

The constitution of umbellulone. Pt. III / by Frank Tutin.

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THE CONSTITUTION
OF
UMBELLULONE

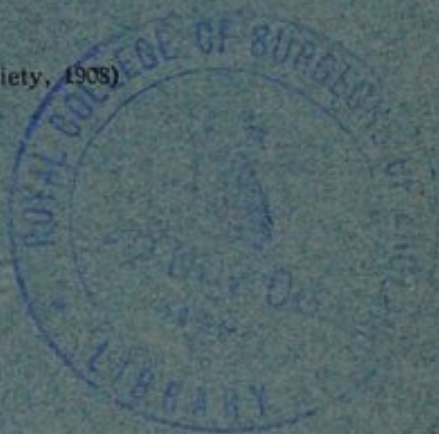
PART III

BY
FRANK TUTIN

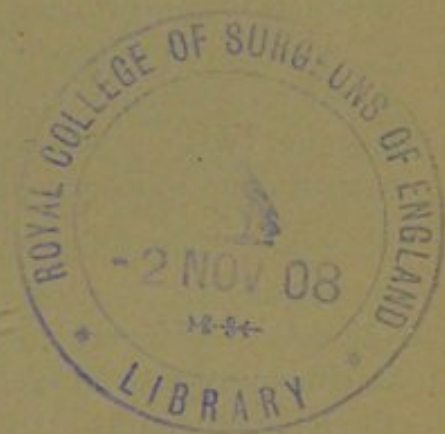
(From the Transactions of the Chemical Society, 1908)



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XXIII.—*The Constitution of Umbellulone. Part III.*

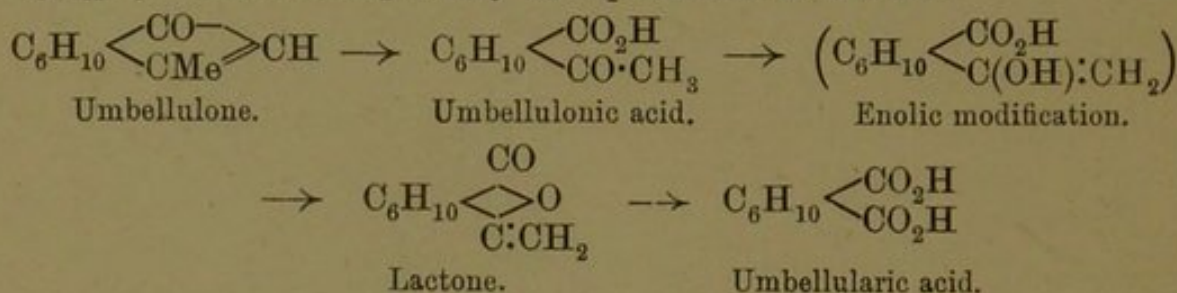
BY FRANK TUTIN.

IN previous communications (Trans., 1906, 89, 1104; 1907, 91, 271) the author's conclusions respecting the constitution of umbellulone have been set forth, but in view of some criticisms recently published by Semmler (*Ber.*, 1907, 40, 5017) it appears desirable that the subject should again be discussed.

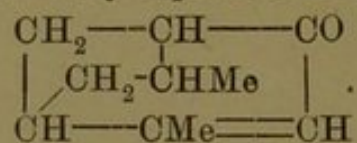
Umbellulone was first isolated by Power and Lees (Trans., 1904, 85, 629) from the essential oil of *Umbellularia Californica*, Nuttall

(Californian laurel). It was shown by them to possess the formula $C_{10}H_{14}O$, and to be a bicyclic ketone containing an ethylenic linking in the $\alpha\beta$ -position with respect to the carbonyl group.

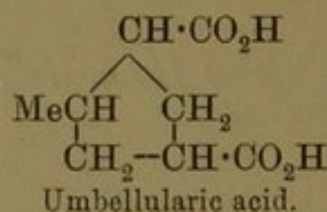
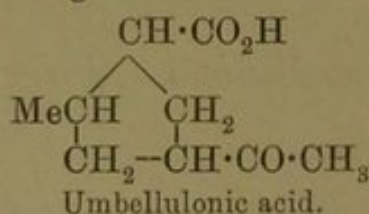
In the first communication by the present author, the behaviour of umbellulone on oxidation with potassium permanganate was studied. When submitted to this treatment, it gave a saturated keto-acid, umbellulonic acid, $C_9H_{14}O_3$, which on distillation passes into an unsaturated lactone, $C_9H_{12}O_2$. The latter, on oxidation, yielded umbellularic acid, a polymethylenedicarboxylic acid, possessing the formula $C_8H_{12}O_4$. These changes may be represented as follows:



It was stated regarding umbellularic acid, that its general properties, especially its great stability, "indicate that it is one of the tetra-, penta-, or hexa-methylenedicarboxylic acids." It was not, however, at that time considered necessary to state in detail the reasons for concluding that it could not be a trimethylene compound. Since the hexamethylenedicarboxylic acids are all known, and the oxidation products of umbellulone are not identical or stereoisomeric with those of pinene, it was concluded that umbellularic acid was most probably a methylpentamethylenedicarboxylic acid. From these results, together with other considerations (*loc. cit.*), it was concluded that umbellulone was most probably represented by the following formula:



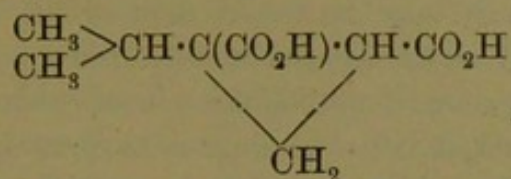
Umbellulonic and umbellularic acids respectively, would then have the following constitutions:



This conclusion is in harmony with the observation, recorded in the author's second paper (*loc. cit.*), that when the ring contained in umbellulonic acid is opened by the addition of two atoms of hydrogen, δ -hydroxy- α -isopropyl- n -hexoic acid is obtained.

Although, as stated above, the reasons for concluding that umbellularic acid was not a trimethylene compound were not detailed

in the original communication, it now appears necessary that these should be considered. If umbellularic acid does not contain a five-membered ring, it must be represented by the following formula :



It is well known, however, that the *cyclopropane* ring is, in general, somewhat unstable. A. Kötze has pointed out (*J. pr. Chem.*, 1903, [ii], 68, 174) the generalisation that simultaneous substitution by a carboxyl group and an alkyl or phenyl radicle decreases the stability of the *cyclopropane* ring, and, furthermore, that in the presence of an alkyl or phenyl group the instability increases with the number of carboxyl groups. With consideration of these conclusions, O. Aschan (*Chemie d. Alicyclischen Verb.*, 1905, p. 244) adds that, in general, the occurrence of a quaternary carbon atom appears to increase the readiness with which the *cyclopropane* ring is opened. According to these generalisations, the *isopropylcyclopropanedicarboxylic acid* represented above should be a compound in which the ring is readily ruptured, for it contains a *cyclopropane* ring substituted with an alkyl radicle and two carboxyl groups, and, moreover, it also contains a quaternary carbon atom.

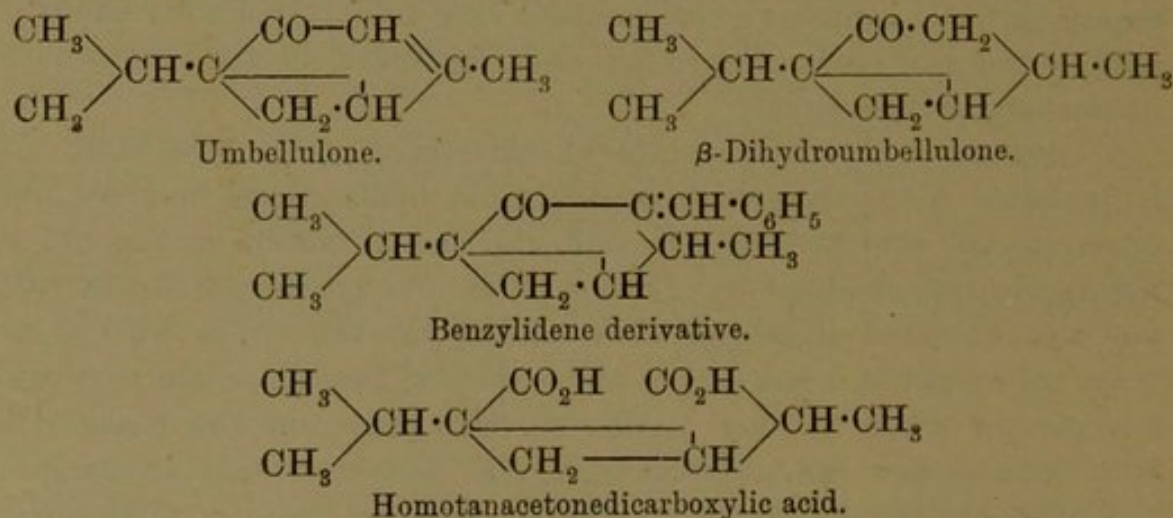
Umbellularic acid, however, is an extremely stable substance. It is unaltered by heating with concentrated hydrochloric acid for five hours at 190°, and hydrobromic acid also has no action on it. It is not appreciably oxidised by alkaline potassium permanganate at 60°, and was recovered unchanged after boiling for ten hours with eight times its weight of a mixture of three parts of fuming nitric acid and one part of water. When heated for two hours on the water-bath with bromine and red phosphorus, it was also recovered unchanged, and after boiling for five hours with undiluted fuming nitric acid, besides unchanged umbellularic acid, only a trace of oxalic acid was obtained. In addition to considerations concerning the stability of the ring, it would not be expected that a compound containing an *isopropyl* group would exhibit such great stability towards nitric acid, as *p*-cymene, for example, when treated with this acid in the cold, gives *p*-tolyl methyl ketone, together with other compounds, and when warmed with nitric acid yields *p*-toluic acid. *iso*Propylsuccinic acid, also, is fairly readily attacked when heated with fuming nitric acid. The properties of umbellularic acid therefore certainly seem to indicate that it does not possess the *cyclopropane* structure.

Semmler, in his recent publication (*loc. cit.*), states in the first place that the physical properties of umbellulone are not in agreement

with those of *bicyclo-2:2:2-octanone* (*Ber.*, 1907, **40**, 4844), and that therefore either umbellulone or the *bicyclo-2:2:2-octanone* must be incorrectly represented.

In this connexion it may be noted first of all that Semmler has evidently never had even approximately pure umbellulone in his possession. Furthermore, if umbellulone is represented by the formula which I have proposed, it is not analogous to Semmler's octanone, since the latter, having the bridge in the para-position, can be represented only as a *cyclohexane* compound with a bridge of two carbon atoms, whilst the former contains a meta-bridge, and can, with equal correctness, be represented as a *cyclohexane* compound with a bridge of two carbon atoms, or as a *cycloheptane* derivative with a bridge of one carbon atom. Lastly, experimental proof of the correctness of the formula assigned by Semmler to his "*bicyclo-2:2:2-octanone*" appears to be lacking.

Semmler then proceeds to prepare the material which I had designated "*β*-dihydroumbellulone," from which he forms a hydroxymethylene and a benzylidene derivative, and, by oxidation of the latter, obtains *d*-homotanacetonedicarboxylic acid. This series of changes he represents as follows:



From these results, Semmler is led to the conclusion that umbellulone is an unsaturated "tanacetone of the menthone series," in which the double linking is adjacent to the ketonic group. Umbellularic acid would consequently be 1-isopropyl*cyclopropane-1:2*-dicarboxylic acid, but, as I have pointed out above, its properties are not in accordance with this view.

With the exception of Semmler's remark concerning the physical properties of umbellulone, which has already been dealt with, his conclusions regarding the constitution of this ketone are based entirely on experiments conducted with "*β*-dihydroumbellulone" and its derivatives. It is of paramount importance therefore to inquire into the nature of the preparation which, in my first paper on

umbellulone, I had designated as " β -dihydroumbellulone." In the first place, however, consideration may be given to the character of the "umbellulone" employed by Semmler.

The material available to Semmler for the purpose of his investigation of umbellulone consisted of 100 grams of the essential oil of *Umbellularia Californica* which had been supplied to him, at his request, by Dr. Power. This oil was a portion of the identical material which had been used in my work on umbellulone. It is stated by Semmler that the umbellulone can be separated from this oil by fractional distillation, but this is not strictly correct, as by this means it is impossible to obtain the pure ketone. Power and Lees (*loc. cit.*), by a very careful and prolonged fractionation of 1200 grams of the oil, obtained a fraction boiling at $217-222^\circ$ ($\alpha_D - 36^\circ 33'$ in a 1-dcm. tube) which gave, on analysis, $C=78.9$; $H=9.9$. On subjecting this to further fractionation, a portion was obtained which boiled constantly at 218° , and, on analysis, gave $C=79.1$; $H=9.8$. Since $C_{10}H_{14}O$ requires $C=80.0$; $H=9.3$, and $C_{10}H_{16}O$ requires $C=78.9$; $H=10.5$, these fractions were evidently mixtures. Moreover, on treating the fraction, b. p. $217-222^\circ$, with semicarbazide, it gave, at the most, only 55 per cent. of the theoretical yield of semicarbazidodihydroumbellulone-semicarbazone. That this deficiency is not due solely to the incomplete interaction of the ketone and the base, is seen from the fact that a very much better yield of the semicarbazido-derivative may be obtained by employing pure, regenerated umbellulone. Umbellulone, when regenerated from its semicarbazidosemicarbazone, has $\alpha_D - 37^\circ$ in a 1-dcm. tube, and gave $C=79.7$; $H=9.3$ ($C_{10}H_{14}O$ requires $C=80.0$; $H=9.3$ per cent.). Since the product which Semmler regarded as umbellulone had $\alpha_D - 31^\circ 30'$ in a 1-dcm. tube, it was evidently still more impure than the fraction (b. p. $217-222^\circ$, $\alpha_D - 36^\circ 33'$) obtained by Power and Lees, which, as shown above, and as recognised by them, was a mixture of substances.

It was therefore with consideration of the uncertainty regarding the composition of the fraction of the essential oil of *U. Californica* which contains umbellulone that my inferences concerning the constitution of the latter were based only on the products obtained from the pure, regenerated ketone.

β -Dihydroumbellulone.

The "umbellulone" which was submitted to the action of sodium and alcohol, both in my experiments and in those conducted by Semmler, was only a particular fraction of the essential oil. As pointed out above, this material is not pure umbellulone, but gives results on analysis which are approximately the mean of those which

would be obtained for substances possessing the formulæ $C_{10}H_{14}O$ and $C_{10}H_{16}O$ respectively.

Reduction of "Umbellulone."—In an unpublished experiment conducted by Mr. Lees, he reduced 25 grams of the umbellulone fraction (b. p. 217—222°) by means of sodium and alcohol. Some resinification ensued, and only 16 grams of volatile product were obtained. This material, which distilled almost entirely at 134—135°/70 mm., and behaved towards bromine as an unsaturated substance, was converted into the acetate. The latter was fractionally distilled, and the most constant-boiling portion (11 grams), which passed over at 144—146°/70 mm., separately collected. This was analysed:

0.1480 gave 0.4004 CO_2 and 0.1344 H_2O . $C = 73.8$; $H = 10.1$.

$C_{10}H_{15} \cdot O \cdot CO \cdot CH_3$ requires $C = 74.2$; $H = 9.3$ per cent.

$C_{10}H_{17} \cdot O \cdot CO \cdot CH_3$ „ $C = 73.5$; $H = 10.2$ „

This acetate of constant boiling point was hydrolysed, and the resulting alcoholic product fractionally distilled, when the greater portion passed over between 207° and 212°. This product, when dissolved in chloroform, readily decolorised a solution of bromine in the same solvent. It was analysed with the following result:

0.0749 gave 0.2146 CO_2 and 0.0784 H_2O . $C = 78.2$; $H = 11.6$.

$C_{10}H_{16}O$ requires $C = 78.9$; $H = 10.5$ per cent.

$C_{10}H_{18}O$ „ $C = 77.9$; $H = 11.7$ „

My own experiments on the reduction of umbellulone, which were not given in full in the previous communications (*loc. cit.*), resulted as follows: 25 grams of the umbellulone fraction (b. p. 215—225°; $\alpha_D - 34.4'$) gave, on reduction, 17 grams of an unsaturated, alcoholic product. This was therefore again submitted to the action of sodium and alcohol, but was recovered apparently unchanged and was still unsaturated, no loss by resinification occurring during the second treatment. The product was then fractionated, when the greater part passed over at 132—134°/70 mm., or at 208—210° under the ordinary pressure. This material had the following constants: $d_{20}^{20} = 0.9307$; $\alpha_D - 27.52'$ in a 1-dm. tube. On analysis:

0.0947 gave 0.2722 CO_2 and 0.0988 H_2O . $C = 78.4$; $H = 11.5$.

$C_{10}H_{16}O$ requires $C = 78.9$; $H = 10.5$ per cent.

$C_{10}H_{18}O$ „ $C = 77.9$; $H = 11.7$ „

This analysis entirely confirms the results obtained by Lees, and the only conclusion that can be drawn is that the product of the action of sodium and alcohol on the umbellulone fraction is a mixture of alcohols possessing the formulæ $C_{10}H_{16}O$ and $C_{10}H_{18}O$ respectively. The result is, in fact, such as might be expected, for the material which was reduced appeared to be a mixture of ketones possessing the formulæ $C_{10}H_{14}O$ and $C_{10}H_{16}O$ respectively.

Since the "dihydroumbellulol" described by Semmler was prepared in the above manner, and from a portion of the identical oil employed by me, it would naturally be expected to consist of a similar mixture. It is stated to have had the following constants: $d_{20} = 0.931$; $n_D^{20} = 1.4730$ in a 1-dm. tube, and, on analysis, gave $C = 77.37$; $H = 11.22$ per cent. These figures for the density and rotation are practically identical with those found by me, as given above, but the analysis cannot be said to agree with any formula. It is evident, however, that Semmler's preparation must have been essentially the same as that obtained by Mr. Lees and by the present author.

Oxidation of the Reduction-product.—Fifteen grams of the above-described mixture of alcohols (see Trans., 1906, 89, 1118) gave, on oxidation with a chromic acid mixture, 6 grams of a product, boiling at $204-209^\circ$, which was designated " β -dihydroumbellulone." This material, when dissolved in chloroform, readily decolorised a solution of bromine in the same solvent, and, on analysis, gave results in agreement with those required for the formula $C_{10}H_{16}O$. This was confirmed by analysis of the semicarbazone. Since 6 grams of a ketonic product, $C_{10}H_{16}O$, had been obtained by oxidising 15 grams of a mixture of unsaturated alcohols, $C_{10}H_{16}O$ and $C_{10}H_{18}O$, it was stated that the former alcohol must have been destroyed.

The semicarbazone of this " β -dihydroumbellulone" was prepared, and was first obtained in a viscous condition, but after standing for some time it became solid. It was then dissolved in alcohol and allowed to crystallise, when a product melting at 150° was obtained. On recrystallisation from a mixture of ethyl acetate and light petroleum, the melting point of this product was raised to $155-156^\circ$. This material has now been fractionally crystallised from ethyl acetate, when the melting point of the most sparingly soluble fraction gradually rose, and eventually about 30 per cent. of the product was obtained in well-defined needles, which were sparingly soluble in ethyl acetate, and melted sharply at 204° . The ketone regenerated from this semicarbazone (m. p. 204°) behaved towards bromine as a saturated compound, and is doubtless the substance which gave rise to Semmler's benzylidene derivative. The more readily soluble portions of the semicarbazone, which formed the greater part of the material, gave a ketone which, when dissolved in chloroform, instantly decolorised a solution of bromine in the same solvent.

The name " β -dihydroumbellulone" ought therefore to be discarded, since the preparation is a mixture.

The " β -dihydroumbellulone" prepared by Semmler had the same characters as the liquid which I had described under that name, but he failed to observe that the preparation is a mixture, consisting, to a considerable extent, of an unsaturated substance. The semicarbazone

obtained by him melted at 150° , and was evidently the above-described mixture.

The foregoing results may be summarised as follows:

The umbellulone obtained by the fractional distillation of the essential oil of Californian laurel is not the pure ketone, $C_{10}H_{14}O$, but, on analysis, gives results agreeing with those yielded by a mixture of substances, $C_{10}H_{14}O$ and $C_{10}H_{16}O$.

When this umbellulone fraction is reduced, it gives about 70 per cent. of its weight of an unsaturated mixture of alcohols, $C_{10}H_{16}O$ and $C_{10}H_{18}O$.

On oxidising this mixture of alcohols, the former one is readily destroyed by the excess of the oxidising agent, and less than a 50 per cent. yield of a ketonic product ("β-dihydroumbellulone"), $C_{10}H_{16}O$ is obtained.

The explanation of this appears to be that the original fraction of the oil is a mixture of ketones, $C_{10}H_{14}O$ and $C_{10}H_{16}O$, which, on reduction, yields the corresponding alcohols, that is, umbellulol and a product, $C_{10}H_{17}OH$. This conclusion is in agreement with the unsaturated character of the material. On treating this mixture with chromic acid, the umbellulol is broken down, and "β-dihydroumbellulone" is obtained from the product, $C_{10}H_{17}OH$, from which consideration it appears highly probable that "β-dihydroumbellulone" is not a derivative of the ketone from which it was named.* Finally, this "β-dihydroumbellulone" is a mixture of at least two ketones, one of which is saturated, and one unsaturated.

It was from a constituent of this mixture of unknown origin that Semmler prepared homotanacetonedicarboxylic acid, and such is the foundation upon which he has based his conclusions respecting the constitution of umbellulone.

Apart from the above considerations, Semmler represents "β-dihydroumbellulone" as umbellulone in which the double linking has been reduced. This view, however, could not possibly be correct, even if "β-dihydroumbellulone" were a definite derivative of umbellulone, since α-dihydroumbellulone (m. p. of semicarbazone 177°), a compound which is certainly a pure, saturated derivative of umbellulone, must be represented in this manner. α-Dihydroumbellulone is not only formed by the reduction of monobromoumbellulone (Lees, Trans., 1904, 85, 639), but can also be obtained by the reduction, with zinc dust and acetic acid, of umbellulone dibromide, the initial product of the interaction of bromine and umbellulone at 0° .

* With the exception of "β-dihydroumbellulone," all compounds described by Power and Lees, by Lees, or myself as derivatives of umbellulone have been proved to be derived from this ketone.

