Table I
Yields of Isothiocyanates by the Reaction of the *N*-Lithio Carbamates 2 with Carbon Disulfide

Amine used (RNH_2)	Registry no.	Reaction temp, °C	RNCS formed: Bp, °C (mm)	Yield, %	Registry no.
$EtNH_2$	75-04-7	*a*	55 (50)	80	542-85-8
n-$PrNH_2$	107-10-8	*a*	50–55 (20)	85	628-30-8
n-$BuNH_2$	109-73-9	*a*	47–48 (10)	81	592-82-5
t-$BuNH_2$	75-64-9	*a*	50–53 (22)	75	590-42-1
Cyclohexyl-NH_2	108-91-8	*a*	109 (10)	74	1122-82-3
$PhCH_2NH_2$	100-46-9	70–80	105–110 (10)	55	622-78-6
$PhNH_2$	62-53-3	80	96–98 (15)	99	103-72-0
p-$CH_3C_6H_4NH_2$	106-49-0	80	77–78 (0.2)	99	622-59-3
α-Naphthyl-NH_2	134-32-7	*b*	109–112 (0.2)	71	551-06-4

[a] Room temperature. [b] Distilled with decomposition.

tilled *in vacuo* (15 mm) at 150° to afford phenyl isothiocyanate in 46% yield.

Thermal Decomposition of Lithium *N*-Phenyldithiocarbamate, 1 (R = Ph). The solution of **1** (R = Ph) in tetrahydrofuran was evaporated to dryness *in vacuo* (15 mm). The residue was pyrolyzed at 150° to afford the mixture of *N,N'*-diphenylthiourea (mp 154–155°, main product) and phenyl isothiocyanate. The latter compound was isolated by filtration of the mixture in 11% yield.

One-Step Thiocarbonylation Reaction of Aniline. Aniline (2.79 g, 30 mmol) was dissolved in dry tetrahydrofuran (30 ml) and treated with butyllithium (66 mmol) under dry nitrogen at room temperature. To the resulting solution was added carbon disulfide (5.02 g, 66 mmol) at 0°. The mixture was refluxed for 4 hr and evaporated to eliminate the solvent. The residue was distilled *in vacuo* (15 mm) to afford crude *N,N'*-diphenylthiourea, contaminated with a trace amount of phenyl isothiocyanate. The crude thiourea was recrystallized from ethanol to give pure *N,N'*-diphenylthiourea, yield 2.80 g (82%), mp 154–155° (lit.[5] mp 154°).

Registry No.—Butyllithium, 109-72-8; carbon disulfide, 75-15-0; *N,N'*-diphenylthiourea, 102-08-9.

References and Notes

(1) J. E. Hodgkins, W. P. Reeves, and M. G. Ettlinger, *J. Org. Chem.*, **21**, 404 (1956); **29**, 3098 (1964).
(2) T. Wagner-Jauregg, H. Arnold, and H. Rausen, *Chem. Ber.*, **74**, 1372 (1941).
(3) K. Itoh, I. K. Lee, I. Matsuda, S. Sakai, and Y. Ishii, *Tetrahedron Lett.*, 2667 (1967).
(4) F. B. Dains, R. Q. Brewster, and C. P. Olander, "Organic Syntheses," Collect. Vol. I, Wiley, New York, N. Y., 1956, p 71.
(5) H. S. Fry, *J. Amer. Chem. Soc.*, **35**, 1539 (1913).

Synthesis of Racemic Globulol *via* Solvolysis–Cyclization of a 2,7-Cyclodecadien-1-ol Derivative

James A. Marshall* and James A. Ruth

Department of Chemistry, Northwestern University, Evanston, Illinois 60201

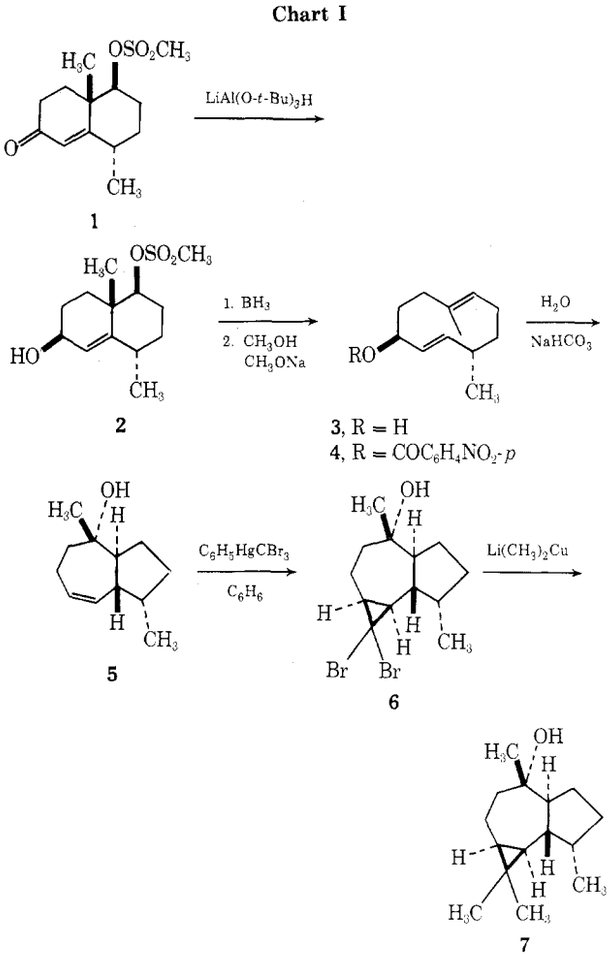
Received February 19, 1974

We have previously shown that 2,7-cyclodecadien-1-ol derivatives undergo facile and stereoselective solvolysis–cyclization to give hydroazulenes in high yield.[1] The cyclodecadienols, in turn, are conveniently prepared from 9-methyl-5(10)-octalin-1,6-dione.[2] In this report we describe an application of this approach to the synthesis of racemic globulol (**7**), a tricyclic hydroazulene sesquiterpene found in eucalyptus.[3]

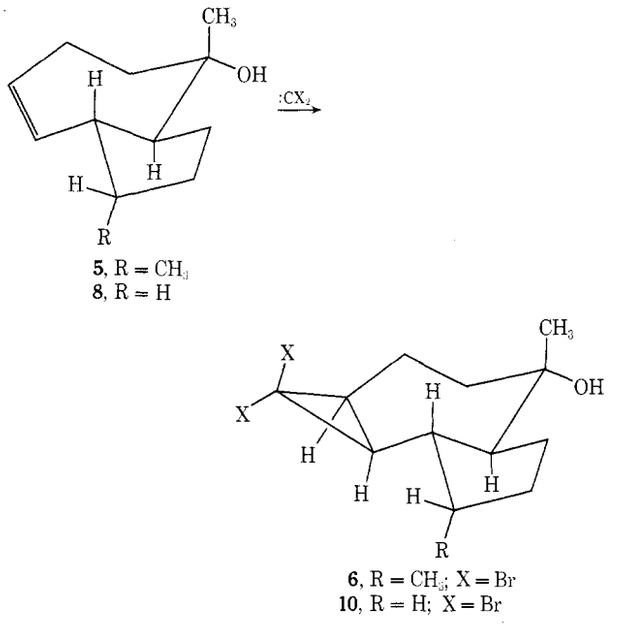
Our previous preparation of cyclodecadienol **3** involved treatment of the unsaturated keto methanesulfonate **1** with borane–tetrahydrofuran followed by methanolic sodium methoxide to effect the boronate fragmentation reaction.[1] Presumably carbonyl reduction precedes hydroboration, in which case the stereochemistry depicted in structure **3** would be expected.[4] This presumption was confirmed in the present study by first reducing enone **1** with lithium tri-*tert*-butoxyaluminum hydride and then subjecting the resulting equatorial alcohol **2** to hydroboration–fragmentation. The cyclodecadienol **3** thus secured gave the identical crystalline *p*-nitrobenzoate derivative **4** with that obtained in the combined reduction–hydroboration–fragmentation sequence.[5] Solvolysis of this *p*-nitrobenzoate in aqueous dioxane containing sodium bicarbonate as previously described yielded the hydroazulenol **5**[1] (Chart I).

While simple hydroazulenes tend to show considerable conformational flexibility, thus rendering stereochemical predictions highly problematical, hydroazulene **5** projects a clear-cut picture upon examination of molecular models. The trans-fused cyclopentane ring tends to restrict cycloheptane pseudorotation and the double bond removes the most serious eclipsing interactions present in the idealized

Chart I



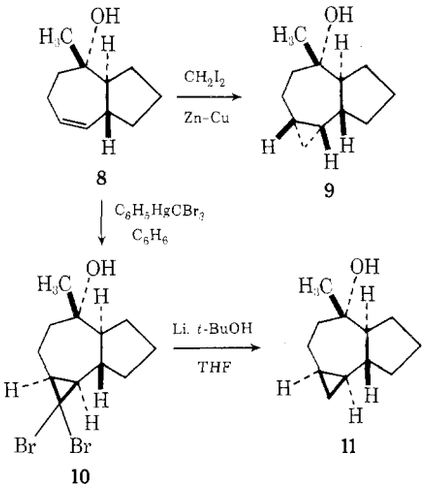
Scheme I



chair conformation.[6] This chair conformation (Scheme I) thus appears to be a highly preferred one for hydroazulene **5**. On this basis the prediction that carbenoid reagents should preferentially attack the top (convex) face of the double bond seemed quite reasonable. In that event adducts (Scheme I) with the assigned stereochemistry of the aromadendrane class of sesquiterpenes would be readily at hand.[7]

A test of this hypothesis (Chart II) was carried out on the more readily available demethyl analog **8**[1] of hydroazulene **5**. Treatment of hydroazulene **8** with the Simmons–Smith reagent derived from methylene iodide afforded the adduct **9** in nearly quantitative yield.[8] Of the numerous methods tried, only that of Seyferth[9] gave a dibromocarbene adduct **10** of hydroazulene **8**. Other methods led to recovery of starting material.[10] Hydrogenolysis of the dibromide **10** afforded the cyclopropane derivative **11**, whose spectral and chromatographic properties indicated an isomeric relationship with the Simmons–Smith-derived cyclopropane **9**. The stereochemistry of cyclopropane **9** can be assigned on the basis of the hydroxyl directing effect of the Simmons–Smith reaction.[8] The carbene adduct **10** would therefore appear to possess the predicted stereochemistry.

Chart II



Addition of the Seyferth reagent to hydroazulene **5** afforded the unstable dibromocyclopropane **6**. Prolonged treatment of this material with lithium dimethylcuprate yielded the methylated derivative **7**, identified as racemic globulol by spectral and chromatographic comparison with natural globulol.[11]

Experimental Section[12]

***c*-1-Methanesulfonoxy-*t*-4,*r*-9-dimethyl-5(10)-octalin-*c*-6-ol (2).** The method of Burgstahler[13] was used. A solution of 0.478 g (2.0 mmol) of the keto mesylate **1**[1] in 15 ml of dry tetrahydrofuran was added to a cold (0°) solution of 1.85 g (8.0 mmol) of lithium tri-*tert*-butoxyaluminum hydride in 25 ml of tetrahydrofuran. The solution was stirred for 0.5 hr at 0° and for 1 hr at room temperature. At the end of this time the mixture was poured into 100 ml of water–ice slurry containing 3 ml of concentrated hydrochloric acid. The product was isolated with ether. Work-up afforded 0.48 g (100%) of a light yellow oil: λ_{max} (film) 3.0, 3.45, 3.53, 6.05, 6.9, 8.55, 9.55, and 11.0 mμ; δ_{TMS} ($CDCl_3$) 1.00 (d, $CHCH_3$, J = 6 Hz), 1.15 (s, CH_3), 3.0 (s, CH_3SO_2), 3.65 (m, CHOH), 4.25 (m, CHOMs), and 5.46 ppm (s, vinyl H).

The crude hydroxy mesylate **2** was subjected to fragmentation conditions described earlier for the enone **1**.[1] The cyclodecadienol obtained in 37% yield had the same spectral properties as that obtained directly from enone fragmentation.

The *p*-nitrobenzoate **4**, mp 90–92°, obtained as described earlier[1] in 92% yield, was identical with that prepared from the enone **1**.

***t*-2,*c*-9-Dimethyl-6,6-dibromo-*r*-1H,*c*-5H,*c*-7H,*t*-8H-tricyclo-[6.3.0.0^{5,7}]undecan-*c*-2-ol (6).** A mixture of 0.180 g (1 mmol) of the hydroazulenol **5**[1] and 1.59 g (3 mmol) of phenyltribromomethylmercury in 25 ml of benzene was refluxed with stirring for 2 hr.[9] The reaction mixture was cooled to room temperature and filtered to remove the precipitated phenylmercuric bromide. Saturated ethanolic sodium borohydride solution was then added dropwise to the filtrate until the vigorous reaction subsided. The mixture was then poured into water, and the product was isolated with ether. The crude product was purified by column chromatography on 10 g of basic Woelm alumina (activity II–III). The benzene eluate afforded 0.17 g (50%) of a light yellow gum, which underwent extensive decomposition upon attempted short-path distillation [oven temperature 160°(0.1 mm)] or upon preparative thick layer chromatography on silica gel H: λ_{max} (film) 3.0, 3.45, 3.53, 5.85, 6.10, 6.90, 7.28, 8.10, 9.05, 9.70, 10.65, 11.05, 13.25, and 13.55 mμ; δ_{TMS} ($CDCl_3$) 1.02 (d, CH_3, J = 6 Hz) and 1.1 ppm (s, CH_3).

***dl*-Globulol (7).** A 0.180-g (0.515 mmol) sample of the dibromohydroazulenol **6** was added to 20 ml of a cold (−15°) solution of 3.5 mmol of lithium dimethylcuprate in ether.[14] The reaction mixture was stored at −15° for 120 hr. At the end of 24-, 48-, and 96-hr reaction times, the mixture was recharged with 20 ml of a fresh solution of 3.5 mmol of lithium dimethylcuprate in ether. After 120 hr the reaction mixture was poured into a slurry of concentrated ammonium hydroxide solution and ice. The product was isolated with ether. The work-up afforded 0.14 g (95%) of a light yellow oil which contained 60% globulol by glc analysis.

A gc–mass spectral comparison was made with the crude product and a sample of authentic globulol.[11] The mass spectra were identical.[15]

An analytical sample was secured by preparative glc on a 6 ft × 0.375 in. column packed with 4% DC-550 on Chromosorb G, followed by short-path distillation [oven temperature 70° (0.1 mm)]: λ_{max} (film) 3.0, 3.45, 3.55, 6.9, 7.3, 8.0, 9.25, 10.70, and 11.3 mμ; δ_{TMS} ($CDCl_3$) 0.98 (d, $CHCH_3$, J = 6 Hz), 0.98 (s, CH_3), 1.0 (s, CH_3) and 1.1 ppm (s, CH_3). Coinjection of this material with an authentic sample of natural globulol on a UCW-98 and DC-550 column gave a single peak. The infrared and nmr spectra were identical.

Anal. Calcd for $C_{15}H_{26}O$: C, 81.01; H, 11.78. Found: C, 81.05; H, 11.51.

***t*-2-Methyl-6,6-dibromo-*r*-1H,*c*-5H,*c*-7H,*t*-8H-tricyclo-[6.3.0.0^{5,7}]undecan-*c*-2-ol (10).** A mixture of 0.166 g (1 mmol) of the hydroazulenol **8**[1] and 1.59 g (3 mmol) of phenyltribromomethylmercury in 25 ml of benzene was refluxed for 2 hr.[9] After cooling to room temperature the mixture was treated with saturated ethanolic sodium borohydride dropwise until the vigorous reaction subsided. The reaction mixture was poured into water, and the product was isolated with ether. The crude product was purified by column chromatography on 10 g of Woelm

(activity II–III) basic alumina. The benzene eluate afforded 0.190 g (56%) of a light yellow oil.

The product underwent slight decomposition upon distillation [short path, oven temperature 140° (0.1 mm)] or upon preparative thick layer chromatography with silica gel H: λ_{max} (film) 3.0, 3.45, 3.55, 5.90, 6.10, 6.92, 7.30, 9.05, 10.60, 11.0, and 13.25 mμ; δ_{TMS} ($CDCl_3$) 1.08 ppm (s, CH_3). After standing for several weeks a sample solidified (mp 77–78°) but satisfactory analytical values could not be obtained.

***t*-2-Methyl-*r*-1H,*c*-5H,*c*-7H,*t*-8H-tricyclo[6.3.0.0^{5,7}]undecan-*c*-2-ol (11).** A mixture of 100 mg (0.55 mmol) of the dibromohydroazulenol **10**, 100 mg of lithium wire, and 3 ml of *tert*-butyl alcohol in 3 ml of tetrahydrofuran was stirred at room temperature for 2 days.[16] The mixture was cautiously quenched with 12 ml of water and the product was isolated with ether. Short-path distillation [oven temperature 70°(0.1 mm)] afforded 50 mg (50%) of a colorless oil, which gave a predominant peak on the gas chromatogram (UCW-98 column at 205°) with retention time of 3.2 min: λ_{max} (film) 3.0, 3.45, 6.9, 7.3, 9.0, 11.0, and 13.75 mμ; δ_{TMS} ($CDCl_3$) 0.68 (m, cyclopropyl H) and 1.10 ppm (s, CH_3).

Anal. Calcd for $C_{12}H_{20}O$: C, 79.94; H, 11.18. Found: C, 79.68; H, 11.19.

***t*-2-Methyl-*r*-1H,*t*-5H,*t*-7H,*t*-8H-tricyclo[6.3.0.0^{5,7}]undecan-*c*-7-ol (9).** A mixture of 0.332 g (2 mmol) of the hydroazulenol **8**,[1] 3.42 g (6.5 mmol) of methylene iodide, and 1.4 g (20 mmol) of zinc–copper couple in 20 ml of ether was stirred at room temperature for 3.5 days.[8] The mixture was filtered, and the ether was washed with 3% aqueous hydrochloric acid. Work-up of the ether solution and short-path distillation [oven temperature 70° (0.1 mm)] of the product afforded 0.350 g (97%) of a colorless oil which showed a predominant peak on the gas chromatogram (UCW-98 column at 205°) with retention time of 3.8 min: λ_{max} (film) 3.0, 3.45, 6.95, 7.35, 9.20, 9.82, 10.62, 11.05, and 13.75 mμ; δ_{TMS} ($CDCl_3$) 0.44 (m, cyclopropyl H) and 1.10 ppm (s, CH_3).

Anal. Calcd for $C_{12}H_{20}O$: C, 79.94; H, 11.18. Found: C, 79.95; H, 11.31.

A sample of this material solidified (mp 43–44°) upon short-path distillation.

Acknowledgment. We are grateful to the National Science Foundation and the National Institutes of Health for support of this work. A sample of authentic globulol was kindly provided by Professor George Büchi.

Registry No.—**1**, 51310-36-2; **2**, 51310-37-3; **4**, 51371-46-1; **5**, 51310-38-4; **6**, 51310-39-5; **7**, 51371-47-2; **8**, 30166-33-7; **9**, 51310-40-8; **10**, 51310-41-9; **11**, 51371-48-3.

References and Notes

(1) J. A. Marshall, W. F. Huffman, and J. A. Ruth, *J. Amer. Chem. Soc.*, **94**, 4691 (1972).
(2) "Aldrich Handbook of Organic Chemicals," Aldrich Chemical Co., Milwaukee, Wis., 1972, p 439; S. Ramanchandran and M. S. Newman, *Org. Syn.* **41**, 38 (1961).
(3) A. Blumann, A. R. H. Cole, K. J. L. Thierberg, and D. E. White, *Chem. Ind. (London)*, 1426 (1954); G. Büchi, S. W. Chow, T. Matsuura, T. L. Popper, H. H. Rennhard, and M. Schach v. Wittenair, *Tetrahedron Lett.*, **6**, 14 (1959); L. Dolejš, O. Motl, M. Souček, V. Herout, and F. Sörm, *Collect. Czech. Chem. Commun.*, **25**, 1483 (1960).
(4) *Cf.* M. Stefanovic and S. Lajsic, *Tetrahedron Lett.*, 1777 (1967).
(5) The unambiguous assignment of stereochemistry to *p*-nitrobenzoate **4** is of interest in connection with a study currently in progress to access the degree of concertedness in the solvolysis–cyclization leading to hydroazulenol **5**.
(6) J. B. Hendrickson, *J. Amer. Chem. Soc.*, **83**, 4537 (1961).
(7) *Cf.* G. Büchi, W. Hofheinz, and J. V. Paukstelis, *J. Amer. Chem. Soc.*, **91**, 6473 (1969).
(8) *Cf.* H. E. Simmons, T. L. Cairns, S. A. Vladuchick, and C. M. Hoiness, *Org. React.*, **20**, 1 (1973).
(9) D. Seyferth, *J. Amer. Chem. Soc.*, **87**, 4259 (1965).
(10) W. von E. Doering, *J. Amer. Chem. Soc.*, **76**, 6162 (1954); P. D. Gardner, *J. Org. Chem.*, **26**, 3518 (1961); C. M. Hall, *Syn. Commun.*, 121 (1972).
(11) We are indebted to Professor G. Büchi for a sample of natural globulol.
(12) The apparatus described by W. S. Johnson and W. P. Schneider ("Organic Syntheses," Collect. Vol. IV, Wiley, New York, N. Y., 1963, p 132) was used to maintain an argon atmosphere. The isolation procedure consisted of thorough extractions with the specified solvent, washing the combined extracts with saturated brine solution, and drying the extracts over anhydrous magnesium sulfate. The solvent was removed from the filtered extracts under reduced pressure on a rotary evaporator. Microanalyses were performed by Micro-Tech Laboratories, Inc., Skokie, Ill. Infrared spectra were obtained with a Perkin-Elmer 137 spectrophotometer. Infrared absorptions are reported in wavelengths (mμ) and are standardized with reference to the 6.24-mμ peak of polystyrene. Nuclear magnetic resonance spectra were recorded with a Varian T-60 spectrometer. Signals are reported as the chemical shift downfield from tetramethylsilane (TMS) in parts per million (ppm) of the applied field. The multiplicity of the peak is abbreviated: singlet, s; doublet, d; triplet, t; quartet, q; and multiplet, m. Coupling constants are reported in hertz (Hz). Melting points were determined on a calibrated Thomas capillary melting point apparatus. Melting points are not corrected.
(13) A. W. Burgstahler and I. C. Nordin, *J. Amer. Chem. Soc.*, **83**, 198 (1961).
(14) E. J. Corey, *J. Amer. Chem. Soc.*, **89**, 3911, 4245 (1967).
(15) We wish to thank Mr. John McNovich of Hewlett-Packard Co., Palo alto, Calif., for performing the glc–mass spectral analyses.
(16) D. Seyferth, *J. Amer. Chem. Soc.*, **92**, 7412 (1970).

Preparation of Azetidine and Some *N*-Aroylazetidines[1]

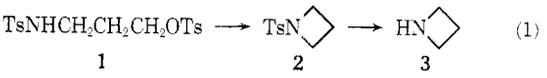
Julian White* and George McGillivray

Department of Chemistry, University of South Africa, Pretoria, South Africa

Received February 13, 1974

In the course of examination of selected amides of potential value in the Vilsmeier–Haack reaction it became evident that little information is available on otherwise unsubstituted *N*-aroylazetidines. Only a few of these compounds appear to have been reported.[2,3] Moreover, existing methods for the preparation[4-7] of azetidine itself are not only lacking in experimental simplicity but are unsuitable when it is desired to prepare small quantities only.

Investigation of certain of the reactions reported indicated that the sequence employed by Vaughan, *et al.* (eq 1) could, by the application of improved methods, be used



1 2 3 (1)

in small-scale operations to afford a somewhat better yield than previously reported.[5] Thus, the cumbersome cyclization of **1** by the action of ethoxide or *tert*-butoxide over 16 hr was found to be unnecessary, as the same result could be obtained by use of aqueous hydroxide over approximately 4 hr with much less effort.

For the reductive detosylation of **2**, sodium naphthalenide[8] in diglyme medium (which in the present context is far superior to dimethoxyethane or tetrahydrofuran) was found to be suitable. The benefit of this method lies not only in considerably improved yields but also in the greater simplicity of operation than that of Vaughan's method where reduction by sodium in amyl alcohol affords some 40% of product only after a somewhat tedious sequence of operations.

The present radical-anion reduction is quick and avoids complex work-up procedures, as the azetidine is obtained as an approximately 1 *M* solution in diglyme by simple distillation from the reaction mixture. The yield of azetidine is approximately 70% of theoretical.

The *N*-aroylazetidines listed in Table I were prepared in fair yield by the use of the azetidine–diglyme solution (to which was added an equimolecular quantity of triethylamine in order to conserve azetidine and simplify purification) and the appropriate aroyl chloride. The identity of each of these derivatives was established by the usual instrumental and analytical means.