HEMOGLOBIN VALUES IN PENNSYLVANIA MASS STUDIES IN HUMAN NUTRITION[1]

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THE appraisal of the status of nutrition in human beings is commanding widespread notice at the present time because of the recognition of the need for valid techniques for this purpose, if bad dietary practices are to be altered favorably. At present, no single measure of nutritional status as a whole is regarded as being adequate, nor is evidence at hand that a satisfactory one-test technique may be developed in the near future. For those whose resources are limited, however, the number of nutritional tests used must be small, and the tests must be selected on the basis of the information which they will yield.

In connection with the mass studies in human nutrition carried on at The Pennsylvania State College since 1935, in which the Department of Health of the Commonwealth of Pennsylvania has cooperated since 1936, the test for hemoglobin has yielded results of sufficient interest to commend it for consideration by those seeking to appraise nutritional status in human beings, whether the number of tests used is extensive or limited. With the isolation of hemoglobin in crystalline form by Funk (8) in 1851, and the development of a clinical method for hemoglobin estimation by Welcher (33) in 1854—probably the first method of this sort proposed—an

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impressive succession of reports has appeared on hemoglobin methodology, and on the findings on human beings obtained by means of the hemoglobin tests developed.

Subjects of the Study

In the Pennsylvania mass studies in human nutrition carried on during the past five years, hemoglobin values have been obtained on 2,400 subjects in the following groups: 100 urban families, including 418 persons—205 males and 213 females—taken from the work of Agnes Pauline Sanders (30); 100 rural families, including 490 persons—246 males and 244 females; and 1,492 children in addition to those in the families previously mentioned—691 males and 801 females, in four different communities.

The urban families were selected in towns and small cities of sub-metropolitan size, to represent a wide range of annual cash income. The rural families were chosen in Adams, Centre, and Lancaster Counties, on the basis: (a) of the type of farm enterprise; and (b) of farm cash receipts. In Adams County (Locality 1), apple production was the chief, and frequently sole enterprise; in Centre County (Locality 2) general farming was carried on, but the level of cash farm incomes was not high; in Lancaster County (Locality 3) dairy farming was coupled with general farming, and the cash farm incomes were higher than in Locality 2. In each of the farm localities, families were selected so as to represent the distribution of annual cash farm incomes characteristic of the locality.

The school children included in this study were from the intermediate grades of public and private schools of four communities, and were selected from families for which the income distributions were typical of the respective communities as a whole. Community 1 was a city of about 82,000 inhabitants, in which railroad shops operating on a much reduced scale for many years were the leading industry. Community 2 was a college town of about 7,000 inhabitants. Community 3 was a rural community in the apple region of

southern Pennsylvania, where the children studied were in one consolidated and in two one-room schools. Community 4 was a city which, with its suburbs, had a population of about 125,000, located in the Pennsylvania anthracite region. The number of children of foreign-born parents or grandparents was higher in Community 4 than in any of the other communities. The number of children tested in the respective communities were:

Community 1	428 children —	166 boys, and	262 girls;
Community 2	147 children —	70 boys, and	77 girls;
Community 3	104 children —	59 boys, and	45 girls;
Community 4	813 children —	396 boys, and	417 girls.

No subjects were included in the study who were known to have a chronic or temporary illness which might interfere with the nutrition tests. In the family study, advice of family physicians was taken on this point. In Community 1 of the child nutrition study, each child was given an examination by the school physician, and in Communities 2, 3, and 4 by a pediatrician associated with the study, in order to exclude those whose responses to the nutrition tests might be affected by conditions other than dietary intake.

Hemoglobin Method

The standard Newcomer method was used to determine the amount of hemoglobin in the blood in terms of grams of hemoglobin per 100 cc. of blood. By this method, two samples, each of 0.01 cc. of blood were drawn into a hemoglobin micro-pipette from a single prick made in the finger by a spring lancet. Each sample was diluted to 5 cc. with 0.1 N hydrochloric acid in a special micro-pipette, and the mixture was discharged into dry Pyrex tubes, where it was allowed to stand for at least 25 minutes. At the end of this time treated samples were matched against a standard Newcomer plate in a colorimeter of the Duboscq type, and the grams of hemoglobin per 100 cc. of blood were calculated from the readings. The average of the results from the two samples was taken.

Results of the Study

Distribution of Individual Cases. The distribution of hemoglobin values according to age of all male and female subjects in the urban family part of the study, is shown in Figure 1. The same distribution for the subjects in the rural family part of the study is given in Figure 2. These case distribution diagrams show a wider range of hemoglobin values for the urban than for the rural subjects, in both sexes and throughout the age groups. There was no marked tendency for the values for either urban or rural subjects to concentrate around a central part of the range.

The dietaries of the urban and rural families will not be discussed until a later paper, except to say that the rural diets showed far less variety in type than did those of the urban families.

Although the hemoglobin values are scattered in the two units of the family study for subjects of the same sex and age, particularly in the case of the urban subjects, a tendency is seen for a lower number of grams of hemoglobin per 100 cc. of blood to be found in young children of both sexes than in older subjects, and for a higher value to be associated with males above 12 years of age than with females of the same age range.

The average hemoglobin values for the various units of the study are given in Table 1 by sex and the following age groups: from birth up to the fourth birthday, from the fourth birthday to the sixth, from the sixth birthday to the twelfth, from the twelfth to the seventeenth, from the seventeenth to the twentieth, from the twentieth to the fortieth, and from the fortieth birthday up. Values for all of the children in the study from 6 to 19 years of age were further averaged by one-year intervals for each of the sexes separately, with the averages given in Table 2.

Average Hemoglobin Values. A diagram showing the average hemoglobin values, by sex and age groups, of all of the 2,400 subjects in the study, is shown in Figure 3. In this diagram the children are

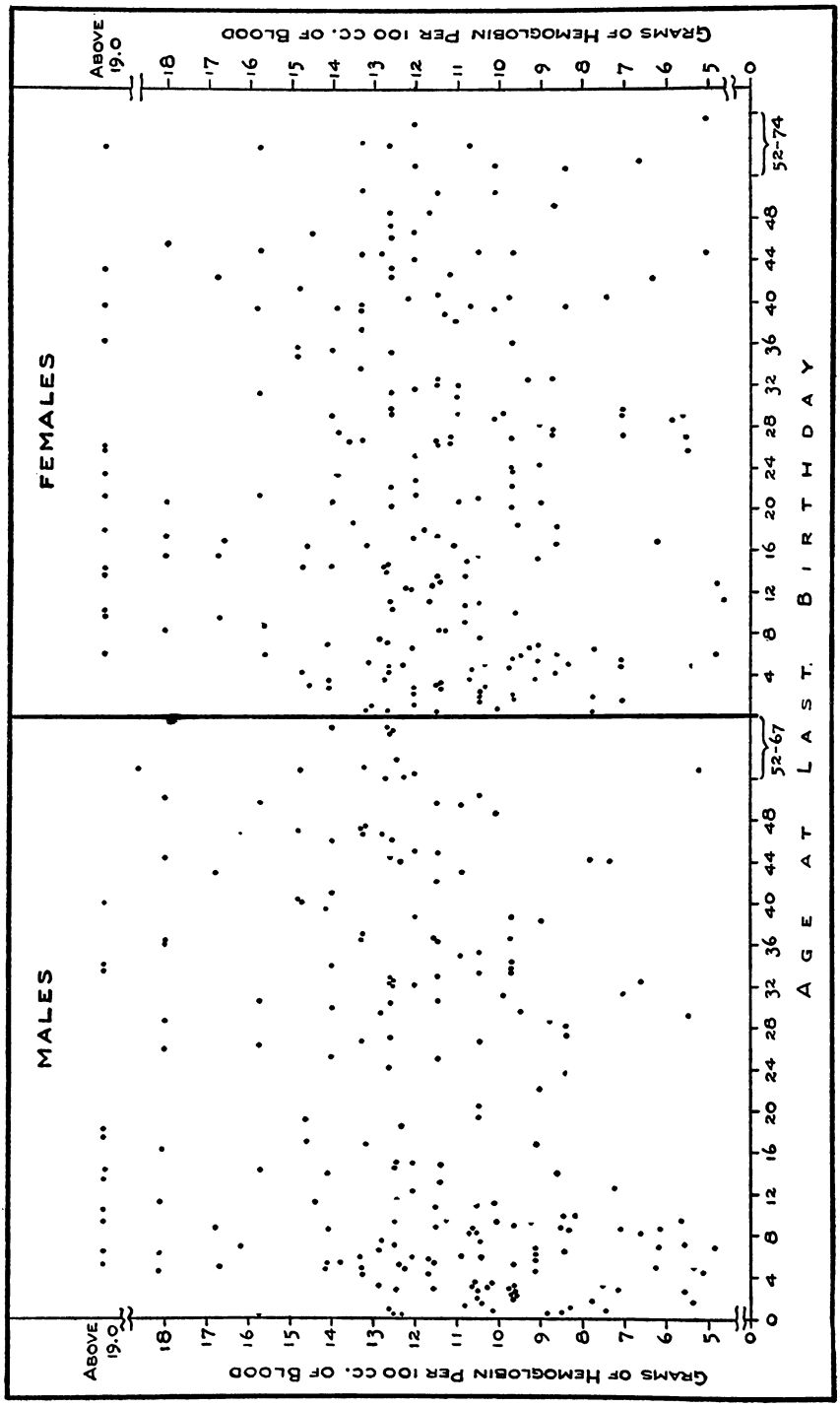

Fig. 1. Distribution of hemoglobin values of males (left) and of females (right) by individual cases, according to age, in urban-family group.

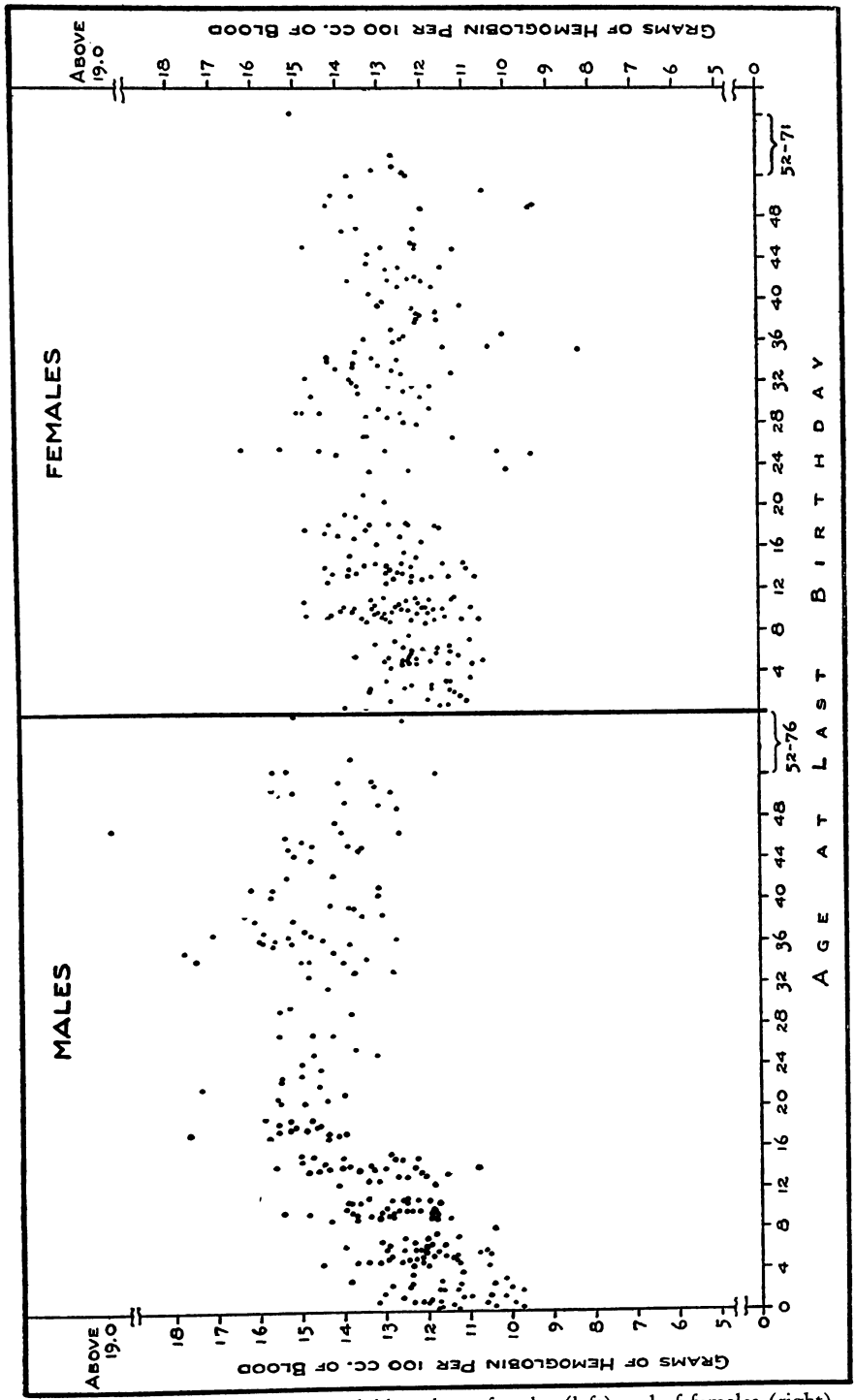

Fig. 2. Distribution of hemoglobin values of males (left) and of females (right) by individual cases, according to age, in rural-family group.

Age Range (Years)	Average Grams of Hemoglobin per 100 cc. Blood							
	Urban Families		Rural Families		School Children		All Subjects	
	Males	Females	Males	Females	Males	Females	Males	Females
Birth to 4 Years	9.72	11.22	11.40	11.18	x	x	10.61	11.16
4 to 5	11.16	10.70	12.05	12.07	11.66	11.12	11.62	11.27
6 to 11	11.29	11.61	12.59	12.59	12.92	12.63	12.79	12.59
12 to 16	14.49	13.88	13.87	13.12	12.93	12.29	13.29	12.68
17 to 19	15.57	14.13	14.97	13.26	15.18	13.24	15.16	13.57
20 to 39	12.22	12.11	14.88	12.75	x	x	13.80	12.40
40 and Above	13.09	12.18	14.35	12.58	x	x	13.62	12.40
	Number of Persons							
Birth to 4 Years	31	26	36	20	x	x	67	46
4 to 5	21	18	19	16	33	28	73	62
6 to 11	42	24	57	58	535	648	634	730
12 to 16	16	24	36	36	120	122	172	182
17 to 19	5	9	10	10	3	3	18	22
20 to 39	51	72	53	67	x	x	104	139
40 and Above	39	40	35	37	x	x	74	77

Table 1. Average hemoglobin values for males and females in different units of the study, by age groups.

Table 2. Average hemoglobin values for all males and females in the study from 6 to 20 years, by year of age.

Age at Last Birthday	Average Grams of Hemoglobin per 100 cc. of Blood		Number of Children	
	Males	Females	Males	Females
6 Years	12.07	11.34	32	17
7	11.99	11.60	39	32
8	11.98	12.00	48	73
9	12.85	12.37	86	121
10	12.93	13.00	264	314
11	12.98	12.56	165	173
12	12.99	12.37	75	86
13	13.06	13.12	43	36
14	13.19	12.51	28	24
15	14.24	13.06	9	18
16	14.80	13.10	17	18
17	16.63	13.97	7	8
18	14.50	12.92	5	8
19	13.99	13.90	6	6

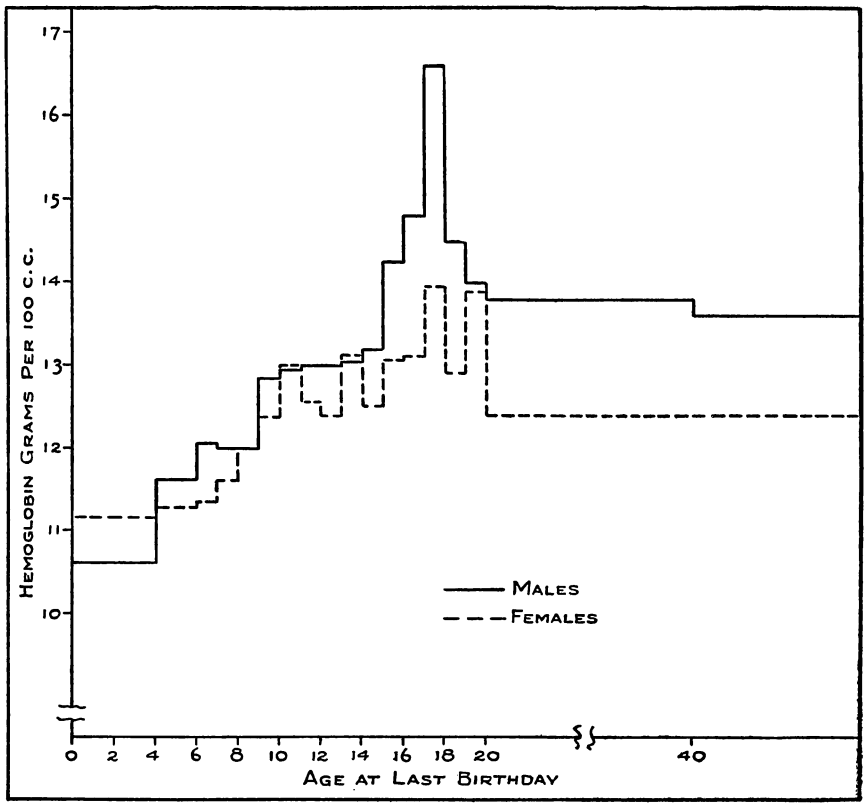

Fig. 3. Average hemoglobin values of all male and female subjects in the study according to age.

shown by one-year intervals from the sixth to the twentieth birthday. Although the sexes were not found to be significantly different in hemoglobin values below 12 years of age, the average values for age groups of each sex under 6 years of age were significantly lower than those for every other age group. Males were found to be significantly higher than females for all age groups beyond 12 years. Both sexes showed marked increases during the ages when puberty is most likely to occur, after which values decreased sharply and remained at a constant average for age groups 20 to 40 years and 40 years and older.

The average number of grams of hemoglobin per 100 cc. of blood for the subjects in the urban family part of the study, by age groups,

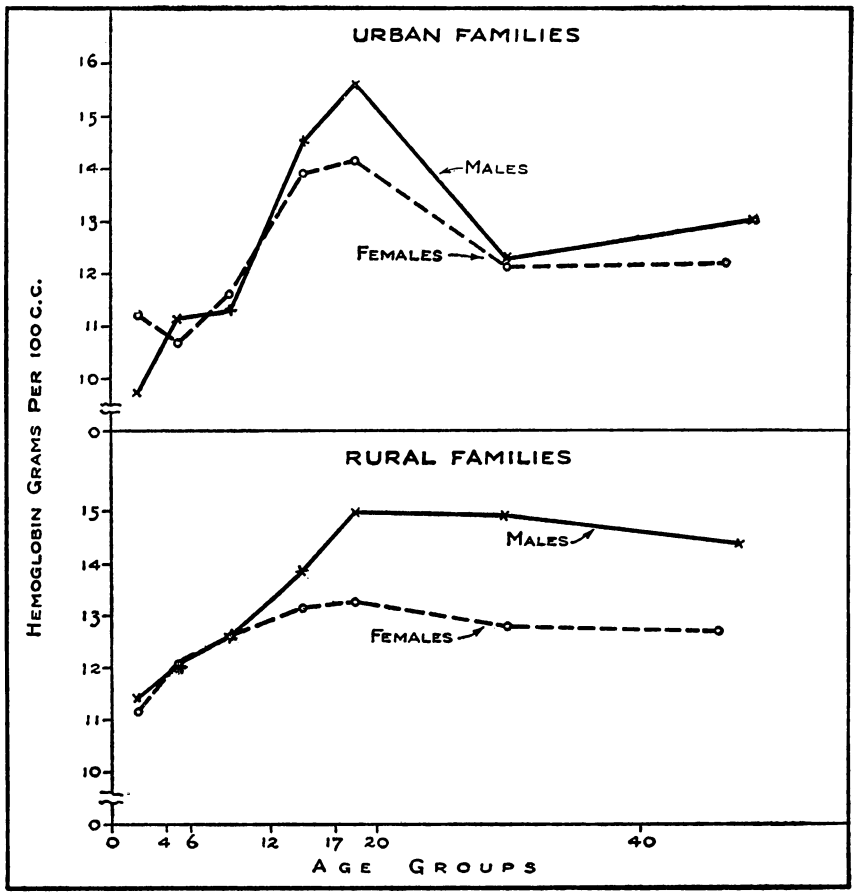

Fig. 4. Average hemoglobin values according to age for males and females in the urban-family group (upper section) and in the rural-family group (lower section).

is given in the upper section of Figure 4, with the sexes graphed separately. The chief distinction between the average urban hemoglobin values shown in this graph and those for all of the subjects of the study, given in Figure 3 previously cited, lies in the fact that a much greater average difference was found between the children up to 12 years of age and all other age groups than was present among the averages for all of the subjects combined, and in the further fact that the urban males over 20 years of age were lower than rural males of the same age group.

The average hemoglobin values of all male and female subjects in the rural family part of the study are graphed according to age in the lower section of Figure 4. The hemoglobin value differences between the younger children and the other subjects in the group were not so extreme as were those of the urban group. Instead, a gradual, but slight, increase in grams of hemoglobin per 100 cc. of blood was found from one age group to the next, for both sexes, up to the 12-to-17 year group. There was but little decrease, however, after 40 years. The average values for rural males in the older age groups were greater than for the corresponding ages in the urban group, as has been mentioned, although the same was not true for females.

Percentage Distribution According to Hemoglobin Values. In order to make comparisons among certain groups in the study as to the percentage of subjects found within certain ranges of hemoglobin values, five arbitrary ranges of response to the hemoglobin test were established as follows: (1) 13.0 or more grams of hemoglobin per 100 cc. of blood; (2) from 11.5 to 12.99 grams; (3) from 10 to 11.49 grams; (4) from 7.5 to 9.99 grams; and (5) below 7.5 grams.

The percentages of all males and of all females in the study, by age groups, within each of the defined ranges of hemoglobin values are shown in Figure 5. The same broad differences between the younger children and all other age groups, and between the sexes after 12 years of age are apparent in these distribution graphs. For example, the percentage both of males and of females in the higher hemoglobin ranges tends to increase while that in the lower ranges decreases as the ages become greater up to the 17-to-20 year group. A higher number of males than of females was found in the higher hemoglobin ranges after 12 years of age.

The percentages of all of the subjects in the urban families and that of the children in these families who were of grade school age (from 6 to 15 years old) in the different ranges of hemoglobin

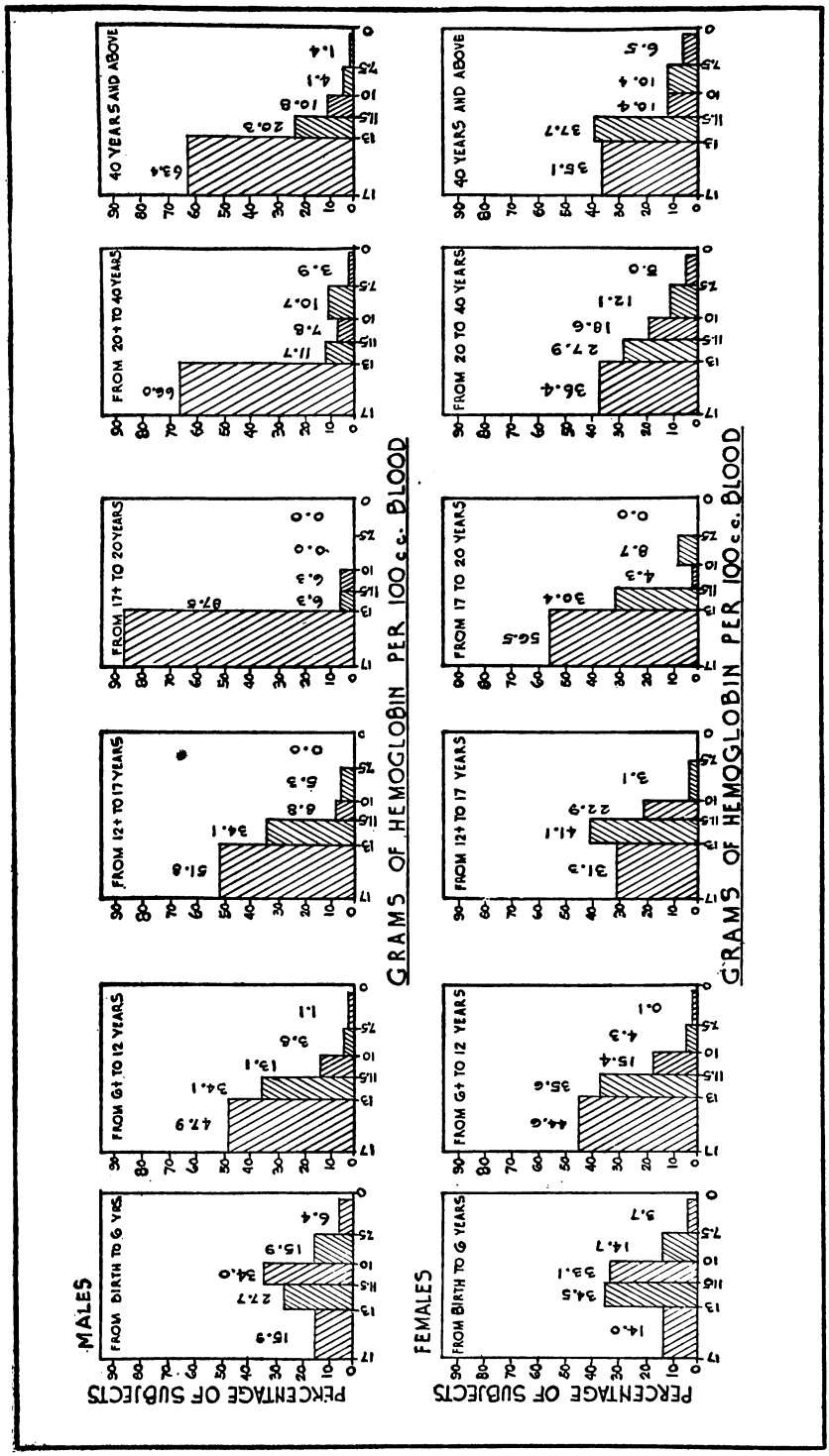

Fig. 5. Percentage distributions of males and of females in specific age groups according to hemoglobin values; all subjects in family unit studies and in school groups are included.

values, are given in Figure 6. The respective percentages for the rural families are likewise shown in the same figure. The higher percentage of all persons, and also of children of grade school age, in the rural families in the higher hemoglobin ranges as compared with that of persons in the urban families, is strikingly apparent.

For the rural families grouped according to type of farm enterprise, the percentages of all subjects and of children from 6 to 15 years of age in the different hemoglobin ranges are shown in Figure 7. The three sub-groups thus formed were all somewhat superior to the urban group in the percentage of subjects in the higher hemoglobin ranges; Locality 3, representing the most prosperous general farming group, was found to be the best in this respect.

The percentages of the 1,492 children in the child nutrition study found in the different hemoglobin ranges are graphed in Figure 8; the different community groups are shown separately. Community 1, previously reported by Zayaz, Mack, Sprague, and Bauman (39), representing a small industrial city of long-time economic depression, was the lowest in the percentage of children in the higher hemoglobin classes. This community, for example, had but 1.2 per cent of the children in the sample in the highest arbitrary hemoglobin range, with but 41.2 per cent in the next highest. The other three communities had 96.5, 97.2, and 97.4 per cent of the children in the highest two ranges. Community 2 (a small college town) had a slightly smaller percentage in the highest hemoglobin range than did Community 3 (a rural community), or Community 4 (another industrial community in better economic circumstances than Community 1). In Community 4, there was a larger percentage of children of foreign-born parents or grandparents than in any of the other three communities (in all of which there was only a small proportion of children of foreign extraction). In this community, the eating habits of the children tended to be different from those of similar income families in the other communities, a fact which is believed to be associated with their better hemoglobin status. As

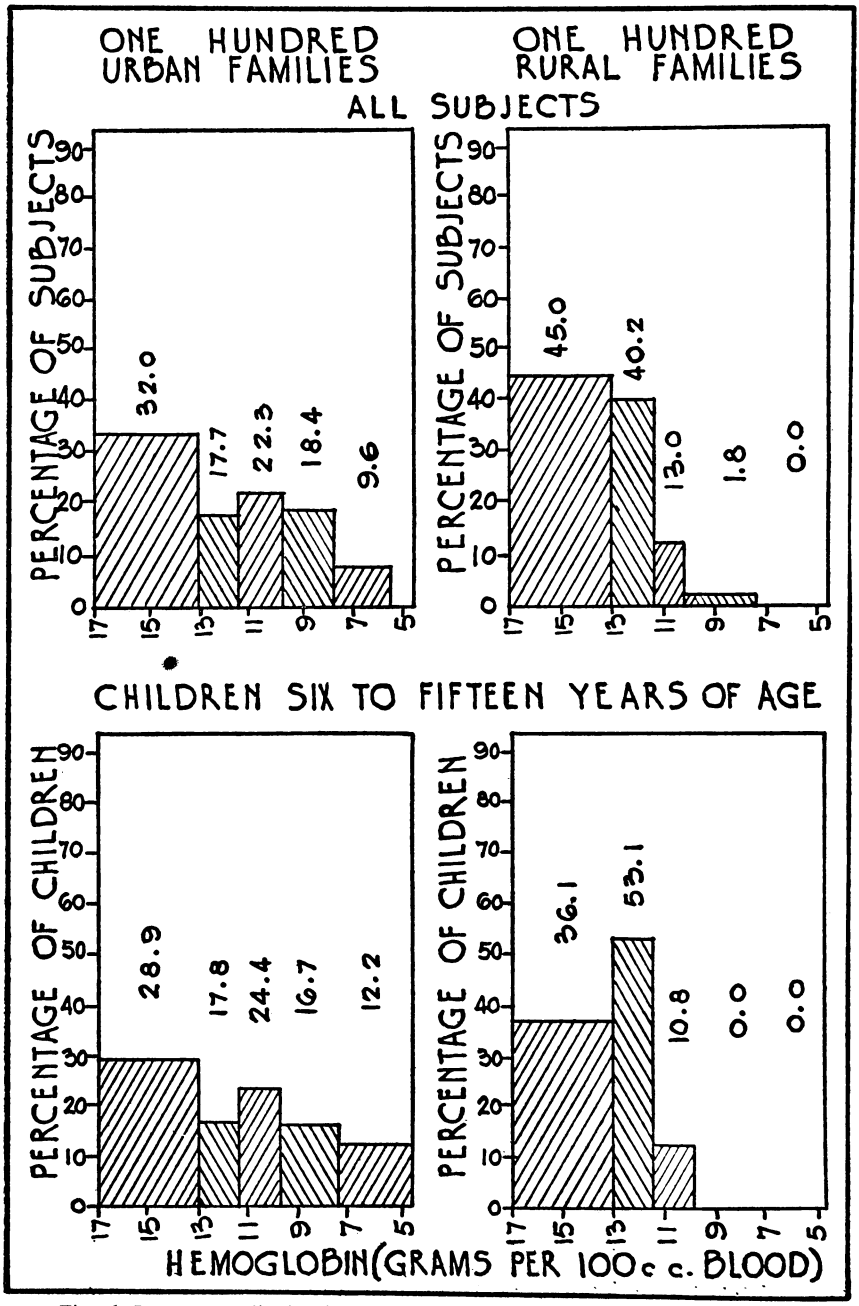

Fig. 6. Percentage distributions according to hemoglobin values of all subjects and of children six to fifteen years of age in the urban-family group and in the rural-family group.

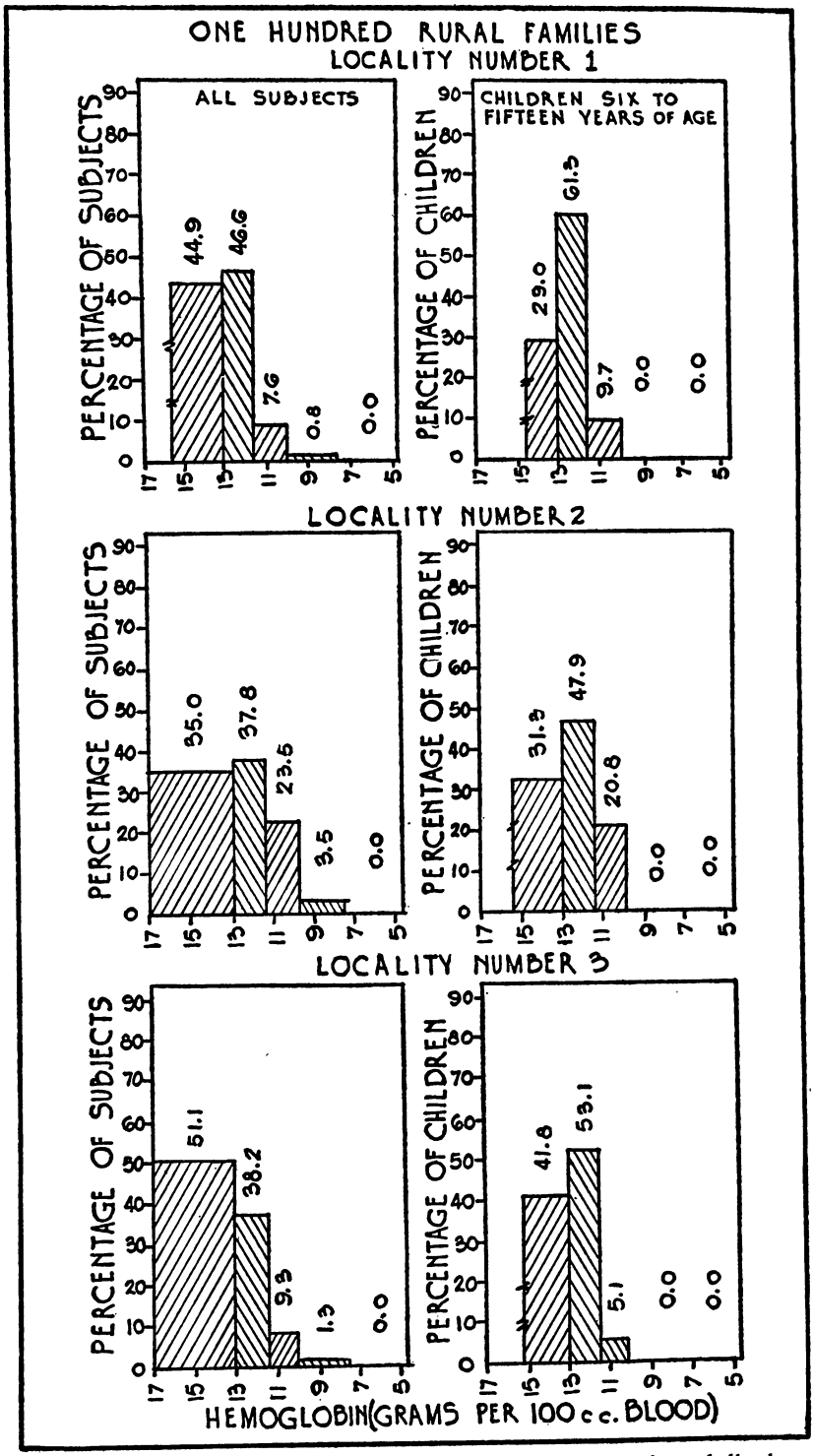

Fig. 7. Percentage distributions according to hemoglobin values of all subjects and of children six to fifteen years of age in each of three localities included in the rural-family group.

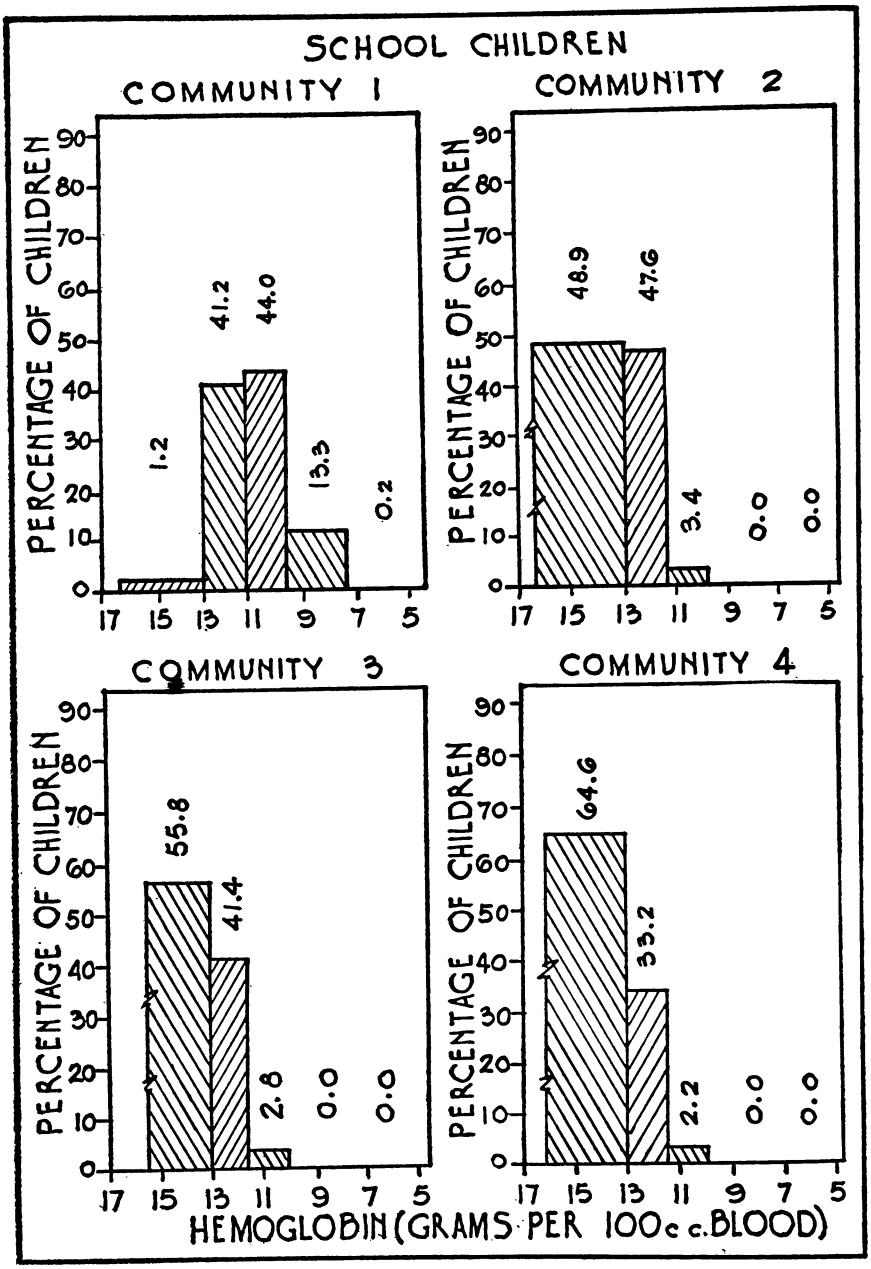

Fig. 8. Percentage distributions according to hemoglobin values of grade-school children in each of four communities.

has been mentioned, the diets of the subjects in this study in relation to hemoglobin status will be discussed in a later report.

Comparison with Other Investigations

In comparing the results of the Pennsylvania hemoglobin measurements with those of other investigators, Mugrage and Andresen (19) in a study of 200 children from birth to 3 years of age state that infants have high hemoglobin values at birth, which decrease in infancy to a minimum at the third or fourth month, with no appreciable increase during the first two years. This substantiates earlier findings by Appleton (2), Drucker (4), Elvehjem, Peterson, and Mendenhall (5), MacKay (15), Merritt and Davidson (16), and Williamson (35). Although there were no new-born infants in the present study, the findings with respect to infants and young children are in conformity with those of the investigators just cited. As has been pointed out, children in this study below 6 years of age had significantly lower hemoglobin values than the subjects in all other age groups, although no sex differences which were statistically significant were found below 12 years of age.

It is generally agreed that there is no sex difference in hemoglobin up to 12 to 13 years of age, in conformity with the results of this study. Mugrage and Andresen (18), for example, in a study of 533 children from birth to 13 years of age found no significant differences between average hemoglobin concentrations of boys and of girls. Similar results were reported by Osgood and Baker (24) in a survey of 215 children from 4 to 13 years of age. In a survey of 259 males and 152 females 14 to 30 years of age, Osgood (23) reported that the adult hemoglobin value for males was attained at 16 years, whereas that for girls was two years earlier. Similar results were reported by Mugrage and Andresen (19) in a study of 160 subjects 13 to 21 years of age.

Many studies have been based on the hemoglobin concentrations of the blood of supposedly normal adult male populations. Aver-

ages have been based on as few as ten cases, with a maximum of 325 cases in one report. Values ranging from 14.07 grams to 17.00 grams per 100 cc. of blood have been reported by the following investigators:

Investigators	*Locality*	*Number of Cases of Males*	*Age Range (Years)*	*Hemoglobin (Grams/100 cc.)*
Everett (6)	Pennsylvania	100	18-24	14.96
Foster and Johnson (7)	New Orleans	115	18-30	15.63
Parodi (26)	Buenos Aires	50	18-30	15.40
Wintrobe (38)	New Orleans	86	18-30	16.00
Haden (10)	Kansas City	70	18-50	15.34
Nelson and Stoker (21)	Kansas	325	18-65	14.38
Horneffer (12)	Germany	40	19-29	16.00
Haden (9)	Kansas City	40	18-50	15.50
Meyers and Eddy (17)*	Cleveland	111	19-30	15.83
Osgood (22)	Oregon	137	19-30	15.76
Tien, Chia yu (31)	Manchuria	320	19-64	16.75
Sachs, Levine, and Fabian (28)	Omaha	200	20-25	14.96
Walters (32)	Kansas	100	20-30	15.12
Wintrobe (36)	New Orleans	100	20-30	17.00
Helmer and Emerson (11)	Indianapolis	18	20-40	15.66
Komacki (14)	Warsaw	17	20-40	14.79
Murphy, Lynch, and Howard (20)	Boston	18	20-40	15.06
Andresen and Mugrage (1)	Denver	40	20-45	16.87
Price-Jones (27)	London	100	20-51	14.50
Broun and Briggs (3)	St. Louis	23	Adults (age not given)	16.60
Jenkins and Don (13)	London	118	Adults (age not given)	15.85

Many of these same investigators have reported hemoglobin averages for supposedly normal adult females. These averages, together with those published by other investigators, have been uniformly lower than those listed for males. Thus, values ranging from 12.80 to 15.28 grams per 100 cc. have been given by the following:

Investigators	*Locality*	*Number of Cases of Females*	*Age Range (Years)*	*Hemoglobin (Grams/100 cc.)*
Wintrobe (38)	New Orleans	101	18-30	14.10
Everett (6)	Pennsylvania	84	18-32	13.16
Haden (10)	Kansas City	30	18-50	13.37
Widdowson and McCance (34)	England	63	18-90	12.80
Haden (9)	Kansas City	12	19-30	13.30
Osgood and Haskins (25)	Oregon	100	18-30	13.70
Sachs, Levine, and Fabian (28)	Omaha	100	20-25	12.96
Meyers and Eddy (17)	Cleveland	48	20-30	13.10
Wintrobe (37)	New Orleans	50	17-30	13.76
Helmer and Emerson (11)	Indianapolis	10	20-40	13.68
Murphy, Lynch, and Howard (20)	Boston	21	20-40	13.90
Andresen and Mugrage (1)	Denver	40	20-45	14.33
Price-Jones (27)	London	100	20-51	13.60
Sackett (29)	Kansas City	——	——	15.28
Jenkins and Don (13)	London	118	Adults (age not given)	15.85
Broun and Briggs (3)	St. Louis	23	Adults (age not given)	16.60

No standards for hemoglobin are generally accepted at the present time, and there are indications that the age and sex differences

found in this study, which confirm the results of previous investigators, may be the result of dietary as well as physiological differences. Thus numerous investigators have raised the hemoglobin values of groups of preschool children and of females above the age of puberty by alterations in the diet. This may therefore lead ultimately to the adoption of standards quite different from the sex and age averages now available.

Summary

This is a report of the hemoglobin values obtained for 2,400 subjects in a mass study in human nutrition carried on in Pennsylvania from 1935 until 1940. One hundred urban families composed of 418 persons, and one hundred rural families with 490 family members were studied, in addition to 1,492 school children in four typical communities. Results have been given by age and sex, and differences in the hemoglobin values of persons in the various communities have been discussed.

Even in the absence of standards, those seeking to appraise the status of nutrition at the present time can well consider hemoglobin determinations as valuable, in view of the wide distribution of values found in the subjects of this study. Thus, rural subjects have been found to be more nearly uniform in value than urban, although even in the former group, women of childbearing age average lower than is certainly desirable. Children of preschool age in the urban families are much lower than those in the same age groups among the rural families, and it may be assumed that their average status is poorer in this respect since there is no occasion to doubt that increased hemoglobin values are generally associated with improved nutritional status, within any age group. Children in an economically depressed industrial community were found to be exceptionally low in hemoglobin values, as compared with those in other communities in better economic condition; scattered cases in all sex and age groups in all parts of the study were far below the

average of the group. These results indicate that, on an individual case basis, instances of poor nutritional status with respect to hemoglobin may be found, even if the optimum status with respect to this value has not yet been ascertained for various ages of the two sexes.

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