g. of β-naphthol and 5 g. of sodium hydroxide in 100 cc. of water. A red precipitate formed, which was filtered by suction and washed with water. A red crystalline product was obtained after crystallization from acetic acid; yield, 2 g.

Anal. Calcd. for $C_{28}H_{20}ON_2$: N, 7.00. Found: N, 6.67, 6.86.

Other compounds were also coupled qualitatively with *m*-diphenylbenzenediazonium chloride, *e. g.*: 1,8-dihydroxynaphthalene-3,6-disulfonic acid, red-purple; 1-naphthol-4-sulfonic acid, bright red; 1,8-aminonaphthol-3,6-disulfonic acid, blue-purple; 2-naphthol-7-sulfonic acid, bright red; 1,8-aminonaphthol-2,4-disulfonic acid, purple; 2-naphthol-3,6-disulfonic acid, light purple.

Summary

1. The mononitro, dinitro and trinitro derivatives of *m*-diphenylbenzene have been prepared.

2. The oxidation of nitro-*m*-diphenylbenzene yielded a nitrodiphenylcarboxylic acid. The oxidation of dinitro-*m*-diphenylbenzene yielded *p*-nitrobenzoic acid. No reaction was observed in the attempted oxidation of trinitro-*m*-diphenylbenzene.

3. The nitro-*m*-diphenylbenzene was reduced to the corresponding amine. The following new derivatives of amino-*m*-diphenylbenzene were prepared: (a) amino-*m*-diphenylbenzene hydrochloride, (b) acetylamino-*m*-diphenylbenzene, (c) benzoylamino-*m*-diphenylbenzene, (d) *m*-diphenylbenzene-azo-β-naphthol, and other dyes.

PITTSBURGH, PENNSYLVANIA

PHENYL SUBSTITUTED ALIPHATIC ACIDS

BY J. HARMON AND C. S. MARVEL

The mechanism of the oxidation of the fatty acids in the animal body has long been the subject of speculation by chemists interested in metabolism. The most satisfactory theory that has been advanced to account for the oxidation of fatty acids to carbon dioxide and water in the animal was propounded by Knoop[1] in 1904. His theory of beta oxidation has been tested on various omega substituted fatty acids of the type C_6H_5-$(CH_2)_xCOOH$ where the phenyl group which is not generally oxidized in the animal body acted as a barrier to further oxidation and left an identifiable residue to be eliminated as a waste product from the body. In these studies all of those acids in which x had an uneven value were found to be burned in the body to phenylacetic acid and those in which x had an even value were burned to benzoic acid.

Thus far most of the experiments which have been devised to test Knoop's theory of β-oxidation have confirmed it. However, it has been

[1] Knoop, *Beitr. Chem. Physiol. Path.*, **6**, 150 (1905).

pointed out by Professor R. C. Corley[2] that only omega substituted acids in which the aliphatic chain is fairly short have been examined and he has suggested that a study of longer straight chain fatty acids with the phenyl group at different distances from the carboxyl group and not in the omega position would be of interest.

Several aliphatic acids containing a phenyl group substituted in other than the alpha or omega positions have been prepared previously. Eijkman[3] prepared γ-phenylvaleric acid by the action of γ-valerolactone on benzene in the presence of aluminum chloride. When he tried to prepare the same acid from Δ^4-pentenoic acid and benzene[4] he obtained a mixture of the γ- and δ-phenyl substituted acids. The same method has been used by other investigators but mixtures of isomers seem invariably to result.[5] For the purpose for which these compounds were desired it seemed essential that pure compounds of known structures should be available. Accordingly, procedures which are known to produce compounds of definite composition were used in this work.

The acids desired for metabolism studies were those with ten to eighteen carbon atoms and having the phenyl group on various even numbered positions beyond six. Since the natural fatty acids have an even number of carbon atoms most of the compounds were of this type. Only one compound with an odd number of carbons in the aliphatic chain was prepared. The compounds which were obtained in sufficient quantity for animal experiments were 6-phenyldecanoic acid, 8-phenyldodecanoic acid, 10-phenyltetradecanoic acid, 6-phenylpentadecanoic acid, 8-phenylhexadecanoic acid, 9-phenyloctadecanoic acid, and 10-phenyloctadecanoic acid.

The last two of these acids served a double purpose; for in addition to being made available for study in the physiological work, they were used to compare with the phenyloctadecanoic acid which Nicolet and deMilt[5b] and Schmidt[5c] have prepared from oleic acid and benzene in the presence of aluminum chloride. The two synthetic acids of known structures were solids whereas the acid prepared from oleic acid is an oil. Comparison of the physical properties of the acids and also of the p-bromophenacyl esters which are given in detail in the experimental part showed that the acid from oleic acid is a mixture of about equal parts of the 9- and 10-phenyloctadecanoic acids.

In the synthesis of these acids the first few reactions were of the same general type and may be represented as follows

    [2] R. C. Corley in a private communication has suggested these facts to us and it was at his suggestion that this synthetic work was undertaken.

    [3] Eijkman, *Chem. Weekblad*, 1, 421 (1904).

    [4] Eijkman, *ibid.*, 4, 727 (1907).

    [5] (a) Eijkman, *ibid.*, 5, 655 (1908); (b) Nicolet and deMilt, THIS JOURNAL, 49, 1103 (1927); (c) Schmidt, *ibid.*, 52, 1172 (1930); (d) Martin and Adams, private communication; (e) Fourneau and Baranger, *Bull. soc. chim.*, [4] 49, 1161 (1931).

$$C_6H_5C\overset{\|}{\underset{O}{}}\!\!-\!\!H \xrightarrow{RMgX} \underset{\underset{C_6H_5}{|}}{RCHOH} \xrightarrow{HCl} \underset{\underset{C_6H_5}{|}}{RCHCl} \xrightarrow[CH_2(COOC_2H_5)_2]{NaOC_2H_5}$$

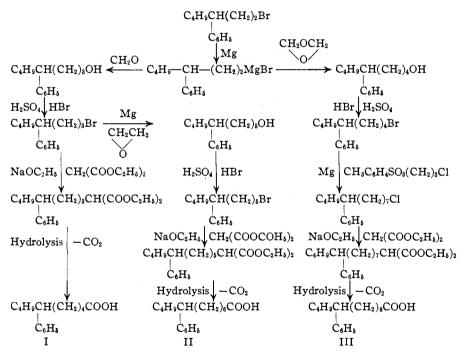$$\underset{\underset{C_6H_5}{|}}{RCHCH(COOC_2H_5)_2} \xrightarrow[-CO_2]{Hydrolysis} \underset{\underset{C_6H_5}{|}}{RCHCH_2COOH} \xrightarrow[H_2SO_4]{C_2H_5OH}$$

$$\underset{\underset{C_6H_5}{|}}{RCHCH_2COOC_2H_5} \xrightarrow[C_2H_5OH]{Na} \underset{\underset{C_6H_5}{|}}{RCH(CH_2)_2OH} \xrightarrow[H_2SO_4]{HBr} \underset{\underset{C_6H_5}{|}}{RCH(CH_2)_2Br}$$
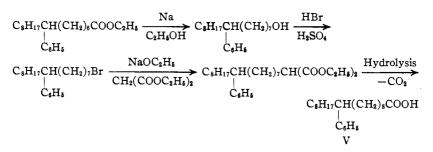
The reactions used in preparing 6-phenyldecanoic acid (I), 8-phenyldodecanoic acid (II) and 10-phenyltetradecanoic acid (III) are outlined below.

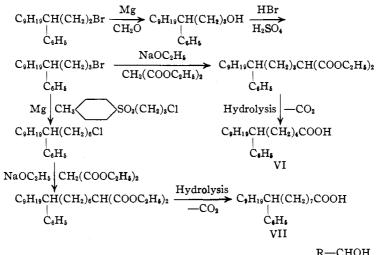$$\underset{\underset{C_6H_5}{|}}{C_4H_9CH(CH_2)_2Br}$$
$$\downarrow Mg$$

$$\underset{\underset{C_6H_5}{|}}{C_4H_9CH(CH_2)_3OH} \xleftarrow{CH_2O} \underset{\underset{C_6H_5}{|}}{C_4H_9\!-\!CH\!-\!(CH_2)_2MgBr} \xrightarrow{CH_2OCH_2 \diagup\!\!O} \underset{\underset{C_6H_5}{|}}{C_4H_9CH(CH_2)_4OH}$$

$$H_2SO_4 \downarrow HBr$$
$$\underset{\underset{C_6H_5}{|}}{C_4H_9CH(CH_2)_3Br} \xrightarrow[CH_2CH_2\diagup\!\!O]{Mg} \qquad \underset{\underset{C_6H_5}{|}}{C_4H_9CH(CH_2)_5OH} \qquad HBr\downarrow H_2SO_4 \quad \underset{\underset{C_6H_5}{|}}{C_4H_9CH(CH_2)_4Br}$$

$$NaOC_2H_5 \Big| CH_2(COOC_2H_5)_2 \qquad H_2SO_4 \Big| HBr \qquad Mg \Big| CH_3C_6H_4SO_3(CH_2)_3Cl$$

$$\underset{\underset{C_6H_5}{|}}{C_4H_9CH(CH_2)_3CH(COOC_2H_5)_2} \qquad \underset{\underset{C_6H_5}{|}}{C_4H_9CH(CH_2)_5Br} \qquad \underset{\underset{C_6H_5}{|}}{C_4H_9CH(CH_2)_7Cl}$$

$$\qquad\qquad NaOC_2H_5\Big| CH_2(COOCOH_5)_2 \quad NaOC_2H_5\Big| CH_2(COOC_2H_5)_2$$
$$Hydrolysis \Big| -CO_2 \quad \underset{\underset{C_6H_5}{|}}{C_4H_9CH(CH_2)_5CH(COOC_2H_5)_2} \quad \underset{\underset{C_6H_5}{|}}{C_4H_9CH(CH_2)_7CH(COOC_2H_5)_2}$$

$$Hydrolysis\Big| -CO_2 \qquad Hydrolysis\Big| -CO_2$$

$$\underset{\underset{C_6H_5}{|}}{C_4H_9CH(CH_2)_4COOH} \qquad \underset{\underset{C_6H_5}{|}}{C_4H_9CH(CH_2)_6COOH} \qquad \underset{\underset{C_6H_5}{|}}{C_4H_9CH(CH_2)_8COOH}$$
$$\qquad I \qquad\qquad\qquad\qquad II \qquad\qquad\qquad\qquad III$$

The methods of preparation used for 8-phenylhexadecanoic acid (IV) and 10-phenyloctadecanoic acid (V) are outlined below

$$\underset{\underset{C_6H_5}{|}}{C_8H_{17}CH(CH_2)_2Br} \xrightarrow[CH_3\!-\!\langle\!\!\rangle\!\!-\!SO_3(CH_2)_3Cl]{Mg} \underset{\underset{C_6H_5}{|}}{C_8H_{17}CH(CH_2)_5Cl} \xrightarrow[CH_2(COOC_2H_5)_2]{NaOC_2H_5}$$

$$\underset{\underset{C_6H_5}{|}}{C_8H_{17}CH(CH_2)_5CH(COOC_2H_5)_2} \xrightarrow[-CO_2]{Hydrolysis} \underset{\underset{C_6H_5}{|}}{C_8H_{17}CH(CH_2)_6COOH} \xrightarrow[H_2SO_4]{C_2H_5OH}$$
$$\qquad\qquad\qquad\qquad\qquad\qquad IV$$

$$C_8H_{17}CH(CH_2)_6COOC_2H_5 \xrightarrow[C_2H_5OH]{Na} C_8H_{17}CH(CH_2)_7OH \xrightarrow[H_2SO_4]{HBr}$$
$$\qquad\quad |\qquad\qquad\qquad\qquad\qquad\qquad\quad |$$
$$\qquad\quad C_6H_5 \qquad\qquad\qquad\qquad\qquad\qquad C_6H_5$$

$$C_8H_{17}CH(CH_2)_7Br \xrightarrow[CH_2(COOC_2H_5)_2]{NaOC_2H_5} C_8H_{17}CH(CH_2)_7CH(COOC_2H_5)_2 \xrightarrow[-CO_2]{Hydrolysis}$$
$$\qquad\quad |\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad |$$
$$\qquad\quad C_6H_5 \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad C_6H_5$$

$$C_8H_{17}CH(CH_2)_8COOH$$
$$|$$
$$C_6H_5$$
$$V$$

The methods used for 6-phenylpentadecanoic acid (VI) and 9-phenyl-octadecanoic acid (VII) are outlined in the following diagram

$$C_9H_{19}CH(CH_2)_2Br \xrightarrow[CH_2O]{Mg} C_9H_{19}CH(CH_2)_3OH \xrightarrow[H_2SO_4]{HBr}$$
$$\qquad\quad |\qquad\qquad\qquad\qquad\qquad\qquad\quad |$$
$$\qquad\quad C_6H_5 \qquad\qquad\qquad\qquad\qquad\qquad C_6H_5$$

$$C_9H_{19}CH(CH_2)_3Br \xrightarrow[CH_2(COOC_2H_5)_2]{NaOC_2H_5} C_9H_{19}CH(CH_2)_3CH(COOC_2H_5)_2$$
$$\qquad\quad |\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad |$$
$$\qquad\quad C_6H_5 \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad C_6H_5$$

$$Mg \Big| CH_3\text{—}\langle\rangle\text{—}SO_3(CH_2)_3Cl \qquad\qquad Hydrolysis \Big| -CO_2$$

$$C_9H_{19}CH(CH_2)_6Cl \qquad\qquad\qquad\qquad C_9H_{19}CH(CH_2)_4COOH$$
$$\qquad\quad |\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad |$$
$$\qquad\quad C_6H_5 \qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad C_6H_5$$
$$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad VI$$

$$NaOC_2H_5 \Big| CH_2(COOC_2H_5)_2$$

$$C_9H_{19}CH(CH_2)_6CH(COOC_2H_5)_2 \xrightarrow[-CO_2]{Hydrolysis} C_9H_{19}CH(CH_2)_7COOH$$
$$\qquad\quad |\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad |$$
$$\qquad\quad C_6H_5 \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad C_6H_5$$
$$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad VII$$

The alkyl phenyl carbinols and chlorides of the type $\underset{C_6H_5}{R\text{—}CHOH}$ and $\underset{C_6H_5}{R\text{—}CHCl}$, respectively, were not usually purified for use in further syntheses because they partially decomposed with the loss of water and hydrogen chloride, respectively, when an attempt was made to distil them. In the preparation of 6-phenyldecanoic acid an attempt was made to prepare the Grignard reagent from *n*-butylphenylchloromethane and to build up the chain by two methylene groups with ethylene oxide. The method could be used but it was not reliable and slight variations in the procedure which did not seem to be controllable resulted in a Würtz synthesis to give 5,6-diphenyldecane, and no Grignard reagent could be found. The malonic ester synthesis from the alkyl phenyl chloromethane gave about 75% yields on the average.

All of the other reactions were carried out according to the usual procedures described in the literature. Each of the new phenyl fatty acids

was characterized by the preparation of the p-bromophenacyl ester according to the procedure of Judefind and Reid.[6]

The results of the physiological experiments will be reported at a later date by Professor Corley.

Experimental Part

Grignard Reagents.—The Grignard reagents were prepared by the usual procedure using, on the average, seven moles of ether[7] per mole of alkyl halide. The ether was dried by distilling from ethylmagnesium bromide. The ether solution of the alkyl halide was added to the reaction mixture at such a rate as to cause very gentle refluxing.

Alkylphenylcarbinols.—The method of Conant and Blatt[8] for the preparation of alkylphenylcarbinols was applied to n-butylphenylcarbinol, n-octylphenylcarbinol and n-nonylphenylcarbinol. The n-butylphenylcarbinol, b. p. 97–104° (5 mm.), was obtained in the same yield which they have reported.

n-**Octylphenylcarbinol.**—Several 2-mole runs of this alcohol were made and the yield of undistilled carbinol averaged 92% of the theoretical amount. It decomposed slowly on distillation under reduced pressure so that it was inadvisable to purify the product to be used in further work. A small sample was purified for analysis: b. p. 124–129° (3 mm.); n_D^{20} 1.4966; sp. gr.$_{25}^{25}$ 0.9238.

Anal. Subs., 0.2089: CO_2, 0.6237; H_2O, 0.2037. Calcd. for $C_{15}H_{24}O$: C, 81.75; H, 10.98. Found: C, 81.45; H, 10.85.

n-**Nonylphenylcarbinol.**—The crude yield of this alcohol from a 2-mole run was 97% of the theoretical amount. The constants were determined on a purified sample: b. p. 121–124° (0.2 mm.); n_D^{20} 1.4953; sp. gr.$_{25}^{25}$ 0.9194.

Anal. Subs., 0.2224: CO_2, 0.6684; H_2O, 0.2223. Calcd. for $C_{16}H_{26}O$: C, 81.98; H, 11.19. Found: C, 81.97; H, 11.18.

Alkylphenylchloromethanes.—The alkylphenylcarbinols were converted to the chlorides by saturating with dry hydrogen chloride and heating the mixture. As a typical case dry hydrogen chloride was passed into 275 g. of crude carbinol contained in a 500-cc. gas washing bottle. Heat was generated and the carbinol at first became turbid and then two layers separated. When the reaction began to subside the bottle containing the reaction mixture was placed in a hot water-bath maintained at 60–70° and the current of dry hydrogen chloride was passed through the mixture about two hours longer. Ether was added to take up the chloride and the layers were separated. The ether solution was washed thoroughly with water and sodium bicarbonate solution to remove hydrogen chloride. It was then dried first over anhydrous magnesium sulfate, filtered and then dried over phosphorus pentoxide. The solution was again filtered and the ether was removed by distillation from a steam cone. The chloride was heated to 100° under 25 mm. pressure for a half an hour to remove low boiling impurities. Only n-butylphenylchloromethane was distilled under reduced pressure. The yield was 83% of the theoretical amount of a product; b. p. 84–87° (4 mm.); n_D^{20} 1.5125; sp. gr.$_{25}^{25}$ 0.9976. This material was not pure but contained some of the unsaturated hydrocarbon due to loss of hydrogen chloride. Chlorine analyses were about 1% too low. The other two chlorides were not distilled. The crude yields were 93% for the n-octyl derivative and 91% for the n-nonyl derivative.

[6] Judefind and Reid, THIS JOURNAL, **42**, 1043 (1920).

[7] (a) Gilman and McCracken, *Rec. trav. chim.*, **46**, 463 (1927); (b) Gilman and Zoellner, THIS JOURNAL, **50**, 425 (1928).

[8] Conant and Blatt, *ibid.*, **50**, 554 (1928).

Malonic Ester Synthesis.—All of the substituted malonic esters prepared in this work were made according to the method described in "Organic Syntheses"[9] except that the alcohol was dried with magnesium methylate[10] and the halide which was used was added more slowly (about 40–60 drops per minute). The reaction mixture was held at about 70° during the addition of the halide.

A record of the various preparations is given in Table I.

<div align="center">

TABLE I

MALONIC ESTER SYNTHESES

</div>

Ester prepared	Halide	Halide, g.	Amount of ma- lonic ester, g.	Yield, %
$C_4H_9CH(C_6H_5)CH(COOC_2H_5)_2$	Cl	365	342	75
$C_8H_{17}CH(C_6H_5)CH(COOC_2H_5)_2$	Crude Cl	476	372	56
$C_9H_{19}CH(C_6H_5)CH(COOC_2H_5)_2$	Crude Cl	252	171	61
$C_4H_9CH(C_6H_5)(CH_2)_3CH(COOC_2H_5)_2$	Br	107.6	64	66
$C_4H_9CH(C_6H_5)(CH_2)_5CH(COOC_2H_5)_2$	Br	44.5	26	67
$C_4H_9CH(C_6H_5)(CH_2)_7CH(COOC_2H_5)_2$	Cl	47.5	28	61
$C_9H_{19}CH(C_6H_5)(CH_2)_3CH(COOC_2H_5)_2$	Br	64	32	72
$C_8H_{17}CH(C_6H_5)(CH_2)_5CH(COOC_2H_5)_2$	Cl	167	92	42
$C_9H_{19}CH(C_6H_5)(CH_2)_6CH(COOC_2H_5)_2$	Cl	84	40	56.5
$C_8H_{17}CH(C_6H_5)(CH_2)_7CH(COOC_2H_5)_2$	Br	16.2	7.5	73

The physical constants and analyses of these esters are recorded in Table II.

<div align="center">

TABLE II

CONSTANTS AND ANALYSES OF MALONIC ESTERS

</div>

R in R—CH(COOC₂H₅)₂	B. p., °C.	Mm.	n_D^{20}	Sp. gr.$_{25}^{25}$	Formula	Calcd. C	H	Found C	H
$C_4H_9CH(C_6H_5)$	143.5–147	3.5	1.4830	1.0401	$C_{18}H_{28}O_4$	70.54	8.56	70.43	8.64
$C_8H_{17}CH(C_6H_5)$	186–191	4	1.4816	0.9854	$C_{22}H_{34}O_4$	72.88	9.45	73.33	9.44
$C_9H_{19}CH(C_6H_5)$	163–166	0.3	1.4800	0.9831	$C_{23}H_{36}O_4$	73.35	9.63	73.34	9.59
$C_4H_9CH(C_6H_5)(CH_2)_3$	176–182	3	1.4812	1.0001	$C_{21}H_{32}O_4$	72.34	9.26	72.12	9.22
$C_4H_9CH(C_6H_5)(CH_2)_5$	185–190	3	1.4804	0.9911	$C_{23}H_{36}O_4$	73.35	9.63	72.94	9.48
$C_4H_9CH(C_6H_5)(CH_2)_7$	180–188	0.13	1.4800	.9735	$C_{25}H_{40}O_4$	74.20	9.96	74.14	9.99
$C_9H_{19}CH(C_6H_5)(CH_2)_3$	187–194	.13	1.4790	.9684	$C_{25}H_{42}O_4$	74.58	10.12	74.32	10.06
$C_8H_{17}CH(C_6H_5)(CH_2)_5$	205–211	.25	1.4788	.9634	$C_{27}H_{44}O_4$	74.94	10.26	75.00	10.32
$C_9H_{19}CH(C_6H_5)(CH_2)_6$	220–225	.2	1.4796	.9511	$C_{29}H_{48}O_4$	75.59	10.51	75.84	10.69
$C_8H_{17}CH(C_6H_5)(CH_2)_7$	217–224	.15	1.4780	.9560	$C_{29}H_{48}O_4$	75.59	10.51	75.77	10.53

Conversion of RMgX to RCH₂OH.—The reactions between the Grignard reagent and formaldehyde were carried out according to the procedure described in "Organic Syntheses."[11] The end of the reaction was noted by the fact that when all of the Grignard reagent had been used the ether ceased to reflux. No more formaldehyde was distilled into the reaction mixture after this drop in temperature of the reaction mixture was noted. The reaction mixture was decomposed with a small volume of saturated ammonium chloride solution and the alcohol was isolated by separating the ether solution, washing it with water and then drying with anhydrous magnesium sulfate. The ether was removed and the alcohol

[9] "Organic Syntheses," **4**, 11 (1924).
[10] "Organic Syntheses," **7**, 37 (1927).
[11] "Organic Syntheses," **6**, 22 (1926).

fractionated under reduced pressure.   In each reaction of this type a high boiling residue of the acetal formed by the action of formaldehyde on the alcohol was left behind.[12]   In the one case where this amounted to 34% of the total yield, hydrolysis to the desired alcohol was effected in 50% yield by refluxing it with alcoholic hydrogen chloride for twenty-two hours.

3-Phenyldodecyl bromide gave a 61% yield of 4-phenyltridecanol-1 and 11% of high boiling acetal which was not treated further.

3-Phenylheptyl bromide gave a 45% yield of 4-phenyloctanol-1 and 34% yield of acetal.   This was hydrolyzed and the final yield of alcohol amounted to 62% of the theoretical amount.   In the last preparation a low boiling fraction was isolated; b. p. 68–71° (3 mm.); sp. gr.$_{25}^{25}$ 0.8585; n_D^{20} 1.4871.

Anal. (3-Phenylheptane)   Subs., 0.2092: CO_2, 0.6785; H_2O, 0.2132.   Calcd. for $C_{13}H_{20}$: C, 88.56; H, 11.44.   Found: C, 88.48; H, 11.34.

The constants on the two new alcohols are given in Table III.

Conversion of RMgX to RCH₂CH₂OH.

Conversion of $RMgX$ to RCH_2CH_2OH.—The reactions between the Grignard reagents and ethylene oxide were carried out as described in "Organic Syntheses"[13] except that the reaction mixture was not allowed to heat much above 0° during the addition of ethylene oxide and after decomposition of the reaction mixture, the ether–benzene solution was thoroughly washed with water, dried over anhydrous magnesium sulfate and the solvent distilled.   The residue was distilled under reduced pressure.

5-Phenylnonanol-1 was obtained in 55% of the theoretical amounts from 3-phenylheptyl bromide and 6-phenyldecanol-1 was obtained in 54% of the theoretical amount from 4-phenyloctyl bromide.

The constants of these alcohols are given in Table III.

TABLE III

CONSTANTS AND ANALYSES OF PHENYL ALKYL ALCOHOLS

Alcohol	B. p. °C.	Mm.	n_D^{20}	Sp. gr.$_{25}^{25}$	Formula	Analyses, % Calcd. C	H	Found C	H
4-Phenyloctanol-1	125–130	3	1.5052	0.9405	$C_{14}H_{22}O$	81.49	10.75	81.31	10.72
4-Phenyltridecanol-1	158–160	0.14	1.4952	.9139	$C_{19}H_{32}O$	82.52	11.67	82.49	11.73
5-Phenylnonanol-1	137–144	0.94	1.5038	.9363	$C_{15}H_{24}O$	81.75	10.99	81.62	11.05
6-Phenyldecanol-1	140–144	3	1.5015	.9295	$C_{16}H_{26}O$	81.98	11.19	81.89	11.05

Preparation of Phenyl Alkyl Bromides.

Preparation of Phenyl Alkyl Bromides.—The method used for preparing the bromides from the various alcohols was essentially that described in "Organic Syntheses"[14] for the higher alcohols.   A mechanical stirrer was used on account of the low solubility of the alcohols.   It was found necessary to reduce the amount of sulfuric acid to somewhat less than that used on the simple alcohols.   The refluxing period was six to eight hours.

[12] Conant, "Organic Syntheses," **8**, 124 (1928); Conant, Webb and Mendum, THIS JOURNAL, **51**, 1246 (1929).

[13] "Organic Syntheses," **6**, 54 (1926).

[14] "Organic Syntheses," **1**, 7 (1921).

The bromides were purified by separating them from the mixture of sulfuric and hydrobromic acid, washing thoroughly with water and sodium bicarbonate solution, drying over anhydrous magnesium sulfate and distilling under reduced pressure. The once distilled bromide was then washed at 0° with small portions of 92.5% sulfuric acid. Stronger acid caused excessive charring and some sulfonation. After treating with five to six portions of sulfuric acid, the acid was no longer colored. This acid treatment had to be carefully done to avoid excessive loss. The bromide was then again washed, dried and distilled as before.

The results of these experiments are recorded in Tables IV and V.

TABLE IV

PREPARATION OF PHENYL ALKYL BROMIDES

Alcohol used	Amt., g.	48% HBr, g.	96% H₂SO₄, g.	Time of refluxing, hr.	Yield of bromide, %
3-Phenylheptanol-1	192	326	126	7.5	87
4-Phenyloctanol-1	206	326	126	7.5	91
5-Phenylnonanol-1	122	170	52	8	75
6-Phenyldecanol-1	112	156	61	7.25	82.5
3-Phenylundecanol-1	190	258	71	6	74
3-Phenyldodecanol-1	131	168	51	7	70
4-Phenyltridecanol-1	249	304	91	7	74
6-Phenylhexadecanol-1	27	29	8	8	57

TABLE V

CONSTANTS AND ANALYSES ON PHENYL ALKYL BROMIDES

Compound	B. p., °C.	Mm.	n_D^{20}	Sp. gr.$_{25}^{25}$	Formula	Br analyses, Calcd.	Found
3-Phenyl-1-bromoheptane	118–121	3	1.5215	1.1681	$C_{13}H_{19}Br$	31.35	31.37
4-Phenyl-1-bromooctane	124–126	3	1.5196	1.1490	$C_{14}H_{21}Br$	29.69	29.68
5-Phenyl-1-bromononane	125–127	2	1.5172	1.1260	$C_{15}H_{22}Br$	28.23	28.00
	140–145	4					
6-Phenyl-1-bromodecane	135–139	3	1.5150	1.1109	$C_{16}H_{25}Br$	26.89	26.89
3-Phenyl-1-bromoundecane	147–150	3	1.5090	1.0934	$C_{17}H_{27}Br$	25.69	25.40
3-Phenyl-1-bromododecane	141–147	0.15	1.5068	1.0770	$C_{18}H_{29}Br$	24.58	24.59
4-Phenyl-1-bromotridecane	150–155	.12	1.5061	1.0680	$C_{19}H_{31}Br$	23.56	23.62
8-Phenyl-1-bromohexadecane	169–172	.10	1.5015	1.0396	$C_{22}H_{37}Br$	20.96	20.97

Conversion of RMgX to $RCH_2CH_2CH_2Cl$.—The procedure used for converting the Grignard reagent to the alkyl chloride containing three more methylene groups was that described by Rossander and Marvel.[15] The yields were increased by avoiding an excess of magnesium in the solution of the Grignard reagent. The impure chlorides obtained by distilling once under reduced pressure and collecting a 20° fraction were purified by carefully washing with small portions of 92.5% sulfuric acid at 0°. Four or five extractions with acid were necessary. The chlorides were

15 Rossander and Marvel, THIS JOURNAL, 50, 1491 (1928).

then washed thoroughly with water and sodium bicarbonate solution, dried over anhydrous magnesium sulfate, and distilled under reduced pressure. The results of these experiments are collected in Table VI.

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TABLE VI

PREPARATION OF PHENYL ALKYL CHLORIDES

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Bromide used	G.	Wt. of γ-chloro-propyl p-toluene sulfonate	Yield, %
5-Phenyl-1-bromononane	113.5	198.5	50
3-Phenyl-1-bromoundecane	215	354	54
4-Phenyl-1-bromotridecane	174	248	51.5

Compound prepared	B. p., °C.	Mm.	n_D^{20}	Sp. gr. $^{25}_{25}$	Cl analyses Calcd.	Found
8-Phenyl-1-chlorododecane	129–136	0.1	1.4974	0.9508	12.63	12.67
6-Phenyl-1-chlorotetradecane	166–173	3	1.4948	.9397	11.49	11.30
7-Phenyl-1-chlorohexadecane	160–165	0.1	1.4923	.9263	10.53	10.43

Preparation of Phenyl Fatty Acids.—All of the phenyl fatty acids were prepared by hydrolysis of the corresponding malonic esters followed by elimination of carbon dioxide. The esters were first saponified by adding one mole of ester to a hot solution of four moles of sodium hydroxide dissolved in alcohol. Four cc. of alcohol was used per gram of ester. The reaction was vigorous and the salt separated at once. When the ester had all been added, enough alcohol was added to make stirring efficient. The mixture was stirred occasionally and refluxed for about ten hours. The mixture was then evaporated to dryness in an open vessel on a steam cone. The salt was made into a paste with water and again evaporated to dryness in order to insure complete removal of the alcohol. The salt was then dried in an oven at 100–120°. The free organic acid was obtained by adding the powdered salt to an excess of hot 16% hydrochloric acid. Stirring was used during this operation. Then the mixture was heated until all of the precipitated organic acid had melted. After cooling the crude malonic acid which was thus formed was transferred to a Claisen flask and converted to the monocarboxylic acid by heating slowly to 190°. Sometimes it was necessary to use ether extraction to separate the organic dibasic acids from the aqueous acid in which they were precipitated.

After decomposition of the malonic acid, the mixture was cooled and the monobasic acid was taken up in ether. The ether solution was washed with water to remove all of the suspended salt and was then dried over anhydrous magnesium sulfate, and the ether was distilled. The residual acid was distilled under reduced pressure. A few of the acids were not purified (except for a small amount of material for analysis) but were used directly for other preparations.

A summary of these preparations is given in Table VII.

TABLE VII

PREPARATION AND PROPERTIES OF PHENYL FATTY ACIDS

Acid	% yield based on malonic ester	B. p. °C.	B. p. Mm.	n_D^{20}	Sp. gr.$_{25}^{24}$
3-Phenylheptanoic	Crude 96	144–149	3	1.5049	1.0117
6-Phenyldecanoic	90	176–180	3	1.5000	0.9817
3-Phenylundecanoic	Crude 99	167–172	2.5	1.4960	.9679
3-Phenyldodecanoic	Crude 99	165–171	0.3	1.4950	.9623
8-Phenyldodecanoic	82.5	184–187	3	1.4970	.9729
10-Phenyltetradecanoic	85	178–183	0.1	1.4936	.9555
6-Phenylpentadecanoic	92	182–185	.1	1.4924	.9470
8-Phenylhexadecanoic	Crude 99	190–195	.12	1.4912	.9417
9-Phenyloctadecanoic	84	200–204	.09	1.4891	.9340
		M. p. 36.5–38°			
10-Phenyloctadecanoic	90	199–205	0.09	1.4894	.9338
		M. p. 40–41.5°			

Formula	Neutral equivalent Calcd.	Neutral equivalent Found	Analyses, % Calcd. C	Calcd. H	Found C	Found H
$C_{13}H_{18}O_2$	206.1	204, 207	75.68	8.80	75.57	8.85
$C_{16}H_{24}O_2$	248.2	246.2	77.36	9.74	77.39	9.71
$C_{17}H_{26}O_2$	262.2	270.2	77.80	9.94	77.89	9.98
$C_{18}H_{28}O_2$	276.2	278	78.17	10.21	77.69	10.12
$C_{18}H_{28}O_2$	276.2	269	78.17	10.21	78.05	10.05
$C_{20}H_{32}O_2$	304.2	306	78.88	10.60	78.84	10.74
$C_{21}H_{34}O_2$	318.3	321	79.18	10.77	79.29	10.87
$C_{22}H_{36}O_2$	332.3	338	79.45	10.92	79.44	10.96
$C_{24}H_{40}O_2$	360.3	363.4	79.93	11.19	79.77	11.03
$C_{24}H_{40}O_2$	360.3	360	79.93	11.19	80.03	11.20

Preparation of Ethyl Esters.—In certain cases these phenyl fatty acids were converted to the ethyl esters by the general procedure outlined in "Organic Syntheses"[16] except calcium oxide (small lumps) was used as the drying agent. It was renewed after about three hours in order to prevent violent bumping. The time allowed for esterification was about twenty

TABLE VIII

ETHYL ESTERS OF PHENYL FATTY ACIDS

Ethyl ester of acid	% yield based on malonic ester	B. p. °C.	B. p. Mm.	n_D^{20}	Sp. gr.$_{25}^{25}$
3-Phenylheptanoic	92	117–120	3	1.4859	0.9625
3-Phenylundecanoic	89	154–159	4	1.4823	.9360
3-Phenyldodecanoic	93	142–148	0.2	1.4827	.9289
8-Phenylhexadecanoic	90	174–180	.13	1.4808	.9194

Formula	Analyses, % Calcd. C	Calcd. H	Found C	Found H
$C_{15}H_{22}O_2$	76.87	9.42	76.85	9.49
$C_{19}H_{30}O_2$	78.55	10.42	78.67	10.47
$C_{20}H_{32}O_2$	78.88	10.60	79.19	10.66
$C_{24}H_{40}O_2$	79.93	11.19	80.00	11.30

16 "Organic Syntheses," **5**, 59 (1925).

hours. To hasten the esterification about 12 cc. of concentrated sulfuric acid for each mole of organic acid was used as a catalyst. The ester was purified by distilling the excess alcohol, washing the residue with water and distilling under reduced pressure. The results of these preparations are summarized in Table VIII.

Reduction of Ethyl Esters to Primary Alcohols.—The reduction. of the esters was carried out according to the general procedure described in "Organic Syntheses";[17] however, the details were varied considerably. About 0.4 mole runs were made using eight gram atoms of sodium per mole of ester and 290 cc. of absolute alcohol[9] per gram atom of sodium.

The sodium was cut into small pieces and placed in the flask under a little dry benzene. The ester was dissolved in about one-fifth of the total volume of ethyl alcohol in one separatory funnel and the remainder of the ethyl alcohol was placed in another separatory funnel. The benzene was warmed nearly to boiling, the alcohol solution of the ester was added all at once and just as the last of it ran in the stirrer was started and the alcohol from the other separatory funnel was added all at once. The sodium usually balled up into a large porous mass and was dashed back and forth in the solution by the stirrer. As soon as the initial vigorous reaction had subsided the reaction mixture was heated on a boiling water-bath and as soon as the sodium had dissolved the water-bath was removed and the hot sodium ethylate solution was decomposed by the cautious addition of a volume of water equal to about one-fourth the volume of the reaction mixture. The almost colorless solution was transferred to another flask and as much alcohol and benzene as possible was distilled from a steam cone. When more than one run was made it was advantageous to combine them at this point. After cooling, the layers were separated and the non-aqueous layer was taken up in an equal volume of ether and carefully washed with water several times. The ether solution was dried over anhydrous magnesium sulfate, filtered, the ether distilled and the residual alcohol was distilled under reduced pressure. The results of these experiments are summarized in Table IX.

TABLE IX
REDUCTION OF ESTERS

Alcohol prepared	Yield, %	°C. B. p.	Mm.	n_D^{20}	Sp. gr. $^{25}_{25}$
3-Phenylheptanol-1	84	116–120	3	1.5070	0.9466
3-Phenylundecanol-1	74	139–145	2.5	1.4971	.9208
3-Phenyldodecanol-1	63.5	140–142	0.2	1.4959	.9169
8-Phenylhexadecanol-1	63	168–174	.1	1.4919	.9060
		M. p. 39–41°			

Formula	Calcd. C	H	Found C	H
$C_{13}H_{20}O$	81.14	10.48	81.18	10.54
$C_{17}H_{28}O$	82.18	11.37	82.14	11.39
$C_{18}H_{30}O$	82.37	11.53	82.37	11.56
$C_{22}H_{35}O$	82.94	12.03	82.51	12.17

p-Bromophenacyl Esters of Phenyl Fatty Acids.—The p-bromophenacyl esters of all of the phenyl fatty acids were prepared according to the method of Judefind and Reid.[6] The esters were crystallized from ethyl alcohol

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[17] "Organic Syntheses," **10**, 62 (1930).

until the melting point was unchanged by further crystallization. Usually six to seven crystallizations were needed. The properties of the new derivatives are summarized in Table X.

TABLE X

p-BROMOPHENACYL ESTERS OF PHENYL FATTY ACIDS

p-Bromophenacyl ester of acid	M. p., °C.	Formula	Br analyses, % Calcd.	Found
3-Phenylheptanoic	47.4–48.2	$C_{21}H_{28}O_3Br$	19.83	19.79
6-Phenyldecanoic	55.5–56	$C_{24}H_{29}O_3Br$	17.95	17.89
3-Phenylundecanoic	65–65.5	$C_{25}H_{31}O_3Br$	17.40	17.34
3-Phenyldodecanoic	74.5–75.5	$C_{26}H_{33}O_3Br$	16.89	16.63
8-Phenyldodecanoic	89–90	$C_{26}H_{33}O_3Br$	16.89	16.86
10-Phenyltetradecanoic	79–80	$C_{28}H_{37}O_3Br$	15.95	16.14
6-Phenylpentadecanoic	73.5–74.5	$C_{29}H_{39}O_3Br$	15.49	15.53
8-Phenylhexadecanoic	77–78	$C_{30}H_{41}O_3Br$	15.10	15.03
9-Phenyloctadenoic	83.5–84.5	$C_{32}H_{45}O_3Br$	14.34	14.39
10-Phenyloctadecanoic	71–72	$C_{32}H_{45}O_3Br$	14.34	14.38

Phenylstearic Acid from Oleic Acid.—This acid was prepared according to the procedure of Nicolet and deMilt.[5b]

The p-bromophenacyl ester was prepared and it melted below 50° when first obtained. Crystallization from alcohol raised the melting point until finally after fourteen recrystallizations the melting point was 79–82°. To compare this acid with the pure samples of 9- and 10-phenyloctadecanoic acids prepared in this work, the properties of all these are summarized in Table XI.

TABLE XI

COMPARISON OF NICOLET AND DEMILTS' PHENYLSTEARIC ACID WITH KNOWN 9- AND 10-PHENYLOCTADECANOIC ACIDS

Acid	B. p., °C.	Mm.	M. p., °C.
Phenyl stearic from oleic acid and benzene	199–203	0.08	Below 0
9-Phenyloctadecanoic	200–204	.09	36.5–38
10-Phenyloctadecanoic	199–205	.09	40–41.5

n_D^{20}	Sp. gr.$_{25}^{25}$	M. p. of p-bromophenacyl ester, °C. Crude	Purified	Number of crystallizations
1.4906	0.9377	Below 50°	79–82	14
1.4891	.9340	81–83	83.5–84.5	7
1.4894	.9338	68–70	71–72	6

A mixture of equal parts of the p-bromophenacyl esters of the 9- and 10-phenyloctadecanoic acids melted at 65–73°. When the ester from Nicolet and deMilt's acid had been crystallized six times it melted at 66–73°. This seems to indicate that it is roughly an equal mixture of the two expected isomers.

Summary

1. Ten new phenyl substituted fatty acids have been prepared in order that certain of them could be used to test Knoop's beta oxidation theory for fatty acids.

2.   The phenylstearic acid of Nicolet and deMilt has been compared with 9- and 10-phenyloctadecanoic acids and it has been found to be a mixture of approximately equal parts of these isomers.

3.   A number of intermediate compounds used in the preparation of these compounds have been characterized.

URBANA, ILLINOIS

THE FATTY ACIDS ASSOCIATED WITH CASSAVA STARCH

BY LEO LEHRMAN

Some of the common cereal starches (corn, rice and wheat) have been shown to have fatty acids combined with carbohydrate in the α-amylose component.[1]   The individual fatty acids found in each of these starches are the same though the amounts are different.   Two tuber starches, cassava and potato, also contain combined fatty acids,[2] but in a much smaller percentage.   Beyond this meager information no tuber starch has been investigated from the point of view of the combined fatty acids occurring in it.   It would be important to know whether the fatty acids in a tuber starch such as cassava are the same as those found in the common cereal starches.

As in the investigations on the cereal starches a search for sterols and other substances that might occur in the starch and then be present in the liberated fatty acids must be made.   This is necessary if there is to be any comparison of the fatty acids found in the different starches.   It is also requisite to investigate the aqueous filtrate from the hydrolysis of the starch for glycerol to be sure that the fatty acids are not present in the starch as extraneous glycerides.

Experimental Part

Mixed Fatty Acids from Cassava Starch.—A sample of the cassava starch[3] was extracted with petroleum ether for several hours and showed a negligible amount of extractable material.   The starch was hydrolyzed by hydrochloric acid[1b] in 2000-g. portions, a portion yielding 2 g. of a light yellow fatty semi-solid, equal to 0.1% "fat by hydrolysis" and having an iodine number of 78.8.[1a]

Examination of Filtrate for Glycerol.—Four liters of filtrate, dark brown in color, from the hydrolysis, was evaporated to 400 cc. of a thick sirupy liquid.   As there is a great deal of frothing during the evaporation it was necessary to heat a volume not ex-

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[1] (a) Taylor and Lehrman, THIS JOURNAL, **48**, 1739 (1926);   (b) Lehrman, *ibid.*, **51**, 2185 (1929);   (c) **52**, 808 (1930).

[2] Taylor and Nelson, *ibid.*, **42**, 1726 (1920).

[3] The author wishes to thank Stein, Hall and Co., Inc., New York City, for their kindness in supplying this material.