and everything that delays or tends to delay must be eradicated from our operations, if speed, accuracy, and comprehensiveness are to be attained. What, under other circumstances, is mere innocent thoughtlessness or harmless oversight may through cumulative action really have, in our case, the ultimate effect of "throwing a monkey wrench into the machinery" and that, I know, is wholly absent from the minds of our members.

In laying out the work to be undertaken by our Society we should endeavor to restrict it, at first, to those items which our Society can by itself do better than any other and then we can expand into those fields wherein we can coöperate effectively with other agencies, being throughout the whole mindful of such things as are specifically chemical and not of general nature, in and of themselves; that is, if we feel that we must have our heads in the clouds, our feet, nevertheless, should always be on the solid ground of chemistry.

There are a number of classes of our Society activities that must, in the very nature of things, proceed simultaneously such as setting and keeping our own house in order on the one hand and on the other hand the appropriate education of the general public and of government officials to the importance of our business in the life of the nation to the ultimate end that thereby the reciprocal obligations of the nation to its chemists and to those activities in which chemistry, in any of its varied phases is an essential or vital factor, will be fully recognized and properly discharged.

OUR OPPORTUNITY

For more than 120 years the chemists of this country have been telling our people and our Government over and over again to what extent and how chemistry is essential to national welfare and growth, and why the nation should foster chemistry. They have backed their faith by their own efforts. But somehow or other the country, as a whole, paid, or seems to have paid, little heed to them. It took this colossal nightmare of a war effectively to impress the cogency of those truths upon the public mind. The present is, therefore, particularly "Our Opportunity" so to coöperate in every direction as to clinch the advantages thus gained and to bring one step nearer to realization the vision our chemist forefathers had of the beneficent influence of chemistry upon our national life and greatness. Some of this clinching will be done by our Society and while it had organizational machinery fully capable of carrying such a load it cannot properly carry it unless we, either as individual members or as committee members or other Society officials, attend to it that that carefully planned and thoughtfully built organization shall function without delay, without friction, and at top speed at all needful times. We have reserved to ourselves, as members, in large measure the initiative in new matters and the execution of routine matters. Ours is, therefore, not only the sole responsibility but the golden opportunity, as well.

CONCLUSION

It must be clear to you that the main point of what I have said this evening is aimed solely at increasing the interest and the direct participation of our individual members and all our sections in all our Society's activities. I am convinced that such an increase is vital to the continued success of our Society. Nor do I pretend to have indicated, much less enumerated, all the ways in which our membership can display its interest and give wholesome effect to its participation. I am wholly confident that once the membership is satisfied that increases in those directions are necessary, these will be forthcoming, enthusiastically and promptly, any and all pessimists and doubting Thomases to the contrary, notwithstanding.

25 BROAD STREET
NEW YORK CITY

THE DISTRIBUTION AND CHARACTERS OF SOME OF THE ODOROUS PRINCIPLES OF PLANTS¹

By FREDERICK B. POWER

The substances which impart to many plants a particular and often characteristic odor are almost infinite in their variety, and comprise some of the most interesting compounds in the domain of organic chemistry. Many of them possess a cyclic structure, while others belong to the class of so-called aliphatic or open-chain compounds, which may be either saturated or unsaturated, and they include representatives of such various groups as the hydrocarbons, alcohols, aldehydes, ketones, phenols and phenol ethers, acids, esters, and lactones. Hydrocyanic acid, which may be regarded as the nitrile of formic acid, occurs among the products of distillation of many plants, and other nitriles represent the principal constituent of some essential oils, such, for example, as that of the nasturtium, *Nasturtium officinale*, Linné, which consists chiefly of phenylpropionitrile, $C_6H_5.CH_2.CH_2.CN$. It is well known that by the distillation of bitter almonds benzaldehyde and hydrocyanic acid are obtained, and that these substances, by prolonged contact, unite to form phenylxyacetoneitrile, $C_6H_5.CH(OH).CN$, which is therefore contained in varying amounts in the essential oil of bitter almonds. Other nitrogen compounds which are represented among the odorous constituents of plants are, for example, indole, C_8H_7N , which is a constituent of the essential oil of jasmine and of orange flowers, and its methyl derivative, skatole, C_9H_9N , which has been found in the wood of an East Indian tree, *Celtis reticulosa*, Miq. or *C. cinnamomea*, Lindl. Notwithstanding the fact that skatole possesses a strong fecal odor, it is employed, as is also indole, in the preparation of synthetic perfumes. Another interesting nitrogen compound, which appears to be somewhat widely distributed in nature and imparts to many floral products a quite distinctive odor, is the methyl ester of anthranilic acid, $C_6H_4(NH_2).CO_2CH_3$. This has been found in the essential oils of orange flowers (neroli), tuberose, jasmine, gardenia, and ylang-ylang, and also in the oils of sweet orange peel and bergamot leaves. A methyl derivative of methyl anthranilate, $C_6H_4(NH.CH_3).CO_2CH_3$, has been found in the essential oils obtained from the fruit and the leaves of the mandarin orange. Compounds containing sulfur as a characteristic constituent, the so-called mustard oils, are yielded by many plants belonging to the family of *Cruciferae*. Numerous sulfur compounds are likewise contained in liliaceous plants, such as the onion and garlic, as also in the gum resin, asafetida, a product obtained from various species of *Ferula*, belonging to the family of *Umbelliferae*.

Although the odorous principles of plants are frequently developed in some particular part or organ of them, such as the petals of the flower, of which examples are afforded by the rose and other fragrant blossoms, they are sometimes found in both the flowers and fruit, as in the orange tree, while in other instances they are contained chiefly in the foliage. It is also of interest to note that when totally distinct parts of a plant, such as the leaves and root, possess odorous or aromatic properties, the substances to which these properties are due may be quite different in character and have little or no direct chemical relationship. A particularly striking instance of this peculiarity is afforded by the essential oils obtained from the root and leaves, respectively, of the sassafras tree, *Sassafras varifolium* (Salisbury), O. Kuntze. The oil distilled from the root, especially the bark of the latter, contains among other substances safrol, camphor, and eugenol, which are not found in the leaves, while on the other hand the leaves contain the olefinic terpene, myrcene, together with citral, linalool, and geraniol, no one of which is contained in the root. Another instance of similar variations is that of the products from the Ceylon cinnamon tree, *Cinnamomum zeylanicum*, Breyne, the oils distilled from the root, leaves, and bark, respectively, being quite different in composition. In the oil from the root camphor is a characteristic constituent, whereas the oil from the leaves contains chiefly eugenol, and in that from the bark cinnamic aldehyde predominates.

It can naturally not be expected that such volatile products of plants as are comprehended under the designation of essential oils should be constant in composition, but, nevertheless, some remarkable differences, other than those already described, have been observed in oils distilled from the same species. Thus the phenol contained in the oil from the common garden thyme, *Thymus vulgaris*, Linné, is as a rule thymol, or isopropyl-metacresol, $C_6H_3.CH_3(1).OH(3).C_2H_5(4)$, but this is sometimes re-

¹ Address of the retiring president of the Chemical Society of Washington. Delivered before a joint meeting of the Chemical Society and the Washington Academy of Sciences, January 9, 1919.

placed partially or even entirely by the isomeric, liquid compound, carvacrol, which is isopropyl-*ortho*-cresol, $C_9H_8CH_3(1)$ - $OH(2)$. $C_9H_7(4)$. The conditions upon which the formation of one or the other of these compounds depends are not known, but variations in soil and climate certainly have in many cases a marked influence upon the constituents of a plant, and important changes often likewise take place on drying. The oil of lavender flowers, which is distilled in France from wild-growing plants (*Lavandula vera*, DC.) is characterized by containing a large proportion of the fragrant alcohol, linalool, $C_{10}H_{18}O$, and its esters, together with geraniol, whereas the oil distilled in England from cultivated plants contains a much smaller proportion of esters and a relatively large amount of cineol, $C_{15}H_{26}O$, a substance having a camphor-like odor, which occurs only in traces in the French oil.

The more or less characteristic odor which many plants possess rarely depends upon the presence of a single substance, but is usually due to a complex mixture of substances, in which, however, some one compound may largely predominate. These odorous principles are generally obtained by a process of steam distillation, and as such products are for the most part in the form of liquids which are sparingly soluble in water, they are comprehended under the broad title of essential oils or volatile oils, in French *essence*, an expression which serves in a way to differentiate them from the so-called fatty or fixed oils, which, however, differ appreciably in their physical and chemical characters. In cases where the oil does not pre-exist in the plant, but is formed by the hydrolysis of a glucoside, as in the mustard seed, bitter almond, gaultheria leaves, and sweet birch bark, a preliminary digestion with water is necessary before distillation. Some of the essential oils which become somewhat impaired by heat are obtained by expression, notably those of the citrus fruits, such as the orange, lemon, and bergamot. In other instances the odor of certain flowers is of so delicate a nature that it can only be obtained in a tangible form by extracting the material with a volatile solvent or by maceration with a fixed solvent, such as an oil or fat, either with or without the aid of heat. The use of heat in the process of maceration appears to be desirable for extracting the perfume from the violet and rose, as also from orange and cassia flowers, and this method of procedure is known by the French expression of *enfleurage à chaud*. For still more delicate flowers, such as those of the jasmine, tuberose, jonquil, lily of the valley, and mignonette, a process of cold maceration or *enfleurage à froid* is employed. This operation is conducted by spreading a specially prepared fat on both sides of a sheet of glass contained in a wooden frame, the apparatus being termed a *châssis*, and upon the upper surface of the glass the flowers are then strewn. These *châssis*, 35 to 40 in number, are placed one above the other in such a manner that the flowers are not only immersed in the fat but have a layer of fat above them to absorb any of the volatile substance exhaled. The length of time during which the flowers are allowed to remain in the *châssis* is said to be about 24 hrs. for jasmine, 48 hrs. for jonquil, and 72 hrs. for the tuberose, and the operation is usually repeated about 30 times in order that the desired degree of absorption or concentration of the perfume may be obtained. With each repetition of the process the arrangement of the *châssis* is reversed, the fresh flowers being strewn on the layer of fat which was previously on the under side of the glass, but which now becomes the upper side, in order to effect an equal distribution of the perfume. The reason for employing the cold method of extraction for certain flowers depends upon the interesting observation that the essential oil to which their fragrance is due does not exist ready formed, or at least in only very insignificant amount, but is continually produced during the life of the cells. If this vital activity were destroyed by means of a volatile liquid or the use of a warm fat the amount of perfume developed would be very greatly diminished. From the fat which has been more or less saturated with the perfume of the flowers—the so-called pomade—the odorous principles may be extracted by treatment with strong alcohol, and by exposing this extract to a low temperature the last portions of fat are separated. In this way many of the concentrated extracts are obtained which constitute the most highly esteemed floral perfumes.

On account of the exceedingly large number of odorous substances contained in plants, as already intimated, it would not be practicable to attempt to enumerate them or to present any classification in accordance with the various groups of organic compounds to which they belong. Such a plan would, moreover, be quite far removed from the purpose of the present paper, which is to indicate somewhat broadly the distribution of some of the more important of these substances in nature, and also to draw attention to some of the points of chemical interest connected with them. With this object in view a con-

sideration based chiefly upon the usual botanical classification of plants would appear to be the most practicable, and such a classification has indeed been adopted by some of the standard works which treat of the essential oils.

The *cryptogamous* or *flowerless plants* do not, as a rule, possess any very marked or distinctive odor, although in a few instances such properties have been observed in certain algae, fungi, lichens, and ferns. The essential oil or other individual substance to which this property is due is, however, always present in very small amount, and as the chemical character of these products is as yet but little known, they cannot be considered to possess any particular interest. The *phanerogamous* or *flowering plants*, on the other hand, contain such a variety of interesting odorous compounds that the selection of such a very limited number as can be considered at this time, and which may be deemed most appropriate for the present purpose, is rendered rather difficult.

CONIFERAE

In pursuance of the proposed plan, some of the more important odorous products which are yielded by the family of *Coniferae* may first be considered, and in connection therewith a few of the interesting compounds which are derived or prepared therefrom will be noted.

One of the essential oils which has been longest known, and which on account of its extended technical applications is generally familiar, is the oil of turpentine, a product obtained by steam distillation from the oleo-resinous exudation of various pines. Several varieties of this oil are known, but the two more important ones are of American and French origin. The American oil is obtained chiefly from *Pinus palustris*, Miller, and *P. heterophylla* (Ell.) Sudworth, and is usually dextrorotatory, while the French oil is yielded by *Pinus pinaster*, Solander, and is levorotatory. The chief constituent of these oils is pinene, $C_{10}H_{18}$, in either the *d* or *l* form, or a mixture of them, and this terpene is also found in a large number of other plants. It is now known, moreover, that the optical isomerides may occur in two distinct forms, which are designated as α and β , and as these differ in their structure they show marked differences in their chemical behavior. In contact with dilute mineral acids pinene is readily converted into the handsomely crystalline compound terpin hydrate, $C_{10}H_{18}(OH)_2 \cdot H_2O$, a primary product of this reaction being terpineol, $C_{10}H_{17}OH$. The terpineol of commerce is usually prepared by the action of dilute sulfuric acid on terpin hydrate, and the liquid product so obtained is the basis of the lilac perfumes. This liquid is, however, not a homogeneous substance, but a mixture of isomeric, crystallizable compounds which are designated as α and β terpineol, and the presence of a liquid terpinenol, $C_{10}H_{18}O$, has also been established. Terpineol is found in nature, but apparently only in the active or inactive α form. In the dextrorotatory modification it occurs in cardamom and linaloe oils, and in the oils of sweet orange, neroli, and lovage root. The levorotatory modification has been found, among other sources, in camphor oil, in the oil from the leaves of the camphor tree, linaloe oil, and the oil of Canada snake root, while in the inactive form it has been obtained in the solid state from cajuput oil, and as a liquid from the oils of nutmeg and boldo leaves.

By the action of concentrated sulfuric acid on oil of turpentine the preparation known as terebene is obtained, which is used to a considerable extent medicinally. This is not an individual substance, but a mixture of hydrocarbons, consisting chiefly of camphene, dipentene, terpinene, and cymene.

In connection with oil of turpentine a brief reference may be made to the subject of synthetic camphor, since it forms the starting point for the technical production of this substance. A number of different methods have been suggested or employed from time to time, which have mostly been the subject of patents, and only one or two illustrations of them need here be given. By leading dry hydrogen chloride into completely dry and cooled pinene, the so-called pinene hydrochloride, or more properly bornyl chloride, $C_{10}H_{17}Cl$, is obtained. As this is a crystalline compound having a camphor-like odor, it formerly received the incorrect appellation of "artificial camphor." By the subsequent elimination of hydrogen chloride from bornyl chloride there is obtained the terpene, camphene, which is of interest as being the only solid hydrocarbon of the formula $C_{10}H_{16}$ which occurs in nature. On treating camphene with glacial acetic and sulfuric acids isobornyl acetate is formed, which on hydrolysis, and subsequent oxidation of the isoborneol, yields camphor. Another method consists in forming an ester of borneol by the action of anhydrous oxalic acid on oil of turpentine, and then subjecting the ester successively to hydrolysis and oxidation.

The essential oils distilled from pine needles differ markedly in character from the proper turpentine oils, as in them the

pinene is replaced to a considerable extent by other terpenes, such as camphene, limonene or dipentene, phellandrene, sylvestrene, and cadinene, and they also contain especially notable proportions of the acetic ester of borneol, amounting in the oil of the hemlock-spruce, *Abies canadensis*, Michaux, or *Tsuga canadensis*, Carr, to as much as 50 per cent. This ester possesses the characteristic fragrant odor of the pine and is used in perfumery.

The resinous balsam obtained from the so-called "Nut Pine" or "Digger Pine," *Pinus sabiniana*, Douglas, is of particular interest inasmuch as it yields on distillation an essential oil which differs completely in composition and properties from the turpentine oils. It is stated to have been first prepared in California during the Civil War, when the production of turpentine in the southern states had ceased, and was brought into commerce for cleansing purposes under various fanciful names, such as abietene, erasine, etc. This oil, like that from *Pinus jeffreyi*, Murray, a pine growing at higher altitudes in the Sierra Nevada mountains, has been found to consist almost entirely of normal heptane, C_7H_{16} , identical with that found in petroleum.

Another product from a coniferous plant is the oil of juniper, which is distilled from the berries of *Juniperus communis*, Linné. This has been found to contain, among other substances, pinene, borneol, and isoborneol, terpinenol, and cadinene. It is chiefly employed in the manufacture of Holland gin, which is said to owe to it its peculiar flavor and diuretic properties.

The wood of the so-called red cedar, *Juniperus virginiana*, Linné, has long been used in the manufacture of cigar boxes, lead pencils, and other articles, and its odor is due to a viscid essential oil, which is considerably used for perfuming soap. This oil contains a sesquiterpene, termed cedrene, $C_{15}H_{24}$, and a sesquiterpene alcohol, cedrenol, $C_{15}H_{24}O$. The leaves of this tree yield on distillation a limpid essential oil which differs entirely in its composition and properties from that obtained from the wood, its constituents being pinene, limonene, borneol, both in the free state and as an ester, and the sesquiterpene, cadinene, $C_{15}H_{24}$. The oil of cedar leaves of commerce appears to be distilled chiefly from the leaves of *Thuja occidentalis*, Linné, commonly known as the *arbor vitae* or white cedar, and consists chiefly of pinene, *l*-fenchone, and thujone. The leaves of *Juniperus sabina*, Linné, or savin, yield an essential oil which is used to some extent medicinally. Its most important constituent is an alcohol, sabinol, $C_{10}H_{18}O$, which is present both in the free state and as an ester, and it has also been found to contain citronellol, geraniol, and a dihydrocumyl alcohol, $C_{10}H_{18}O$. The latter two compounds likewise occur together in ginger-grass oil.

GRAMINEAE

The *Gramineae* (grass family) yield a number of fragrant essential oils which are used to a very large extent in perfumery, and are therefore of great commercial importance. Among this class of products the following oils and their botanical sources may briefly be noted:

Palmarosa oil, also known as East Indian geranium oil, is obtained from *Cymbopogon martini*, Stapf, a plant which was formerly referred to the genus *Andropogon*, and under this botanical name it has many botanical synonyms. A variety of the same plant yields the so-called ginger-grass oil. Lemon-grass oil is likewise obtained from species of *Cymbopogon*, which differ according to the source of production of the oil. *Cymbopogon flexuosus*, Stapf, which is distilled in the East Indies, yields the lemon-grass oil of commerce, whereas on the Malabar coast an oil of somewhat different character is distilled from *C. citratus*, Stapf. Citronella oil is distilled in Ceylon and Java from the grass *Cymbopogon nardus*, Rendle. Vetiver oil, unlike the other grass oils, is distilled from the root of the plant, which in India is known as "Cus-cus" or "khas-khas," meaning an aromatic root. The plant is now botanically referred to as *Vetiveria zizanioides*, Stapf. In India the roots of the vetiver have long been employed for making baskets, as also for screens and mats, which are placed in doorways or hung over windows, and in hot weather are frequently sprinkled with water, when they serve to cool and perfume the air.

With regard to the chemical constituents of the grass oils, it may be noted that palmarosa oil, which has a pleasant rose-like odor, consists to a large extent of the aliphatic terpene alcohol, geraniol, $C_{10}H_{18}O$, together with a relatively small proportion of its esters. The name geraniol was in fact first applied to the compound obtained from this source, but it has since been found to be a predominating constituent of the otto of rose, and is contained in numerous other essential oils. The commercial importance of palmarosa oil may be indicated by the fact that the amount annually exported from Bombay has been estimated to be about 50,000 lbs. This, however, is considered to

relate only to the oil produced in Bombay and the central provinces of India, for in the year 1902-3 the actual amount exported was 125,000 lbs., and this is attributed to the greatly increased production of the southern provinces. In the year 1905-6 the total amount of essential oils exported from Bombay was 23,436 gals., representing a value of approximately \$250,000. This consisted chiefly of palmarosa oil, only about one-fourth having been ginger-grass oil.

Ginger-grass oil consists chiefly of a mixture of geraniol and a dihydrocumyl alcohol, the odor of the latter recalling that of both linalool and terpineol. Besides these compounds there are relatively small amounts of *d*-phellandrene, dipentene, *d*-limonene, isocarvone, and other substances.

Lemon-grass oil, which possesses a strong lemon-like odor, contains as its most important constituent the aliphatic aldehyde, citral, $C_{10}H_{16}O$. This compound, which is an essential constituent of lemon oil and is quite widely distributed in nature, is the aldehyde corresponding to geraniol, from which it may readily be obtained by oxidation. Citral, apart from its individual value as a constituent of many fragrant oils, is of particular interest and importance from the fact that from it, by condensation with acetone, there is produced the substance known as ionone, which is the basis of the artificial violet perfumes. In the first step of this process citral and acetone, in the presence of alkalis, condense with the elimination of water to form a compound termed pseudo-ionone:

The pseudo-ionone, when heated with acids or acid salts, is converted into an isomeric, unsaturated, cyclic ketone, termed ionone, $C_{18}H_{20}O$, which possesses a characteristic violet odor. This interesting compound will subsequently be further considered.

Citronella oil is largely employed for perfuming the cheaper kinds of soap, and is of very complex composition. The constituent to which its characteristic odor is most largely due is an aldehyde of the formula $C_{10}H_{18}O$, which has been termed citronellal. Other oxygenated compounds contained in the oil are *l*-borneol, nerol, geraniol, esters of geraniol and citronellol, and eugenol methyl ether, together with the terpenes camphene, dipentene, *l*-limonene, and one or more sesquiterpenes. The amount of citronella oil exported from Ceylon in 1911 was 1,524,275 lbs., and in 1917 Java exported 1,137,051 lbs.

Vetiver oil, which is used in perfumery, is more or less viscid in character and possesses a high boiling point. Its constituents have not been sufficiently studied as yet to render their consideration of special interest.

PALMAE

The palm family does not contain many odorous substances. It may be considered of interest to note, however, that by treating crude coconut oil with steam under pressure for the purpose of rendering it edible an essential oil of unpleasant odor is obtained. This has been found to contain methylheptylketone, $CH_3CO.C_7H_{15}$, and methylnonylketone, $CH_3CO.C_9H_{19}$, and the corresponding carbinols, $CH_3CH(OH).C_7H_{15}$ and $CH_3CH(OH).C_9H_{19}$. These compounds also represent the chief constituents of an Algerian oil of rue, but while the alcohols obtained from coconut oil are dextrorotatory, those from rue oil are levorotatory. It has recently been ascertained that palm kernel oil, when subjected to similar treatment, yields an essential oil which consists to the extent of 90 per cent of methylnonylketone.

LILIACEAE

It has already been indicated that several plants belonging to the family of *Liliaceae* yield essential oils which consist to a large extent of sulfur compounds, such, for example, as the garlic, *Allium sativum*, Linné, and the common onion, *Allium cepa*, Linné. It was for a long time assumed that the chief constituent of the oil of garlic is allyl sulfide, $(C_2H_5)_2S$, but it has more recently been shown that this is not contained in either the oil of garlic or that of the onion, both of which consist of mixtures of much more complex sulfur compounds. The same family is represented by plants with such fragrant blossoms as the hyacinth, *Hyacinthus orientalis*, Linné, and the lily of the valley, *Convallaria majalis*, Linné. The substances to which the perfume of the last-mentioned flowers is due have not as yet been fully investigated, but it is known that the hyacinth contains benzyl benzoate, with probably free benzyl alcohol, and also esters of cinnamic alcohol. The odors have been well imitated in various artificial oils and extracts, the exact composition of which is generally a trade secret, but it may be noted that phenylacetic aldehyde, $C_6H_5.CH_2.CO.H$, possesses an intense hyacinth-like odor, and is considerably used in perfumery. The fragrance of the lily of the valley appears to be due, at least in part, to the presence of the aliphatic sesquiterpene alco-

which imparts to various species of *Melilotus* or sweet clover the familiar fragrant odor, and is also found in considerable amount in the leaves of *Tritisia odoratissima*, Cass. (*Liatris odoratissima*, Willd.), the so-called deer's tongue or hound's tongue, an herbaceous composite plant which is common in the low pine barrens of Virginia and southward.

Coumarin is largely used in perfumery, and it is said to be the principal ingredient in the artificial extract of new-mown hay, the odor of which it closely resembles. It is probably now produced entirely by synthetic methods, one of which, known as the Perkin synthesis, consists in the action of acetic anhydride and anhydrous sodium acetate on salicylic aldehyde.

Another crystalline synthetic compound, which has been considerably employed for perfuming soap, was introduced into commerce some years ago under the fanciful name of "nerolin." This is the methyl ether of β -naphthol, $C_{10}H_7OCH_3$. Although its odor somewhat resembles that of the oil of neroli or orange flowers, it bears no chemical relationship to any of the constituents of this fragrant oil. The corresponding ethyl ether, which differs somewhat in odor from the methyl compound, has been used for a similar purpose.

ARISTOLOCHIACEAE

The family of *Aristolochiaceae* is represented by a few plants which possess aromatic properties, and among these there may be noted some species of *Asarum*. The rhizome and roots of the very unpretentious American plant, *Asarum canadense*, Linné, commonly known as Canada snakeroot, yield on distillation with water a highly aromatic essential oil, which has been used to a considerable extent in perfumery. This oil is of very complex composition, containing, besides a small amount of pinene, the fragrant alcohols *d*-linalool, geraniol, *l*- α -terpineol, and *l*-borneol, both in the free state and as esters, eugenol, and a large amount of eugenol methyl ether, together with an oil of a deep blue color, and other substances. Another American species of *Asarum*, namely *A. arifolium*, Mich., yields an oil which possesses a sassafras-like odor, and consists chiefly of safrol, with smaller amounts of eugenol and its methyl ether, *l*-pinene, and asarone. The crystalline compound asarone, $C_{12}H_{10}O_2$, is a propenyltrimethoxybenzene,

and was first found more than a hundred years ago in the essential oil of *Asarum europaeum*, Linné, from which it separated in the solid state. In accordance with a custom of that time it was designated as "*asarum camphor*," the term camphor having formerly been applied to a great variety of solid substances which were obtained in this manner, such, for example, as menthol, which was known as "peppermint camphor." It is remarkable that the oil of *Asarum europaeum* appears to contain none of the fragrant alcohols which are present in the *Asarum canadense*, since the two species are botanically so closely related, and on the other hand the oil from the last-mentioned American plant contains no asarone.

A Chinese species of *Asarum*, namely *A. blumei*, Duch., is said to yield an essential oil possessing a sassafras-like odor, and in which the presence of safrol has been determined.

ANNONACEAE

One of the essential oils of most exquisite fragrance is that distilled from the flowers of *Cananga odorata*, Hooker f. et Thomson, a tree belonging to the family of *Annonaceae*, which is distributed throughout the entire tropical portion of eastern Asia. In Manila the tree is known as "ylang-ylang," but in most of the provinces of the Philippines as "atangilang," a word which is said to denote something loosely pendent and fluttering, for the flowers as well as the branches of the older trees are drooping and readily stirred by the wind.

The finest ylang-ylang oil, which is used in the preparation of some of the choicest perfumes, is obtained from the Philippines, although the tree has also been cultivated in the islands of Java and Réunion for the production of the essential oil. The composition of the oil is exceedingly complex, and its constituents do not appear as yet to have been fully determined. It is, however, known to contain *l*-linalool and geraniol, which are probably present in part in the form of acetic and benzoic esters, eugenol and eugenol methyl ether, methyl benzoate and salicylate, benzyl acetate and benzoate, and free benzyl alcohol. A constituent which also contributes to the characteristic odor of the oil is the methyl ether of *p*-cresol, $CH_3 \cdot C_6H_4 \cdot OCH_3$. Formic acid and safrol have also been found, and a small amount of methyl anthranilate has been assumed to be present. The terpenes *d*- α -pinene and cadinene are likewise contained in the oil.

The oil distilled in Java, which is known in commerce as cananga oil, has been found to contain the aliphatic alcohol nerol, $C_{10}H_{18}O$, and the sesquiterpene alcohol farnesol, $C_{15}H_{26}O$, which has already been mentioned as a constituent of several fragrant flowers.

MYRISTICACEAE

The family of *Myristicaceae* yields the familiar products known as nutmeg and mace, which, on account of their aromatic properties, are largely employed for flavoring purposes or as a spice. The essential oil of nutmeg has in recent years been very completely examined, and has been shown to be very complex in composition, since more than twenty distinct chemical compounds have been identified among its constituents. The more important of these substances may be briefly enumerated, without consideration of the proportions in which they occur in the oil, as follows: α - and β -pinene, camphene, dipentene, *p*-cymene, *d*-linalool, terpinenol, borneol, α -terpineol, geraniol, safrol, eugenol and isoeugenol, eugenol methyl ether, myristicin, and various volatile acids. The substance termed myristicin, $C_{11}H_{12}O_3$, is 3-methoxy-4,5-methylene dioxy-1-allyl benzene. It represents the highest boiling constituent of the oil, and to it are due the narcotic effects of the nutmeg, such as have been observed in cases of so-called "nutmeg poisoning." It is also of special chemical interest from the fact that by a complicated series of reactions it has been found possible to pass from it to the basic substance known as cotarnine or stypticine, $C_{12}H_{15}O_4N$, which is an oxidation product of the opium alkaloid narcotine, $C_{22}H_{23}O_7N$.

LAURACEAE

The family of *Lauraceae* includes a number of plants which afford products that are not only of exceptional chemical interest but also of great economic importance. There may be mentioned in the first place the camphor tree, *Cinnamomum camphora*, Nees et Ebermayer, which is indigenous to southern China, Formosa and Japan. This tree affords the well known commercial products, camphor and camphor oil, which are at present produced most largely in Formosa and are obtained by the distillation of the wood with steam. Relatively small amounts of camphor have also been found in a considerable number of essential oils.

The ordinary camphor or *d*-camphor, which is chemically

a ketone, $C_{10}H_{16}O$, or, as it may be written, $C_8H_{14} \begin{cases} \text{CH}_2 \\ \text{CO} \end{cases}$, is too

well known to need description. It belongs to the class of hydroaromatic compounds, and there are probably few substances which have been the subject of such extended chemical investigation, more especially for the purpose of determining its constitution, which has now been definitely established.

Enormous amounts of camphor are consumed in the arts, especially in the manufacture of celluloid, and it enters into the composition of some smokeless powders, while considerable quantities are likewise used for disinfecting and medicinal purposes.

Camphor oil is a by-product in the Japanese camphor industry, and is of exceedingly complex composition, as no less than twenty-five distinct chemical substances have been identified among its constituents. It contains several terpenes, such as pinene, camphene, fenchene, phellandrene, dipentene, and limonene, together with a number of oxygenated compounds, among which camphor and safrol may be considered the most important. Safrol, $C_{10}H_{10}O_2$, is the chief constituent of sassafras oil, which will presently be mentioned, and it was first obtained from this source, but it can be produced much more cheaply from camphor oil. It is largely employed for perfuming soaps, and also, after its conversion into isosafrol, for the production of piperonal or heliotropin, as has already been mentioned.

The sassafras tree, *Sassafras variifolium* (Salisbury) O. Kuntze, is distributed throughout the greater part of the United States, and is particularly abundant in the eastern and southeastern sections. The bark of the root is highly aromatic, and yields on distillation with steam from 6 to 9 per cent of essential oil, whereas the woody portion yields less than 1 per cent. The oil contains about 80 per cent of safrol, together with terpenes, *d*-camphor, and a small amount of eugenol. The characteristic odor of the oil is due to safrol, which is the methylene ether of *m*-allylcatechol:

and has been found in relatively small portions in several other oils. This substance, which seems to have first been observed

as early as 1738, was formerly known as "sassafras-camphor." At low temperatures it separates from the oil in crystals which are sometimes as much as 4 in. in length and an inch in diameter, and which melt at 8° C. It is of interest to note that camphor oil contains the same constituents as sassafras oil, and when carefully fractionated to remove the portions of lower density and boiling point a product may be obtained which is scarcely distinguishable from genuine sassafras oil. Such a product has indeed been brought into commerce under the incorrect and rather misleading appellation of "artificial sassafras oil." The remarkable difference in composition of the oils obtained from the root and the leaves of the sassafras tree has already been indicated.

Another American plant which is deserving of mention in this connection is the California laurel or mountain laurel, *Umbellularia californica*, Nutt. The leaves of this tree yield from about 2 to 5 per cent of an essential oil, the odor of which is at first agreeably aromatic and somewhat camphoraceous, but when strongly inhaled is exceedingly pungent, affecting particularly the mucous membranes of the nose and eyes and causing a flow of tears. These properties are due to the presence of a ketone of cyclic structure, which has the empirical formula $C_{10}H_{14}O$, and has been designated umbellulone. When heated in a sealed tube for several hours at 280°, umbellulone is converted quantitatively, through a simple molecular transformation, into thymol. Besides umbellulone, which is the chief constituent, the oil contains pinene, and small amounts of eugenol and safrol, together with eugenol methyl ether.

Some plants of the laurel family that are indigenous to the Far East yield aromatic products of considerable commercial importance, such as the essential oils of cinnamon and cassia. The true oil of cinnamon is distilled from the bark of Ceylon cinnamon, *Cinnamomum zeylanicum*, Nees, whereas cassia oil, which is sometimes known as the oil of Chinese cinnamon, is obtained from *Cinnamomum cassia*, Blume, and for its production both the leaves and twigs appear to be employed. Although both of these oils contain cinnamic aldehyde, $C_6H_5 \cdot CH : CH \cdot COH$, as their chief and most important constituent, that from the Ceylon cinnamon possesses the more delicate odor, and is therefore more highly esteemed, especially for use in perfumery. The other compounds which have been found to be contained in Ceylon cinnamon oil are pinene, phellandrene, methylamylketone, benzaldehyde, nonyllic aldehyde, cumic aldehyde, linalool, eugenol, and the sesquiterpene caryophyllene. The constituents of cassia oil, other than cinnamic aldehyde, are cinnamyl acetate, benzaldehyde, salicylaldehyde, methyl salicylaldehyde, methyl *o*-coumaric aldehyde, benzoic and salicylic acids, and coumarin.

Considerable amounts of cinnamic aldehyde are now produced synthetically by the condensation of benzaldehyde with acetic aldehyde.

CRUCIFERAE

It has already been noted that many plants belonging to the family of *Cruciferae* yield volatile products which consist to a large extent of sulfur compounds and are known by the generic name of "mustard oils." These oils do not generally pre-exist in the plant, but are formed by the action of a particular ferment or enzyme on a glucoside, and they consist as a rule of esters of isothiocyanic acid, HNCS. A typical example of a mustard oil is that obtained from the seeds of the black mustard, *Brassica nigra*, Koch, and *Brassica juncea*, Hooker f. et Thomson, and this oil consists almost entirely of allyl isothiocyanate, $CH_2 : CH \cdot CH_2 \cdot NCS$. It is produced by the action of the ferment myrosin on the glucoside sinigrin (potassium myronate), when besides the volatile mustard oil, dextrose and potassium hydrogen sulfate are formed:

This mustard oil is also produced on a large scale synthetically by the action of allyl iodide on potassium thiocyanate in alcoholic solution, the heat employed in the operation causing the molecular transformation of the allylthiocyanate first formed into the isothiocyanate.

The white mustard seed, from *Sinapis alba*, Linné, differ essentially in composition from those of the black mustard, and do not yield a volatile product on distillation. They contain the very complex glucoside sinalbin, which by the action of myrosin, in the presence of water, yields the so-called sinalbin mustard oil, dextrose, and the acid sulfate of a base termed sinapine:

The sinalbin mustard oil, or parahydroxybenzylisothiocyanate, $C_6H_4 \cdot OH \cdot CH_2 \cdot NCS$, is an oily liquid which is not vola-

tile in steam or at least only in traces. It possesses a burning taste, and causes blisters when brought on the skin, but only develops a pungent odor on heating.

A volatile oil obtained from rape seed, *Brassica napus*, Linné, or *B. campestris*, Linné, by the same method as that employed in the distillation of black mustard, has been found to consist of crotonylisothiocyanate, $CH_2 : CH \cdot CH_2 \cdot NCS$.

Cochlearia officinalis, Linné, the so-called scurvy-grass or spoonwort, yields a ferment oil, the chief constituent of which is the isothiocyanate of secondary butyl alcohol, $CH_3 \cdot CH_2 \cdot (CH_3) \cdot CH \cdot NCS$. The essential oil obtained from the root of the horse-radish, *Cochlearia armoracea*, Linné, appears to be identical in composition with the oil of black mustard seed, and, like the latter, is a ferment oil.

Inasmuch as the flowers of the garden mignonette, *Reseda odorata*, Linné, family of *Resedaceae*, possess a delicate fragrance, it is remarkable that the fresh roots of this plant, when distilled with steam, yield a product which belongs to the class of mustard oils. This oil, which has a radish-like odor, consists chiefly of phenylethylisothiocyanate, $C_6H_5 \cdot C_2H_4 \cdot NCS$.

ROSACEAE

Any attempted description of the odorous constituents of plants would certainly be incomplete without consideration of the rose, whose exquisite perfume, as well as beauty of form and color, certainly entitle it to be designated as the "queen of flowers." Although several thousand varieties of the rose have been produced by cultivation, there are but a few species employed for the distillation of the essential oil, known as the otto or attar of rose, or for the production of rose water and rose pomade. The rose which is cultivated in the Balkans, in southern Bulgaria, where by far the largest proportion of oil is produced, is *Rosa damascena*, Mill., and the same species has been successfully cultivated in Germany, near Leipzig, for the purpose of obtaining the oil. In southern France, where the rose is cultivated chiefly for the production of rose water and the preparation of rose pomade, the species employed is the *Rosa centifolia*, Linné.

The otto of rose, as has been seen to be the case in so many other odorous products, is somewhat complex in composition. Although the aliphatic alcohol geraniol, $C_{15}H_{17}H$, is the predominating constituent, the peculiar fragrance of the oil is due in part to the presence of a number of other compounds, such as *l*-linalool, *l*-citronellol, nerol, phenylethyl alcohol, citral, *n*-nonylic aldehyde, eugenol, and an aliphatic sesquiterpene alcohol, $C_{15}H_{26}O$, which apparently is identical with farnesol.

Another important product of the rose family, although not itself imparting an odor to the plant, is the essential oil of bitter almonds. This oil, as is well known, does not pre-exist, but is formed, together with hydrogen cyanide, by the action of an enzyme on the glucoside amygdalin, $C_{20}H_{27}O_{11}N$. It is said that for the technical production of the oil, apricot kernels are chiefly used, since they yield an oil identical in composition with that from the bitter almond, and are available in larger quantities. In either case the fatty oil is first removed from the kernels before they are subjected to distillation.

GERANIACEAE

An oil somewhat similar in character to the otto of rose is that of the rose geranium, which is distilled from the leaves of various species of *Pelargonium*. The species of this plant, or their cultivated varieties, which have been considered to be the source of the oil, are *Pelargonium odoratissimum* (Sol.) Ait., *P. capitatum*, Ait., and *P. roseum*, Willd., but it has quite recently been stated that in Algeria *P. graveolens*, Ait., is exclusively cultivated for this purpose.

The oil of rose geranium, of which several commercial sorts are known, has a pleasant rose-like odor. Its chief constituent is the alcohol geraniol, $C_{15}H_{17}OH$, but it also contains several other alcohols, such as citronellol, linalool, terpineol, and phenylethyl alcohol, partly in the form of esters, together with small amounts of menthone, citral, and terpenes. It may be well again to recall the fact that the so-called East Indian geranium oil, known also as palmarosa oil, is not obtained from a *Pelargonium*, but from a grass belonging to the genus *Cymbopogon*.

MYRTACEAE

The family of *Myrtaceae* yields some valuable aromatic products to which at least a brief reference should here be made. One of these products is the familiar spice, the clove, which consists of the dried flower buds of *Eugenia aromatica* (Linné), O. Kuntze. The aromatic properties of the clove are due to an essential oil, which is yielded by the variety known commercially as Zanzibar cloves to the extent of 15 to 18 per cent. The most valuable and characteristic constituent of the oil is the phenol known as eugenol, $C_{10}H_{12}O_2$, or the methyl ether of dihydroxyallylbenzene, $C_6H_3 \cdot C_3H_5(1) \cdot (OCH_3)(3) \cdot OH(4)$, of which it con-

tains from 70 to 85 per cent. Although eugenol has a strong, clove-like odor, this is modified in the oil by the presence of small amounts of other substances, such as eugenyl acetate, methyl-amyketone and a sesquiterpene, $C_{15}H_{24}$, termed caryophyllene.

Eugenol is used to some extent in medicine and perfumery, but chiefly in the manufacture of vanillin, for which purpose it is converted by the action of alkalies into the more readily oxidizable isoeugenol, the isomerism consisting in the change of the allyl to a propenyl group. Isoeugenol is of further interest, inasmuch as it is said to form the basis of the carnation perfumes, which represent the odor of the garden carnation or clove pink, *Dianthus caryophyllus*, Linné.

The oil of pimenta or allspice, distilled from the unripe fruit of *Pimenta officinalis*, Lindley, is similar in composition to clove oil, inasmuch as it consists chiefly of eugenol and a sesquiterpene.

Bay oil, which is used to a considerable extent in perfumery, and especially for the preparation of the refreshing spirit known as bay rum, is distilled from the leaves of the West Indian tree, *Pimenta acris*, Wight, and possibly other closely related species of *Pimenta*. The oil contains from about 50 to 65 per cent of the phenols, eugenol and chavicol, together with their methyl ethers, citral, phellandrene, and the olefinic terpene $C_{10}H_{16}$, which has been designated myrcene. The occurrence of this compound in bay oil is of special interest, inasmuch as it was the first representative of its class. On hydration it is converted into a fragrant alcohol having the characteristics of linalool, $C_{10}H_{17}.OH$.

The essential oils distilled from the leaves of various species of *Eucalyptus* represent an exceedingly important class of natural products, which are also of great chemical interest. These oils have been distilled chiefly in Australia, where the products from more than 160 distinct species of the genus have been investigated with respect to their chemical constituents.

On account of the great variation in the character and composition of the eucalyptus oils only a very brief reference can here be made to them. One of the most important constituents is the compound known as cineol, $C_{10}H_{18}O$, which is sometimes designated as eucalyptol. This is contained in large proportions in the oils from *Eucalyptus polybractea*, *E. smithii*, and *E. australiana*, the latter having formerly been considered by botanists to be *E. amygdalina*, and these species are therefore now most extensively utilized in eastern Australia for the production of oil for pharmaceutical or medicinal purposes. Another important species which is now known as *Eucalyptus dives*, but was formerly classified as a variety of *E. amygdalina*, yields an oil which consists principally of levorotatory phellandrene, $C_{10}H_{16}$. The oil from *Eucalyptus macarthuri* is said to contain 60 per cent of geraniol and geranyl acetate, and is therefore valuable in the preparation of perfumes, while that from *E. citriodora* consists to the extent of 80 to 90 per cent of citronellal, $C_{10}H_{18}O$, and is much used for perfuming soap. *Eucalyptus staigeriana* yields an oil which possesses an odor resembling that of the lemon or verberna, and consists chiefly of citral, $C_{10}H_{16}O$, together with terpenes.

Cineol, at ordinary temperatures, is an optically inactive liquid, which possesses a camphor-like odor, but at a temperature of $+1^{\circ}C$. it forms a crystalline solid. With reference to its constitution it occupies a somewhat unique position among the constituents of essential oils, inasmuch as it represents an organic oxide. It is largely used medicinally, and possesses valuable antiseptic properties.

One of the most important technical uses of a eucalyptus oil is for the separation of minerals by the method of floatations and for this purpose an oil of the phellandrene type, such as that from the above-mentioned *E. dives*, is considered to be the best. The amount required for the treatment of the ore ranges from 1/20 to 3/4 lb. of oil per ton of ore, and the extent of its use may be indicated by a recent statement that in the De Bavay process of mineral separation upwards of 300 tons of eucalyptus oil are annually employed.

UMBELLIFERAE

The family of *Umbelliferae* contains a considerable number of harmless aromatic plants, as well as some which possess acrid, narcotic properties. Unlike many other plants, the aromatic constituents of this group are not developed in a single part or organ of the plant, but are frequently more generally distributed. They are thus found not only in the leaves and fruit, but also in the root, as for example, in the edible roots of the carrot, celery, and parsnip, to which they impart a characteristic flavor. In the time available it will not be possible to consider more than a very few of the compounds to which the aromatic properties of these plants are due.

The fruits of the anise, *Pimpinella anisum*, Linné, yield an essential oil which consists chiefly of two isomeric compounds

of the formula $C_{10}H_{12}O$. One of these, which constitutes about 80 to 90 per cent of the oil, is anethol, or *p*-propenylanisol,

a substance which is solid at ordinary temperatures, and crystallizes in snow-white laminae. It has a strong anise-like odor, and an intensely sweet taste. The other isomeric compound is methylchavicol, or *p*-allylanisol,

a liquid which has a slight anise-like odor.

The commercial oil of anise is obtained chiefly from the fruits of the star anise, *Illicium verum*, Hooker fil., belonging to the family of *Magnoliaceae*. The tree which yields these fruits is found in the southwest provinces of China and in the French colony of Tonkin, the essential oil being distilled on a large scale in both of these countries. The oil of the star anise, like that of true anise, consists chiefly of anethol, together with some methylchavicol, terpenes, and other substances.

Anisaldehyde, or *p*-methoxybenzaldehyde, $C_6H_4.(OCH_3).COH$, which is produced by the oxidation of anethol, occurs in commerce under the name of aubépine. It is of interest on account of its use in perfumery, since it possesses in a marked degree the odor of the hawthorn or May blossom, *Crataegus oxyacantha*, Linné, belonging to the family of *Rosaceae*. The so-called aubépine is in fact the basis of all the artificial hawthorn perfumes.

The essential oil distilled from the fruits of the fennel, *Foeniculum vulgare*, Miller, has been known for several centuries. As produced from the fruit grown in different countries it varies somewhat in composition, but the commercial oil, like that of anise, consists to a large extent of anethol. It also contains, however, in addition to methylchavicol and terpenes, a ketone known as fenchone, $C_{10}H_{16}O$, which is isomeric with camphor and gives a series of analogous derivatives. Fenchone is liquid at ordinary temperatures, and, as obtained from the oil of fennel, is dextrorotatory. In the levorotatory form it is a constituent of Thuja oil, which is distilled from the leafy twigs of *Thuja occidentalis*, Linné, or *Arbor vitae*.

The fruits of the caraway, commonly called caraway seed, from *Carum carvi*, Linné, yield an essential oil which contains as its chief constituent the unsaturated, cyclic ketone known as carvone, $C_{10}H_{14}O$. This ketone, which possesses the characteristic odor of the caraway, has the interesting property of forming a crystalline compound with hydrogen sulfide, $(C_{10}H_{14}O)_2.H_2S$, from which it may be regenerated in a pure state. It is accompanied in the oil by about an equal amount of *d*-limonene.

The oil of dill, distilled from the fruits of *Anethum graveolens*, Linné, contains about 40 to 60 per cent of carvone, identical with that contained in the oil of caraway, together with *d*-limonene.

The fruits of the coriander, *Coriandrum sativum*, Linné, yield an essential oil, of which the most important constituent is an open-chain terpene alcohol of the composition $C_{10}H_{18}O$. This substance, which possesses a fragrant odor, was first designated as coriandrol, but is now known as *d*-linalool, since its optical antipode is contained in an oil distilled from the Mexican linaloe wood, from species of *Bursera*. Both of these optical modifications of linalool, either in the free state or in the form of esters, have in recent years been observed to occur in a considerable number of plants. The acetic ester, or linalyl acetate, $CH_3COOC_{10}H_{17}$, is considered to be the most valuable constituent of the oils of bergamot and lavender.

The well-known celery, *Apium graveolens*, Linné, contains in all parts of the plant an essential oil, which, however, is particularly abundant in the fruit. The oil from the fruit consists to the extent of about 90 per cent of hydrocarbons, the chief portion of which is *d*-limonene, and it also contains small amounts of phenols and other compounds. The characteristic odor of celery is attributed to two compounds, one of which is a lactone termed sedanolid, $C_{12}H_{18}O_2$, while the other represents the anhydride of sedanonic acid, $C_{12}H_{16}O_2$.

The common parsley, *Petroselinum sativum*, Hoffmann, like the celery, contains an essential oil in all parts of the plant, but which is present to the largest extent in the fruit. The chief constituent of this oil is the crystalline substance termed apiol, $C_{15}H_{14}O_4$, which is a dimethoxymethylenedioxylallylbenzene. It differs only from the myristicin of nutmeg oil in containing an additional methoxyl group, and myristicin has indeed been found in French parsley oil, which is poorer in apiol.

An umbelliferous plant which is largely cultivated in India, the *Carum ajowan*, Benth. et Hook., is of special interest and importance on account of the character of the essential oil distilled from the fruit. The oil contains from 40 to 50 per cent of thymol, $C_{10}H_{14}O$, which is used to a considerable extent medicinally on account of its antiseptic and germicidal properties.

It is well known that a number of umbelliferous plants possess poisonous properties, and attention may be called to one of these on account of its delusive character. The *Oenanthe crocata*, Linné, known as water hemlock, has a root consisting of a number of thick, whitish, parsnip-like tubers, and on account of its sweetish and aromatic taste is sometimes mistaken for the parsnip. It is therefore sometimes eaten both by children and cattle, and often with fatal results, for it is one of the most virulent of the vegetable poisons. The sweet taste of the roots is due to the presence of a considerable proportion of cane sugar, while the toxic properties are attributed to an undetermined constituent of the resinous material.

ERICACEAE

The family of *Ericaceae* contains many plants of special attractiveness as well as of chemical interest, for one is reminded of the beauty of the rhododendrons and the exquisite fragrance of the flowers of the trailing arbutus, *Epigaea repens*, Linné. In the present consideration of odoriferous compounds, a brief reference should at least be made to one of the members of this family, namely, *Gaultheria procumbens*, Linné, the leaves of which yield the highly aromatic wintergreen oil. The true oil of gaultheria is now rarely obtainable in commerce, having been almost entirely replaced by an oil distilled from the bark of the sweet birch, *Betula lenta*, Linné. These oils do not pre-exist in the respective plants, but are formed through the hydrolytic action of an enzyme upon a glucoside termed gaultherin. Both of them consist chiefly of methyl salicylate, and they have in turn been superseded to a large extent by a synthetic product, which is produced in a high degree of purity, and is known in commerce as synthetic oil of wintergreen.

The occurrence of methyl salicylate, or the glucoside yielding it, is not restricted to the sources just mentioned, since it has been found in comparatively small amounts in a very large number of plants. As examples of its distribution it may be noted that it occurs in tea and coca leaves, in the flowers of the tuberose and meadow sweet (*Spiraea ulmaria*, Linné), and in other instances may be contained in either the bark or root of the plant.

Another ester of salicylic acid, which is not known to occur in nature but is largely used in perfumery, is amyl salicylate. This is a colorless liquid, possessing a strongly aromatic odor, resembling that of the flowers of some of the orchids. It is said to form the basis of the artificial clover perfumes.

LABIATAE

The mint family contains such an exceedingly large number of aromatic plants, that only a very few can be considered for the purpose of illustrating the character of their odoriferous constituents. There may be mentioned in the first place, as one of the more important and familiar representatives of the family, the peppermint, *Mentha piperita*, Linné. The leaves of this plant yield an essential oil which is one of the most complex in composition of this class of products, since seventeen distinct chemical compounds have thus far been identified in it. The chief constituent of the oil is the well known secondary alcohol menthol, $C_{10}H_{19}OH$, which occurs both in the free state and in the form of its acetic and valeric esters.

The Japanese peppermint oil, distilled from varieties of *Mentha arvensis*, DC., is largely utilized for the production of menthol. It has quite recently been shown that this oil contains a new and interesting compound, which is a hexenylphenylacetate of the constitution $CH_2(C_6H_5).CO_2.CH_2.CH_2.CH_2.CH_2.CH_3$. In the pure state this compound is said to possess an onion-like odor.

Spearmint, *Mentha viridis*, Linné, although botanically so closely related to the peppermint, yields an essential oil of quite different odor and composition, its chief constituent being *l*-carvone, $C_{10}H_{14}O$, which is accompanied by phellandrene, *l*-limonene, and possibly *l*-pinene. The characteristic odor of the oil has been ascertained to be due to the presence of dihydrocumyl acetate.

The American pennyroyal, *Hedeoma pulegioides*, Persoon, yields an essential oil which possesses a highly aromatic, mint-like odor. The chief and most characteristic constituent of this oil is the ketone known as pulegone, $C_{10}H_{16}O$, but it also contains *l*-menthone, *d*-isomenthone, and methylcyclohexanone.

Several species of *Monarda* yield essential oils of chemical interest, and that from *Monarda punctata*, Linné, the so-called horse mint, is of considerable economic importance, inasmuch as it contains a large proportion of thymol, $C_{10}H_{14}O$, and is utilized for the production of this substance. The essential oil of

Monarda fistulosa, Linné, or so-called wild bergamot, appears to contain no thymol but its isomeric carvacrol. It also contains the interesting compound, thymohydroquinine, $C_{10}H_{14}O_2$, which is of rare occurrence in nature, but its dimethyl ether forms the chief constituent of the oil of arnica root, from *Arnica montana*, Linné.

The occurrence of thymol in an oil distilled from the fruit of an umbelliferous plant, *Carum ajowan*, Benth. et Hook., has already been noted, and it is also contained in a number of labiate plants other than the *Monarda*. It is a constituent, for example, of the oil of thyme, *Thymus vulgaris*, Linné, from which its name is derived, and of the oils obtained from species of *Ocimum*, *Satureja*, and *Origanum*.

A labiate plant which is highly esteemed on account of the fragrance of its flowers and the oil distilled therefrom is the lavender, *Lavandula vera*, DC. The essential oil of lavender is used almost exclusively as a perfume, especially in the form of the popular lavender water. With regard to the composition of the oil, it has already been noted that the oil distilled in England from the flowers of cultivated plants differs very greatly from that produced in France from the wild-growing plants of mountainous regions. The French oil is characterized by its large percentage of esters, chiefly linalyl acetate, together with some butyrate, and possibly propionate and valerate. It also contains free linalool and geraniol, *d*-borneol, and small amounts of several other compounds. The English oil contains a very much smaller proportion of esters, and is relatively rich in cineol.

The lavender is valued not only on account of its refreshing fragrance, but its essential oil is also considered to possess decided antiseptic properties. In this connection it has been of interest to observe that during the recent war many appeals were made in England for lavender bags for hospitals, and the flowering stalks of lavender, tied in bundles, are said to have been employed for fumigation in hospital wards.

COMPOSITAE

The family of *Compositae*, although an exceedingly large one, does not appear to contain so large a proportion of plants possessing odoriferous constituents as some of the smaller families already mentioned. Nevertheless, a considerable number of volatile products have been obtained from plants of this family, and some of the more important of these may be briefly considered.

In the first place there may be noted the chamomile, of which two varieties are known in commerce and employed medicinally. The so-called Roman or English chamomile consists of the flower heads of *Anthemis nobilis*, Linné, whereas the German chamomile represents the flower heads of *Matricaria chamomilla*, Linné. The essential oil of the Roman chamomile, when freshly distilled, has a pale blue color, and has been found to contain, among other substances, cumic aldehyde, and the esters of isobutyric, methyl-ethylacetic, angelic and tiglic acids, with isobutyl, amyl and methylethylpropyl alcohols. The freshly distilled oil of the German chamomile, of whose composition but little is known, is remarkable for its deep blue color, a character which is possessed, however, by several other oils or fractions obtained from them, such as those of the yarrow (*Achillea millefolium*, Linné), wormwood (*Artemisia absinthium*, Linné), valerian (*Valeriana officinalis*, Linné), Canada snake-root (*Asarum canadense*, Linné), Algerian rue, and asafoetida.

The constituent of the oil of chamomile to which its deep blue color is due has recently been ascertained to be a highly unsaturated hydrocarbon of the composition $C_{15}H_{18}$, which has been termed azulene. This hydrocarbon is an intensely blue, viscous liquid, having a phenolic odor. It is tricyclic, and contains four ethylenic linkings. On reduction it is converted quantitatively into a tricyclic dihydro-sesquiterpene, $C_{15}H_{26}$.

The wormwood, *Artemisia absinthium*, Linné, yields an oil which contains dextrorotatory or β -thujone, $C_{10}H_{16}O$, thujyl alcohol, $C_{10}H_{18}O$, both in the free state and in combination with acetic, valeric, and palmitic acids, together with phellandrene, cadinene, and the previously mentioned blue oil or azulene. Wormwood oil possesses toxic properties, and is used in the preparation of the liqueur known as absinthe.

The essential oil of tansy, from *Tanacetum vulgare*, Linné, contains β -thujone (tanacetone) as its chief constituent, together with *l*-camphor and borneol. It is said to be exceedingly poisonous.

Several species of *Solidago*, or golden rod have aromatic properties, the leaves of *S. odora*, Aiton, when crushed, exhaling a pleasant, anise-like odor. *Solidago canadensis*, Linné, yields an essential oil which consists chiefly of pinene, together with phellandrene and dipentene. It also contains about 10 per cent of borneol, 4 per cent of bornyl acetate, and cadinene.

The fleabane, *Erigeron canadensis*, Linné, is a common weed which yields an essential oil that has been used to some extent medicinally. The chief constituent of the oil is *d*-limonene.

A product of a composite plant which is of somewhat special interest is the Ngai camphor of the Chinese. This is obtained from *Blumea balsamifera*, DC., which is indigenous to India, and consists of nearly pure *l*-borneol. Although ordinary camphor, which is produced in Japan and Formosa, and has already been referred to, is largely used by the Chinese, the so-called Ngai camphor is highly esteemed by them for medicinal and ritualistic purposes, and is also used for perfuming the finer kinds of Chinese ink.

ESSENTIAL OILS IN COMMERCE

In the present representation of the odorous constituents of plants an attempt has been made to illustrate, by means of more or less familiar examples, their wide distribution and extremely varied chemical character. Although the limitations of time have rendered it impossible to consider more than a small proportion of the plants whose odorous constituents are known, the few that have been selected may nevertheless serve to indicate the degree of interest pertaining to investigations in this field of science.

	Weight Lbs.	Value Dollars
Oil of peppermint, crude.....	254,793	353,076
Oil of peppermint, refined.....	109,198	248,541
Oil of spearmint.....	94,209	238,074
Oil of black birch.....	41,178	67,691
Oil of wintergreen.....	6,000	24,538
Oil of wormwood.....	4,702	9,040
Other essential oils.....	...	348,522

From a practical point of view it may be noted that the essential oils and substances related to them play a very considerable part in the world's commerce. According to the Census of Manufactures for 1914, as issued by the Department of Commerce in 1918, the number of establishments in the United States engaged in the production of volatile or essential oils was 107, and the total value of these products was \$1,289,482.¹ The

¹ These figures do not include the turpentine production of the country, which in 1914 amounted to 27,648,939 gal., representing a value of \$10,740,327.

distribution of these oils, with reference to their amounts and value, is given in the preceding tabulation.

The essential oils not enumerated include, in addition to the oils of sassafras, cedar, pennyroyal, and tansy, considerable quantities of the oils of sandalwood, camphor, cloves, parsley, patchouli, lemon, and orange.

The total value of the essential oils imported into the United States during the year ended June 30, 1916, as given in the year-book of the Department of Agriculture, 1917, was \$3,109,656. The amounts and value of the camphor imported during the same period was as follows:

Camphor, crude.....	4,574,430 lbs.	Value, \$1,236,172
Camphor, refined.....	1,866,154 lbs.	Value, \$ 619,320

These amounts, especially of refined camphor, were greatly increased during the year 1917.

As an indication of the importance of a single essential oil, it has recently been stated that before the European war the exports of sandalwood oil from India were valued at about \$500,000 per annum, but that the factories established in Mysore since the beginning of the war are alone capable of producing nearly \$100,000 worth of sandalwood oil per month.

While some of the essential oils, notably those of turpentine and eucalyptus, are used to an enormous extent for technical purposes, and a number of others in much smaller amounts medicinally, very large quantities of the more fragrant oils are used for the production of perfumes and as flavoring agents. Perfumes, although so largely employed, are generally regarded as a luxury, but, apart from the refreshing qualities of some of these preparations, many of the essential oils which enter into their composition have been shown to possess antiseptic or bactericidal properties, and they may therefore be considered to have a decided hygienic value.

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REPORT OF THE ALIEN PROPERTY CUSTODIAN ON THE CHEMICAL INDUSTRY

The report of the Alien Property Custodian, A. Mitchell Palmer, was made public on March 9, 1919. On February 15, 1919, practically all known enemy alien property in the country had been seized and its total value was approximately \$700,000,000. The report divides enemy investments in America into two classes—those made in a small way by Germans attracted by the possibilities in America, and those made by combined capital in Germany having close affiliations with the great political and financial powers of the empire. Those in the first class are being treated as largely friendly and held in trust pending final action by Congress, but of the second or hostile class the report says, "No obligation is owed to their private owners to conserve or care for them with a view of ever returning them in kind." The chapter of the report entitled "The Chemical Industry" is printed in full herewith.—[EDITOR.]

The great field of chemical industry presented, at the outset, perhaps the most difficult of the many problems which the Alien Property Custodian was expected to solve. It was, or had been until importations ceased, saturated through and through with German influence. In regard to no branch of human endeavor was the myth of German invincibility more firmly fixed in the public mind. The country was flooded with German chemists; and those who were not German by origin, were mostly German, directly or indirectly, by training. A vast proportion of the persons engaged in the business bore German names. Connections more or less close between American and German houses were frequent and obvious. There was unquestionably a considerable German interest in such manufacturing as was being carried on. In view of the well known and uniform policy of the great German government-aided combinations to embark in foreign manufacture only when export from Ger-

many was not feasible, this interest seemed unlikely to be large; but, unless it could be discovered and rooted out, no substantial Americanization of the industry was possible. The German chemical industry, which had so thoroughly penetrated and permeated our own, was gigantic, perhaps the strongest, and certainly the most remunerative of all Teutonic industries. The task of identifying and taking over its property in the United States was thus a direct attack upon a most formidable opponent; while the information on which the work had to be based, had to be derived, to an exceptional extent, from men hostile by birth or tradition.

In order to give a fair understanding of the situation, it is necessary to sketch briefly the history of the German chemical industry. From about the middle of the nineteenth century, the practical application of chemical science began to occupy the attention of a constantly increasing number of the best scientific and industrial minds of Germany. A combination of natural advantages and national characteristics led to rapid advance. The industrial districts in which the necessary materials and other facilities were found or developed were exceptionally compact. Distances were short and transportation easy. Labor was cheap, docile, and stable. On the other hand, the national habit of mind was peculiarly fitted for chemical research work, and particularly for the interminable tasks presented by such research, in the way of exhausting the immensely numerous possible combinations available within a particular field. From the first, scientific attainment, and particularly accomplished in the field of research, appealed strongly to the public mind. Men of science, and particularly research workers, were more highly regarded than in other countries. This tendency was strongly fostered by the government, which, by conferring honors and titles, did everything possible to exalt the position of the successful scientist.