613. *The Molecular Rotations of Polycyclic Compounds. Part II.* Diterpenoids and Sesquiterpenoids.*

By W. KLYNE.

The general method of molecular-rotation differences discussed in Part I * is used to correlate the stereochemistry of the diterpenoids and some sesquiterpenoids with that of the triterpenoids and the steroids. Conclusions for the A–B ring union in the diterpenoids agree with those previously reached on chemical grounds by Ruzicka, Jeger, and Lederer, and their colleagues.

The rotation contributions of conjugated diene types are discussed, and configurations at $C_{(13)}$ are allotted for abietic, lævopimaric, and *neo*abietic acids, and (provisionally) for some compounds of the manoöl–sclareol–agathenedicarboxylic acid group. Preliminary observations are made on the rotation contributions of five- and six-membered lactone rings. The sesquiterpenoids considered are those of decalin types which carry angle-methyl groups; they include the cyperones, selinene, eudesmol, and the "anomalous" compound eremophilone.

Suggestions for the nomenclature of the diterpenoids are made.

DITERPENOIDS

Nomenclature.—The same general principles are applied as for steroids (*J.*, 1951, 3526) and triterpenoids (Halsall, Jones, and Meakins, *J.*, 1952, 2862).

Fundamental hydrocarbons. The names abietane, pimarane (C_{20}), and podocarpane (C_{17}) are allotted to the hydrocarbons (I), (II), and (III) respectively. Agathene and manoöl derivatives are named as derivatives of 7 : 8-*seco*pimarane (IV) for purposes of this paper.

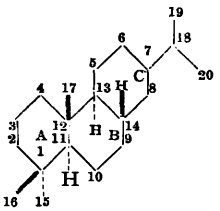
Numbering. This follows present practice for (I—III) (phenanthrene-type numbering).

Lettering of rings. This will be as shown in (I); in many previous papers the ring containing atoms 5—8 has been called B, but in view of the close relations between the diterpenoids and triterpenoids it seems better to denote corresponding rings in the same way.

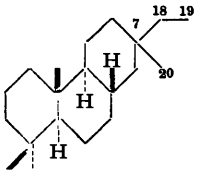
Orientation of substituents. This will be indicated by α and β, and broken and heavy lines respectively, as for steroids. It is shown in the present paper that the angle-methyl

* Part I, *J.*, 1952, 2916.

group at $C_{(12)}$ in the diterpenoids is oriented in the same way as the corresponding angle-methyl group at $C_{(10)}$ in the triterpenoids (V) and the steroids (VI). The numbering of rings A and B in the triterpenoids is now as in the steroids (*J.*, 1953, 3024).



(I) Abietane



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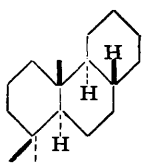
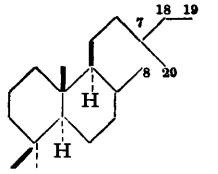
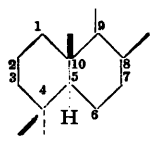


(III) Podocarpane

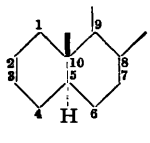


(IV) 7 : 8-*seco*Pimarane

Stereochemistry of ring-unions. The stereochemistry of the (unknown) fundamental hydrocarbons (*trans-anti-trans*) is as shown in formulæ (I—III). If inversion has taken place at a ring junction, this will be indicated by a prefix giving the number of the carbon atom and the Greek letter α or β indicating the orientation of the hydrogen atom or substituent. Thus lævopimaric acid, shown below to be (VII), is named systematically 13β-abieta-6 : 8(14)-dien-15-oic acid.



(V)



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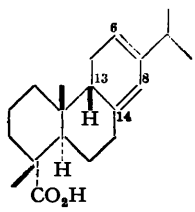


(VII)

Points of stereochemistry as yet unknown. Orientations at $C_{(7)}$ in many abietane, pimarane, and agathene derivatives, and at $C_{(13)}$ and $C_{(14)}$ in many pimarane and 7 : 8-*seco*-derivatives, are unknown. This is indicated by the use of ordinary lines for valency bonds to substituents, and the letter ξ in names, as required.

The author is indebted to the Editor of the *Journal* for helpful suggestions on these proposals.

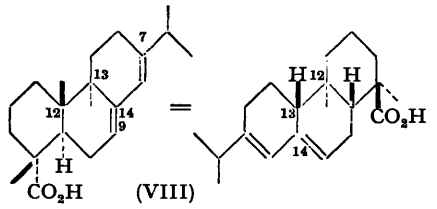
General.—Part I of this series (*J.*, 1952, 2916) described the general principles involved in the application of the method of molecular-rotation differences to the stereochemical correlation of polycyclic systems. It was shown that if present-day steroid conventions are used, as in (VI), the A–B ring union of the triterpenoids is of the same form as in (V). This correlation has been confirmed by Prelog *et al.* (*Helv. Chim. Acta*, 1953, **36**, 308, 320, 325), using the method of asymmetric synthesis. They have also shown that the steroid–triterpenoid convention and the glyceraldehyde convention are in agreement (cf. Mills, *J.*, 1952, 4976; *Chem. and Ind.*, 1953, 218).

Ruzicka, Jeger, and Lederer, and their colleagues have shown by purely chemical methods that the A–B ring union in the diterpenoids is of the same form as that in the triterpenoids and that it should therefore be written as in (I—III). (For summaries with references, see Barton, *Quart. Reviews*, 1949, **3**, 36, on diterpenoids; Jeger, *Fortschr. Chem. org. Naturstoffe*, 1950, **7**, 1, on triterpenoids.)

In the present paper the method of molecular-rotation differences will be applied to some stereochemical problems of the diterpenoids (and, to a smaller extent, the sesquiterpenoids) with particular reference to rotation differences associated with conjugated diene systems and aromatic nuclei. Experimental data, definitions, and conventions are as in Part I. $[M]_D$ values are shown in parentheses.

A very detailed review of the chemistry of the diterpenoids and sesquiterpenoids is given by Simonsen and Barton (" The Terpenes," Cambridge Univ. Press, 2nd edn., Vol. III, 1952). Shorter accounts are given by Barton (*loc. cit.*) and by Fieser and Fieser

(" Natural Products Related to Phenanthrene," Reinhold Publ. Corp., New York, 3rd edn., 1949). Where no references for rotation values are given in this paper, they may be found in one of these reviews. Rotations of steroids, where not stated otherwise, are taken from Part I (*loc. cit.*) or from Barton and Klyne (*Chem. and Ind.*, 1948, 755).



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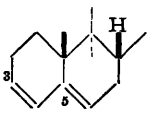

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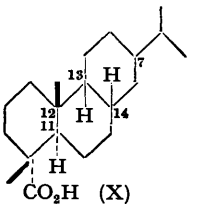


(X)

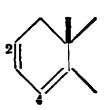
Configurations at Ring Junctions.—Configurations at $C_{(13)}$. Barton (*loc. cit.*) has suggested that in abietic acid [abieta-7 : 14(9)-dien-15-oic acid] the substituents at $C_{(13)}$ and $C_{(12)}$ are *trans* (VIII), since it is stable to acid whilst other isomers are not. This is supported by rotational evidence. If formula (VIII) is correct, abietic acid is an analogue of cholesta-3 : 5-diene (IX). The Δ values for the conjugated double bonds in these two compounds with reference to the corresponding saturated compounds are of the same sign and order of magnitude, which supports the formula (VIII).

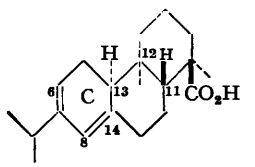
$$\Delta(\text{C:C–C:C}) \text{ in (VIII)} = (-314°) - (+21°) = -335°$$
$$\Delta(\text{C:C–C:C}) \text{ in (IX)} = (-458°) - (+91°) = -549°$$

The saturated reference compound used in the diterpenoid series is the tetrahydroabietic acid (7ξ : 13ξ : 14ξ-abietan-15-oic acid (X) (m. p. *ca.* 182°, Ruzicka and Meyer, *Helv. Chim. Acta*, 1922, **5**, 315). Comparisons in the steroid field (Klyne, *loc. cit.*, Table 4) show that with saturated hydrocarbons the difference in $[M]_D$ values between *cis*- and *trans*-decalin types is very small.

The same kind of reasoning shows that lævopimaric acid must be (VII) ($C_{(13)}$-H *cis* to $C_{(12)}$-Me) [13β-abieta-6 : 8(14)-dien-15-oic acid]. This compound on isomerisation with acid gives abietic acid; its configuration at $C_{(11)}$ and $C_{(12)}$ must therefore be the same as in (VIII). If the $C_{(13)}$-H in lævopimaric acid were *trans* to the $C_{(12)}$-methyl group, ring C of this acid would be of the same type as ring A of cholesta-2 : 4-diene (XI), which has a large

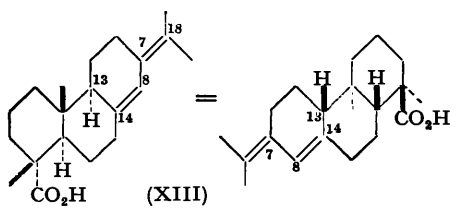
(XI)





(XII)

positive Δ value for the C:C–C:C grouping, *viz.*, (+627°) − (+91°) = +536°. Since lævopimaric acid has a large negative rotation (−830°) its C-ring must be enantiomeric to the A-ring of cholesta-2 : 4-diene, *i.e.*, the acid must be (VII), which may be rewritten as (XII) for comparison. This is contrary to the conclusion reached by Fieser and Fieser (*op. cit.*, pp. 74—75), who attempted to allot rotational contributions to individual carbon atoms. The present method of considering terminal ring-units seems preferable.



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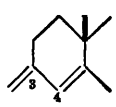


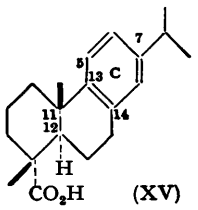
(XIV)

*neo*Abietic acid, obtained by Harris and Sanderson (*J. Amer. Chem. Soc.*, 1948, **70**, 339, 344), is very probably (XIII); its positive rotation (+480°) indicates that it must be of

similar type to its nearest steroid analogue, the 3-methylenecholest-4-ene (XIV; +192°) of Musgrave (*J.*, 1951, 3121).

Configurations at $C_{(11)}$ *and* $C_{(12)}$. Rotational evidence is available which supports the purely chemical evidence cited above regarding the stereochemistry of $C_{(11)}$ and $C_{(12)}$.

Dehydroabietic acid [abieta-5 : 7 : 14(13)-trien-15-oic acid] (XV; +186°) and tetrahydroabietic acid (7ξ : 13ξ : 14ξ-abietan-15-oic acid) (X; +21°) differ in that ring C is aromatic in (XV). The difference is similar to that between the steroids deoxo-œstrone and androstan-3β-ol which may be written as (XVI) and (XVII).



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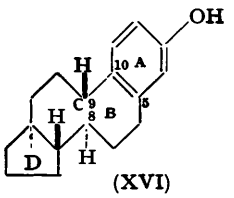

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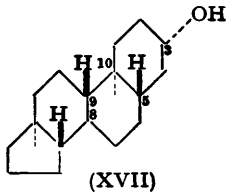
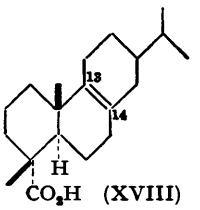


(XVII)

The Δ value for (XVI — XVII) which represents the effect of making ring A aromatic (ΔAr) is (+230°) — (+3°) = +227°. The ΔAr value for (XV — X) = (+186°) — (+21°) = +165°, which is of the sign and order of magnitude expected. Many dehydroabietic acids substituted in the aromatic ring are known (for a summary see Elsevier's " Encyclopaedia of Organic Chemistry," 1946, Vol. XIII, p. 961). These all have positive rotations, mostly differing from the rotation of the unsubstituted acid by not more than 50°.

Dihydroabietic acids. Simonsen and Barton (*op. cit.*, p. 409) have suggested that Lombard's " β "- and " α "-dihydroabietic acids (*Bull. Soc. chim.*, 1942, **9**, 833; 1944, **11**, 526) may be the Δ^{13}- and $\Delta^{9(14)}$-isomers (XVIII) and (XIX) respectively, since the compound (XVIII) with the ditertiary double bond would be the most stable.



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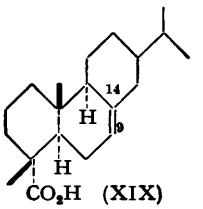

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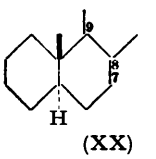


(XX)

The signs of the rotation differences between the dihydro-acids and the saturated tetrahydro-acid (+21°) support these suggestions. The two dihydro-acids are formally analogous to $\Delta^{8(9)}$- and Δ^{7}-5α-steroids (cf. XX for numbering) respectively. Δ(C:C) values are :

" β "-Dihydroabietic acid (XVIII ?)	*ca.* +350°	" α "-Dihydroabietic acid (XIX ?)	−100°
$\Delta^{8(9)}$-5α-Steroid	+100	Δ^{7}-5α-Steroid	− 70

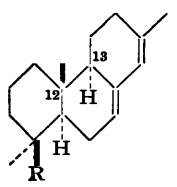
Configurations at $C_{(13)}$ *in the* 7 : 8-seco*pimaranes* (*agathenedicarboxylic acid, manoöl, sclareol group*). Chemical correlations by Ruzicka, Jeger, and Hosking, and their colleagues (for references see Barton and Jeger, *locc. cit.*) have shown that the stereochemistry of the union between the two rings of the agathenedicarboxylic acid, manoöl, and sclareol diterpenoids (7 : 8-*seco*pimaranes) is the same as that between the A- and the B-ring in abietic acid (cf. IV).

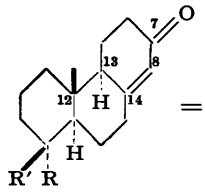
Rotational evidence (mentioned briefly by Barton, *loc. cit.*, p. 62) shows that certain degradation products of these 7 : 8-*seco*pimaranes have the hydrogen atom at $C_{(13)}$ *trans* to the angle-methyl group at $C_{(12)}$ [$C_{(13)}$α-H, as in (XXI)], although this is not rigid proof that the $C_{(13)}$-hydrogen atom is α in the original compounds.

The dienes (XXI; R = CO_2Me or Me), from agathenedicarboxylic acid and manoöl respectively, have large negative rotations (−308°, −342°), which indicate that the $C_{(13)}$-hydrogen atom is α as in abietic acid (VIII) (−314°).

The unsaturated ketones (XXII; R = CO_2Me, R′ = Me, from *neo*abietic acid; and R = Me, R′ = CO_2Me, from agathenedicarboxylic acid) both have positive rotations

(+91° *, +142°) as would be expected if the $C_{(13)}$-hydrogen atom is α [compare cholest-4-en-3-one (XXIII; R = Me), for which Δ(C:C·C:O) is +266°; steroids not carrying a methyl group at $C_{(10)}$ (XXIII; R = H) have smaller positive Δ(C:C·C:O) values, *ca.* +150° (Klyne, *loc. cit.*)].


(XXI)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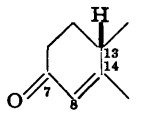
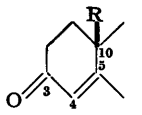
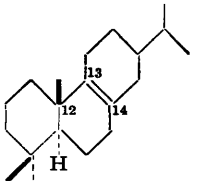



(XXIII)

12-*Nor*-13-*methylabietane derivatives*. Barton (*Chem. and Ind.*, 1948, 638, where previous references are given) discussed the structure of the lactone $C_{20}H_{32}O_2$ (−6°) obtained from various dihydro-abietic and -lævopimaric acids (*e.g.*, XXIV) by treatment with strongly acidic reagents, and proposed for it the formula (XXVI) (12α-hydroxy-13β-methyl-12-nor-11β-abietan-15-oic lactone). He suggested that the lactone (XXVI) was formed from (XXIV) by a carbonium-ion rearrangement, the angle-methyl group moving from $C_{(12)}$ to $C_{(13)}$, followed by the formation of the $\Delta^{11(12)}$-acid (XXV), which then lactonised to (XXVI) with a β-hydrogen atom at $C_{(11)}$, " in order that the $C_{(1)}$-CO_2H : $C_{(11)}$-H relationship may be changed from *cis* to *trans*."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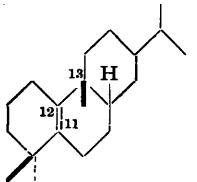
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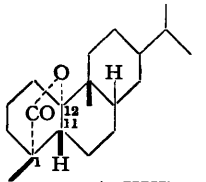
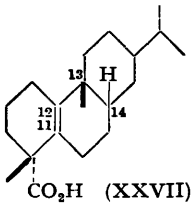

(XXVI)

When the lactone was treated with methylmagnesium iodide, two unsaturated acids [(−110°), m. p. 185—186°; and (+208°), m. p. 147—148°] were obtained. On the basis of their reactions with nitrosyl chloride or butyl nitrite, Simonsen and Barton (*op. cit.*, p. 410) allotted the formulæ (XXVII) and (XXVIII) to these acids respectively (stereochemistry at $C_{(14)}$ *not* indicated). (XXVII) is of a type enantiomeric to an 8(9)-unsaturated steroid and has the expected negative rotation (−110°) (cf. XX for numbering). The surroundings of the double bond in the isomer (XXVIII) are enantiomeric to those in the triterpenoid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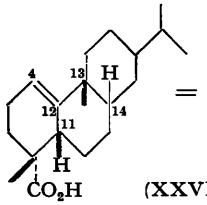
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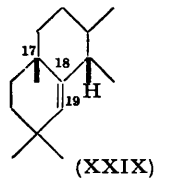
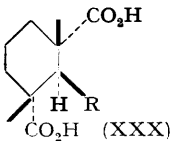

(XXIX)

germanicol (XXIX); the Δ(C:C) value in the latter compound is negative (*ca.* −120°; Klyne, *loc. cit.*, Table 12); the rotation of (XXVIII) is positive (+208°) as expected on this analogy. It must be pointed out that the negative Δ(C:C) value of germanicol is anomalous, and no explanation of this anomaly can as yet be given.

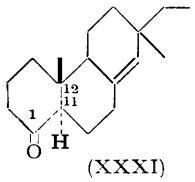
Dextropimaric acid. The A–B ring union in this acid must be *trans* as in abietic acid, since both acids on vigorous oxidation give a mixture of two optically inactive tricarboxylic acids, $C_{11}H_{16}O_6$ and $C_{12}H_{18}O_6$ (XXX; R = CO_2H and CH_2·CO_2H respectively) (Ruzicka, de Graaff, Goldberg, and Frank, *Helv. Chim. Acta*, 1932, **15**, 915, and earlier references

* This value is an unpublished observation for which the author is indebted to Dr. G. C. Harris (cf. Harris and Sanderson, *J. Amer. Chem. Soc.*, 1948, **70**, 339).

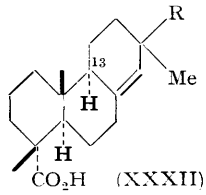
given there; Barton and Schmeidler, *J.*, 1948, 1197). That this ring union in dextropimaric acid is of the same *trans* type as in abietic acid is shown by the following evidence. Brossi and Jeger (*Helv. Chim. Acta*, 1951, **34**, 2446) degraded dextropimaric acid to the ketone (XXXI) and the corresponding hydrocarbon. The positive Δ(C:O) value (+16°) shows that the A–B ring union in this compound is as shown in (XXXI), corresponding to abietic acid, the steroids, and triterpenoids. [This fact alone would not prove the configuration of the hydrogen atom at $C_{(11)}$ in dextropimaric acid, since (XXXI) is an α-decalone and might have rearranged at $C_{(11)}$.] The configuration at $C_{(13)}$ in dextropimaric acid (+220°) cannot be allotted with certainty, although it is probably α (cf. XXXII; R = ·CH:CH_2). The acid may be reduced to a dihydrodextropimaric acid (+60°) in



(XXX)



(XXXI)

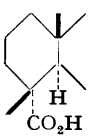


(XXXII)

which the vinyl group has been reduced (Tschugaeff and Teearm, *Ber.*, 1913, **46**, 1769; Ruzicka and Bales, *Helv. Chim. Acta*, 1923, **6**, 677). The positive rotation of this dihydro-acid suggests that it is probably (XXXII; R = Et): this would be analogous to a Δ^4-steroid which has a positive rotation. Reduction in more vigorous conditions (PtO_2 in acetic acid at 50°; Ruzicka, Huyser, and Seidel, *Rec. Trav. chim.*, 1928, **47**, 363) gives a mixture of tetrahydro-acids for which no rotation is given.

Substituents.—Keto-groups in the A- *and* B-*rings.* By analogy with the steroids and triterpenoids, it would be expected that diterpenoids carrying keto-groups in the A- and the B-rings would have positive and negative Δ(C:O) values respectively. This is borne out by the few diterpenoid ketones known. The Δ(C:O) values are as follows. A-Ring ketones: 3-ketomanoyl oxide (+76°); hinokione [keto-group probably at $C_{(3)}$ (Fieser and Fieser, *op. cit.*, p. 71), possibly at $C_{(2)}$ or $C_{(4)}$] (+192°); compound (XXXI) from dextropimaric acid (see above, +16°). B-Ring ketones: sugiol [6-hydroxyabieta-5 : 7 : 14(13)-trien-9-one) and its acetate (−57°, −105°)]; 9-ketohinokiol derivatives (four values, −25° to −100°; diketone −340°) (for references see Simonsen and Barton, *op. cit.*, pp. 359, 365—368, 372; Brandt and Thomas, *J.*, 1952, 2442).

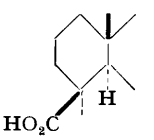
Unsaturated compounds. Subluskey *et al.* (to be published) have prepared several dehydroabietic acid derivatives containing an additional double bond at $C_{(9)}$:$C_{(10)}$, corresponding to $C_{(6)}$:$C_{(7)}$ in the steroids. The Δ(C:C) values of these compounds are negative, as expected on the analogy of Δ^6-dehydro-œstrone [Δ(C:C-6), −770°] and similar compounds (Djerassi, Rosenkranz, *et al.*, *J. Amer. Chem. Soc.*, 1950, **72**, 4531, 4540).



(XXXIII)

Abietic acid and gypsogenin series

Less positive $[M]_D$



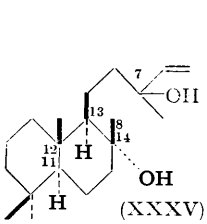
(XXXIV)

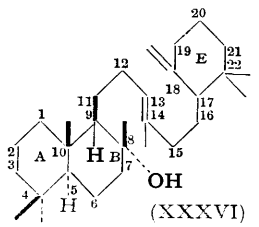
Podocarpic acid, agathenedicarboxylic acid, and α-boswellic acid series

More positive $[M]_D$

Carboxyl groups at $C_{(1)}$. Fieser and Fieser (*op. cit.*, p. 74) have pointed out that 1-carboxyl derivatives (XXXIII) of the abietic acid series are less dextrorotatory than the epimeric 1-carboxyl derivatives (XXXIV) of the podocarpic acid and agathenedicarboxylic acid series. (They use the terms α and β in the opposite sense to that used in this paper.) The configurations of the carboxyl groups in the diterpenoids being known (Barton, *loc. cit.*, p. 61), Vogel, Jeger, and Ruzicka (*Helv. Chim. Acta*, 1951, **34**, 2321) have used optical-rotation evidence to correlate with these substances the stereochemistry of the functional groups at $C_{(4)}$ in certain triterpenoids (gypsogenin and α-boswellic acid).

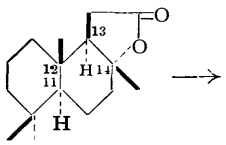
O-*Heterocyclic Derivatives.*—Five-membered lactone derivatives from sclareol (XXXV) are known; the same compounds and similar six-membered lactones have been obtained from the triterpenoid ambrein (XXXVI) (for a review see Jeger, *loc. cit.*). (XXXVI) conforms here with the new numbering for the pentacyclic triterpenoids; if it is written in this way the analogy between rings A and B and those of the pentacyclic triterpenoids

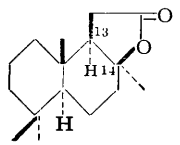

(XXXV)

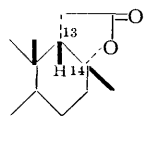

(XXXVI)

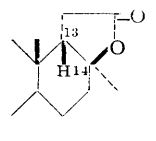
and the 7 : 8-*seco*pimaranes is clear. (Barton, *loc. cit.*, allots letters D and E to the bicyclic portion.)

Five-membered lactones. If it is assumed—and this seems probable though not rigidly proved (see p. 3075)—that the $C_{(13)}$-hydrogen atom is α in the 7 : 8-*seco*pimaranes, the five-membered lactones of this group may be represented as follows. The lactone $C_{16}H_{26}O_2$ (XXXVII) is obtained by oxidation from sclareol (Ruzicka and Janot, *Helv. Chim. Acta*, 1931, **14**, 645; Ruzicka, Seidel, and Engel, *ibid.*, 1942, **25**, 621), and from ambrein (Lederer and Mercier, *Experientia*, 1947, **3**, 188). This lactone (+117°) is isomerised by ethanolic hydrogen bromide to another lactone (−30°) (presumably XXXVIII). This change is probably due to the rearrangement of a *trans*-fused system to a *cis*-fused system. *cis*-Fusion of a five-membered and a six-membered ring is more stable than *trans*-fusion for ketones and anhydrides (for a review see Linstead, *Ann. Reports*, 1935, **32**, 313).

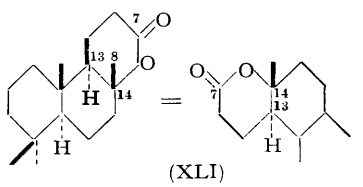

(XXXVII)

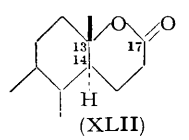

(XXXVIII)


(XXXIX)


(XL)

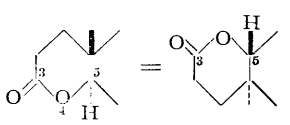
Consideration of the conformations of the decalin system in (XXXVII) and (XXXVIII) provides further indirect evidence for allotting the α-configuration to the hydrogen atom at $C_{(13)}$. If the $C_{(13)}$-H were β, the *cis*-lactone (XXXIX) could be formed readily. The *trans*-lactone (XL) *cannot* be formed if ring B is a chair form as usual; it can be formed only if ring B is a boat form and, whilst this is not impossible, it seems unlikely. Since (XXXVII) is obtained from sclareol without reaction at $C_{(13)}$ or $C_{(14)}$, the stereochemistry of the latter compound is very probably as in (XXXV), and that of ambrein must be similar.


(XLI)

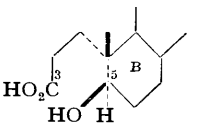

(XLII)

Six-membered lactones. As a result of the stereochemical arguments in the last section, the six-membered lactone, ambreinolide (+79°, +90°) obtained by Ruzicka and Lardon (*Helv. Chim. Acta*, 1946, **29**, 912) and by Lederer *et al.* (*ibid.*, p. 1354) from ambrein may be written as (XLI). This is of enantiomeric type to the D-ring lactones (XLII) obtained from 17-keto-steroids by oxidation with hydrogen peroxide in acetic acid. The latter compounds show a negative Δ value with reference to the corresponding saturated hydrocarbons—*e.g.*, the lactone from œstrone acetate (+138°) (Jacobsen, *J. Biol. Chem.*, 1947, **171**, 61); the corresponding hydrocarbon deoxo-œstrone (+227°); Δ value −89°.

Other related compounds are the 3-keto-4-oxasteroids (XLIII) described by Bolt (*Rec. Trav. chim.*, 1951, **70**, 940) (cf. Turner, *J. Amer. Chem. Soc.*, 1950, **72**, 579), which show large positive Δ values with reference to the corresponding saturated hydrocarbons (*e.g.*, 4-oxa-5α-cholestan-3-one, +345°, +312°; cholestane, +91°; Δ *ca.* +250°). Bolt states



(XLIII)



(XLIV)

that his compounds probably have the 5α-configuration shown in (XLIII). This seems certain, since the hydroxy-acids (XLIV) were obtained by reduction of the corresponding keto-acids with sodium and alcohol: this process is known to give equatorial hydroxy-groups (Barton, *Experientia*, 1950, **6**, 316), and the 5β-hydroxy-group is equatorial with reference to ring B.

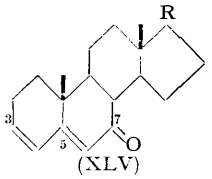
Turner (*loc. cit.*) obtained two 5-epimeric lactones by catalytic reduction of the corresponding 5-unsaturated enol lactone. His allotment of the 5α- and the 5β-configuration respectively to the isomers of higher and lower rotation [(+345°, +312°), m. p. 116°, and (+71°), m. p. 110°] was based on analogy with 5α-cholestan-3-one (+162°) and 5β-cholestan-3-one (coprostanone, +134°). This analogy seems a little dangerous, since we have no general knowledge of the effect of hetero-atoms on molecular rotations. Fortunately Turner's formulation is confirmed by the arguments above.

Sesquiterpenoids

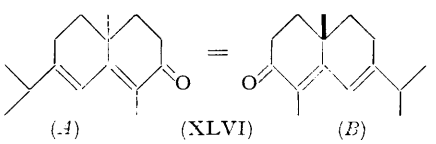
The sesquiterpenoids considered below are all of decalin types which carry angle-methyl groups, *viz.*, the cyperones, selinene, eudesmol, and the "anomalous" compound eremophilone. It is hoped to consider santonin, the alantolactones, and related compounds in a subsequent paper.

Cyperones.—Steroid 3 : 5-dien-7-ones have very large negative rotations, *e.g.*, (XLV; R = C_8H_{17}) −1150° (Prelog, Ruzicka, and Stein, *Helv. Chim. Acta*, 1943, **26**, 2236) and (XLV; R = :O) −940° (Billeter and Miescher, *ibid.*, 1948, **31**, 629). 4 : 6-Dien-3-ones have positive rotations, *e.g.*, methyl 3-ketoetia-4 : 6-dienate (+410°; Δ value, +248°) (Djerassi, *J. Amer. Chem. Soc.*, 1949, **71**, 1003).

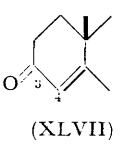
β-Cyperone (McQuillin, *J.*, 1951, 716) has a large positive rotation (+*745*°); it must therefore be written as (XLVI) in terms of steroid conventions. ($[M]_D$ values in italics are for the Hg 5461 Å green line).



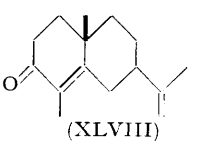
(XLV)



(*A*) (XLVI) (*B*)



(XLVII)



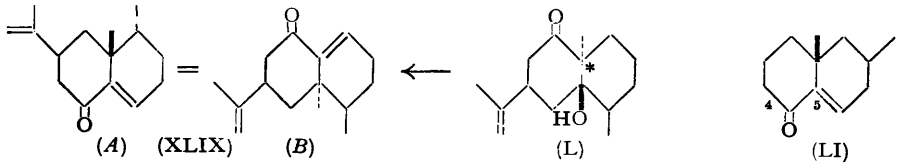
(XLVIII)

Steroid 4-en-3-ones (XLVII) have a large positive Δ value with reference to the corresponding saturated hydrocarbon (+266°). α-Cyperone, which can be transformed into β-cyperone (for references see McQuillin, *loc. cit.*), has a large positive rotation (+300°) in agreement with the formula (XLVIII). The corresponding tetrahydro-ketone has (+*33*°) (Simonsen and Barton, *op. cit.*, p. 205).

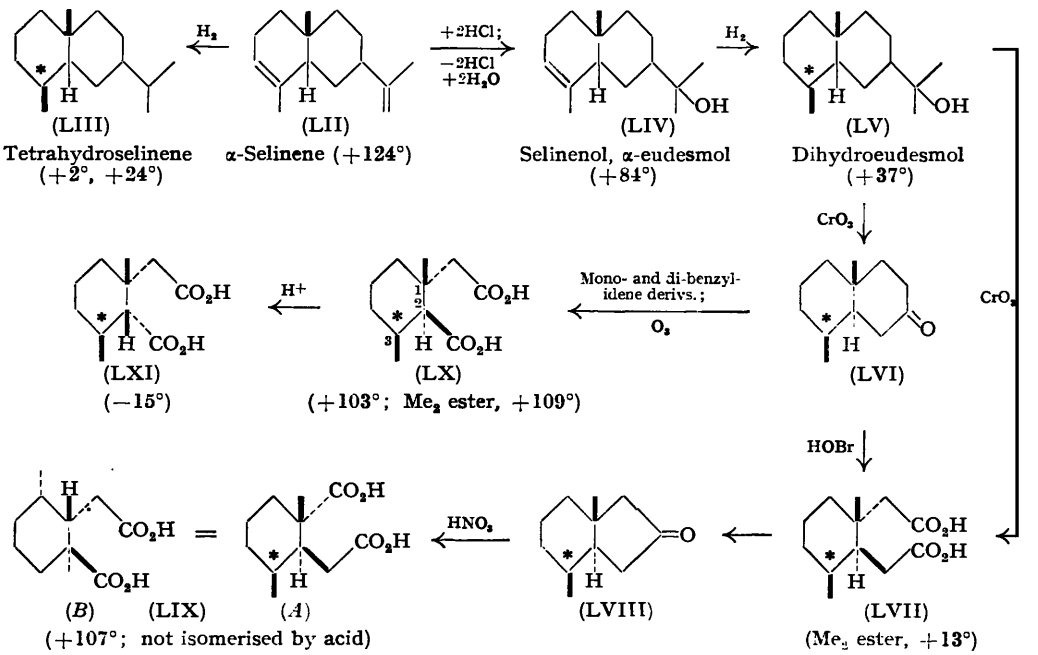
Eremophilone.—This ketone (XLIX) has a large negative rotation (−*451*°), in contrast to the tetrahydro-ketone (+*27*°) (Simonsen and Barton, *op. cit.*, pp. 212, 224). This indicates that eremophilone must be of the same stereochemical type as a steroid 5-en-4-one (LI). Butenandt and Ruhenstroh-Bauer (*Ber.*, 1944, **77**, 397) give (−123°) for cholest-5-en-4-one; the Δ value with reference to cholestane is (−214°).

Robinson (cf. Penfold and Simonsen, *J.*, 1939, 87) has suggested that eremophilone

(which does not fit the isoprene rule) might arise by dehydration and rearrangement of a structure such as (L) to (XLIX*B*). This imaginary precursor (L) has the same carbon skeleton as the cyperones (see, *e.g.*, XLVI*A*); the stereochemistry of the quaternary carbon atom (marked * in L) is the same in both cases. If the methyl attached to C* migrates, it should be α in (XLIX*B*)—as indeed the rotation of eremophilone shows it to be.



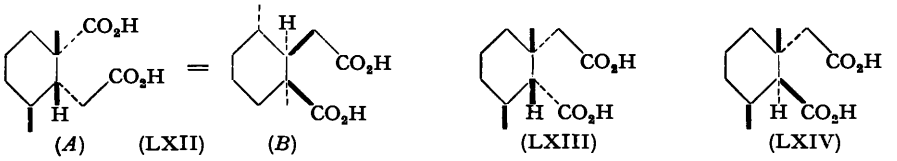
Selinene–Eudesmol Group.—Prof. D. H. R. Barton (personal communication to the author; cf. *Chem. and Ind.*, 1953, 664) has pointed out that a recent development of conformational analysis (Barton, *J.*, 1953, 1027) indicates that the decalin system in the selinene–eudesmol group is *trans*-fused, and not *cis*-fused as proposed by Ruzicka, Koolhaas, and Wind (*Helv. Chim. Acta*, 1931, **14**, 1171) on the basis of the physical properties of some derived hydrocarbons. Barton's suggestion is supported by a study of the rotations of some degradation products of eudesmol. Rotations also indicate that these compounds are of the same enantiomeric type as the cyperones. (In order to simplify the presentation of the argument, the correct stereochemical formulæ will be used from the start.)



The relevant degradations of selinene and eudesmol are summarised in formulæ (LII—LXI) (Ruzicka, Plattner, and Fürst, *ibid.*, 1942, **25**, 1364; Plattner, Fürst, and Hellerbach, *ibid.*, 1947, **30**, 2158). The isomerisation of 2-carboxy-1 : 3-dimethyl*cyclo*hexylacetic acid (LX to LXI) was at first thought to be a change from a *cis*- to a *trans*-arrangement of the acid substituents (Plattner *et al.*, *loc. cit.*). Barton (*Chem. and Ind.*, 1953, 664) has shown that the change must in fact be from *trans to cis*, his arguments depending on the justifiable assumption that the methyl group marked * in (LIII) and (LV—LXI) is almost certainly β since catalytic addition of hydrogen to selinene or eudesmol will take place more easily from the less hindered (α) side of the molecule.

The rotations of the dicarboxylic acids (LIX—LXI) support the conformational argument. If the decalin system in eudesmol were *cis*-fused, the acids (LIX—LXI) would become (LXII—LXIV) respectively.

Structures (LXII*B*) and (LXIII) are of enantiomeric types and should have rotations of opposite sign. Structures (LIX) and (LX) are of the same stereochemical type, differing only in the position of two methyl groups, as may be seen if (LIX*A*) is rewritten as (LIX*B*). The formulations of the two acids shown in the larger chart are supported by the fact that their rotations are almost identical.



(*A*) (LXII) (*B*) (LXIII) (LXIV)

Thus conformational and rotational analysis together indicate that eudesmol and selinene are *trans*-decalin derivatives. The allotment of the particular enantiomeric structures (with reference to the steroids) shown above is based on the Δ(C:C) values for the endocyclic double bonds in α-selinene and eudesmol. Both values are positive (approx. +100° and +47°; the Δ value for the side-chain double bond in $CMe{:}CH_2$ is small), and the compounds are therefore analogous to Δ^3-steroids [Δ(C:C-3), +149°].

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