vitaminartigen Coferments, tritt[1]. Das zellfremde Sulfanilamidderivat vermag die Funktionen des verdrängten Coferments nicht auszuüben, der bakterielle Stoffwechsel bleibt stehen und der so gehemmte Parasit verliert sein Teilungsvermögen und seine Widerstandskraft gegenüber dem Wirtsorganismus. Durch Zugabe von überschüssiger p-Aminobenzoesäure wird das Sulfanilamidderivat wieder verdrängt und die bakteriostatische Wirkung aufgehoben. *Der therapeutische Effekt der Sulfanilamidderivate beruht also in letzter Linie auf der Verdrängung eines vitaminartigen Coferments* aus dem Protoplasmaverband der Bakterien. Neben dieser sich therapeutisch auswirkenden Avitaminose der pathogenen Bakterien kann die Sulfanilamidtherapie auch zu einer *Verdrängung von Vitaminen aus den Fermentsystemen des Wirtsorganismus* führen. Hiedurch erklären sich die unerwünschten Nebenwirkungen, wie Darmstörungen, Leberschädigungen, Dermatosen, krankhafte Veränderungen des Blutbildes, die im Anschluß an eine Sulfanilamidtherapie auftreten können und sich durch vermehrte Zufuhr von Vitaminen günstig beeinflussen lassen.

In der Voraussetzung, daß die bakteriostatische Wirkung der Sulfanilamidderivate auf einer konstitutionell chemischen Analogie des Sulfanilamids zur p-Aminobenzoesäure beruht, haben sich verschiedene Forscher[2,3,4,5] bemüht, durch Synthese von Substanzen mit vitaminähnlicher, aber nicht identischer chemischer Struktur zu chemotherapeutisch aktiven Wirkstoffen zu gelangen. Tatsächlich zeigte sich ein Antagonismus zwischen Pyridin-3-sulfonsäure und Nicotinsäure, zwischen Pantoyltaurin (Thiopansäure) und Pantoyl-β-alanin (Pantothensäure), zwischen Pyrithiamin und Thiamin (Aneurin), zwischen Isoascorbinsäure und Ascorbinsäure, zwischen Isoriboflavin und Riboflavin.

[1] D. D. WOODS, Brit. J. exp. Path. *21*, 74 (1940).
[2] D. W. WOOLLEY, Science *100*, 579 (1944).
[3] H. MCILWAIN, Brit. J. exp. Path. *21*, 136 (1940); J. chem. Soc. *1941*, 75; Biochem. J. *36*, 417 (1942).
[4] E. E. SNELL, J. biol. Chem. *139*, 975 (1941).
[5] R. KUHN, T. WIELAND und E. T. MÖLLER, Ber. dtsch. chem. Ges. *74*, 1605 (1941).

Die Erwartungen der Forscher, welche in der chemischen Konstitution der Vitamine eine bequeme Schablone für die Synthese von chemotherapeutisch aktiven Heilmitteln erblickt haben, blieben bisher unerfüllt. Die grundlegende Bedeutung der Erkenntnisse, welche zu der fermentchemischen Erklärung der Sulfanilamidwirkung geführt haben, bleibt dessenungeachtet bestehen. Die Vitamine haben diese Erkenntnisse gefördert, indem sie die therapeutischen Leistungen und die Nebenwirkungen synthetischer Chemotherapeutika in Zusammenhang brachten mit den fermentativ geleiteten Stoffwechselvorgängen, die sich in den Mikroorganismen und in dem von ihnen infizierten Wirtsorganismus abspielen. Als Cofermente in wirklichem wie übertragenem Sinne kommt ihnen das Verdienst zu, die Arzneimittelforschung, die Pathologie und die Therapie mit der Ernährungsphysiologie und der allgemeinen Biologie auf dem festen Boden der Biochemie vereinigt zu haben. Sie schufen damit eine erweiterte und einheitliche Grundlage, auf der sich alle diese Wissenschaften gegenseitig fördern und systematisch weiterentwickeln können.

Summary

The vital importance of the vitamins resides in their *coferment function*, which enables them to catalyse enzymatic processes in living tissues. The term "coferment" is used in this connection to designate organic compounds of relatively low molecular weight, which in conjunction with the specific proteinous apoferments bring about the transformation of definite substrates. The vitamins are, however, catabolized like ordinary substrates when they come into contact with enzymatic systems in which they have no coferment function. This explains why normal life cannot be sustained, if the living organisms do not receive as *nutritional factors* the vitamins which they cannot synthesize. From a biochemical point of view not only exogenous hypo- or avitaminoses but all pathological changes may be regarded as the sequelae of disturbances in one or several enzymatic systems. The vitamins may exert a regulating influence also in these enzymatic disturbances which are not directly caused by vitamin deficiency. In such cases they will act as *remedies*.

Hashish

By A. R. TODD, Cambridge

The hemp plant (*Cannabis sativa* L.) has been cultivated for thousands of years and owes its commercial importance primarily to the fibre which it yields and to the oil obtained from its seeds. It also contains an intoxicating principle which has been used from remote times both as a medicament and in the preparation of a number of drugs of addiction. These drugs appear under a multitude of names of which hashish is only one, although it has come to be applied commonly in Europe as a generic term for all of them. Hemp is an annual plant which can be grown almost anywhere from the temperate zone to tropical regions, and according to variety and climatic conditions it ranges in height from 3–18 ft. It is dioecious, the male and female flowers occurring on separate plants, and the female flowering tops are covered with tiny gland-

ular hairs which secrete a greenish brown resin believed by some to protect the ripening seeds. This resin, which also occurs in lesser amount in other parts of the plant, has a powerful physiological action and it forms the active basis of the *Cannabis indica* of the Pharmacopoeias and of all the various hemp drugs. The amount of resin produced and the activity which it shows depends on the variety and the locality in which the plant is grown. Although it is difficult to obtain precise information, it seems to be generally agreed that hemp grown in Asia (probably the original habitat of the plant) is the most potent and that the smaller varieties are the best drug producers. The hemp drugs are known under a large number of names according to locality and mode of preparation, i.e. whether prepared from the resin itself, from chopped leaves and flowering tops, or from decoctions of the plant. Thus among the commoner preparations we find *charas, ganja, bhang* in India, *hashish* in Egypt and Asia Minor, *kif* in North Africa and *marihuana* in North, Central and South America. As most of these drugs appear only on the illicit market they are frequently of doubtful origin and vary enormously in potency.

Hemp was cultivated for its fibre in China as early as 3000 B.C., but although it seems to have been applied medically to some extent, there is no record of the abuse of hemp drugs in early chinese writings. In India, on the other hand, the use of hemp drugs was certainly known two thousand years ago, and it is now so well established that the plant has assumed a divine status in some parts of that country. In Egypt and the Near East too, hashish addiction is of long standing and is such a serious social problem that vigorous measures have had to be taken against it. Oddly enough it has never been much of a problem in Western Europe. Indeed, apart from the literary hashish parties in Paris in the middle of the last century, there is little evidence of widespread addiction since efforts were first made in the 18th century to introduce hemp into European medicine. It was for long maintained that the absence of the hashish vice among Europeans was due to temperamental incompatibility, but this view would seem to be at variance with recent experience in the United States. There the drug, under the name *marihuana*, was introduced into the southern states from Mexico and its use has spread rapidly over the whole country to become the major drug problem of America[1].

Hemp drugs are usually eaten or smoked, the effects being rather slower in developing in the former case. The modern method of smoking in cigarettes, alone or mixed with tobacco, is closely allied to the traditional oriental pipe smoking. Consumption mixed with sugar and other ingredients in the form of sweetmeats is a common mode of ingestion in India and in the Near East.

It is difficult to give an accurate description of the physiological effects of hashish partly because they are more subjective than objective in nature and partly because there is wide variation in individual response. There are, of course, many recorded descriptions of hashish intoxication but many of these are highly coloured and unreliable. Some of the better known (e.g. that by DUMAS in the *Count of Monte Cristo*) were probably taken at secondhand from articles written by literary dabblers in the vice, who were more concerned with artistic effect than with scientific accuracy. Nevertheless from all these descriptions it is possible to arrive at a general picture. The action of the drug is primarily on the central nervous system and peripheral effects are few. Among the most commonly recorded subjective symptoms are a feeling of wellbeing, an extension of time and space, musical phenomena and various hallucinations, among them double consciousness. Objectively there is a period of excitation and exaltation followed by a deep sleep or coma. It is said that the taker of hashish experiences no undesirable after effects and that, although addiction leads to moral degeneration, the drug is not physically habit forming, i.e. complete withdrawal causes no physical symptoms such as occur in morphine or cocaine addiction. As might be expected from the nature of the above effects, the biological testing of hashish is difficult to put on a really quantitative basis. Of the various methods which have been suggested, two are chiefly employed to-day and have been a necessary part of the chemical investigations to be described here. The first of these, employed by the writer and his colleagues is the GAYER test[1] in which the smallest dose necessary to destroy the corneal reflex in rabbits is measured, and the second, used by ADAMS and his collaborators, estimates the degree of ataxia produced in dogs. Neither of these methods is very accurate and the results obtained in them are not always strictly comparable. The exact relationship between results obtained by either method and the clinical effect of natural and synthetic materials is not yet wholly clear and will be mentioned again later.

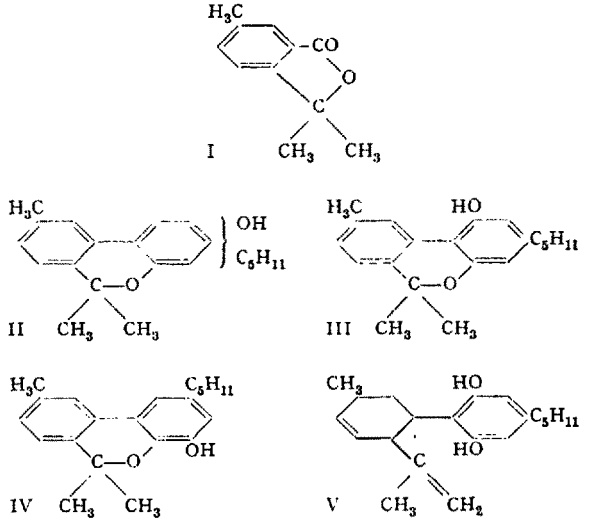
Following the introduction of the drug to Western Europe efforts were made to apply it to a wide variety of medical uses. These efforts yielded very indifferent results, partly because of the great and apparently uncontrollable variation in the potency of the materials used and the unscientific approach to their application. These facts, coupled with fear of addiction, caused the drug to fall gradually into disrepute until, in 1932, *Cannabis* was removed from the British Pharmacopoeia, although it remains in the United States and several European Pharmacopoeias. Despite this,

[1] WALTON, Marihuana, America's New Drug Problem, Lippincott, New York 1938.

[1] GAYER, Arch. exp. path. Pharm. *129*, 312 (1928); MARX and ECKHARDT, ibid. *170*, 395 (1933).

hashish is worthy of some attention in medicine. In the opinion of some alienists, hemp preparations are of value in the treatment of depressive mental conditions. The active constituents of hashish also possess analgesic properties and might well find therapeutic application on that account.

Chemical investigation of hashish has been pursued intermittently for nearly a century. In 1857 the brothers T. and H. SMITH of Edinburgh showed that the physiologically active principle resided in the alkali-insoluble, high-boiling portion of hemp resin and that it was not an alkaloid[1]. From this time onwards many workers have studied the resin, but until very recent times a good many of the investigations were rendered valueless through the failure of their authors to realize that, although the high-boiling resin distils at a more or less steady temperature, it is not a single substance but an exceedingly complex mixture. Three Cambridge chemists, WOOD, SPIVEY and EASTERFIELD, effected a considerable purification of the resin in 1896 and obtained an active glassy product, b.p. 265°/20 mm, which they named cannabinol[2]. Although at first they fell into the trap of believing this product to be homogeneous they[3], and independently DUNSTAN and HENRY[4], later found that this was not so and isolated from it, after acetylation, a crystalline acetate in a yield of 25%, which could be hydrolyzed to a resinous cryptophenol $C_{21}H_{26}O_2$. To this product they transferred the name cannabinol and henceforth their earlier product was designated "crude cannabinol"; it is in this sense that the term cannabinol is now employed. WOOD, SPIVEY and EASTERFIELD carried out a number of degradative experiments on "crude cannabinol," but their results remained unexplained for more than thirty years when CAHN[5] took up the subject afresh and in a few years largely elucidated the structure of cannabinol. The results of CAHN's researches can be briefly summarized. Oxidative nitration of cannabinol yielded nitrocannabinolactone, $C_{11}H_{11}O_4N$, converted by standard procedures to cannabinolactone $C_{11}H_{12}O_2$ or to hydroxycannabinolactone, $C_{11}H_{12}O_3$. The latter substance yielded, on fusion with alkali, acetone and 6-hydroxy-*m*-toluic acid and on oxidation hydroxytrimellitic acid. Furthermore oxidation of cannabinolactone with alkaline permanganate gave cannabinolactonic acid, $C_{11}H_{10}O_4$, in which the lactone ring was still present and a methyl group in the starting material had been oxidized to carboxyl; the most satisfactory explanation for this was clearly that cannabinolactone was the γ-lactone of an acid containing a tertiary hydroxyl group. Taking these various facts into consideration CAHN allotted structure (I) to cannabinolactone and the correctness of his deduction was confirmed by the elegant synthesis of this compound by BERGEL[1] and the identity of cannabinolactonic acid with a product synthesized earlier in a different field of work by BARGELLINI and FORLI-FORTI[2]. Eleven of the twenty-one carbon atoms of cannabinol were thus accounted for and there remained the problem of the remaining ten. From the cryptophenolic properties of cannabinol, CAHN argued that there must be in the molecule an aromatic nucleus bearing a hydroxyl group, and that, since *n*-caproic acid was always found among the oxidation products of cannabinol, this phenolic nucleus must bear an *n*-amyl substituent. If this were so, it would follow that one of the carbon atoms of cannabinolactone forms part of the phenolic ring, and, by making the reasonable assumption that the second inert oxygen atom of cannabinol is present in an ether linkage, CAHN was led to propose structure (II) for cannabinol, the relative positions of the *n*-amyl and hydroxyl groups remaining uncertain.



CAHN's researches terminated in 1934 and it was not until some four or five years that further progress was made, the subject being then opened afresh by the writer and his colleagues in Britain and by ADAMS and his school in America. As a result of these newer investigations a good deal of light has been thrown on the whole hashish problem. The work was facilitated by the discovery that cannabinol could be fairly readily separated from purified Indian hemp resin by distillation followed by *p*-nitrobenzoylation, when cannabinol formed a crystalline sparingly soluble *p*-nitrobenzoate. The important observation was made

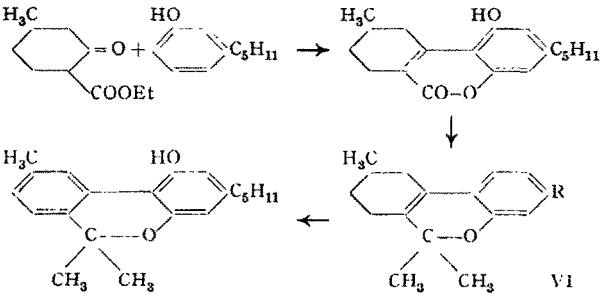
[1] T. and H. SMITH, J. chem. Soc. *21*, 47 (1857).
[2] WOOD, SPIVEY and EASTERFIELD, J. chem. Soc. *69*, 539 (1896).
[3] WOOD, SPIVEY and EASTERFIELD, J. chem. Soc. *75*, 20 (1899).
[4] DUNSTAN and HENRY, Proc. chem. Soc. 44 (1898).
[5] CAHN, J. chem. Soc. 986 (1930); 630 (1931); 1342 (1932); 1400 (1933).

[1] BERGEL, Annalen, *493*, 250 (1932).
[2] BARGELLINI and FORLI-FORTI, Gazz. chim. *40*, ii, 74 (1910).

that cannabinol showed no hashish activity in rabbits and that the active material remained in the non-crystalline portion of the esterified resin[1]; the nature of this active material will be discussed later. It was evident from CAHN's work that little more decisive evidence regarding the structure of cannabinol was likely to emerge from oxidative degradation and it was decided to employ, in the main, synthetic methods of approach. The number of possible structures (assuming the validity of the dibenzopyran skeleton) could be narrowed down when it was observed that cannabinol gave a strongly positive indophenol reaction indicating that the *p*-position to the phenolic hydroxyl was unsubstituted. Only four out of the twelve possible variants of (II) fulfilled this requirement and when the ready dinitration of cannabinol in the phenolic nucleus was taken into account it seemed clear that it must have structure (III) or (IV).

A decision between these two possible structures became possible at an early stage in the synthetic experiments as a result of evidence obtained from the study of another *Cannabis* constituent. ADAMS and his collaborators[2] working with marihuana isolated, in the form of its crystalline 3:5-dinitrobenzoate, a new substance cannabidiol, $C_{21}H_{30}O_2$; the same substance was isolated by JACOB and TODD[3] from Egyptian hashish. It may be observed in passing that there is considerable variation in the amount of cannabidiol which can be isolated from hemp of different origins. American hemp appears to contain large amounts of cannabidiol and the Indian variety very little; Egyptian material is intermediate in this respect as it also is in potency. Cannabidiol has no hashish activity and it appears to be the substance mainly responsible for the *Cannabis* colour reaction known as the Beam test, which, incidentally, is not given by the active principle of the drug. It is a cryptophenol containing two hydroxyl groups and two double bonds, and degradative evidence suggests for its structure (V), in which the position of the cylic double bond, although probably correct, has not been rigidly established[4]. The orientation of the hydroxyl groups in cannabidiol, shown by production of olivetol on pyrolysis with pyridine hydrochloride, together with the simultaneous occurrence of cannabinol and cannabidiol in hemp made it vitually certain that cannabinol was correctly represented by (III) and this was rapidly confirmed by two independent syntheses of cannabinol due to ADAMS, BAKER and WEARN[5] and GHOSH, TODD and WILKINSON[6].

[1] WORK, BERGEL and TODD, Biochem. J. *33*, 123 (1939).
[2] ADAMS, HUNT and CLARK, J. Amer. chem. Soc. *62*, 196 (1940).
[3] JACOB and TODD, Nature *145*, 350 (1940); J. chem. Soc. 649 (1940).
[4] ADAMS et alii, J. Amer. chem. Soc. *62*, 2566 (1940).
[5] ADAMS, BAKER and WEARN, J. Amer. chem. Soc. *62*, 2204 (1940).
[6] GHOSH, TODD and WILKINSON, J. chem. Soc. 1121, 1393 (1940).



VI

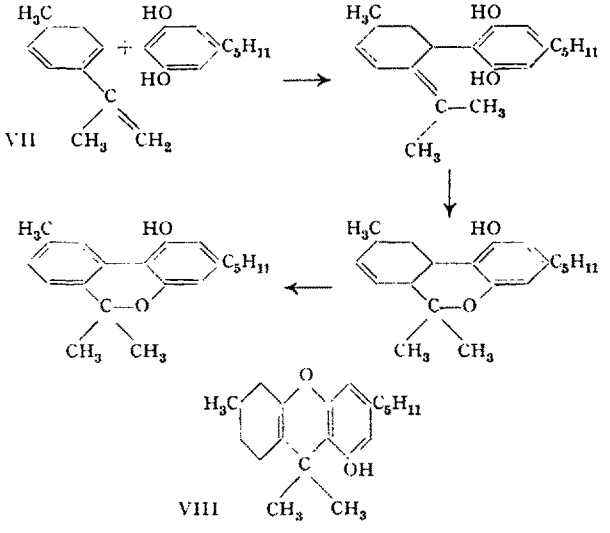
The synthetic route used by the latter authors, shown above is of particular interest, because the intermediate tetrahydrocannabinol (VI; $R = n\text{-}C_5H_{11}$) has been found to exhibit in a high degree the characteristic effects of hashish in animals and in man. This discovery led to the synthesis and pharmacological examination of a wide variety of related substances in the hope of elucidating the relationship between chemical constitution and hashish activity[1]. Whilst this goal has not yet been achieved some of the results obtained are of considerable interest and importance. In analogues of (VI) in which the side chain R is varied, activity in the *n*-alkyl series rises to a maximum at *n*-hexyl and then falls off again. Among analogues with a branched side chain only those in which branching occurs at the α-carbon atom show marked activity and one of them, viz. (VI; $R = -CH(CH_3)CH_2CH_2CH_2CH_2CH_3$) is about 16 times as active as the synthetic tetrahydrocannabinol in the dog test and is at least as active as the best material so far obtained from natural hemp resin. The tetrahydrocannabinol (VI; $R = n - C_5H_{11}$) obtained in the course of the original cannabinol synthesis was, of course, racemic, whereas all physiologically active fractions of the natural drug are strongly laevorotatory. By starting from the appropriate optically active methyl-*cyclo*hexanone, *d*-tetrahydrocannabinol has been synthesized by the standard route; from the relation between its activity and that of the racemic material it has been deduced that the *l*-form of the compound must be several times more active than the *d*-form[2]. The synthetic substance (VI) is not the only physiologically active tetrahydrocannabinol which exists; it has been shown by ADAMS[3] that cannabidiol can be cyclised under acid conditions to yield a mixture of optically and physiologically active tetrahydrocannabinols which presumably differ from one another in the location of the ethenoid linkage and/or stereochemically.

Following the results of these synthetic studies attention has again been focussed on the active fractions of hemp resin. Here great difficulties have been encountered owing to the intractable nature of the ma-

[1] TODD et alii, J. chem. Soc. 169, 826 (1941); 286 (1943); ADAMS et alii, J. Amer. chem. Soc. *63*, 1971, 1973, 1977 (1941); *67*, 1534 (1945).
[2] LEAF, TODD and WILKINSON, J. chem. Soc. 185 (1942).
[3] ADAMS et alii, J. Amer. chem. Soc. *62*, 2402, 2566 (1940).

terial and, despite various claims which have been made from time to time[1,2], there is no substantiated instance of a homogeneous crystalline active constituent having been isolated. By repeated fractionation using molecular distillation and chromatographic adsorption a highly active, almost colourless glass can be obtained from Indian hemp resin, which does not appear to undergo further separation into different components by available methods. It analyzes consistently for $C_{21}H_{30}O_2$, contains one double bond and one hydroxyl group, closely resembles synthetic tetrahydrocannabinol in the position of its ultraviolet absorption bands and gives cannabinol in excellent yield on catalytic dehydrogenation. In short, it has the properties of a tetrahydrocannabinol, but in the absence of more rigid evidence the claim of homogeneity made by American workers[3] remains doubtful. On spectroscopic evidence obtained with materials of this nature the writer inclines to the view that they are mixtures of tetrahydrocannabinols; the intensity of absorption between 2750 Å and 2800 Å lies between the values expected for synthetic tetrahydrocannabinol and for isomers, in which the double bond is not conjugated with the aromatic ring. However, it would appear to be established that the activity of hemp resin, in rabbits and dogs at least, is to be attributed in the main to tetrahydrocannabinols.

The problem of the origin of plant products is one which inevitably attracts the attention of investigators and a consideration of the formulae of cannabidiol, tetrahydrocannabinol and cannabinol has led the writer to suggest that all these products might originate in the plant from an initial condensation of a terpene derivative with olivetol. A hypothetical scheme of biogenesis based on this view is shown below[4].



[1] HAAGEN, SMIT et alii, Science *91*, 602 (1940).
[2] POWELL et alii, Science *93*, 522 (1941).
[3] WOLLNER, MATCHETT, LEVINE and LOEWE, J. Amer. chem. Soc., *64*, 26 (1942).
[4] SIMONSEN and TODD, J. chem. Soc. 188 (1942).

The initial step in the process leads to formation of a cannabidiol type which then undergoes ring closure to an active tetrahydrocannabinol; the latter may then pass by dehydrogenation into the inert cannabinol. This scheme, incidentally, offers a ready explanation of the variation in the composition of resin obtained from hemp grown under different climatic conditions. In the scheme outlined above, the position of the third double bond in the menthatriene (VII) is, of course, purely arbitrary. Some support for the scheme has been provided by a study of the low-boiling terpene fraction of Egyptian hashish which consists mainly of *p*-cymene and methyl-4-*iso*propenylbenzene[1]. If the unstable menthatriene (VII) did exist as an intermediate in the hemp plant, it would be expected to undergo ready conversion by isomerisation to *p*-cymene and by dehydrogenation to methyl-4-*iso*propenylbenzene, the products actually isolated as the main components of the essential oil of hemp resin.

It would, of course, be interesting to realize this scheme in the laboratory by effecting the initial stage; the conversion of cannabidiol through tetrahydrocannabinol to cannabinol has been accomplished in the course of work already described. Unfortunately, it has not been possible as yet to obtain the necessary methatriene, but a somewhat similar condensation of the readily available pulegone with olivetol in the presence of acidic catalysts does yield a product from which *d*-tetrahydrocannabinol can be isolated in fairly good yield[2,3]. Accompanying it, in approximately equal quantity, is an isomeric substance showing no hashish activity, when tested in the normal way on dogs or rabbits. This product, like tetrahydrocannabinol, contains one double bond and one hydroxyl group, and its ultraviolet absorption spectrum shows a band of low intensity (no conjugation) in the same position as the tetrahydrocannabinol band, but it yields no cannabinol on dehydrogenation. Available evidence, largely obtained on the corresponding pulegone-orcinol condensation product, suggests that this by-product is a xanthene derivative (VIII). It is natural to ask whether compounds of this nature occur in hashish; if the biogenetic scheme above suggested holds good, one might expect this to be so. For the present this must remain an open question, but it is a fact that, in concentrating the active constituents of hemp resins, considerable quantities of inert resinous material are obtained, which show properties very similar to the synthetic product (VIII) and further work may establish the identity of the two.

Since the synthesis of tetrahydrocannabinol was realized, clinical experiments have been carried out both in Britain and in America on this substance and its analogues as well as on highly purified hashish

[1] SIMONSEN and TODD, J. chem. Soc. 188 (1942).
[2] LEAF, TODD and WILKINSON, J. chem. Soc. 185 (1942).
[3] GHOSH, TODD and WRIGHT, J. chem. Soc. 137 (1941).

preparations. It is perhaps too early yet to assess the value of these materials in medicine, but one interesting feature of the experiments is worthy of mention. It has been reported to the writer (Dr. G. TAYLEUR STOCKINGS, private communication) that hashish shows certain effects in man which are not produced by the synthetic materials examined. This is perhaps not surprising when one remembers that the exact relationship between corneal areflexia in rabbits, ataxia in dogs and hashish activity in man has not been established[1], and that the tetrahydrocannabinol fraction represents only a small proportion of the hemp resin. Such findings do, however, emphasize that, although substantial progress has been made in the chemical investigation of hashish, more remains to be done before the problem presented by this remarkable drug can be regarded as completely solved.

[1] LOEWE, J. Pharmacol. *84*, 78 (1945).

Zusammenfassung

Der Autor referiert über die frühere chemische Bearbeitung des Haschischproblems, wobei namentlich die Arbeiten von CAHN (bis 1933) wichtig sind. Die beiden Substanzen Cannabinol und Cannabidiol aus Haschisch sind inaktiv, der Träger der physiologischen Wirkung konnte noch nicht rein dargestellt werden. Synthetische Tetrahydrocannabinole zeigen zum Teil starke Haschischwirkung. Der Autor vermutet, daß die Struktur des natürlichen Wirkungsträgers ähnlich sein wird wie diejenige der aktiven synthetischen Produkte.

L'énergie atomique

Par M. F. JOLIOT-CURIE, Paris

C'est une tâche bien délicate et une lourde responsabilité d'écrire en un bref exposé un sujet déjà si vaste: la libération de l'énergie atomique. Hélas! c'est par le fracas de l'explosion de Hiroshima que cette nouvelle conquête de la science nous fut révélée. En dépit de cette apparition terrifiante, je suis convaincu que cette conquête apportera aux hommes plus de bien que de mal.

Il ne se passe peut-être pas de jour sans que dans les conversations, dans la presse, il ne soit question de la bombe atomique. Une grande excitation règne dans le monde. L'inquiétude s'est emparée de chacun, entretenue par des articles de presse, d'ailleurs souvent fantaisistes, et il faut le reconnaître par les mesures de secret maintenues par les nations réalisatrices. Il est vrai que le président TRUMAN et les savants, en particulier en France, ont déclaré que les découvertes, grâce auxquelles fut réalisée cette arme redoutable, permettaient aussi de libérer, à des fins bienfaisantes, l'immense réserve d'énergie contenue dans les atomes. Enfin notre connaissance déjà profonde de la matière nous permet de conclure que le phénomène explosif dont les éléments de la bombe sont le siège, ne peut se propager aux autres éléments de la planète. Voilà qui est rassurant!

Utilisation à des fins bienfaisantes, sécurité pour le sort de notre planète, tout cela doit concourir à calmer notre inquiétude et nous donner l'espérance d'une nouvelle et rapide libération matérielle, condition nécessaire de notre libération spirituelle. Ce double aspect des applications de la science n'est pas particulier aux domaines qui nous préoccupent aujourd'hui. Les explosifs ordinaires déjà très puissants sont également utilisés pour les œuvres de paix et pour la guerre. La biologie pourrait aussi nous fournir des exemples.

Je pense que la grande inquiétude créée par l'apparition de la bombe atomique ne peut que provoquer un grand courant d'idées et de réalisations en faveur d'une bonne utilisation de la science. La pire des catastrophes serait pour l'humanité d'arrêter le développement de la science, rendant celle-ci responsable des guerres et des troubles économiques et d'autres maux encore. La nature elle-même, si de telles mesures étaient prises, se chargerait tôt ou tard de nous faire cruellement sentir cette erreur.

Je voudrais maintenant tenter de retracer les principales étapes des recherches qui ont conduit aux réalisations qui nous intéressent aujourd'hui.

Les cinquante dernières années ont vu l'éclosion de nombreuses découvertes qui nous ont permis d'acquérir une connaissance profonde de la matière. Il faut remonter à la fin du siècle dernier pour voir bouleverser le dogme de l'immutabilité des atomes par les découvertes fondamentales de la radio-activité par HENRI BEQUEREL et les radio-éléments par PIERRE et MARIE CURIE. Certains éléments chimiques comme l'uranium, le radium, se transforment spontanément au cours du temps en d'autres éléments chimiques en libérant de l'énergie emportée par des rayonnements corpusculaires ou semblables aux rayons X. Les radio-éléments sont des sources d'énergie, mais pratiquement inutilisables en raison de leur très faible débit. Quatre cents grammes d'uranium sont équivalents à 160 tonnes de charbon, mais le débit de chaleur dû aux désintégrations des atomes d'uranium est si faible qu'il faudrait attendre quelques milliards d'années