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FOREWORD

Concerning Supplements to

The Journal of Nutrition

To meet the need for publication of meritorious but unusually long manuscripts the Journal of Nutrition instituted in April 1954 the policy of publishing such papers in the form of supplements to regular issues. The authors provide the full cost of such publication. For a more complete statement regarding this policy see volume 52, Supplement 1, April, 1954.

George R. Cowgill, *Editor*

TRYPTOPHAN-NIACIN RELATIONSHIPS IN MAN

STUDIES WITH DIETS DEFICIENT IN RIBOFLAVIN AND NIACIN, TOGETHER WITH OBSERVATIONS ON THE EXCRETION OF NITROGEN AND NIACIN METABOLITES

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STUDIES WITH DIETS DEFICIENT IN RIBOFLAVIN AND NIACIN, TOGETHER WITH OBSERVATIONS ON THE EXCRETION OF NITROGEN AND NIACIN METABOLITES [1]

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Although the prevalence of pellagra in areas where maize formed a considerable portion of the diet had been observed for several centuries, it is only in recent years that it has been possible to attempt to define the relative roles of niacin (Smith, '42), riboflavin (Sebrell and Butler, '38; Horwitt et al., '49b; Hills et al., '51) and tryptophan (Krehl et al., '46; Elvehjem, '48 and Goldsmith et al., '52) in the etiology of this disease. From these studies it would appear that the association of corn products with pellagra is more a function of the low tryptophan content of corn than of any "toxin" (Woolley, '46). The possibility remains that some links in this puzzle may still be missing.

[1] This project was supported by grants from the National Vitamin Foundation, Inc., and was sponsored by the Committee on Vitamin Studies at Elgin State Hospital, Food and Nutrition Board, National Research Council. During the period of this study, the committee was constituted as follows: Dr. Russell M. Wilder, chairman; Dr. O. A. Bessey, Dr. E. S. G. Barron, Dr. R. S. Goodhart, Dr. M. K. Horwitt, Dr. A. C. Ivy, Dr. R. M. Kark, Mr. Park Livingston, Dr. Erich Liebert, Dr. A. A. Lieberman, Dr. D. L. Steinberg and Dr. Phyllis Wittman.

[2] U. S. Public Health Service Fellow, 1950–51. Now at Mayo Clinic, Rochester, Minn. Dr. H. H. Hiatt was a U. S. Public Health Service Fellow on this project from June, 1951 to March, 1952, during which period he made important contributions.

This report will describe that part of Elgin National Research Council Project no. 3 which dealt with attempts to evaluate man's need for niacin and tryptophan in diets low in corn products and both adequate and deficient in riboflavin. In order to decrease the level of tryptophan in the basal diets without using large amounts of corn meal, it was necessary to keep the protein intake at a low level. As a consequence of either this low protein level or of some other factor, changes in liver functions were observed after 5 months. These observations of liver dysfunction in man, produced and ameliorated by varying protein intake (Horwitt, '53; Horwitt, Rothwell and Kark, '53; Kark et al., '53) and the associated alterations in carbohydrate metabolism, will be discussed elsewhere, as these effects had no apparent direct relationship to niacin requirements although the implications of liver dysfunction did necessitate alterations in the original plan of the project. Though the liver dysfunction might possibly influence the rate at which the metabolites studied appeared in the urine in a short-term sample, such effects could not be noted in the 24- or 72-hour urine samples studied. Therefore, the data reported in this paper are considered to be similar to those which might be obtained from healthy subjects.

METHODS OF STUDY

As in previous long-term nutritional studies at Elgin (Horwitt et al., '48), the selection of subjects was made after evaluating the physical and mental qualities of a large number of mental patients. Choice was based upon chronicity of mental illness, adequacy of physical condition, and the presence of a reasonable amount of emotional stability. After a three-month trial period during which attitudes, cooperativeness and appetite habits were observed, 40 male subjects were divided into 5 experimental groups. The subjects were relatively young. All but one were 30 years or over, 8 were over 45 years and only three were over 60 years at the start of the study.

Diets, dietary supplements and division of subjects

The organization of the diet kitchen and the techniques used to control the dietary intake were similar to those previously described (Horwitt et al., '49c). The three basal diets used are given in table 1. Three different sets of recipes were available so that, in effect, 9 different daily menus were rotated in an effort to provide some variety. A sample of the diet was homogenized and analyzed daily for nitrogen. Other constituents were determined at frequent intervals. The basal diets provided approximately 2300 Cal., 6.5 gm of protein nitrogen, 86 gm of fat, 5.8 mg of niacin, 265 mg of tryptophan and 415 µg of riboflavin.

As the quality of the protein in the diet may be of greater significance than the amount, it is pertinent to point out that the average amounts from wheat flour, zein [4] and gelatin used in the three basic diets were 15.1, 6.0 and 3.9 gm per day, respectively. It should also be noted that, since these diets contained approximately 41 gm of protein (6.59 gm of protein nitrogen) per day, they provided about 15 gm less protein than the diets of the previous Elgin studies. The 6.0 gm of zein and the 3.9 gm of gelatin were included as part of the total allotment in order to decrease further the tryptophan content of the diet. All of the above-mentioned data were calculated on the basis of 100% consumption of the diet. Actually, two subjects were allotted 90%, 21 subjects received 100%, three subjects received 110% and 5 subjects received 120% of all the ingredients of the basal diet in accordance with their appetite, size and personal preference as determined during the preliminary period. During the experimental period the percentage of the allotted food not consumed by any subject was negligible (less than 2%).

All subjects on the controlled diets received a daily vitamin supplement which contained 30 mg of ascorbic acid,

[3] Feeding of the basal diet began November 6, 1950.

[4] Miss Alice Hay, who served as dietitian during the early stages of this work, demonstrated considerable ingenuity in devising tea rolls and doughnuts which combined zein and flour in proportions that were palatable.

TABLE 1

Constituents of daily diets used in Elgin project no. 3

FOOD	SOURCE	WT.	DIET 1				DIET 2				DIET 3			
			Protein	Tryptophan	Niacin	Riboflavin	Protein	Tryptophan	Niacin	Riboflavin	Protein	Tryptophan	Niacin	Riboflavin
		gm	gm	mg	μg	μg	gm	mg	μg	μg	gm	mg	μg	μg
Salt pork	Purchased	25	1.0	12	225	10	1.0	12	225	10	1.0	12	225	10
Farina [1]	Special	30	3.3	36	240	18								
Cornflakes [1]	Special	30					2.4	12	480	30	2.4	12	480	30
Pears	Home canned	100	0.2	2	100	20								
Pears	Home canned	50									0.1	1	50	10
Applesauce	Dried apples	100	0.4		200	20	0.4		200	20	0.4		200	20
Bread [2]	Special	120	8.6	70	1080	131	8.6	70	1080	131	8.6	70	1080	131
Margarine	A.P.	40	0.2				0.2				0.2			
Jelly	Homemade	60	0.1		120	12	0.1		120	12	0.1		120	12
Beef	Round [3]	25	4.9	69	1175	42	4.9	69	1175	42	4.9	69	1175	42
Potatoes	Varied	100	2.0	16	1200	40					2.0	16	1200	40
Spaghetti [4]	A.P.	50					6.4	51	1000	30				
Rice	Boiled	30	2.3	24	480	9	2.3	24	480	9	2.3	24	480	9
Cookies	Special	67	2.6	24	209	12								
Cabbage	Varied	50					0.7	7	150	25				
Sauerkraut	Homemade	50									0.6	6	50	30
Pudding	Vanilla	100					0.1							
Cream, 40%	A.P.	25	0.6	5	25	28	0.6	5	25	28	0.6	5	25	28
Sugar [5]														
Cake	Special	75									3.2	26	266	15
Tomatoes	Home canned	50	0.5	5	350	15	0.5	5	350	15				
Jello	34%	34	3.9				3.9				3.9			
Zein crackers	Special	55	9.9	33	270	15								
Zein rolls	Special	46					7.8	20	151	8				
Zein doughnuts	Special	106									9.6	38	341	19
Rhubarb	Home canned	100					0.4	4	100					
Dill pickles	Canned	25									0.2	2		15
Total (calculated) [6]			40.5	296	5674	372	40.3	290	5536	361	40.1	281	5692	411
Total (as analyzed)			40.6 [7]	274	5790	413	40.0	251	5570	422	41.1	268	5910	408
			± 2.5	± 20	± 630	± 37	± 2.8	± 8	± 360	± 35	± 2.2	± 17	± 310	± 34

[1] Prepared on special order by Quaker Oats Company.
[2] Baked from unenriched flour.
[3] Diets 1 and 3: round roast; diet 2: round ground.
[4] Unenriched, as purchased.
[5] Diets 1 and 2: 20 gm; diet 3: 10 gm.
[6] Agricultural Handbook no. 8.
[7] Grams nitrogen multiplied by 6.25.

0.6 mg of thiamine, 1.0 mg of pyridoxine, 3.0 mg of calcium pantothenate, 0.001 mg of vitamin B_{12}, 0.1 mg of folic acid, 0.05 mg of biotin, 4000 I.U. of vitamin A and 400 I.U. of vitamin D.[5] In addition, tricalcium phosphate, 0.5 gm, and ferrous sulfate, 0.25 gm were given three times a week.

At the end of the three-month preliminary period, during which time base line data were accumulated, an attempt was made to distribute the 40 subjects uniformly with respect to age, weight, and psychological state, into the following 5 groups:

1. U group (unsupplemented). Eight subjects received the basal diet (one 90%, 6 100%, and one 120%) plus 0.1 mg of riboflavin per day; this small addition of riboflavin raised the intake of this vitamin to the level used in Elgin Project no. 2 (Horwitt et al., '49c). (After 38 weeks, in order to repair the ariboflavinosis which had developed, this group was supplemented with additional riboflavin, so that in effect, this group was thereafter equated with the "R" group.)
2. R group (riboflavin supplemented). Eight subjects received the basal diet (five 100%, two 110% and one 120%) plus 2 mg of riboflavin, daily.
3. NR group (niacinamide and riboflavin supplemented). Seven subjects received the basal diet (four 100% and three 120%) plus 2 mg of riboflavin and 10 mg of niacinamide, daily.
4. TR group (tryptophan and riboflavin supplemented). Eight subjects received the basal diet (one 90%, 6 100% and one 110%) plus 2 mg of riboflavin and 50 mg of L-tryptophan daily. The tryptophan supplement was doubled to 100 mg after 10 weeks.
5. HD group (Hospital diet). Nine subjects partook of the general hospital diet ad libitum, and were simultaneously subjected to the various procedures applied to the patients on the experimental diet. As a precaution they received a commercial vitamin mixture[6] three times a week which provided ap-

[5] This special formula prepared by Hoffmann-La Roche Inc., through the courtesy of Dr. E. L. Sevringhaus and Dr. M. D. Schiffrin.

[6] Vi-Penta capsules.

proximately 4 mg of niacinamide per day beyond that in the regular diet. The vitamin supplementation for this group was discontinued at the 38th week.

In former Elgin projects, it was relatively simple to maintain a given research plan similar to the one described above. In the present study only the first 37 weeks might be considered to have proceeded according to plan. The problem of liver dysfunction which developed after 5 months on the low-protein diet and the relative urgency of obtaining data which might be related to kwashiorkor made it expedient to alter the original goal somewhat in the hope that liver dysfunction might be proved and repaired without vitiating later interpretation of the data on niacin requirements. The following changes in the dietary supplements were made during the course of the experiment:

22nd to 38th week: An additional 0.5 mg of thiamine was given to half of the subjects in the U, R, NR and TR groups. Above average increases in blood lactic and pyruvic acids had been obtained after glucose ingestion and, although previous experience had indicated that the level of thiamine provided (approximately 0.9 mg per day) was not responsible for this metabolic change and that it was probably a manifestation of liver dysfunction, it was considered wise to supplement half the experimental subjects with thiamine for about 4 months in order to eliminate any doubt on this point. Further addition of 5 mg of thiamine, twice daily, was later tested on three subjects who had a marked disturbance of lactate and pyruvate metabolism (61st to 65th week) but increases in blood lactic and pyruvic acids were not reversed until after 30 gm of lactalbumin was given as a supplement, or a diet high in protein foods was fed.

39th to 61st weeks: lactalbumin, 10 gm daily, was administered to one-third of the subjects in the U, R, NR and TR groups, hereafter called subgroup I.

39th to 52nd weeks: L-lysine, 500 mg twice daily, was administered to another one-third of subjects, hereafter called subgroup II; DL-methionine, 165 mg twice daily, administered to final third of subiects, hereafter called subgroup III.

52nd to 61st week: zein in basal diet of subgroup II was replaced by equivalent amount of lactalbumin, 7 gm daily, to check possible "toxic effect" of zein.

52nd to 61st weeks: choline dihydrogen citrate, 0.65 gm twice daily, was given to subjects in subgroup III to replace methionine.

52nd week: two subjects, one from TR and one from NR group, each with high bromsulfalein retention, were placed on the HD diet with added animal protein. Decrease in BSP retention level obtained (Horwitt, '53).

61st to 88th week: lactalbumin, 30 mg daily was administered to all remaining subjects (18) from U, R, NR and TR groups who had given evidence suggestive of hepatic dysfunction or of impaired lactic and pyruvic acid metabolism.

61st to 89th week: folic acid, calcium pantothenate, pyridoxine and vitamin B_{12} were removed from the vitamin supplements of the 6 subjects with no apparent aberration of either liver function or of lactic acid and pyruvic acid metabolism. This step was taken in an effort to determine whether these vitamins were preventing or delaying the development of a pellagra syndrome.

88th week: all subjects were placed on extra meat plus regular hospital diet similar to that which had been given to the original 9 subjects in the HD group.

Although most of the subjects were maintained in the experimental unit for the duration of the study, the following separations from the original groups did occur:

Subject U3, 42nd week, was transferred to HD group following appendectomy for acute appendicitis with perforation.

Subject TR5, 66th week, was placed on high-protein, low-calorie diet because of increasing obesity and high glucose tolerance curve. As a consequence of psychotic behavior, subjects U2 and U4 were transferred from their experimental diet to the hospital diet in 69th week. Subjects U8, R1 and TR2 were discharged from unit in 69th, 69th and 38th week, respectively, for unrelated clinical reasons.

The above separations are not considered to be directly related to the experimental procedures but are more a function of normal turnover. The fact that several of the separations came from the "U" group is probably not significant, as their behavior was consistent with their pre-experimental records. There was some question about the accuracy of the food intake of subject R7-110. Consequently, data from this individual have been omitted from the final tabulations.

Tests employed

Some of the procedures used were:

Nitrogen. A complete day's diet (100%) was acidified with acetic acid and homogenized. Samples of the homogenate were analyzed for nitrogen by a modification of the semi-micro method of Redemann ('39). Aliquots of the same homogenate were used for the other dietary assays listed below. The analyses of nitrogen in the urine were made on 72-hour collections. These three-day samples were acidified, cooled or frozen, depending upon when they were to be analyzed and used for all the urine analyses listed.

Fat in the diet. This was estimated by extraction with a 3 to 1 alcohol-ether mixture. The portion of the dried extract soluble in petroleum ether was considered "fat."

Riboflavin. The riboflavin in the diet and in an acidified aliquot of the 72-hour urine sample was analyzed by the microbiological technique of Roberts and Snell ('46). Riboflavin in the red blood cells and plasma was determined by the method of Burch et al. ('48) and will be discussed in a separate communication.

Nicotinic acid. The microbiological method used was similar to the U.S.P. modification of the method of Snell and Wright ('41). Because of the high fat content of the diet it was necessary first to extract most of the lipids with an alcohol-ether mixture.

Quinolinic acid. The method of Henderson ('49) (decarboxylation with glacial acetic acid) was used to treat the urine in order to convert quinolinic acid to nicotinic acid. The total niacin was then determined by the method described above and the quinolinic acid estimated as the difference between the free nicotinic acid in the urine and the total obtained after decarboxylation.

N^1-Methylnicotinamide (N^1-Me). Urinary N^1-Me was determined by the method described by Carpenter and Kodicek ('50)

Xanthurenic acid. The amount in urine was estimated by the technique of Porter et al. ('47, '48).

6-Pyridone of N^1-methylnicotinamide (6-pyr). The amounts in urine were estimated by the methods of Holman and de Lange ('49) and Rosen et al. ('49).

Tryptophan. Diets were dried and defatted. Samples for tryptophan assay were hydrolyzed enzymatically by the method of Greenhut et al. ('46). The amounts of tryptophan in the diets and urine were determined by using the microbiological assay method of Greene and Black ('44), using *L. arabinosus.* Some of the urine samples were also assayed using *S. faecalis* and the medium of Henderson and Snell ('48).

Lysine. Defatted diet samples were analyzed for lysine by the microbiological method of Steele et al. ('49). A similar technique was used for estimation of lysine in the urine. Current chromatographic techniques were also employed as qualitative confirmations.

Creatinine. The amount in urine was estimated by the technique of Bonsnes and Taussky ('45).

Glucose, pyruvic acid and lactic acid in blood. The methods used for the estimation of these compounds and the technique of combining a glucose tolerance test with the simultaneous administration of mild exercise have been described by Horwitt and Kreisler ('49)

Bromsulfalein retention time. The percentage of bromsulfalein remaining 45 minutes after injection of 5 mg per kilo was determined photometrically.[7]

Eosinophils. The extent of eosinopenia produced by adrenocorticotropic hormone (ACTH) was determined by taking an eosinophil count on venous blood before and 4 hours following intramuscular injections of 25 mg of ACTH according to the method of Thorn et al. ('48). Results reported by Hiatt et al. ('52).

Packed cell volume, albumin/globulin ratios, hemoglobin, erythrocyte counts, differential counts, gastric hydrochloric acid, serum cholesterol, N.P.N. and urinary sediments. Determined quantitatively by standard techniques described in Hepler ('49).

Urine was analyzed qualitatively for pathological constituents, such as hemoglobin, albumin and glucose.

The *clinical tests* used included frequent examinations of the skin, oral cavity, cardiovascular system, metabolic rate blood pressure, pulse rate, and gastrointestinal and liver functions. An attempt was made to evaluate the effects of ultraviolet and infra-red light exposure. The latter experiments were motivated by the findings of Smith and Ruffin ('37) that typical dermatitis could be produced in a pellagrın by exposure to heat as well as sunlight. The subjects were weighed before bedtime every Saturday and more often when a weight change was suspected.

OBSERVATIONS

No change in mental status was observed beyond the variations which might be anticipated in two years (preliminary plus experimental periods) in a group of patients with dementia praecox. There was no apparent diminution in appetite or change in bowel function (patients' complaints were practically non-existent). During the 35th week a subject in the "U" group (riboflavin- and niacin-deficient) with a rather

[7] These were read by Miss D. Rix in Dr. R. M. Kark's laboratory at the University of Illinois in order to facilitate comparison with other liver function tests being conducted simultaneously.

marked erythema of the oral mucus membranes complained casually of a "soreness of the mouth." No other subjective complaints could be evoked even from those subjects of the "U" group who had marked oral pathology or scrotal dermatitis. A few of the subjects had mild upper respiratory infections from which they recovered without apparent sequelae.

Ariboflavinosis

The striking changes noted in the subjects on the low-riboflavin regimen completely confirmed those noted in the previous study (Horwitt et al., '49b) during which the diet provided an equivalent amount of riboflavin (0.55 mg per day), more protein (57 gm), a supplement of 10 mg of niacinamide per day, but did not provide a vitamin B_{12} supplement. Of the 8 subjects in the "U" group, 4 developed diffuse erythema of the buccal and palatal mucosa and a "beefy" redness (but no magenta color) of the tongue with little or no papillary atrophy, within 27 to 36 weeks after the institution of the experimental diet. There were 16 instances of angular stomatitis in 6 or these subjects. Thirteen of these lesions appeared before supplementation with riboflavin, 8 disappeared before supplementation. The average duration of the fissures which disappeared spontaneously was 4 weeks, while those that did not disappear until after supplementation (2 mg per day) persisted for an average of 7 weeks. In groups "R," "NR" and "TR," comprising 23 subjects (i.e., those supplemented with riboflavin) 7 fissures were seen in 4 subjects. These were considerably less severe than the lesions seen in the subjects of the "U" group and lasted an average of three and one-half weeks.

The other lesion noted with frequency in the subjects of the "U" group was scrotal dermatitis. Erythema and scaling of the scrotum, sparing the medium raphe, were observed in 5 of the 8 subjects. The dermatitis lasted from one to 6 weeks, did not regress spontaneously, but did disappear within from one to 5 weeks following supplementation with riboflavin. Table 2 lists the subjects of the "U" group with the relative degree of involvement noted before riboflavin (2 mg per day) was added to their regimen. Analyses of riboflavin in the urine which produced data which compared well with those previously reported (Horwitt et al., '49a) will be discussed in a subsequent publication. It is significant that although the present diet differed from that in the previous study in that vitamin B_{12} was provided as a supplement and niacin was quite low, there were no noticeable differences in either the development or the repair of ariboflavinosis.

TABLE 2

Relative pathology of subjects on riboflavin depleted diet

SUBJECT	ORAL CHANGES (Angular stomatitis, glossitis, mucosal erythema)	SCROTAL DERMATITIS	CONJUNCTIVITIS AND SEBORRHEA
U1 (100) [1]	+	+	0
U2 (100)	0	0	0
U3 (90)	+++	++	0
U4 (100)	±	0	0
U5 (100)	++++	++++	++++
U6 (100)	+++	+++	+++
U7 (120)	0	0	0
U8 (100)	+++	++	0

[1] Figures within parentheses indicate the percentage of food allotted.

A patient with the most severe scrotal dermatitis and penile involvement requires special comment. At the time supplementation was begun he showed unilateral angular stomatitis diffuse erythema involving the tongue and buccal mucosa, retroaural seborrhea, and moderately severe scrotal dermatitis. During the first week after the daily supplementation with 2 mg of riboflavin there suddenly appeared severe blepharitis and conjunctivitis with photophobia, seborrhea and cracking of the skin in the nasolabial folds, marked bilateral angular stomatitis and cheilosis, and the severe penile and scrotal dermatitis described above. These lesions gradually cleared during the next 4 weeks leaving no apparent residue. Another patient with very marked scrotal dermatitis also had seborrhea and conjunctivitis, but to a less severe degree.

Clinical changes not associated with riboflavin deficiency

Physical changes other than those attributed to riboflavin deficiency were not peculiar to any of the groups. No cutaneous lesions resembling those typical of pellagra were seen. Changes in skin sensitivity to single ultra-violet light exposure were not observed. The fore-arms of several of the subjects were exposed to infra-red light and although small third-degree burns were inadvertently produced in three subjects, no resultant adjacent dermatitis occurred.

Nine subjects showed slight to moderate degrees of redness of the anterior portion of the tip of the tongue, with very slight or no papillary atrophy. These included 4 in the "R" group, three in the "NR," one in the "TR" and one member of the "HD" group.

There was little significant variation in blood pressure, heart size, or electrocardiographic tracings. No significant changes were noted in serum cholesterol, N.P.N., gastric hydrochloric acid, urinary sediment or the hematopoietic system. Results on changes in blood lactic and pyruvic acid will be reported elsewhere.

Urinary excretion of nitrogen

The analyses of 596 daily samples of the three basal diets used indicated that they averaged 6.53, 6.39 and 6.58 gm of nitrogen per day, respectively, at the 100% feeding level (table 1). Five of the subjects, U7, R6, TR4, TR6 and TR7, received 120% of this basic level, two, R7 and R8, received 110% and TR8 was allotted 90% of the basal level eaten by the 23 remaining subjects on the controlled dietary intake. At the start of the experiment, the average daily nitrogen excretion for all groups was between 10 and 12 gm of nitrogen (fig. 1). The subjects are not divided into experimental groups in this figure inasmuch as variations in riboflavin, niacin or tryptophan, at the levels studied, had no apparent effect on the amounts of nitrogen excreted. The urinary nitrogen did not reach minimum levels until after the experimental diet had been fed for more than three months. Thus, after two weeks on the experimental diet, the average excretion of nitrogen in the urine was 6.18 gm for the 100% group, which ate

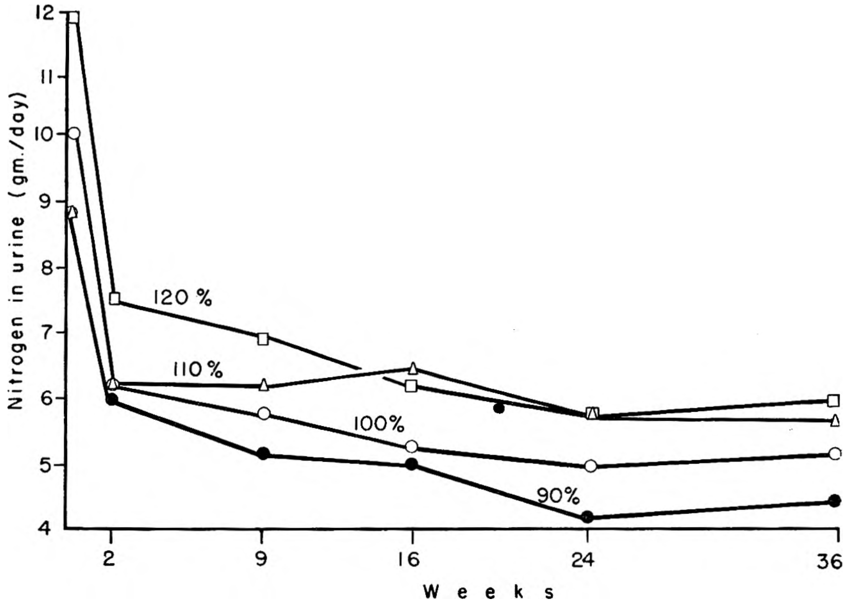

Fig. 1 Average urinary nitrogen excretions at 4 levels of nitrogen intake during first 36 weeks of controlled feeding; the 90, 100, 110 and 120% diets provided average of 5.85, 6.50, 7.15 and 7.80 gm nitrogen per day, respectively.

6.5 gm of nitrogen per day, and 7.54 gm for the 120% group which ate 7.8 gm of nitrogen per day. (The 110 and 90% groups gave parallel data but they represented only two subjects on each intake.) If one assumes that about 1 gm of nitrogen [8] was excreted in the feces, daily, then all these sub-

[8] Such an estimation of fecal nitrogen which is unacceptable in short-term nitrogen balance studies might be considered tolerable under the long-term plan of this experiment. The extra effort and expense that would have been involved in the collection of feces from 40 subjects would have made it impossible to conduct other phases of this project that appeared to show greater promise of producing significant data. Maximum variations in fecal nitrogen that might be expected in men repeating the same diet for many months do not appear to be large enough to have an important effect on the trends observed.

jects were in negative balance on their respective diets at two weeks. This "negative nitrogen balance" continued for at least another 5 weeks with gradual improvement at a rate equivalent to about 0.01 gm of nitrogen per day. Note that this small change per day is difficult to measure and that a short-term metabolic study would have given results indicating that a steady state had been reached, when in fact this slight change, so insignificant in comparing two successive daily analyses, could continue for weeks, to show a sizeable difference for the longer period. At 109 days, the 21 subjects who received 6.5 gm nitrogen per day (100% diet) had an average urinary excretion of 5.20 mg which might be considered a plateau level. Four subjects who were continued on this basal diet for a much longer time had average daily urinary nitrogen excretions of 5.19, 5.08 and 5.07 gm at 319, 410 and 525 days, respectively (not shown in fig. 1).

In interpreting these data, one should note that body weight changes were relatively small during the entire experiment, that the activity of the subjects did not change from pre-experimental patterns and that the data are uncomplicated by effects of bed-rest (Dietrick et al., '48). Thus the average subject on controlled diets weighed 63 kg at the start of the experiment and 62 kg 250 days later. Tests were made for the presence of edema but increases in body water were not proved. For the following 12 months the picture was complicated, in many of the subjects, by the use of amino acid, choline and protein supplements which were supplied in an effort to determine the factor (or factors) responsible for the liver dysfunctions observed. Table 3 lists the nitrogen excretion of 6 individuals on the 100% diet who were given 10 gm of lactalbumin midway in the experiment. In two analyses made during the ad libitum feeding preliminary period at 81 and 13 days before the start of the experimental diet, a definite relationship was established between these subjects which seems to have been maintained during the later experimental and supplementation periods. One must assume that some of the later differences were due to the individual

TABLE 3

Urinary nitrogen, in grams per day, excreted by those subjects on 100% dietary intake who were supplemented with 10 gm of lactalbumin before being given 30 gm of lactalbumin

WEEKS	PRELIMINARY PERIOD		BASAL DIETS [1]					BASAL DIETS PLUS 10 GM LACTALBUMIN [2] STARTED AT 38TH WEEK		BASAL DIETS PLUS 30 GM LACTALBUMIN [3] STARTED AT 61ST WEEK	
	−12	−2	2	9	16	24	36	46	59	75	85
Subject	*gm*	*gm*	*gm*	*gm*	*gm*	*gm*	*gm*	*gm*	*gm*	*gm*	*gm*
U 4	9.3	10.0	6.2	5.5	5.7	5.3	5.0	6.0	6.5	10.4	7.7
R 2	7.5	8.1	5.3	5.8	5.4	5.6	5.5	5.8	6.6	9.0	7.8
R 5	4.6	5.2	4.6	4.6	3.7	3.6	3.6	4.5	5.4	6.2	6.8
NR 3	8.8	8.3	5.7	5.2	4.9	4.8	4.2	4.6	5.1	7.8	8.3
TR 3	12.9	11.8	5.9	5.8	5.0	4.8	4.5	5.0	..[4]		
TR 6	19.0	12.4	6.9	6.3	5.7	5.6	5.7	6.5	6.3	9.4	9.0
Average	8.9	9.3	5 8	5.5	5.1	5.0	4.8	5.4	6.0	8.6	7.9

[1] Basal diet provided an average of 6.5 gm of nitrogen.
[2] The 10 gm of lactalbumin provided 1.26 gm of nitrogen.
[3] The daily supplement of 30 gm of lactalbumin was difficult to ingest and these data are probably low.
[4] Subject TR 3 transferred to hospital diet in 52nd week.

variations in fecal nitrogen, but one cannot be certain without complete knowledge of the nitrogen-intake pattern which each subject had maintained during previous years. The length of time it may take to establish such a pattern is not generally appreciated. In the experience of the Elgin investigators, one does not achieve a steady state of urinary nitrogen excretion until at least three months after a major decrease has been made in the level of protein intake; this time factor being dependont on previous levels of protein intake. This fact is not too well appreciated by some investigators who employ short-term nitrogen balance techniques where small changes in nitrogen excretion on successive days are difficult to evaluate. The data in table 3 show that it took approximately 24 weeks to achieve relatively stable urinary nitrogen excretion after the start of the regimen which provided approximately 6 5 gm of nitrogen. Subject R5, who had the lowest excretion during the preliminary period, excreted the least nitrogen at later intervals. In the 46th week, which was 7 weeks after the supplementation with 10 gm of lactalbumin had begun, the nitrogen excretions were considerably lower than on the 19th week of such supplementation (59th week) indicating that even with this relatively small supplement more than 7 weeks were required to achieve a steady state of nitrogen excretion.

Urinary excretion of N¹-methylnicotinamide before lysine, methionine or lactalbumin supplementation

Before the subjects started eating the experimental diet, the group averages for urinary excretion of N^1-Me for subjects on 100% intake fell within the limits of 3.64 mg (R-100) and 4.80 mg (U-100) per day. Figure 2 shows the variations in the averages during the first 36 weeks. Data for later intervals are included in table 4. After 9 weeks on the experimental diet, the excretions of the U-100, R-100 and TR-100 groups had dropped to average values of 1.46, 0.96 and 2.42 mg, respectively, while the NR-100 group (which was supple-

TABLE 4

Urinary excretion of N¹-methylnicotinamide (mg/day)

(U, R, NR, TR and HD refer to original classification of subject as being in the unsupplemented, riboflavin, niacin plus riboflavin, tryptophan plus riboflavin or hospital diet groups, respectively. Data are subgrouped according to percentage of food allotted and similarity of supplementation in 46th week.)

SUBJECT		PRELIMINARY PERIOD	TIME IN WEEKS									
No.	Body wt.		2	9	16	24	36	46 [1]	59	75	84	95 [2]
	kg	*mg/day*	*mg/day*	*mg/day*	*mg/day*	*mg/day*	*mg/day*	*mg/day*	*mg/day*	*mg/day*	*mg/day*	*mg/day*
U2-100	61	4.04	2.49	1.53	2.00	1.37	1.07	0.69 [3]	(0.49) [4]	4.76 [5]	5.57	8.01
U5-100	53	3.76	4.26	0.96	1.20	0.85	1.00	0.64 [3]	1.05 [4]	0.66 [6]	0.69	4.28
U6-100	55	3.66	1.69	1.19	1.29	1.42	0.56	0.49 [7]	0.96 [8]	1.12 [6]	0.91	3.72
U-8-100	59	6.30	5.90	1.56	1.53	0.77	0.86	0.98 [3]	1.29 [4]	. . . [9]	. . .	. . .
U3-90	63	5.39	1.63	2.06	1.10	1.96	1.28	6.06 [10]	3.25 [11]	6.24 [12]	6.50	9.14
U1-100	69	7.63	2.47	2.37	2.10	1.42	1.49	1.81 [13]	2.61	3.14 [14]	3.33	7.03
U4-100	63	3.42	2.23	1.16	1.10	1.25	0.60	2.04 [12]	2.33	5.01 [5]	2.96	3.00
U7-120	65	5.49	3.61	1.68	2.03	2.67	1.63	1.61 [13]	2.13	3.87 [15]	4.79	4.84
R1-100	61	3.41	2.54	1.18	1.33	0.96	0.47	0.38 [7]	0.63 [8]	. . . [9]	. . .	. . .
R3-100	59	3.15	1.84	1.28	1.39	1.11	1.40	0.87 [3]	1.23 [4]	1.38 [6]	1.34	8.43
R4-100	58	3.44	2.09	0.59	1.07	0.88	0.87	0.82 [7]	0.59 [8]	0.98 [6]	0.81	3.86
R6-120	71	5.69	3.22	2.54	1.75	1.76	1.17	0.77 [3]	0.75 [4]	1.87 [14]	2.11	3.08
R2-100	64	2.58	1.55	0.72	0.61	(0.26) [16]	(1.04) [16]	0.61 [13]	0.72	3.00 [14]	1.93	8.15
R5-100	65	. . .	2.59	1.04	0.96	0.80	0.92	(0.55) [17]	1.09	1.47 [14]	1.91	2.40
R8-110	55	5.16	2.37	1.60	1.21	0.75	1.05	1.92 [13]	1.42	1.45 [6]	1.20	5.18
NR1-100	73	4.69	6.37	5.89	5.36	5.27	0.12	3.22 [7]	2.79 [8]	5.47 [14]	5.53	6.02
NR2-100	62	4.87	6.91	4.99	6.90	4.25	4.00	4.03 [3]	4.27 [11]	9.65	7.03	8.45
NR5-100	61	3.87	3.36	4.11	3.22	2.81	3.38	2.68	2.55 [8]	2.36 [6]	3.57	5.93
NR4-120	69	5.05	6.78	5.47	5.15	3.32	4.04	4.72 [3]	5.47 [4]	6.98 [15]	5.98	5.62
NR7-120	77	. . .	4.78	3.08	4.83	4.76	3.16	3.57 [3]	6.23 [4]	5.76 [14]	4.44	5.06
NR3-100	58	3.44	6.24	6.56	5.09	4.55	3.52	5.43 [13]	5.34	7.23 [14]	6.47	8.48
NR6-120	63	4.53	3.88	4.78	5.10	2.95	5.44	6.30 [13]	3.39	5.53 [14]	5.30	6.38

TR1-100	58	2.25	1.47	1.79	1.57	0.96	1.12	1.06 [1]	0.72 [5]	2.20		
TR4-100	61	3.64	2.03	1.88	1.11	1.71	1.86	1.12 [3]	1.40 [4]	1.55 [14]	2.41	4.40
TR5-100	76	5.64	1.58	2.47	1.80	2.23	1.46	1.17 [7]	1. 8 [8]	6.15 [17]	4.14	5.39
TR7-100	76	4.90	2.12	1.83	2.16	2.43	1.84	1.03 [3]	1.74 [4]	3.65 [14]	3.41	6.87
TR8-90	57	5.39	2.16	2.00	1.68	2.19	1.32	1.31 [7].	0.96 [8]	3.33 [14]	2.61	7.44
TR2-110	68	2.56	3.03	3.29	1.82	1.86	1.19	... [9]	...	...	...	...
TR3-100	65	4.16	4.03	3.43	2.73	1.02	1.76	1.83 [13]	5.54 [11]	8.33	9.34	7.13
TR6-100	62	4.87	2.58	3.09	1.51	2.12	1.46	1.69 [13]	1.35	4.27 [14]	2.50	6.84
HD1	70	3.16	...	...	...	...	...	2.59 [18]	3.37	3.36	3.45	4.97
HD2	54	3.65	...	4.57	4.10	3.85	6.00	3.99 [18]	3.79	6.20	4.02	3.57
HD3	63	1.50	...	5.48	5.83	4.39	3.87	5.39 [18]	5.17	3.68	3.42	3.41
HD4	70	...	...	...	...	...	...	5.03 [18]	4.52	6.32	6.03	10.42
HD5	65	6.02	...	8.96	8.57	8.84	6.56	4.17 [18]	4.37	8.10	7.55	8.86
HD6	57	7.33	...	6.74	8.88	7.28	10.12	5.19 [18]	4.36	6.55	4.95	7.34
HD7	62	5.92	...	...	...	...	...	7.41 [18]	3.64	5.62	...	...
HD8	53	3.64	...	...	...	...	...	2.37 [18]	2.61	5.21	3.61	4.25
HD9	72	3.79	...	...	...	...	...	6.47 [18]	6.22	4.83	4.04	5.69

[1] In 39th week U-group received 2 mg additional riboflavin (same as R-group).

[2] All subjects returned to ad libitum feeding with increased meat ration in 88th week.

[3] Supplemented with 1 gm of L-lysine per day in 39th week and continued until 52nd week (subgroup II).

[4] Zein in diet replaced by lactalbumin supplying equal amount of nitrogen from 52nd week to 61st week (subgroup II).

[5] Placed on hospital diet in 69th week.

[6] Folic acid, calcium pantothenate, pyridoxine, and vitamin B_{12} removed from diet in 61st week.

[7] Supplemented with 330 mg of DL-methionine in 39th week and continued until 52nd week (subgroup III).

[8] Methionine supplementation ceased in 52nd week and supplemented with 1.3 gm of choline dihydogen citrate daily from 52nd week to 61st week.

[9] Removed from project.

[10] Placed on high protein diet following surgery in 42nd week.

[11] Placed on hospital diet in 52nd week.

[12] In General Hospital 69th to 88th week.

[13] Supplemented with 10 gm of lactalbumin in 39th week (subgroup I).

[14] Supplemented with 30 gm of lactalbumin in 61st week.

[15] Supplemented with 30 gm of lactalbumin in 65th week.

[16] Results in parentheses considered unreliable.

[17] Placed on hospital diet in 65th week (high protein).

[18] Supplementation of HD group with Vi-Penta tablets ceased in 38th week.

mented with 10 mg of niacinamide) increased to 5.39 mg per day. At the same time, the HD group which received the hospital diet plus a supplement of 10 mg of niacinamide, three times a week, reached a plateau level of 6.44 mg.

The R-100 group was close to its minimum average excretion level at the 9th week with only minor fluctuations thereafter. The U-100 group average took somewhat longer to come

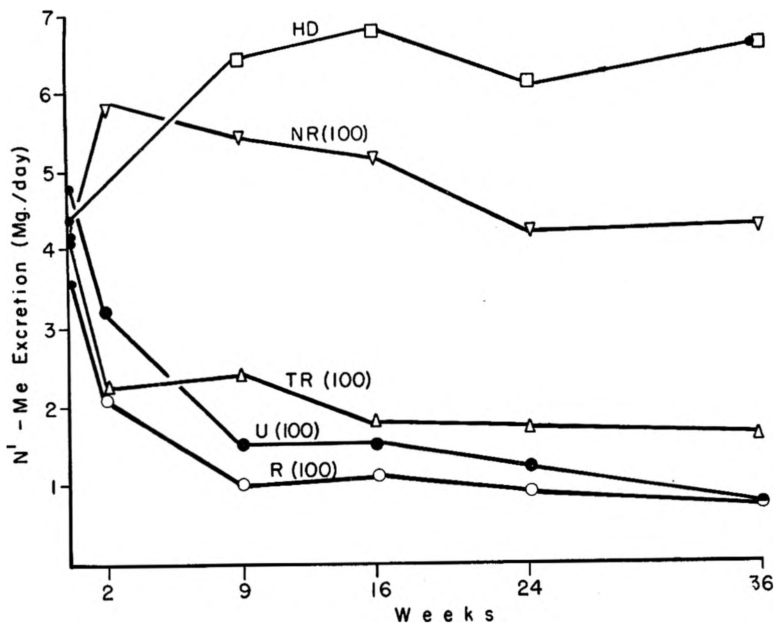

Fig. 2 Average daily excretion of N¹-methylnicotinamide of the experimental groups.

down to a similar low level of about 1.0 mg N¹-Me per day but this time difference is probably related to the higher initial reserve shown by the U-100 subjects in the preliminary period. At two weeks the average values for the TR-100 (2.30 mg), U-100 (3.17 mg) and R-100 (2.12 mg) groups were still a function of the pre-experimental levels. The data from the 9th week gave definite confirmation of the conversion of tryptophan to N¹-Me even though the L-tryptophan supplement was only 50 mg per day at that time. L-Tryptophan supplementation of the TR-100 group was raised from 50 to 100 mg during the 10th week. The importance of initial reserves of niacin cannot be overemphasized in evaluating any depletion experiment in man that has a duration of less than several months.

The initial sharp rise in N^1-Me excretion by the NR-100 group was not maintained. This may be due to the fact that when niacinamide was first given to these individuals, they had good niacin reserves which were gradually diminished as they continued on the basal diet plus the niacin supplement. These data may indicate that this basal diet plus 10 mg of niacin represented no more total niacin than that which had been their intake on the hospital diet. Thus, after 24 weeks, the NR-100 group was not excreting any more N^1-Me than at the start of the experiment despite the fact that they were receiving the niacin supplement. There is the possibility that the decrease in N^1-Me excretion during the first few months was partially ameliorated by tissue products due to the slight negative nitrogen balance which existed at that time. Reference to figure 1 will show that urinary nitrogen excretion was not stabilized until the 24th week in the groups on 100% intake.

The high results in the HD group (HD2, HD3, HD5 and HD6) were due to the administration of a commercial vitamin capsule[9] three times a week in conjunction with ingestion of about 75 gm of protein, daily. When the vitamin supplementation of this group was discontinued at 38 weeks, the N^1-Me excretions dropped back to their pre-experimental levels of about 4.3 mg per day.

Evaluation of the data in table 4 must take into consideration the fact that, in each experimental group, there were some subjects who received more or less than 100% of the basal diet. The difference in tryptophan and niacin ingested by a subject on 100% intake (265 mg of tryptophan and 5.8 mg of niacin) and one on 120% intake was approximately 53 mg of tryptophan and 1.2 mg of niacin, respectively. Thus, a subject

[9] See footnote 6.

in an unsupplemented group (U or R group) who received 120% of the basal diet was being allotted 318 mg of tryptophan, which is not much less than 338 mg of tryptophan which the subject on 90% intake was receiving in the TR group (basal diet plus 100 mg of tryptophan).

Table 4 shows that several of the subjects had low excretions of N^1-Me which approached the upper limits of those reported by Goldsmith et al. ('52), levels which were associated with clinical pellagra on a corn diet. In the latter study, excretions of 0.5 and 0.6 mg of N^1-Me were obtained in 50 to 60 days. In the present study, only one subject (R2-100) excreted less than 0.96 mg at 16 weeks and although, between 46 and 59 weeks, 6 subjects (U2-100, U5-100, U6 100, R1-100, R2-100 and R5-100) recorded excretions of 0.6 mg or less, clinical evidence of pellagra was not apparent. These results are not inconsistent with similar observations on wheat diets which were being conducted at Tulane University (Goldsmith et al., '52) at about the same time. In the latter study, the depletion period was 95 days at which time some of the subjects in the Elgin study had also reached their minimal levels of N^1-Me excretion.

Effects of lysine supplementation on N^1-methylnicotinamide excretion

The apparent changes in N^1-Me excretion observed (table 4, footnote 10) when 1 gm of L-lysine per day was given (39th week) to subjects U2-100, U5-100, R3-100 and R6-120 deserve special comment. These subjects had a decrease in N^1-Me excretion, presumably due to the amino acid imbalance associated with lysine supplementation (Koeppe and Henderson, '55). These suggestions of decreases were in contrast to larger excretions obtained at the same time, in 6 subjects in the same group who were supplemented with 10 gm of lactalbumin per day, although two of these subjects (R2 100 and R5-100) needed more time to show the ameliorative effect of the lactalbumin. The two subjects in the TR group (TR4-100 and TR7-100) who received 1 gm of L-lysine per day had marked decreases in their N^1-Me excretion, but no effects of lysine supplementation on the NR group were apparent.

Effects of methionine and choline supplementation on N^1-methylnicotinamide excretion

The addition of 330 mg of DL-methionine per day to 8 subjects during the 39th week had effects on the N^1-Me excretion which were qualitatively similar to those obtained with L-lysine (table 4, footnote 11). Although each subject given methionine subsequently had a lower excretion of N^1-Me, the changes obtained were insignificant in the U and R group as these subjects were already excreting very little N^1-Me during the interval which preceded methionine supplementation. One of the two subjects in the NR group (NR1-100 and NR5-100) who received methionine showed a decrease in N^1-Me excretion.

All of the subjects who had been receiving methionine were changed to supplementation with choline dihydrogen citrate (1.30 gm per day) in the 52nd week. (This was done to decrease the high retention of bromsulfalein and was not directly related to the studies of N^1-Me at that time.) While no definitive changes in N^1-Me excretion were observed during the period of choline supplementation, the pattern obtained with the previous supplementation with methionine was continued.

Effects of lactalbumin supplementation on N^1-methylnicotinamide excretion

As mentioned above, the addition of 10 gm of lactalbumin during the 38th week (table 4, footnote 7) produced increases in the excretion of N^1-Me. In comparing the effects of supplementation with L-tryptophan or lactalbumin one can select the subjects in the TR group who were not supplemented with lactalbumin and compare them with those in the U and R groups who received lactalbumin. The tryptophan content of the 10 gm of lactalbumin used [10] was approximately 200 mg. As the amount of tryptophan in 10 gm of lactalbumin is about twice the 100 mg added daily to the basal diet given to the subjects in the TR group, the increased efficiency of the lactalbumin supplementation on N^1-Me can be calculated as a function of the additional tryptophan so provided. To estimate the comparative value of tryptophan from lactalbumin and of the 10 mg of niacin given to the NR subjects, one can compare the pre-lactalbumin supplementation data from the 36th week with data obtained during the 59th week. The average increase in the excretion of N^1-Me due to the addition of 10 gm of lactalbumin in the 39th week to 6 subjects who appear to have given reliable data (U1 100, U4-100, U7-120, R8-110, NR3-100 and TR6-100) was approximately 1 mg per day. The difference between the amounts excreted by the NR-100 and U and R-100 groups was approximately 3 mg per day (see fig. 2). On this basis one might regard 1 mg of niacin as being equivalent to about 3 gm of lactalbumin or to about 60 mg of tryptophan provided in the form of lactalbumin. While this calculated result cannot be proved statistically significant from the data presented, it can serve as a reference point for estimating the niacin equivalence of tryptophan-containing compounds; some additional justification for this relationship is presented below in the section in which N^1-Me excretion produced by ingestion of niacin or tryptophan is discussed. When lactalbumin replaced zein in the basal diet (52nd to 61st week, table 4, footnote 12), subjects U5-100, U8-100 and R3-100 showed increases in N^1-Me excretion of 0.64 to 1.05, 0.98 to 1.29 and 0.87 to 1.23 mg, respectively, after 7 weeks. Since this tryptophan addition of approximately 140 mg per day followed the cessation of lysine supplementation, these data are difficult to evaluate.

Urinary excretion of quinolinic acid, niacin and tryptophan

The excretion data for quinolinic acid indicate that this analysis, though of theoretical importance, does not produce

[10] Labco Brand, purchased from The Borden Company (nitrogen content 12.6%).

as good correlations with tryptophan ingestion as does N^1-Me. Table 5 records all the quinolinic acid data obtained in this project. There seem to be few significant changes in the average quinolinic acid excretion of each group after the first few weeks of the experiment. Quinolinic acid excretion is not increased much by supplementation with either nicotinic acid or 10 gm of lactalbumin, but it is increased markedly by feeding 1 gm doses of tryptophan (Goldsmith et al., '52). Quinolinic acid or the method of assay used is not a good index of niacin deficiency. In comparing the data reported here with those from other laboratories, it should be noted that some of the older reports give much lower figures for quinolinic acid in urine inasmuch as the assays were performed before it was known that autoclaving with 1 N sulfuric acid was not as efficient in converting quinolinic acid to niacin as autoclaving with glacial acetic acid (Sarett, '51).

There were no significant changes in the levels of niacin excretion in the urine (table 6). These data show that niacin in urine is not directly related to the nutritional state of the subject.

The urinary excretions of tryptophan (table 7) seemed to be about the same for all groups and did not charge appreciably during depletion periods. However, despite the tendency for each subject to retain a pattern of tryptophan excretion which, as with the other amino acids, appears to be an individual characteristic (Brewer et al., '47; Harvey and Horwitt, '49) there was an increase in tryptophan excretion when the subjects were placed on a diet high in animal protein (95th week). As the individual differences in tryptophan excretion on a given diet were quite marked, this test has not been useful in the evaluation of niacin-tryptophan requirements. For what it is worth, it may be noted that after 36 weeks of depletion, none of the subjects in the depleted groups had excretions greater than 16 mg of tryptophan per day, whereas, excretions of over 20 mg were not infrequent in the subjects receiving better diets.

Urinary excretion of quinolinic acid (mg/day)

SUBJECT		PRELIMINARY PERIOD	TIME IN WEEKS									
No.	Body wt.		2	9	16	24	36	46[1]	59	75	84	95[2]
	kg	mg/day	mg/day	mg/day	mg/day	mg/day	mg/day	mg/day	mg/day	mg/day	mg/day	mg/day
U2-100	61	3.88	4.56	4.33	4.46	2.92	3.60	4.51 [3]	3.29 [4]	3.68 [5]	3.78	3.55
U5-100	53	2.73	4.35	2.35	3.51	1.97	2.45	2.43 [3]	2.50 [4]	2.53 [6]	1.37	3.68
U6-100	55	3.19	3.31	2.23	3.60	3.56	3.01	2.67 [7]	2.62 [8]	2.87 [6]	1.80	2.38
U8-100	59	6.63	4.87	3.42	5.05	3.45	3.57	3.48 [3]	3.05 [4]	. . . [9]	. . .	. . .
U3-90	63	3.77	3.66	1.94	4.04	1.87	2.26	. . . [10]	. . . [11]	2.55 [12]	1.68	2.94
U1-100	69	3.87	4.14	2.98	4.53	2.26	3.09	3.72 [13]	4.42	2.10 [14]	3.73	3.39
U4-100	63	3.33	3.63	2.50	4.43	1.96	2.63	3.60 [13]	3.10	3.17 [5]	2.58	3.16
U7-120	65	5.02	5.00	3.99	4.59	4.42	4.47	5.05 [13]	3.84	3.69 [15]	4.14	4.12
R1-100	61	3.29	3.45	1.87	3.42	2.18	3.25	2.51 [7]	2.03 [8]	. . . [9]	. . .	7.73
R3-100	59	4.19	4.13	4.19	6.29	3.60	4.26	3.43 [3]	3.69 [4]	3.36 [6]	3.00	2.45
R4-100	58	3.15	3.76	3.00	4.12	2.86	3.86	3.48 [7]	1.74 [8]	2.97 [6]	2. 8	2.96
R6-120	71	3.55	4.25	4.22	7.12	4.06	3.62	3.86 [3]	2.81 [4]	3.87 [14]	3.62	2.02
R2-100	64	3.07	3.55	3.21	4.66	3.41	4.74	3.54 [13]	2.59	3.11 [14]	3.[illegible]8	3.25
R5-100	65	1.84	3.16	1.89	3.65	2.63	2.47	2.56 [13]	2.27	3.01 [14]	2.69	1.92
R8-110	55	4.91	4.62	3.42	4.75	2.90	4.34	3.91 [13]	4.16	4.12 [6]	4.06	4.33
NR1-100	73	3.82	4.38	3.30	4.28	2.61	3.59	3.28 [7]	1.12 [8]	4.09 [14]	3.41	3.91
NR2-100	62	6.30	8.61	7.88	7.53	8.61	6.55	6.46 [3]	7.57 [11]	6.72	7.32	6.81
NR5-100	61	3.00	3.92	2.79	4.18	3.91	3.83	3.44 [7]	2.84 [8]	2.51 [6]	2.84	3.98
NR4-120	69	4.70	4.62	3.61	5.12	6.01	4.42	4.08 [3]	4.11 [4]	4.33 [15]	4.88	4.71
NR7-120	77	2.49	4.20	3.26	4.97	4.60	3.53	3.76 [3]	3.05 [4]	2.75 [14]	3.84	5.93
NR3-100	58	4.63	6.01	5.15	5.67	3.83	5.10	5.35 [13]	3.77	4.61 [14]	5.12	6.02
NR6-120	63	4.32	5.41	3.84	5.04	4.52	4.69	5.51 [13]	4.22	3.49 [14]	4.77	3.88
TR1-100	58	3.68	5.19	4.96	3.42	4.89	3.48	4.12 [7]	2.62 [8]	1.26 [14]	3.66	4.02
TR4-100	61	5.53	5.88	4.64	3.91	5.54	5.06	5.23 [3]	3.71 [4]	4.84 [14]	4.99	4.41
TR5-100	76	4.69	4.40	3.95	4.22	3.13	4.51	4.22 [7]	3.26 [8]	3.68 [17]	8.81	4.44
TR7-100	76	5.28	4.43	5.36	3.95	4.60	4.70	3.76 [3]	3.65 [4]	3.93 [14]	4.89	5.58
TR8-90	57	4.02	4.60	3.73	3.91	3.73	3.71	3.70 [7]	2.39 [8]	3.97 [14]	3.75	3.91
TR2-110	68	3.90	4.86	5.09	4.87	3.36	3.43	. . . [9]	. . .	. . .	. . .	. . .
TR3-100	65	3.92	3.79	3.02	3.34	3.79	4.19	3.65 [13]	3.08 [11]	2.62	3.57	4.15
TR6-100	62	4.45	4.03	3.63	3.57	4.20	3.35	4.64 [13]	3.65	3.75 [14]	2.84	4.15
HD1	70	4.18	. . .	. . .	. . .	. . .	. . .	3.87 [18]	4.18	4.98	5.46	4.09
HD2	54	3.68	. . .	3.95	3.46	4.83	4.41	4.17 [18]	3.02	4.87	3.52	3.57
HD3	63	3.67	. . .	3.91	3.43	3.83	3.00	3.71 [18]	6.02	3.85	2.86	4.23
HD4	70		. . .	. . .	. . .	. . .	. . .	5.47 [18]	5.42	7.47	5.12	8.57
HD5	65	3.55	. . .	4.58	4.40	4.34	3.72	4.39 [18]	2.85	4.6[illegible]	3.86	3.97
HD6	57	2.88	. . .	3.99	4.67	4.10	3.73	3.55 [18]	3.21	3.27	3.50	3.66
HD7	62	4.22	. . .	. . .	. . .	. . .	. . .	1.87 [13]	3.28	2.69	. . .	. . .
HD8	53	3.74	. . .	. . .	. . .	. . .	. . .	3.80 [18]	3.32	7.99	8.50	12.06
HD9	72	4.75	. . .	. . .	. . .	. . .	. . .	10.34 [13]	4.97	4.43	3.39	7.57

Urinary excretion of free niacin

SUBJECT		PRELIMINARY PERIOD	TIME IN WEEKS									
No.	Body wt.		2	9	16	24	36	46 [1]	59	73	84	95 [2]
	kg	mg/day	mg/day	mg/day	mg/day	mg/day	mg/day	mg/day	mg/day	mg/day	mg/day	mg/day
U2-100	61	0.80	0.54	0.74	0.55	0.62	0.44	0.68 [3]	0.79 [4]	0.84 [5]	0.79	0.86
U5-100	53	0.56	0.45	0.53	0.45	0.34	0.37	0.49 [3]	0.98 [4]	0.39 [6]	0.61	0.60
U6-100	55	0.65	0.47	0.53	0.45	0.55	0.33	0.45 [7]	0.57 [8]	0.56 [6]	0.61	0.68
U8-100	59	0.87	0.52	0.58	0.47	0.55	0.30	0.62 [3]	0.71 [4]	... [9]	...	...
U3-90	63	0.72	0.61	0.87	0.63	0.57	0.36	1.02 [10]	0.88 [11]	0.87 [12]	1.07	0.95
U1-100	69	0.77	0.58	0.67	0.64	0.64	0.49	0.61 [13]	0.96	0.70 [14]	0.60	0.84
U4-100	63	0.61	0.41	0.52	0.46	0.54	0.33	0.53 [13]	0.61	0.69 [5]	0.61	0.56
U7-120	65	0.84	0.70	0.84	0.69	0.84	0.59	0.76 [13]	0.98	0.86 [15]	1.41	1.00
R1-100	61	0.78	0.58	0.52	0.45	0.54	0.35	0.46 [7]	0.54 [8]	... [9]	...	0.69
R3-100	59	0.64	0.66	0.79	0.59	0.65	0.47	0.50 [3]	0.87 [4]	0.56 [6]	0.24	0.65
R4-100	58	0.62	0.45	0.49	0.49	0.57	0.39	0.47 [7]	0.64 [8]	0.47 [6]	0.62	0.70
R6-120	71	0.89	0.75	0.68	0.68	0.82	0.50	0.60 [3]	0.85 [4]	0.70 [14]	0.88	0.6[illegible]
R2-100	64	0.53	0.54	0.51	0.60	0.82	0.48	0.52 [13]	0.94	0.54 [14]	0.93	0.79
R5-100	65	0.44	0.72	0.61	0.58	0.56	0.42	0.68 [13]	0.94	0.53 [14]	0.91	0.75
R8-110	55	0.60	0.56	0.54	0.64	0.62	0.43	0.52 [13]	0.84	0.67 [6]	0.80	0.77
NR1-100	73	0.72	0.71	0.61	0.69	0.74	0.69	0.74 [7]	0.80 [8]	0.79 [14]	0.90	0.90
NR2-100	62	0.70	0.76	0.60	0.63	0.70	0.61	0.69 [3]	0.86 [11]	0.58	0.95	0.77
NR5-100	61	0.54	0.58	0.61	0.71	0.72	0.63	1.01 [7]	0.69 [8]	0.61 [6]	0.83	0.90
NR4-120	69	0.88	0.80	0.66	0.76	0.83	0.56	0.76 [3]	0.73 [4]	0.52 [15]	1.18	0.97
NR7-120	77	1.06	0.77	0.65	0.71	1.06	0.57	1.06 [3]	1.30 [4]	0.84 [14]	1.16	0.87
NR3-100	58	0.72	0.66	0.62	0.61	0.82	0.54	0.67 [13]	0.79	0.67 [14]	0.97	0.91
NR6-120	63	0.80	0.63	0.61	0.72	0.81	0.72	0.94 [13]	1.21	0.71 [14]	0.[illegible]7	0.92
TR1-100	58	0.56	0.48	0.64	0.52	0.62	0.42	0.53 [7]	0.63 [8]	0.60 [14]	0.89	0.79
TR4-100	61	0.66	0.54	0.49	0.52	0.61	0.48	0.54 [3]	0.69 [4]	0.44 [14]	0.74	0.74
TR5-100	76	0.66	0.50	0.49	0.50	0.76	0.50	0.52 [7]	0.82 [8]	0.41 [17]	0.78	0.74
TR7-100	76	0.72	0.43	0.59	0.51	0.58	0.55	0.50 [3]	0.70 [4]	0.44 [14]	0.78	0.77
TR8-90	57	0.70	0.55	0.51	0.53	0.58	0.51	0.54 [7]	0.65 [8]	0.46 [14]	0.66	0.78
TR2-110	68	0.60	0.49	0.68	0.72	0.76	0.59	... [9]	...	...	...	...
TR3-100	65	0.74	0.60	0.60	0.62	0.59	0.56	0.75 [13]	0.80 [11]	0.74	0.80	0.81
TR6-100	62	0.62	0.60	0.57	0.53	0.64	0.56	0.62 [13]	0.80	0.64 [14]	0.88	0.85
HD1	70	0.61	...	...	...	...	...	0.50 [18]	0.80	0.50	0.70	0.66
HD2	54	0.52	...	0.41	0.58	0.55	0.69	0.62 [18]	0.92	0.63	0.70	0.67
HD3	63	0.64	...	0.50	0.74	0.61	0.57	0.72 [18]	0.83	0.57	0.83	0.64
HD4	70	...	...	...	...	...	...	0.85 [18]	1.12	0.75	1.26	0.92
HD5	65	0.82	...	0.54	0.70	0.74	0.75	0.61 [13]	0.81	0.79	1.26	1.11
HD6	57	0.70	...	0.53	0.63	0.52	0.69	0.58 [18]	0.82	0.77	0.69	0.88
HD7	62	0.57	...	...	...	...	...	0.91 [18]	0.80	0.58	...	...
HD8	53	0.65	...	...	...	...	...	0.44 [18]	0.72	0.54	0.79	0.74
HD9	72	0.72	...	...	...	...	...	0.77 [18]	0.83	0.51	1.78	0.85

See table 4 for description of footnotes.

TABLE 7

Urinary excretion of L-tryptophan

SUBJECT		PRELIMINARY PERIOD	TIME IN WEEKS									
No.	Body wt.		2	9	16	24	36	46 [1]	59	75	84	95 [2]
	kg	*mg/day*	*mg/day*	*mg/day*	*mg/day*	*mg/day*	*mg/day*	*mg/day*	*mg/day*	*mg/day*	*mg/day*	*mg/day*
U2-100	61	9.6	8.9	11.9	10.8	9.1	9.1	10.6 [3]	6.0 [4]	26.7 [5]	16.0	12.6
U5-100	53	7.0	6.4	11.6	7.8	6.7	8.4	6.8 [3]	. . [4]	9.4 [6]	10.5	11.7
U6-100	55	10.0	12.0	13.2	12.6	11.7	12.2	12.0 [7]	7.4 [8]	15.7 [6]	14.3	17.2
U8-100	59	7.4	14.2	10.0	8.4	9.4	8.7	8.0 [3]	4.8 [4]	. . . [9]	. . .	. . .
U3-90	63	10.3	10.3	11.7	10.2	10.3	10.4	12.6 [10]	. . . [11]	23.6 [12]	17.8	16.4
U1-100	69	23.9	18.8	14.1	13.0	12.3	14.5	16.8 [13]	18.5	20.0 [14]	12.4	15.9
U4-100	63	11.9	14.7	16.6	14.2	13.7	13.0	16.4 [13]	17.7	18.6 [5]	11.5	13.3
U7-120	65	13.2	16.6	15.6	13.0	14.9	14.8	17.6 [13]	17.6	17.5 [15]	23.9	21.1
R1-100	61	12.1	18.7	12.9	11.4	12.4	13.4	12.0 [7]	20.0 [8]	. . . [9]	. . .	26.0
R3-100	59	9.2	13.0	11.1	8.0	14.4	8.1	7.4 [3]	6.7 [4]	5.9 [6]	8.3	15.5
R4-100	58	12.6	19.5	16.3	13.4	13.2	16.2	13.5 [7]	8.8 [8]	7.2 [6]	14.7	25.5
R6-120	71	7.5	10.8	12.4	9.0	8.3	7.9	8.0 [3]	6.8 [4]	18.3 [14]	10.0	8.6
R2-100	64	6.7	6.7	11.3	8.8	9.4	8.3	8.2 [13]	. .	9.5 [14]	14.7	12.9
R5-100	65	5.9	12.3	10.8	6.8	8.8	7.4	9.3 [13]	5.6	8.8 [14]	9.2	14.0
R8-110	55	7.4	8.7	11.8	9.5	8.4	6.1	8.8 [13]	10.2	11.6 [6]	11.9	14.2
NR1-100	73	19.3	22.7	18.8	17.5	16.7	16.8	14.9 [7]	9.9 [8]	8.1 [14]	19.8	25.2
NR2-100	62	8.0	7.8	8.4	6.0	6.9	5.6	4.9 [3]	6.8 [11]	12.9	9.3	27.5
NR5-100	61	15.8	9.9	17.0	10.1	11.6	9.1	9.2 [7]	18.0 [8]	11.2 [6]	9.0	15.9
NR4-120	69	9.3	16.5	14.3	12.7	11.4	11.2	11.3 [3]	5.3 [4]	19.4 [15]	14.2	17.3
NR7-120	77	14.9	13.7	20.8	19.4	24.0	19.2	19.8 [3]	18.4 [4]	21.9 [14]	18.5	24.3
NR3-100	58	15.2	11.7	10.8	8.7	9.7	8.4	7.8 [13]	12.2	11.9 [14]	10.4	13.2
NR6-120	63	12.1	16.6	13.2	10.8	12.8	12.1	15.1 [13]	18.0	12.6 [14]	12.0	18.4
TR1-100	58	7.8	11.8	13.7	7.8	7.7	7.3	7.1 [7]	7.2 [8]	9.9 [14]	7.5	15.2
TR4-100	61	11.8	19.0	17.3	14.4	24.6	17.8	14.8 [3]	6.1 [4]	16.2 [14]	20.0	31.0
TR5-100	76	19.2	20.9	20.2	18.6	23.8	22.2	22.2 [7]	19.4 [8]	16.6 [14]	20.0	28.6
TR7-100	76	12.4	16.3	19.4	14.9	12.9	14.5	[illegible] [3]	11.3 [4]	18.4 [14]	15.9	20.4
TR8-90	57	7.6	7.8	14.0	7.5	7.6	7.8	8.9 [7]	8.5 [8]	10.3 [14]	8.2	11.1
TR2-110	68	10.1	9.8	17.0	12.2	10.3	12.8	. . [9]	. .	. . .	. .	. . .
TR3-100	65	12.2	13.4	11.4	9.1	12.3	12.0	11.4 [13]	13.3 [11]	12.5	11.6	14.3
TR6-100	62	7.9	15.1	12.0	8.7	8.3	8.2	9.4 [13]	5.0	10.7 [14]	12.1	13.8
HD1	70	9.8	. . .	. . .	. . .	. . .	. . .	17.1 [13]	16.9	18.5	18.6	16.2
HD2	54	8.2	. . .	30.6	11.6	14.6	18.6	14.5 [18]	. . .	20.2	12.3	17.8
HD3	63	11.7	. . .	31.6	35.6	20.2	20.5	23.6 [18]	. . .	20.6	18.2	26.7
HD4	70	9.2	. . .	. . .	. . .	. . .	. . .	11.4 [18]	. . .	13.6	13.0	14.0
HD5	65	7.1	. . .	16.6	11.7	9.7	9.8	10.0 [18]	. . .	10.7	12.2	15.0
HD6	57	10.9	. . .	18.5	15.0	13.2	13.6	15.6 [18]	. . .	22.8	20.0	18.1
HD7	62	7.7	. . .	. . .	. . .	. . .	. . .	21.3 [18]	. . .	17.3	. . .	. . .
HD8	53	7.2	. . .	. . .	. . .	. . .	. . .	10.2 [18]	16.3	14.4	12.0	12.1
HD9	72	10.0	. . .	. . .	. . .	. . .	. . .	19.2 [18]	. . .	17.8	23.4	17.5

See table 4 for description of footnotes.

Urinary excretion of 6-pyridone of N^1-methylnicotinamide and xanthurenic acid

The determination of 6-pyr may be quite reliable when conducted on urines from individuals receiving large excesses of niacin or tryptophan, and 6-pyr may be a preferred excretion path when large amounts of niacinamide or tryptophan are administered, but the assay of this compound in urines from individuals on low or borderline diets is relatively difficult. Thus, insignificant amounts of 6-pyr were found in urines collected during the pre-experimental period and within a few days after the experimental diet started. Furthermore, the addition of 100 mg of tryptophan a day to the basal diet did not raise the excretion of 6-pyr a measurable amount. Some of the difficulties encountered may be related to the high and variable blank, which is an integral part of the method and which this laboratory could not minimize in the time available. Agreement between duplicate analyses by different workers on different days was poor. This experience, while not inconsistent with personal communications from other laboratories, should not eliminate consideration of the possibility that future work may improve the technique and permit better measurement of small amounts of 6-pyr in urine. It is of interest to note that Goldsmith et al. ('52) found "non-detectable amounts" of 6-pyr in the urine of their subjects after 22 days on their niacin-deficient diets and that when one of their subjects was supplemented with 2 mg niacinamide per day for three months the 6-pyr remained "non-detectable" despite the fact that the N^1-Me excretion did not decrease below 0.9 mg per day on this regimen.

Xanthurenic acid was determined in all urines collected during the first 24 weeks of the depletion period. The amounts in all groups were similar, the U, R, NR, TR and HD groups averaging 12.9, 12.0, 15.5, 12.4 and 15.3 mg per day, respectively. This agrees with previous results (Sarett and Goldsmith, '50).

Effects of withdrawal of folic acid, calcium pantothenate, pyridoxine and vitamin B_{12} from the vitamin supplement

As clinical signs of pellagra had not appeared in any of the subjects by the 62nd week, folic acid, calcium pantothenate, pyridoxine and vitamin B_{12} were removed at this time from the vitamin supplement of 6 of the subjects who were not receiving any lactalbumin. This was done to determine whether these vitamins were preventing the development of a pellagra syndrome. These subjects (U5-100, U6-100, R3-100 R4-100, R8-110 and NR5-100) were chosen for observation of possible effects of prolonged feeding of the basal diet because they had not shown any evidence of liver dysfunction, as determined by bromsulfalein retention test, during the course of the project and therefore had not received any protein supplements. During the following 25 weeks, these subjects showed no significant alterations in their previous clinical or biochemical patterns. It should be noted that two subjects (U6-100 and R4-100) received the basal 100% diet (5.6 mg of niacin and 265 mg% tryptophan) for 87 weeks without any symptoms of pellagra becoming evident. Two other subjects (U5-100 and R3-100) received the basal diet for the same 87-week period except that 7 gm of lactalbumin replaced 7 gm of zein in their diet from the 52nd to 61st week.

Comparison of increases in N^1-methylnicotinamide excretion produced by tryptophan and by niacin

The importance of evaluating tryptophan as a substitute or supplement for niacin should be apparent as any estimation of the niacin equivalence of a given diet must depend upon the amount of tryptophan in the protein supplied (Horwitt, '55). Estimations of how much tryptophan is convertible to niacin and its derivatives depend largely upon the study of the three main excretory products of niacin-tryptophan metabolism, N^1-Me, the 6-pyridone of N^1-Me, and quinolinic acid. Analysis for 6-pyr can give useful information when relatively large amounts of N^1-Me are excreted, but when the levels of N^1-Me approach the critical range in which some doubts may arise about the niacin adequacy of the diet, the amounts of the pyridone found in urine, using the analytical methods now available, are negligible. Quinolinic acid excretion does not appear to be as sensitive an index as N^1-Me to decreases in the niacin equivalence of the diet. The average quinolinic acid excretion for the subjects on the U-100 and R-100 diets declined to about 2.9 mg per day in the second month and did not show a significant decrease for the remainer of the experiment (see discussion of quinolinic acid data). It therefore appears expedient to judge niacin equivalence in terms of N^1-Me excretion as this compound is the most sensitive index at low levels of niacin-tryptophan intake and its determination is less subject to analytical errors than that available for either 6-pyr or quinolinic acid.

If one takes the average of N^1-Me excretion of the combined U-100 and R-100 groups and compares these data with those from the subjects in the NR-100 and TR-100 groups at 16, 24 and 36 weeks, one obtains a niacin:tryptophan efficiency of 1:86, 1:46 and 1:52, respectively. An example of the calculation used to obtain these ratios follows: taking the data from the 36th week (see fig. 2) the average daily N^1-Me excretions of the combined U-100 and R-100 groups, the NR-100 group and the TR-100 group are 0.92, 4.26 and 1.58, respectively. The average increase in N^1-Me excretion produced by feeding 10 mg of niacin is 4.26 mg minus 0.92 mg or 3.34 mg or 0.334 per milligram of niacin. Similarly, the average increase, above that obtained with the basal diet by feeding an additional 100 mg of tryptophan is 1.58 mg minus 0.92 mg or 0.66 mg, or 0.0066 mg N^1-Me per milligram of tryptophan. Therefore, during the 36th week, each milligram of niacin produced as much N^1-Me as 52 mg of tryptophan.

A similar calculation made from the average data obtained during the 46th week on those subjects who had not received lactalbumin gave, for three subjects in the NR-100 group, 4 from the TR-100 and 6 from the UR-100 group, a ratio of

1:65. In subsequent weeks, there were too few subjects not receiving extra protein to warrant such calculations.

From such data as presented above, a factor of 1:60 has been chosen to designate the relative efficacy of tryptophan in substituting for niacin. It is the opinion of the senior author, after attempting to analyze the data from each subject that, though there are large individual variations, a factor of 1:60 is a logical starting point for future studies. Past experience with "load tests" with other vitamins has shown that the proportions of a vitamin or its products excreted after ingestion are dependent upon the nutritional state of the subject being tested. Thus, the administration of a vitamin supplement equivalent to one day's requirement would, if given to a deficient subject, produce little urinary excretion of the given vitamin or its products. Therefore, since the calculations above compare groups in different stages of niacin saturation, one can predict that a larger proportion of the administered niacin would be excreted by the NR group than by the TR group which would produce an apparent ratio that would make tryptophan seem less effective than niacin. In other words, the 1:60 ratio includes a considerable margin of safety; less tryptophan than suggested by the ratio of 1:60 would probably be needed to replace each milligram of niacin in the non-growing adult.

The data discussed in the section on the effects of lactalbumin supplementation on N^1-Me excretion, though meager do not show any marked differences between the effects of tryptophan fed as a component of lactalbumin and of L-tryptophan fed as an isolated amino acid.

DISCUSSION OF NIACIN RATIOS

Analysis of the data reported should take into account the results of the Tulane studies (Goldsmith et al., '52) some of which were conducted at the same time as the Elgin project. These workers produced niacin deficiency in three subjects in 50 days on a corn diet which contained about 4.7 mg of niacin and 190 mg of tryptophan. On the other hand, no clinical signs of pellagra were noted in 95 days on a "wheat" diet which contained 5.7 mg of niacin and 230 mg of tryptophan. The Elgin project might, in part, be considered an extension of the Tulane "wheat" study as the 5.8 mg of nicotinic acid and 265 mg of tryptophan were given for as long as 87 weeks, and although some of the N^1-Me excretions obtained in Elgin were as low as the lowest obtained in subjects who showed clinical pellagra in the Tulane study on corn, the rate of decrease in N^1-Me excretion was slower in the Elgin study

As a consequence of impressions gained from much research which preceded the establishment of the fact that tryptophan in dietary protein can replace niacin in the diet, the literature on niacin requirements has become overly complicated. If one restricts the discussion of niacin-tryptophan relationships to that part of the pellagra syndrome which is ameliorated by feeding niacin or tryptophan or both, one can obtain a practical viewpoint of the problem.

It is not reasonable to assume that an inflexible relationship exists between niacin and tryptophan which could be maintained through all genetic and dietary variation (including loss in preparation or differences in availability) but in this respect the requirements for niacin are not different from the requirements for other vitamins. The attention focused on the relationship between corn consumption and pellagra has been so intensive that when certain population groups which subsisted almost entirely on corn were found to be free of pellagra, reasons other than variations in intake of niacin and tryptophan have been sought to explain the observations.

Table 8 attempts to correlate the pellagragenic potential of several diets by assuming that 60 mg of tryptophan is equivalent to 1 mg of niacin. Except for the estimations of the "Goldberger" diet, the figures for niacin and tryptophan in table 8 are based on analyses of the cooked diet as served. Approximations of the tryptophan content of the "Goldberger" diet are hazardous to estimate despite the use of the excellent data published by Frazier and Friedemann ('46).

TABLE 8

Niacin ratios of experimental diets

DIET	CALORIES	NIACIN	TRYPTOPHAN	NIACIN EQUIVALENTS	NIACIN RATIO (niacin equivalents per 1000 Cal.)[1]	PROPORTION WITH PELLAGRA SYMPTOMS[2]
		mg	*mg*			
Tulane "corn"[3]	1700–2100[1]	4.4–4.6	177–195	7.4–7.8	(3.7–3.9)	3/3
Tulane "wheat"[4]	1600–1900	4.2–4.7	177–193	7.3–7.8	(3.7–3.9)	2/3
Goldberger[5]	3000	6.7	330	12.2	4.1	6/11
Tulane "wheat"[4]	1750	4.9	200	8.2	(4.1)	1/2
Elgin (90%)	2070	5.2	238	9.2	4.4	0/1
Elgin (100%)	2300	5.8	265	10.2	4.4	0/11
Elgin (110%)	2530	6.4	292	11.3	4.4	0/1
Elgin (120%)	2760	7.0	318	12.3	4.4	0/2
Tulane "corn" + niacin[6]	1970	6.7	190	9.9	4.9	0/1

[1] Diets providing less than 2000 calories are arbitrarily calculated as containing 2000 calories on assumption that there is a minimum basal requirement for niacin-tryptophan of approximately 8.8 niacin equivalents and that increased needs for greater caloric consumption are measurable above this level as a multiple of 1000 calories (see text, pp. 35, 36).

[2] Calculation of data presented in a recent summary of the Tulane experiments (Goldsmith, personal communication) shows that symptoms of pellagra were obtained in 13 out of 15 individual subject trials when 8.7, or less, niacin equivalents were fed. Of these 15 subjects, symptoms were obtained in three out of 5 on wheat diets, 4 on U. S. corn, three on lime treated Guatemalan corn, and two on untreated Guatemalan corn.

[3] Goldsmith et al. ('52).

[4] Goldsmith, personal communication.

[5] Calculated from Frazier and Friedemann ('46).

[6] Same diet as "Tulane corn" above, plus 2 mg of niacinamide per day.

Ten per cent was deducted for cooking loss (see table 1) from the estimated tryptophan content of the components of the "Goldberger" diet; the resulting calculated figure of 330 mg of tryptophan per 3000 calories for a diet high in corn products is not inconsistent with recent analytical experience.

It has been customary to calculate niacin requirements in terms of caloric intake (N.R.C. Recommended Dietary Allowances, '53). This procedure was originated before tryptophan was known as a niacin precursor, more because niacin requirements were estimated as 10 times the thiamine needs, than because of any special research to prove the relationship of niacin with caloric intake.

The data in table 8 suggest that it may be as practical to calculate "niacin equivalents" as it is to estimate the riboflavin or thiamine content of a diet and that the onset of pellagra may be predictable from the available "niacin ratio ("niacin equivalents" per 1000 calories) of a diet as consumed. The data suggest further that additional corn, *per se,* in a diet may not necessarily be pellagragenic since corn itself, if given in sufficient amounts can provide adequate niacin equivalents, depending on it's source and preparation. (It should be emphasized that corn remains an inadequate source of good protein and that other nutritional inadequacies may become apparent if it forms too large a proportion of the diet.) It is recognized that other factors have been reported to affect niacin requirements on a corn-containing diet, but it now seems desirable to evaluate these factors in terms of the "niacin ratio."

In evaluating needs for tryptophan, which is required for many important functions other than conversion to niacin, one must consider this amino acid, like other protein components, as being required in amounts proportional to the size of the individual. To avoid the complications of making separate calculations for basal requirements and the requirements for the utilization of energy, it is suggested that 2000 calories be considered as a base line. In other words, in estimating the "niacin ratio" of a diet, one never uses less than 2000 calories in the calculation even though the subject in question is consuming less than this amount. This eliminates the possibility of having an apparently adequate value of this ratio in a subject consuming only a small part of a well-balanced diet. In effect, the amount adequate for 2000 calories would be the minimum basal requirement for the adult.

An alternate calculation of the minimum niacin-tryptophan requirements of man might be made by subtracting a minimum figure for tryptophan requirements (Rose, '49) for maintenance (about 150 mg or 2.5 niacin equivalents) and then estimating the remaining niacin equivalents. However, since less than 200 mg of tryptophan are found only in experimental diets or in areas of severe starvation, no practical point is served by treating the maintenance requirement separately. The niacin ratio, if used as suggested, tends to correct for differences in the size of the individual, as size, protein and basal caloric needs are all related although it is recognized that the tryptophan needs are only indirectly related to caloric intake.

Table 9 lists the niacin ratios of some representative foods to show how relatively unimportant can be the niacin content of good sources of tryptophan. This table also demonstrates how corn itself can vary. To obtain the data on corn, calculations were based on the niacin and tryptophan contents of 23 different varieties of Guatemalan corn as reported by Aguirre et al. ('53). The 4 Guatemalan corns chosen in table 9 are those which contained the lowest niacin, the lowest tryptophan, the highest niacin and the highest tryptophan contents, respectively. In order to estimate the caloric content of these corns, the results published by Bressani et al. ('53) were calculated from their data on fat, nitrogen, crude fiber and ash. The average niacin ratio of the Guatemalan corns is about 6.7 and pellagra is relatively uncommon in Central America where it is claimed that the average Indian consumes about 500 gm of corn per day. This is considered to provide about 80% of the total calories ingested. The average North American maize does not appear to be significantly different from Central American maize in tryptophan-niacin content (Teas and Newton, '51). It is of interest to note that white flour, which, when substituted for corn in an experimental diet (Goldsmith et al., '52) produced only a slightly greater excretion of N^1-Me, has a niacin ratio of 7.4. Salt pork and

TABLE 9

Niacin ratios of representative foods [1]

FOOD	NIACIN	TRYPTOPHAN	NIACIN RATIO
	mg/1000 Cal.	*mg/1000 Cal.*	
Cow's milk	1.21 [2]	673 [3]	12.4
Human milk	2.46 [2]	443 [3]	9.84
Beef, round	24.7	1280	46.0
Whole eggs	0.60	1150	19.8
Salt pork	1.15	61	2.17
Wheat flour	2.48	297	7.43
Corn grits [4]	1.83	70	3.00
Guatemalan corn			
lowest niacin	3.37	132	5.57
lowest tryptophan	5.07	35	5.65
highest niacin	6.94	101	8.62
highest tryptophan	4.50	158	7.13

[1] Block and Bolling ('51) used for tryptophan data in this table unless otherwise noted.

[2] Macy, Kelley and Sloan ('50).

[3] Williamson ('44)

[4] Calculated from data of Krehl et al. ('46).

[5] See text.

corn grits, common constituents of pellagragenic diets in this country, have low "niacin ratios."

Although corn products have the lowest "niacin ratio" of any common high-protein foods (table 9) and pellagra is usually associated with corn consumption, corn, itself, may not be a direct cause of pellagra. In this country, pellagragenic diets are mixtures of unenriched corn products and other foods. These other foods are high in caloric content but very low in niacin equivalents. From the data in tables 8 and 9 one might conclude that if one-third to one-half the corn in the Guatemalan diet were to be replaced by "civilized" forms of carbohydrate, such as corn syrup, corn starch or sucrose, pellagra would be common in that country.

The statements made, herein, are not intended to eliminate the possibility that some corn products may have such low "niacin ratios," or such low niacin-tryptophan availability, that their consumption, exclusively, would promote pellagra. Rather it is an attempt to focus more attention on a simple relationship of the niacin-tryptophan content of the diet in terms of total calories consumed. Justification for using calories as a base line, rather than body weight, may be obtained from comparisons of the Goldberger, Tulane and Elgin diets and from experience with animals where niacin and thiamine needs were directly related. The Goldberger prison diet (Goldberger and Wheeler, '20) provided relatively high amounts of niacin and tryptophan but the caloric intake was also high. The prisoners had work to perform, whereas the Tulane and Elgin subjects had a minimum amount of activity. Krehl et al. ('46) have pointed out that their estimations of the tryptophan requirement of the rat was considerably less than the level of 0.2% suggested by Rose ('37) who used a diet relatively high in fat and calories.

The data which suggest that L-lysine supplementation (1 gm per day) had a deleterious effect on the formation of N^1-Me reinforce reports (Koeppe and Henderson, '55; Hankes et al., '49) that amino acids in the diet must be properly balanced.

When the diet of the TR group (about 9% protein) was fed to weanling rats (Horwitt, '53) their growth rate averaged less than 1.3 gm per day and fatty livers were produced. Adult men were reasonably well maintained on the same diet although some evidence of liver dysfunction was obtained. The addition of lactalbumin to this diet produced normal rats with a growth rate of 4.3 gm per day. These observations should be considered in the light of the increased protein requirements for rapid growth, and the high frequency of kwashiorkor in Guatemalan children on corn diets which do not produce pellagra.

SUMMARY

Controlled feeding of a diet which provided only 5.8 mg of niacin and 265 mg of tryptophan per 2300 calories to 15 subjects for from 38 to 87 weeks produced no clinical evidence of pellagra. Data from studies of niacin metabolites excreted in the urine of these subjects were compared with results obtained at the same time from 15 other subjects who received the experimental diet plus controlled amounts of tryptophan, niacin and lactalbumin. Another group of 9 subjects who ate the regular hospital diet, were observed simultaneously.

Comparisons of the levels of N^1-methylnicotinamide excreted at different levels of niacin and tryptophan intake showed that approximately 60 mg of tryptophan are equivalent to 1 mg of niacin. It is suggested that one "niacin equivalent" be considered as equal to either of these amounts. To simplify discussions of food values, the term "niacin ratio" is suggested as the number of niacin equivalents per 1000 calories. The niacin ratio of representative foods and of some experimental diets which have promoted pellagra are presented and compared to show the predictability of pellagragenic diets.

From a comparison of the data obtained in this study with previously published information from other sources, it is estimated that the base line level for the development of pellagra is 8.8 niacin equivalents for the first 2000 calories, or part thereof, plus an additional 0.44 equivalents for each 100 calories above 2000.

Tryptophan in lactalbumin appears to be as readily available for conversion to niacin derivatives as is L-tryptophan, itself.

The nitrogen excretion data reported emphasize the length of time which it may take to achieve a steady state of urinary nitrogen excretion (24 weeks) after a major change has been made in the protein intake. This observation is consistent with experience on all previous Elgin projects.

Data on urinary excretions of quinolinic acid could be only roughly related to the amounts of niacin and tryptophan in the diet; the results were not so consistent or as reliable as similar data obtained on N^1-methylnicotinamide excretion.

Urinary excretions of niacin and tryptophan were not directly related to the usual levels at which these were present in the diet.

Data pertaining to the possibility that lysine or methionine added as supplements may inhibit the formation of niacin metabolites are presented and discussed.

While attempting to correlate the effects of riboflavin deficiency on "pellagragenic" diets the following observations were made; (1) That a diet low in niacin and tryptophan did not cause any noticeable alterations in the previously reported course of ariboflavinosis; (2) that supplementation with vitamin B_{12} produced no changes in either the development or repair of ariboflavinosis and (3) confirmed a previous report that scrotal dermatitis was a consistent observation in ariboflavinosis in man.

The withdrawal of folic acid, calcium pantothenate, pyridoxine, and vitamin B_{12} as supplements to the basal diet of 5 subjects for a period of 25 weeks had no noticeable effect on the subjects involved. One may assume that either the basal diet was not grossly deficient in these vitamins or that the previous 62 weeks of supplementation had created a large reserve.

The level of excretion of N^1-methylnicotinamide has been confirmed as an indicator of the ability of the organism to extract niacin derivatives from the diet and in this manner may prove to be a useful index of niacin-tryptophan availability.

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FOREWORD

Concerning Supplements to

The Journal of Nutrition

To meet the need for publication of meritorious but unusually long manuscripts the Journal of Nutrition instituted in April 1954 the policy of publishing such papers in the form of supplements to regular issues. The authors provide the full cost of such publication. For a more complete statement regarding this policy see volume 52, Supplement 1, April, 1954.

GEORGE R. COWGILL, *Editor*

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IN MEMORY OF

The late Harold R. Sandstead, who, with forty-three others, met a tragic death aboard the ill-fated plane on November 1, 1955; his interest, diligence, and enthusiasm contributed in a very large degree to the success of this study.

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"NAVAJO MAIDS PREPARING FOR EAT"

Painting by Beatien Yazz

Grinding corn

Burning cedar branch to make ashes for mixing with corn meal

Carrying water

Cooking tortillas

A STUDY OF THE DIETARY BACKGROUND AND NUTRITURE OF THE NAVAJO INDIAN

I. BACKGROUND AND FOOD PRODUCTION

WILLIAM J. DARBY, CLARENCE G. SALSBURY, WILLIAM J. MCGANITY,[1]
HOWARD F. JOHNSON, EDWIN B. BRIDGFORTH,
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II. DIETARY PATTERN

WILLIAM J. DARBY, CATHERINE M. ADAMS, MARTHA POLLARD,
ETTA DALTON, AND PAULINE MCKINLEY

III. PHYSICAL FINDINGS

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I.

BACKGROUND AND FOOD PRODUCTION

INTRODUCTION

Despite a wide-spread interest in the cultural anthropology (Kluckhohn and Leighton, '51; Kluckhohn and Spencer, '40; Leighton and Kluckhohn, '48; Roberts, '51; Underhill, '53; Underhill, n.d.) of the Navajo, his agricultural and land use practices (Hill, '38) and ethnobotany (Castetter, '35; Castetter and Bell, '41; Elmore, '44; The Franciscan Fathers, '10; Jones, '42; Matthews, 1886; Vestal, '52; Wyman and Harris, '41, '51) there is strikingly limited knowledge of his present-day dietary practices and a dearth of information concerning his nutritional status. In fact, Kraus ('54) states that "scientifically conducted surveys of nutritional status among Indian populations of the Southwest have been almost totally lacking." Most standard references on the Navajo fail to discuss foods except in rare instances where a passing mention may be made of the use of foods in ceremonials. A few works (Castetter, '35; Castetter and Bell, '41; Elmore, '44; The Franciscan Fathers, '10; Jones, '42; Vestal, '52; Whiting, '39; Wyman and Harris, '41, '51; Young, '38) list wild plants and game which serve(d) as foods and note that the diet of the Navajo is based upon corn, squash, melons and mutton. No objective effort seems to have been made to appraise the adequacy of the traditional or present-day diet, to define trends occurring in dietary practices, or to assess the nutriture of "The People." The present report is an initial effort to begin to fill these deficits.

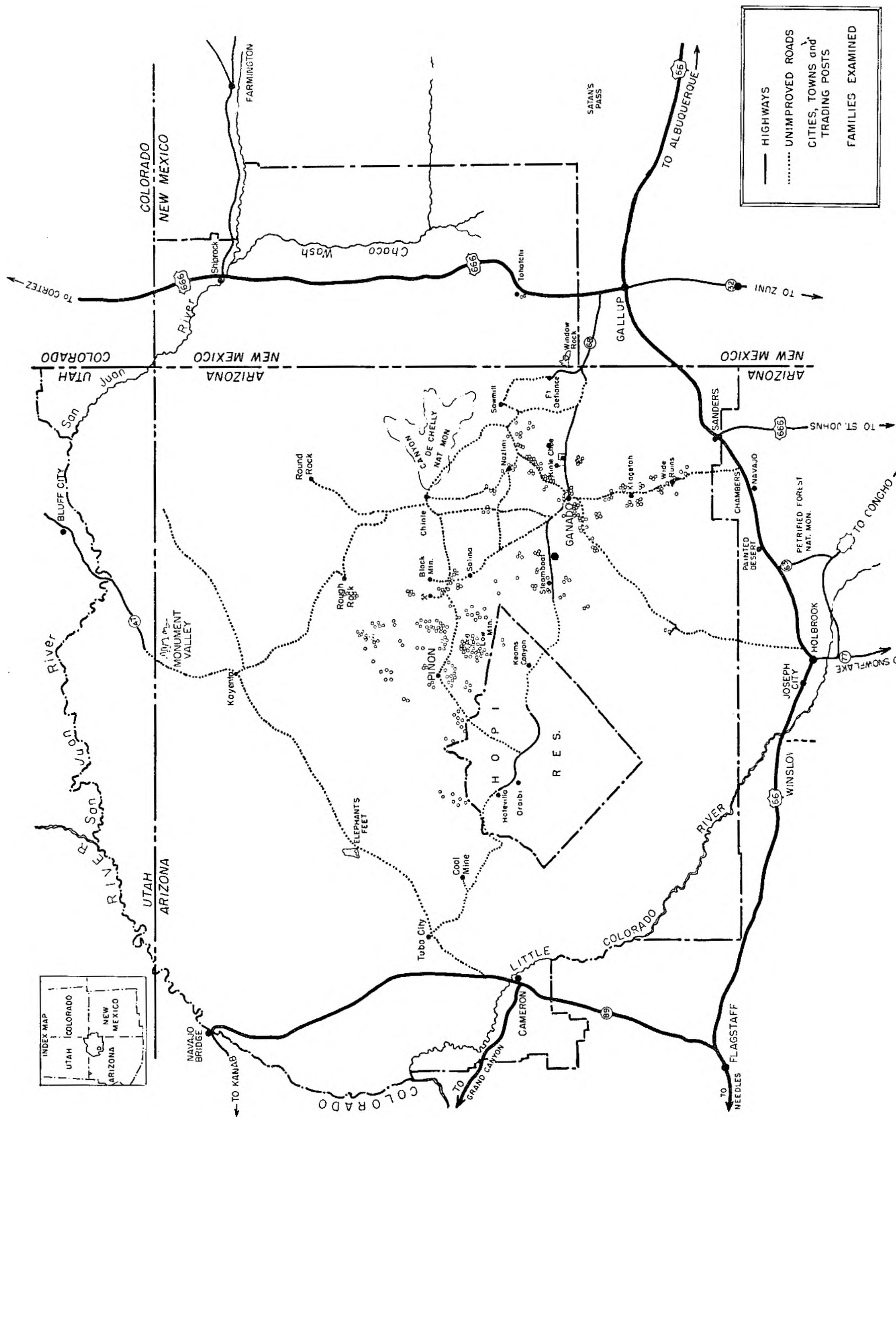

Fig. 1 The Navajo Reservation.

BACKGROUND

In 1864 the Navajo were overrun in Canyon de Chelly. Twenty-five thousand of "The People" made the long walk from Arizona to Fort Sumner, New Mexico, where they were held in captivity until 1868. Seventy-five hundred survived imprisonment and were returned to their old lands. Now, 88 years later, in spite of high rates of infant and preschool mortality, endemic disease, and indescribable hardships, their number has increased to in excess of 78,000. This increase is evidence of the admirable resourcefulness and sturdiness of the Navajo.

The Navajo Reservation (fig. 1) consists of over 15,000,000 acres of semi-arid, eroded land — mainly in Northeastern Arizona, but extending into the neighboring states of New Mexico and Utah. The population is scattered over these arid lands — the size of West Virginia — living in isolated family groups. Villages and towns do not exist; a trading post is not an urban center. The nearest equivalents to settlements are located around government stations and missions. The majority of the Navajo still live in a primitive hogan; only 20% of the population speak English, and a much smaller percentage are professed Christians. Communication and transportation facilities and roads are underdeveloped so that most residents are isolated and the region is dependent to an unusual extent upon home-produced fresh and dried foods and meats.

The initial impetus to the present evaluation of the nutritional status of the Navajo stemmed from unpublished observations made by one of us (C.G.S.) in relation to the apparent low incidence of malignancy among the Navajo. This impression was based on the experience at the Sage Memorial Hospital at Ganado, Arizona, and an analysis in 1953 of the records of all hospitals on the Navajo Reservation. In this latter study of 60,000 records examined, only 208 patients had a diagnosis of malignancy. This indicates a much lower incidence than is expected in the general population, and confirms similar observations made on the Canadian Indian by Warwick and Phillips ('54). Speculation as to environmental influences possibly contributing to these findings led to a consideration of nutrition. An imtial study was begun in the summer of 1954 in the areas around Ganado and Rough Rock, Arizona. These were indecisive, but clearly indicated a deficit of basic nutritional information of "The People." The present study was designed to supply some of this basic nutritional information concerning the Navajo and was made in the area around Ganado and Pinon (fig. 1).

TABLE 1

Navajo agency 1950 population by age and sex[1]

AGE	MALE	FEMALE	TOTAL
Under 5	5,561	5,373	10,934
5–9	5,021	5,139	10,160
10–14	4,535	4,126	8,661
15–44	12,538	13,188	25,726
45 +	4,789	4,004	8,793
TOTAL	32,444	31,830	64,274

[1] Source: U. S. Bureau of the Census (1953).

POPULATION

The population estimates from the 1950 census (U. S. Bureau of the Census, '53) are given in table 1. Certain limitations in the accuracy of these have been noted by Hadley ('55) and Kraus ('54), but they stand as the best estimates available.

The limited educational background and the high illiteracy rate are evident from the data on years of school completed by persons 25 years of age and over in 1950 (table 2). The major occupational groups of employed individuals are very nearly entirely non-professional in category and most of the employed individuals are engaged in farming and stock raising, with a smaller group serving as laborers and operatives (table 3). Data on income are probably of doubtful validity, but for 1949 almost half of the persons 14 years old and over were listed as having no income, and 76% of those reporting had an income of less than $500 per year.

Hadley ('55) has emphasized the under-reporting and uncertainty of vital statistics on the Navajo. With the limited statistics vailable the infant mortality rate per 1000 live births amounts to 139.4, or 5 times that of the United States average; the death rate from tuberculosis is 1.9 per 1000, or 8 times that of the United States average; from enteritis, gastritis, and related causes, 1.3 per 1000, or 25 times that

TABLE 2

Years of school completed, 1950, by Navajo Indians, aged 25 years and older [1]

YEARS OF SCHOOL COMPLETED	MALE	FEMALE
0	5,540	5,595
1 to 4	1,150	670
5 to 7	1,150	895
8	465	335
9 to 11	635	540
12	510	400
13 to 15	65	45
16 or more	10	15
Not reported	1,135	1,115
TOTAL	10,660	10,610

[1] Source: U. S. Bureau of the Census (1953).

TABLE 3

Major occupational groups of employed Navajo Indians, 14 years old and over, 1950 census [1]

	MALE	FEMALE
Professional, technical, and kindred workers	243	75
Farmers and farm managers	4,586	688
Managers, officials and proprietors except farm	146	12
Clerical, sales, and kindred workers	168	86
Craftsmen, foremen, and kindred workers	636	10
Operatives and kindred workers	1,290	2,205
Private household workers	15	179
Service workers, except private household	127	368
Farm laborers, unpaid family workers	1,967	1,029
Farm laborers, except unpaid, and farm foremen	711	134
Laborers, except farm and mine	1,922	27
Occupation not reported	333	100
TOTAL	12,144	4,913

[1] Source: U. S. Bureau of the Census (1953).

for the United States. The leading causes of death among the Navajo in 1950 were, in order: tuberculosis: enteritis, gastritis, and related diseases; "ill-defined and unknown"; diseases peculiar to infancy; influenza and pneumonia; and accidental deaths. The three leading causes of death in the general population of the United States (diseases of the heart, malignant neoplasms, and vascular lesions affecting the central nervous system) were not among the 6 leading causes of death for the Navajo.

The sociologic and anthropologic aspects of the Navajo have been reviewed on many occasions. The reader is referred to several excellent monographs (Kluckhohn and

TABLE 4

Closing livestock inventory 1953, Navajo reservation

	NUMBER OF LIVESTOCK	NUMBER OF FAMILIES OWNING
Beef cattle	17,078	1,445
Dairy cattle	0	6
Sheep	387,601	6,575
Swine	0	0
Horses and mules	37,335	8,500
Poultry	0	0
Goats	68,028	5,411

Leighton, '51; Leighton and Kluckhohn, '48; Underhill, '53; Underhill, n.d.) for additional background so pertinent to one's overall appreciation of "The People."

FOOD PRODUCTION

Title to the Navajo Reservation is held in trust by the United States Government "for the use and benefit of the Navajo Indians." Supervision and protection of the lands are the responsibility of the U. S. Government; the lands are held in common by the members of the Navajo Tribe, are non-taxable, and cannot be sold or disposed of without consent of the Tribe and the Congress of the United States. In addition to the 15,107,983 acres of tribal lands, upwards of another 1,500,000 acres are available to the Navajo (665,021 acres of trust allotted, 4,678 acres of fee patent grazing land, plus 883,891 acres of grazing land in New Mexico).

The agriculture is primarily a combination of sheep-goat grazing and cereal production. The 1953 agricultural income of some $5,000,000 was predominantly from sheep. Other livestock of economic importance are indicated by the figures (table 4) from the Extension Report, 1953, Navajo Reservation.

Estimates of the cereal and food crop production are given in table 5. It is apparent that the consumption of home-produced cereals and other food crops is insufficient to support the population, and therefore, that large "imports" of basic cereals must be the rule. The deduction may be made that home-produced fruits and green vegetables are in short supply for the population.

To obtain a picture of the food supply over the recent past, it is necessary to examine the agricultural trends of the last decade or more. These trends reflect at least three major influences: (1) an intensive program of resource development activity; (2) a 7-year period of drought; and (3) the changing economic status of the Navajo, resulting from employment off of the Reservation, the influence of military service experience, and so forth.

A great decrease in the acreage "cropped" has occurred since 1941. That this is especially striking from 1941 to 1951 is seen from the tabulation (table 6) from the report "Resources Activities for the Window Rock Area, Navajo Reservation, 1953."

The trend in the livestock population over the interval from 1936 to 1952 is given in figure 2.[3] A sharper decline in numbers between 1930 and 1936 (Spicer, '52) was a result of the program of reduction in herd size instituted to protect against overgrazing. Except for cattle (beef) the livestock popula-

[3] The amount of forage required to support one sheep for a period of 12 months is expressed as one sheep unit. On the Navajo Reservation one goat unit is equivalent to one sheep unit, one cattle equals 4 sheep units and one horse, 5 sheep units.

TABLE 5

Production and consumption of home produced food crops on the Navajo reservation

(Taken from Extension Reports of year indicated)

YEAR	USED FOR FOOD					PRODUCED				
	1941	1942	1951	1952	1953	1941	1942	1951	1952	1953
Grain (bu.)	213,183	310,401	27,344	109,212	37,746	272,865	529,525	75,066	317,909	122,456
Corn (bu.)	198,777	304,208	26,424	107,833	36,670	253,318	508,697	70,422	309,460	116,291
Wheat (bu.)	14,406	6,193	920	1,379	1,076	18,993	18,180	3,532	6,078	3,288
Oats (bu.)	.....	......	.....	......	.....	554	2,648	1,112	2,365	2,877
Potatoes (bu.)	14,082	91,343	926	5,276	2,535	16,049	113,041	991	7,428	7,338
Beans (cwt.)	1,921	1,728	306	1,140	535	5,286	4,216	2,088	3,587	3,483
Squash (ton)	2,376	1,441	123	646	289	2,376	1,451	149	926	349
Melons (ton)		286	706	1,928	784		668	1,007	2 530	1,344
No. of families in area	8,333	9,506	12,536	12,737	13,018					

TABLE 6

Acres of irrigated and dry farm land planted to crops

YEAR	IRRIGATE	DRY
1941	19,006	31,517
1942	17,833	29,249
1943	16,029	26,733
1944	16,734	19,676
1945	17,164	16,344
1946	15,141	16,926
1947	15,870	15,937
1948	17,472	15,086
1949	18,160	15,651
1950	12,076	6,884
1951	9,482	8,886
1952	17,280	19,440

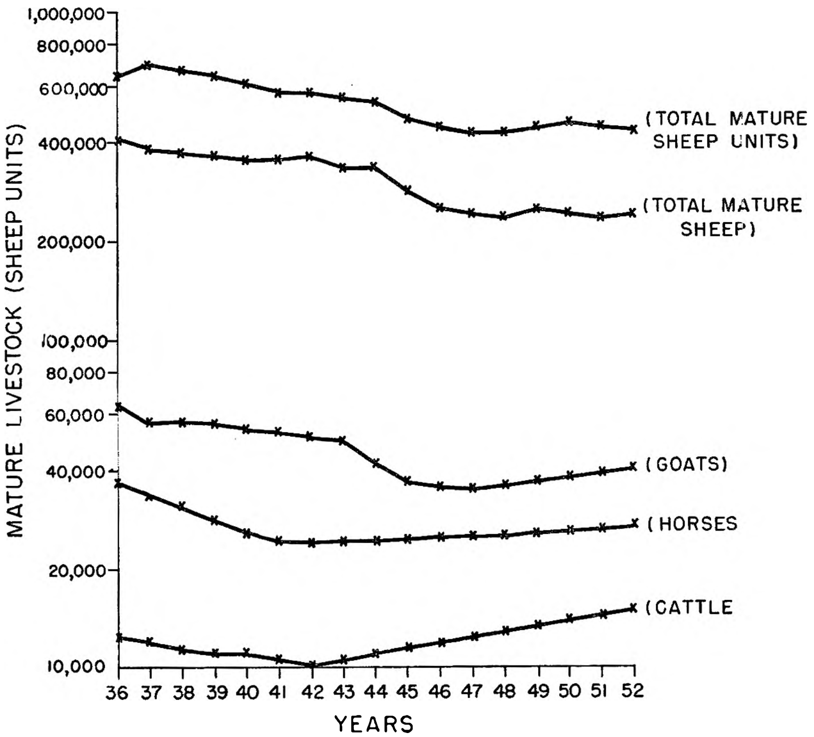

Fig. 2 Mature livestock on Navajo reservation, 1936 to 1952.

TABLE 7

Annual home consumption of meat produced on the reservation

(Data taken from Extension Reports for years indicated)

Expressed as $\frac{\text{pounds consumed}}{\text{families producing}}$

	1941	1942	1947	1948	1949	1950	1951
Beef cattle	994,828 / 700	114,500 / 1,217	255,575 / 1,304	245,265 / 1,320	231,139 / 1,347	246,122 / 1,385	72,865 / 1,420
Sheep	3,216,708 / 6,210	5,822,180 / 5,324	3,471,181 / 6,862	3,191,238 / 6,756	3,242,151 / 6,819	3,520,136 / 6,972	3,001,517 / 6,848
Goats	1,274,800 / 6,210	1,738,765 / 4,639	620,890 / 5,457	1,148,621 / 5,267	1,109,310 / 5,374	942,636 / 5,499	1,004,121 / 5,512
Horses and mules	403,800 / 7,202	490,000 / 6,946	91,900 / 8,366	634,650 / 8,309	537,719 / 8,282	289,275 / 8,489	457,315 / 8,492

tion of the Reservation has remained steady for the past several years, and it appears that the home consumption for 1947 to 1951 was at a reasona ly constant rate. Data on meat production are given in table 7. Meat, in contrast to cereal and field crops, seems more stabilized as a home-produced commodity.

Review of these production and consumption trends indicates that the basic pattern of the diet has shifted toward less home-produced grains, potatoes, squash and melons, beans, and somewhat less meat. The latter is stabilized at a reasonably satisfactory per capita level of consumption. The types of meat eaten have remained similar over the years — sheep, goat, beef and horse — in order of decreasing quantity. The decrease in production primarily reflects drought conditions during this long period, and affects both production figures and gross farm income.

The change in reservation-produced food supply is illustrated by comparing the production and home-use figures for grains and other food crops in the 1952–1953 Extension Reports with similar figures in 1941 and 1942 (table 5). Despite year-to-year variations which reflect climate and other agricultural conditions, it is obvious that much less home-produced food was available for the diet than was true some 12 to 15 years ago. This trend is particularly noteworthy for corn, the traditional staple food, and the shift is in keeping with the impression of a general increase in the use of wheat flour purchased from the trader.

Data on the home consumption of meat per family unit are given in table 7. It is probably not valid to assume that consumption was restricted to the producing family, but a concept of the per capita meat consumption is obtained by noting that in 1951 a total of over 4,500,000 lbs. of meat was consumed at home. This represents a daily per capita consumption of some 1/6 lb. This level of consumption may be lower than that of some years (see table 7). A comparison of the 1939 Trading Statistics with the 1953 Extension Report shows that the consumption in small animal units has decreased. Thus, in 1939, the 8,383 families consumed a minimum of 55,618 sheep and 40,859 goats (figures based on pelt purchase by trader, hence minimal) [4] and in 1953 the 13,018 families consumed 69,574 sheep and 41,747 goats. Herd improvement during this interval may partly equalize the actual meat consumption more nearly than is indicated by these figures based on animal units.

PLAN OF STUDY

This study describes the dietary habits and nutritional status of the Navajo in two contrasting regions, viz. the areas around Ganado and Pinon, Arizona, and defines the additional information necessary to obtain a valid picture which could be generalized to the remainder of the population of the Reservation.

The region around Ganado has been considerably influenced by the white culture due to the long contact (since 1904) with the Ganado Presbyterian Mission, its school and hospital, and St. Michael's Mission. Three long-established trading posts are at Ganado and the center is readily accessible to Gallup, New Mexico, and Fort Defiance, Arizona. Pinon, on the other hand, is relatively inaccessible over unimproved roads and has had no medical facility closer than Ganado or Keams Canyon. Pinon has two trading posts and a small mission. The penetration of white culture is limited. Both Ganado and Pinon are sites of recently constructed public schools.

During the months of June and July, 1955, nutrition study clinics were established at Ganado and Pinon (fig. 1). The clinic staff included physicians experienced in nutritional surveys, nutritional biochemists, nutritionists, nurses, interpreters, secretaries, drivers, and other supporting personnel. The work was initiated at Ganado on June 1. The initial period at Ganado served to orient all workers, and any member

[4] The 1939 Annual Extension Report shows 219,434 sheep and goats butchered, representing 4,504,580 pounds of meat for home-consumption. In addition, there was consumed 523,725 pounds of beef and 328,510 pounds of horse and burro meat.

of the staff who joined the study at a later date underwent an orientation period at Ganado. Some interchange of personnel between the two centers was carried on in order to familiarize key personnel with the situations existing in the two study areas.

The main laboratory was maintained at Ganado, with a field unit operating at Pinon. This permitted uniform control of the biochemical methods and made for the most efficient use of trained personnel and supplies. Laboratory studies included the estimation of the concentration of the following constituents of blood which are influenced by nutritional status: hemoglobin, total serum protein, ascorbic acid (vitamin C), carotene, vitamin A, and total serum cholesterol.

Physical examinations were made by the physicians who had worked jointly for preliminary periods. Standardized check-lists of findings on punch cards identical with those used at Norris Point, Newfoundland (Goldsmith et al., '50) were used. Each record was signed in order to permit analysis for any examiner bias. Medical histories were taken by a nurse-interpreter, by an interpreter coached in the recording of histories, or by the physician through an interpreter. Detailed medical histories were not obtainable on every subject. The physical examinations were made primarily at Ganado and Pinon, but the physicians at Ganado held several mobile clinics at schools, trading posts, and lumber camps in that vicinity.

Each subject, separately or in a small family group, was interviewed by the nutritionist, employing an interpreter where necessary. Lack of confidence in the reliability of quantitative estimates of food consumed by individuals led to the adoption of a descriptive inquiry to obtain information on family use habits and sources of foods. Visits to families were made by the nutritionists and others of the staff. The families so visited included not only individuals attending the clinics, but others as well. Visits were made in company with the Director of the Good Shepherds Mission, home demonstration agents, various Navajo nurses, interpreters, and drivers. Numerous observations were made at trading posts and discussions held with traders, as well as frequent contact with school teachers and public health nurses throughout the area. The staff of the Division of Resources of the Indian Service at Window Rock, Arizona, generously assisted through helpful discussions and by providing access to their extensive records of food production and land use on the Reservation. By combining the information so obtained a valid description of the broad dietary patterns of the population is possible.

Prior to initiation of the clinics, publicity was given to them through radio broadcasts in the Navajo language, posters at trading posts, and contact with various tribal leaders. Persons voluntarily coming to the clinic were examined and requested to return with their families. Drivers and staff made numerous personal contacts with families and transported many to the clinic. By judicious use of available local knowledge of the approximate economic position of families and of their geographic location (employing detailed district maps available for school purposes), an effort was made to obtain a representative sample of the population. The sample is biased, however, by the uncontrollable effects of refusal or willingness to participate, by the attendance of those who recognized a need for medical care (of especial influence at Ganado), and by other less identifiable factors. Nevertheless, it is our opinion that the sample provides a useful, if not absolutely representative sample of the population, and that it would be difficult under practical conditions to obtain a more representative group. The composition of the sample and a comparison of it with the 1950 census data are given in tables 8 and 9. The emphasis on adults, and especially those over 45 years of age, was a result of the interest in studying the "cancer age."

The geographical location of the families participating in this survey is shown on the accompanying map (fig. 1). Large areas of the Reservation are not included in the sampling, hence the generalization permitted is limited and additional sampling is needed.

Measurements of the growth of children provide a valuable index of nutritional status, especially when the data extend over a period of a year or more. Observations on height-weight-age were made available to us by several of the schools and by the public health nurses. Data on school feeding were also obtained, including menu patterns and school purchases. These will be reported separately.

TABLE 8

Number of individuals in the Navajo study

AGE	GANADO, ARIZONA			PINON, ARIZONA		
	Male	Female	Total	Male	Female	Total
years						
5–9	27	46	72	40	72	112
10–14	31	39	70	35	40	75
15–44	84	208 [1]	292	71	192 [1]	263
45+	77	133	210	78	73	151
TOTAL	219	426	645	224	377	601

[1] The reproductive status of the women aged 15–44 was:
Ganado: 29 pregnant, 44 lactating, 135 neither;
Pinon: 22 pregnant, 73 lactating, 97 neither.

TABLE 9

Distribution of individuals by sex and age

A comparison of Navajo study sample and census statistics

AGE	1955 SURVEY SAMPLE			1950 NAVAJO POPULATION		
	Males	Females	Total	Males	Females	Total
years	%	%	%	%	%	%
5–9	15.1	14.7	14.9	18.7	19.4	19.1
10–14	14.9	9.8	12.4	16.9	15.6	16.2
15–44	35.0	49.8	42.4	46.6	49.9	48.2
45+	35.0	25.7	30.3	17.8	15.1	16.5
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0

SUMMARY

Reflection on the low recorded incidence of malignant neoplasms among the Navajo indicated that nutrition as an environmental factor might bear on the observations. Ac-

cordingly, an evaluation of the nutritional status of a group of Navajos living on the reservation was made during the summer of 1955. The study was designed to supply basic nutritional information concerning the Navajo Indian in the areas around Ganado and Pinon, Arizona.

From 7500 individuals in 1868, the Navajo population has increased to in excess of 78,000 despite high rates of infant and pre-school mortality, endemic diseases and indescribable hardships. Among these people educational opportunities and background have been limited. A high rate of illiteracy continues. The earned income of the majority of "The People" has been reported as less than $500 per annum.

Agriculture is based on a combination of sheep-goat grazing and cereal production. The home production of fruits and green vegetables is very limited. A comparison of the agricultural trends of the last two decades reflects the intensive program of resource development, a 7-year drought, and the changing economic status of the Navajo. As a result the production and consumption of their basic diet has shifted toward less home-grown grain, fruits, and vegetables. However, meat has remained reasonably stabilized and satis factory.

Two contrasting areas of the reservation were selected for study. One around Ganado reflected considerable influence of the white man's culture and was readily accessible to urban centers, whereas the region around Pinon has had more limited penetration of the white man's culture, and is relatively isolated because of unimproved roads and distant medical facilities.

Dietary appraisal, biochemical assessment and physical examinations were performed on 1246 subjects. This sample is adequate to reflect age, sex, locale and gestational trends. However, large areas of the reservation are not included; hence, generalization is not permissible for all areas on the reservation.

II

DIETARY PATTERN

INTRODUCTION

Several compilations identify foods used by the Navajo (Franciscan Fathers, '10; Elmore, '44; Castetter, '35; Castetter and Bell, '41; Underhill, n.d.; Matthews, 1886; Vestal, '52; Whiting, '39; Jones, '42; Steggarda and Eckardt, '41; Wyman and Harris, '51; Young, '38). These treat primarily with the uncultivated plants. Hill ('38) has provided an excellent account of the agricultural and hunting methods of this tribe. Interspersed in each of these publications are descriptions of food preparation. Additional recipes and descriptions of food preparation are given by Carpenter and Steggarda ('39), Steggarda and Eckardt ('41), in mimeographed pamphlets by Young ('34, '36a, b), and by Roberts ('51), Bailey ('40) and Wetherhill ('46). The only semi-quantitative studies of the diet are those of Carpenter and Steggarda ('39). These studies are insufficient to permit any generalization. Since the patterns of food procurement and of diet of the modern Navajo have not been well described, we have endeavored to obtain these for the regions of the present investigation.

Our initial inquiries were designed to obtain, by recall, estimates of the quantities of foods consumed by individuals. This proved impractical when attempted through an interpreter and under the conditions of living and customs pertaining on the Reservation. Hence, qualitative information was accumulated on food production, storage, and the frequency with which certain items are included in the diet; purchase lists were obtained from trading posts, and inquiry made as to the frequency of eating and source of foods by families in the survey; discussions were held with informants (Navajo personnel, teachers, mission workers, traders, merchants, agricultural and home demonstration workers, Public Health personnel, museum personnel, and so on), and observations made in some of the hogans, at ceremorials, and at various gatherings (sheep dipping, rodeos, and other exhibitions).

Formerly the Navajo subsisted chiefly on corn, wild game, mutton or goat meat (after the introduction of sheep and goats by the Spaniards), and a large variety of wild plants. Small patches of beans, squashes, and melons constituted the gardens. The usual drink was water, a continually scarce commodity and one which today must often be hauled great distances in barrels. A variety of native herbs were used to make occasional drinks.

Much of the early uncultivated food has been given up. The tedious harvesting of grass seeds is seldom practiced, wild game is now scarce and displaced by mutton, goat, horse and some beef. Squashes, melons, pumpkins, and some beans and potatoes are grown for home consumption. Corn is widely grown, but as the staple item in the diet is largely replaced by wheat flour purchased from the trading post. Herb beverages have been displaced by coffee, tea and soda pop. The extent of the break from the traditional and some of the influences responsible for the changes may be appreciated from the following observations.

Food is obtained from trading posts, from neighbors or is produced at home. Quantitatively there is no large dependence on wild plants as sources of food. That such plants are still consumed both in the fresh and preserved state, how ever, is evidenced by the fact that a member of the staff, Mrs Pauline McKinley, procured examples of 20 such edible foods from one region. Very little wild game was reported as eaten, and that mentioned included only rabbits, prairie dogs, venison (a few families only) and porcupine. Pigs and fowl are most uncommon. The wild foods were identified as follows:

"WILD SPINACH" (bee weed) Waa'. The tender stems and leaves are gathered in late June and early July. They are washed, boiled and drained three times to remove the bitter taste. The cooked stems and leaves are placed on the roof of the hogan to dry or hung by a string on a line to dry in the sun. The dried leaves and stems are boiled again before eating. Often added to mutton stew.

WILD MOUNTAIN TEA (C'il dehi). This plant is gathered in June and July, dried, arranged in tied bundles about one inch in diameter and 5 inches in length. Each bundle is called "one boiling." Tea is made by boiling a "bundle" in a half gallon of water for about 20 minutes. It is used as a hot beverage, adding sugar at drinking time.

"WILD MOUNTAIN TOBACCO" (Tzi nát'ooh). July is the month in which this plant is gathered. It is dried by spreading it on the hogan roof or tied in bunches and hung in the sun. It is crushed in the hands to the consistency of commercial tobacco and stored in bags. Rectangular pieces cut from dried corn husks (2″ × 1″ in size) are used for "cigarette papers" to contain the tobacco for smoking. Some of the older Navajos say they have a preference for this tobacco, but that it is rarely available any more. Smoking the wild tobacco supposedly helps to drive away the evil spirits.

MARIPOSA LILLY ROOT ('Aaltsînne). The root bulbs are occasionally included in the Navajo's present-day diet. The plants are found in most parts of the reservation. The bulbs are gathered in the spring before blossom time and are eaten raw.

WILD CARROT ROOTS (Chanšh-têzi). The plant above the ground is a single stalk with fern-like leaf of a blue-gray color. The roots are dug in April and eaten after a bark-like covering is removed. The root is brittle and of a fibrous nature.

DRIED FRUIT OF THE WIDE LEAF YUCCA (Hush-K'ōn). This plant is sometimes called Spanish Bayonet or Banana Plant. The fruit is included in the Navajo's present-day diet, but is less plentiful than formerly. Sheep and cattle are fond of the fruit and leaves. Consequently, today it is found in places inaccessible to these animals. The fruit is shaped like a banana, with pulp and black seeds inside a shell-like covering. It is picked soon after the blossoms fall off. Fruit, as soon as it is picked, is put in a bed of hot ashes to cook. Cooking time is about an hour. After cooking, the "banana" is cut in half and the seeds are scraped out. The covering is then pulled away from the "meat." Some of the "meat" is eaten immediately and the other is dried on a flat surface in the sun for future food use. The dried pulp has a flavor similar to that of dried figs.

NARROW LEAF YUCCA FRUIT (Nîdo-dlohî-). The fruit of this plant is used as that of the wide-leaf yucca.

WILD POTATOES AND CLAY (Nîmŭsī-glêsh). The wild potato is a root bulb which is dug in July. It is boiled and the tough outer skin removed, then eaten with a chalk-like white clay. Without the clay the potatoes have a bitter taste. The wild potatoes are increasingly rare.

PRICKLY PEAR FRUIT (Whosh). This fruit is gathered either in late August or early September when it is ripe, a dark red in color. A forked stick is used to remove the fruit from the cactus plant. The prickly thistles on the fruit are removed by rolling in the grass. They are either eaten as they come from the plant or dried for later use Only the pulp of the fruit is eaten, the seeds and outer skin being removed. It has a sweet flavor.

SOUR BERRIES (Chil-chinbinu). These berries are usually picked in late June or July. Sometimes they are eaten raw soon after picking Some are stone-ground into a paste and mixed with the calk-like white clay. The clay reduces the extremely sour taste of the berries. Occasionally this paste mixture is dried.

WILD CURRANTS (k'înjîlahi). This small mild flavored pulpy fruit is a deep orange-red in color and is ripe in July. It is eaten raw, sometimes dried.

ORANGE BERRIES AND CLAY (hush-ĉe-dan and glésh). These berries are used in the same way as sour berries are. The clay is added to improve the flavor.

SALT WEED (dî k'onzi). This plant is rarely used in modern times to season food. However, it is used now for the animals. It is found on the plains and in the valleys where the soil is very alkaline. The animals are driven to the areas where the salt weed grows about once every three months and allowed to graze.

WILD SPINACH SEED (Cloh-dai-bĭ-nah). The plants bearing seeds are gathered in August. The seeds are stone-ground into a fine meal. This meal is mixed with boiling water to make a mush and is eaten as a cereal. Sometimes it is also mixed with cornmeal to make mush.

GRASS SEEDS (tlos-tsé). These seeds are used the same way as the wild spinach seed is used.

DRIED CURRANTS AND CLAY (Tsîdzeh-glesh). This is the dried form of currants. The berries are stone-(matate) ground, mixed with clay and, sometimes, coarsely ground cornmeal and boiled until it forms a very thick paste. This paste as spread about an inch thick on a flat rock to dry in the sun. It is broken off in small pieces after it is thoroughly dry for eating.

WILD ONIONS (T' loh chin). The bulbs are small in size like that of the mariposa lily. They are gathered in June or July and are eaten raw or cooked with potatoes and in mutton stew.

JUNIPER BERRIES (T'sî-dz eh). The berries are picked in August or early September. Some are eaten raw, others are toasted, stone-ground into a meal-like substance and mixed with the white clay. Some water is added to this batter. Cakes are made, dried in sun on a flat rock and used as needed.

ACORNS (Tsé-ĉîl-bĭ-ñah). These acorns grow in the timber areas on a tree which is commonly called the scrub oak. They are gathered in the fall soon after the first frost. They are roasted in either a bed of ashes or in a pan on top of the stove. They are stored in paper bags for use in winter. Occasionally some of them are stone-ground after roasting and mixed with cornmeal for making bread.

PINYON NUTS (Neesh-ĉhéé). They grow on the pinyon trees and are gathered in the fall when they mature. Some are sold to the trading post and others are kept for home consumption. A few families report buying them occasionally at the store.

TRADING POSTS

Trading posts handle a variety of canned and packaged foods as well as vegetables, meats, and other perishables. Most posts have a refrigerated counter for vegetables and some have refrigerators for meat storage. Fresh vegetables common only for sale are carrots, cabbage, head lettuce, potatoes, onions and fruits (including apples, bananas, oranges, and, in season, apricots, plums, bing cherries, peaches, pears, grapes, and melons). Staples are primarily flour, baking powder, salt, cereal, shortening, and sugar. Canned evaporated milk is sold almost to the exclusion of other milk.

Traders have reported an increased sale of meats in recent years. The meat is either locally grown and killed or purchased from packers in the larger cities such as Phoenix. In the trading posts no organ meats were on display. This is in contrast to the usual practice of consuming practically all of the viscera of home-slaughtered animals.

White wheat flour is the most popular staple and is usually purchased in 25-pound sacks or larger. Most of the flour is enriched. For example, only one unenriched brand was found at the two trading posts in Pinon. Oatmeal, cream of wheat, and corn flakes are the most popular cereals. Both lard and vegetable shortening are purchased in three- to 5-pound cans. But little butter or margarine is sold, preference being given to the former. A small number of canned vegetables are purchased in limited variety. Canned fruit cocktail, pears and peaches are popular but "luxury" items. Fresh fruit is purchased in season regardless of the price. Such fruits include watermelons, cantaloupes, peaches, apricots, grapes, bing cherries, and pears. These are usually bought in small quantity to be consumed at the time of the shopping trip or immediately upon return to the hogan.

Breads available at the trading posts include sliced enriched white bread, French bread, brown "whole wheat" bread, sweet rolls and coffee cakes. Sweet rolls, pies, sweets, cookies, preserves, sugar and candy are in increasing demand. Soft drinks, especially in the 12-ounce and quart size bottles, are consumed in large amounts, particularly during the summer.

Some seasonal pattern in grocery purchases is evident. There is an increased sale of rice, raisins, and soups in the winter, of milk in the spring and of fruits and soda pop in the summer.

TABLE 10

Frequency of purchase of food items in 47 grocery orders observed at random

Ganado area, July, 1955

FOOD	NO. OF ORDERS INCLUDING THE FOOD
Sliced bread	20
Fresh fruit	18
Canned fruit or juice	17
Bologna, spiced ham, wieners	15
Shortening	15
Potatoes	14
Pop	14
Candy	13
Coffee	13
Sugar	12
Flour	11
Crackers	11
Cookies, donuts, jelly rolls, Boston cream pies	10
Milk	10
Mutton	10
Baking powder	8
Plain salt	8
French bread	7
Canned vegetables	7
Cabbage	6
Canned meats or sardines	6
Bacon or salt pork	[illegible]
Sweet rolls, coffee cake	5
Ice cream	4
Rice	3
Iodized salt	3
Chile peppers	3
Tea	3
Noodles, macaroni	2
Koolaid	2
Cheese	2
Oatmeal	2
Raisins, chewing gum, ketchup, potato chips, pancake mix, beef, waffle syrup, pinto beans, cocoa, onions, pork chops, soup, buns, each	1

The Navajo purchases from the trader "on account," the accounts being carried until lambing or wool season and sometimes as long as a year. The credit rating of an individual may be determined by the approximate number of sheep which he owns.

Frequency of shopping trips to the trading posts varies with distance, transportation, condition of the roads and weather, as well as with various domestic situations. Families nearby may shop daily or two or three times a week. In the Ganado area only a few families reported shopping as infrequently as once a month. At Pinon some 50% of the families reported shopping once a week, 20% every two weeks, another 20% once a month, less than 10% twice a week, and two of the 167 families every two months.

The trading post of choice is usually the nearest one, but approximately 50% of the families in the Pinon group shopped at more than one post.

The basic purchase pattern at Pinon was flour (usually a 25-pound bag, enriched), lard or vegetable fat for shortening, baking powder, potatoes, coffee, sugar, salt. Other items such as fruit and vegetables, either canned or fresh, and meat were then purchased as money allowed. Examination of the grocery orders in trading posts in the Ganado-Nazlini area indicated a similar pattern with some tendency toward smaller, more varied purchases. An analysis of 47 consecutive food purchases in the Ganado region revealed the purchase pattern given in table 10.

HOME PRODUCTION OF FOODS

The sparsity of gardens and orchards referred to previously was verified by inquiry into home-produced foods. The most frequently produced foods include corn, pinto beans, pumpkin, squash, watermelon, and muskmelon. Home production of food reported by 238 families in the Ganado area is indicated in table 11.

Production of several foods by one family is unusual. None of the families of the Pinon area produced more than 6 kinds of food and 34 of the families raised no vegetables, fruits or cereals. There is obviously less variety among the foods produced in the Pinon area.

FOOD PRESERVATION AND STORAGE

Drying and salting continue as the most commonly used methods of food preservation. Home refrigeration is practically unavailable. Root cellars are in fairly common use, but the foods suitable to such storage are restricted to the root crops, melons, and pumpkins. Bags or strings of dried foods and dried salted meats were commonly noted hanging from the rafters of the hogan.

TABLE 11

Home production of foods by 238 families in Ganado area and 167 families in Pinon area

	NO. OF FAMILIES PRODUCING THE FOOD	
	Ganado	Pinon
Corn	216	129
Beans	132	42
Squash [1]	125	89
Pumpkin [1]	33	89
Watermelon	96	91
Other melons	35	18
Potatoes	28	13
Carrots	12	1
Peaches	12	1
Other vegetables or fruits	[2]	

[1] Pumpkin and squash not always clearly distinguished by informant.

[2] No other vegetable or fruit raised by more than 7 families at Ganado and one family at Pinon.

COOKING PRACTICES

Hogans usually contain wood-burning stoves with ovens. Camp-fire cooking is popular, especially in the summer. Foods may be baked over coals, in coals, on the surface of the ground, in the ground, in a range oven, or in a separate "bee-hive" type of bread oven. Roasting is carried out over coals or in an oven. Frying or boiling is done on stoves or over camp-fires. Cooking equipment usually consists of a grate or rack, iron frying pans, and enamel stew pots, coffee pots, and occasionally a Dutch oven or roaster. Enamelware cups and bowls, and teaspoons, tablespoons and forks are the common utensils for eating. Metates[5] (see frontispiece) were observed in only about one third of the homes visited. Meals may be served on rough home-made tables for eating or on an oil cloth square on the ground. Canned foods are often eaten directly from the container. Stews are customarily eaten directly from the common pot.

BASIC MEAL PATTERNS

The Navajo usually eats three meals a day, but this may vary from two to 4. As a symbol of hospitality food is prepared whenever company arrives. The sheep herder may or may not carry a lunch with him. In many instances drinking water is not carried and he drinks wherever water may be found for the animals. If carried, lunch may consist of fried bread or tortillas and meat, sandwiches made of bakers' bread, hard boiled eggs, fruit, or soft drinks, coffee or water.

Menus for a given meal show little variety from day to day. Mutton (roasted, fried, or stewed with potatoes and onions), bread and coffee or tea serve as the basic items of the menus. Typical basic meal patterns given at interview are shown in table 12.

Large quantities of bread are eaten. Tortillas made of wheat flour and fried bread are the most common home-made breads. When bakers' bread is served 4 to 6 slices will usually be eaten per person. Two kinds of bread may be served at a meal.

Trips to the trading posts or to town constitute an occasion, and meals are made of foods bought from the store. Such

[5] The metate is the hollowed-out understone which is used in conjunction with the mano or upper "manual" stone as a primitive mortar-pestle form to grind grains. The interested reader is referred to John Storch and Walter D. Teague, Flour for Mano Bread, University of Minnesota ('52) for an account of the origin and use of the metate.

lunches include soft drinks, sweet rolls, Boston cream pies, cookies, bologna, candy bars, ice cream, and fruits and melons in season. At ceremonials, rodeos, sheep dippings, and similar gatherings meals are cooked camp-style and consist of mutton, roasted corn, tortillas or bakers' bread and coffee.

TABLE 12

Illustrative basic meal patterns of the Navajo

	THE FAMILY OF MEANS [1]	MODERATELY WELL-TO-DO FAMILY [1]	INDIGENT FAMILY
Breakfast —	Mutton usually, or fried potatoes Oatmeal with evap. milk and sugar Tortillas Coffee with evap. milk and sugar	Fried potatoes or oatmeal or other cereal Indian biscuit or fried bread Coffee with evap. milk and sugar, or tea with sugar	Fried potatoes with onions Tortillas Coffee with sugar
Noon meal —	Stew with mutton, potatoes, onions and Chile Tortillas or fried bread or Indian biscuit Coffee with evap. milk and sugar	Roast mutton or stew Bread or tortillas Coffee with evap. milk and sugar	Boiled potatoes Tortillas Coffee with sugar
Evening meal —	Same as noon	Same as noon	Potatoes or tortillas Coffee with sugar

[1] Families with herds include goat or sheep milk or both in their diets when it is available.

TABLE 13

Frequency of consumption of foods

Percentage of families consuming various foods at indicated frequency
Ganado and Pinon, Arizona, 1955

FOODS	GANADO Daily	GANADO 2–3 × weekly	GANADO Once weekly	GANADO Twice monthly	GANADO Once monthly	GANADO Occasionally	GANADO No indicated consumption	PINON Daily	PINON 2–3 × weekly	PINON Once weekly	PINON Twice monthly	PINON Once monthly	PINON Occasionally	PINON No indicated consumption
Breads														
Tortillas	73.8	23.5	0.9	0.0	0.3	1.5	0.0	85.6	0.0	0.6	0.0	0.0	0.6	13.2
Fried bread	31.0	27.4	27.4	1.2	7.7	5.4	0.0	7.2	16.8	4.8	0.0	0.0	0.6	70.7
Bakers' bread	25.3	30.7	28.9	14.9	7.1	1.8	0.3	1.2	6.6	29.3	7.8	16.2	0.6	38.3
Other breads	[illegible]	27.1	23.8	3.3	4.2	18.8	0.0	10.2	26.3	29.3	10.2	7.8	2.4	13.8
Cereals	69.6	21.1	3.6	1.2	0.6	3.3	0.6	37.7	21.6	15.6	9.0	5.4	0.6	10.2
Fats														
Lard and vegetable shortening	100.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
Bacon	7.1	8.0	20.5	12.5	13.4	6.0	32.4	6.6	9.0	13.2	11.4	9.6	2.4	47.9
Butter and margarine	11.9	6.0	14.0	9.8	19.3	6.3	32.7	4.8	3.6	1.8	3.6	2.4	3.0	81.4
Green, leafy or yellow vegetables	8.6	37.8	28.9	17.3	3.0	3.3	1.2	3.6	24.6	32.3	18.0	6.6	0.6	14.4
Chile peppers	3.3	3.3	1.5	0.3	0.0	1.2	90.5	3.0	1.2	6.6	3.0	0.6	0.6	85.0
Citrus fruits and juices	12.5	23.8	31.5	17.6	7.4	4.2	3.0	13.8	16.8	20.4	11.4	7.8	0.6	29.3
Tomatoes and juice	2.7	26.8	36.3	22.9	5.7	3.6	2.1	2.4	16.2	34.7	22.8	10.2	0.0	[illegible]
Raw cabbage	0.6	3.3	11.0	24.7	32.4	22.3	5.4	1.8	2.4	4.2	3.6	4.8	1.2	82.0
Potatoes	91.4	5.4	1.8	0.9	0.0	0.3	0.3	98.8	0.0	0.6	0.6	0.0	0.0	0.0
Other fruits and vegetables	14.3	39.3	25.9	12.2	3.9	4.2	0.3	17.4	29.3	35.3	11.4	3.0	0.6	3.0
Milk	80.7	7.1	3.9	3.3	1.8	1.2	2.1	60.5	12.6	12.6	3.6	2.4	0.6	7.8
Ice cream	0.5	2.4	9.2	5.7	1.5	0.9	79.6	0.0	0.6	0.0	2.4	1.8	7.2	88.0
Cheese	2.1	0.5	14.9	11.3	24.4	20.5	20.2	0.0	3.6	7.8	6.6	7.2	1.2	73.1
Eggs	32.4	25.6	20.8	6.5	7.1	3.6	3.9	16.8	19.2	16.2	14.4	5.4	1.8	26.3
Meat	58.6	33.6	6.3	1.2	0.3	0.0	0.0	43.7	46.7	9.0	0.6	0.0	0.0	0.0
Nuts and peanut butter	14.6	28.3	31.2	13.4	8.3	3.9	0.3	3.6	13.8	18.0	6.0	4.8	0.0	53.9
Sweets	82.1	7.7	5.1	1.8	0.0	2.4	0.9	95.2	1.8	1.2	0.0	0.6	0.6	0.6
Coffee and tea	95.5	0.0	0.0	0.0	0.0	0.9	3.6	100.0	0.0	0.0	0.0	0.0	0.0	0.0
Soft drinks	22.0	24.4	31.8	10.4	8.0	2.7	0.6	18.0	16.2	33.5	12.0	9.0	0.0	11.4

The frequency of reported consumption of foods was tabulated for 336 families from the Ganado area and for 167 families in the Pinon area. The interviews for the former group included 596 individuals; for the latter 543 persons. These tabulations are presented in table 13.

These consumption frequencies again demonstrate the basic character of the dietary: breads, cereals, fats, potatoes, meats, sweets and beverages. Evaporated milk is the type most often used, and its regular appearance in an appreciable percentage of the diets reflects the use of appreciable quantities of coffee.

Since bread and meat occupy such key positions in the diet, they deserve special mention. Corn is no longer the dominant cereal of the diet. White, yellow, blue or red corn may be eaten. Bread may be prepared from dried corn or from fresh or green corn. The latter is employed in making "kneel down bread." Blue corn bread, blue corn mush, and blue corn soup are usually prepared with the addition of cedar ashes to the ground corn at the time of preparation. Corn, because of its religious significance, continues to be used in the preparation of ceremonial cake.

Tortillas (see frontispiece) are thin, round cakes, 5 to 9 inches in diameter, made of wheat flour, water, shortening and small amounts of baking powder. They are either baked on an iron griddle or grilled over hot coals and are distinguished from fried bread which is cooked in hot fat in much the same way as a doughnut.

Mutton is the usual meat. This term may be applied to either sheep or goat meat. Indeed, flocks are often mixed, containing both sheep and goats. Relatively few families have cattle and the larger size and lack of facilities for refrigeration make cattle less convenient for home slaughtering than smaller animals.

When a sheep or goat is slaughtered the blood is retained for the preparation of blood sausage. The animal is skinned and the viscera removed and rapidly cleaned. After cleaning, the intestines are wrapped around strips of fat, broiled and eaten while hot. Liver is cut into large pieces, salted and broiled with omental fat. Heart, lungs, trachea, and diaphragm are used in stews, roasted or broiled. The animal's head is singed and baked in hot ashes. The brain may be eaten or used in the tanning of hides. Blood collected during slaughtering is mixed with corn meal, salt, bits of fat, and diced muscle (potatoes and onions if available) and encased in the everted stomach and boiled. This delicacy is consumed hot or cold, sliced and eaten with tortillas or fried bread. Feet are singed, cleaned and roasted. Kidneys are cut into half and broiled. The perirenal fat is used in cooking. Ribs are broiled over a bed of coals. It is obvious that all portions of the animal are consummed except for the skin, bones, hoofs, the gall bladder and intestinal contents.

An animal may last the family from three to 14 days, depending upon the number of members in the family, the exchange with neighbors, and so on. Unused meat which is not likely to be consumed before it spoils may be preserved by slicing thinly, salting and drying (so-called jerked meat). The frequency of butchering reported by the 167 families at Pinon was once a week by 10 families; once in two weeks by 30 families; once in three weeks by three families; once a month, 56 families; once in two months, 9 families; three times a year, one family; once a year, one family. The frequency of slaughtering was unknown for 25 families.

Deer meat, when available, is used in much the same manner as mutton. Heart, lungs and kidney are eaten, but the head and intestines are not. Porcupine, prairie dog and rabbits are cleaned, the viscera removed, and the head discarded. The carcass is roasted over coals.

THE DIET DURING PREGNANCY AND LACTATION

There appear to be few, if any, dietary taboos connected with pregnancy or lactation. All informants questioned stated that during pregnancy the usual foods were eaten unless there were some specific instance of a food disagreeing with the individual. It was reported that the nursing mother is advised to drink broth to produce milk, and that blue corn gruel is an especially appropriate food to include in the diet from the onset of labor until the end of lactation. This gruel is often advised during illness and is reputed to be a traditional source of strength. Indeed, the association of blue corn gruel with lactation is so strong that an inquiry as to the frequency of eating blue corn mush often evokes a smile or chuckle.

Bailey ('40) records that for several days following delivery restrictions are passed on the mother against eating meat, potatoes, beans and bread containing either salt or baking powder in the belief that this prevents recurrence of labor pains and aids in the healing of the baby's cord.

Infants are breast fed unless for some very pertinent reason it is impossible to do so successfully. Such instances seem rare. Where the mother cannot breast-feed the infant a member of the family may wet-nurse the child. The common basic artificial food for the infant is evaporated milk which is poured from the can into the bottle and to which an unmeasured amount of water is added. Nursing bottles are seldom sterilized but may be rinsed with a small amount of water just prior to mixing a new batch of formula. Boiled goat's milk is sometimes given and may be fed to the young infant from a spoon. In the absence of any milk, finely ground white corn may be mixed with water and fed. This practice appears to be uncommon, however.

Adult foods are added as supplements from 4 to 7 months of age without any particular pattern. Broth from mutton stew, potato mashed between the thumb and finger, and mush are commonly given. Coffee is frequently given and may be offered to child as early as 4 months. It is not an infrequent sight to observe an infant taking coffee from a nursing bottle. Members of the family are seen generously sharing their bottle of soft drink with the infant.

Milk of some sort, however, remains the basic item of the diet until more than a year of age. Indeed, children may be put to the breast until two or two and a half years of age.

Toddlers are weaned to the family diet. Prepared infant foods are not widely used and are available in but a distinct minority of the trading posts. Where stocked the traders stated that they sold slowly and primarily to their white customers.

The diet of older children is not appreciably different from that of the adult. Coffee and tea are usually allowed. In common with families elsewhere a few parents reported buying oranges, juice, milk and candy "just for the children."

The school feeding practices were studied, but will be discussed in a separate report on the growth of school children.

SUMMARY

A description of the present-day diet of the Navajo is given. This is based on qualitative information accumulated from over 1200 Navajo individuals as to food production, storage, preservation and cooking methods. Inquiry was made as to eating habits, basic menus, frequency with which certain items are included in the diet and the sources of food by families. Purchase lists were obtained from trading posts and discussions were held with numerous informants working with the Navajo on the reservation.

From the data it is apparent the Navajo has practically abandoned his primitive diet of wild game, Indian corn, wild berries, fruits and plants. He lives by combining home-produced meat and a few other products with a variety of foodstuffs purchased from the trading posts.

Examples of 20 edible wild plants were procured from one region. These are tabulated by Indian and English name and described briefly.

III

PHYSICAL FINDINGS

There is a paucity of information pertaining to the nutritional status of the Navajo Indian (Kraus, '54). The popular press and lay journals have commented upon the high prevalence of diseases and have attributed much of this to dietary deficiencies. Such statements have been without scientific support. An objective study of nutritional status, therefore, is most desirable.

In June and July of 1955 an assessment of the nutriture of the Navajo was begun at two locations on the reservation. These were selected to reflect varying degrees of influence and penetration of the white man's culture. Ganado, Arizona, has been a mission, educational and medical center on the reservation since the turn of the century. It is now readily accessible to urban communities over paved roads. On the other hand, Pinon, Arizona, has only a public school and two trading posts. It is located over a hundred miles from the nearest urban center over unpaved roads.

The design of the study, agricultural background and dietary patterns have been described in the earlier chapters. Over 1200 individuals were entered in the study. Evaluation of their nutriture was based on dietary history of basic food patterns, biochemical assessment, medical history and physical examination.

THE EXAMINATION AND FINDINGS

Medical histories were taken and physical examinations were made as part of the nutritional assessment of the Navajo. The sample studied has been indicated earlier in this report. The interrogations were performed by or under the super-

TABLE 14

Distribution of population sample by examiner, location, sex and age

Navajo study 1955

EXAMINER	GANADO											PINON											Combined total
	Males				Females							Males				Females							
	Age in years				Age in years							Age in years				Age in years							
	5–9	10–14	15–44	45+	5–9	10–14	15–44			45+	Total	5–9	10–14	15–44	45+	5–9	10–14	15–44				Total	
							Non preg.	Preg.	Lact.									Non preg.	Preg.	Lact.			
1	1	3	7	17	1	2	10	5	5	16	67	38	29	53	48	65	32	79	20	48	52	464	531
2	4	6	9	8	9	5	28	4	7	21	101	2	6	18	30	7	8	16	1	23	21	132	233
3	7	7	21	16	17	14	26	7	14	32	161	0	0	0	0	0	0	2	1	2	0	5	166
4	15	15	47	35	19	15	68	13	18	61	306	0	0	0	0	0	0	0	0	0	0	0	306
None	0	0	0	1	0	3	3	0	0	3	10	0	0	0	0	0	0	0	0	0	0	0	10
TOTAL	27	31	84	77	46	39	135	[illegible]	44	133	645	40	35	71	78	72	40	97	22	73	73	601	1246

vision of one of the physicians. The physical xaminations were done by one of the 4 physicians. In an effort to attain a common level of recognition and evaluation of physical signs of possible nutritional interest, all examiners underwent an initial period of training at Ganado. The variations which occurred in recording certain less definite signs serve as another illustration (Bean, '48; Darby, '50) of the difficulty of standardizing completely examiner's subjective appraisal. The distribution of examinations by examiners in the two locations of Ganado and Pinon is indicated in table 14.

The locale, age, and sex characteristics of this sample of 1246 individuals are given in table 14. At both centers the sample size is sufficient to permit consideration of logically composed groups. The slightly greater proportion of children at Pinon is due to the inclusion of 40 boarding school children aged 5 to 8 years. Pregnant and lactating women from the two locales are sufficient in number to allow meaningful comparisons with other groups.

Of the 645 subjects studied at Ganado, 288 had medical histories taken. At Pinon, 595 of the 601 had medical histories recorded. The history (Goldsmith, et al., '50) was designed to elicit evidence of general medical disease with particular emphasis on symptoms which might be indicative of nutritional deficiency. The diseases and symptoms most frequently recorded as positive in the medical history for the two locations are shown in tables 15 and 16. These concern the history of disturbances affecting the skin (easy bruising and dermatitis), eyes (burning, photophobia, lacrimation, night-, snow- or sand-blindness), bleeding gums, and gastrointestinal disturbances. In the general evaluation of the results from the two areas, there is (1) an apparent increase of prevalence, with age, of most of the symptoms recorded (table16) and (2) an increased history of gum disorders, edema, and leg cramps in pregnant or lactating women or both (table 27). In addition, there is a greater frequency of reported prevalence of most symptoms among patients examined at Pinon than among those examined in the Ganado area.

In the whole study, only one indisputable case of a frank vitamin deficiency disease was encountered. This was a case of mild pellagra in an elderly woman who lived alone and adhered to bizarre dietary habits. Otherwise the sample was

TABLE 15

Medical history data

Navajo study 1955

SYMPTOM	GANADO		PINON	
	No.	%	N	%
Total entered in study	645		601	
Total with medical history	288		595	
Easy bruising or dermatitis	51	17.7	167	28.1
Burning of eyes	62	21.5	174	29.2
Photophobia	99	34.4	260	43.[illegible]
Excess lacrimation	93	32.3	247	41.5
Visual fatigue with blurring of vision	107	37.2	258	43.4
Sand, snow and night blindness	95	33.0	287	48.2
Burning, painful, tongue	12	4.2	34	5.7
Cracked lips	12	4.2	106	17.8
Angular fissures of mouth	6	2.1	91	15.3
Bleeding gums	20	6.9	163	27.4
Chronic cough	10	3.5	21	3.5
Exertional dyspnea	40	13.9	107	18.0
Palpitation	28	9.7	104	17.5
Precordial pain	37	12.8	73	12.3
Dependent edema	27	9.4	45	7.6
Anorexia	19	6.6	72	12.1
Indigestion	38	13.2	58	9.7
Chronic diarrhea, hemorrhoids with bleeding	18	6.2	71	11.9
Numbness and tingling of extremities	48	16.7	120	20.2
Syncope and dizziness	41	14.2	169	28.4
Burning feet	32	11.1	80	13.4
Leg cramps	59	20.5	149	25.0
Nervousness and irritability	65	22.6	178	30.0
A. Eye tests	633		578	
B. Either eye under 20/30 vision	190	30.0	141	24.4

free of classical deficiency diseases. This is in keeping with the recorded diagnosis of deficiency diseases found in the analysis of 60,000 admissions to hospitals on the Navajo Reservations (Salsbury, '55) and the clinical experience of

TABLE 16

Percentage distribution of positive findings in the medical history

(Pregnant and lactating women excluded)

Navajo study 1955

SYMPTOM	ANADO								PINON							
	Male				Female				Male				Female			
	Age in years				Age in years				Age in years				Age in years			
	5–9	10–1	15–44	45+	5–9	10–14	15–44	45+	5–9	10–14	15–44	45+	5–9	10–14	15–44	45+
	Number				Number				Number				Number			
	11	20	27	37	22	10	62	66	40	34	71	78	69	39	97	72
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Easy bruising or dermatitis	9	10	11	16	5	10	26	24	8	38	25	24	19	18	39	35
Burning of eyes	9	10	11	27	5	10	26	29	5	6	30	45	7	15	33	51
Photophobia	45	35	33	35	9	10	45	26	18	26	41	62	25	31	52	69
Excessive lacrimation	18	10	22	49	5	10	37	38	8	32	39	64	14	26	48	69
Visual fatigue with blurring of vision	9	10	22	59	0	10	44	53	5	21	37	74	4	26	49	81
Sand, snow and night blindness	9	20	41	49	0	10	39	36	15	35	44	68	9	28	61	75
Bleeding gums	0	10	11	0	0	0	6	9	30	32	20	24	26	15	[illegible]	26
Dependent edema	0	0	4	8	0	0	5	26	0	0	1	19	0	5	7	15
Anorexia	9	5	7	11	0	0	8	5	2	3	7	8	6	18	23	10
Indigestion	0	0	4	24	0	0	18	20	0	0	8	19	0	5	15	15
Chronic diarrhea, hemorrhoids with bleeding	0	0	7	8	5	10	0	15	12	18	6	24	6	0	11	10
Either eye under 20/30 vision [1]	12	13	10	47	22	5	28	58	21	9	15	45	12	16	12	59

[1] Based on larger groups approximating totals indicated in table 14.

physicians at the Sage Memorial Hospital, Ganado, Arizona. Among the 60,000 records examined nutritional diseases were recorded as follows: pellagra, 10; scurvy, 2; beriberi, 2; rickets, 1; and "malnutrition, 97.

Among the so-called "subclinical signs" of nutritional deficiency disease, there were variations in the frequency with which they were recorded by individual examiners. Some group differences were associated with location, age, sex, and whether pregnant or non-pregnant. The multiplicity of these factors complicates the interpretation of the findings.

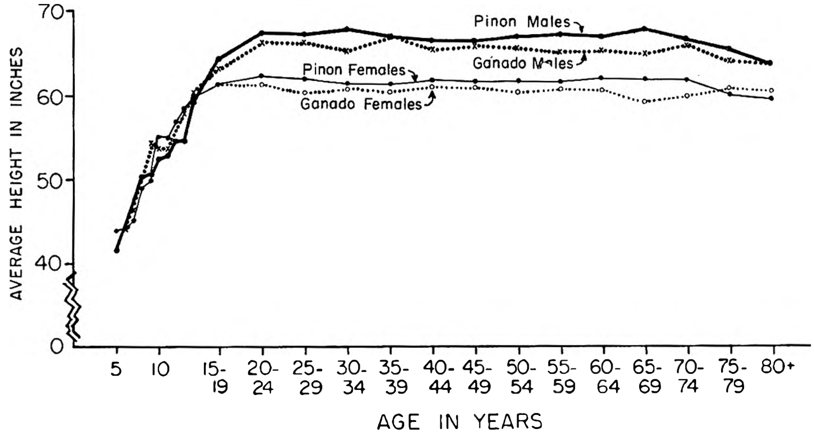

Fig. 3 Height versus age.

The correlation between these findings and laboratory data is helpful in some instances; in others, the mterrelationship is indecisive.

Among the 1195 subjects (excluding the 51 pregnant women) who were examined at Ganado and Pinon, the pattern of average heights by age groups is shown in figure 3. The patterns for males and females in either location parallel each other and reveal no significant differences from 5 through 15 years. Above that age, as expected, a sex difference becomes apparent. The female reaches maximum height by the age of 17 years, and subsequently has a mean height of between 61 and 62 inches. The male reaches maximum height by the age of 21 years at 66 to 67 inches. At Pinon, the height of adults averaged one to two inches more than in Ganado.

The mean weight by age is illustrated in figure 4. Since no significant variations existed between residents of the Pinon area as compared to the Ganado area, it is permissible to combine the results of the 1195 subjects. From the ages of 8 to 16 years significant differences existed in the weights for males and females. For the females the maximum mean weight is reached at 17 years, whereas the males continue to gain weight until 23 years of age. Following these respective

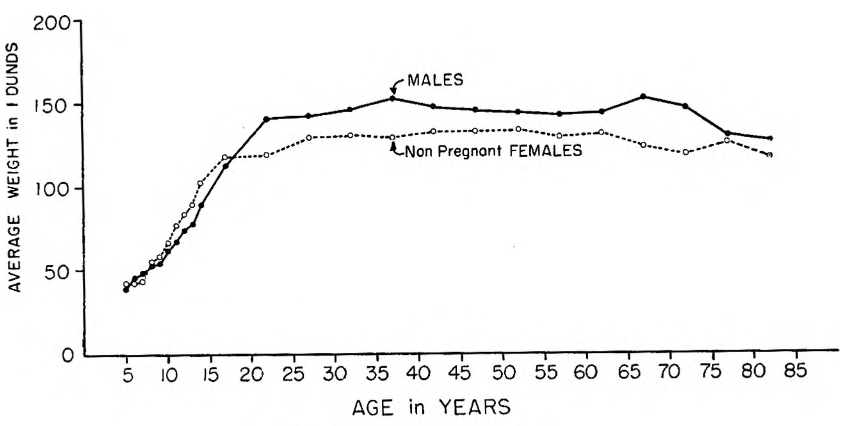

Fig. 4 Weight versus age.

maxima the mean weights remain stationary until 60 to 65 years of age for women and 65 to 70 for the men when a slight geriatric decline is apparent.

Comparison of average height and weight of the Navajo with data from a recent Canadian sample (Pett, '55) (all racial groups) reveals several interesting relationships (table 17). Until the age of 10 years there are no significant differences in height between the groups regardless of sex. From 10 to 45 years of age, the Canadians are consistently taller by three to 4 inches. Canadians and Navajos aged 45 and over are similar in height. It is apparent that among subjects born prior to 1910 growth, as reflected by height, was

TABLE 17

Average height and weight of Navajo Indians,[1] by age and sex, compared to Canadian 1953 survey

AGE (years)	NUMBER OF NAVAJO SUBJECTS		AVERAGE HEIGHT (inches)				AVERAGE WEIGHT (pounds)			
	Males	Females	Males		Females		Males		Females	
			Canada	Navajo	Canada	Navajo	Canada	Navajo	Canada	avajo
5	4	9	41.9	41.7	41.8	43.3	40	40	41	42
6	26	29	44.6	44.6	44.2	44.3	46	45	44	43
7	15	16	47.0	47.0	46.5	45.4	50	49	49	45
8	16	36	49.1	49.5	48.9	48.9	57	54	57	55
9	5	25	51.3	51.2	51.0	50.5	63	55	63	58
10	13	13	53.5	52.8	53.3	52.9	70	62	69	66
11	16	16	55.4	53.1	55.3	54.9	77	67	77	77
12	14	21	57.4	55.7	58.2	56.9	84	74	92	84
13	10	11	59.3	56.7	60.4	58.1	94	78	102	90
14	9	14	62.2	59.7	61.3	60.4	108	89	107	102
15	10	13	64.7	61.3	62.2	60.8	119	101	112	114
16–17	14	19	66.7	65.1	62.5	60.8	136	115	120	115
18–19	9	30	68.0	64.8	62.6	61.7	144	122	124	121
20–24	27	69	67.9	67.1	62.8	61.9	154	140	124	119
25–29	29	66	68.3	66.8	62.7	61.8	160	142	126	129
30–34	28	47	68.0	66.8	62.8	60.9	167	145	130	130
35–44	37	93	67.5	66.8	62.4	61.4	167	150	135	131
45–54	45	71	66.0	66.8	61.8	61.5	164	145	144	134
55–64	55	67	66.0	66.8	61.3	61.5	161	144	147	130
Over 65	51	62	65.5	66.3	60.6	60.9	155	142	138	123

[1] Age was attained years; height-weight taken without shoes and with subject stripped to waist; weight recorded to nearest one-half pound. For conditions of Canadian study see Pett, L. B. and G. F. Ogilvie, Human Biology, *28:* 177 (1956).

comparable in both groups. However, since 1910 various influences (including nutrition) have resulted in taller (15 to 45-year-old) Canadians, but these influences are not demonstrable among the Navajo. The average Canadian male weighs three to 22 pounds more than the Navajo from 8 years of age on. For the female, the magnitude of the difference in favor of the Canadian is less, and is not clearly apparent until after the age of 45 years.

The height-weight data were compared with the Baldwin-Wood standards (Bigwood, '39) and expressed as "per cent of standard weights." On this basis there was no difference

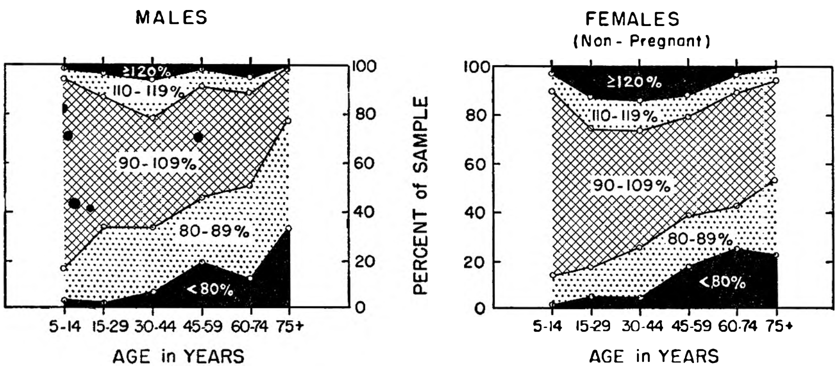

Fig. 5 Percentage distribution of "per cent of standard weight.

attributable to locale; hence, the data were combined (fig. 5). For both sexes increasing age was associated with an increasing percentage of subjects less than 80 or 90% of standard weight. Obesity among the males was infrequent, an incidence of less than 5%. It occurred in some 15% of the women between the ages of 15 and 45 years.

A correlation has been observed among adults between "per cent of standard weight" and the concentration of hemoglobin and of serum ascorbic acid (Darby, '56). The present data on the Navajo revealed no evidence of a relationship between weight and levels of serum vitamin C. However, a fairly strong relationship exists between hemoglobin concentrations and weight, except for women between 15 and 44 years of age. This relationship is such that there occurs an increase in concentration with increasing "per cent of standard weight" (table 18) This is similar to observations in pregnant women (Darby, '56)

Skin-fold measurements were performed, primarily at Pinon, on persons over the age of 15 years (except pregnant females). Three body areas were chosen: (1) skin over the posterior lateral aspect of the mid-upper arm, (2) the upper outer quadrant of the chest, and (3) either the right or left upper quadrant of the abdomen. These locations and the calipers used were in keeping with the studies of the Army

TABLE 18

"Per cent of standard weight" of adult male and female subjects
versus
Hemoglobin concentration

Navajo study 1955
(Ganado and Pinon combined — excluding 51 pregnant women)

SUBJECTS	PER CENT OF STANDARD WEIGHT			Total
	< 90.0	90–109	≥ 110.0	
		Hemoglobin levels (*gm/100 ml*)		
Males 15–44 yrs.	15.86 ± 0.15	16.09 ± 0.12	16.41 ± 0.24	16.06 ± 0.09
Males 45+ years.	15.40 ± 0.16	16.34 ± 0.16	16.75 ± 0.26	15.92 ± 0.11
Females 15–44 yrs.	14.27 ± 0.18	14.01 ± 0.13	14.24 ± 0.16	14.14 ± 0.09
Females 45+ yrs.	14.42 ± 0.14	14.84 ± 0.11	15.28 ± 0.22	14.73 ± 0.08

Medical Nutrition Laboratory (Best, '53). Despite examiner variation (table 19) in the absolute measurements, particularly at the arm site, the skin-fold thickness increased with "per cent standard weight" (table 19). Any effort to interpret further the significance of such skin-fold measurements is sharply limited by the absence of information on the influence of body configuration of various racial groups on the skin thickness measures, body composition, and their correlative significance.

Table 20 summarizes the physical findings of the sample of 1246 individuals, including the 51 pregnant and 117 lactating women.

Skin. With the exception of dryness or scaling of the skin or both, and thick and pigmented pressure points, the recorded prevalence of other skin defects was low or negligible (tables 20, 21). Dryness and scaling occurred more frequently

TABLE 19

Skin fold thickness by "per cent of standard weight"

Pinon — Females — Abdomen

SKIN FOLD THICKNESS	PER CENT STANDARD WEIGHT						TOTAL	
mm	Under 80	80–89	90–99	100–109	110–119	Over 120	No.	Per cent
Under 1.0	14	2	2	0	0	0	6	3
1.0–1.9	68	48	34	19	11	0	73	33
2.0–2.9	18	41	48	60	58	42	102	46
3.0–3.9	0	9	16	21	31	47	39	17
4.0+	0	0	0	0	0	11	2	1
TOTAL Per cent	100	100	100	100	100	100		100
TOTAL Number	28	46	58	52	19	19	222	

Pinon — Males — Arm

(By examiners)

EXAMINER 1	Under 80	80–89	90–99	100–109	110–119	Over 120	Total
Under 1.0 mm	13	30	22	12	5	0	82
1.0–1.9 mm	0	0	0	3	2	2	7
2.0+ mm	0	0	0	0	0	0	0
TOTAL	13	30	22	15	7	2	89
EXAMINER 2							
Under 1.0 mm	[illegible]	1	1	0	0	0	5
1.0–1.9 mm	3	11	14	7	1	0	36
2.0+ mm	0	0	2	2	2	1	7
TOTAL	6	12	17	9	3	1	48

at Pinon in both boys and girls under 15 years of age. Examiner differences account largely for the locale variation in these signs. Excessive pigmentation increased with age, particularly for women in both locales. To a considerable extent this is a result of pigmented hyperkeratoses over the feet and knuckles arising from repeated pressure during weaving

TABLE 20

Physical findings among 1246 subjects

Navajo study 1955

PHYSICAL FINDINGS	GANADO No.	GANADO %	PINON No.	PINON %	TOTAL No.
Apathetic	34	5.4	14	2.3	48
Seborrhea, nasolabial	21	3.3	12	2.0	33
Seborrhea, other	2	0.3	5	0.8	7
Erythema	6	0.9	7	1.2	13
Folliculosis	0	0.0	3	0.5	3
Staring hair	1	0.2	20	3.3	21
Skin					
Follicular keratosis Grade I and II	71	11.2	67	11.1	138
Dryness and scaling	106	16.7	241	40.1	347
Crackled skin	34	5.4	81	13.5	115
Perifolliculosis	0	0.0	2	0.3	2
Acneiform eruption	12	1.9	27	4.5	39
Thick and pigmented pressure points	66	10.4	349	58.1	415
Purpura and petechia	1	0.2	7	1.2	8
Bluish-red, cold extremities	2	0.3	0	0.0	2
Pellagraform	18	2.8	35	5.8	53
Eyes					
Thickened conjunctive					
Grade I	179	28.2	230	38.3	40
Grade II	257	40.5	296	49.3	553
Bitot's spots	2	0.3	1	2	3
Circumcorneal injection	61	9.6	169	28.1	230
Conjunctival injection	199	31.3	442	73.5	641
Blepharitis	148	23.3	412	68.6	560
Lips and mouth					
Angular lesions and scars	62	9.8	129	21.5	191
Cheilosis	28	4.4	65	0.8	93
Pallor	0	0.0	9	1.5	9
Ulcers of mouth	0	0.0	1	0.2	1
Angular lesions and scars or cheilosis	80	12.6	167	27.8	247
Tongue					
Papillary atrophy	69	10.9	94	15.6	163
Papillary hypertrophy	44	6.9	35	5.8	79
Patchy denuded areas	0	0.0	0	0.0	0
Magenta colored	9	1.4	6	1.0	15

TABLE 20 (*continued*)

PHYSICAL FINDINGS	GANADO		PIÑON		TOTAL
	No.	%	No.	%	No.
Red tip and/or sides	5	0.8	7	1.2	12
Fissures	54	8.5	10	1.7	64
Erosion or ulcers	0	0.0	0	0.0	0
Serrations and swelling	7	1.1	0	0.0	7
Teeth					
Caries	350	55.1	383	63.7	733
Edentulous	98	15.4	19	3.2	117
Fluorosis	8	1.3	18	3.0	26
Gums					
Marginal redness	215	33.9	382	63.6	597
Marginal swellings	221	34.8	404	67.2	625
Atrophy of papillae	144	22.7	208	34.6	352
Recession with debris	151	23.8	133	22.1	284
Bleeding gums	36	5.7	19	3.2	55
Atrophy of papillae or recession with debris or bleeding gums	223	35.1	221	36.8	444
Marginal redness, swellings, atrophy of papillae, recession with debris or bleeding gums	328	51.7	428	71.2	756
Thyroid enlarged	5	0.8	7	1.2	12
Calf tenderness	1	0.2	4	0.7	5
Loss of AJ or KJ	12	1.9	22	3.7	34
Plantar dysesthesia	0	0.0	0	0.0	0
Motor weakness	1	0.2	0	0.0	1
Loss of vibratory sense to 128	18	2.8	7	1.2	25
Blood pressure > 140/90	45	7.1	25	4.2	70
Cardiac murmur	5	0.8	16	2.7	21
Pitting edema	7	1.1	17	2.8	24
Frontal or parietal bosses	0	0.0	3	0.5	3
Protuberant abdomen	1	0.2	36	6.0	37
Harrison's groove	1	0.2	13	2.2	14
Knock knees and bow legs	2	0.3	67	11.1	69
Enlarged joints	35	5.5	88	14.6	123
Facial hyperpigmentation	152	23.9	315	52.4	467
Parotid enlargement	49	7.7	69	11.5	118
No. of physical examinations	635	100	601	100	1236 [1]

[1] Ten of the subjects who participated in this study did not have physical examinations.

TABLE 21

Per cent occurrence of selected physical findings by age, sex, location

(Pregnant and lactating women excluded)

Navajo study 1955

PHYSICAL FINDINGS	GANADO								PINON							
	Male				Female				Male				Female			
Age	5–9	10–14	15–44	45+	5–9	10–14	15–44	45+	5–9	10–14	15–44	45+	5–9	10–14	15–44	45+
No.	27	31	84	76	46	36	132	130	40	35	71	78	72	40	97	73
Dryness and scaling of skin	11	23	7	25	28	3	11	28	60	71	17	36	[illegible]4	60	30	41
Thick and pigmented pressure points	4	6	6	7	7	6	12	19	20	49	49	54	31	58	71	81
Thickened conjunctiva	30	48	80	96	7	28	67	93	85	77	90	100	[illegible]9	72	91	99
Angular lesions and scars	22	29	8	1	26	11	11	3	48	31	13	19	45	28	8	[illegible]8
Cheilosis	19	23	5	1	13	3	2	0	10	34	8	6	19	25	2	4
Papillary atrophy	0	0	2	25	4	0	7	25	2	3	4	55	0	0	7	49
Papillary hypertrophy	4	10	11	5	0	6	8	9	20	6	3	1	21	9	3	0
Caries	41	39	38	71	59	39	54	68	68	69	42	92	74	30	47	90
Edentulous	0	0	4	29	0	0	6	46	0	0	0	12	0	0	0	14
Marginal gingivitis	7	52	52	57	17	14	44	41	60	66	66	94	68	38	60	89
Atrophy of papillae	0	6	15	64	0	0	18	38	5	9	30	86	1	2	24	86
Recession with debris	0	10	17	58	0	0	19	36	2	0	11	69	1	0	11	67
Bleeding gums	4	15	6	4	7	3	6	3	2	6	1	5	6	0	4	0
Blood pressure > 140/90	0	0	6	13	0	0	2	20	0	0	4	10	0	0	2	15
Facial hyperpigmentation	22	19	17	30	13	8	22	38	80	46	55	46	50	65	43	56
Parotid enlargement	7	0	10	13	2	3	7	12	5	9	25	22	4	0	9	5

or the grinding of flour. The greater frequency of these findings at Pinon was not due to examiner variation, and probably reflected living conditions and occupational differences. No correlations existed between any of the skin lesions and levels of serum vitamin A or carotene.

Eyes. Numerous subjects had grossly impaired visual acuity (vision less than 20/30 in either eye using AO chart number 1942; see tables 15, 16) and among the adults this was frequently associated with corneal scarring due to old trachoma, opacities, extensive pterygium or pannus. Except for Bitot spots and circumcorneal injection, ocular signs (tables 20, 21) were commonly recorded in both locations in the older age groups, particularly over 45 years of age. There were no apparent differences between males or females in ocular signs. The greater numbers with positive eye signs (e.g., conjunctival thickening) in the Pinon area may in part reflect observer differences, since one examiner there recorded such findings more frequently than did the others. Pinon, however, is a treeless, windswept, sandy area, and the factor of irritation from dust and wind and brilliant sunlight cannot be dismissed. At any rate, the satisfactory levels of vitamin A in the blood allow one to dismiss avitaminosis A as the cause of these findings.

Oral and lingual lesions. Lesions of the angles of the mouth (table 20) were not commonly seen among the subjects at either Ganado or Pinon. Angular fissures and cheilosis (table 21) were concentrated among the children between 5 and 15 years of age at both centers. Both signs were found more frequently at Pinon than at Ganado. Papillary changes in the tongue (tables 20, 21) occurred in less than one-fifth of the subjects. Moderate papillary atrophy was recorded with equal prevalence among men and women and was limited to subjects over 45 years of age in both locales. Papillary hypertrophy was of minimal degree, occurring mainly in the young. Although no laboratory measures of vitamin B-complex levels were possible, at neither clinic did the oral or lingual findings indicate extensive evidence of a B-complex deficiency state, and the levels of blood hemoglobin were adequate.

Teeth. Dental care and therapy are limited among the population. As a result, one could anticipate considerable gross dental pathology. There was noted an unusual attrition of the teeth, particularly in the older age group. and also a frequent occurrence of mal-position and mal-development of the permanent teeth. Examination of the teeth (tables 20, 21) revealed two extreme patterns, namely, beautiful acarious ones or rampant caries. Unfortunately, the latter condition was more common, occurring in all age groups and in over 40% of persons past 45 years. There was no detectable difference in amount of caries between Ganado and Pinon; however, adentia was more common at Ganado, and dental plates were absent at both locales. A few circumscribed areas were peculiarly low in caries; for example, a region about Low Mountain, Arizona (see map), was essentially caries-free. We did not investigate the possible role of fluoride in the water in this region. It is plausible, however, that a high fluoride water supply may have been responsible for the lowered prevalence of caries.

Gums. Gingival lesions were the most prevalent stigmata observed in the study (tables 20, 21, 26). Marginal redness or swelling or both were more common for all ages at Pinon than at Ganado (70.2 vs. 14.3%). With increasing age, and particularly over 45 years, secondary changes, atrophy of papillae and recessions with debris became appreciable. Bleeding gums were not frequently observed, but when present were always associated with other evidence of gingivitis. Serum ascorbic acid levels were lower in subjects from the Pinon area than in those from Ganado. This finding, together with the higher incidence of gingival lesions, might suggest that vitamin C insufficiency was responsible. However, division of all cases with gingivitis by examiner and vitamin C level in the serum failed to reveal a positive correlation. It is apparent that poor oral hygiene and inadequate dental care are major factors responsible for this high prevalence of gingival disorders and dental caries. Low vitamin C intake is probably a secondary factor

Thyroid, neuromuscular, skeletal. No large goiters were seen. Only 12 women had evidence of thyroid enlargement. No clinically evident hyperthyroidism was detected. Neuromuscular abnormalities or neuropathies were very nearly nonexistent. Skeletal defects were concentrated in the 5- to 14-year olds, and with the exception of unassociated mild knock-knees, bow-legs, and some joint enlargements, the recorded prevalence was minimal. Clinical evidence of acute rickets was lacking.

Cardiovascular. Elevation of blood pressure was not commonly encountered at either center. At Ganado 7.1% and at Pinon 4.2% of the subjects had readings above 140 mm of mercury systolic and 90 mm diastolic. Table 21 reveals an absence of "hypertension" (greater than 140/90) in the 5- to 14-year age group; an incidence increasing with age, regardless of sex, and a somewhat greater incidence among women over 45 years of age than among men of the same age group. Comparison of the incidence of "hypertension" among the Navajo with that among the general population of the United States is hazardous, for despite an abundant literature on hypertension, its definition and limits are not generally agreed upon (Morsell, '51). However, the recording of "hypertension" among the Navajo appears to be somewhat lower than one might anticipate for similar age and sex groups encountered in our general population.

When the 70 subjects with "hypertension" were grouped on the basis of their standard weights (table 22), both sexes showed an increased occurrence of hypertension in the 15- to 44-year-old range when their weight exceeded 110% of the standard. Over 45 years of age "hypertension" was more common in the women weighing less than 90% or more than 110% of standard weight than in those of standard weight. In the older men no consistent or significant pattern of variation with weight was evident.

TABLE 22

"Hypertensive" blood pressure levels according to "per cent of standard weight"

Navajo study 1955

CRITERION	15–44 YEARS: Per cent of standard weight, Number of subjects					45 YEARS +: Per cent of standard weight, Number of subjects				
	< 90%	90–109%	≥ 110%	Unknown	Total	< 90%	90–109%	≥ 110%	Unknown	Total
			MALE					MALE		
> 140/90	1	2	5	0	8	6	10	0	2	8
Total	52	77	25	1	155	79	59	13	4	155
Per cent hyper-tension	2	3	20		5	8	17	0		12
			FEMALE					FEMALE		
> 140/90	0	1	5	0	6	17	11	8	1	37
Total	70	179	88	11	348	73	85	32	7	207
Per cent hyper-tension	0	1	6		2	23	13	25		18

Levels of serum cholesterol were related to the occurrence of "hypertension" among the subjects (table 23). Higher values of serum cholesterol were found in the older and heavier groups (table 24). There was a significant difference (P = 0.05) in the mean levels of serum cholesterol among the 18 hypertensive (236.0 ± 10 mg per 100 ml) and the 300 non-hypertensive (214.2 ± 3 mg per 100 ml) individuals aged 15 to 44 years. Over the age of 44 years differences in cholesterol values were not apparent between 48 hypertensives (236.0 ± 8.5 mg per 100 ml) and 313 non-hypertensives (234.0 ± 3 mg

TABLE 23

Comparison of serum cholesterol with prevalence of "hypertension"

Navajo study 1955

SERUM CHOLESTEROL	NUMBER WITH GIVEN LEVEL OF SERUM CHOLESTEROL		PERCENTAGE WITH BLOOD PRESSURE OVER 140/90	
	15–44 yr.	45+ yr.	15–44 yr.	45+ yr.
mg/100 ml				
< 200	126	72	0.8	15.3
200–249	127	136	7.1	15.4
250–299	48	81	4.2	14.8
≧ 300	12	24	8.3	16.7
Sub-total	313	313	4.2	15.3
Unknowns	51	43	0.0	16.3
TOTAL	364	356	3.6	15.4

TABLE 24

Cholesterol averages, by "per cent of standard weight"

Navajo study 1955

SUBJECTS	PER CENT STANDARD WEIGHT			Total
	< 90%	90–109.9	≧ 110%	
		mg/100 ml		
Males 15–44 years	206	220	247	219
Females 15–44 years	202	211	221	212
Males 45 years +	228	241	250	235
Females 45 years +	224	241	241	233

per 100 ml . Of possible significance ($P = 0.05$) is the occurrence of greater variability in cholesterol level among the "hypertensives." For all age and sex groups, levels of serum cholesterol were higher in individuals whose weights exceeded 110% of the standard.

No significant relationship was found between pulse rates and body weight. The pulse rates were 6 to 7 per minute faster in women than in men, regardless of examiner. The pulse rates of the "hypertensive" group were faster than that of the "non-hypertensive" subjects (table 25)

TABLE 25

Pulse values, by blood pressure classification by sex and age

SUBJECTS	BLOOD PRESSURE > 140/90	BLOOD PRESSURE ≤ 140/90	BLOOD PRESSURE UNKNOWN	TOTALS
Males, 15–44 yrs.	77.0±2.3 (8)[1]	71.3±0.8 (134)[1]	81.0±4.3 (9)[1]	72.2±0.8 (151)[1]
Males, 45 yrs. +	78.6±2.6 (18)	70.8±0.8 (132)	(0)	71.7±0.8 (150)
Females, 15–44 yrs.	85.0±6.1 (6)	79.0±0.5 (321)	94.0±3.6 (4)	79.3±0.6 (331)
Females, 45 yrs. +	81.5±2.0 (35)	76.4±0.8 (158)	(0)	77.3±0.7 (193)

[1] Numbers of subjects are in parentheses.

Facial hyperpigmentation. By the end of the initial two weeks of the study, a symmetrical bronzing pigmentation of the skin, particularly over the malar region, was noted by some of the examiners. This resembled that observed in certain oriental groups. Whether these changes are indicative of any nutritional inadequacy is undecided; certainly, exposure to the wind, dry atmosphere, and direct and reflected sunlight may determine or influence the findings. The recorded incidence of this finding varied so with observers (table 26) that any apparent age, sex, and locale variants are probably entirely artifacts. The observation that during the period of the study, adequately-fed white children playing

TABLE 26

Distribution of gingivitis and facial hyperpigmentation by examiners

Navajo study 1955

EXAMINER		Ganado Males 5–9 (27)	Ganado Males 10–14 (31)	Ganado Males 15–44 (84)	Ganado Males 45+ (76)	Ganado Females 5–9 (46)	Ganado Females 10–14 (36)	Ganado Females 15–44 (132)	Ganado Females 45+ (130)	Pinon Males 5–9 (40)	Pinon Males 10–14 (35)	Pinon Males 15–44 (71)	Pinon Males 45+ (48)	Pinon Females 5–9 (72)	Pinon Females 10–14 (40)	Pinon Females 15–44 (97)	Pinon Females 45+ (73)
		Age and number examined				Age and number examined				Age and number examined				Age and number examined			
MARGINAL GINGIVITIS																	
1	Number	1	3	3	16	1	1	7	13	24	23	38	43	49	14	53	50
	Per cen.	..	..	43	94	..	..	70	81	63	79	72	90	75	44	67	96
2	Number	0	1	3	4	0	0	8	6	0	0	9	30	0	1	3	15
	Per cent	..	17	33	50	..	..	29	29	..	..	50	100	..	12	19	71
3	Number	0	2	12	9	3	0	14	20	..	..	..	..	..	..	2	..
	Per cent	..	29	57	56	18	0	54	62	..	..	..	..	..	..	100	..
4	Number	1	10	26	14	4	4	29	14	..	..	..	..	..	..	..	..
	Per cent	7	67	55	40	21	27	43	23	..	..	..	..	..	..	..	..
Total	Number	2	16	44	43	8	5	58	53	24	23	47	73	49	15	58	[illegible]
	Per cent	7	52	52	57	17	14	44	41	60	66	66	94	68	34	60	[illegible]
FACIAL HYPERPIGMENTATION																	
1	Number	0	0	0	0	0	0	0	0	32	16	37	22	36	25	37	30
	Per cent	..	..	..	..	..	..	..	..	84	55	70	46	55	78	[illegible]	58
2	Number	0	0	0	0	0	0	0	1	0	0	2	14	0	1	5	11
	Per cent	..	..	..	..	..	..	..	5	..	..	11	47	..	12	31	52
3	Number	0	0	0	0	0	0	0	..	..	..	..	..	..	..	0	..
	Per cent	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
4	Number	6	6	14	23	6	3	31	49	..	..	..	..	..	..	..	..
	Per cent	40	40	30	66	32	20	46	80	..	..	..	..	..	..	..	..
Total	Number	6	6	14	23	6	3	31	50	32	16	39	36	36	26	42	41
	Per cent	22	19	17	30	13	8	23	38	80	46	55	46	50	65	43	56

outdoors with the Indian children at Pinon also developed similar pigmentation renders doubtful the nutritional significance in these lesions. Other evidence of any meaningful insufficiency of vitamins A and B-complex was lacking among the Navajo subjects.

Parotid enlargement. In view of descriptions of enlargement of the parotid glands and of the association of these changes with chronic malnutrition among people in the F and Middle East (Sandstead et al., '55), the Navajo patients were screened for parotid enlargement. The examiners obviously employed different criteria for the classification and description of the glands, and two examiners accounted for 91% of the cases at both Ganado and Pinon. This variant makes it impossible to determine age and sex relationships In an effort to appraise the possible value of this sign as a nutritional stigma, subjects with "parotid enlargement" were compared with those for which no enlargement was recorded. These comparisons included " per cent of standard weight," concentration of total serum protein, and other physical signs of possible nutritional significance. Among the adult groups (15 years of age and older) the recording of positive findings increased with "per cent of standard weight" of the patient, and this increase was particularly apparent when the weight exceeded 110% of standard. In this study we are unable to relate enlargement of the parotid gland to evidence of nutritional inadequacies (physical signs, hemoglobin or total serum protein concentration). Further evaluation of this sign is obviously required before validating it as indicative of malnutrition.

Pregnancy and lactation. Of the women 19 to 44 years of age, 51 were pregnant and 117 were lactating at the time of examination. The pregnant women were distributed as follows: Ganado, 29; Pinon, 22; first trimester, 5; second trimester, 20; third trimester, 26. No subject under 19 years of age was or had been pregnant; the oldest pregnant woman examined was 44 years. This age range of reproduction commenced later than had been anticipated.

Prenatal care and hospitalization for delivery are presently limited to those who live close to government or mission hospitals. In the remote areas, the labor and delivery are attended by Navajo midwives. It was surprising that under such conditions no woman exhibited clinical evidence of preeclampsia. Brief inquiry into the past history of obstetric complications revealed very few abnormalities. Abortion, stillbirth, toxemia and obstetric hemorrhage were infrequently reported.

Pediatric guidance is relatively unavailable to the majority of Navajo women. Pediatric complications are frequent; the neonatal and infant mortality has been reported (Hadley, '55) as 5 times that of the average in the United States. Breast feeding is continued until approximately two years of age; it was common to see toddlers nursing. Supplemental feeding of cereals, pureed vegetables and fruits or preparations of vitamins C and D are uncommon. Yet, deficiency diseases were not grossly apparent among the preschool children seen at either Ganado or Pinon.

In both symptoms and signs on physical examination there was a trend to a higher prevalence of recorded findings among pregnant and lactating women at Pinon than among similar subjects at Ganado. Symptoms of visual fatigue, night blindness, bleeding gums, dependent edema, and leg cramps were recorded more frequently among the pregnant subjects than among either lactating or non-pregnant women 15 to 45 years of age (table 27). Lesions of the gums and the dependent edema were observed (table 27) with greater prevalence during pregnancy than either lactation or the non-pregnant state. "Hypertensive" levels of blood pressure were found in only two subjects; one at Ganado (lactating) and one at Pinon (third trimester of pregnancy) and in neither instance was there additional evidence of toxemia.

With the exception of serum carotene levels which were consistently low, the biochemical assessment of these women revealed changes during pregnancy and lactation similar to those observed in the Vanderbilt and Detroit studies (Moyer

TABLE 27

Per cent incidence of medical history data and physical findings among women 15–44 years according to reproductive status

Navajo study 1955

MEDICAL HISTORY DATA	Groups	GANADO NP-NL[1]	GANADO Preg.	GANADO Lact.	PINON NP-NL	PINON Preg.	PINON Lact.
	Number	62	17	16	97	22	73
Easy bruising and dermatitis		26	24	6	39	41	30
Burning or itching eyes		26	24	31	33	36	36
Photophobia		45	53	50	52	55	36
Excessive lacrimation		37	47	44	48	50	37
Visual fatigue with blurring of vision		44	47	31	49	64	44
Sand, snow and night blindness		39	35	38	61	77	52
Burning and painful tongue		5	6	0	8	27	5
Bleeding gums		6	18	12	28	59	33
Dependent edema		5	18	0	7	23	5
Anorexia		8	12	[illegible]	23	27	18
Indigestion		18	24	0	15	18	7
Chronic diarrhea hemorrhoids with bleeding		0		0	11	14	16
Leg cramps		13	24	19	24	68	26
Either eye under 20/30 vision		28	11	26	12	41	13

PHYSICAL FINDINGS	Groups	GANADO NP-NL	GANADO Preg.	GANADO Lact.	PINON NP-NL	PINON Preg.	PINON Lact.
	Number	132	29	44	97	22	73
Dryness and scaling of skin		11	10	7	30	45	27
Thick and pigmented pressure points		12	10	[illegible]	71	91	74
Thickened conjunctiva		67	66	73	91	100	85
Angular lesions and scars		11	7	7	8	14	[illegible]
Cheilosis		2	3	0	2	14	8
Papillary atrophy		7	3	9	7	0	4
Papillary hypertrophy		8	7	0	3	0	1
Caries		54	38	68	47	68	52
Edentulous		6	7	7	0	0	0
Marginal gingivitis		44	48	43	60	86	67
Atrophy of papillae		18	3	14	34	45	23
Recession with debris		19	21	27	11	18	7
Bleeding gums		6	14	5	4	5	3
Blood pressure over 140/90		2	0	2	2	5	0
Pitting edema		1	7	0	4	27	4
Facial hyperpigmentation		25	21	16	43	59	47
Parotid enlargement		7	7	7	9	18	12

[1] NP-NL = Non-pregnant — non-lactating.

et al., '54) and widely in the southern region (Darby et al., '53a) Hemoglobin and total serum protein were lower during pregnancy than in the non-pregnant or lactating women. Serum vitamin C was lower during gestation and was further reduced during lactation. The increase in the findings of gingivitis and the low values of serum ascorbic acid are suggestive of physical and biochemical changes in part attributable to a lowered intake of ascorbic acid. During gestation serum cholesterol levels were higher than during either lactation or the non-pregnant state. Despite the evidence of the expected lipemia of pregnancy (Darby et al., '53b) serum carotene values were low during both pregnancy and lactation. This reflects the overall low values for serum carotene and the low dietary intake of this pigment by the Navajo. The satisfactory levels of serum vitamin A are consistent with an adequate dietary supply of this nutrient.

DISCUSSION

Physical tests of over 1200 Navajo individuals examined at Ganado and Pinon have revealed a variety of findings which might possibly have nutritional significance. In only one person, however, was frank clinical vitamin deficiency disease present — a pellagrin with bizarre dietary habits. In the present study the findings vary with age, sex, pregnancy and lactation and the examiner. Interpretation of these findings must take into account the influences of obvious environmental hardships, exposure to wind, sun, excessive atmospheric dryness and water shortage of the region.

Among the subjects (excluding pregnant and lactating women) symptoms referable to the skin, eyes, gums and gastrointestinal tract were most commonly recorded. Dependent edema and leg cramps were additional symptoms noted by women during pregnancy and lactation. The recorded prevalence of these "ills" is similar to that observed in Newfoundland (Aykroyd et al., '49; Goldsmith et al., '50), in North Carolina (Milam and Anderson, '44) and among the Otomi Indians in Mexico (Anderson et al., '46a).

Underweight among the Navajo is relatively uncommon prior to 30 years of age. Above this age both males and females show an increasing percentage of individuals who may be considered underweight — less than either 80 or 90% of standard weight. This is in contrast to trends prevalent among adult white populations in the United States and Canada (Pett, '50). It may be worth speculation as to whether this may contribute to the observed low incidence of hypertension (blood pressure > 140 mm Hg systolic/90 mm Hg diastolic) found in the Navajo subjects. The greater height among the adult men and women in the Pinon area may reflect a true hereditary trait.

The recorded changes in the skin, of dryness and scaling and hyperkeratotic lesions, are obviously influenced by the dry atmospheric conditions and by the working posture during weaving and food preparation. The satisfactory levels of vitamin A in the blood indicate that there is no widespread deficit of the nutrient which contributes to these skin changes. Both signs were more frequent among the Navajo than in the population of Newfoundland (Aykroyd et al., '49; Goldsmith et al., '50; Adamson et al., '45; Pett, '50) but less frequent than among Otomi Indians in Mexico (Anderson et al., '46a).

Continual exposure to the elements — sun, wind, direct and reflected sunlight — no doubt contributes to the high percentage of ocular lesions. The residua of trachoma are included in the findings. These ocular changes were more common in the present survey than in Newfoundland, North Carolina, or Mexico.

Gingival lesions were more frequent among this sample than has been noted in several other population groups (Aykroyd et al., '49; Goldsmith et al., '50) except for the Otomi Indians. The latter had a remarkably high intake of ascorbic acid. In the present survey the examinees at Pinon had more gingivitis and their serum level and the dietary study indicated that they had vitamin C intakes lower than the subjects examined at Ganado. Frank scurvy was lacking in both locations. Gross caries, poor oral hygiene and minimal dental care were very common. The combination of the restricted dietary supply of vitamin C, the low levels of ascorbic acid in the serum, the high incidence of gingival changes and the locale differences is indicative of a nutritional insufficiency.

A biochemical assessment of the vitamin B-complex nutriture was not undertaken. Lesions of the mouth and tongue were not commonly encountered. The observed frequency of cheilosis, angular lesions, and glossitis was less than in the studies of population samples in Newfoundland, North Carolina, Mexico and was similar to the Canadian study (Pett, '50). It may be concluded that B-complex lack is rare among this population.

Physical evidence of anemia, protein undernutrition, rickets, or other nutritional deficiencies were lacking.

The following patterns of physical findings are worthy of summarizing:

(1) Influence of location (Pinon vs. Ganado): Adults were one to two inches taller at Pinon. Lesions of the eyes, skin and gums were more common at Pinon. Hypertensive blood pressure levels were less often recorded at Pinon.

(2) Influence of age: As expected, height and weight varied with age, increasing to adult maturity and then following a plateau. After 60 years of age, there is a decrease in weight with increasing age. This decrease in weight with age included a decrease in "per cent of standard weight." hyperkeratotic lesions of the skin, changes in the eyes, dental caries, marginal gingivitis and blood pressure increased with age. Angular lesions of the mouth (maceration, angular fissures, and cheilosis) were more common in the children. Skeletal variants were more commonly noted in children, but no cases of rickets were diagnosed.

(3) Influence of sex: Height and weight were greater in men than women. The incidence of obesity (over 100% of standard weight) was greatest among the women 15 to 44 years of age. Hyperkeratotic lesions of the skin, hypertensive levels of blood pressure, and higher pulse rates were more frequent among women.

(4) Influence of pregnancy and lactation: Symptoms of visual fatigue, night blindness, bleeding gums, dependent edema and leg cramps were recorded and lesions of the mouth, gums, and dependent edema were observed more commonly among pregnant subjects than among either lactating or non-pregnant women of the same age group. Hypertensive levels of blood pressure were not more frequent, and no clinically diagnosable case of toxemia was found in either center.

SUMMARY

1. The nutritional status of 1236 Navajo individuals has been assessed by medical history and physical examination. The study group included men, women and children, with an age spread of 5 to 92 years.

2. Frank deficiency diseases were essentially non-existent.

3. Only in the assessment of ascorbic acid nutriture was there indication of widespread insufficiency.

4. The observed minor physical changes appear to be largely a result of conditions local to the area, such as exposure to the elements in the semi-arid environment.

5. The patterns of occurrence of the various findings are described.

BIOCHEMICAL FINDINGS

A biochemical appraisal of nutriture was made at the time of the physical examination on the subjects aged 15 years or older. Most individuals willingly cooperated in allowing the physician or nurse to procure the requisite quantity of venous blood for these studies. A small percentage of the examinees refused this portion of the examination; in addition, there occurred the inevitable laboratory or clinic loss of samples. During the first week of work at Pinon no laboratory studies were made. These various losses, however, were not of systematic pattern and do not, in our opinion, affect the interpretation of the results unduly. The biochemical findings provide valuable quantitative evidences of the nutrient intake levels and are consistent with the other information bearing on the nutritional level of the Navajo.

METHODS

Blood from the antecubital vein was collected from adults as follows: 15 to 20 ml directly into a commerically available vacuum container[6] and allowed to clot for serum preparation; 5 ml directly into a smaller, but similar, tube[7] containing 6 mg of ammonium oxalate and 4 mg of potassium oxalate. Capillary blood was obtained from children by pricking the fingertip with a disposable sterile lancet[8] and filling two heparinized capillary tubes[9] for use in the hemoglobin estimation and two clean capillary tubes for preparation of serum. Serum was obtained from clotted samples after cen-

[6] B-D vacutainer no. 3208.
[7] B-D vacutainer no. 3204.
[8] "Hemolet," American Hospital Supply Company.
[9] Capillary Tubes, Heparinized no. 23922, A. S. Aloe Company.

trifugation. Surplus plasma from oxalated samples was combined with serum for estimation of cholesterol, carotene or vitamin A, but not for ascorbic acid.

The laboratory at Pinon completed the estimates for hemoglobin and of total serum protein on samples from that clinic. Serum aliquots for estimation of vitamin C were precipitated with 6% metaphosphoric acid, and, along with serum for the other estimations, refrigerated and transported to Ganado for completion of the determination. All samples obtained at Ganado were processed in the laboratory there.

The particular laboratory procedures employed were selected on the basis of convenience and dependability under field conditions and with a view to allowing for valid comparison with a number of similar studies on population groups. The methods were as follows:

Hemoglobin and total serum protein. The copper sulfate specific gravity method of Phillips and Van Slyke ('45) was used, the specific gravity intervals of 0.004 adopted and gravities recorded to 0.001 unit. The recommended correction was made for oxalate where present. When the sample was insufficient for determination of total serum protein the average value of 7.2 gm per 100 ml was used to calculate the hemoglobin content. Personnel limitations dictated that during the first week of the clinic at Pinon and for almost all children throughout the study at that clinic there was but simplified screening of hemoglobin level by determining whether the concentration was above or below the two limits of 12.3 or 14.2 gm/100 ml, assuming an average total serum protein of 7.2.

Serum ascorbic acid. A photoelectric procedure (Association of Vitamin Chemists, '51; Mindlin, '38; Bessey, '38), which employed 2, 6-dichlorophenolindophenol as an indicator, metaphosphoric acid as a protein precipitant, and citrate buffer was used. These reagents were prepared in deionized water which was obtained by passing distilled water through a mixed bed ion exchange resin. All analyses were stabilized immediately and completed within 4 days.

Serum carotene and vitamin A. The serum was extracted with petroleum ether, the carotenoids estimated photoelectrically, and vitamin A determined by an adaptation of the Carr-Price reaction (Dann and Evelyn. '38; Lewis, Bodansky and Haig, '41; Kaser and Stekol, '43).

Serum cholesterol. The method of Pearson, Stern and McGavock ('52) using *p*-toluene-sulfonic acid, was employed. This was found to give values consistent with those obtained by means of the Liebermann-Burchard reaction.

FINDINGS

The results of the studies on adult groups are summarized in table 28. The hemoglobin levels in children are given in tables 29 and 30. Throughout the groups a rather consistent pattern is apparent.

The average hemoglobin concentrations are high — approximately 1.5 gm above the level found by Milam and Muench ('46) for a healthy white population in North Carolina, and about 2.0 gm above the level for Negroes in this same region. For non-pregnant Navajo women the mean hemoglobin concentration was approximately 2 gm above those reported for white women in Newfoundland in 1948 by Goldsmith et al. ('50), 1–2 gm above similar groups in Tennessee (Darby et al., '53a), as well as above the levels reported for young adults of either sex in the Northeastern region (Clayton et al., '53). This higher concentration of hemoglobin than for similar white groups also held for the reproductive interlude (pregnancy and lactation). In our study of nutrition in pregnancy in Nashville, Tennessee, the average hemoglobin level ranged from 12.1 gm for the 5th to 9th week of gestation to 11.4 gm for the 27th to 32nd, and an average of 11.6 to 12.1 gm for lactating mothers up to 8 weeks postpartum. These are to be contrasted with the averages, for Navajo women, of slightly more than 13 gm during pregnancy and 14 gm during lactation. These higher-than-usual values probably result from the altitude at which this population lives. However, we cannot rule out a genetic influence as accounting

TABLE 28

Nutritional biochemical findings, Navajo Indians, June–July, 1955

SEX	MALES				FEMALES				FEMALES		FEMALES	
					Non-pregnant, non-lactating				Pregnant		Lactating	
LOCATION	Ganado		Pinon		Ganado		Pinon		Ganado	Pinon	Ganado	Pinon
AGE (*yrs.*)	15–44	45+	15–44	45+	15–44	45+	15–44	45+	18–44	18–45	18–44	18–45
					Hemoglobin (gm/100 ml)							
Number	80	72	60	58	117	129	66	56	27	16	[illegible]	59
Mean	15.98	15.76	16.17	16.12	14.11	14.72	14.27	14.75	13.04	13.20	14.06	14.14
S.E.	0.12	0.14	0.13	0.19	0.14	0.11	0.17	0.13	0.26	0.40	0.21	0.21
S.D.	1.07	1.19	1.01	1.42	1.49	1.22	1.39	0.95	1.37	1.61	1.37	1.62
					Total serum protein (gm/100 ml)							
Number	78	70	60	59	118	126	66	56	25	16	41	59
Mean	7.55	7.24	7.44	7.59	7.64	7.56	7.71	7.70	7.07	6.86	7.69	7.96
S.E.	0.05	0.06	0.06	0.08	0.05	0.05	0.08	0.08	0.11	0.12	[illegible]	0.07
S.D.	0.48	0.49	0.47	0.58	0.58	0.53	0.63	0.60	0.55	0.47	0.49	0.54
					Serum cholesterol (mg/100 ml)							
Number	79	74	59	58	118	129	66	56	26	[illegible]	44	60
Mean	228	242	208	227	218	236	199	227	257	306	219	[illegible]
S.E.	4	6	5	6	5	4	6	6	10	14	8	7
S.D.	38	53	41	47	51	50	46	45	51	57	56	51
					Serum vitamin A (I.U./100 ml)							
Number	74	70	57	57	109	121	65	54	26	16	41	57
Mean	180	181	183	[illegible]	146	162	147	157	187	150	136	165
S.E.	8	8	9	8	5	6	7	9	15	13	7	9
S.D.	68	65	65	[illegible]	55	64	53	65	75	52	46	67
					Serum carotene (µg/100 ml)							
Number	75	71	59	58	109	122	65	54	26	16	41	57
Percentile 10th	30	26	20	21	25	28	18	22	34	32	14	16
Percentile 25th	45	36	34	29	40	39	30	34	[illegible]	44	28	26
Percentile 50th	71	54	62	46	63	58	53	52	72	64	[illegible]	39
Percentile 75th	93	86	86	80	96	84	90	72	[illegible]	91	67	56
Percentile 90th	128	137	117	102	146	124	132	98	167	134	93	77
					Serum vitamin C (mg/100 ml)							
Number	78	73	[illegible]	57	118	128	64	56	25	16	44	58
Percentile 10th	0.11	0.00	0.03	0.00	0.07	0.02	0.00	0.00	0.05	0.02	0.00	0.00
Percentile 25th	0.18	0.02	[illegible]	0.04	0.16	0.11	0.12	0.05	0.17	0.08	[illegible]	0.05
Percentile 50th	0.33	0.15	[illegible]	0.14	0.37	[illegible]	0.27	0.13	0.34	0.16	0.12	0.13
Percentile 75th	0.58	0.26	[illegible]	0.27	0.70	0.42	0.56	[illegible]	0.57	0.26	0.26	0.24
Percentile 90th	0.86	[illegible]	1.00	0.54	1.10	0.68	0.88	0.46	0.94	0.54	0.56	0.62

for the different hemoglobin levels in racial groups, such as these high levels in the Indians, the lower levels in Negroes in North Carolina (Milam and Muench, '46), in Florida and Michigan (Nutrition Branch and Program Analysis Branch, USPHS, '49) and in Tennessee (Darby et al., '53a). It is of some interest that Anderson et al. ('46a) noted levels of hemoglobin similar to those found in the Navajo in the Otomi Indians of Mexico living at 6500 feet altitude, in others living at altitudes of 6000 to 7500 feet (Anderson et al., '48), and among pregnant and lactating women in Mexico City (Anderson et al., '46b). By contrast, Totter and Shukers ('48) found that Alaskan Eskimos had mean hemoglobin levels lower than those we observed among the Navajo.

TABLE 29

Hemoglobin levels among 114 Navajo children

June–July 1955

(Ganado and Pinon combined)

	MALE	FEMALE	MALE	FEMALE
	5–9 Years		10–14 Years	
Number	31	43	20	20
Mean hemoglobin *gm/100 ml*	14.03	13.94	14.65	14.50
S.E.	± 0.17	± 0.15	± 0.29	± 0.28
S.D.	0.92	0.96	1.28	1.23

As implied by the average values, very few abnormally low hemoglobin values were encountered. None of the men examined had values below 12 gm per 100 ml, only 9 of the 368 non-pregnant non-lactating women exhibited levels below 11 gm. (8 of these were in the 15- to 44-year age group), and but 7 of 146 pregnant or lactating women had values below 11 gm.

Among the children levels of hemoglobin (table 29) were adequate, only 5 to 7% of the 5- to 14-year olds having values below 12.3 gm per 100 ml (table 30). No sex differences in mean hemoglobin levels were present in comparable age groups. However, the usual increase in values was found in the 10- to 14-year-old children, and there was a significantly increased proportion of girls 10 to 14 years of age with hemoglobin concentrations above 14.2 gm per 100 ml (table 30). These results are comparable to the means and distributions of values found by Anderson et al. ('46a) among the Otomi Indians. The Navajo children had values 1.0 and 2.0 gm higher than do white or Negro children respectively in North Carolina (Milam and Anderson, '44) and than white children in Nashville (Darby et al., '47).

TABLE 30

Percentage of hemoglobin limits among 246 [1] *Navajo children*

June–July 1955

(Ganado and Pinon combined)

	MALE	FEMALE	MALE	FEMALE
	5–9 Years		10–14 Years	
Number	46	87	52	61
	%	%	%	%
Hemoglobin *gm/100 ml*				
Less than 12.3	7	5	6	7
12.3–14.2	59	61	50	36
Greater than 14.2	35	34	44	57

[1] Included are 114 children from table 29. The remaining 132 children from Pinon were screened assuming an average plasma protein of 7.2 gm, 100 ml.

It is apparent that any problem of iron deficiency or, indeed, a lack of any nutrient essential for hemoglobin formation in this population is minimal. Insofar as hemoglobin levels are concerned, the group of men more nearly resemble the Olympic athletes reported on by Berry et al. ('49) than they do a deficient population. The consistently higher average values at Pinon, the area less sophisticated because of its greater isolation, than at Ganado, seems logically attributable to the slightly greater altitude at which the families in this area lived.

The values for total serum protein are consistent with those of healthy groups — only 4 subjects (three adults and one child) had values below 6.1 gm. These findings are comparable to or slightly higher than those reported by Milam ('46), about 0.5 gm higher than found in the earlier surveys in Middle Tennessee (Youmans et al., '43), similarly higher than one now finds among pregnant or lactating white women in Middle Tennessee (Darby et al., '53b), and generally similar to the slightly "elevated" values reported for Negroes (Milam, '46: Nutrition Branch and Program Analysis Branch, USPHS, '49), for the Otomi Indians (Anderson et al., '46a), for inhabitants of Central America and Panama (Scrimshaw et al., '51), and for a population in Mexico City (Robinson et al., '44). The findings do not suggest any problem of protein malnutrition among this population. There is no consistent pattern of differences in total serum protein between the two localities.

The measurements of serum cholesterol resulted in values which are in accord with those widely found for omnivorous human populations (Keys and Keys, '54; Keys et al., '55) and which fall in the range judged to be normal. The following expected pattern in different physiologic groups pertain: (a) slightly lower values in younger women than in men; (b) a rise in cholesterol and a disappearance of the sex difference with age; and (c) an appreciable increase during pregnancy. These levels are of interest because of the intermittently generous fat diet of the Navajo in which mutton plays such a prominent part, as well as the reportedly low incidence of atherosclerosis and coronary thrombosis among members of this tribe (Gilbert, '55).

These observations on a sample of 785 Navajo individuals from the general population are some 40 mg % higher on the average than the means reported by Page, Lewis and Gilbert ('56) on 36 hospitalized Navajo patients. In fact, our findings are indistinguishable from the values taken by Page, Lewis and Gilbert as controls — a group of white subjects in Cleveland.

The average values for vitamin A in the serum were within the range associated with good nutriture, but the distribution of the individual values was wide. Four women (two non-pregnant, non-lactating, one each pregnant and lactating) had levels below 40 I.U. per 100 ml, i.e. unquestionably low values which are usually associated with measurable changes in retinal function. Three men and 16 non-pregnant, non-lactating women had levels below the less rigid, widely used "limit of normal" of 70 I.U. per 100 ml. Despite the failure to detect clinically manifest avitaminosis A among this group, one must conclude that a small portion of them fails to ingest sufficient vitamin A or its precursors. These low values are masked in considering only means, since an appreciable number of samples contained 320 I.U. per 100 ml or above — no doubt reflecting the recent ingestion of visceral meats rich in this vitamin.

The distribution of carotene measurements was skewed toward the low side; accordingly, the values are presented as percentiles (table 28). These levels reflect an unusually low consumption of carotene-containing foods, and are similar to those observed in Norris Point, Newfoundland (Goldsmith et al., '50) where, however, the average vitamin A values were lower. Although carotene levels of the Navajo are lower than are those of the Otomi Indian (Anderson et al., '46a), the vitamin A status of the former is decidedly better. Indeed, the mean vitamin A level of the Navajo is higher than that recorded for either white or Negro southern population groups (Milam and Anderson, '44) while the carotene levels of the blood are decidedly lower.

No general decrease in serum vitamin A occurs in the older age groups, such as is reported for older white subjects (Nutrition Reviews, *14*, '56). Furthermore, the depression of the vitamin level in pregnancy (Darby et al., '53b) observed in white groups was not manifested. The rise in serum carotene level during pregnancy and the subsequent fall during lactation were observed.

It is evident that the Navajo has a low carotene, predominantly (preformed) vitamin A intake and that this intake is adequate in most instances. There is, however, a small percentage of individuals whose intake is insufficient to maintain adequate vitamin A stores.

Despite this seeming dissociation of carotene and vitamin A, it is of interest that they are interrelated (table 31). This

TABLE 31

Serum vitamin A levels, according to levels of serum carotene

Navajo groups, June–July 1955

SERUM CAROTENE LEVEL (µg/100 ml)	SERUM VITAMIN A (I.U./100 ml)					
	Ages 15–44 yr.		Ages 45+ yr.		Lactating	
	No.	Av. ± S.E.	No.	Av. ± S.E.	No.	Av. ± S.E.
0– 24	37	133 ± 10	27	142 ± 11	21	124 ± 12
25– 49	72	148 ± 8	109	158 ± 6	42	153 ± 7
50– 74	81	174 ± 7	80	186 ± 7	22	185 ± 18
75– 99	56	174 ± 8	41	195 ± 8	7	145 ± 16
100–149	41	160 ± 10	31	172 ± 8	6	164 ± 7
≥ 150	18	182 ± 15	14	182 ± 26	0	. . .
TOTAL	305	161 ± 4	302	172 ± 4	98	153 ± 6

TABLE 32

Serum cholesterol levels, according to levels of serum carotene

Navajo groups, June–July 1955

SERUM CAROTENE LEVEL (µg/100 ml)	SERUM CHOLESTEROL (mg/100 ml)					
	Ages 15–44 yr.		Ages 45+ yr.		Lactating	
	No.	Av. ± S.E.	No.	Av. ± S.E.	No.	Av. ± S.E.
0– 24	36	194 ± 7	28	203 ± 8	21	201 ± 10
25– 49	72	205 ± 4	110	223 ± 4	42	210 ± 7
50– 74	82	208 ± 5	80	245 ± 6	22	209 ± 9
75– 99	57	226 ± 5	41	235 ± 7	7	246 ± 36
100–149	42	233 ± 8	31	257 ± 9	6	233 ± 35
≥ 150	18	241 ± 17	14	257 ± 16	0	. . .
TOTAL	307	214 ± 3	304	234 ± 3	98	212 ± 5

relationship is such that those persons with the lowest levels of carotene are the individuals whose vitamin A nutriture is also lower, and who would have less protection against a reduced dietary supply of preformed vitamin A.

The existence of an association between serum cholesterol concentration and serum carotene (table 32) is worthy of mention as another example of the relationship between lipid-soluble constituents in serum, an association which has been previously noted (Darby, Cannon and Kaser, '48; Darby et al., '4[illegible]; Darby et al., '[illegible]3b; Ferguson et al., '55). The similar behavior of carotene, cholesterol and tocopherol under a variety of conditions and the occasional divergence of vitamin A is probably indicative of similar transport mechanisms for these three factors so often associated, and of a rather different mechanism in the instance of vitamin A.

TABLE 33

Serum cholesterol levels, according to levels of serum vitamin C
Navajo groups, June–July 1955

SERUM VITAMIN C LEVEL (mg/100 ml)	SERUM CHOLESTEROL (mg/100 ml)					
	Ages 15–44 yr.		Ages 45+ yr.		Lactating	
	No.	Av. ± S.E.	No.	Av. ± S.E.	No.	Av. ± S.E.
0.00–0.09	44	210 ± 7	97	233 ± 5	43	208 ± 7
0.10–0.19	62	218 ± 6	70	231 ± 5	27	212 ± 11
0.20–0.29	43	212 ± 7	44	242 ± 7	12	20[illegible] ± 14
0.30–59	89	212 ± 4	72	231 ± 6	9	224 ± 24
≥ 0.60	78	219 ± 6	29	242 ± 8	11	224 ± 22
TOTAL	316	215 ± 3	312	234 ± 3	102	212 ± 5

The ascorbic acid levels in the serum were low in the majority of cases in all groups. The distribution was skewed and, accordingly, the data are presented in percentiles (table 28). It is strikingly clear that those in the 90th percentile were abundantly nourished insofar as vitamin C is concerned.

The data permit certain generalizations; at least half of all groups, and a larger portion of several, have vitamin C level below 0.3 mg per 100 ml. More low values occur among the older adults and among lactating or pregnant women. The values from the Pinon area are lower than are those for similar groups around Ganado — a finding consistent with the results of the physical examination of a greater incidence of gingivitis in the Pinon group. From these serum levels one may conclude that some half of the people had a dietary intake of ascorbic acid of not more than 30 mg. The low nutriture with respect to ascorbic acid is in keeping with, albeit below, the findings reported in the limited study by Pijoan, Elkin and Eslinger ('43) on the Papago Indians. The Navajo is decidedly below the Otomi (Anderson et al., '46a) in ascorbic acid status as well as other groups in Mexico (Anderson et al., '48). The vitamin C nutriture of the Navajo more nearly resembles that found in Newfoundland in 1948 (Goldsmith et al., '50; Aykroyd et al., '49) and in some of the groups in the Southern United States. For example, in a sample of a county population in North Carolina it was found that 27% of the white and 31% of the colored inhabitants had serum vitamin C levels below 0.3 mg (Darby and Milam, '45).

In view of the experimental finding of Becker et al. ('53) that ascorbic acid reduced cholesterol synthesis it was of interest to seek evidence from this epidemiologic study which might bear on any such relationship in man. Table 33 indicates the absence of any influence of serum level of vitamin C on cholesterol level in man as detectable in this survey.

INTERPRETATION

This study, incomplete though it is, dispels several widespread misconceptions concerning the Navajo. He has abandoned his primitive diet — he no longer depends on the hunt, on Indian corn, on the gathered wild plants, berries, and fruits for his food. He lives by combining home-produced meat and a few other products with flour, shortening, coffee, potatoes, sweets, some milk and fruits and a limited variety of other foods purchased at the trading post. His purchases remind one somewhat of the selection made at the "country store" of 30 to 40 years ago.

The Navajo seldom shows clinical evidence of gross nutritional deficiency. He is, by and large, acceptably nourished calorically. The exceptions to this generalization are leaness, primarily among the older members, and obesity, especially in the women of childbearing age.

He has no problem of anemia or of protein malnutrition. Indeed, during this study we watched carefully for evidences of kwashiorkor among infants and children and at Pinon (where no regular medical service was available) we held each morning a "pediatric clinic" to care for ill babies and children who might be brought in. Although a few poorly fed infants were seen, no cases of true protein malnutrition were observed. This fortunate situation is attributable to the high incidence of breast feeding, the good nutriture of the mothers, the prevalent use of canned milk when breast milk is not available for infant feeding, the availability of milk (canned, especially) at the trading post, and the wide use of mutton, goat and other meats in the diet.

The absence of anemia speaks for a good intake of iron and other hemopoietic essentials, as well as for a very low incidence of infestation with parasites which might produce iron-deficiency anemia.

Among the adults no residua clearly attributable to childhood rickets were noted and among the children no certain cases of clinically diagnosable rickets were seen. Serum phosphatase determinations were not done and no other laboratory or x-ray studies were undertaken. Breast feeding, the use of evaporated milk (which is fortified with vitamin D), the free exposure to the sun during much of the year, and the absence of a whole-cereal dietary contribute to this good situation relative to rickets.

Iodine lack as reflected by endemic goiter was not encountered to an extent to be considered of nutritional significance. Fluorosis is not severe in the population studied. Dental caries, however, was variable—in some geographic regions it was severe, in a few groups it was strikingly rare. In the examinees at Pinon, the region less influenced by white man's culture, the recorded incidence of noteworthy caries was slightly greater, but evidence of dental care (number of edentulous persons) was less. There was, in our opinion, no real difference between the dental status in these two regions, in contrast to that which one might expect from the widespread belief that the closer the food habits approach the primitive, the fewer dental ills.

Clinical evidence, vital statistics, and hospital experience reveal no widespread severe vitamin B-complex deficiency. There are no real problems of pellagra, of beriberi or of sprue. Such evidence is in accord with the qualitative dietary pattern. Oral lesions and conjunctival injection may speak for some incidence of ariboflavinosis, but no biochemical tests were made to decide this question. The dietary of some appears low in this nutrient, especially where milk is used in less quantity. It is suggestive that the incidence of these signs was greater at Pinon where the frequency of milk consumption was less. These observations lend support to the obvious need to increase the production, availability, and use of milk on the Reservation.

vitamin C nutriture is low. An unusually high percentage of the population had serum levels indicating a daily intake well below 30 mg and despite the absence of scurvy there is in the physical findings evidence of impairment due to the low levels of vitamin C.

The vitamin A status seems largely determined by the intake of visceral meats, only a minimal quantity of vitamin A activity being derived from plant sources. The findings are in direct confirmation of the dietary information and evidence on food production and consumption. Garden vegetables and fruits are in short supply; fresh fruits (other than melons) are deemed luxuries by most Navajos and are not regular items of the diet; home preservation of fruits and vegetables (except drying, which decreases the ascorbic acid content greatly) is widely non-existent. Attention should be given to these needs in agricultural planning, home demonstration teaching, in schools, by mission workers, by public health nurses and other personnel, and in all sound educational activities. In educational work (Sasaki and Adair, 52) it is essential, however, to recognize that the Navajo is making the transition from the more self-produced diet to the bought, processed food of the white man — he is becoming dietarily aculturated. In this process it is essential that the remaining beneficial traditional practices be retained — for example, the home slaughtering and Navajo style of preparation of sheep and goat provides good amounts of vitamin A (visceral portions, blood sausage, etc.) and is no doubt responsible for the high degree of protection which now exists against clinical avitaminois A. The wide and regular use of potatoes must contribute largely to the limited intake of vitamin C. Changes in food procurement and dietary sophistication must not suddenly be permitted to alter or render these important foods unattainable.

A number of non-nutritional observations were made by our teams. No effort to discuss these will be made, but it is pertinent to remark on the exceptionally high incidence of visual impairment, partial blindness, and corneal scarring which we observed. These changes were sometimes of traumatic origin; more frequently, however, they were associated with evidence of an old trachomatous infection. History consistent with severe avitaminosis A was not obtainable in relation to these findings and the biochemical and other evidence fails to support a thesis that such impairment is attributable to malnutrition.

The serum cholesterol values among the Navajo fall into the usual pattern for omnivorous populations, and the levels found do not support the thesis that they may be responsible for a low incidence of coronary heart disease.

Since the initial impetus for this investigation was the exploration of a possible dietary influence on malignancy, it is appropriate to comment on this point. The nutritional level of the Navajo has not been found to differ markedly from that of several other populations which have been investigated. There is no pronounced peculiarity of the nutrititure which in our present state of knowledge one might seize upon as a likely explanation of any true difference in malignancy rate which may exist between the Navajo and other groups. The extent of the present use of wild or native foods does not seem to us to justify the expectation that among these there is a likely explanation of the phenomenon. Further experimental studies of the effect of the particular diet as here described might conceivably reveal subtle unexpected effects, but in view of the well-recognized differences between racial groups in rate of incidence of cancer and other diseases it may logically be hypothesized that a genetic influence is a more likely explanation than a dietary one. This conclusion is similar to that entertained concerning the low incidence of cervical cancer among Jewish women (Anonymous, '56).

This study is an initial step toward meeting the need expressed by Kraus ('54) for "scientifically conducted surveys of nutritional status among Indian populations of the Southwest..." It is hoped that it may be followed by additional investigations among this tribe and among the other Indian groups. We believe that information of this type made widely available should serve as a sound guide for the work numerous groups concerned with the improvement of the health of the American Indian. Furthermore, modern chemical and nutritional investigations of the wild or native foods of the American Indian can be expected to contribute to the better use of arid lands throughout many regions of the

To all concerned with this study we are most indebted. To the Navajo Tribe and its leaders we owe particular gratitude for their understanding support of and participation in the work. If these studies serve better to understand the nutritional needs of "The People" and thereby to exert a favorable influence on their education, agriculture and health, they will have served their purpose and repaid the efforts of all concerned

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