

## 24. *The Synthesis of Long-chain Aliphatic Acids from Acetylenic Compounds. Part I. The Synthesis of a Geometrical Isomer of Herculin.*

By R. A. RAPHAEL and FRANZ SONDHEIMER.\*

Attempts to synthesise the insecticide herculin (I; configuration about the double bonds unknown) are described. The diacetylenic analogue (VI) and the *cis*-ethylenic-acetylenic analogue (XV) have been prepared by the methods indicated in the scheme on p. 116. Partial hydrogenation of these compounds gave the *isobutylamide* of undeca-1(*cis*):7(*cis*)-diene-1-carboxylic acid (*cis-cis* herculin) (I); this was not identical with the natural insecticide.

A PUNGENT *N-isobutyl* unsaturated acid amide has been isolated from the bark of the southern prickly ash, *Zanthoxylum clavaherculis* L., by Jacobson (*J. Amer. Chem. Soc.*, 1948, **70**, 4234). The substance, which was shown to have the structure (I) (*N-isobutylundeca-1:7*-diene-1-carboxamide), has approximately the same order of paralysing action and toxicity to house flies as the pyrethrins, and is also toxic to several other species of insects. When the synthesis of a compound of this structure is considered, it becomes apparent that any one of four configurations is possible according to the geometrical isomerism about the double bonds (*trans-trans*, *trans-cis*, *cis-trans*, and *cis-cis*). No speculation about the configuration of the natural compound was made by Jacobson.

We have synthesised by two routes a compound of structure (I), possessing the *cis*-configuration about both double bonds; this, however, was not identical with natural herculin, and the latter must therefore have one of the three remaining configurations.

When octa-1:7-diyne (II) (prepared from tetramethylene dibromide and sodium acetylide as described by Bader, Cross, Heilbron, and Jones, *J.*, 1949, 619) was treated first with 1.1 moles of sodamide in liquid ammonia, and then with propyl iodide, the required monoalkylation product *undeca-1:7*-diyne (III) was obtained in 86% yield (allowing for the recovered starting material). This type of differential condensation of a diacetylene has been found to be of general applicability, and it has been employed in other syntheses (Sondheimer, forthcoming publication; Leese and Raphael, forthcoming publication). The Grignard complex of (III) was carbonated with solid carbon dioxide at atmospheric pressure to give *undeca-1:7*-diyne-1-carboxylic acid (IV) (*S-benzylthiuronium* salt) in 65% yield, the structure of which was confirmed by hydrogenation to lauric acid. Heating (IV) under reflux with oxalyl chloride (cf. Adams and Ulich, *J. Amer. Chem. Soc.*, 1920, **42**, 599) produced the acid chloride (V) which on treatment with excess of *isobutylamine* furnished the crystalline diacetylenic *N-isobutyl-amide* (VI) in excellent yield. When this absorbed two moles of hydrogen in the presence of a palladium-calcium carbonate catalyst, *N-isobutylundeca-1(cis):7(cis)-diene-1-carboxamide* (*cis-cis-herculin*) (I) was obtained as a homogeneous liquid.

The formulation of this compound, and others described below, as the *cis-cis*-isomer, is based on many recorded observations regarding the catalytic hydrogenation of triple bonds (*inter al.*, Bourguel, *Bull. Soc. chim.*, 1929, **45**, [4], 1067; Stoll and Rouvé, *Helv. Chim. Acta*, 1938, **21**, 1542; *idem*, *Ber.*, 1940, **73**, 1358; Campbell *et al.*, *J. Amer. Chem. Soc.*, 1941, **63**, 216, 2683; *Chem. Reviews*, 1942, **31**, 90; Lauer and Gensler, *J. Amer. Chem. Soc.*, 1945, **67**, 1171; Ahmad, Bumpus, and Strong, *ibid.*, 1948, **70**, 3391). However, infra-red absorption has indicated that this type of hydrogenation (employing a palladium-calcium carbonate catalyst at room temperature) may also give rise to a small proportion of the *trans*-isomer (Sondheimer, forthcoming publication); for convenience this fact is neglected in the nomenclature of the hydrogenation compounds described in this paper.

Alternatively, the acid (IV) was partially hydrogenated to *undeca-1(cis):7(cis)-diene-1-carboxylic acid* (VII) (*S-benzylthiuronium* salt). The structure of this acid was confirmed by its light-absorption properties, the intensity of absorption at 2160 Å. being double that of the unchanged acetylenic acid (IV) (cf. Braude, *Ann. Reports*, 1945, **42**, 105; Haynes and Jones, *J.*, 1946, 503). Heating this acid under reflux with oxalyl chloride gave the corresponding acid chloride, which, undistilled, reacted with *isobutylamine* to product an excellent yield of (I), identical with that obtained above.

The second route to *cis-cis-herculin* (I) employs the differential reaction of a mixed dihalide with a sodium acetylide (cf. Henne and Greenlee, *J. Amer. Chem. Soc.*, 1945, **67**, 484; Ahmad, Strong, *et al.*, *ibid.*, 1948, **70**, 1699, 3391; Newman and Wotiz, *ibid.*, 1949, **71**, 1292).

\* This work was started independently by the two authors; when this was realised, it was decided to publish the results jointly.



Condensation of propyl iodide with sodium acetylide (this must not be made from sodamide; see Experimental) in liquid ammonia gave pent-1-yne, which, because of its volatility, was not isolated, but converted into its sodium salt by addition of 1 mole of sodamide. Reaction with 1-chloro-4-bromobutane (prepared from tetrahydrofuran as described by Newman and Wotiz, *loc. cit.*) gave 1-chloronon-5-yne (VIII) in 64% yield. Refluxing the chloro-compound with sodium iodide in acetone gave the iodo-compound (IX) which was condensed without purification with sodium acetylide in liquid ammonia. The undeca-1 : 7-diyne (III) thus obtained in 44% yield had identical physical properties with that obtained above.

Partial hydrogenation of the acetylenic chloride (VIII) in the presence of a palladium-calcium carbonate catalyst, or better Raney nickel, gave 1-chloronon-5(cis)-ene (X), which when heated under reflux with sodium iodide in acetone yielded the iodide (XI). The crude iodide was condensed with sodium acetylide in liquid ammonia whereby undec-7(cis)-en-1-yne (XII) was obtained in 62% yield [based on (X)]. Carbonation of the Grignard complex of (XII) at atmospheric pressure gave undec-7(cis)-en-1-yne-1-carboxylic acid (XIII) in 57% yield. The acid chloride (XIV), prepared by refluxing the acid with oxalyl chloride, was condensed with excess of isobutylamine and *N*-isobutylundec-7(cis)-en-1-yne-1-carboxamide (XV) was formed. Partial hydrogenation in the presence of a palladium-calcium carbonate catalyst then gave *cis-cis*-herculin (I), having physical properties identical with those of (I), prepared as above.

The *cis-cis*-analogue (I), obtained by these routes, was a colourless liquid, which could not be induced to crystallise, whereas natural herculin is a crystalline solid, m. p. 59–60°. Moreover it was quite stable at room temperature, whereas natural herculin (Jacobson, *loc. cit.*) has been reported to be unstable under these conditions. Again it shows none of the physiological properties (burning taste, etc.) described by the American author.

The structure of (I) was rigidly confirmed by complete hydrogenation to the crystalline *N*-isobutyl-lauramide, and by potassium permanganate oxidation, whereby the three fragments (butyric, adipic, and *N*-isobutyloxamic acids) were isolated in yields very similar to those obtained by Jacobson (*loc. cit.*) for the natural herculin.

The three herculin analogues, *cis-cis*-herculin (I), 1 : 2-dehydro-*cis*-herculin (XV), and 1 : 2 : 7 : 8-tetrahydroherculin (VI), are being tested by Dr. R. A. E. Galley of the Agricultural Research Council for insecticidal properties, and the results will be recorded later.

Attempts to convert both the *cis-cis*-acid (VII) and the *cis-cis-N*-isobutyl-amide (I) into the *trans-trans*-compounds by various methods have so far been unsuccessful. Thus even when the acid (VII) was heated with selenium at 200° for 10 minutes (cf. Ahmad, Bumpus, and Strong, *J. Amer. Chem. Soc.*, 1948, **70**, 3391), it was recovered unchanged. It is known however that the partial reduction of an acetylene with sodium in liquid ammonia leads to the *trans*-ethylenic compound (Campbell and Eby, *J. Amer. Chem. Soc.*, 1941, **63**, 216, 2683; Campbell and Campbell, *Chem. Reviews*, 1942, **31**, 90; Sondheimer, forthcoming publication). Application of this method to the analogues (VI) and (XV) should furnish the 1(*trans*) : 7(*trans*)- and 1(*trans*) : 7(*cis*)-herculins. It is now considered that the latter isomer will most probably be identical with the natural compound (cf. the short discussion presented in the following paper regarding the stereochemical configuration of the closely related insecticide, pellitorine), and further work on these compounds is now in progress in these laboratories. Moreover the methods described in this paper are being used for the synthesis of the various possible stereoisomers of other related insecticides, and the preparation of a geometrical isomer of the insecticide pellitorine is described in the following communication.

#### EXPERIMENTAL.

(Light-absorption data were determined in ethanol.)

*Undeca-1 : 7-diyne* (III).—To a suspension of sodamide in liquid ammonia (150 c.c.) [from sodium (5.0 g.), the ferric nitrate catalyst described by Vaughn, Vogt, and Nieuwland (*J. Amer. Chem. Soc.*, 1934, **56**, 2120) being used to catalyse the transformation] octa-1 : 7-diyne (21.2 g.) in dry ether (25 c.c.) was added during 10 minutes with stirring and cooling (alcohol-carbon dioxide). The reaction mixture was stirred for 2 hours, and propyl iodide (41 g.) in ether (30 c.c.) was gradually added. Stirring was continued for another 6 hours, the temperature being kept at *ca.* -40°. The solvent was evaporated on the steam-bath, water and ether were added, and the ether layer after being washed with water, dilute sulphuric acid, and sodium hydrogen carbonate solution, was dried and evaporated. Distillation of the residue through a short Vigreux column gave unchanged octadiyne (9.2 g.) and undeca-1 : 7-diyne (14.4 g., 86% yield, 49% conversion) as a mobile pleasant-smelling liquid, b. p. 97–99°/20 mm.,  $n_D^{20}$  1.4576 (Found: C, 88.75; H, 10.9.  $C_{11}H_{18}$  requires C, 89.1; H, 10.9%). In addition, a product (2.1 g.) was obtained, b. p. 135–140°/18 mm.,  $n_D^{20}$  1.4650, believed to be the dialkylation product, tetradeca-4 : 10-diyne; this was not further investigated.

When propyl bromide was substituted for the iodide in the above experiment, the yield of undecadiyne was considerably reduced.

*Undeca-1:7-diyne-1-carboxylic Acid* (IV).—Undeca-1:7-diyne (7.4 g.) in dry ether (20 c.c.) was added during 5 minutes to a stirred solution of ethylmagnesium bromide (from magnesium, 1.6 g.) in ether (120 c.c.) in an atmosphere of nitrogen. The solution was heated under reflux for 90 minutes, and then cooled in ice. It was poured on to a large excess of solid carbon dioxide in a conical flask, and the flask was shaken occasionally. After *ca.* 1 hour, when most of the solid had disappeared, more solid carbon dioxide was added, and the mixture was set aside overnight. The solid complex was decomposed with dilute sulphuric acid, and the ethereal layer was washed with water and sodium hydrogen carbonate solution. The latter extract was washed with ether, acidified, and again shaken with ether. This last ether extract was dried, evaporated, and the residue distilled. *Undeca-1:7-diyne-1-carboxylic acid* (6.2 g., 65%) was obtained as a colourless liquid, b. p. 134—135°/10<sup>-3</sup> mm.,  $n_D^{20}$  1.4882 (Found: C, 75.3; H, 8.55. C<sub>12</sub>H<sub>16</sub>O<sub>2</sub> requires C, 75.0; H, 8.4%). Light absorption:  $\epsilon = 6,700$  ( $\lambda$ , 2160 Å.). The *S-benzylthiuronium* salt crystallised from a large volume of ethyl acetate in plates, m. p. 174° (Found: C, 67.25; H, 7.45; N, 7.95. C<sub>20</sub>H<sub>26</sub>O<sub>2</sub>N<sub>2</sub>S requires C, 67.0; H, 7.3; N, 7.8%).

The acid (0.55 g.) in ethyl acetate (20 c.c.) was shaken with hydrogen in the presence of platinum oxide until absorption was complete (274 c.c. of gas were absorbed at 16°/780 mm., equivalent to 4.05 F). The residue (0.56 g.), after removal of the catalyst and solvent, completely solidified, and then had m. p. 43° undepressed on admixture with an authentic sample of lauric acid.

*Undeca-1:7-diyne-1-carboxyl Chloride* (V).—The diacetylenic acid (3.0 g.) and oxalyl chloride (7.5 g.) were heated under reflux for 40 minutes (gas evolution ceased after *ca.* 25 minutes). The excess of oxalyl chloride was removed at the water-pump, the temperature being kept below 60°. The residue was rapidly distilled to give the acid chloride (2.8 g.) as a mobile pungent liquid, b. p. 97—99°/10<sup>-2</sup> mm.,  $n_D^{20}$  1.4903, which hydrolysed too rapidly in air to permit of accurate analysis.

In another experiment, in which the excess of oxalyl chloride was removed at too high a temperature, considerable polymerisation occurred, and only a very poor yield of the required acid chloride was obtained.

*N-isoButylundeca-1:7-diyne-1-carboxamide* (VI).—A solution of *isobutylamine* (4.5 g.) in dry ether (10 c.c.) was added dropwise during 5 minutes to the diacetylenic acid chloride (V) (2.6 g.) in ether (10 c.c.), with ice cooling and continuous shaking. After 1 hour at room temperature, the reaction mixture was diluted with more ether and washed with dilute sulphuric acid, sodium hydrogen carbonate solution, and water. The dried extract was evaporated to give the diacetylenic *N-isobutyl-amide* (2.95 g.) as a colourless liquid, which completely solidified on cooling and then had m. p. 45—47°. One crystallisation from light petroleum (b. p. 40—60°) gave needles, m. p. 47—48°, not raised by further crystallisation (Found: C, 77.35; H, 10.35; N, 5.65. C<sub>16</sub>H<sub>25</sub>ON requires C, 77.7; H, 10.2; N, 5.65%).

*N-isoButylundeca-1(cis):7(cis)-diene-1-carboxamide* (*cis-cis-Herculin*) (I) from (VI).—The diacetylenic *N-isobutyl-amide* (VI) (1.14 g.) in ethyl acetate (20 c.c.) was shaken with hydrogen in the presence of a palladium-calcium carbonate catalyst (0.14 g.; 2% Pd) until 2 moles of hydrogen (222 c.c. at 18°/768 mm.) had been absorbed. The residue, after removal of the catalyst and solvent, was distilled to give *cis-cis-herculin* (0.91 g.) as a colourless liquid, b. p. 140—142°/10<sup>-3</sup> mm.,  $n_D^{21}$  1.4838 (Found: C, 76.25; H, 11.7; N, 5.65. C<sub>16</sub>H<sub>29</sub>ON requires C, 76.45; H, 11.65; N, 5.55%).

*Undeca-1(cis):7(cis)-diene-1-carboxylic Acid* (VII).—The diacetylenic acid (IV) (4.68 g.) in ethyl acetate (20 c.c.) was shaken with hydrogen in the presence of a palladium-calcium carbonate catalyst (0.3 g.; 2% Pd) until 2 moles of hydrogen (1174 c.c. at 19°/771 mm.) had been absorbed (no reaction of the calcium carbonate substrate with the acid was detectable). The catalyst was filtered off, the solvent evaporated, and the residue distilled. This gave the diethylenic acid (4.3 g.) as a colourless liquid, b. p. 108—109°/10<sup>-4</sup> mm.,  $n_D^{20}$  1.4740—1.4742 (Found: C, 73.9; H, 10.55. C<sub>12</sub>H<sub>20</sub>O<sub>2</sub> requires C, 73.45; H, 10.3%). Light absorption:  $\epsilon = 13,700$  ( $\lambda$ , 2160 Å.). The *S-benzylthiuronium* salt crystallised from ethyl acetate in plates, m. p. 129—130° (Found: N, 7.85. C<sub>20</sub>H<sub>30</sub>O<sub>2</sub>N<sub>2</sub>S requires N, 7.75%).

*N-isoButylundeca-1(cis):7(cis)-diene-1-carboxamide* (*cis-cis-Herculin*) (I) from (VII).—The diethylenic acid (1.4 g.) (VII) and oxalyl chloride (3.6 g.) were heated under reflux for 1 hour. The excess of oxalyl chloride was removed at the water-pump, and dry benzene was added to the residue, which was again concentrated at the water-pump to give the crude acid chloride (1.65 g.) as a yellow pungent liquid,  $n_D^{21}$  1.4800.

A solution of *isobutylamine* (2.7 g.) in dry ether (10 c.c.) was added dropwise during 5 minutes to the crude acid chloride (1.63 g.) in ether (10 c.c.), with ice-cooling and continuous shaking. After 20 minutes, the product was isolated as described above, and distillation gave *cis-cis-herculin* (1.6 g.), b. p. 145—146°/10<sup>-2</sup> mm.,  $n_D^{21}$  1.4824—1.4827.

*1-Chloronon-5-yne* (VIII).—Sodium (5.5 g.), in small pieces, was added to liquid ammonia (300 c.c.) through which acetylene was bubbled, with stirring and cooling (alcohol-carbon dioxide), at such a rate that the blue colour just disappeared before the next piece of sodium was added. The acetylene flow was stopped at the exact moment when the blue colour disappeared after the last piece of sodium had been added (this ensured that no excess of acetylene was present in solution), and propyl iodide (41 g.) was gradually added. The reaction mixture was stirred for 4 hours, and a suspension of sodamide in liquid ammonia (150 c.c.), prepared from sodium (5.8 g.) by aid of the ferric nitrate catalyst, was then added in portions with strong cooling. The mixture was stirred for another 1 hour, and 1-chloro-4-bromobutane (41 g.) was added dropwise. The reaction was completed by stirring and cooling for another 12 hours, and ammonium chloride (15 g.) was added. The ammonia was evaporated off on the steam-bath, water and ether were added to the residue, and the ethereal layer was washed successively with water, dilute sulphuric acid, sodium hydrogen carbonate solution, and water. The dried extract was evaporated, and distillation of the residue gave unchanged chlorobromobutane (5.3 g.) and 1-chloronon-5-yne VIII (24.2 g., 64%) as a colourless mobile liquid, b. p. 83—84°/15 mm.,  $n_D^{18}$  1.4620 (Found: C, 68.4; H, 9.9. C<sub>9</sub>H<sub>12</sub>Cl requires C, 68.1; H, 9.55%).

In another experiment, propyl bromide (45 g.) was added to a solution of sodium acetylide in liquid ammonia (400 c.c.), prepared by passing acetylene through a suspension of sodamide (from sodium, 8.5 g., with the ferric nitrate catalyst). As the complete conversion of sodamide into sodium acetylide is not accompanied by a well-defined colour change, the presence of excess of dissolved acetylene in the

sodium acetylide solution so formed cannot be avoided. After 3 hours' stirring, a suspension of sodamide in liquid ammonia (200 c.c.), prepared from sodium (9 g.) with the ferric nitrate catalyst, was added in portions. The cooled reaction mixture was stirred for 1 hour, 1-chloro-4-bromobutane (50 g.) was gradually added, and stirring was continued for another 4 hours. After being isolated as described previously, the product was distilled to give 1-chloronon-5-yne (3.0 g., 6%), b. p. 81°/12 mm.,  $n_D^{20}$  1.4620. The lower boiling fractions (32 g.) on redistillation gave a colourless liquid, b. p. 37–38°/10 mm.,  $n_D^{20}$  1.4461, believed to be 1-chlorohex-5-yne (formed by reaction of the chlorobromobutane with sodium acetylide, produced by the preferential reaction of the second mole of sodamide with the excess of acetylene in solution).

*Undeca-1 : 7-diyne* (III) from (VIII).—The chloro-compound (VIII) (2.1 g.) and a solution of sodium iodide (5 g.) in dry acetone (25 c.c.) were heated under reflux for 2 hours. The filtered solution was evaporated, the residue treated with dry ether, and the ethereal solution refiltered. This ether extract, containing the iodide (IX), was added dropwise, with stirring and cooling, to a solution of sodium acetylide in liquid ammonia (500 c.c.), prepared from sodium (3 g.) by the usual catalytic procedure. The reaction mixture was stirred for a further 3 hours, and ammonium chloride (ca. 10 g.) was then added. Isolation with ether gave undeca-1 : 7-diyne (0.85 g., 44%), b. p. 95°/15 mm.,  $n_D^{21}$  1.4573.

*1-Chloronon-5(cis)-ene* (X).—The chloro-compound (VIII) (10.52 g.) in methyl acetate (40 c.c.) was shaken with hydrogen in the presence of a palladium-calcium carbonate catalyst (1.5 g.; 0.3% Pd), until 1 mole of hydrogen (1582 c.c. at 14°/763 mm.) had been absorbed. The filtered solution was evaporated, and the residue distilled, to give *1-chloronon-5-(cis)-ene* (8.6 g.; 81%) as a colourless mobile liquid, b. p. 75°/12 mm.,  $n_D^{17}$  1.4515 (Found : C, 66.9; H, 10.8.  $C_9H_{11}Cl$  requires C, 67.25; H, 10.7%). When Raney nickel was substituted for the palladium catalyst, hydrogenation proceeded considerably more rapidly to give a similar yield of (X).

*Undec-7(cis)-en-1-yne* (XII).—The chloro-olefin (X) (8.0 g.) was heated under reflux with a solution of sodium iodide (15 g.) in dry acetone (75 c.c.) for 15 hours. The filtered solution was evaporated, and the residue triturated with dry ether, which was again filtered. This ethereal extract, containing the iodide (XI), was added dropwise to a cooled and stirred solution of sodium acetylide (prepared from sodium, 5 g., *via* sodamide by the catalytic method) in liquid ammonia (500 c.c.). The cooled mixture was stirred for another 4 hours, and ammonium chloride (20 g.) was added. The ammonia was evaporated off on the steam-bath, and water and ether were added to the residue. The usual isolation procedure then gave *undec-7(cis)-en-1-yne* (4.6 g., 62%) as a mobile pleasant-smelling liquid, b. p. 73°/10 mm.,  $n_D^{20}$  1.4462 (Found : C, 87.5; H, 12.1.  $C_{11}H_{18}$  requires C, 87.9; H, 12.1%).

*Undec-7(cis)-en-1-yne-1-carboxylic Acid* (XIII).—The hydrocarbon (XII) (4.2 g.) in dry ether (20 c.c.) was added during 5 minutes to a stirred solution of ethylmagnesium bromide (from magnesium, 1.0 g.) in dry ether (50 c.c.) in an atmosphere of nitrogen. The solution was heated under reflux for 2 hours, and the Grignard complex was then carbonated with solid carbon dioxide at atmospheric pressure as already described for the diacetylenic acid. After decomposition with dilute sulphuric acid, the acid fraction was isolated and gave *undec-7(cis)-en-1-yne-1-carboxylic acid* (3.1 g., 57%) as a colourless liquid, b. p. 116°/5 × 10<sup>-4</sup> mm.,  $n_D^{16}$  1.4788–1.4790 (Found : C, 74.4; H, 9.5.  $C_{12}H_{18}O_2$  requires C, 74.2; H, 9.35%).

*N-isoButylundec-7(cis)-en-1-yne-1-carboxamide* (XV).—The ethylenic acetylenic acid (XIII) (1.5 g.) and oxalyl chloride (3.0 g.) were heated under reflux for 30 minutes. The excess of oxalyl chloride was removed under reduced pressure, dry benzene was added to the residue, and the benzene solution concentrated, to give the crude acid chloride (XIV) as a yellow pungent liquid. This was not distilled, as, in a previous experiment, attempted distillation resulted in extensive polymerisation.

*isoButylamine* (3.0 g.) in dry ether (10 c.c.) was added dropwise to the acid chloride in dry ether (10 c.c.) with ice-cooling and shaking. After 30 minutes, the product was isolated as described previously, and distillation gave the *N-isoButylundec-7(cis)-en-1-yne-1-carboxamide* (1.3 g.) as a colourless liquid, b. p. 145–148°/10<sup>-3</sup> mm.,  $n_D^{18}$  1.4876 (Found : C, 77.2; H, 11.0.  $C_{16}H_{22}ON$  requires C, 77.05; H, 10.9%).

*N-isoButylundeca-1(cis) : 7(cis)-diene-1-carboxamide* (cis-cis-*Herculin*) (I) from (XV).—The *N-iso-butyl-amide* (XV) (0.35 g.) in ethyl acetate (10 c.c.) was shaken with hydrogen in the presence of a palladium-calcium carbonate catalyst (0.04 g.; 2% of Pd) until 1 mole of hydrogen (35 c.c. at 17.5°/750 mm.) had been absorbed. The filtered solution was evaporated, whereupon distillation gave *cis-cis-herculin* (0.21 g.), b. p. 150–155° (bath temp.)/10<sup>-3</sup> mm.,  $n_D^{18}$  1.4840.

*N-isoButyl-lauramide*.—*cis-cis-Herculin* (0.21 g.) in ethyl acetate (10 c.c.) was shaken with hydrogen in the presence of platinum oxide until absorption was complete (46 c.c. of gas were absorbed at 21°/763 mm., equivalent to 2.2 F). Removal of catalyst and solvent, followed by crystallisation of the solid residue from pentane gave *N-isoButyl-lauramide* as needles, m. p. 52–53° (Jacobson, *J. Amer. Chem. Soc.*, 1948, **70**, 4234, gives m. p. 51.5–52°).

*Permanganate Oxidation of cis-cis-Herculin* (I).—This oxidation was carried out with *cis-cis-herculin* (500 mg.) and potassium permanganate (1.7 g.) in water (50 c.c.) in exactly the manner described by Jacobson (*loc. cit.*) for natural herculin. The material not volatile in steam gave *N-isoButylloxamic acid* (230 mg., 82%) as needles, m. p. 105–106° (Jacobson gives 75% yield; m. p. 106–107°), and adipic acid (135 mg., 48%) as prisms, m. p. 150–152° (Jacobson gives 59% yield; m. p. 151–152°). Titration of the steam distillate with 0.1N-sodium hydroxide indicated that butyric acid had been obtained in 71% yield. It was identified as its *p*-bromophenacyl ester, m. p. 70°, undepressed on admixture with an authentic specimen (m. p. 70°).

The authors thank Sir Ian Heilbron, D.S.O., F.R.S., and Dr. S. H. Harper for their interest in this work, which was carried out during the tenure of an I.C.I. Fellowship (R. A. R.) and a D.S.I.R. Senior Award (F. S.). The authors are indebted to the Chemical Society for a Research Grant.