, *Roccella* spp.) by fermentation, is used as an indicator.

Iceland moss, *Cetraria islandica*, has been used for disguising the taste of nauseous medicines and with other species (e.g. *Cladonia* spp.) for the treatment of cough. It contains the very bitter depsidone, cetraric acid. Many lichens have antibiotic properties as illustrated by usnic acid, found in *Cladonia* and *Usnea* spp. (see E. R. Correché *et al*. 1998, *Fitoterapia*, **69**, 493; V. Marcano *et al*., *J. Ethnopharmacology*, 1999, **66**, 343); 29 species of Icelandic lichens have recently been investigated for their cancer chemopreventive and cytotoxic activity (K. Ingólfsdóttir *et al*., *Pharm. Biol*., 2000, **38**, 313).

It is possible to isolate and grow the algae from lichens as suspension cultures (see P. Härmälä *et al*., *Fitoterapia*, 1992, **63**, 217).

The accompanying list indicates some of the families and genera of recent interest.

Order	Family	Genera
Roccellales	Roccellaceae	*Roccella* (31 spp.)
Lecanorales	Pertusariaceae	*Pertusaria* (608 spp.)
	Lecanoraceae	*Lecanora* (1100 spp.)
	Parmeliaceae	*Parmelia* (800 spp.)
		Cetraria (62 spp.)
	Usneaceae	*Usnea* (500 spp.)
		Evernia (8 spp.)
		Alectoria (48 spp.)
Caloplacales	Caloplacaceae	*Caloplaca* (480 spp.)
	Teloschistaceae	*Xanthoria* (21 spp.)

BRYOPHYTES AND PTERIDOPHYTES

These two phyla are of relatively small pharmaceutical importance, but have some phytochemical interest.

BRYOPHYTA

The phylum is divided into two classes, Hepaticae (liverworts) and Musci (mosses). Both show alternation of generations. The more conspicuous gametophyte generation is a leaf-like thallus in the liverworts and a leafy plant with a stem in the mosses. On the latter is borne the sporophyte generation with sporangium.

Of the many bryophyte orders, families and genera, a few which have been subjects of recent research are listed below.

Class	Order	Genera
Hepaticae	Jungermaniinales	*Bazzania, Solenostoma, Gymnomitrion, Diplophyllum*
	Jubulineales	*Lunularia*
Musci	Sphagnales	*Sphagnum* (336 spp.)
	Dicranales	*Dicranum* (52 spp.)
	Funariales	*Funaria* (117 spp.)

Peat, long used as a domestic fuel, consists of partly decayed mosses and other plants. In some areas (e.g. parts of Ireland) deposits of bog moss (largely species of *Sphagnum*) are many feet thick, and after the surface has been skimmed off, soil may be excavated in a very pure form. Sphagnum moss, consisting of a mixture of various species of *Sphagnum*, can be collected in many parts of Britain. It may be used (enclosed in muslin bags) as an absorbent dressing or compressed into sheets, making absorbent mattresses. Large quantities were used in this way in World War I.

The pharmacologically active terpenoids (sesquiterpenes, diterpenes) and aromatic compounds of the bryophytes have been well studied. (For a review see Y. Asakawa, *Proc. Phytochem. Soc. Eur*., 1990, **29**, 369. This volume (eds. H. D. Zinsmeister and R. Mues), published by Clarendon Press, Oxford, also includes a further 28 review articles covering the chemistry and chemical taxonomy of the Bryophytes.)

PTERIDOPHYTA

The Pteridophyta includes the Filices (ferns), Articulatae (horsetails) and Lycopsida (club mosses). They show an alternation of generations, the sporophyte being the larger. A few are of medical importance.

Of the many families, subfamilies and genera the following may be noted.

Class	Order	Family	Genera
Filices	Filicales	Polypodiaceae (divided into many subfamilies)	*Polypodium* (about 50 spp.)
			Dryopteris (about 150 spp.)
			Pteris (280 spp.)
			Pteridium (1 sp.)
			Onychium (6 spp.)
			Dennstaedtia (70 spp.)
			Adiantum (about 200 spp.)
			Athyrium (180 spp.)
			Asplenium (about 700 spp.)
Articulatae	Equisetales	Equisetaceae	*Equisetum* (32 spp.)
Lycopsida	Lycopodiales	Lycopodiaceae	*Lycopodium* (about 450 spp.)

Male fern rhizome (q.v.) derived from *Dryopteris filix-mas* is one of many ferns containing phloroglucinol derivatives. The insect-moulding hormones or pterosins are widely distributed in ferns and attract considerable research.

Various species of *Adiantum* (the maiden hair ferns) are recorded as used in traditional medicine in Europe, Saudi Arabia, Africa and the Indian subcontinent. They contain hopane triterpenoids, a group of squalane-derived compounds more commonly associated with bacterial membranes. G. Brahmachari and D. Chatterjee record the isolation of a new one-such constituent from *A. lunulactum* (syn. *A. philippense*) (*Fitoterapia*, 2002, **73**, 363).

The dried sterile stems of the horsetail, *Equisetum arvense* are used in herbal medicine and are listed in the *BHP* (1996) and the *BP*/*EP*. There are apparently two chemotypes of the species with different flavonoid compositions. Horsetails give a high mineral ash containing considerable amounts of silica. Correct identification of the herb is important because the related species *E. palustre* is poisonous.

The spores of lycopodium (*Lycopodium clavatum*) are used in quantitative microscopy (q.v.) and to a limited extent in medicated snuffs, dusting powders and lubricants. As a dusting powder for rubber gloves it has been known to give rise to dermatitis and mild caution has been expressed regarding its use as a lubricant non-stick agent for condoms relative to a possible cause of granulomas. The lycopodium alkaloids have been extensively studied (for a review see W. A. Ayer and L. S. Trifonov, *Alkaloids*, 1994, **45**, 233). *Huperzia serrata* (a club moss), now assigned to *Lycopodium*, contains the unusual alkaloid huperzine A and has been long-used in Chinese medicine for the treatment Alzheimer's and related conditions (see also Chapter 8).

Bracken (*Pteridium aquilinum*) has been a recent cause of concern owing to its carcinogenic properties and known bovine poisoning. The use of the young shoots for culinary purposes is discouraged and avoidance of bracken spores in the atmosphere suggested. The toxic constituent is ptaquiloside, an unstable glycoside of an illudane-type norsesquiterpene. Other similar compounds are widely distributed in the genus *Pteridium*.

GYMNOSPERMS

The division Gymnospermae contains many fossil members. Of the 11 orders in the Engler classification, it is only necessary to mention five orders and 10 families:

Orders	Families
Cycadales	Cycadaceae
Ginkgoales	Ginkgoaceae
Coniferae	Pinaceae, Taxodiaceae, Cupressaceae, Araucariaceae, Podocarpaceae, Cephalotaxaceae
Taxales	Taxaceae
Gnetales	Ephedraceae

The gymnosperms are one of the two great divisions of the seed-bearing plants or spermaphyta. They differ from the angiosperms in having ovules which are not enclosed in an ovary. A perianth is absent except in the Gnetales. The seeds usually contain one mature embryo with from two to 15 cotyledons embedded in endosperm. The wood is composed largely of tracheids, vessels being absent.

CYCADALES

Cycadaceae

The order contains only 10 genera and about 100 species. The family Cycadaceae contains the single genus *Cycas*, with 20 species. A sago (not to be confused with that from certain palms) is obtained from the pith of *Cycas circinalis* and *C. revolula*.

GINKGOALES

Ginkgoaceae

With the exception of *Ginkgo biloba*, the maidenhair-tree, the plants of this order are found only as fossils. In recent years, owing to their increasing use for the treatment of various diseases associated with the ageing process, the leaves of the ginkgo tree have been extensively investigated. For further details see 'Diterpenoids'.

CONIFERAE (OR CONIFERALES)

Pinaceae

All members of the order are trees or shrubs; mostly evergreen with needle-like leaves; monoecious or dioecious. Sporophylls usually in cones. Resin ducts occur in all parts.

The Pinaceae are trees, rarely shrubs. Important genera are: *Abies* (50 spp.), *Pseudotsuga* (7 spp.), *Tsuga* (15 spp.), *Picea* (50 spp.), *Larix* (11 spp.), *Cedrus* (4 spp.), and *Pinus* (70–100 spp.). They are abundant in the northern hemisphere and extend southwards to Indonesia and Central America. Apart from their great value as timber and paper-making material, many species (e.g. *Pinus*) yield oleoresin (see 'Colophony Resin and Crude Turpentine'). Other species are *Abies balsamea*, yielding Canada balsam; *Pseudotsuga taxifolia* (Douglas fir); *Picea abies* (Norway spruce); and *Larix europaeus* (larch). The barks of larch and hemlock spruce are tanning materials. *Pinus pinea* (the umbrella pine) produces large edible seeds (pignons). An extract of the bark of *P. pinaster* (*P. maritima*) var. *atlantica* containing bioflavonoids, particularly procyanidins (q.v.), is marketed as a food supplement (Pycnogenol®) having antioxidant properties. Some members of the family are a potential source of shikimic acid (q.v.).

Taxodiaceae

A small family of 10 genera, including *Sequoia*, *Taxodium*, *Cryptomeria*, *Tetraclinis*, *Taiwania* and *Cunninghamia*; 16 species.

The resin sandarac is produced in North Africa and Spain from *Tetraclinis articulata*. Some of the family contain antifungal diterpenes, others alkaloids.

Cupressaceae

A family of 19 genera and 130 species of trees and shrubs.

Members differ from the Pinaceae in that the leaves and cone-scales are usually opposite or whorled and the ovules erect. The genera include *Callitris* (16 spp., Australasia), *Thuja* (5 spp., China, Japan and North America), *Cupressus* (15–20 spp.), *Chamaecyparis* (7 spp.), *Juniperus* (60 spp., northern hemisphere). *Juniperus communis* yields juniper berries and volatile oil (q.v.); *J. virginiana*, the red cedar wood used for pencils; and *J. sabina*, volatile oil of savin; *J. oxycedrus*, by destructive distillation, yields oil of cade, which was formerly much used in veterinary work. This tar-like oil contains cadinene and phenols. Various diterpenes and flavonoids of the family have been studied.

Araucariaceae

Two genera and 38 species of trees, which sometimes have pungent leaves.

Araucaria (18 spp.) provides useful timbers; and *Agathis* (20 spp.), the resins known as copals or animes, which are used for varnish. Manila copal is obtained from the Malaysian *Agathis alba*; and kauri copal from *A. australis*, the kauri pine, in Australia and New Zealand. The best copals are usually those found in the ground long after the trees are dead.

Podocarpaceae

Six genera and 125 species of trees and shrubs. The largest genus, *Podocarpus* (100 spp.), extends from tropical to temperate zones and yields valuable timbers. A characteristic chemical feature of this genus is the widespread occurrence of norditerpene and bisnorditerpene dilactones; these compounds exhibit a variety of biological activities (see I. Kubo *et al*., *Phytochemistry*, 1992, **31**, 1545).

Cephalotaxaceae

A family of one genus (*Cephalotaxus*) and seven species of trees and shrubs (plum yews) found from the eastern Himalayas to Japan. They have been intensively studied for their antitumour constituents in particular, the alkaloids harringtonine and homoharringtonine from *C. harringtonia*.

TAXALES

Taxaceae

An order of only one family, which includes the genera *Taxus* (10 spp.), *Pseudotaxus*, *Torreya*, *Austrotaxus* and *Amentotaxus*.

The common yew, *Taxus baccata*, produces valuable wood. The fruit has a fleshy red aril. All parts of the plant are very poisonous, and cattle and horses can die very rapidly after eating the leaves and stems. In addition to alkaloids, a cyanogenetic glycoside and antitumour agent have been reported in the genus.

Taxus brevifolia (the Pacific yew). The bark of this species yields the anticancer drug taxol, a nitrogenous diterpene. Low yields from the bark and the scarcity of raw material leading to damage to forests by, often illegal, over-collection hampered the development of the drug. The investigation of alternative sources led to tissue culture procedures for the production of taxol but the yields are still low. A development involving a renewable source has been the isolation of 10-deacetylbaccatin from the fresh needles of *T. baccata* in up to 0.1% yield and its chemical conversion to taxol. *T. media*, *T. cuspidata* and *T. chinensis* are other species investigated for taxane alkaloids.

GNETALES

Ephedraceae

The order consists of three families (Gnetaceae, Ephedraceae and Welwitchiaceae), three genera and about 70–75 species.

The Ephedraceae contains the single genus *Ephedra* (q.v.), about 40 species of shrubs. They occur in arid regions of the subtropics and tropics. Their seed, with two cotyledons, is enclosed in a perianth which becomes woody. Various species yield the drug ephedra (q.v.) and the alkaloid ephedrine.

ANGIOSPERMS: DICOTYLEDONS

The angiosperms or flowering plants include more than 250 000 species of herbs, shrubs and trees. The sporophylls (stamens and carpels) are usually arranged with other leaves (the perianth) to form a 'flower'. The ovules are enclosed in a chamber (the ovary) formed from the carpels, and a stigma is provided for the reception and germination of the pollen. The embryo plant contained in the seed has one or two seed leaves or cotyledons. The wood almost invariably contains true vessels. The phylum is divided into monocotyledons and dicotyledons.

The dicotyledons are herbs, shrubs or trees, the seeds of which have two cotyledons. The leaves are usually reticulately veined and the typical stem structure is a ring of open vascular bundles. Unlike the monocotyledons, which typically have their floral parts in threes, dicotyledonous flowers are usually pentamerous or tetramerous. The flowers may be unisexual (e.g. Salicaceae), but are more usually bisexual. The perianth may or may not be differentiated into sepals and petals, and the latter may be free from one another or fused.

The classification adopted in the following pages is that of Engler, who divides the dicotyledons into two groups, the Archichlamydeae and Sympetalae. The Archichlamydeae are further divided into 37 orders and about 226 families and the Sympetalae into 11 orders and about 63 families.

The names of the orders terminate in '-ales', suborders in '-neae', families usually in '-aceae' (Compositae, Gramineae and Labiatae are exceptions), and sometimes into subfamilies ending in '-oideae'.

The Archichlamydeae contain those families that in early editions were grouped under Monochlamydeae and Dialypetalae. The flowers have either no perianth or a perianth that is differentiated into sepals and petals, the latter being free. Engler's classification of the Dicotyledons is given in a somewhat abbreviated form below.

Order	Family
Subclass Archichlamydeae	
Juglandales	Myricaceae, Juglandaceae
Salicales	Salicaceae
Fagales	Betulaceae, Fagaceae
Urticales	Ulmaceae, Moraceae (including Cannabinaceae) and Urticaceae
Proteales	Proteaceae
Santalales	Olacaceae, Santalaceae, Loranthaceae
Polygonales	Polygonaceae
Centrospermae	Phytolaccaceae, Caryophyllaceae, Chenopodiaceae
Cactales	Cactaceae
Magnoliales	Magnoliaceae, Winteraceae, Annonaceae, Eupomatiaceae, Myristicaceae, Canellaceae, Schisandraceae, Illiciaceae, Monimiaceae, Calycanthaceae, Lauraceae, Hernandiaceae
Ranunculales	Ranunculaceae, Berberidaceae, Menispermaceae, Nymphaeaceae
Piperales	Piperaceae
Aristolochiales	Aristolochiaceae
Guttiferales	Paeoniaceae, Dipterocarpaceae, Theaceae, Guttiferae
Sarraceniales	Sarraceniaceae, Nepenthaceae, Droseraceae
Papaverales	Papaveraceae (including Fumariaceae), Capparaceae, Cruciferae
Rosales	Hamamelidaceae, Crassulaceae, Saxifragaceae, Rosaceae, Leguminosae, Krameriaceae
Geraniales	Geraniaceae, Zygophyllaceae, Linaceae, Erythroxylaceae, Euphorbiaceae

(Continued)

Order	Family
Subclass Archichlamydeae (continued)	
Rutales	Rutaceae, Simaroubaceae, Burseraceae, Meliaceae, Malpighiaceae, Polygalaceae
Sapindales	Anacardiaceae, Aceraceae, Sapindaceae, Hippocastanaceae
Celastrales	Aquifoliaceae, Celastraceae, Buxaceae
Rhamnales	Rhamnaceae, Vitaceae
Malvales	Elaeocarpaceae, Tiliaceae, Malvaceae, Bombacaceae, Sterculiaceae
Thymelaeales	Thymelaeaceae, Elaeagnaceae
Violales	Flacourtiaceae, Violaceae, Turneraceae, Passifloraceae, Cistaceae, Bixaceae, Tamaricaceae, Caricaceae
Cucurbitales	Cucurbitaceae
Myrtiflorae	Lythraceae, Myrtaceae, Punicaceae, Rhizophoraceae, Combretaceae, Onagraceae
Umbelliflorae	Alangiaceae, Cornaceae, Garryaceae, Araliaceae, Umbelliferae
Subclass Sympetalae	
Ericales	Ericaceae
Primulales	Myrsinaceae, Primulaceae
Plumbaginales	Plumbaginaceae
Ebenales	Sapotaceae, Ebenaceae, Styracaceae
Oleales	Oleaceae
Gentianales	Loganiaceae, Gentianaceae, Menyanthaceae, Apocynaceae, Asclepiadaceae, Rubiaceae
Tubiflorae	Polemoniaceae, Convolvulaceae, Boraginaceae, Verbenaceae, Labiatae, Solanaceae, Buddlejaceae, Scrophulariaceae, Bignoniaceae, Acanthaceae, Pedaliaceae, Gesneriaceae, Myoporaceae
Plantaginales	Plantaginaceae
Dipsacales	Caprifoliaceae, Valerianaceae, Dipsacaceae
Campanulales	Campanulaceae (including Lobeliaceae), Compositae

SUBCLASS ARCHICHLAMYDEAE

JUGLANDALES

Myricaceae and Juglandaceae

The order contains only these two small families.

The Myricaceae has three or four genera of trees and shrubs with unisexual flowers. Some members contain volatile oil (e.g. *Myrica gale*, the bog myrtle).

The Juglandaceae has seven or eight genera and the best-known species is the walnut, *Juglans regia*, which produces timber and edible nuts. *Juglans* contains the naphthoquinone juglone, the sugars raffinose and stachyose, flavonoids and phenolic acids.

The leaves and pericarp of *J. regia* have long been used as extracts in traditional medicine and pharmacologically demonstrated to be antihelmintic, antidiarrhoeal, antifungal, astringent, hypoglycaemic and, more recently, sedative; see M. Girzu *et al*., *Pharm. Biol*., 1998, **36**, 280.

SALICALES

Salicaceae

The single family of the order contains only two genera, *Salix* (500 spp.) and *Populus* (35 spp.). The dioecious flowers are in catkins.

Both genera contain phenolic glycosides such as fragilin, salicin and populin. Salicin, formerly used in medicine, has been replaced by other drugs. Willow charcoal is the chief kind of wood charcoal used in Britain. Osiers (*Salix purpurea* and *S. viminalis*) are used for basket-making, and *S. alba* var. *caerulea* is used for cricket-bats. Species of *Populus* contain raffinose and stachyose. The dried winter buds of various species of poplar (*P. nigra*, *P. candicans*, *P. tacamahaca*) constitute Balm of Gilead Bud *BHP* 1996, *BHC* Vol 1, 1992. It is used as an expectorant and contains flavonoids, phenolic esters and free acids (caffeic acid, etc.). The hive product propolis may be derived from poplar bud exudates.

FAGALES

Betulaceae and Fagaceae

These families consist of monoecious trees and shrubs. Their classification together is confirmed by similarities in constituents.

The Betulaceae has two genera, *Alnus* (35 spp.) and *Betula* (60 spp.). Constituents include many phenolic substances such as myricetin, delphinidin and ellagic acid; also terpenoids such as lupeol and betulin. The wood of *Betula alba* is used for charcoal.

The Fagaceae has eight genera and about 900 species. *Fagus* (10 spp.) includes the beech, *F. sylvatica*, the nuts of which are expressed to yield oil; *Castanea* (12 spp.) includes the sweet chestnut, *C. sativa*, which yields timber and a bark used for tanning. The edible nut serves as a component of a gluten-free diet in cases of coeliac disease and in paediatrics for the treatment of gastroenteritis. For the isolation of a pyrrole alkaloid from the seeds, see A. Hiermann *et al*., *Fitoterapia*, 2002, **73**, 22. *Quercus* (450 spp.) provides valuable timber. Different *Quercus* spp. contain shikimic acid (a cyclitol), methyl salicylate and terpenoids. The cupules and unripe acorns of *Q. aegelops* (valonia) are used in tanning. *Q. ilex* and *Q. robur* yield tanning barks and *Q. tinctoria*, a yellow dye. *Q. suber* affords the commonly used cork, in an industry worth (1987) some £120 million p.a. to Portugal's economy; because there was no planned re-afforestation the industry now faces a decline. An extract of *Q. stenophylla* has been marketed for the acceleration of the elimination of renal and urethral calculi. Turkish galls (q.v.), an important source of tannic acid, are vegetable growths formed on the young twigs of the dyer's oak, *Q. infectoria*, as a result of the activity of a gall-wasp. Similar galls are produced on the English oak, *Q. robur*.

URTICALES

Ulmaceae, Moraceae, Cannabinaceae, Urticaceae

The Cannabinaceae, originally included in the Moraceae, is now regarded as a separate family.

1. The Ulmaceae contains 15 genera and 200 species of tropical or temperate shrubs and trees. Genera include *Ulmus* (45 spp.), *Celtis* (80 spp.) and *Trema* (30 spp.). Members contain no latex (distinction from Moraceae). Mucilage is abundant in the barks of *Ulmus rubra* (see 'Slippery Elm Bark') and *U. campestris*; raffinose and stachyose occur in *Ulmus*, an indole alkaloid occurs in *Celtis*.
2. The Moraceae has about 53 genera and 1400 species. They are mainly tropical or subtropical shrubs or trees containing latex. The fruit is often multiple, as in *Ficus*, the fig. The large genus *Ficus* (about 800 spp.) includes trees and shrubs of very varied habit.

These include *F. benghalensis* (banyan), *F. elastica* (indiarubber tree) and *F. carica* (common fig). The latex is often anthelmintic, owing to the proteolytic enzyme ficin. Another genus *Castilloa* (10 spp.), yields, from *C. elastica*, Panama rubber or caoutchouc. Among other constituents reported in the family are cardenolides (in five genera) and pyridine alkaloids (in two genera). Species of *Morus* are used in oriental medicine.

3. The Cannabinaceae or Cannabidaceae consists of the two genera *Cannabis* and *Humulus* comprising C. *sativa* (hemp), *H. lupulus* (common hop) (q.v.) and *H. japonica* (Japanese hop). The chemistry of these plants is a justification for their separation from the Moraceae. *Cannabis* produces the best hemp when grown in a temperate climate, whilst the more active samples of Indian hemp (q.v.) are usually associated with warmer climates.
4. The Urticaceae has 45 genera and 550 species; tropical or temperate herbs or undershrubs without latex. Some genera have stinging hairs (e.g. *Urtica*, 50 species of stinging nettle), others lack such-hairs (e.g. *Pilea*, *Boehmeria* and *Parietaria*). Root and leaf extracts of the common stinging nettle (q.v.) are used in herbal medicine, often in combination with other species, for the treatment of benign prostate hyperplasia. For a review with 78 references see E. Bombardelli and P. Morazzoni, *Fitoterapia*, 1997, **68**, 387.

PROTEALES

Proteaceae

The single family of the order, the Proteaceae, contains 62 genera and 1050 species. Shrubs and trees are particularly abundant in Australia, New Zealand and South Africa. Many species have been examined chemically, and the constituents reported include cyanogenetic compounds, alkaloids, tannins, leucoanthocyanins, arbutin and the sugar alcohol polygalitol. Genera include *Protea* (130 spp.), *Grevillea*, *Persoonia*, *Hakea* and *Knightia*.

SANTALALES

Olacaceae, Santalaceae, Loranthaceae

The order contains seven families of which only four need be mentioned.

The Olacaceae has about 27 genera and 250 species. Few have been examined chemically. Acetylenic acids occur in *Olax stricta*.

The Santalaceae contains about 30 genera and 400 species. Of the genera, *Santalum* contains 25 species and *Thesium* about 325 species. Monoterpenes and sesquiterpenes occur in several genera. The plants are hemiparasitic herbs, shrubs and small trees. *Santalum album* yields sandalwood and sandalwood oil (q.v.) and is rich in sesquiterpene alcohols. Australian sandalwood and its oil are obtained from another member of the family, *Eucarya spicata*.

The Loranthaceae is a fairly large family of 36 genera and 1300 species. The genus *Viscum* consists of about 60 species of parasitic evergreen shrubs, which often contain cyclitols. The dried aerial parts of the common mistletoe, *Viscum album*, which grows on apple and other trees are included in the *BHP* 1996 and are used for various circulatory conditions. It contains glycoproteins (the mistletoe lectins), polypeptides (viscotoxins), lignans, flavonoids, etc. The flavonoid glycosides involve glucose, apiose and *trans*-cinnamic acid; for glycoside isolations from *V. album* ssp. *atlantica* grown on apricot (*Armeniaca vulgaris*) in Turkey, see D. Deliorman Orhan *et al*., *Pharm. Biol*., 2002, **40**, 380.

POLYGONALES

Polygonaceae

This one-family order occupies an isolated position. It has about 40 genera and 800 species, mostly herbs. About 29 species are indigenous to Britain. Genera include *Rheum* (50 spp.), *Rumex* (about 180 spp.), *Fagopyrum* (15 spp.), *Coccoloba* (150 spp.) and *Polygonum*. The fruit is a one-seeded, usually three-winged nut (e.g. dock and buckwheat). Anthocyanin pigments are common; also flavones and flavonols—for example, buckwheat, *Fagopyrum esculentum*, is a commercial source of rutin. Quinones (anthraquinones, phenanthraquinones, anthrones and dianthrones) are found in many species of *Rheum* (q.v.), *Rumex* and *Polygonum*. The root of *Rumex crispus* (yellow dock, curled dock), *BHP* 1983, contains hydroxyanthraquinone derivatives; it is indicated for the treatment of chronic skin diseases, obstructive jaundice and psoriasis.

CENTROSPERMAE

Phytolaccaceae, Caryophyllaceae, Chenopodiaceae

The order contains 13 families which show a passage from the monochlamydeous type of flower (e.g. Phytolaccaceae and Chenopodiaceae) to the dichlamydeous type of flower (e.g. Caryophyllaceae). Most families of the order, except the Caryophyllaceae, produce characteristic betacyanin and betaxanthin pigments, which indicate affinity with the Cactales (the next order, below).

The Phytolaccaceae is a family of 12 genera and 100 species; herbs, shrubs and trees, found particularly in tropical America and South Africa. *Phytolacca* (35 spp.) includes *Phytolacca americana* (Poke root), the leaves and roots of which have been found as an adulterant of belladonna: its berries contain a dyestuff. The roots which contain saponins are included in the *BHP* (1996) for the treatment of rheumatic diseases; however, arising from its toxicity the drug is not strongly recommended and excessive use should be avoided. The toxicity is primarily due to mitogenic proteins (lectins) and triterpene saponins. Other species have been shown to have molluscicidal activity.

The Caryophyllaceae has 70 genera and about 1750 species, mostly herbs, and is wide-spread. Genera include *Saponaria*, *Stellaria*, *Arenaria*, *Spergularia*, *Herniaria*, *Silene*, *Lychnis*, *Gypsophila* (125 spp.) and *Dianthus* (300 spp.). Many of these plants are rich in saponins. The root of *Saponaria officinalis* has been included in many pharmacopoeias. It contains about 5% of saponins and is widely used as a domestic detergent.

The Chenopodiaceae contains 102 genera and 1400 species; most grow naturally in soils containing much salt (halophytes). Genera include *Beta* (6 spp.), *Chenopodium* (100–150 spp.), *Salicornia*, *Atriplex* and *Anabasis*. From the wild *Beta vulgaris* (sea-beet) have been derived garden beetroot, sugar-beet and the mangold-wurzel. *Chenopodium anthelminticum* yields the anthelmintic Mexican tea or 'wormseed' and its oil of chenopodium (q.v.).

CACTALES

Cactaceae

The Cactaceae is the only family of the order and contains from 50 to 150 genera and about 2000 species. The plants are xerophytes and, with possibly one exception, are all native to the Americas. They will not grow where there is virtually no rainfall, but thrive in deserts where there is a reasonable rainfall even if rain occurs very infrequently. Some cacti occur in rain forests, where they are often epiphytes (e.g. *Epiphyllum*). The majority are succulent and store water in their stems. The plant body is usually globular or cylindrical and bears wool, spines

and flowers, but in *Epiphyllum* the stems are flattened and consist of jointed segments, which are often mistaken for leaves. Among the genera are *Epiphyllum* (21 spp.), *Opuntia* (250 spp.), *Cephalocereus* (48 spp.), *Cereus* (50 spp.) and *Echinocereus* (75 spp.). The leaves of *Opuntia* and *Nopolea* provide food for cochineal insects (q.v.). *Opuntia ficus-indica*, the prickly-pear, is sometimes grown as a hedge but can become a troublesome weed. Dried cactus flowers (*Opuntia* spp.) are used as an astringent herbal remedy. *O. dillenii* finds various medicinal uses in India. *Lophophora williamsii* is the plant producing peyote, anhalonium or 'mescal buttons'; it contains mescaline (q.v.). Several genera contain simple isoquinoline alkaloids; cyanogenetic glycosides are very rare or absent; most species contain abundant mucilage.

MAGNOLIALES

Magnoliaceae, Winteraceae, Annonaceae, Myristicaceae, Canellaceae, Schisandraceae, Illiciaceae, Monimiaceae, Lauraceae and Hernandiaceae

This order contains 22 families.

1. The Magnoliaceae contains 12 genera and about 230 species, which occur in both temperate and tropical regions. They are trees or shrubs with oil cells in the parenchyma. Genera include *Magnolia* (180 spp.), *Michelia* (50 spp.) and *Liriodendron* (1 sp.), tulip tree. The remedial properties of *L. tulipifera*, which is reported to contain alkaloids (e.g. dihydroglaucine) and sesquiterpenes, have been assessed (Crellin, J. K. *Pharm. J.*, 1988, **240**, 29).
2. The Winteraceae comprises 7 genera and 120 species. *Drimys winteri* (Winter's bark) has been much used for its stimulant and tonic properties and a number of pharmacological investigations have been reported in the literature. The bark contains volatile oil, sesquiterpenes, lactones, flavonoids and polygodial derivatives (V. C. Filho *et al*., *J. Ethnopharmacology*, 1998, **62**, 223).
3. The Annonaceae contains 120 genera and about 2100 species, which are found mainly in the tropical regions of the Old World. Genera include *Uvaria* (150 spp.), *Xylopia* (100–150 spp.), *Monodora* (20 spp.) and *Annona* (120 spp.). The seeds of *Monodora myristica* are used like nutmegs. Many members of the family contain alkaloids mainly of the isoquinoline type. The family is of importance in folk medicine.
4. The Myristicaceae is a family of 18 genera and 300 species, which are mainly found in tropical Asia. Genera include *Myristica* (120 spp.), *Virola* (60 spp.), *Horsfieldia* (80 spp.) and *Knema* (37 spp.). The flowers are dioecious and consist of an inconspicuous three-lobed perianth with 3–18 monadelphous stamens or a solitary carpel containing a basal anatropous ovule. The fruit is a fleshy drupe, which splits along both dorsal and ventral sutures. The single seed is more or less completely enveloped in a lobed aril. The chemistry of the family has not been thoroughly investigated. Some species (see 'Nutmeg' and 'Mace') contain volatile oil and hallucinogenic substances.
5. The Canellaceae is a small family of five genera and 16 species; trees with gland-dotted leaves. Fruit is a berry. Genera include *Canella*, *Cinnamodendron* and *Warburgia*. Canella bark, a spice, is obtained from *Canella alba*, grown in the Bahamas and Florida.
6. The Schisandraceae comprises two genera and 47 species of climbing shrubs. *Schisandra* has 25 species; lignans are common constituents. *S. chinensis* produces antihepatoxic constituents (q.v.).
7. The Illiciaceae, sometimes classified under Magnoliaceae, has the single genus *Illicium* (42 spp.), found in Asia, Atlantic North America and the West Indies. See 'Star-anise Fruit and Oil'.
8. The Monimiaceae includes 20 genera and 150 species of trees and shrubs, which often contain volatile oil and resin. In South America there are many traditional uses of plants of this family; G. G. Leitao *et al*. (*J. Ethnopharmacology*, 1999, **65**, 87), have reviewed the pharmacology and chemistry. The genera include *Hedycarya* (25 spp.) and *Peumus* (one sp.). *Peumus boldus* (q.v.) has a hard wood, its bark yields a dye and its leaves contain the alkaloid boldine.
9. The Lauraceae has 32 genera and about 2000–2500 species. These are tropical or subtropical trees and shrubs with leathery, evergreen leaves; the flowers are usually bisexual (e.g. *Cinnamomum*), rarely unisexual (e.g. *Laurus*). The fruit is a berry or drupe. Alkaloids, volatile oils and fixed oils occur in many species. Volatile oil cells occur in the leaves and cortex. Genera include *Persea* (150 spp.), *Ocotea* (300–400 spp.), *Cinnamomum* (250 spp.), *Aniba* (40 spp.), *Litsea* (400 spp.), *Neolitsea* (80 spp.), *Lindera* (100 spp.), *Laurus* (2 spp.) and *Cryptocarya* (200–250 spp.). A number of Taiwanese species of the above genera have been tested for bioactivity (C. T. Lin *et al*., *Pharm. Biol*., 2007, **45**, 638).

   The bark of *Cryptocarya massoia* yields an essential oil that has a coconut-like aroma and is used as a cosmetic additive, e.g. in shampoos; *C. moschata* gives the mace of Brazilian nutmeg. The bay laurel, *Laurus nobilis*, is the only European representative of the family; 45 constituents of the essential oil have been identified, the principal one being 1,8-cineole. Other constituents of the leaves are glycosylated flavonoids, (−)-epicatechin, (+)-catechin, (+)-epigallocatechin and procyanidins. For research and other references, see C. Fiorini *et al*., *Phytochemistry*, 1998, **47**, 1821; M. Simić *et al.*, *Fitoterapia*, 2003, **74**, 613; S. D. Acqua *et al*., *Chem. Pharm. Bull*., 2006, **54**, 1187. For drugs see 'Cinnamon bark', 'Cassia bark' and 'Camphor'.
10. The Hernandiaceae has three genera and 54 species. Members are tropical trees, shrubs or lianes with oil cells. Species of *Hernandia* (24 spp.) contain tumour-inhibiting alkaloids and lignans including podophyllotoxin; they have been used in traditional Samoan medicine. About 128 alkaloids belonging to 17 structural types are known for the family, see L. M. Conserva *et al.*, *The Alkaloids*, 2005, **62**, 175.

RANUNCULALES:

Ranunculaceae, Berberidaceae, Menispermaceae and Nymphaeaceae

Of the seven families in this order the above four are of medicinal interest. The families show a considerable variety of plant constituents and alkaloids are very common. In the four named families the alkaloids are often based on benzylisoquinoline, bisbenzylisoquinoline or aporphine.

1. The Ranunculaceae comprises 59 genera and about 1900 species. The plants are mostly perennial herbs with a rhizome or rootstock. They are well represented in Britain. Many members are poisonous. The flowers are bisexual, regular (e.g. *Ranunculus*) or zygomorphic (e.g. *Aconitum*). The perianth is simple or differentiated into calyx and corolla. The stamens are numerous and free. The carpels are usually numerous in the regular flowers or fewer in the zygomorphic ones. The fruit is an etaerio of achenes or follicles, or a berry. Genera include *Helleborus* (20 spp.), *Aconitum* (300 spp.), *Thalictrum* (150 spp.), *Clematis* (250 spp.), *Actaea* (10 spp.), *Ranunculus* (400 spp.), *Anemone* (150 spp.), *Delphinium* (250 spp.), *Adonis* (20 spp.) and *Hepatica* (10 spp.). The family has diverse chemical constituents and is of considerable phytochemical and chemotaxonomic interest. For example, the chromosomes, based

on size and shape, fall into two distinct groups, the *Ranunculus* type (R-type) and the *Thalictrum* type (T-type). The glycoside ranunculin has been found only in plants of the R-type. This glycoside hydrolyses to protoanemonin, which is vesicant and accounts for this property in many species. Isoquinoline-derived alkaloids occur in *Thalictrum*, *Aquilegia* and *Hydrastis*; diterpene-derived alkaloids in *Delphinium* and *Aconitum*. Saponins, mainly triterpenoid, occur in *Ranunculus*, *Trollius*, *Clematis*, *Anemone* and *Thalictrum*, cyanogenetic glycosides in *Ranunculus* and *Clematis*; cardenolides in *Adonis*, bufodienolides in *Helleborus*. Black hellebore rhizome, from *Helleborus niger*, contains very powerful cardiac glycosides but is now little used in medicine. Various aconite roots, containing highly toxic alkaloids (q.v.) have also lost much of their former popularity. Black Cohosh *BHP* 1996 is the dried rhizome of *Cimicifuga racemosa*; it contains triterpenoid glycosides structurally related to cycloartenol, also isoflavones including formononetin. The drug contains substances with endocrine activity and is used in herbal medicine to treat menopausal and other female disorders, and also various rheumatic conditions. A number of other species e.g. *C. simplex*, are used in Chinese medicine (see, for example, A. Kussano *et al*., *Chem. Pharm. Bull*., 1999, **47**, 1175). The European *C. foetida* (bugbane) is a traditional vermin preventative.

2. The Berberidaceae has 14 genera and about 575 species, they are perennial shrubs usually with spiny leaves. The flowers are hermaphrodite, regular and hypogynous. The perianth is differentiated into calyx and corolla. The stamens are generally in two whorls and the ovary is composed of one carpel. The fruit is a berry with one to numerous seeds. Genera include *Berberis* (450 spp.), *Mahonia* (70 spp.), *Epimedium*, *Vancouveria* and *Leontice*.

   The Berberidaceae contains alkaloids of the benzylisoquinoline, bisbenzylisoquinoline and aporphine types. *Leontice* contains an alkaloidal amine and quinolizidine. Lignans such as dehydropodophyllotoxin occur; also triterpenoid saponins. The root tubers of *Leontice leontopetalum* contain saponin and alkaloids and have been used for the treatment of epilepsy. For other drugs see under 'Hydrastis', 'Podophyllum' and 'Indian Podophyllum'.

   In some members of the family there is a close resemblance to the Ranunculaceae. *Hydrastis*, for example, is sometimes placed in the Ranunculaceae in the same tribe as the peony. There are also relationships with the Papaveraceae, narcotine being found in both families.

3. The Menispermaceae is a family of 65 genera and 350 species; mainly tropical twining shrubs, herbs or trees. The plants usually have palmately lobed leaves and dioecious flowers. Anomalous stem structure is frequently found and abnormal secondary growth often takes place in the roots (e.g. of *Chondodendron tomentosum*), successive cambia being produced to give concentric rings of wood. The broad primary medullary rays found in the stem of *Coscinium* are a family characteristic. The fruit is a drupe the dorsal side of which develops more rapidly than the ventral, as in the fish berry *Anamirta cocculus*. These contain the highly toxic substance picrotoxin. For drugs see 'Calumba' and 'Curare'.

   The genera include *Chondodendron* (8 spp.), *Tiliacora* (25 spp.), *Triclisia* (25 spp.), *Anamirta* (1 sp.), *Coscinium* (8 spp.), *Tinospora* (40 spp.), *Jateorhiza* (2 spp.), *Abuta* (35 spp.), *Cocculus* (11 spp.), *Menispermum* (3 spp.), *Stephania* (40 spp.), *Cissampelos* (30 spp.) and *Cyclea* (30 spp.).

   Alkaloids are important constituents of the family and have been reviewed (J. M. Barbosa-Filho *et al*., *The Alkaloids*, 2000, **54**, 1). Saponins are present in many species. *Coscinium fenestratum* ('false calumba', 'tree turmeric') stems are widely used in SE Asia and India for the treatment of a variety of ailments. The principal alkaloid constituents are berberine and jatrorrhizine, the former being responsible for its antibacterial activity (G. M. Nair *et al*., *Fitoterapia*, 2005, **76**, 285); for an investigation of the hypotensive and toxicological properties of an extract, see T. Wongcome *et al*., *J. Ethnopharm*., 2007, **111**, 468. *Stephania pierrii* (*S. erecta*) contains bisbenzylisoquinoline alkaloids and is used in Thai folk medicine as a muscle relaxant. *Tinospora cordifolia* is used in Ayurvedic medicine and a considerable number of pharmacological actions, including immunomodulatory, have been demonstrated for the drug. For other drugs see 'Calumba' and 'Curare'.

4. The Nymphaeaceae is a small family of about six genera and 70 species. Species of *Nymphaea* (water-lilies) are widely cultivated. The genera include *Nymphaea* (50 spp.), *Nuphar* (25 spp.), *Nelumbo* (2 spp.) and *Ondinea*. Alkaloids occur which resemble those of other families of the order but the chemistry of the family requires further research. *Nuphar variegatum* rhizomes contain antibacterial tannins and have long been used in folk medicine, similarly *Nymphaea* spp.. *Nelumbo nucifera* (the sacred lotus) and *Nymphaea lotus* (the white lotus) were revered in the ancient civilizations of India, China, Tibet and Egypt. *Nymphaea stellata* has been traditionally used in Indian medicine.

PIPERALES

Piperaceae

Four families are included in the Piperales; only the Piperaceae is considered here.

The Piperaceae (excluding the Peperomiaceae) consists of four genera and about 2000 species. The plants are tropical, mostly climbing shrubs or lianes, with swollen nodes and fleshy spikes of flowers. The leaves contain oil cells. The one-celled ovary has a single basal ovule and develops into a berry. The seeds contain endosperm and abundant perisperm. The four genera are *Piper* (about 2000 spp.), *Trianaeopiper* (18 spp.), *Ottonia* (70 spp.) and *Pothomorphe* (10 spp.). In addition to the above, Engler includes in the Piperaceae the Peperomiaceae with its four genera and about 1000 species of succulent herbs and subshrubs. All but 5 of its species belong to the genus *Peperomia*. The Piperaceae contains phenolic esters and ethers; pyrrolidine alkaloids; volatile oils and lignans. The peppers (q.v.) are widely used as condiments. Cubebs, *Piper cubeba*, was formerly used in medicine but is now obsolescent. In the South Pacific islands an aqueous extract of the roots of *P. methysticum* (kava-kava) is consumed as a ritual stimulant; large doses cause intoxication. In herbal medicine the root is used as a diuretic, stimulant and tonic. the active principles are pyrone derivatives (kava lactones); a number of piperidine alkaloids, including pipermethysticine, have also been isolated (K. Dragull *et al*., *Phytochemistry*, 2003, **63**, 193).

ARISTOLOCHIALES

Aristolochiaceae

The order comprises three families, of which only the Aristolochiaceae is of importance.

The Aristolochiaceae has seven genera and about 500 species. Members occur in the tropics and warm temperate zones, excluding Australia. Most are herbs or climbing shrubs. Oil-secreting cells occur throughout the family, often forming transparent dots on the leaves. The principal genera are *Aristolochia* (350 spp.) and *Asarum* (70 spp.). Constituents of the family include alkaloids (aporphine and protoberberine), aristolochic acid, phenolic esters and ethers, volatile oils and flavonoids. Some species show tumour-inhibiting properties. *Asarum europaeum*, asarabacca root, was formerly used in European medicine.

GUTTIFERALES

Paeoniaceae, Dipterocarpaceae, Theaceae, Guttiferae

Of the 16 families in the order, only the four above need be noted.

1. The Paeoniaceae contains the single genus *Paeonia* with 33 species which are perennial rhizomatous herbs, occasionally shrubby. *Paeonia mascula* is one of Britain's rarest wild plants; it grows on the island of Steep Holme, in the Bristol Channel, having been introduced there by monks in the 14th century for medicinal purposes. Peony root is important in Chinese medicine and the species used, *P. lactiflora*, has been extensively investigated. It is a constituent of a herbal tea which, in the UK, has come into prominence for the treatment of children's eczema. The active anti-inflammatory ingredient appears to be paeonol, 2'-hydroxy-4'-methoxyacetophenone; other constituents of the rhizome are monoterpenoid glycosides one of which, paeoniflorin, is used as a basis for the quality control of the drug by HPLC. New glycosidic paeoniflorin derivatives have recently been reported (A. Braca *et al*., *Fitoterapia*, 2008, **79**, 117).
2. The Dipterocarpaceae has 15 genera and about 580 species. Many are large trees yielding useful timbers. Oleoresins are a character of the family. Genera include *Dipterocarpus* (76 spp.), *Shorea* (180 spp.), *Dryobalanops* (9 spp.) and *Hopea* (90 spp.). Products include: gurjun balsam from *Dipterocarpus turbinatus*; varnish resins from species of *Shorea*, *Hopea* and *Balanocarpus*; an edible fat which can be used instead of cocoa butter in chocolate manufacture, from the nuts of *Shorea macrophylla*; and Borneo camphor, from *Dryobalanops aromatica*.
3. The Theaceae or Ternstroemiaceae consists of 16 genera and about 500 species of tropical and subtropical trees and shrubs. Genera include *Camellia* (82 spp.) and *Ternstroemia* (100 spp.). Among the constituents are purine bases in *Camellia*, saponins, tannins and fixed oils. By far the most important plant commercially is *Camellia sinensis*, which yields tea and caffeine. The so-called 'tea seed oil' is an edible oil which is a possible adulterant of the more expensive olive oil and is obtained from *Camellia sasanqa*.
4. The Guttiferae contains about 40 genera and 1000 species. They are trees, shrubs or lianes, except *Hypericum*, which is often treated as a separate family, the Hypericaceae. The main genera are *Hypericum* (400 spp.), *Kielmeyera* (20 spp.), *Clusia* (145 spp.), *Garcinia* (400 spp.) and *Calophyllum* (112 spp.). Constituents of the family include resins, volatile oils, alkaloids, xanthones and seed oils. Products include resin from *Calophyllum* and gamboge, a coloured gum resin, from *Garcinia*. The edible fruit mangosteen is obtained from *Garcinia mangostana*.

SARRACENIALES

Sarraceniaceae, Nepenthaceae, Droseraceae

The three small families of insectivorous plants forming this order are of minor pharmaceutical interest.

The Sarraceniaceae consists of three genera and 17 species of pitcher-plants. The Nepenthaceae has two genera and 68 species, of which 67 belong to *Nepenthes*. In these plants, which occur mainly in tropical Asia, the leaves are modified into pitchers, which attract insects by their colour and honey-like secretion. The Droseraceae has four genera and 105 species. Of these, 100 belong to *Drosera*, which is represented in Britain by three sundews. The European sundew, *Drosera rotundifolia*, has long been employed in folk medicine and has been included in some pharmacopoeias (*BHP* 1983). In Italy it is an ingredient of a liqueur. It contains the naphthoquinone plumbagone, which has antimicrobial activity.

PAPAVERALES

Papaveraceae, Fumariaceae, Capparaceae, Cruciferae

An order of seven families, if the Fumariaceae is separated from the Papaveraceae. The Papaveraceae belongs to the suborder Papaverineae and the Capparaceae and Cruciferae to the Capparineae. Some workers regard the Papaveraceae as related to the Ranunculales and the Capparineae as derived from the Cistales. Chemical support for this view is that alkaloids of the Papaveraceae are related to those of the Ranunculaceae, and that thiogluconates are absent from the Papaveraceae but present in the other two families.

1. The Papaveraceae is a family of 26 genera and about 300 species. The plants are usually herbs with solitary, showy flowers of the floral formula K 2 – 3, C 2 + 2 or 2 + 4, A ∞, G (2 – ∞). The fruit is generally a capsule, with numerous seeds, each containing a small embryo in an oily endosperm. Genera include *Platystemon* (about 60 spp.), *Romneya* (2 spp.), *Eschscholtzia* (10 spp.), *Sanguinaria* (1 sp.), *Chelidonium* (1 sp.), *Bocconia* (10 spp.), *Glaucium* (25 spp.), *Meconopsis* (43 spp.), *Argemone* (10 spp.) and *Papaver* (100 spp.). All members contain latex tissue. The latex is sometimes in vessels which accompany the vascular system (e.g. in *Papaver*); sometimes in latex sacs (e.g. *Sanguinaria*). The family is rich in alkaloids. Some, such as the opium alkaloids (q.v.), are of great medical and economic importance. *Eschscholtzia californica*, used by the Californian Indians as a sedative and now similarly prescribed in Europe, has been validated experimentally. The aerial parts of *Glaucium grandiflorum* are used in Iranian medicine for the treatment of dermatitis (K. Morteza-Semnani *et al*., *Fitoterapia*, 2004, **75**, 123). Mustard oil glycosides appear to be absent from the family (compare Capparaceae and Cruciferae).
2. Fumariaceae. Included in the Papaveraceae by Engler but now generally regarded as a separate family. It contains 16 genera and about 55 species: they contain a watery, not milky, juice. Isoquinoline alkaloids are a feature of the family. Fumitory is used for liver disorders, see Chapter 29.
3. Capparaceae. A family of 30 genera and 650 species; usually trees or shrubs, often xerophytic. The genus *Capparis* (250 spp.) includes *Capparis spinosa*, the buds of which (capers) are used in flavouring. Like the Cruciferae, the family has myrosin cells and mustard-oil glycosides such as glucocapparin. The only alkaloid reported is pyrrolidine in two genera. Cardenolides, which occur in some Cruciferae, have not been found in the Capparaceae.
4. Cruciferae. A family of 375 genera and about 3200 species; herbs and a few undershrubs. The inflorescence is typically a raceme without bracts. The flowers are of the type, K 2 + 2, C 2 + 2, A 2 + 4, G(2). The stamens are tetradynamous and the ovary is divided into two loculi by a replum uniting the two parietal placentas. The fruit is called a siliqua when elongated, as in the wallflower and mustards; or silicula when almost as broad as long, as in shepherd's purse and horseradish. The testas of the seeds often contain mucilage. Genera include *Brassica* (about 30 spp.), *Sinapis* (10 spp.), *Nasturtium* (6 spp.), *Lepidium* (150 spp.), *Hesperis* (30 spp.), *Cheiranthus* (10 spp.), *Isatis* (45 spp.), *Erysimum* (100 spp.), *Crambe* (25 spp.) and *Lunaria* (3 spp.). Cultivated *Brassica* species include: *B. nigra* (black mustard); *B. oleracea* (cabbage, cauliflower, broccoli, etc.); *B. campestris*, turnip; and *B. napus*, rape or colza oil. *Sinapis alba* yields white mustard; *Nasturtium officinale*, water cress; *Lepidium sativum*, garden cress; *Crambe maritima*, the sea kale. The ancient dyestuff woad was made by grinding and fermenting the leaves of *Isatis tinctoria* to produce deep blue indigo, isatin A being the major indoxyl glycoside precursor of the dye. For the significance

of indoxyl derivatives in this connection and further studies, see T. Kokubun *et al*., *Phytochemistry*, 1998, **49**, 79; C. Oberthur *et al*., *Phytochemistry*, 2004, **65**, 3261 and 'Colourants', Chapter 33. Many members of the Cruciferae contain mustard-oil glycosides and in special myrosin cells contain the enzymes necessary for their hydrolysis. Cardiac glycosides occur in some genera and the seeds usually contain mucilage and fixed oil.

ROSALES

Hamamelidaceae, Crassulaceae, Saxifragaceae, Rosaceae, Leguminosae, Krameriaceae

The order Rosales consists of 19 families divided into four suborders. The families to be considered fall into the suborders as follows: Hamamelidineae (Hamamelidaceae); Saxifragineae (Crassulaceae, Saxifragaceae and Pittosporaceae); Rosineae (Rosaceae); Leguminosineae (Leguminosae and Krameriaceae). The flowers are usually hermaphrodite (rarely bisexual by abortion: e.g. kousso flowers from *Brayera*); hypogynous, perigynous or epigynous. The sepals and petals are usually free; stamens and carpels free or united.

1. Hamamelidaceae. A family of 26 genera and 106 species of trees and shrubs, chiefly subtropical. Genera include *Hamamelis* (6 spp.) and *Liquidambar* (6 spp.). Drugs (q.v.) include hamamelis leaves (*Hamamelis virginiana*), Levant storax (*Liquidambar orientalis*) and American storax or sweet gum (*L. styraciflua*). The family contains tannins, balsamic resins, phenolic acids and cyclitols; alkaloids are absent.
2. Crassulaceae. A family of 35 genera and 1500 species; many perennial xerophytes. Genera include *Sedum* (about 600 spp.), *Sempervivum* (25 spp.), (*Rhodiola*) and *Crassula* (about 300 spp.). An interesting chemical character of the family is the presence, often in large amounts, of isocitric acid; it was in this xerophytic family that a distinctive build-up of malic acid during the hours of darkness was first noticed and the term crassulacean acid metabolism (CAM) given to this particular adaptation of the photosynthetic cycle (see Chapter 18). The carbohydrate sedoheptulose occurs in both the Crassulaceae and the Saxifragaceae. Cyanogenetic glycosides and cardiac glycosides occur in some species; tannins are common but alkaloids rare. Species of *Sedum* have been used medicinally as antihepatotoxics. The roots and rhizomes of *Rhodiola rosea* (arctic root), indigenous to Northern Europe and Northern Asia, have been used in traditional medicine for centuries. Recently, the drug has attracted considerable attention in the West, principally as an adaptogen for the treatment of stress. It has been extensively investigated, pharmacologically and chemically. Constituents include flavonoids, proanthocyanidin glycosides, e.g. rosavin, monoterpenoid glycosides, lotaustralin, etc. For further information, see R. P. Brown and G. Gerberg with B. Graham 2004, *The Rhodiola Revolution*, 260 pp., Rodale, New York; G. Ma *et al*., *Chem. Pharm. Bull*., 2006, **54**, 1229.
3. The Saxifragaceae is a family of 30 genera and about 580 species; chiefly north temperate herbs. Genera include *Saxifrage* (370 spp.), *Astilbe* and *Ribes*. The latter, sometimes separated as the family Grossulariaceae, includes such well-known fruits as the blackcurrant, redcurrant and gooseberry. These are rich in citric and malic acids and in ascorbic acid. Black Currant Syrup is used medicinally. Some members of the Saxifragaceae contain tannins and saponins, but alkaloids are rare.
4. Rosaceae. A family which includes about 100 genera and 2000 species of herbs, shrubs and trees. The leaves are simple (e.g. *Prunus*) or compound (e.g. *Rosa*). Considerable variety exists in the flowers and fruits. There are no anatomical features characteristic of the family as a whole, and the various subfamilies frequently show differences in stomatal arrangement, origin of cork, etc. Genera include *Spiraea* (100 spp.), *Quillaja* (3 spp.), *Pyrus* (3 spp.), *Malus* (35 spp.), *Sorbus* (100 spp.), *Kerria* (1 sp.), Rubus (250 spp.), *Potentilla* (500 spp.), *Geum* (40 spp.), *Alchemilla* (250 spp.), *Agrimonia* (15 spp.), *Poterium* (25 spp.), *Rosa* (250 spp.), *Prunus*, including *Laurocerasus* (430 spp.) and *Crataegus* (200 spp.). Constituents of the Rosaceae include cyanogenetic glycosides, saponins, tannins, seed fats, sugar alcohols, cyclitols, terpenoids and mucilage; alkaloids and coumarins are rare. The secondary metabolites of the family have been the basis for a number of chemosystematic studies (for such studies involving hydrolysable tannins see T. Okuda *et al*., *Phytochemistry*, 1992, **31**, 3091). Important products (q.v.) are oil of rose (*Rosa damascena*), rose hips (*R. canina*), wild cherry bark (*Prunus serotina*), almond oil (*Prunus amygdalus*), quillaia bark (*Quillaia saponaria*), hawthorn (*Crataegus oxycanthoides*). Other products are cherry-laurel leaves (*Prunus laurocerasus*), quince seeds (*Pyrus cydonia*), prunes (*Prunus domestica*), raspberry fruits and leaves (*Rubus idaeus*) and morello cherries (*Prunus cerasus*). Comparative studies on the antibacterial and free-radical scavenging activities of extracts of *Prunus padus* (bird cherry) and *P. spinosa* (blackthorn, sloe) have been reported (Y. Kumarasamy *et al*., *Fitoterapia*, 2004, **75**, 77).
5. Leguminosae. This is the second-largest family of flowering plants and contains 600 genera and about 12000 species. It includes more important drugs than any other family. It is divided into three subfamilies—the Papilionaceae, the Mimosoideae and the Caesalpinoideae, containing, respectively, about 377, 40 and 133 genera. Important characters and genera in each subfamily are:

   (1) Papilionaceae: Herbs, shrubs or trees; leaves simple or compound; flowers zygomorphic and papilionaceous (e.g. in broom); stamens 10, monadelphous or diadelphous; fruit a legume. Genera include *Myroxylon* (2 spp.), *Sophora* (50 spp.), *Crotalaria* (550 spp.), *Lupinus* (200 spp.), *Cytisus* (25–30 spp.), *Ononis* (75 spp.), *Medicago* (100 spp.), *Melilotus* (25 spp.), *Trifolium* (300 spp.), *Psoralea* (130 spp.), *Indigofera* (700 spp.), *Astragalus* (2000 spp.), *Vicia* (150 spp.), *Lens* (10 spp.), *Lathyrus* (130 spp.), *Pisum* (6 spp.), *Abrus* (12 spp.), *Glycine* (10 spp.), *Erythrina* (100 spp.), *Mucuna* (120 spp.), *Phaseolus* (200–240 spp.), *Arachis* (15 spp.), *Trigonella* (about 100 spp.), *Butea* (30 spp.), *Derris* (80 spp.), *Lonchocarpus* (150 spp.), *Copaifera* (25 spp.) and *Erythrophleum* (17 spp.). Drugs (q.v.) from this subfamily are fenugreek seeds, calabar bean, tonco seed, liquorice root, derris, lonchocarpus, Tolu balsam, Peru balsam, arachis oil and tragacanth gum. Common British plants with poisonous properties include broom (*Cytisus scoparius*), laburnum (*Cytisus laburnum*) and many species of *Lupinus*. Among economic products other than drugs may be mentioned sunn hemp (*Crotalaria juncea*), lentils (*Lens esculents*), peas (*Pisum sativum*), soya bean (*Glycine hispida*), scarlet runner, French and Lima beans (*Phaseolus* spp.), groundnut (*Arachis hypogaea*) and copaiba oleoresin and copals (*Copaifera* spp.). Species of *Indigofera*, including *I. tinctoria*, are a source of indigo (for biosynthesis of indigo see Z.-Q. Xia and M. H. Zenk, *Phytochemistry*, 1992, **31**, 2695).

   (2) Mimosoideae: Most members of this subfamily are trees or shrubs; leaves usually bipinnate; flowers regular; calyx usually gamosepalous; stamens equal in number to the petals or twice as numerous; fruit a legume. Important genera are *Mimosa* (450–500 spp.) and *Acacia* (750–800 spp.). Products include acacia gums from *Acacia* spp., wattle barks used in tanning from

Acacia spp. and volatile oil such as oil of cassie (*A. farnesiana*), which are used in perfumery.

(3) Caesalpinoideae: Members are trees or shrubs; leaves pinnate or bipinnate; flowers zygomorphic; typical floral formula K5, C5, A 5 + 5, G1. Drugs derived from this subfamily are senna leaves and pods, cassia pods and tamarinds. Other products are the redwoods logwood, from *Haematoxylon*, and sappan wood, from *Caesalpinia*; sassy bark, from *Erythrophleum guineense*, and carob beans from *Ceratonia siliqua*. *Caesalpina bonducella* seeds are traditionally used in Indian medicine for a variety of conditions.

Of the three subfamilies, the Mimosoideae and Caesalpinoideae are mostly tropical plants, while the Papilionaceae occur in both tropical and temperate regions. Tannin sacs are common, particularly in the Mimosoideae and Caesalpinoideae. The constituents of the Leguminosae show many similarities to those of the Rosaceae. Both contain cyanogenetic glycosides, saponins, tannins, mucilage and anthocyanins. Alkaloids, however, are common in the Leguminosae but rare in the Rosaceae. For a discussion of the chemotaxonomic relevance of seed polysaccharides and flavonoids in the family see R. Hegnauer and R. J. Grayer-Barkmeijer, *Phytochem*., 1993, **34**, 3. An important work of reference for the family is *Phytochemical Dictionary of the Leguminosae*, Vols 1 and 2 (1994), compiled by I. W. Southon and published by Chapman and Hall, London.

(4) Krameriaceae: This, often included in the Leguminosae (q.v.), is a family of one genus, *Krameria*, and 20 species. They are shrubs or herbs found from the southern USA to the Argentine. The flowers resemble the Caesalpinoideae, but two of the petals are modified into glands and there are only three stamens. They contain phlobatannins; see 'Rhatany'.

GERANIALES

Geraniaceae, Zygophyllaceae, Linaceae, Erythroxylaceae, Euphorbiaceae

The order Geraniales consists of nine families.

1. The Geraniaceae consists of five genera and 750 species; mostly herbs. Members of the two large genera, *Geranium* (400 spp.) and *Pelargonium* (250 spp.) are popularly called 'geraniums' and the commercial rose geranium oil is obtained from a *Pelargonium*. The family contains volatile oils which are widely used in perfumery; more research is needed on other constituents.
2. The Zygophyllaceae is a family of 25 genera and 240 species; mostly woody perennials, tropical and subtropical. Genera include *Zygophyllum* (100 spp.), *Tribulus* (20 spp.), *Guaiacum* (6 spp.), *Peganum* (5 or 6 spp.) and *Balanites* (25 spp.). *Peganum harmala* and *Tribulus terrestris* are used in Indian medicine; the alkaloids of the former (harmine, harmaline and derivatives) have been produced in hairy root cultures and the saponins of the latter have been extensively studied (see Y.-X. Xu *et al*., *Phytochemistry*, 1998, **49**, 199; J. Conrad *et al*., *Fitoterapia*, 2004, **75**, 117). Some members contain alkaloids, steroidal saponins or lignans. For drugs see 'Guaiacum Resin'.
3. The Linaceae is a family of 19 genera and about 290 species; mostly herbs or shrubs. About 230 of the species belong to *Linum*. Constituents of the family include cyanogenetic glycosides, fixed oils, mucilages, diterpenes and triterpenes. Flax and linseed and its oil (q.v.) are obtained from *Linum usitatissimum*.
4. The Erythroxylaceae is closely related to the Linaceae and comprises some three to four genera with *Erythroxylum* pre-eminent (about 200 spp). The other small genera including *Nectaropetalum* are represented by about 10 species. *Erythroxylum* spp. are distributed widely throughout tropical and subtropical regions with large areas of diversification in South America and Madagascar. Alkaloids have been found in most species analysed by modern methods; these are principally esters of the tropane type together with biosynthetically related bases such as hygrine, hygroline and cuscohygrine. Nicotine is of limited occurrence, cocaine and cinnamoylcocaine appear to be restricted to the cultivated species *E. coca* and *E. novogranatense*. The small trees or shrubs produce hard woods which constitute a rich source of diterpenoid compounds. Quinones and saponins probably contribute to the colour and durability of the wood. Phenolic constituents in the form of aromatic acids such as caffeic and chlorogenic acids, and flavonoids may have chemosystematic importance.
5. The Euphorbiaceae is a large family of about 300 genera and 6000 or more species. Most members are trees or shrubs, a few herbs. Some genera (e.g. *Euphorbia*) are xerophytic. The flowers are unisexual and regular with usually five perianth leaves; stamens may be numerous and are free or united. The superior ovary of three carpels forms a trilocular capsule. Genera include *Euphorbia* (about 2000 spp.), *Phyllanthus* (about 550 spp.), *Mallotus* (2 spp.), *Ricinus* (1 sp.), *Croton* (750 spp.), *Hevea* (12 spp.), *Jatropha* (175 spp.), *Manihot* (170 spp.), *Sapium* (120 spp.), *Poranthera* (10 spp.), *Securinega* (25 spp.), *Aleurites* (2 spp.) and *Hippomane* (5 spp.). In addition to castor seeds and castor oil (q.v.), products include the dye and taenicide kamala (from *Mallotus philippinensis*); rubber, from species of *Hevea, Manihot* and *Sapium*; manihot or cassava starch, from *Manihot esculentus* (*utilis*); Chinese tallow, a fat, from *Sapium sebiferum*; and a drying oil, from *Aleurites moluccana. Phyllanthus* is a widespread tropical genus and has been much employed in traditional medicines. Minor drugs are croton oil, from *Croton tiglium*, and cascarilla bark, from *C. cascarilla* and *C. eleuteria*. In some cases the latex is poisonous or irritant (e.g. that of *Hippomane*), and the resinous product 'euphorbium' was formerly much used as an antifouling agent for ships' hulls. Many species contain irritant or piscicidal substances. Some members such as cassava may contain cyanogenetic glycosides. This plant, *Manihot esculentus*, occurs in two varieties, sweet and bitter, only the latter yielding prussic acid. In addition to the constituents already mentioned, some members contain anthraquinones, triterpenoids, fatty acid epoxides, unsaturated fatty acids and antitumour agents. Alkaloids, when present, are usually of the aporphine, pyridine, indole, quinoline or tropane types. For a review of *Securinega suffruticosa* and its contained alkaloid securinine see D. Raj and M. Luczkiewicz, *Fitoterapia*, 2008, **79**, 419–427 (54 refs). Latices from *Euphorbia* species have widely varying biochemical properties with respect to their protein and carbohydrate properties, the type and amounts of enzymes present, and their haemagglutinating activities. For early reviews of the chemistry, taxonomy, and economic botany of the family, see *The Euphorbiales*, S. L. Jury, T. Reynolds, and D. F. Cutler (eds) (1987), London, UK: Academic Press and for a review (293 refs) of the phytoconstituents of *Euphorbia* spp. see A. K. Singla and K. Pathak, *Fitoterapia*, 1990, **61**, 483.

RUTALES

Rutaceae, Simaroubaceae, Burseraceae, Meliaceae, Malpighiaceae, Polygalaceae

This order is closely allied to the Geraniales. The chief difference is that in the Rutales the plants are mainly shrubs or trees. The flowers have a disc between the androecium and the gynaecium. Oil glands are of general occurrence. The order contains 12 families and is divided

into three suborders. Of the families mentioned above, the Rutaceae, Simaroubaceae, Burseraceae and Meliaceae all belong to the same suborder, the Rutineae.

1. Rutaceae. The family consists of about 150 genera and 900 species; mainly shrubs and trees; distributed in both temperate and tropical countries, but particularly abundant in South Africa and Australia. Oil glands are present in the leaves and other parts. The flowers are usually in cymes with 4–5 sepals, 4–5 petals, 8 or 10 stamens and a superior ovary. The fruits are of various types, but in the orange subfamily, the Aurantioideae, it is a hesperidium. Fruits include orange and lemon (q.v.), lime (*Citrus limetta* and *C. medica* var. *acida*), citron, bergamot, shaddock and grapefruit. There are 12 different species of *Citrus*. Other genera include *Zanthoxylum* (20–30 spp.), *Fagara* (250 spp.), *Choisya* (6 spp.), *Ruta* (7 spp.), *Dictamnus* (6 spp.), *Diosma* (15 spp.), *Galipea* (13 spp.), *Cusparia (Angostura)* (30 spp.), *Ptelea* (3 spp.), *Toddalia* (1 sp.), *Skimmia* (7–8 spp.), *Limonia* (1 sp.), *Aegle* (3 spp.), *Moniera* (2 spp.), *Haplophyllum* (70 spp.), *Teclea* (30 spp.), *Esenbeckia* (38 spp.) and *Murraya* (12 spp.). Products not mentioned above are buchu leaves (*Barosma* spp.); jaborandi leaves and their alkaloid, pilocarpine (*Pilocarpus* spp.); Japan pepper (*Zanthoxylum piperitum*); elephant-apple (*Limonia acidissima*); Brazilian angostura (*Esenbeckia febrifuga*); and angostura or cusparia (*Galipea officinalis*). Species of *Haplophyllum*, *Evodia*, *Clausena*, *Phellodendron*, and *Zanthoxylum* have all been used in traditional medicine. Bael fruits (*Aegle marmelos*) are an important Ayurvedic medicine; they contain coumarins, flavonoids (rutin and marmesin) and a glucosylated propelargonidin containing up to five units of pelargonidin with immunomodulatory activity (A. M. Abeysekera *et al*., *Fitoterapia*, 1996, **67**, 367). Southern Prickly Ash bark of the *BHP* 1996 is derived from *Zanthoxylum clava-herculis*; among other constituents it contains alkaloids e.g. chelerythrine and nitidine, a lignan-asarinin and an *n*-isobutyl polyeneamide. It is used as an antirheumatic. Northern Prickly Ash Bark (*BHP* 1983), *Z. americanum*, grows in the north-easterly parts of the USA. It contains similar alkaloidal constituents to the Southern species. Of 14 alkaloids of *Haplophyllum* screened for cytotoxic activity the furoquinoline, haplamine, was the most active (O. Jansen *et al*., *J. Ethnopharm*., 2006, **105**, 241). The bis-indole alkaloid yeuhchukene from *Murraya paniculata* has been studied for its antiimplantation, contraceptive activity; for information on the uses, activity and phytochemistry of this species, together with a report on the isolation of cinnamates and coumarins from the leaves, see Atta-ur-Rahman *et al*., *Phytochemistry*, 1997, **44**, 683. Constituents of the Rutaceae include a wide variety of alkaloids, volatile oils, rhamno-glucosides, coumarins and terpenoids. Alkaloids include alkaloidal amines, imidazole, indole, isoquinoline, pyridine, pyrrolidine, quinazoline and quinoline types. Many of the fruits are rich in citric and other acids and in vitamin C.
2. Simaroubaceae. A family of 20 genera and about 120 species; tropical and subtropical shrubs and trees. Members differ from the Rutaceae in not containing oil glands. Bitter principles are a characteristic of the family. Genera include *Quassia* (*Simarouba*) (40 spp.), *Picrasma* (*Aeschrion*) (6 spp.), *Brucea* (10 spp.), *Soulamea* (10 spp.), *Ailanthus* (10 spp.), and *Perriera* (1 sp.). Quassia woods (q.v.) are used as bitters. *Ailanthus glandulosa*, Tree of Heaven, is widely cultivated and its leaves have been used to adulterate belladonna and mint. For a discussion of the quassinoids of the family see 'Quassia'.
3. Burseraceae. A family of about 16 genera and 500 species; tropical shrubs and trees. Many representatives in north-east Africa, Arabia and tropical America. The leaves, like the Rutaceae, are gland-dotted. Oleoresin canals are found in the phloem and sometimes in the pith. Genera include *Commiphora* (185 spp.), *Boswellia* (24 spp.), *Bursera* (80 spp.), and *Canarium* (75 spp.). The best-known product of the family is myrrh (q.v.). Other products are frankincense (*Boswellia* spp.), American elemi (*Bursera gummifer*), Manila elemi and Java almond from *Canarium luzonicum*.
4. Meliaceae. A family of 50 genera and about 1400 species; trees or shrubs. Some yield timber (e.g. mahogany from *Swietenia mahagoni*); others, seed oils. Genera include *Cedrela, Swietenia, Khaya, Carapa, Melia* and *Azadirachta. Azadirachta indica* (Neem) is an important Indian medicinal plant (q.v.); bark, leaves and seeds are used. For recent research, see Y. Fukuyama *et al*., *Chem. Pharm. Bull*., 2006, **54**, 1222. Significant constituents of the family are triterpenoids and limonoids.
5. Malpighiaceae. A family of 60 genera and 800 species; shrubs or small trees. Genera include *Malpighia* (35 spp.) and *Banisteriopsis*. Some members have stinging hairs. *Banisteriopsis* contains indole alkaloids, and plants may be hallucinogenic (q.v.).
6. Polygalaceae. A family of 12 genera and about 800 species, of which some 600 species belong to *Polygala*. It is represented in Britain by the milkwort, *Polygala vulgaris*. Other genera are *Monnina, Securidaca* and *Carpolobia*. Senega root (q.v.) is obtained from the North American *Polygala senega*. Characteristic constituents are triterpenoid saponins and, in *Polygala*, the sugar alcohol polygalitol. Methyl salicylate is common to a number of genera.

SAPINDALES

Anacardiaceae, Aceraceae, Sapindaceae, Hippocastanaceae

The Sapindales consist of 10 families.

1. Anacardiaceae. A family of 60 genera and some 600 species; mainly tropical trees and shrubs. Genera include *Mangifera* (40 spp.), *Anacardium* (15 spp.), *Rhus* (250 spp.), *Pistacia* (10 spp.), *Toxicodendron* (15 spp.), *Lannea* (70 spp.), *Cotinus* (3 spp.) and *Schinus* (30 spp.). Products include the mango, *Mangifera indica*; cashew nut, *Anacardium occidentale*; sumac leaves, used in dyeing and tanning, *Rhus coriaria*; the Japanese wax tree, *Thus succedanea*; mastic resin, *Pistacia lentiscus*; and pistachio nuts, *Pistacia vera*. The leaves of *Pistachia lentiscus* and *P. terebinthus* are a popular traditional medicine in Mediterranean regions; they contain vitamin E (α-tocopherol) for which a quantitative method for its determination has recently been published (B. Kivçak and S. Akay, *Fitoterapia*, 2005, **76**, 62). The family contains dyeing and tanning materials, and phenolic compounds some of which cause dermatitis (e.g. the vesicant constituents of the poison ivy, *Rhus toxicodendron*). Other species of *Rhus* yield Japanese lacquer and the fat known as Japan wax. Mastic resin contains triterpenoid acids and alcohols.
2. Aceraceae. A family of trees and shrubs. In the genus *Acer* (100 spp.) is *Acer saccharum*, which yields maple sugar.
3. Sapindaceae. A family of about 150 genera and 2000 species; tropical and subtropical. Genera include *Paullinia* (180 spp.), *Sapindus* (13 spp.), *Cardiospermum* (12 spp.), *Eriocoelum*, *Blighia* and *Radlkofera*. The seeds of *Paullinia cupana* are made into a paste and dried to form guarana; this contains caffeine and is used as a beverage. *Sapindus saponaria* has been used in Brazil and India as a soap and for the treatment of several diseases; it contains saponins with hederagenin (q.v.) as an aglycone. Constituents of the family include saponins, cyanogenetic glycosides, cyclitols (e.g. shikimic acid); the seed fats contain a high proportion of oleic acid. Alkaloids have been reported in a few species, including caffeine and theobromine in *Paullinia*.

4. Hippocastanaceae. A small family of only two genera and 15 species; tropical trees and shrubs of southern Africa. *Aesculus* (13 spp.) contains the horse chestnut, *A. hippocastanum*. Its seed fat, like the Sapindaceae, contains a high proportion, about 65–70%, of oleic acid. Several of the species examined contain phenolic acids, coumarins, cyclitols and saponins; alkaloids appear to be absent.

CELASTRALES

Aquifoliaceae, Celastraceae, Buxaceae

An order of 13 families; trees and shrubs with simple leaves.

1. Aquifoliaceae. The holly family consists of two genera and about 400 species, all but one of which belong to the genus *Ilex*. Members are trees and shrubs found in the temperate and tropical regions. Maté or Paraguay tea is obtained from *Ilex paraguariensis* and other species. A similar caffeine-containing product is cassina, the leaves of *Ilex cassine*. Constituents reported in the family include caffeine, theobromine, cyclitols (shikimic acid and inositol), triterpenes and triterpenoid saponins.
2. Celastraceae. A family of 55 genera and 850 species; tropical and temperate trees and shrubs. Genera include *Euonymus* (176 spp.), *Celastrus* (39 spp.), *Cassine* (40 spp.), *Maytenus* (225 spp.), *Prionstemma*, *Catha*, *Tripterygium* and *Peripterygia*. *Catha edulis* yields the leaves known as khat or Abyssinian tea; these contain the alkaloid cathine (norpseudoephedrine). The root bark of *Euonymus atropurpureus* contains cardioactive glycosides and is included in the *BHP* 1996. The large genus *Maytenus* has been widely used in traditional medicine and investigated for pharmacological and phytochemical properties. The alkaloid maytansine, isolated from *M. serrata* received considerable attention as a possible anticancer drug. Recently the morphology and histology of *M. ilicifolia* has been described (M. R. Duarte and M. C. Debur, *Fitoterapia*, 2005, **76**, 41). Constituents of the family include alkaloidal amines, alkaloids of the pyridine and purine types, sugar alcohols (dulcitol), saponins, cardenolides, terpenoids and substances having antitumour activity.
3. Buxaceae. A family of five genera and 100 species of tropical and temperate, usually evergreen, shrubs. The genera are *Buxus* (70 spp.), *Notobuxus* (7 spp.), *Sarcocolla* (16–20 spp.), *Pachysandra* and *Simmondsia*. Much research has been done on the steroidal alkaloids of the family, including the genus *Buxus*, some species of which find use in traditional medicine; see Atta-ur-Rahman *et al*., *J. Nat. Prod*., 1997, **60**, 976 for a study of *B. longifolia*. Other constituents include phenolic acids and waxes. The seeds of *Simmondsia chinensis* yield the liquid wax, jojoba wax, which consists of straight chain esters of 20:1, 22:1, 24:1 fatty acids (q.v.) and alcohols.

RHAMNALES

Rhamnaceae, Vitaceae

The order contains three families.

1. Rhamnaceae. A family of 59 genera and about 900 species; cosmopolitan, usually trees or shrubs. Genera include *Rhamnus* (110 spp.), *Zizyphus* (100 spp.), *Scutia* (9 spp.), *Discaria* (10 spp.), *Columbrina* (17 spp.), *Maesopsis* and *Hovenia*. British species are the alder buckthorn, *Rhamnus alnus*, and the buckthorn, *Rhamnus cathartica*. These, like *R. purshiana*, which produces cascara bark, contain quinones. The edible fruits of *Ziziphus jujuba* are known as French jujubes and are used in traditional Chinese medicine as a mild sedative; cytotoxic lupane-type triterpenes have been isolated from the fruits (S. M. Lee *et al*., *Planta Medica*, 2003, **69**, 1051). *Z. vulgaris* is similarly used in traditional medicine; ursane-type triterpenoids occur in the roots (H. M. Mukhtar *et al*., *Pharm. Biol*., 2005, **43**, 392). The constituents of the family include purgative quinones (anthraquinones, anthranols and their glycosides). Alkaloidal peptides occur in some genera; also terpenoids and triterpenoid saponins.
2. Vitaceae. The family contains about 65 spp. of *Vitis* (vines). *V. vitifera* produces grapes, wine, raisins and currants. There has been considerable recent interest in the beneficial effect of red wine arising from its antioxidant properties with respect to low-density lipoprotein and protection against atherosclerosis and coronary heart disease; see E. N. Frankel and A. S. Meyer, *Pharm. Biol*., 1998, **36** (suppl.), 14. The compounds involved include flavonoids, anthocyanins, flavonols and phenolic acids. For a review of *Vitis vinifera* with 108 references, see E. Bombardelli and P. Morazzoni, *Fitoterpia*, 1995, **66**, 291.

MALVALES

Elaeocarpaceae, Tiliaceae, Malvaceae, Bombacaceae, Sterculiaceae

An order of seven families. Herbs, shrubs or trees; tropical and temperate. Many species contain mucilage; alkaloids are rare.

1. Elaeocarpaceae. A family of 12 genera and 350 species of tropical and subtropical trees and shrubs. Chief genera *Elaeocarpus* (200 spp.) and *Sloanea* (120 spp.). Indolizidine alkaloids occur in *Elaeocarpus*. Antibabesial ellagic acid rhamnosides, active against infections of dogs with parasitic *Babesia gibsoni*, have been isolated from *Elaeocarpus parvifolius* (A. Elkhateeb *et al*., *Phytochemistry*, 2005, **66**, 2577).
2. Tiliaceae. A family of 50 genera and some 450 species; usually trees or shrubs. Genera include *Corchorus* (100 spp.) and *Tilia* (50 spp.). Jute fibre is obtained from *Corchorus capsularis* and *C. olitorius*. Lime Tree Flower *BHP* (1996), *BP*/*EP* is the dried inflorescences of *Tilia platyphyllos* or *T. cordata* (q.v.). The American lime yields phloem fibres, used by gardeners under the name of 'bass'. Cardiac glycosides are reported from *Corchorus*; alkaloids are absent.
3. Malvaceae. The family contains 75 genera and about 1000 species of herbs, shrubs and trees; tropical and temperate. Genera include *Malva* (40 spp.), *Gossypium* (20–47 spp., authorities differ), *Hibiscus* (300 spp.), *Althaea* (12 spp.), *Pavonia* (200 spp.) and *Thespesia* (15 spp.). The cottons, species of *Gossypium*, are important both for their seed hairs and seed oil (q.v.). Marshmallow root, from *Althaea officinalis*, is used as a demulcent (q.v.). The common hollyhock is *Althaea rosea*. Few species have been studied chemically, but saponins, tannins, leucoanthocyanins and phenolic acids occur; typical alkaloids appear to be absent.
4. Bombacaceae. A small family of about 20 genera and 180 species of tropical trees. Genera include *Bombax* (8 spp.), *Ceiba* and *Adansonia*. In tropical Africa the fruit pulp and bark of the baobab tree (*A. digitata*) are used medicinally and the edible seed oil is used in cooking and as a skin emollient. A range of constituents have been isolated; recently, procyanidins have been recorded in a methanolic extract of the pericarp (A. A. Shahat, *Pharm. Biol*., 2006, **44**, 445). Kapok, which consists of the lignified, silky hairs which line the fruits of various species of *Bombax* and *Ceiba*, has been used for life-belts and as a stuffing material.
5. Sterculiaceae. A family of 60 genera and 700 species; mainly tropical. Genera include *Sterculia* (300 spp.), *Theobroma* (30 spp.), *Cola* (125 spp.) and *Brachychiton*. Cocoa, oil of theobroma and

chocolate are prepared from *Theobroma cacao*; kola or cola nuts come from *Cola vera* and *C. acuminata*; and sterculia or karaya gum come from *Sterculia urens*. As in the Malvaceae, mucilage is common; purine bases occur in *Theobroma* and *Cola*.

THYMELAEALES

Thymelaeaceae, Elaeagnaceae

An order of five families.

1. Thymelaeaceae. A family of 90 genera and 500 species; mostly temperate and tropical shrubs. Genera include *Gnidia* (100 spp.), *Daphne* (70 spp.) and *Pimelea* (80 spp.). Some species of *Daphne* are poisonous and contain vesicant resins. The bark of *Daphne mezereum* was formerly official; the floral fragrance is composed of about 95% s-(+)-linalool. Mucilage and coumarins common in the family; alkaloids absent.
2. Elaeagnaceae. A family of three genera and about 50 species, including *Hippophae* (3 spp.), *Elaeagnus* (45 spp.) and *Shepherdia* (3 spp.). Among the constituents are indole alkaloids and cyclitols.

VIOLALES

Flacourtiaceae, Violaceae, Turneraceae, Passifloraceae, Cistaceae, Bixaceae, Tamaricaceae, Caricaceae

An order of 20 families. It includes herbs, shrubs and trees; tropical and temperate. Cyanogenetic glycosides occur in some of the families (e.g. Flacourtiaceae, Turneraceae and Passifloraceae), but are absent from others (e.g. Violaceae).

1. Flacourtiaceae. A family of 93 genera and over 1000 species. Genera include *Erythrospermum* (6 spp.), *Hydnocarpus* (40 spp.), *Flacourtia* (15 spp.) and *Homalium* (200 spp.). The seed oils have been particularly studied, as species of *Hydnocarpus* contain cyclic, unsaturated acids which are bactericidal towards the micrococcus of leprosy. Other constituents of the family include cyanogenetic glycosides, tannins and phenolic acids. Alkaloids reported only in one genus, *Ryania*.
2. Violaceae. A family of 22 genera and about 900 species; cosmopolitan, herbs and shrubs. Genera include *Viola* (500 spp.), *Hybanthus* (150 spp.) and *Hymenanthera* (7 spp.). The pansy (*Viola tricolor*), sweet violet (*V. odorata*) and dog violet (*V. canina*) have been used medicinally. They contain volatile oil and anthocyanin, flavonoid (rutin) and carotenoid pigments. Cyclotoxic cyclotides (a family of small proteins) have been recorded in the aerial parts of a commercial sample of *V. tricolor* (E. Svangärd *et al*., *J. Nat. Prod*., 2004, **67**, 114). *Hybanthus ipecacuanha* has occurred as an adulterant of genuine ipecacuanha.
3. Turneraceae. A family of seven genera and 120 species of trees, shrubs and herbs. *Turnera* has 61 species and *T. diffusa* is the source of damiana leaves.
4. Passifloraceae. A family of 12 genera and 600 species; tropical and warm temperate; shrubs and trees, often climbers. The main genera are *Passiflora* (500 spp.), *Adenia* (92 spp.) and *Tetrapathaea*, the latter a single species from New Zealand. Some of the fruits are edible (e.g. passion fruit, from *Passiflora edulis*). The dried aerial parts of *P. incarnata* are a popular herbal sedative; they contain flavonoids and traces of cyanogenetic glycosides, volatile oil and harmane-type alkaloids. Pharmacological tests have supported the traditional usage (R. Soulimani *et al*., *J. Ethnopharmacology*, 1997, **57**, 11).
5. Cistaceae. A family of eight genera and 200 species. Members are herbs and shrubs, particularly found on chalk or sand. The genera include *Helianthemum* (100 spp.), *Cistus* (20 spp.) and *Halimium*. Species of *Cistus* yield the oleo-gum resin ladanum, used in perfumery and for embalming.
6. Bixaceae. This consists of the single genus *Bixa* with four species. *Bixa orellana* is cultivated for the colouring matter of its seeds. This, under the name of 'annatto', is used as an edible colourant, see Chapter 33.
7. Tamaricaceae. A family of four genera and 120 species; herbs and shrubs. *Tamarix* (54 spp.) includes *T. mannifera*, a plant which when punctured by scale insects yields the manna of the Bedouins.
8. Caricaceae. A family of four genera and 55 species; small trees mainly found in tropical America and Africa. *Carica* contains 45 species, and *Carica papaya* (papaw) is cultivated for the milky juice which is the source of the proteolytic enzyme papain.

CUCURBITALES

Cucurbitaceae

An order containing the single family Cucurbitaceae.

A family of about 110 genera and 640 species; abundant in the tropics; mostly herbs climbing by tendrils, with abundant sap and very rapid growth. Flowers are generally unisexual, regular and pentamerous, except in the gynaecium, which is reduced to three. The fruit is the fleshy type seen in the cucumber. Most members have bicollateral vascular bundles. Genera include *Cucurbita* (5 spp.), *Cucumis* (25 spp.), *Ecballium* (1 sp.), *Citrullus* (3 spp.), *Luffa* (6 spp.), *Bryonia* (4 spp.) and *Momordica* (45 spp.), *Cucurbita pepo* is vegetable marrow; *C. maxima*, great pumpkin; *Cucumis melo*, the melon; *C. sativus*, the cucumber; *Ecballium elaterium*, the squirting cucumber, yields the purgative elaterium; *Citrullus colocynthis* yields colocynth; *C. lanatus*, the water melon. The vascular network of the pericarp of *Luffa* is used as a bath sponge (loofah). The fruits and seeds of *L. acutangula* contain saponins and are used in Ayurvedic medicine. Bryony root, from *Bryonia dioica*, was formerly used as a purgative and for the treatment of gout; it contains saponins and sterols. *Bryonia alba* contains antitumour substances. The enzyme elaterase hydrolyses the bitter glucosides of the family to cucurbitacins and glucose. The cucurbitacins are triterpenoid bitter principles named A to Q, and the compound formerly known as α-elaterin is cucurbitacin-E. For their formation in tissue cultures of *Ecballium elatarium* see G. A. Attard and A. Scicluna-Spiteri, *Fitoterapia*, 2001, **72**, 146; G. Toker *et al*., *Fitoterapia*, 2003, **74**, 618.

MYRTIFLORAE

Lythraceae, Myrtaceae, Punicaceae, Rhizophoraceae, Combretaceae, Onagraceae

An order of 17 families. Many members rich in tannins.

1. Lythraceae. A family of 25 genera and 550 species; herbs, shrubs and trees. Genera include *Rotala* (50 spp.), *Lythrum* (35 spp.), *Decodon* (1 sp.), *Lagerstroemia* (35 spp.), *Heimia* (3 spp.) and *Lawsonia* (1 sp.). The naphthoquinone lawsone occurs in henna, the leaves of *Lawsonia inermis*. Some species contain alkaloids.
2. Myrtaceae. A family of about 100 genera and 3000 species of evergreen shrubs and trees; well represented in Australia, the East Indies and tropical America. The family is divided into two subfamilies, the Myrtoideae (fruit a berry or drupe) and the Leptospermoideae (fruit a loculicidal capsule). Genera of the Myrtoideae include *Myrtus* (100 spp.), *Psidium* (140 spp.), *Pimenta* (18 spp.), *Eugenia* (1000 spp.), *Pseudocaryophyllus* and *Syzygium* (*Jambosa*). To the Leptospermoideae belong *Eucalyptus* (over 500 spp.), *Leptospermum*

(50 spp.) and *Melaleuca* (about 100 spp.). The large genus *Eucalyptus* has presented taxonomic problems and following a recent revision for *Flora of Australia* the nine, previously established, subgenera are each afforded generic status. Many of the genera provide important volatile oils and spices—for example, cloves and its oil (q.v.), eucalyptus oil, cajuput oil and pimento. *Psidium guajava* gives the edible fruit guava. Constituents of the family other than volatile oils are leucoanthocyanins, cyclitols, tannins (e.g. in eucalyptus kinos), phenolic acids and esters. Cyanogenetic glycosides and alkaloids are rare.

3. Punicaceae. The family contains the single genus *Punica* with two species. The fruit rind of *Punica granatum*, the pomegranate, contains tannin; in its stem and root bark tannin is accompanied by the liquid alkaloids pelletierine and isopelletierine. Pelletierine tannate was formerly official. Tannin-rich fractions have been investigated for their antioxidant, antimalarial and antimicrobial activities (M. K. Reddy *et al*., *Planta Medica*, 2007, **73**, 461).
4. Rhizophoraceae. A family of 16 genera and 120 species; often trees of mangrove habit. *Rhizophora* (7 spp.) yields the tanning material mangrove cutch.
5. Combretaceae. A family of 20 genera and 600 species; tropical and subtropical trees and shrubs; usually rich in tannin. Genera include *Terminalia* (250 spp.), *Combretum* (250 spp.), *Quisqualis* (17 spp.) and *Anogeissus* (11 spp.). Myrobalans, the fruits of *Terminalia chebula*, are rich in tannin and are used both in tanning and in medicine. For an extensive microscopical examination of *T. australis*, used in traditional medicine in a number of S. American countries, see M. T. Castro *et al*., *Pharm. Biol*., 2005, **43**, 439; *Combretum butyrosum* yields a butter-like substance; and *Anogeissus latifolia* yields the gum known as ghatti gum.
6. Onagraceae. A family of 21 genera and 640 species; temperate and tropical; mostly perennial herbs, but a few shrubs and trees. Genera include *Fuchsia* (100 spp.), *Oenothera* (80 spp.), *Clarkia* (36 spp.) and *Epilobium* (215 spp.). Many are cultivated for their flowers. Seeds of *Oenothera* spp. have become important as sources of evening primrose oil (q.v.). Various species of *Epilobium* e.g. *E. angustifolium* and *E. hirsutum* are used traditionally for the treatment of benign prostate hyperplasia; the active components appear to be two macrocyclic ellagitannins oenothein A & B (B. Ducrey *et al*., *Planta Medica*, 1997, **63**, 111). Tannins and a few cyanogenetic plants are recorded; alkaloids are rare or absent.

UMBELLIFLORAE

Alangiaceae, Cornaceae, Garryaceae, Araliaceae, Umbelliferae

An order of seven families. All, except the Umbelliferae and Araliaceae, are small. Acetylenic compounds occur throughout the order.

1. Alangiaceae. A family of 2 genera and 20 species, of which 17 belong to *Alangium*; tropical trees and shrubs. Alkaloids and triterpenoid saponins occur. *A. lamarkii* is an Indian medicinal plant.
2. Cornaceae. A family of 12 genera and 100 species; trees and shrubs, rarely herbs. Genera include *Cornus* (4 spp.) and *Acuba* (3 spp.).
3. Garryaceae. Contains only *Garrya*, with 18 species. Shrubs containing alkaloids.
4. Araliaceae. A family of 55 genera and 700 species; mainly tropical trees and shrubs, some climbing (e.g. ivy). Genera include *Panax* (8 spp.), *Tetrapanax* (1 sp.), *Aralia* (35 spp.), *Hedera* (15 spp.), *Cussonia* (25 spp.), *Pseudopanax* (6 spp.), *Fatsia* (1 sp.) and *Sciadodendron* (1 sp.). The best-known drug, which has been used for many centuries, is ginseng, from *Panax schinseng* (*P. ginseng*). *Tetrapanax papyriferum* is the ricepaper tree, and *Hedera helix* the common ivy (q.v.). Resin passages occur in the family. Constituents include saponins, a few alkaloids, acetylenic compounds and diterpenoids and triterpenoids.
5. Umbelliferae. The family contains about 275 genera and 2850 species. Most members are herbs with furrowed stems and hollow internodes. Some are annuals (e.g. coriander), some biennials (e.g. hemlock) and some perennials (e.g. species of *Ferula*). The three subfamilies and main genera are as follows: (1) Hydrocotyloideae includes *Hydrocotyle* (100 species); (2) Saniculoideae includes *Eryngium* (230 spp.), *Astrantia* (10 spp.) and *Sanicula* (37 spp.); (3) Apioideae includes *Chaerophyllum* (40 spp.), *Coriandrum* (2 spp.), *Smyrnium* (8 spp.), *Conium* (4 spp.), *Bupleurum* (150 spp.), *Apium* (1 sp.), *Petroselinum* (5 spp.), *Carum* (30 spp.), *Pimpinella* (150 spp.), *Seseli* (80 spp.), *Foeniculum* (5 spp.), *Oenanthe* (40 spp.), *Ligusticum* (60 spp.), *Angelica* (80 spp.), *Ferula* (133 spp.), *Peucedanum* (120 spp.), *Pastinaca* (15 spp.), *Laserpitium* (35 spp.), *Thapsia* (6 spp.), *Daucus* (60 spp.), *Ammi* (10 spp.), *Heracleum* (70 spp.), *Prangos* (30 spp.) and *Anethum* (1 sp.). The leaves are usually large and have a sheathing base and much-divided lamina. The flowers are small and arranged in simple or compound umbels. Each has a five-lobed calyx, five petals, five stamens, and an inferior two-celled ovary. The fruit is a cremocarp, which is frequently crowned with a stigma-bearing disc known as the stylopodium. When ripe, the two mericarps separate from one another but frequently remain attached to the simple or forked carpophore which lies between them. The line separating the two mericarps is known as the commissure. Each mericarp contains a single seed which consists of a large endosperm, which has a small embryo embedded in it near the apex. Five primary ridges containing fibrovascular bundles run from base to apex in the pericarp, and secondary ridges sometimes alternate with these. Between the ridges are schizogenous oleoresin canals known as vittae. Members of the family differ in the number and arrangement of the vittae in each mericarp, but six is common, four on the dorsal surface and two on the commissural. Similar ducts occur in the stem and roots and in species of *Ferula* yield the oleo-gum resins and asafoetida, ammoniacum and galbanum.

The main umbelliferous fruits and their volatile oils used in pharmacy are fennel, *Foeniculum vulgare*; caraway, *Carum carvi*; dill, *Anethum graveolens*; coriander, *Coriandrum sativum*; aniseed, *Pimpinella anisum*; and cumin, *Cumminum cyminum*. *Bupleurum falcatum* roots contain oleanene saponins and are an important antihepatotoxic drug in oriental medicine. Visnaga, from *Ammi visnaga*, yields khellin, a dimethoxyfuranochromone. Among poisonous plants of the family may be mentioned *Conium maculatum*, the spotted hemlock, which contains the alkaloid coniine; and *Oenanthe crocata*, the hemlock waterdropwort, which contains oenanthotoxin. Other well-known plants of the family are celery, *Apium graveolens*; parsley, *Petroselinum crispum*; parsnip, *Pastinaca sativa*; and carrot, *Daucus carota*. Constituents of the family, other than volatile oils and resins, include coumarins (e.g. umbelliferone), furocoumarins, chromono-coumarins, terpenes and sesquiterpenes, triterpenoid saponins and acetylenic compounds. Alkaloids occur (e.g. coniine) but are rare.

SUBCLASS SYMPETALAE

The Sympetalae derive their name from the fact that their petals are fused. The subclass consists of 11 orders and 63 families, the chief of which have already been tabulated.

ERICALES

Ericaceae

An order of five families, including the Pyrolaceae, Epacridaceae and Ericaceae. Only the last family, the largest, will be described.

Ericaceae. A family of about 80 genera and 2000 species; particularly common on moors and peaty soils. Members are shrubs or small trees. The genera include *Rhododendron* (500–600 spp.), *Ledum* (10 spp.), *Erica* (over 500 spp.), *Calluna* (1 sp.), *Vaccinium* (300–400 spp.), *Gaylussacia* (49 spp.), *Gaultheria* (about 210 spp.), *Pieris* (10 spp.), *Lyonia* (30 spp.), *Arbutus* (20 spp.) and *Arctostaphylos* (71 spp.). In addition to the well-known garden plants, the family includes the wintergreen, *Gaultheria procumbens*, which yields natural oil of wintergreen (now generally replaced by synthetic methyl salicylate); and bearberry leaves from *Arctostaphylos uva-ursi*, which contain the phenolic glycoside arbutin and are again official. The medicinal properties of *Vaccinium myrtillus* (bilberry, blueberry, whortleberry) have been utilized since the Middle Ages and have been reviewed (P. Morazzoni and E. Bombardelli, *Fitoterapia*, 1996, **67**, 3); the fruits are included in the *BP*/*EP*. The family produces phenolic acids, phenolic glycosides (e.g. arbutin), aucubin glycosides, diterpenoids (grayanotoxin), triterpenoids (ursolic acid), cyclitols and leucoanthocyanins. A few species are cyanogenetic; saponins are absent.

PRIMULALES

Myrsinaceae, Primulaceae

An order of three families.

The Primulaceae consists of 20 genera and about 1000 species of herbaceous perennials with rhizomes or tubers. Especially common in the north temperate regions. Many members are cultivated as garden plants. Genera include *Primula* (500 spp.), *Cyclamen* (15 spp.), *Anagallis* (31 spp.) and *Dionysia* (41 spp.). The dried flowers of *Primula veris* (the cowslip) are used in herbal medicine for insomnia and as a sedative in combination with other herbs. The flowers are particularly rich in flavonoids. Saponins are present in some species; also phenolic esters and ethers. Alkaloids appear to be absent. Anthocyanin pigments are common, but not betacyanins or betaxanthins.

PLUMBAGINALES

Plumbaginaceae

The Plumbaginaceae is the only family of the order, and contains 19 genera and about 775 species. Members are herbs or shrubs often found on sea coasts or salt steppes. Genera include *Plumbago* (12 spp.) and *Ceratostigma*. Roots of *Plumbago* spp. are used in traditional Indian medicine; immunosuppressive and antitumour activities have been demonstrated. Constituents found in the family include phenolic acids, tannins, anthocyanin pigments and naphthoquinones (e.g. plumbagin).

EBENALES

Sapotaceae, Ebenaceae, Styracaceae

An order of seven families consisting mainly of trees and shrubs.

1. Sapotaceae. A family of some 35–75 ill-defined genera and about 800 species; most are tropical trees, often yielding good timber. Genera include *Mimusops* (57 spp.), *Madhuca* (*Bassia*) (85 spp.), *Achras* (70 spp.), *Pierreodendron* (2 spp.), *Palaquium* (about 115 spp.) and *Butyrospermum* (1 sp.). Latex sacs occur in the leaves, and in the cortex, phloem and pith of the stems. Gutta-percha is the coagulated latex from species of *Palaquium* and *Payena*. The oily seeds of *Butyrospermum parkii* are expressed to yield shea butter which can be used as an ointment and cream base for topical applications. Constituents of the family include latex, seed fats, cyanogenetic glycosides, saponins, tannins, leucoanthocyanins, pyrrolizidine alkaloids and the cyclitol D-quercitol.
2. Ebenaceae. A family of three genera and about 500 species; tropical trees and shrubs. The chief genera are *Diospyros* (about 500 spp.) and *Euclea* (20 spp.). Varieties of ebony are obtained from *Diospyros ebenum* and *Euclea pseudebenus*. In South-East Asia the fresh unripe fruits of *D. mollis* have long been used as an anthelmintic (hookworms and tapeworms). Other species yield edible fruits, 'date-plums'. For phytochemical research on the root- and stem-barks of *Diospyros* spp. involving the isolation of triterpenoids, diquinones and napthoquinones see M. R. Khan and D. Timi, *Fitoterapia*, 1999, **70**, 194; 209. Further details are given in Chapter 21 (naphthoquinones). Naphthoquinones are a characteristic of the family.
3. Styracaceae. A family of 12 genera and 180 species of trees and shrubs. Genera include *Styrax* (130 spp.) and *Halensia*. Benzoins (q.v.) are obtained from species of *Styrax*. Constituents of the family include balsamic resins, phenolic acids, tannins and the benzofuran egonol.

OLEALES

Oleaceae

The Oleaceae is the only family of the order. It is widely distributed, and contains 29 genera and about 600 species. Genera include *Olea* (20 spp.), *Forsythia* (7 spp.), *Fraxinus* (70 spp.), *Syringa* (30 spp.), *Osmanthus* (15 spp.), *Jasminum* (300 spp.) and *Ligustrum* (40–50 spp.). Many species are grown in Britain (e.g. *Syringa vulgaris*, the lilac). The manna of present-day commerce is obtained by making incisions in the stem of the manna ash, *Fraxinus ornus*. *F. oxyphylla* and *F. excelsior* afford Ash Leaf *BP*/*EP*. Of great economic importance is the olive, *Olea europoea*. In addition to olive oil (q.v.), the family produces sugar alcohols (e.g. the mannitol of manna), saponins, tannins, coumarins and iridoid glycosides. Alkaloids are rare.

GENTIANALES

Loganiaceae, Gentianaceae, Menyanthaceae, Apocynaceae, Asclepiadaceae, Rubiaceae

An order of seven families which is of medical and chemical interest. All the families contain alkaloids, but important glycoside-containing genera also occur.

1. Loganiaceae. A family of 18 genera and 500 species; trees, shrubs and herbs, some lianes. Genera include *Strychnos* (200 spp.), *Logania* (25 spp.), *Gelsemium* (2 spp.), *Geniostoma* (60 spp.), *Anthocleista* (14 spp.) and *Gardneria* (5 spp.). Nux vomica seeds (q.v.), the seeds of *Strychnos nux-vomica*, are the principal source of strychnine and brucine; calabash-curare (see 'Curare') owes its activity largely to *Strychnos* species. The family is rich in alkaloids of the indole and oxindole groups. Other constitutents are the aucubin glycoside loganin, and iridoids.
2. Gentianaceae. A family of 80 genera and about 1000 species; herbs and a few shrubs widely distributed. The leaves are opposite and decussate, the corolla lobes are contorted in the bud and the axis shows bicollateral bundles and interxylary phloem. Genera include *Gentiana* (400 spp.), *Exacum* (40 spp.), *Sebaca* (100 spp.), *Erythraea* (*Centaurium*) (30 spp.), *Chironia* (30 spp.), *Swertia* (100 spp.), *Halenia* (about 100 spp.) and *Enicostema* (3 or 4 spp.). Gentian root

(see 'Gentian'), from *Gentiana lutea*, has long been used in medicine. The herb of *Swertia chirata* (Chiretta) is described in the *BHP* (1983); it is used to stimulate the appetite in anorexia. *S. japonica* is used in Japan as a stomachic; hairy root cultures produce xanthone derivatives, the secoiridoids amarogentin and amaroswerin, and phenylglucosides. Some members, on account of their bitter principles, are used in liqueurs. The family contains alkaloids; iridoid glycosides; flavones, xanthones and their glycosides; phenolic acids; tannins; and the trisaccharide gentianose.

3. Menyanthaceae. This small family of five genera and 33 species is sometimes included in the Gentianaceae. It consists of aquatic or marsh herbs such as the British plant *Menyanthes trifoliata*, the buckbean (Bogbean Leaf *BHP* 1996, *BP*/*EP*). Like the Gentianaceae, the family contains bitter principles but the leaves instead of being opposite and decussate are alternate.
4. Apocynaceae. A family of about 250 genera and 2000 species which is closely allied to the Asclepiadaceae. Many members are woody climbers found in the tropics and subtropics. The only British species are the periwinkles, *Vinca major* and *V. minor*. Types of fruit are a pair of follicles, a berry, capsules or two indehiscent mericarps. The plants contain latex in non-articulated, branched or unbranched laticifers. The vascular bundles are bicollateral. Important genera, arranged under two subfamilies, are as follows: A. Plumieroideae: *Arduina–Carissa* (35 spp.), *Allamanda* (15 spp.), *Landolphia* (55 spp.), *Carpodinus* (50 spp.), *Hancornia* (1 sp.), *Pleiocarpa* (3 spp.), *Plumeria* (7 spp.), *Alstonia* (50 spp.), *Aspidosperma* (80 spp.), *Rhazya* (2 spp.), *Amsonia* (25 spp.), *Lochnera–Catharanthus* (5 spp.), *Vinca* (5 spp.), *Tabernaemontana* (100 spp.), *Voacanga* (25 spp.), *Rauwolfia* (100 spp.), *Ochrosia* (30 spp.) and *Cerbera* (6 spp.); B. Apocynoideae: *Mandevilla* (114 spp.), *Funtumia* (3 spp.), *Apocyanum* (7 spp.), *Nerium* (3 spp.), *Strophanthus* (60 spp.), *Wrightia* (23 spp.), *Parsonia* (100 spp.), *Lyonsia* (24 spp.) and *Malouetia* (25 spp.). Drugs include the Madagascaran periwinkle, *Catharanthus roseus* (also known as *Lochnera rosea* and *Vinca rosea*); strophanthus seeds; rauwolfia roots; kurchi or holarrhena bark; alstonia barks; and aspidosperma barks. Many species of *Landolphia, Carpondinus* and *Hancornia* yield rubber latex. [For a review (148 refs) of *Rhazya stricta* and *R. orientalis*, used in Unani medicine, see Atta-Ur-Rahman *et al*., *Fitoterapia*, 1989, **60**, 291. For uses, chemistry and pharmacology of *Malouetia* spp. (41 refs) see N. G. Bisset, *J. Ethnopharm*., 1992, **36**, 43.]
   Constituents of the Plumieroideae include a vast range of indoline alkaloids; over 500 in *Alstonia*, *Aspidospermum*, *Catharanthus*, *Hunteria*, *Pleiocarpa*, *Tabernaemontana*, *Rauwolfia* and *Voacanga*. Steroidal alkaloids occur in *Holarrhena* and harman-type alkaloids in *Amsonia* and *Aspidosperma*. Cardioactive glycosides occur in *Acokanthera*, *Carissa* and *Melodinus* and in *Apocyanum*, *Nerium* and *Strophanthus*. Other constituents of the family are cyanogenetic glycosides, leucoanthocyanins, saponins, tannins, coumarins, phenolic acids, cyclitols and triterpenoids. Widely grown ornamental plants of the family include species of *Amsonia*, *Nerium* (oleander), *Vinca, Plumeria* (frangipani), *Thevetia* (yellow oleander) and *Mandevilla* (Chilean jasmine).
5. Asclepiadaceae. A family of 130 genera and 2000 species; tropical and subtropical shrubs, often twining, or perennial herbs. Genera include *Asclepias* (120 spp.), *Tylophora* (150 spp.), *Xysmalobium* (1 sp.), *Cryptostegia* (2 spp.), *Hoodia* (10 spp.), *Cynanchum, Marsdenia, Pergularia* and *Hemidesmus*. The latex cells usually contain a latex rich in triterpenes. Other constituents include: alkaloids of the indole, phenanthroindolizidine and pyridine groups; cardenolides; cyanogenetic glycosides; saponins, tannins, and cyclitols. Although the family yields no important drugs, Pleurisy Root, *Asclepius tuberosa*, was official in the *BHP* 1983) many members are used in folk medicine in their countries of origin and others as arrow poisons. Among the better-known are Indian sarsaparilla, from *Hemidesmus indicus*, and condurango bark, from *Marsdenia condurango*. *Cryptostegia grandiflora*, the rubber vine or pink allamanda, contains poisonous cardenolides with some therapeutic potential; the plant, introduced to Australia as an ornamental, has become an aggressive weed. *Hoodia gordonii*, a succulent plant of the Kalahari desert, has been traditionally used by the San Bushmen as an appetite suppressant. In the West it has achieved popularity for the treatment of obesity, but it is now in danger of over-collection.
6. Rubiaceae. A family of about 500 genera and 6000 species, most of which are tropical trees and shrubs. A few members are herbs growing in temperate climates (e.g. species of *Galium*, such as the bedstraws, goosegrass or cleavers of Britain). The first subfamily is the Cinchonoideae, the carpels of which bear numerous ovules and which includes *Oldenlandia* (300 spp.), *Condaminea* (3 spp.), *Cinchona* (40 spp.), *Uncaria* (60 spp.), *Nauclea* (35 spp.), *Gardenia* (250 spp.) and *Mitragyna* (12 spp.). The second subfamily, Rubioideae, has only one ovule in each loculus; it includes the genera *Coffea* (40 spp.), *Ixora* (400 spp.), *Pavetta* (400 spp.), *Psychotria* (700 spp.), *Cephaëlis-Uragoga* (180 spp.), *Mitchella* (2 spp.), *Asperula* (200 spp.), *Galium* (400 spp.) and *Rubia* (60 spp.). Products include cinchona barks and their alkaloids such as quinine (q.v.), ipecacuanha root (see 'Ipecacuanha'), catechu, from *Uncaria gambier*, and coffee (q.v.), from *Coffea arabica* and other species. *Psychotria viridis* is a component of the hallucinogenic preparation ayahuasca (q.v); other species such as *P. brachypoda* and *P. colorata* are constituents of traditional painkillers (M. B. Leal and E. Elisabetsky, *Int. J. Pharmacognosy*, 1996, **34**, 267). It is of interest that, with *Psychotria*, analgesic activity is found in alkaloids with diverse structures as exemplified by the study of F. L. Both *et al*. on the alkaloid umbellatine from *P. umbellata* (*Pharm. Biol*., 2002, **40**, 366). Of the many other alkaloid-containing species may be mentioned mitragyna leaves, from species of *Mitragyna*, and yohimbe bark, from *Pansinystalia yohimbe*. In the family, alkaloids of the indole, oxindole, quinoline and purine types are common; anthraquinones occur in *Morinda*, *Rubia* and *Galium*, and many have long been used as dyes (e.g. madder, from *Rubia tinctorum*). Anthocyanins occur in *Cinchona*; aucubin glycosides (e.g. asperulin), cyclitols (e.g. quinic acid), coumarins, depsides in *Coffea*; phlobatannins, catechins (e.g. in *Uncaria*); diterpenoids and triterpenoids and iridoid glycosides in *Genipa. Morinda reticulata* is interesting, as it accumulates selenium and is very toxic; *M. citrifolia*, *M. elliptica* and *M. lucida* are all employed in traditional medicine, some anthraquinones (e.g. alizarin-1-methyl-ether) have been shown to possess antifungal properties. For iridoids and anthraquinones of *M. citrifolia* fruits, see K. Kamiya *et al*., *Chem. Pharm. Bull*., 2005, **53**, 1597; the phytochemistry, pharmacology and safety of the fruits have been reviewed (O. Potterat and M. Hamburger, *Planta Medica*, 2007, **73**, 191).

TUBIFLORAE

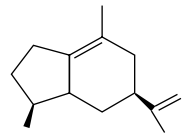
Polemoniaceae, Convolvulaceae, Boraginaceae, Verbenaceae, Labiatae, Solanaceae, Scrophulariaceae, Bignoniaceae, Acanthaceae, Pedaliaceae, Gesneriaceae, Myoporaceae

An order of six suborders and 26 families containing many important drugs. The families considered below fall into the following suborders:

1. Convolvulineae: Polemoniaceae and Convolvulaceae.
2. Boraginineae: Boraginaceae.
3. Verbenineae: Verbenaceae and Labiatae.
4. Solanineae: Solanaceae, Scrophulariaceae, Bignoniaceae, Acanthaceae, Pedaliaceae and Gesneriaceae.
5. Myopineae: Myoporaceae.

Members of these families are usually herbs with alternate or opposite simple leaves. The flowers are generally bisexual and often zygomorphic. They usually have two or four epipetalous stamens and a bicarpellary superior ovary.

1. Polemoniaceae. A family of 15 genera and 300 species; herbs which are often cultivated as border plants. Genera include *Phlox* (67 spp.) and *Polemonium* (50 spp.). The chemistry of the family is imperfectly known, but constituents include saponins and tannins.
2. Convolvulaceae. A family of about 55 genera and 1650 species. Most are annual or perennial herbs, often with twining stems; a few shrubs and trees. Genera include *Convolvulus* (250 spp.), *Ipomoea* (500 spp.), *Pharbitis–Ipomoea*, *Argyreia* (91 spp.) and *Cuscuta* (170 spp.). The genus *Cuscuta* consists of parasites which are sometimes placed in a separate family, the Cuscutaceae. Species of dodder are parasitic on clover and on flax. *C. reflexa* found in the Indian subcontinent is used in a number of folk remedies; an alcoholic extract of the plant has hypotensive and bradycardiac effects.
   Anatomical characters include the presence of latex cells, bicollateral bundles and frequently abnormal vascular development such as is found in drugs such as ipomoea and jalap (q.v.). Brazilian arrowroot is the starch obtained from the tubers of the sweet potato, *Ipomoea batatas*. Many species contain hallucinogens (q.v.) such as ololiuqui, from *Rivea corymbosa*, and morning glory seeds, from species of *Ipomoea*. The family contains indole, isoquinoline, pyrrolidine and tropane alkaloids, purgative resins, phenolic acids and triterpenoid saponins. Pyrrolizidine alkaloids have been reported in the family (seeds of *I. hederifolia*).
3. Boraginaceae. A family of about 100 genera and 2000 species; mostly herbs, often perennial. Inflorescence a coiled cincinnus. The flowers change colour during development. Genera include *Heliotropium* (250 spp.), *Cynoglossum* (50–60 spp.), *Symphytum* (25 spp.), *Borago* (3 spp.), *Anchusa* (50 spp.), *Alkanna* (25–30 spp.), *Pulmonaria* (10 spp.) and *Lithospermum* (60 spp.). Products include species of *Lithospermum*, which have hormone activity; alkanna or anchusa root, from *Alkanna tinctoria*, which contains red colouring matters. Both the *Lithospermum* species and *Alkanna* contain naphthoquinone derivatives. Formerly official were *Cynoglossum officinale* (hound's tongue), *Borago officinale* (borage) and *Pulmonaria officinale* (lung-wort). The seed oil of borage is particularly rich in γ-linolenic acid (q.v.) and the plant is now being cultivated in England for its oil. Naphthoquinones, the ureide allantoin, pyrrolizidine alkaloids, cyclitols, phenolic acids and tannins, occur in the family. Allantoin is particularly abundant in the root of comfrey, *Symphytum officinale*. The common occurrence of pyrrolizidine alkaloids (*Alkana*, *Borago*, *Cynoglossum*, *Heliotropium*, *Symphytum*) has caused concern regarding the herbal use of a number of species.
4. Verbenaceae. A family of about 100 genera and 3000 species; herbs, shrubs and trees, many lianes. Genera include *Tectona* (3 spp.), *Lippia* (220 spp.), *Verbena* (250 spp.), *Callicarpa* (140 spp.), *Vitex* (250 spp.), *Nyctanthes*, *Duranta* and *Stilbe*. Teak is obtained from *Tectona grandis*; verbena oil from *Lippia citriodora*; and vervain, formerly official, from *Verbena officinalis*. *Vitex agnus-castus*, now included in the *BP*/*EP* 2007, has been used medicinally in Europe at least since classical Greek and Roman times and today is still available as a herbal preparation for the treatment of female conditions relating to the premenstrual syndrome and the menopause. (For a report of research see *Pharm. J.*, 2001, **265**, 106.) Among the constituents found in the family are volatile oils, saponins, tannins, quinones, iridoids, piscicidal substances; alkaloids appear to be rare.
5. Labiatae (Lamiaceae). A family of about 200 genera and 3300 species; aromatic, annual or perennial herbs or undershrubs. The family is well represented in the Mediterranean area and in Britain. The flowers are bisexual, zygomorphic, usually have the floral formula K(5), C(5), A4, G(2), and are arranged in verticillasters. The corolla is bilabiate and the stamens didynamous. With the exception of *Rosmarinus*, the genera have a gynobasic style and the four nutlets have only a small surface of contact with one another. Rosemary also differs from most genera in having only two stamens. The herbaceous members of the family have square stems. The leaves and other aerial parts have clothing hairs (see Fig. 42.4) and glandular hairs (Fig. 43.5), which secrete the volatile oil. The genera include *Ajuga* (40 spp.), *Teucrium* (300 spp.), *Rosmarinus* (3 spp.), *Scutellaria* (300 spp.), *Lavandula* (28 spp.), *Marrubium* (40 spp.), *Nepeta* (250 spp.), *Lamium* (40–50 spp.), *Ballota* (35 spp.), *Stachys* (300 spp.), *Salvia* (700 spp.), *Monarda* (12 spp.), *Satureja* (30 spp.), *Origanum* (15–20 spp.), *Thymus* (300–400 spp.), *Mentha* (18 spp. and 13 hybrid spp.), *Pogostemon* (40 spp.), *Ocimum* (150 spp.), *Leonurus* (14 spp.) and *Leonotis* (41 spp.). Many members of the family are used as culinary or medicinal herbs, as sources of volatile oils and in some cases for the preparation of constituents of the volatile oils such as menthol and thymol; chemical races are common. In addition to those drugs described elsewhere, note pennyroyal (*Mentha pulegium*), patchouli (*Pogostemon patchouli*), germander (*Teucrium chamaedrys*), wood sage (*T. scorodonia*), wood betony (*Stachys officinalis*), sweet basil (*Ocimum basilicum*), holy basil (*O. sanctum*), savory (*Satureja* spp.), and hyssop (*Hyssopus officinalis*). Also, thyme (*Thymus vulgaris*) and *Monarda punctata* are both important sources of thymol. Patchouli oil obtained from *Pogostemon cablin* (*P. patchouli*) is used medicinally in China, and also cultivated in India. Of the 41 constituents of the volatile oil, α-guaiene (*ca*. 21%) and α-bulnescene (*ca*. 16%) have been reported as the principal components, with α-bulnescene being active against PAF-induced platelet aggregation (Y.-C. Tsai *et al*., *Fitoterapia*, 2007, **78**, 7).



α-Bulnescene

In addition to the volatile oils, constituents of the family include diterpenoids and triterpenoids, saponins, a few pyridine and pyrrolidine alkaloids, insect-moulting hormones, polyphenols and tannins, iridoids and their glycosides, quinones, furanoids, cyclitols, coumarin, and the sugars raffinose and stachyose.
6. Solanaceae. A family of about 90 genera and over 2000 species; tropical and temperate; herbs, shrubs or small trees. Genera include *Nicandra* (1 sp.), *Lycium* (80–90 spp.), *Atropa* (4 spp.), *Hyoscyamus* (20 spp.), *Physalis* (100 spp.), *Capsicum* (about 50 spp.), *Solanum* including *Lycopersicon* (1700 spp.), *Mandragora* (6 spp.), *Datura* (10 spp.), *Solandra* (10 spp.), *Cestrum* (150 spp.), *Nicotiana* (66 spp.), *Petunia* (40 spp.), *Salpiglossis* (18 spp.), *Schizanthus* (15 spp.), *Scopolia* (6 spp.), *Withania* (10 spp.), *Duboisia* (2 spp.), *Acnistus* (50 spp.) and *Fabiana* (25 spp.). Only five species are indigenous to Britain but many others are cultivated. The indigenous ones are *Datura stramonium*, thornapple; *Solanum dulcamara*,

bittersweet or woody nightshade; *Solanum nigrum*, black nightshade; *Atropa belladonna*, deadly nightshade; *Hyoscyamus niger*, henbane. Among species commonly cultivated in England are *Solanum tuberosum*, potato; *Solanum lycopersicum*, tomato; *Nicotiana tabacum*, tobacco; *Physalis alkekengi*, Chinese lantern; *Capsicum* spp., red and green peppers; *Solanum pseudocapsicum*, winter cherry; *Lycium halimifolium*, Duke of Argyll's Tea-plant; *L. barbarum*, wolfberry, and related spp. are traditional drugs of Chinese medicine for the treatment of age-related conditions (N. L. Etkin, Symposium Report, *Pharm. Biol*., 2002, **40**, 80).

The flowers are bisexual and seldom markedly zygomorphic, although the carpels are placed obliquely. They have the floral formula K(5), C(5), A5, G(2). The ovary is typically bilocular, but frequently becomes falsely three- to five-locular (e.g. *Datura*). On the flowering branches adnation of the leaves with their axillary branches often occurs and the true origin of the parts is only made out by cutting sections. All members of the family have intraxylary phloem which is often accompanied by sclerenchymatous fibres.

Products of the Solanaceae include: stramonium leaves; henbane leaves; belladonna herb and root; capsicums; potato starch from *Solanum tuberosum*; mandrake, from *Mandragora officinarum*; duboisia, from species of *Duboisia* which are used for the manufacture of tropane alkaloids; scopolia leaves and roots, sources of tropane alkaloids; tobacco from *Nicotiana tabacum*, the waste products of which are used for the extraction of the insecticide nicotine. The family contains a wide range of alkaloids which are of great taxonomic interest. Types of alkaloid recorded are tropane, alkaloidal amine, indole, isoquinoline, purine, pyrazole, pyridine, pyrrolidine, quinazolizidine, steroid alkaloids and glycoalkaloids. Other constituents include steroidal saponins, withanolides, coumarins, cyclitols, pungent principles (e.g. in *Capsicum*), flavones, carotenoids and anthraquinones in *Fabiana*.

7. Buddlejaceae. A family of 6–10 genera are 150 spp.; principal genera are *Buddleja* (100 spp.) and *Nuxia* (40 spp.). Although *Buddleja* spp. have been used in traditional medicine in many parts of the world it was only relatively recently (e.g. P. J. Houghton, *J. Nat. Prod*., 1985, **48**, 1005) that detailed phytochemical investigations were initiated. The genus produces flavonoids, iridoids and acylated iridoid glycosides, sesquiterpenoids, phenylethanoids, lignans and saponins (saikosaponins). Until the isolation of saikosaponins by Yamamoto *et al*. (*Chem. Pharm. Bull*., 1991, **39**, 2764) these compounds were known only in *Bupleurum* spp. (Umbelliferae). Apparently, the eating habits of some insects indicate a similarity between *Buddleja* and the Scrophulariaceae.
8. Scrophulariaceae. A family of 220 genera and about 3000 species; annual or perennial herbs or undershrubs, a few trees; some semiparasites. Members differ from the Solanaceae in that they have carpels placed in an anterior–posterior plane, in the aestivation of the corolla and in not possessing bicollateral bundles. The flowers are usually zygomorphic and the stamens reduced to four. Anatomical characters include glandular hairs in which the head is divided by vertical walls only, and the stomata, which are surrounded by three or more epidermal cells. Calcium oxalate is relatively rare; when present, it occurs in small solitary crystals. Genera are *Verbascum* (306 spp.), *Calceolaria* (300–400 spp.), *Linaria* (150 spp.), *Antirrhinum* (42 spp.), *Scrophularia* (about 300 spp.), *Penstemon* (250 spp.), *Mimulus* (100 spp.), *Gratiola* (20 spp.), *Veronica* (300 spp.), *Digitalis* (20–30 spp.), *Isoplexis* (4 spp.), *Melampyrum* (35 spp.), *Euphrasia* (200 spp.), *Bartsia* (30 spp.), *Pedicularis* (500 spp.), *Rhinanthus* (50 spp.), *Odontitis* (30 spp.), *Chaenorrhinum* (20 spp.), *Bacopa* (100 spp.) and *Gratiola* (20 spp.). Important drugs are the leaves of *Digitalis purpurea* and *D. lanata* and their cardiac glycosides. Picrorhiza rhizome or 'Indian gentian' from *Picrorhiza kurroa* contains bitter iridoid glycosides; it is used in India to treat liver ailments. *Verbascum thapsus* (mullein) (q.v.) commonly cited as an adulterant of digitalis, is used as a herbal medicine in Europe and India, particularly for bronchial conditions. The four species of *Isoplexis*, formerly placed in the genus *Digitalis*, are found only in the Canary Islands and Madeira. Cardenolides which are mono- and diglucosides only (cf. *Digitalis*), occur in both genera; the clonal propagation of *I. canariensis* has been described (F. Schaller and W. Kreis, *Planta Medica*, 1996, **62**, 450). Other constituents of the family include: steroidal and triterpenoid saponins; cyanogenetic glycosides in *Linaria* spp.; aucubin glycosides; naphthoquinones and anthraquinones; aurones; iridoids. Alkaloids are not very common, but monoterpenoid, quinazoline and quinolizidine types occur in some species.
9. Bignoniaceae. A family of about 120 genera and 650 species; mainly tropical trees, shrubs or lianes; particularly abundant in Brazil. Genera include *Jacaranda* (50 spp.), *Catalpa* (11 spp.), *Mussatia* (3 spp.), *Kigelia* (1 sp.) and *Tecomella* (1 sp.). *Kigelia pinnata* bark is used in traditional Nigerian medicine; it contains naphthoquinoids and iridoids and has been investigated for antibacterial activity by P. Houghton at King's College, London (*Pharm. J*., 1993, **250**, 848). *K. africana*, the sausage tree, occurs across sub-Saharan Africa. Most parts of the tree are used indigenously and commercial fruit extract is used in skin-care products. Hippos distribute the seeds. In South America the leaves of *Mussatia hyacinthina* and other species are chewed alone or mixed with coca leaves for their sweetening, euphoric or medicinal effects. The above genera have received considerable phytochemical attention and constituents of the family include iridoids and iridoid glycosides, saponins, phenylpropanoids, tannins and quinones; alkaloids are rare.
10. Acanthaceae. A family of 250 genera and 2500 species. Shrubs and herbs, including some climbing plants and xerophytes. Abundant in the tropics but also found in the Mediterranean, Australia and the USA. Genera include *Acanthus* (50 spp.), *Andrographis* (20 spp.), *Blepharis* (100 spp.), *Adhatoda* (20 spp.) and *Barleria* (230 spp.). The leaves of *Adhatoda vasica* are used in India as a uterotonic and for the treatment of cough and allergies; they contain the alkaloid vascine (peganine); the antitussive activity has been demonstrated pharmacologically (J. N. Dhuley, *J. Ethnopharmacology*, 1999, **67**, 361), so too the hepatoprotective property in rats (D. Bhattacharyya *et al*., *Fitoterapia*, 2005, **76**, 223). *Andrographis paniculata* (q.v.) is also an important Indian drug plant. In addition to alkaloids, the family contains tannins, diterpenoids, cyanogenetic compounds and saponins.
11. Pedaliaceae. A small family of 12 genera and 50 species; tropical herbs, or rarely shrubs; mostly shore or desert plants. The genera include *Harpagophytum* (8 spp.), *Pedalium* (1 sp.) and *Sesamum* (30 spp.). *Sesamum indicum* yields the fixed oil sesame or gingili oil. *Harpagophytum procumbens* (Devil's Claw) is found especially in the Kalahari desert and Namibian steppes. Its secondary tuberized roots are much used in traditional medicine and it is now included in western medicine (q.v.). Other constituents of the family include phenolics and flavonoids.
12. Gesneriaceae. A family of 120 genera and 2000 species; mainly tropical and subtropical herbs. The genus *Streptocarpus* has 132 species. Tannins, naphthoquinones, chalcones and anthraquinones but no alkaloids have been reported.
13. Myoporaceae. A family of three genera and some 240 species. The genus *Eremkophila* (209 spp.) is entirely Australian and has been used in aboriginal medicine. *Myoporum* (*c*. 30 spp.) occurs in the

S.W. Pacific area and the monotypic *Bontia* is found only in the West Indies. The family contains a striking range of terpenoids and also tannins, cyanogenetic glycosides and furans. (For a review (150 refs) see E. L. Ghisalberti, *Phytochemistry*, 1994, **35**, 7).

PLANTAGINALES

Plantaginaceae

An order containing the single family Plantaginaceae, which consists of three genera and about 270 species; annual or perennial herbs. All but four species belong to the genus *Plantago* (plantains). The seeds of several species are used in medicine; see 'Psyllium'.

DIPSACALES

Caprifoliaceae, Valerianaceae, Dipsacaceae

An order of four families; includes herbs, shrubs and small trees.

1. Caprifoliaceae. A family of 12 genera and about 450 species; mainly north temperate, herbs and small trees. Important genera are *Viburnum* (200 spp.), *Lonicera* (200 spp.) and *Sambucus* (40 spp.). British members include the common elder, *Sambucus nigra*; honeysuckles, species of *Lonicera*; the guelder-rose, *Viburnum opulus*. Elder flowers, usually in the form of an ointment, are used as a domestic remedy and are included in the *BP*/*EP*. The root bark of black haw, *Viburnum prunifolium*, is official in the *BHP* (1996). Constituents reported in the family are valerianic acid (compare Valerianaceae), aucubin glycosides, saponins, coumarins and cyanogenetic glycosides.
2. Valerianaceae. A family of 13 genera and about 360 species. Herbs, rarely shrubs. Genera include *Valeriana* (over 200 spp.), *Valerianella* (80 spp.), *Centranthus* (12 spp.) and *Patrina* (20 spp.). The first three of these genera are represented in Britain. The flowers of *Valeriana* and *Valerianella* have three stamens, those of *Centranthus* only one. *Centranthus ruber* is the common red valerian. The valerian roots of commerce are derived from the European *Valeriana officinalis* (q.v.) and the Indian valerian, *V. wallichii*. The family contains esters yielding isovalerianic acid (compare Caprifoliaceae), alkaloids and iridoids; valepotriates are characteristic of the tribe Valerianeae but are not found in the tribe Patrinieae.
3. Dipsacaceae. A family of eight genera and about 150 species. Genera include *Scabiosa* (100 spp.), *Knautia* (50 spp.) and *Dipsacus* (15 spp.). The ripe flower-heads of *Dipsacus fullorum* (fuller's teasel) are still used to a limited extent for raising nap on certain cloths. Constituents reported for the family include a *C*-glycoside, a few alkaloids, and tannins.

CAMPANULALES

Campanulaceae, Compositae

An order of eight families. In the families considered below, the anthers are either in contact with one another or fused so as to form a tube into which the pollen is shed. The flowers are hermaphrodite or unisexual by suppression. Mainly herbs with latex vessels or oil passages.

1. Campanulaceae. A family of about 70 genera and 2000 species. Tropical or subtropical herbs; a few trees or shrubs. The subfamily Campanuloideae contains *Campanula* (about 300 spp.) and has regular flowers, generally with free anthers. The subfamily Lobelioideae (which has sometimes been considered as a separate family, the Lobeliaceae) contains *Lobelia* (200–300 spp.). In this subfamily the flowers are zygomorphic and the anthers syngenesious. Family characters include the presence of latex vessels and inulin. Of medicinal importance is lobelia herb or Indian tobacco, *Lobelia inflata*, which contains alkaloids (q.v.). Indian lobelia, from *L. nicotaniaefolia*, also contains lobeline. In addition to the constituents already mentioned, members of the family contain phenolic compounds, tannins and triterpenoid glycosides. The piperidine alkaloids found in the Lobelioideae have not been found in the other subfamilies, but they are not considered sufficiently significant to justify a separate family.
2. Compositae. The Compositae is the largest family of flowering plants and contains about 900 genera and some 13 000 species. Compared with some other large families such as the Leguminosae, the number of important economic products derived from it is relatively small. Chemical research in recent years has increased medical interest in the family and we now have a better knowledge of many almost-discarded folk remedies as well as hitherto uninvestigated plants. The latter include some having antitumour or antibacterial activity and others forming commercial sources of rubber latex. The two subfamilies and their main genera are as follows.
   (1) Tubuliflorae: In this subfamily latex vessels are absent, but schizogenous oil ducts are common. The corollas of the disc-florets are nonligulate. Genera include *Senecio* (1300 spp.), *Xanthium* (30 spp.), *Ambrosia* (30–40 spp.), *Zinnia* (20 spp.), *Helianthus* (110 spp.), *Dahlia* (27 spp.), *Helenium* (40 spp.), *Tagetes* (50 spp.), *Solidago* (100 spp.), *Bellis* (15 spp.), *Aster* (500 spp.), *Erigeron* (200 spp.), *Achillea* (200 spp.), *Anthemis* (200 spp.), *Chrysanthemum* (*c*. 200 spp.), *Matricaria* (40 spp.), *Tanacetum* (50–60 spp.), *Artemisia* (400 spp.), *Blumea* (50 spp.), *Inula* (200 spp.), *Doronicum* (35 spp.), *Calendula* (20–30 spp.), *Eupatorium* (1200 spp.), *Arnica* (32 spp.), *Vernonia* (600 spp.), *Echinops* (100 spp.), *Carlina* (20 spp.), *Arctium* (5 spp.), *Carduus* (100 spp.), *Centaurea* (600 spp.), *Carthamus* (13 spp.) and *Gerbera* (70 spp.). Omitting the huge number of cultivated garden plants, note chamomile or Roman chamomile flowers, from *Anthemis nobilis*; German chamomile, *Matricaria chamomilla*; insect flowers, *Chrysanthemum cinerariifolium*; wormseed or santonica, *Artemisia cina*; arnica flowers and rhizome, *Arnica montana*; calendula flowers, *Calendula officinalis*; yarrow herb, *Achillea millefolium*; grindelia herb, *Grindelia camporum*; blessed thistle leaves, *Cnicus benedictus*; coltsfoot leaves, *Tussilago farfara*; wormwood herb, *Artemisia absinthium*; pellitory or pyrethrum root, *Anacyclus pyrethrum*; elecampane root, *Inula helenium*; Ngai camphor, from *Blumea balsamifera*. The florets of the safflower, *Carthamus tinctorius*, are used as dye and as a substitute for saffron. Refined Sunflower Oil *EP/BP* is expressed from the seeds of *Helianthus annuus* and subsequently refined.
   (2) Liguliflorae: In this subfamily latex vessels are present but volatile oil is rare. All the flowers have ligulate corollas. Genera include *Cichorium* (9 spp.), *Crepis* (200 spp.), *Hieracium* (over 1000 spp.), *Taraxacum* (60 spp.), *Lactuca* (100 spp.), *Scorzonera* (150 spp.) and *Sonchus* (50 spp.). Vegetables obtained from this group include lettuce, scorzonera root, chicory and endive. Of members used medicinally may be noted dandelion root, *Taraxacum officinale*; lactucarium or lettuce-opium, *Lactuca virosa*; mouse-ear hawkweed, *Hieracium pilosella*—which has antibiotic activity and has been used for the treatment of Malta fever. Chicory root and dandelion root were used, particularly in war-time Europe, as adulterants of or substitutes for coffee.

As might be expected from its size, the Compositae contains a wide variety of chemical constituents and the literature is enormous. Already mentioned are the latex of the Liguliflorae and inulin which is

often present in very large amounts (e.g. in dahlia tubers). Some of the volatile oils found in the Tubuliflorae contain acetylenic compounds. Sesquiterpenes known as azulenes give the blue colour to freshly distilled oil of chamomile and yarrow. Many sesquiterpene lactones occur and are of varying types, including eudesmanolides (e.g. santonin), germacranolides, guaianolides and pseudoguaianolides; some of these have cytotoxic activity. The toxic *Senecio* alkaloids derived from pyrrolizidine have been much researched. Some cause liver damage and are therefore dangerous to livestock. Alkaloids of the pyridine, quinoline and diterpenoid types also occur in the family. Other constituents include the insecticidal esters of pyrethrum (q.v.) triterpenoid saponins of grindelia, cyclitols, coumarins and flavonols. *Stevia rebaudiana*, a herb indigenous to North Eastern Paraguay, is the source of stevioside, an ent-kaurene glycoside used as a sweetener for soft drinks, etc.

ANGIOSPERMS: MONOCOTYLEDONS

As the name indicates, monocotyledons have an embryo with one cotyledon. Many members are herbs, usually with parallel-veined leaves. The stele has scattered, closed vascular bundles; the flowers are usually trimerous.

As with the dicotyledons a much abbreviated form of Engler's classification indicating the main orders and families of pharmaceutical and phytochemical interest is given below.

Orders	Families
Liliiflorae	Liliaceae, Agavaceae, Amaryllidaceae, Hypoxidaceae, Dioscoreaceae, Iridaceae
Bromeliales	Bromeliaceae
Graminales	Gramineae
Principes	Palmae
Spathiflorae	Araceae, Lemnaceae
Cyperales	Cyperaceae
Scitamineae	Musaceae, Zingiberaceae, Cannaceae, Marantaceae
Microspermae	Orchidaceae

LILIIFLORAE

Liliaceae, Agavaceae, Hypoxidaceae, Amaryllidaceae, Dioscoreaceae, Iridaceae

The order is divided into five suborders and 17 families. Some botanists favour further subdivision—for example, the separation from the Liliaceae of *Smilax* and *Ruscus* into separate families, the Smilaceae and Ruscaceae respectively.

Many members of the group are perennial herbs having a bulb, corm or rhizome. The flowers are hermaphrodite, regular or zygomorphic, and typically have the floral formula P 3 + 3, A 3 + 3 or 3 + 0, G(3). The perianth is usually petaloid; the ovary superior (e.g. Liliaceae) or inferior (e.g. Iridaceae). Fruit a capsule or berry.

1. Liliaceae. A widely distributed family of about 250 genera and 3700 species; mostly perennial herbs with a rhizome or bulb. The flowers usually have six stamens and a superior (rarely semi-inferior) ovary, with numerous anatropous ovules attached to axile placentas. The fruit is a loculicidal or septicidal capsule, or a berry.
   Without troubling the reader with the names of subfamilies or tribes, the numbers inserted below will indicate the principal genera within each: 1. *Veratrum* (25 spp.), *Gloriosa* (5 spp.) and *Colchicum* (65 spp.); 2. *Herreria* (8 spp.); 3. *Asphodelus* (12 spp.), *Bowiea* (2 spp.), *Funkia–Hosta* (10 spp.), *Kniphofia* (75 spp.) and *Aloe* (about 330 spp.); 4. *Gagea* (70 spp.), *Allium* (450 spp.); 5. *Lilium* (80 spp.), Fritillaria (85 spp.), *Tulipa* (100 spp.); 6. *Scilla* (80 spp.), *Urginea* (100 spp.), *Ornithogalum* (150 spp.), *Hyacinthus* (30 spp.), *Muscari* (60 spp.); 7. *Asparagus* (300 spp.), *Polygonatum* (50 spp.), *Convallaria* (1 spp.), *Trillium* (30 spp.), *Paris* (20 spp.); 8. *Ophiopogon* (20 spp.); 9. *Aletris* (25 spp.); 10. *Smilax* (about 350 spp.). For *Yucca, Dracaena* and *Agave* see below under 'Agavaceae'.

   Some members of the family are cultivated for their flowers, others for food. Drugs include squill, sarsaparilla, veratrum, colchicum seed and corm, aloes and cevadilla seed. Garlic *(Allium sativum)*, an age-old remedy frequently used for the treatment of colds, bronchitis, etc., has recently received much attention as a preventative of heart disease, as an antibiotic and as an anticancer drug.

   Many members of the family contain alkaloids, which are of the steroidal, isoquinoline or purine types. Other steroidal substances include sterols, cardenolides, bufadienolides and steroidal saponins. The amino acid azetidine-2-carboxylic acid occurs in many genera and is also found in the Agavaceae. Other constituents include quinones (benzoquinones, naphthoquinones, anthraquinones and anthrones); flavonoids (anthocyanins and flavonols); the γ-pyrone chelidonic acid; cyanogenetic substances; and fructosan-type carbohydrates. Some volatile oils of the family have antimicrobial properties.
2. Agavaceae. A family of 20 genera and 670 species. The genera include *Yucca* (40 spp.), *Agave* (300 spp.), *Cordyline* (15 spp.), *Dracaena* (150 spp.), *Sansevieria* (60 spp.), *Phormium* (2 spp.), *Nolina* (30 spp.) and *Furcraea* (20 spp.). Dragon's blood is a dark red secretion from the leaves and trunk of *Dracaena draco* and *D. cinnabari*; the former is a native of the Canary Islands and Willis (*A Dictionary of the Flowering Plants and Ferns*, 1985) cites a tree blown down in 1868, 70 ft high and 45 ft in girth, that was supposed to be 6000 years old. Steroidal saponins have been reported as constituents of the resin (Y. Mimaki *et al*., *Phytochemistry*, 1999, **50**, 805). *D. cinnabari* was the source of commercial Socotra dragon's blood, the flavonoids of which have been studied (M. Masaoud *et al*., *Phytochemistry*, 1995, **38**, 745; 751). The resin is traditionally used as an astringent in the treatment of diarrhoea; it also has haemostatic and antiseptic properties. Chinese dragon's blood derived from *D. cochinchinensis* is reported to contain anti-*Helicobacter pylori* and thrombin inhibitory properties (Y. Zhu *et al*., *J. Nat. Prod*., 2007, **70**, 1570). For other products also known as dragon's blood, see *Daemonorops* spp. (Palmae) and *Croton lechleri* (Euphorbiaceae).

   Steroidal saponins occur in species of *Yucca*, *Agave* and *Furcraea*; *Sansevieria zeylanica* yields bow-string hemp and *Furcraea gigantea* Mauritius hemp. The leaves of *Agave sisalana* yield the fibre sisal which is produced in large quantities in Central America and Kenya; the fermented sap of this plant forms the Mexican drink pulque. Species of *Sansevieria* are common house-plants under the name of 'mother-in-law's tongue'. Alkaloids and cardenolides appear to be absent from the family but the constituents otherwise closely resemble those of the Liliaceae.
3. Amaryllidaceae. A family of 85 genera and about 1100 species; mostly tropical or subtropical, and often xerophytes. Many have bulbs or rhizomes. Perianth petaloid, A 3 + 3, G(3). Fruit a loculicidal capsule or berry. Genera include *Galanthus* (20 spp.), *Leucojum* (12 spp.), *Amaryllis* (1 sp.), *Nerine* (30 spp.), *Pancratium* (15 spp.), *Hymenocallis* (50 spp.), *Narcissus* (60 spp.), *Ungernia* (6 spp.), *Hippeastrum* (75 spp.) and *Sternbergia* (8 spp.). The family contains types of alkaloid unlike those of any other family in

the order. One of these alkaloids, lycorine, has a marked fungicidal action; another, galanthamine, obtained from *Leucojum aestivum* and other species, is a newly marketed drug for the treatment of Alzheimer's disease.

4. Hypoxidaceae. A family of seven genera and 120 species. Herbs from a tuberous rhizome or corm. Several *Hypoxis* spp. have found use in traditional medicine as anti-inflammatory and antitumour drugs. A lipophilic extract is marketed in Germany, and the dried corm in South Africa, for treatment of prostate hypertrophy. The genus contains phenolic glycosides of the norlignan type.
5. Dioscoreaceae. A family of five genera and about 750 species; tropical or warm temperate climbing herbs or shrubs. The plants have fleshy tubers (called yams) or rhizomes. The leaves are often arrow-shaped. Flowers dioecious. Fruit a capsule or berry. The genera are *Dioscorea* (over 600 spp.), *Tamus* (5 spp.), *Rajana* (25 spp.), *Stenomeris* (2 spp.). *Tamus communis*, the black bryony, is exceptional in that it grows in Europe. It is common in English hedgerows and its scarlet berries are poisonous; a number of phenanthrone derivatives have been reported from the rhizome as well as dioscin and gracillin. The yams of *Dioscorea batatas* contain abundant starch and are important foodstuffs in the tropics. Steroidal saponins are present in many species of *Dioscorea* and *Tamus* and their extraction has become an important industry (see Chapter 23).
6. Iridaceae. A family of more than 60 genera and 800 species. Found in both tropical and temperate regions. Many perennial herbs with corm (e.g. *Crocus*) or rhizome (e.g. *Iris*). Flowers hermaphrodite, regular or zygomorphic; P3 + 3 petaloid, A3, G(3), inferior (or rarely superior). The fruit is a loculicidal capsule with numerous seeds. The genera include *Crocus* (75 spp.), *Romulea* (90 spp.), *Sisyrinchium* (100 spp.), *Tritonia* (55 spp.), *Freesia* (20 spp.) and *Iris* (about 300 spp.). Products of this family are saffron, from *Crocus sativus*, and orris root, from species of *Iris*. Constituents include quinones (naphthoquinones and anthraquinones), aromatic ketones (e.g. in *Iris*), carotenoid pigments (e.g. in saffron), terpenoids (mono-, sesqui-, di-and tetraterpenoids), and flavonoids (anthocyanins, flavones, flavonols and isoflavones).

BROMELIALES

Bromeliaceae

The Bromeliaceae is the only family of the order and contains about 44 genera and 1400 species; mainly tropical and subtropical, xerophytes and epiphytes. Fruit a berry or capsule. These interesting plants vary very much in size and habitat; many are grown as house-plants or in greenhouses. Genera include *Bromelia* (40 spp.) and *Ananas* (5 spp.). *Ananas comosus* (syn. *A. sativus*) is the pineapple, the juice of which contains bromelain, a protein-splitting enzyme which can be used as an adjunct in the treatment of trauma and oedema arising from surgery and for soft tissue inflammation. It is cited as an aid to digestion and studies (*Gut*, 1998, **43**, 196) have suggested it as a possible cure for travellers' diarrhoea. The chemistry of the family requires more study, but many species contain gums and mucilages and there are reports of tannins, phenolic acids and flavonoids.

GRAMINALES

Gramineae

An order of one family.

The Gramineae contains about 620 genera and 10 000 species. Mostly herbs with fibrous roots; rarely shrubs or trees. Annuals, biennials and perennials almost universally distributed and many of great economic importance. Leaves alternate, with sheath; blade usually long and narrow; veins normally parallel. Inflorescence of numerous spikelets, with scales. Flowers bisexual, protected by palea; stamens usually three; ovary unilocular with one ovule. Fruit one-seeded, usually a caryopsis (rarely a nut or berry). Some important genera are *Bambusa* (70 spp.), *Arundinaria* (150 spp.), *Oryza* (25 spp.), *Arundo* (12 spp.), *Triticum* (about 20 spp.), *Agropyron* (100–150 spp.), *Hordeum* (20 spp.), *Secale* (4 spp.), *Avena* (70 spp.), *Sorghum* (60 spp.), *Zea* (1 sp.), *Saccharum* (5 spp.) and *Andropogon* (113 spp.), *Cymbopogon* (60 spp.), *Phalaris* (20 spp.) and *Vetiveria* (10 spp.). Products include bamboos of many different sizes, from species of *Bambusa* and *Arundinaria*, rice from *Oryza sativa*, wheat from *Triticum*, barley from *Hordeum*, rye from *Secale*, millet or guinea corn from *Sorghum vulgare*, maize or Indian corn from *Zea mays* and sugar cane from *Saccharum officinarum*. The tribe Paniceae, which includes *Andropogon*, *Cymbopogon* and *Vetiveria*, is rich in volatile oils. These grass oils are relatively cheap and are much used in perfumery, especially for scenting soap. They include citronella oils, lemon-grass and palmarosa (geranium) oils from species of *Cymbopogon*; oil of vetivert from *Vetiveria zizanioides*. The roots of the latter plant, khus-khus, are used both in perfumery and as a drug and are also woven into fragrant-smelling mats and fans.

The Gramineae contains a very wide range of constituents but a large proportion of the chemical work has been devoted to the above-mentioned foodstuffs, starches, sugar and volatile oils. Other constituents include 11 different classes of alkaloid (for details see R. D. Gibbs, *Chemotaxonomy of Flowering Plants*, Montreal, Canada: McGill University Press), saponins, cyanogenetic substances, phenolic acids, flavonoids and terpenoids.

PRINCIPES

Palmae

The order contains the single family Palmae.

The Palmae has 217 genera and about 2500 species. Widely distributed in the tropics and subtropics. Mostly trees with an unbranched stem bearing a crown of large, often branched leaves. The flowers are usually unisexual and regular, consisting of two trimerous whorls of small perianth leaves, six stamens and three superior carpels. The carpels may be free or united and develop into a berry, drupe or nut. The seeds contain a very small embryo but abundant endosperm. Important genera are *Phoenix* (17 spp.), *Sabal* (25 spp.), *Copernicia* (30 spp.), *Metroxylon* (15 spp.), *Calamus* (375 spp.), *Areca* (54 spp.), *Elaeis* (2 spp.), *Cocos* (1 sp.), *Phytelephas* (15 spp.), *Serenoa* (1 sp.) and *Daemonorops* (100 spp.). Of economic interest are the date palm, *Phoenix dactylifera*; sago from the stems of *Metroxylon rumpii* and *M. laeve*; rattan canes from species of *Calamus*; areca or betel nuts from *Areca catechu*; palm oil and palm kernel oil from *Elaeis guineensis*; coconut from *Cocos nucifera*; carnauba wax from *Copernicia cerifera*. The resin from species of *Daemonorops* gives the East Asian dragon's blood and this appears (1997) to be the only available commercial source; the constituents investigated are of flavonoid origin, some derived from 5-methoxyflavan-7-ol and 5-methoxy-6-methylflavan-7-ol. Isolated compounds have been named dracoflavans (A. Arnone *et al*., *J. Nat. Prod*., 1997, **60**, 971). For the botany, chemistry and therapeutic uses of this, and other types of dragon's blood (species of *Croton*, *Dracaena* and *Pterocarpus*), see D. Gupta *et al*., *J. Ethnopharm*., 2008, **115**, 361. The fruits of *Serenoa repens* (saw-palmetto) native to the S.E. coastal states of North America are a popular remedy for male impotence and are used in the treatment of the symptoms of benign prostate hyperplasia (q.v.). Seeds of *Phytelephas* spp. (*P. aequatorialis* in Ecuador) are the basis of the vegetable ivory industry (for a report see A. S. Barfod *et al*., *Econ. Bot*., 1990, **44**, 293).

In addition to the fixed oil, carbohydrates and leaf wax mentioned above, the family contains saponins, tannins, catechins, flavonoids, terpenoids and ketones. Alkaloids occur in *Areca*, but few have been found in other genera. Steroidal substances occur (e.g. estrone in the pollen of *Phoenix*).

SPATHIFLORAE

Araceae

The order consists of two families, the Araceae and the Lemnaceae. The latter, which contains only six genera and 30 species of aquatic herbs, is of little importance.

The Araceae has 115 genera and about 2000 species; mainly herbs or climbing shrubs and over 90% tropical; many members contain poisonous latex, the poison being destroyed by heat. The genera include *Acorus* (2 spp.), *Arum* (15 spp.), *Monstera* (50 spp.), *Dracuncula*, *Amorphophallus* and *Cryptocoryne*. Calamus or sweet flag rhizome is derived from the perennial herb *Acorus calamus*, which is widely distributed in damp situations in Europe and North America. Arum, also known as lords and ladies, cuckoo-pint and wake robin, is *Arum maculatum*, a common hedgerow plant in England. It and other species of *Arum* are poisonous; these plants contain amines and cyanogenetic compounds. Species of *Monstera* are often grown as house-plants. The rhizome of *Cryptocoryne spiralis* is known as 'Indian ipecacuanha'. *Amorphophallus campanulatus* is the elephant-foot yam. Many members of the family are cyanogenetic. Alkaloids, either pyridine or indole types, are reported in a few genera. Other constituents include saponins, tannins, phenolic acids, amines and terpenoids.

CYPERALES

Cyperaceae

The order contains the single family.

The Cyperaceae has about 90 genera and 4000 species; widely distributed herbs. Genera include *Cyperus* (550 spp.), *Scirpus* (300 spp.) and *Carex* (150–200 spp.). Formerly official in a number of pharmacopoeias were the rhizomes of *Carex arenaria* and *Cyperus rotundus*. Papyrus, used in ancient times as paper, is derived from *Cyperus papyrus*. Like some members of the Gramineae, certain species of *Scirpus* and *Ampelodesma* serve as host plants for species of *Claviceps* and produce ergot-like sclerotia. Other family constituents include volatile oils, tannins, phenolic acids, flavonoids and sesquiterpenoids.

SCITAMINEAE

Musaceae, Zingiberaceae, Cannaceae, Marantaceae

An order of five families.

1. Musaceae. A family of two genera and 42 species, namely *Musa* (35 spp.) and *Enseta* (7 spp.). The plants are giant herbs with 'false' aerial stems and sheathed leaves arising from a rhizome. Fruit a berry. Of economic importance are the fruits of *Musa paradisiaca* (plantain) and *M. sapientum* (banana), which are rich in starch; bananas constitute a food source of potassium. Manila hemp or abaca is derived from *Musa textilis*. Constituents of the family include starch and fructosans, phenolic acids, anthocyanins, terpenoids and sterols; only isolated examples of alkaloids (alkaloidal amine and an indole alkaloid) are reported.
2. Zingiberaceae. A family of about 49 genera and 1300 species. Perennial aromatic herbs with fleshy rhizomes and tuberous roots; flowers in racemes, heads or cymes. Perianth 6-merous, the outer calyx-like, the inner corolla-like. Two of the stamens modified as a petaloid labellum. Fruit a loculicidal capsule. Seed with perisperm. Genera include *Curcuma* (5 spp.), *Alpinia* (250 spp.), *Zingiber* (80–90 spp.), *Amomum* (150 spp.), *Elettaria* (7 spp.), *Aframomum* (50 spp.) and *Hedychium* (50 spp.). *Costus* (150 spp.) is included by Engler in the Zingiberaceae, but is sometimes separated as a distinct family. Its main difference from the other genera listed is that its aerial parts are not aromatic. Products of the family include turmeric, the rhizomes of *Curcuma longa*; ginger, the rhizome of *Zingiber officinale*; cardamom fruits from *Elettaria cardamomum*; and grains of paradise, the seeds of *Aframomum melegueta*. Volatile oils and pungent principles such as are found in ginger (q.v.) are a feature of the family. Other constituents include the colouring matters known as curcuminoids (see 'Turmeric'), tannins, phenolic acids, leucoanthocyanins, flavonoids, ketones and terpenoids. Only a few isolated examples of alkaloids have been reported.
3. Cannaceae. This family contains only the single genus *Canna* (55 spp.). The rhizome of *Canna edulis* yields the starch, Queensland arrowroot.
4. Marantaceae. A family of 30 genera and 400 species of tropical herbaceous perennials. The genus *Maranta* (23 spp.) contains *Maranta arundinacea*, the rhizome of which yields West Indian arrowroot.

MICROSPERMAE

Orchidaceae

The order contains a single family.

The Orchidaceae is one of the largest families of flowering plants, with some 735 genera, over 17 000 species and many hybrids. Cosmopolitan perennial herbs, some terrestrial but many tropical epiphytes (e.g. *Vanilla*). The ovary is inferior and the fruit a capsule; seeds very small and light. Genera include *Orchis* (35 spp.), *Cypripedium* (50 spp.), *Phalaenopsis* (35 spp.), *Dendrobium* (1400 spp.), *Liparis* (250 spp.), *Malaxis* (300 spp.), *Vanda* (60 spp.), *Cryptostylis* (20 spp.) and *Vanilla* (90 spp.). The glycosides of vanilla, which produce vanillin and other aromatic substances by slow enzymic change, have long been known. More recently, attention has been directed to the numerous alkaloids present in the family. Some of these are of an unusual indolizidine type, others are derivatives of indole, pyrrolidine and pyrrolizidine. Other constituents include phenolic acids, tannin, flavonoids, coumarins and terpenoids.

ANIMAL PRODUCTS

As with the Plant Kingdom, animals are classified into Phyla, Classes, Orders, Families, Genera and Species. Although the number of pharmacognostical products derived from animal sources is limited there has been, in recent years, an immense interest in the chemistry of many marine creatures as potential sources of drugs and biologically active materials. In this respect much research has been published on the simpler marine organisms, see G. Blunden in Trease and Evans 2002 *Pharmacognosy*, 15th ed., p. 18.

Listed below are selected animal phyla which embrace species of interest (the many animal products used in traditional medicines of Africa, India and the Orient are not included).

PROTOZOA

Unicellular microorganisms including parasites causing malaria (*Plasmodium*), sleeping sickness (*Trypanosoma*) and dysentery (*Entamoeba*). Some dinoflagellates (*Prorocentrum, Dinophysis*) produce polyether toxins responsible for some shell-fish poisoning.

PORIFERA

(Sponges)

Metabolites include bromophenols (antibacterial properties), cyclic peroxides and peroxyketals (antimicrobial, ichthyotoxic, cytotoxic activities), modified sesquiterpenes (antimalarial, antifungal, antibacterial, anticancer activities). Siliceous sponge spicules are often found in samples of kieselguhr and agar (q.v.).

COELENTERATA

(Jellyfishes, sea anemones, corals)

The soft coral *Plexaura homomalla* is a rich source of prostaglandin A_2 and *Sarcophyton glaucum* contains diterpenoids (sarcophytols A and B) which inhibit tumour promotion. As with the sponges there is much current biochemical interest in this phylum.

PLATYHELMINTHES

(Flatworms)

This phylum includes the Trematodes (the parasitic flukes such as the liver fluke and *Schistosoma*) and the Cestoda (tapeworms).

NEMATODA

(Roundworms)

Some are parasitic in man and animals.

MOLLUSCA

Class Gastropoda includes the snails, slugs and limpets. Some snails are vectors of parasites such as *Schistosoma*.

Class Lamellibranchia includes scallops, mussels, oysters and clams.

Class Cephalopoda includes the squids, cuttlefishes and octopuses. Cuttlefish bone (from *Sepia officinalis*) has been employed in dentifrices and as an antacid.

ANNELIDA

(Segmented worms)

Earthworms, lugworms and leeches (q.v.) belong to this phylum. The potent neurotoxic agent nereistoxin is obtained from the Japanese species *Lumbriconereis heteropoda*.

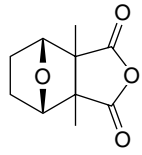
ARTHROPODA

A very large phylum of jointed animals including the crustaceans, insects and arachnids.

Class Crustacea includes the shrimps, crabs, lobsters, centipedes and millipedes. Of little medicinal significance, nevertheless brine shrimps are being increasingly used in place of higher animals for the preliminary testing of phytochemicals for toxicity.

Class Insecta. Of the many orders of this taxon the following have medicinal interest:

1. Order Anoplura (Lice): Commonly infest birds and mammals. Important from human standpoint is *Pediculus humanus* encountered as the body louse (*corporis*) and the head louse (*capitis*); it is a proven carrier of typhus fever and an indirect transmitter of relapsing fever.
2. Order Hemiptera (Bugs): The cochineal beetle (q.v.) is an important colourant and shellac is a resinous substance prepared from a secretion that encrusts the bodies of a scale insect *Laccifer lacca*.
3. Order Coleoptera (Beetles): Beetles of the genera *Cantharis* and *Mylabris*, known as blistering beetles contain cantharidin derivatives and possess vesicant properties. Preparations of *C. vesicatoria* were at one time used in Western medicine in the form of plasters, collodions etc. as rubefacients and vesicants. Their use continues in the traditional medicine of Eastern Asia (R. W. Pemberton, *J. Ethnopharmacology*, 1999, **65**, 181). The Chinese blister beetle, *M. phalerata*, is used in Chinese traditional medicine for the treatment of cancer; various novel cantharidin-related compounds have recently been described (T. Nakatani *et al*., *Chem. Pharm. Bull*., 2004, **52**, 8079; 2007, **55**, 92).



Cantharidin

A number of small beetles are important infestants of stored drugs (see Chapter 15).
4. Order Lepidoptera (Butterflies and moths): Some moths infest stored drugs (see Chapter 15). Silk has been traditionally used in pharmacy in the form of oiled silk.
5. Order Hymenoptera (Ants, bees, wasps, etc.): Hive products derived from *Apis mellifica* include honey, beeswax, royal jelly and propolis (q.v.).
6. Order Diptera (Flies, gnats and midges): The successful use of maggots in the treatment of wounds infected with antibiotic-resistant *Staphylococcus aureus* has received recent attention. Sterile larvae of the common greenbottle *Lucilia sericata* are used. For a report see *Pharm. J*., 1999, **262**, 422.

Class Arachnida. Arthropods with two divisions to the body (cephalothorax and abdomen) including spiders, scorpions and mites.

Order Acarina (Mites): the common housemite (q.v.) is a cause of allergy in humans; other species infest stored drugs (see Chapter 15).

CHORDATA

The most important subphylum of the Chordata is the Vertebrata (Craniata) composed of all those animals with backbones; a number of classification schemes will be found in the literature and two major groupings often referred to as superclasses are the Pisces (aquatic vertebrates) and the Tetrapoda (terrestrial vertebrates) each divided into four classes. The following four classes have medicinal significance:

1. **Class Osteichthyes** (Bony fish). The following families and species are important:

Gadidae: Cod Pleurnectidae: Halibut	Liver oils, sources of vitamins A and D
Engraulidae: Anchovies Carangidae: Jacks and pompanos Clupeidae: Herrings Osmeridae: Smelts Scombridae: Mackerels and tunas Ammodytidae: Sand eels Salmonidae: Trout, salmon, whitefish and graylings	Body oils, rich in omega-3 acids

2. **Class Amphibia** (Frogs and toads). Dried and powdered toadskins contain cardioactive principles and were used for the treatment of dropsy before the widespread adoption of digitalis.
3. **Class Reptilia** (Crocodiles, snakes and lizards). Snake venoms are important products.
4. **Class Mammalia** (Warm-blooded animals which suckle their young). Variously divided into subclasses, infraclasses and orders.

Subclass **Eutheria** embraces the placental mammals, e.g. bats, rodents, carnivores, whales, ungulates and primates. Formerly important was the whale-product spermaceti but its collection is now illegal. Other pharmaceuticals include lard, suet, wool fat, wool, gelatin, musk, catgut, heart-replacement valves from the pig, insulin, hormones, blood and liver products, vaccines and sera.