Chemicals from plants

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Casual examination of plants in a botanic garden gives the impression of great variation of structure but little visible activity, in contrast to a zoo, where the exhibits, if not asleep, are usually rushing around. To the biochemist, however, plants are active, versatile, synthetic organisms. Whereas in animals the emphasis is on the breakdown of complex foodstuffs followed by limited build-up, in plants it is the reverse.

One of the more obvious groups of substances made by plants is the carbohydrates, the simplest of which are glucose and fructose, present in all plant material but occurring in large quantities in many fruits. Sucrose, which is also domestic table sugar, similarly occurs in all plants but appears in some, notably sugar cane and sugar beet, at high concentrations. The white sugar obtained from these is 99 per cent pure; one of the cheapest natural products of such purity. The two well known complex carbohydrates starch and cellulose are also found in all plants, their molecules consisting of long chains of glucose units, bound by α-glucosyl links in the case of starch and by β-glucosyl links in the case of cellulose. Cotton (*Gossypium* spp. Malvaceae) produces almost pure cellulose as unicellular hairs on the seeds. Absorbant cotton wool is 94 per cent pure and is produced by removal of the seeds and a small amount of oil.

Table I
Plants used commercially as sources of sucrose

Plant	*Species*	*Family*
Sugar cane	*Saccharum officinarum* L.	Gramineae
Sugar beet	*Beta vulgaris* L.	Chenopodiaceae
Jaggery	*Arenga saccharifera* Labill.	Palmae
Jaggery	*Borassus flabellifer* L.	Palmae
Sugar palm	*Phoenix sylvestris* Roxb.	Palmae
Sweet sorghum	*Sorghum vulgare* var. *saccharatum* Koern	Gramineae
Maple	*Acer saccharum* Marshall	Aceraceae

Useful plant fibres can be divided into two types, the soft fibres, such as cotton and flax, and the hard fibres, such as jute and sisal, where lignin is present in addition to cellulose.

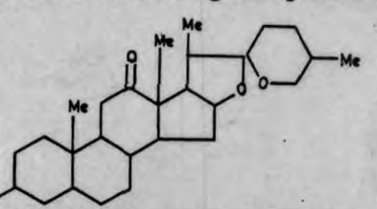

Fig. 1 *Hecogenin, a precursor of cortisone, from sisal*

Sisal (*Agave sisalana*, Perrine, Agavaceae) is an example of an interesting chemical factory. It is grown primarily for the hard fibres in the leaves but at the same time the leaf juice contains a glycoside (saponin) of the sapogenin, hecogenin, which can be used as a starting point for cortisone synthesis. As an added bonus the workmen can refresh themselves with tequila, brewed from the fermented juice.

Another chemically interesting group of plants contains those which secrete latex in special organs termed laticifers. The most widely used latex is that which yields rubber and is found in a number of plants of which the most important is Para rubber. This plant contains about 30 per cent rubber in its latex. Rubber is a hydrocarbon polymer, made up of chains of isoprene units. It has well known elastic properties and in this contrasts with a similar latex hydrocarbon, gutta, which is thermoplastic, though also made up of isoprene units; the difference lies in the configuration. Gutta percha, used as insulation, is produced from *Palaquium oblongifolium* Burck (Sapotaceae), while balata comes from *Mimusops balata* Crueg. (Sapotaceae). Chicle, an even more plastic material, used originally as a base for chewing gum, is derived from *Achras zapota* L. (Sapotaceae) which also bears an edible fruit, the sapodilla. A great many other compounds apart from rubber occur in latex, a familiar example being the opium alkaloids from poppy (*Papaver somniferum* L. Papaveraceae).

Table II
Plants which have been used as sources of rubber

Plant	*Family*
Hevea brasiliensis Muell. Arg. (Para rubber)	Euphorbiaceae
Manihot glaziovii Muell. Arg.	Euphorbiaceae
Castilla elastica Cerv.	Moraceae
Solidago leavenworthii Torr. et Gray	Compositae
Parthenium argentatum Gray. (Guayule)	Compositae
Taraxacum kok-saghyz Rodm.	Compositae
Scorzonera tau-saghyz Lipschitz et Bosse	Compositae
Cryptostegia grandiflora R.Br.	Asclepiadaceae
Landolphia spp.	Apocynaceae
Funtumia elastica Stapf.	Apocynaceae
Carpodinus lanceolatus K.Schum.	Apocynaceae
Asclepias subulata Decne	Asclepiadaceae
Ficus elastica Roxb.	Moraceae

Drugs from plants

Turning now to plants which produce drugs, it is interesting to consider how many cases have appeared recently of plants used in traditional folk medicine, yielding pharmacologically useful compounds. An outstanding example is the Indian Snake Root (*Rauwolfia serpentina* (L.) Benth. ex Kurz, Apocynaceae). An extract of this has been used in both India and Africa for centuries as an antidote for snake bites and more importantly for its calming effect on the mentally disturbed. Recent research has revealed a panoply of alkaloids of which one of the most active is reserpine. This compound is characterised by its tranquillising effect

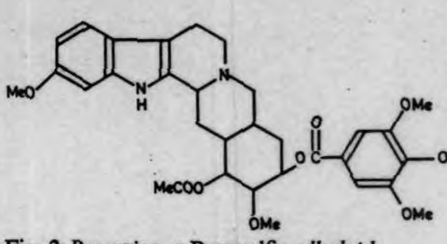

Fig. 2 *Reserpine, a* Rauwolfia *alkaloid*

and also, most usefully, by its activity in reducing blood pressure. As in the crude drug, it takes several days for its activity to become manifest.

South American Indians were known to possess a substance known by various names, commonly curare, which was used for tipping poisoned arrows, with dramatically lethal effect on the victims. Examination of the substance by Waterton in the nineteenth century showed that the apparently deadly poison has only a somewhat restricted action. It attacks the junction between nerve and muscle causing paralysis so that death is due to respiration failure and the heart is not directly affected. It is harmless if taken by mouth and has to be introduced into the blood stream. By giving artificial respiration he was able to revive a curarised donkey, which recovered comparatively quickly from the effect of the poison and survived happily for 25 years. In modern medicine curare is used to relax muscles in cases of muscle spasms, such as tetanus and epilepsy, and also during surgical operations, especially with older people. Two types of curare have been described. One, from the eastern part of South America, is derived from the bark of *Strychnos toxifera* Schomb. (Loganiaceae), the main active component being the alkaloid toxiferine. The other, from the western part, is derived from *Chondodendron tomentosum* Ruiz and Pav. (Menispermaceae) and contains the more widely used alkaloid tubocurarine. Other examples of plants

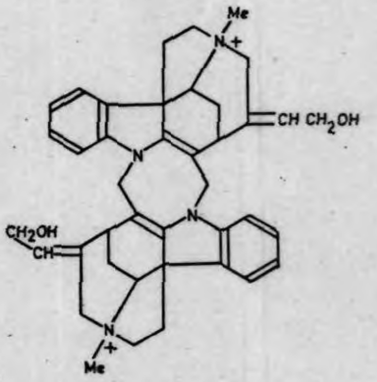

Fig. 3 *Toxiferine from* Strychnos *curare*

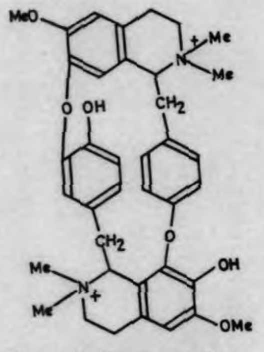

Fig. 4 *Tubocurarine from* Chondodendron *curare*

used in traditional folk medicine in which interest has been revived following identification of the active constituents are *Digitalis* spp. (Scrophulariaceae) and *Strophanthus* spp. (Apocynaceae), which yield cardiac glycosides, *Ephedra* spp. (*Ephedraceae*) yielding ephedrine, *Atropa* spp. (Solanaceae) and *Hyoscyamus* spp. (Solanaceae), which yield mydriatic alkaloids, and *Hydnocarpus* spp. (Flacourtiaceae) which yields chaulmoorgra and hydnocarpus oils for treatment of leprosy.

Insecticides

Besides the substances which are active in mammals, there is a group of plant products active against insects. These have been somewhat eclipsed by the advent of synthetic insecticides such as DDT, but can be expected to come into prominence as fears of pollution by chlorinated hydrocarbons grow. In addition it seems that in some cases insects become resistant more slowly to the plant products. Leaving aside crude insect repellents such as camphor and turpentine, plant insecticides fall into three groups, alkaloids, pyrethrins and rotenoids. Among the alkaloids, nicotine from Nicotiana spp. is the best known although its

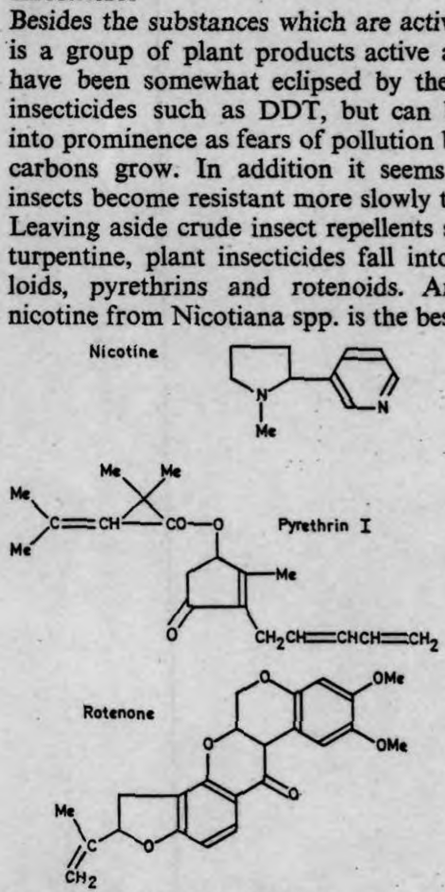

Fig. 5 *Insecticidal compounds*

toxicity to man restricts its use. However pyrethrins and some rotenoid formulations, although toxic to insects, are without effect on plants, humans, or domestic animals and therefore have potentially widespread use and in fact have been on the market for many years. Pyrethrins are contact insecticides secreted in the achenes of *Chrysanthemum*

Table III
Plants yielding insecticides

Insecticide	*Plant*	*Family*
Alkaloids		
Nicotine	*Nicotiana tabacum* L.	Solanaceae
Nicotine	*Nicotiana rustica* L.	Solanaceae
Nicotine	*Nicotiana silvestris* Spec. et Comes	Solanaceae
Anabasine	*Anabasis aphylla* L.	Chenopodiaceae
Ryanodine	*Ryania speciosa* Vahl	Flacourtiaceae
Veratrine	*Schoenocaulon officinale* Gray	Liliaceae
Pyrethrins		
Pyrethrins I and II	*Chrysanthemum cinerariifolium* Vis	Compositae
Cinerin I	*Chrysanthemum cinerariifolium* Vis	Compositae
Jasmolins I and II	*Chrysanthemum roseum* Adam	Compositae
Rotenoids		
Rotenone	*Derris elliptica* Benth.	Leguminosae
α-Toxicarol	*Derris malaccensis* Prain	Leguminosae
Deguelin	*Lonchocarpus nicou* DC.	Leguminosae
Tephrosin	*Lonchocarpus nicou* DC.	Leguminosae
Tephrosin also in	*Tephrosia* spp.	Leguminosae
(not identified)	*Dioscorea piscatorum* Prain et Burkill	Dioscoreaceae

cinerariifolium Vis. (Compositae), a preparation of the dried flower heads being once used under the name of 'Dalmatian' insect powder. Today extracts are used in the form of dusts and sprays. Activity is characterised by rapid knockdown of the insects, repulsion as well as killing and low mammalian toxicity, and may be enhanced by the addition of synergists. Derris root (Tuba) also used in the powdered form is an active fish poison with the advantage that the floating corpses are perfectly edible. Extracts are also used, although a degree of mammalian toxicity of such preparations restricts its use. This toxicity varies greatly with the method of administration and the animals involved but has resulted in rotenone preparations no longer being considered completely safe.

Related to the rotenones is a group of plant constituents called furocoumarins. Besides a similar action as fish poisons, they have varied effects on humans. One group causes photosensitisation of the skin whereby lesions resembling acute sunburn are produced on exposure to light. An example is psoralen from *Psoralea corylifolia* L. (Leguminosae) which was used in Burma to treat dermatitis

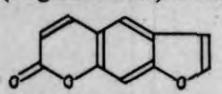

Fig. 6 *Psoralen, a photosensitising agent*

and has also been used to induce artificial suntan. Distress is often caused to bare legged walkers by photosensitising compounds in wild umbelliferous plants, the recently notorious Giant Hogweed being only one of many, and more serious symptoms are shown by stock grazing on active plants. Another manifestation of furocoumarin activity in meadow plants is oestrogenic activity, shown mainly by coumestrol, in various fodder plants such as lucerne and some clovers. This raises the possibility that effective contraceptive agents may one day be obtained from plant sources.

Terpenoids

Of the vast array of terpenoids found in plants only one, which has a double interest, will be mentioned here. The Paraguayan shrub *Stevia rebaudiana* Bertoni (Compositae) (Kaà hê-ê) has leaves with a very sweet taste due to a substance, stevioside, which is a triglucoside of the diterpenoid

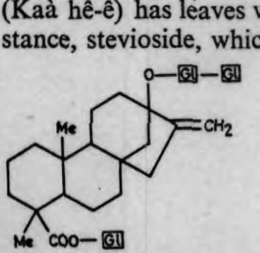

Fig. 7 *Stevioside, sweet tasting glycoside of the growth stimulator steviol*

steviol. Stevioside is 300 times sweeter than sucrose and was until recently the sweetest substance known, that honour having been usurped by a compound of unknown structure from the berry of *Dioscoreophyllum cumminsii* Diels (Menispermaceae) which is 800-1500 times sweeter than sucrose. The aglycone, steviol, is also of interest because it shows growth stimulating properties, of a lesser degree than, but resembling, those of gibberellic acid.

From another diverse group of compounds, the plant phenolics, the well known flavouring, vanillin, has been chosen for discussion here. This is produced in the pods of the climbing orchid *Vanilla planifolia* Andr. The pods reach maturity 8–9 months after hand pollinating and are then slowly cured in the sun, vanillin being released from a glycoside over a three-month period. The full bouquet of true vanilla flavour is due to a whole spectrum of compounds in addition to vanillin. These are not found in the synthetic substitute which is produced from eugenol in clove oil.

Further research

Consideration of the synthetic ability of plants poses many fascinating questions, some already answered, some more obscure. The first point is that all the carbon atoms in plant products derive from atmospheric carbon dioxide which is fixed by the process of photosynthesis. In Fig. 8 the process by which most other compounds are built up *via* certain key intermediates is shown in outline. This scheme is

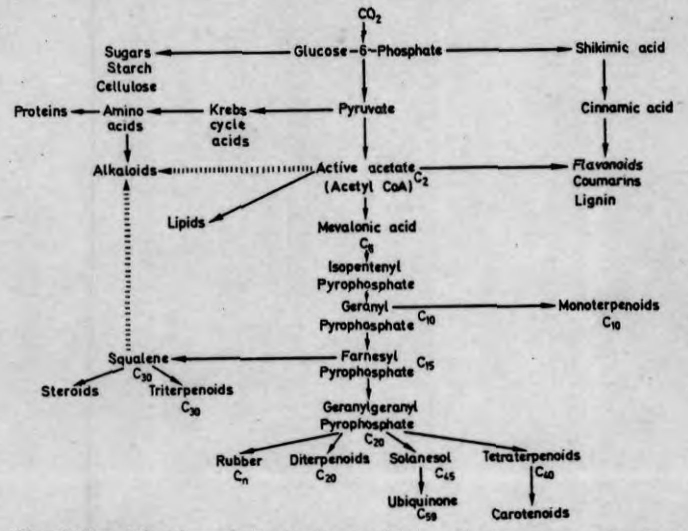

Fig. 8 *Simplified hypothetical scheme of biosynthetic processes in plants showing build up of complex compounds from carbon dioxide. The lower part of the diagram shows how the length of the carbon chain is increased*

hypothetical and nothing like it has been demonstrated for any one plant but rather it has been built up from the results of hundreds of different investigations. However no doubt it approximates to the truth. Equally fascinating, but completely mysterious is the question of the metabolic significance of some of the more unusual substances, if indeed they have any significance. Curare is very useful to the Indian but does it have any function in the parent vine? Steviol is a growth promoter, but does it affect the growth of *Stevia rebaudiana*? Answers to questions concerning physiological activity in both plant and animal will be sought more and more in future research. For instance, very recently, L-dihydroxyphenyl alanine (L-DOPA) has been found to relieve Parkinson's disease and also to occur in french bean seeds. Why it should occur in the seed, no one yet knows, but if it were to be found out, many useful and significant facts might emerge.

The study of chemicals from plants from a dynamic as well as a descriptive point of view will throw light on many problems in pharmacology, plant and animal physiology, ecology and economic botany.

out the residual gases by the application of liquid helium to the walls of the container. Such vacua represent pressures around one million million millionth of an atmosphere; these figures are so small that it begins to become more sensible to talk about the number of molecules that are still left in a cubic centimetre, for even at such very low pressures, there are still a good many molecules left, perhaps as many as $1000/cm^3$. This is about the present limit of conventional vacuum work, but Professor Kurti calculates that in his low temperature apparatus at 0·15°K he has one atom of helium/cm^3 – about the density of interstellar space – and that at 0·03°K he has a density of one atom galaxy^{-1}!

Epilogue

Is the search for these higher vacua worth while? Here I would echo the faith of Faraday and Crookes in their time; and we have seen how well their faith has been justified. Vacuum has become an essential part of our civilisation. Here, in the City of London, we might suggest that it would be a fitting theme for the Lord Mayor's Show, for we now have a great industry adding enormously to the richness – and dangers – of human life. And all this has come out of the vacuum pump, an invention that is unique to our own civilisation. Dr Needham, who has found that so many of our inventions had been anticipated in ancient China, tells me that he has found no trace of a vacuum pump there.

One of the famous sayings of the ancient world was that of Marcus Aurelius, who took the reasonable view that 'Nothing can come out of nothing', but in the study of vacuum it seems that much has come out of nothing. It would be tempting to leave you with this curious thought and to speculate how much further it might take us. For the mystery of vacuum – space without body – remains much as it was when Newton first posed the question: how are forces, great forces that keep the solar system together, transmitted through a vacuum?

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Institute of Physics and the Physical Society Awards

The Council of the Institute of Physics and the Physical Society has made the following awards for 1971; the presentations will be made in London at the annual dinner on 4 May 1971.

The Guthrie Medal and Prize has been awarded to Mr J. A. Ratcliffe formerly of the Radio Research Station, for his contributions to radio physics and to the physics of the upper atmosphere; The Glazebrook Medal and Prize has been awarded to Dr F. E. Jones of Mullard Ltd, for his applications of semiconductor physics and for management in a physics based industry; The Thomas Young Medal and Prize has been awarded to Professor C. G. Wynne of Imperial College of Science and Technology, University of London, for his work on the design of complex lens systems and other optical devices; The Maxwell Medal and Prize has been awarded to Dr J. B. Taylor of the Culham Laboratory, UKAEA, for his contributions to the theory of the dynamics of high temperature magnetised plasma; The Charles Chree Medal and Prize has been awarded to Mr D. G. King-Hele of the Royal Aircraft Establishment, for his contributions to the understanding of satellite orbits; The Duddell Medal and Prize has been awarded jointly to Dr V. E. Cosslett and Dr K. C. A. Smith of the University of Cambridge, for the development of the high voltage electron microscope; The Charles Vernon Boys Prize has been awarded to Dr M. Hart of the University of Bristol, for his experimental contributions to X-ray interferometry; The Bragg Medal and Prize has been awarded to Mr G. R. Noakes formerly of Uppingham School, for his contribution to the development of new approaches to the teaching of physics particularly through the medium of textbooks and the A. B. Wood Medal and Prize has been awarded to Dr R. E. Apfel of Harvard University, for his work on cavitation.

The Council has also nominated Mr I. D. Duff as Prizeman for the 1970 graduateship Examination of the Institute and Society for his exceptional all-round merit in the examination.