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EXPERIMENTAL CARIES WITH HUMAN FOODS

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SEVERAL types of diets have been used in the study of dental caries. One of the more common diets^{1, 2} used contains ingredients, such as coarse corn meal, which cause fracturing associated with caries production. Another general type of diet^{3, 4, 5} is largely synthetic and contains large amounts of sucrose. A third dietary type^{6, 7, 8} contains human foods with smaller amounts of sucrose. In this latter group, a limited variety of human foods are used, which are dehydrated, ground in a mill, and fed to the animals. As generally recognized, particle size, moisture content, and physical consistency of the food may affect the amount of caries produced.

The caries-susceptible albino rats used in these studies were descendants of 8 animals obtained from the Naval Medical Research Institute at Bethesda, Maryland.

The diets employed represent the average American diet and modifications thereof and are composed of human foods as customarily prepared and eaten. The foods were thoroughly mixed to make a uniform moist mass of rations which were fed to the animals ad libitum.

MATERIALS AND METHODS

Basis of Formulating the Diets.—The percentage composition of the diet is based on the table of U. S. food supply as computed by Callison and co-workers.⁹ This is in close agreement with the findings of Hardinge and Stare¹⁰ who made a study of food consumption in California.

From the basic diet thus computed, the cereals and desserts were removed and were substituted on an equicaloric basis with whole grain cereals (in place of refined cereals), and fruits or fruits and vegetables (in place of desserts). The latter presented the problem of replacing concentrated foods high in calories with foods low in calories but high in fiber and water.

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In the consumption of the individual foods or food groups in both the basic ration and the accessory groups, namely cereals, fruits, vegetables, and desserts, the amount of the individual constituents were proportioned according to the average American per capita consumption.¹¹ For practical reasons, only representative foods, used in the largest amounts in each food group, were proportioned according to their popularity in this country as follows: meat—beef and pork; dairy products—milk, cheese, eggs; potatoes—white; vegetables other than potatoes—carrots, cabbage; fruits—apple, orange, and banana; cereals—refined wheat and corn, whole wheat and corn; desserts—cake and pie; fats—dairy butter, lard, hydrogenated shortening. The composition of the various foods groups is shown in Table I.

TABLE I
COMPOSITION OF FOOD GROUPS

| GROUP | FOODS | WEIGHT (GM.) | GROUP | FOODS | WEIGHT (GM.) | |
|--------|----------------------|---------------------|-------|---------------------|----------------------------|-----|
| A | Basic Ration | | C | Whole Grain Cereals | | |
| | Canned beef | 61 | | Whole wheat bread | 824 | |
| | Canned pork | 51 | | Unbolted corn meal | 176 | |
| | B | Canned potatoes | 120 | D | Desserts | |
| | | Whole milk | 610 | | Cake, plain white, iced | 502 |
| | | Canned carrots | 83 | Pie, lemon meringue | 498 | |
| | | Raw cabbage | 92 | E | Fruits | |
| | | Canned kidney beans | 100 | | Apple, raw | 394 |
| | | Eggs | 54 | | Orange | 444 |
| | | Raw apple | 94 | Banana, raw | 162 | |
| | | Orange | 89 | F | Fruits and Vegetables | |
| | | Canned peaches | 41 | | Carrots, raw | 122 |
| | | Butter | 23 | | Cabbage, raw | 270 |
| Crisco | 19 | Apple, raw | 240 | | | |
| Lard | 20 | Orange | 270 | | | |
| | | Banana, raw | 98 | | | |
| B | Refined Cereals | | | | | |
| | White enriched bread | 807 | | | | |
| | Refined corn meal | 193 | | | | |

The diets consisted of many of the combinations of these groups, as shown in Table II. The quantity of food mixture from individual groups combined to make up the several diets, was so proportioned as to keep the diets isocaloric, as well as to provide nearly equal intakes of carbohydrate and protein.

TABLE II
COMPOSITION OF DIETS

| DIET | FOOD GROUPS | WEIGHT (GM.) | DIET | FOOD GROUPS | WEIGHT (GM.) |
|------|-------------|-----------------|------|-------------|-----------------|
| I | A | 784 | V | A | 504 |
| | B | 95 | | C | 69 |
| | D | 121 | | E | 427 |
| II | A | 508 | VI | A | 459 |
| | B | 62 | | C | 63 |
| | E | 430 | | F | 478 |
| III | A | 462 | VII | A | 892 |
| | B | 56 | | B | 108 |
| | F | 482 | VIII | A | 880 |
| IV | A | 774 | | C | 120 |
| | C | 106 | | | |
| | D | 120 | | | |

For purposes of comparison a modification of the synthetic diet of Sognaes⁵ was fed to Group IX as a control. This diet had the following composition: casein, 24; sucrose, 65; salts U.S.P. XIV, 4; dehydrated liver, 4; vitamin mix,² 2; choline, 0.2; corn oil, 5.

An analysis of the various diets is given in Table III.

TABLE III
FOOD ANALYSIS OF VARIOUS DIETS

| DIET | WEIGHT (GM.) | CAL- ORIES | PRO- TEIN (GM.) | FAT (GM.) | CHO (GM.) | Ca (MG.) | P (MG.) | Fe (MG.) | A* (I. U.) | C (MG.) | B ₁ (MG.) | B ₂ (MG.) | NIA- CIN (MG.) |
|---------|-----------------|---------------|-----------------------|--------------|--------------|-------------|------------|-------------|---------------|------------|-------------------------|-------------------------|----------------------|
| I ABD | 1902 | 3000 | 86 | 108 | 334 | 1165 | 1375 | 10.8 | 13,300 | 125 | 1.68 | 2.73 | 9.58 |
| II ABE | 2931 | 3000 | 85 | 93 | 403 | 1237 | 1434 | 14.7 | 15,400 | 444 | 3.09 | 2.98 | 12.6 |
| III ABF | 3225 | 3000 | 91 | 93 | 395 | 1444 | 1576 | 17.0 | 35,700 | 584 | 3.53 | 4.13 | 13.8 |
| IV ACD | 1925 | 3000 | 89 | 108 | 339 | 1232 | 1758 | 14.1 | 13,400 | 125 | 3.45 | 2.86 | 13.6 |
| V ACE | 2954 | 3000 | 88 | 93 | 408 | 1304 | 1814 | 18.9 | 13,900 | 444 | 3.60 | 3.10 | 16.6 |
| VI ACF | 3248 | 3000 | 94 | 94 | 400 | 1511 | 1956 | 20.0 | 35,700 | 584 | 4.05 | 4.29 | 17.9 |
| VII AB | 2228 | 3000 | 101 | 119 | 289 | 1336 | 1600 | 14.0 | 17,200 | 167 | 2.17 | 3.31 | 12.12 |
| VIII AC | 2258 | 3000 | 105 | 120 | 299 | 1431 | 2107 | 17.2 | 17,600 | 167 | 2.84 | 3.59 | 17.6 |

*Includes carotene.

The foods comprising each diet were passed through a Hobart food grinder twice and then thoroughly mixed. To limit further the preferential selection of individual foods within a diet, only enough food was given to last the animals 1 day. The foods were prepared fresh 3 times a week and stored in the refrigerator until served to the animals. To make the foods as uniform as possible throughout the 16 weeks, canned foods were purchased by the case.

One hundred seventeen weanling rats, 21 days of age, were divided by litters into 9 groups of 13 animals each and placed on their respective diets. Similar groups and numbers of animals were employed for successive generations. Ten weeks after weaning, 3 females and 1 male, generally littermates, were selected from each of the 9 diet groups for breeding each generation. The animals remained on their respective diets throughout breeding, gestation, and lactation. At the end of 16 weeks, the animals were sacrificed and the teeth examined with a 20 × dissecting microscope by grinding successive planes parallel to occlusal surface. Individual charts which showed the relationship of the enamel, dentin, and the pulp of each molar were used to record the carious process. The lesions were scored by the method of Shaw and co-workers.³

The nutritional status of the animals from generation to generation was quantitatively evaluated by noting weaning weights, weekly gain, total weight, length of mandible (measured from the distal surface of the third molar to the tip of the incisor), ability to reproduce, and general physical appearance. Considerable difficulty was encountered in breeding the third generation of animals on Diet VI. Twenty-one days following birth, the young weighed an average of 18 grams. Since this weight was too small for weaning, the animals were left with their mothers for an additional 2 weeks to attain sufficient weight.

FINDINGS

The caries score and nutritional status were determined for each group of animals through successive generations. This information is summarized in Table IV.

TABLE IV
THE EFFECT OF VARIOUS DIETS ON CARIES SCORE AND NUTRITIONAL STATUS THROUGH SUCCESSIVE GENERATIONS

| TYPE OF DIET | NUMBER OF ANIMALS | GENERATION | CARIES SCORE | STANDARD ERROR OF THE MEAN | WEANING WEIGHT | NUTRITIONAL STATUS | | | REPEITION OF BLEEDING | LENGTH OF MANDIBLE | GENERAL APPEARANCE |
|--------------|-------------------|------------|--------------|----------------------------|----------------|---------------------|-----------------|-------------|-----------------------|--------------------|--------------------|
| | | | | | | AVERAGE WEEKLY GAIN | TEN-WEEK WEIGHT | WEEKLY GAIN | | | |
| I ABD | 13 | 1 | 13.6 | 3.88 | 56 | 20.2 | 228 | | * | 19.51 | |
| | 13 | 2 | 23.0 | 4.16 | 43 | 21.0 | 236 | 1 | | 19.13 | |
| | 13 | 3 | 23.2 | 2.64 | 35 | 17.5 | 204 | 2 | | | |
| II ABE | 13 | 1 | 11.8 | 2.76 | 53 | 18.0 | 201 | | * | 19.15 | |
| | 13 | 2 | 26.5 | 5.20 | 26 | 14.2 | 152 | | | 19.48 | |
| | 13 | 3 | 13.3 | 2.36 | 39 | 15.4 | 184 | | | | |
| III ABF | 13 | 1 | 7.0 | 1.42 | 54 | 18.0 | 202 | | * | | |
| | 13 | 2 | 8.6 | 1.51 | 37 | 15.6 | 153 | | | 19.37 | |
| | 13 | 3 | 14.1 | 2.66 | 27 | 11.8 | 147 | | | 19.51 | |
| IV ACD | 13 | 1 | 1.3 | 0.84 | 57 | 23.0 | 228 | | * | | Poor |
| | 13 | 2 | 16.3 | 3.54 | 34 | 19.0 | 199 | | | 19.23 | |
| | 13 | 3 | 28.8 | 5.65 | 30 | 18.0 | 216 | | | 19.97 | |
| V ACE | 13 | 1 | 2.33 | 0.98 | 58 | 20.0 | 215 | | * | | |
| | 13 | 2 | 13.8 | 2.53 | 31 | 15.6 | 160 | | | 18.62 | |
| | 13 | 3 | 10.5 | 1.76 | 39 | 16.8 | 195 | | | 19.27 | |
| VI ACF | 13 | 1 | 5.5 | 1.47 | 55 | 15.8 | 192 | | * | | |
| | 13 | 2 | 27.7 | 4.76 | 38 | 13.6 | 180 | 2 | | 18.90 | |
| | 13 | 3 | 37.5 | 3.58 | 18 | 11.0 | 151 | 3 | | 18.63 | |
| VII AB | 13 | 1 | 1.5 | 0.62 | 55 | 29.0 | 232 | | * | | |
| | 13 | 2 | 1.1 | 0.40 | 52 | 23.8 | 228 | | | 19.64 | |
| | 13 | 3 | 7.7 | 2.18 | 48 | 23.6 | 254 | | | 20.16 | |
| VIII AC | 13 | 1 | 0.23 | 0.16 | 56 | 26.2 | 255 | | * | | Good |
| | 13 | 2 | 1.2 | 0.55 | 38 | 21.6 | 204 | | | 19.39 | |
| | 13 | 3 | 2.8 | 0.99 | 45 | 21.6 | 236 | | | 19.79 | |
| IX SYN. | 13 | 1 | 6.3 | 2.86 | 55 | 26.4 | 245 | | * | | |
| | 13 | 2 | 4.2 | 1.02 | 49 | 30.2 | 260 | | | 19.89 | |
| | 13 | 3 | 10.5 | 2.68 | 64 | 25.2 | 256 | | | 19.96 | |

*First generation mandibles not available.

TABLE V
TABLE OF CARIES INDEX AND NUTRITIONAL INDEX AS DETERMINED FROM PHYSICAL FINDINGS

| GROUP | GENERATION | CARIES INDEX (C) | WEANING WEIGHT | AVERAGE WEEKLY GAIN | 10-WEEK WEIGHT | BREEDING | MANDIBLE LENGTH | GENERAL APPEARANCE | NUTRITIONAL INDEX (X) |
|-------|------------|------------------|----------------|---------------------|----------------|----------|-----------------|--------------------|-----------------------|
| I | 1 | 64.1 | 82.6 | 47.9 | 71.7 | 100 | * | 25 | 65.4 |
| | 2 | 38.9 | 54.3 | 52.1 | 69.9 | 67 | 57.9 | 25 | 54.3 |
| | 3 | 38.4 | 37.0 | 33.9 | 50.0 | 33 | 33.2 | 25 | 35.4 |
| II | 1 | 69.0 | 76.1 | 36.5 | 47.8 | 100 | * | 25 | 57.1 |
| | 2 | 29.5 | 17.4 | 16.7 | 4.4 | 100 | 34.4 | 25 | 33.0 |
| | 3 | 64.9 | 45.7 | 22.9 | 32.7 | 100 | 55.8 | 25 | 47.1 |
| III | 1 | 81.8 | 78.3 | 36.5 | 48.7 | 100 | * | 25 | 57.7 |
| | 2 | 77.5 | 43.3 | 24.0 | 5.3 | 100 | 48.7 | 25 | 40.7 |
| | 3 | 62.8 | 19.6 | 4.2 | 00.0 | 100 | 57.8 | 25 | 34.5 |
| IV | 1 | 97.1 | 84.8 | 62.5 | 71.7 | 100 | * | 25 | 68.8 |
| | 2 | 56.9 | 34.8 | 41.7 | 46.0 | 100 | 39.6 | 25 | 47.7 |
| | 3 | 23.3 | 26.1 | 36.5 | 61.1 | 100 | 22.7 | 25 | 45.3 |
| V | 1 | 94.4 | 87.0 | 46.9 | 60.2 | 100 | * | 25 | 63.8 |
| | 2 | 63.9 | 28.3 | 24.0 | 11.5 | 100 | 0.0 | 25 | 31.5 |
| | 3 | 72.4 | 45.7 | 30.2 | 42.5 | 100 | 42.2 | 25 | 47.6 |
| VI | 1 | 85.9 | 80.4 | 25.0 | 39.8 | 100 | * | 25 | 54.0 |
| | 2 | 26.3 | 43.5 | 13.5 | 29.2 | 33 | 18.2 | 25 | 27.0 |
| | 3 | 00.0 | 0.0 | 0.0 | 3.5 | 00 | 0.7 | 25 | 4.9 |
| VII | 1 | 96.9 | 80.4 | 93.8 | 75.2 | 100 | * | 75 | 84.9 |
| | 2 | 97.7 | 73.9 | 66.7 | 71.7 | 100 | 66.2 | 75 | 75.6 |
| | 3 | 80.0 | 65.2 | 65.6 | 94.7 | 100 | 100.0 | 75 | 83.5 |
| VIII | 1 | 100.0 | 82.6 | 79.6 | 95.6 | 100 | * | 75 | 86.6 |
| | 2 | 97.4 | 43.5 | 55.2 | 50.0 | 100 | 50.0 | 75 | 62.0 |
| | 3 | 93.1 | 58.7 | 55.2 | 78.8 | 100 | 76.0 | 75 | 73.9 |
| IX | 1 | 83.7 | 80.1 | 80.2 | 86.7 | 100 | * | 75 | 84.5 |
| | 2 | 89.3 | 67.4 | 100 | 100 | 100 | 82.5 | 75 | 87.5 |
| | 3 | 72.4 | 100 | 74.0 | 96.5 | 100 | 87.0 | 75 | 88.8 |
| Mean | | 68.8 | | | | | | | 57.1 |

*First Generation mandible measurement not available.

In order to evaluate the nutritional state and the incidence of caries, the various measurements used to define nutritional state were scored on a scale of 1 to 100. An average for the nutritional state of each group was determined. For purposes of convenience this has been called the "nutritional index." Similarly the caries score was rated in order to obtain what has been called the "caries index." These are presented in Table V.

As seen in Table VI the differences in length of mandibles in the third generation of animals are small. The mean length of mandibles of each group was statistically compared with the mean length of the group having the shortest mandibles, namely Group VI. As can be seen from Table VI the variations in mandibular lengths are highly significant.

TABLE VI
STATISTICAL ANALYSIS OF MANDIBLE MEASUREMENTS* OF THIRD GENERATION ON VARIOUS DIETS

| | | | <i>Significance</i> |
|-----------|---|----------|---------------------|
| Diet I | X = 19.13 σ = 0.6 SE = 0.172 | t = 2.31 | .04 |
| Diet II | X = 19.48 σ = 0.435 SE = 0.125 | t = 4.61 | .01 |
| Diet III | X = 11.51 σ = 0.624 SE = 0.208 | t = 3.53 | .01 |
| Diet IV | X = 18.97 σ = 0.787 SE = 0.227 | t = 1.21 | >.05 |
| Diet V | X = 19.27 σ = 0.485 SE = 0.140 | t = 3.33 | .01 |
| Diet VI | X = 18.63 σ = 0.469 SE = 0.132 | | |
| Diet VII | X = 20.16 σ = 0.538 SE = 0.156 | t = 7.50 | .001 |
| Diet VIII | X = 19.79 σ = 0.705 SE = 0.213 | t = 4.64 | .01 |
| Diet IX | X = 19.96 σ = 0.608 SE = 0.180 | t = 5.96 | .01 |

*Mean mandible length of respective groups compared with mean mandible length of group with shortest mandible, i.e., Diet VI.

DISCUSSION

A detailed analysis of the nutrient content of the various diets used in this study was presented. The long-term effect of these diets is of special significance since minor differences in nutrient content will tend to be either compensated for or magnified through successive generations. An attempt has

been made to compare these differences by means of the nutritional and caries indices. By formulating a caries index "C" and a nutritional index "N," regression lines were derived and the coefficient of correlation calculated for these indices (Fig. 1). The regression of "C" on "N" is 0.965. The coefficient of correlation is 0.78 ± 0.05 . If the nutritional index is known, the most probable

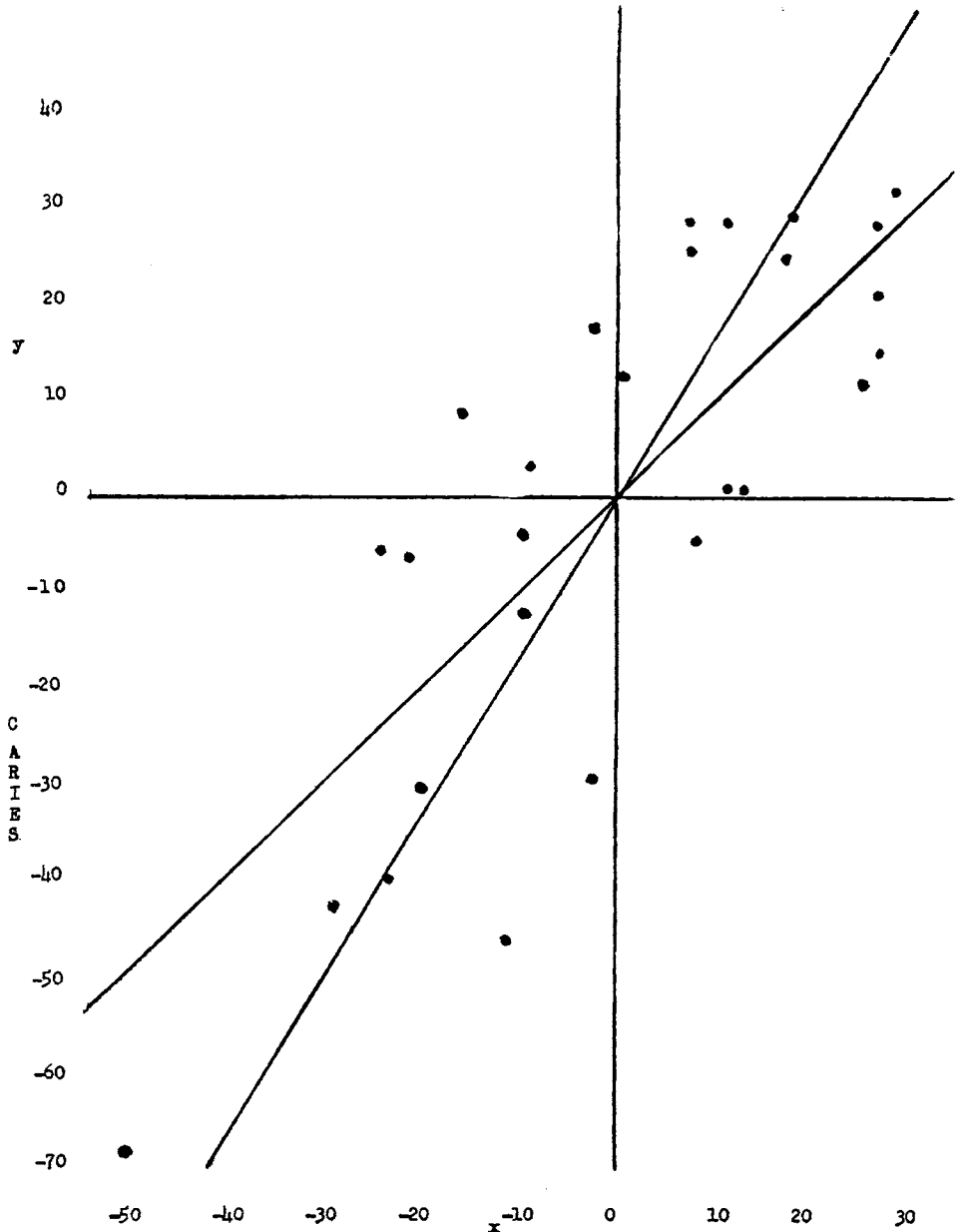


Fig. 1.

caries index may be calculated from the following formula:

$$\begin{aligned} I_c &= \text{Mean Caries Index} + \text{most probable deviation from the mean} \pm \\ &\quad \text{the probable error of the Index} \\ &= 68.8 - .965 (I_n - 57.1) \pm 11.5 \\ &= .965 I_n + 13.7 \pm 11.5. \end{aligned}$$

The statistical evidence indicates a high inverse correlation between general nutritive status and caries incidence.

The nutritional state of all animals at the beginning of the first generation was uniformly high. It was not until the beginning of the second generation that noticeable differences in weaning weights occurred. Groups I and VI did not reproduce as well as did the other groups.

In Groups I, III, IV, and VI there was a steady decline in general nutritional status in the second and third generations. This was most noticeable in Group VI. This physical deterioration was associated with a concomitant increase in caries.

The nutritional well-being of Groups II and V degenerated between the first to the second generation with a corresponding increase in caries. It would appear that these two groups adapted to their dietaries between the second and third generations with an improvement in their nutritional state associated with a decline in caries incidence.

The general physical well-being of Groups VII and VIII remained high and did not significantly vary during the 3 generations studied. Throughout this period, the caries incidence varied but little and remained low. In Group IX, where the standard cariogenic diet was employed for comparative purposes, a constant and relatively high state of nutrition was maintained through successive generations. Again this constancy in physical well-being was accompanied by only minor fluctuations in caries incidence.

CONCLUSION

A critical analysis of the data obtained from 3 generations of rats fed on 8 different combinations of human foods is presented. The nutritional status and physical well-being of all animals showed an inverse correlation with caries incidence. It would appear that with these diets, good nutritional status is associated with a low caries incidence while nutritional deterioration is accompanied by an increase in caries.

REFERENCES

1. Shibata, M.: On the Experimental Dental Caries of Molars of the White Rat, *Jap. J. Exper. Med.* 7: 247, 1929.
2. Hoppert, C. A., Webber, P. A., and Canniff, T. L.: The Production of Dental Caries in Rats Fed on Adequate Diet, *Science* 74: 77, 1931.
3. Shaw, J. H., Schweigert, B. S., McIntire, J. M., Elvehjem, C. A., and Phillips, P. H.: Dental Caries in Cotton Rat. I. Methods of Study and Preliminary Nutritional Experiments, *J. Nutrition* 28: 333, 1944.
4. McClure, F. J.: Observations on Induced Caries in Rats. V. Effects of Excessive Sugar in the Diet, *J. D. Res.* 24: 239, 1945.
5. Sognnaes, R. F.: Caries-conductive Effect of a Purified Diet When Fed to Rodents During Tooth Development, *J. A. D. A.* 37: 676, 1948.

6. Constant, M. A., Phillips, P. H., and Elvehjem, C. A.: The Effect of Whole Grain and Processed Cereals on Dental Caries Production, *J. Nutrition* 46: 271, 1952.
7. Zeppelin, M., Smith, J. K., Parsons, H. T., Phillips, P. H., and Elvehjem, C. A.: The Effect of Feeding a Natural Diet Comparable to Human Diet, *J. Nutrition* 40: 203, 1950.
8. McClure, F. J.: Dental Caries in Rats Fed a Diet Containing Processed Cereal Foods and a Low Content of Refined Sugar, *Science* 116: 229, 1952.
9. Callison, E. C., Orent-Keiles, E., and Makower, R. U.: The Effect of Some Combinations of Human Foods on the Growth and Health of the Laboratory Rat, *J. Nutrition* 43: 131, 1951.
10. Hardinge, M. G., and Stare, F. J.: Nutritional Studies of Vegetarians, *Am. J. Clin. Nutrition* 2: 73, 1954.
11. U. S. Bureau of Agricultural Economics, 1949. Consumption of Food in the United States, 1909-1948, U. S. Dept. of Agriculture Misc. Publication 691.
12. Register, U. D.: Effect of Vitamin B₁₂ on Liver and Blood Non-protein Sulfhydryl Compounds, *J. Biol. Chem.* 206: 705, 1954.