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W H E A T S T U D I E S

OF THE FOOD RESEARCH INSTITUTE

VOL. V, NO. 4

FEBRUARY 1929

THE PLACE OF WHEAT IN THE DIET

WH E A T now contributes about one-fourth of the calories of the American diet. It is still the outstanding single staple foodstuff. In most southern European countries wheat contributes a larger proportion of the total calories than in the United States; but in countries where rye or rice is the staple cereal, its contribution is smaller. Its nutritional importance in the United States lies primarily in the starch content, not in the content of protein, mineral elements, vitamins, or roughage.

To consume our wheat as whole wheat bread instead of white bread would make no essential contribution to the national health, and would not be in the interest of national economy, at least if the present American diet continues to prevail. Protein, minerals, vitamins, and roughage are adequately available in other foodstuffs. Nutritional security in the diet is to be sought in the milk supply; and perhaps more than an eighth of the milk supply is secured from mill offals of wheat.

Wheat now ranks as one of the cheapest foods. Per capita consumption appears to be increasing in the world at large, but not in the United States or in Great Britain, Canada, and Australasia. Under present conditions of American prosperity, there is little reason to anticipate increased per capita consumption here.

STANFORD UNIVERSITY, CALIFORNIA

February 1929

W H E A T S T U D I E S

OF THE

FOOD RESEARCH INSTITUTE

The central feature of the series is a periodic analysis of the world wheat situation, with special reference to the outlook for supplies, requirements, trade, and prices. Each volume includes a comprehensive review of the preceding crop year, and three surveys of current developments at intervals of about four months. These issues contain a careful selection of relevant statistical material, presented in detail in appendix tables for reference purposes, and in summary form in text tables and charts.

Each volume also includes six special studies bearing on the interpretation of the wheat situation and outlook or upon important problems of national policy. Subjects of issues published in recent volumes are listed inside the back cover.

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Entered as second-class matter February 11, 1925, at the post-office at Palo Alto, Stanford University Branch, California, under the Act of August 24, 1912.
Published by Stanford University for the Food Research Institute.

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FOOD RESEARCH INSTITUTE
STANFORD UNIVERSITY, CALIFORNIA

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The Food Research Institute was established at Stanford University in 1921 jointly by the Carnegie Corporation of New York and the Trustees of Leland Stanford Junior University, for research in the production, distribution, and consumption of food.

THE PLACE OF WHEAT IN THE DIET

I. INTERNATIONAL BACKGROUND

There is an astounding diversity among different peoples, different classes, and different periods in respect to the place in the diet that is occupied by cereals as a group or by wheat in particular. Under primitive conditions, the character of the diet is largely determined by natural resources and local conditions of production. A pastoral people subsists predominantly on animal products. When it turns to tillage of the soil, the diet becomes more vegetarian. As the stock of capital and technical knowledge is increased, some diversity of the diet can be obtained even in areas isolated one from another. With continuous improvements in transportation and finance, the causes of local peculiarities in the diet exert diminishing influence, and dietaries in different regions, and among different classes, tend to become less diverse. As

standards of living rise so that food constitutes a smaller fraction of the total requirement, certain pecuniary causes of dietary diversity diminish. Tradition, custom, prejudice, religious taboos, and the like, many of which originated under sanitary or economic conditions which gave them a practical basis, continue to exert influence long after the conditions have changed; but such factors are in general of decreasing importance in determining the character of dietaries. Uniformity in diets the world over is not to be expected, so great are the influences of climate on production and food requirements, and the influences of shipment costs on relative values. But it is not difficult to envisage a day when the diets of all peoples will resemble one another much more closely than they do today. Similarity of diet involves, however, to some extent, similarity in housing, in clothing, and in social institutions.

With increases in the population of the world, especially with the development of transportation and trade, the average diet tends to become more highly vegetarian. The cereals, sugar, the starchy roots and tubers, legumes, and the oil seeds all participate in this trend. The reasons are several. Given natural resources will yield larger supplies of food in these forms than in the form of animal products. By and large, animals and animal products are more expensive to ship and store than are most of the vegetable products. Improvements in the science and technique of production make a larger contribution both to the productive areas and to yields for vegetable products than for animal production. But as against this, improvements in refrigeration and in the processing of animal products tend to widen the circle of use of the foodstuffs which are

otherwise highly perishable.

The several vegetable constituents of the diet differ in their susceptibility to increase. The sugar resources of the world are already highly developed. By contrast, the oil-seed resources and trade are in a comparatively early stage, and it is their increasing competition with certain animal products that constitutes one of the larger food problems of the present day. Expansion in the use of starchy roots and tubers is limited by transportation costs, though there is the possibility that with advances in technique these obstacles may be partially overcome. Cereal culture and trade stand on a fairly high level of development, but have by no means reached either extensive or intensive limits.

Cereals constitute the outstanding fuel food. A people with a high incidence of sedentary occupation, or living in a warm climate, other things being equal, will con-

CONTENTS	
	PAGE
<i>International Background</i> ..	147
<i>Wheat in the Food Supply of the United States</i>	149
<i>Wheat as a Source of Nutrient Materials</i>	154
<i>General Observations on Nutritional Competency of Foodstuffs</i>	165
<i>The Economic Bearings of Wheat Consumption</i>	167
<i>Conclusion</i>	173

sume less of cereals than a people living in a cold climate or heavily engaged in arduous occupations. Circumstances and prices determine in what proportions cereals, sugar, or fats are used as fuels. Other things equal, moderate workers prefer carbohydrate to fat; heavy workers incline to fat in order to reduce the bulk of the diet.

Since dietary habits differ so greatly throughout the world from a great diversity of causes, to describe with precision the general position either of the cereals as a group or of wheat in particular is practically impossible. Yet certain broad statements, especially with respect to trends in consumption, may be helpful as an introduction to the subsequent discussion.

TRENDS IN CEREAL CONSUMPTION

Trends in cereal consumption are not clearly discernible in Asia and the adjacent islands. Though wheat is nutritionally superior to sorghum grains, the latter yield more heavily per acre. The use of rice is supported by custom, preference, and shortage of fuel. In some areas land is being taken from rice and devoted to the growing of industrial raw materials. Apparently, the potato is just beginning a successful invasion of China and India, being well adapted to large regions in those countries. To Asiatics, legumes are superior to wheat as a source of protein. The populations involved are so large, the diversities between regions so pronounced, transportation is so undeveloped, the security of commerce so inadequate, and numerous other factors are so imponderable that precise characterization is impossible of the trend in Asia, either in the use of cereals or in the position of wheat. All that can be said is that in certain coastal areas a trend in favor of wheat seems discernible.

Nor is a trend readily discernible in Europe. The losses of agriculture during the war, the financial and other impediments to reconstruction of agriculture since the war, the depreciation of currencies, parcelation of large estates, and the establishment of new frontiers, have combined to obscure the developments of agriculture in Europe. With diminution of purchasing power, Europe might well seek a cheap food supply, which would favor the expanded

use of cereals. But the urban classes insist on animal products; also the trend of agriculture is toward animal husbandry and away from cereals. Whatever the situation with the cereals as a class, there can be no question that wheat is replacing rye and corn as breadstuff in Europe; and in Caucasian countries generally, consumption of sugar has for several decades tended to increase at the expense, presumably, of cereal consumption.¹

Of the cereal foodstuffs, wheat is quite the most important. Rice, rye, corn, and sorghum grains are more important in certain regions, some of them maintaining large populations; but generally wheat is preferred over all of these except rice. There seems to be no doubt that, in the world at large, wheat is being consumed in increasing amounts, and that it tends to gain at the expense of other cereals. Broadly speaking (disregarding Asia), it appears that per capita consumption of wheat is tending upward except only in those countries, regions, or classes where other cereals have already been relegated to a minor position, and where the standard of living is such as to permit a diversification of the diet which leaves wheat a smaller place. This is probably the case in the United States, Great Britain, Canada, and Australasia, but in few other countries. To some extent the increasing mechanization of human activities, improvements in housing and heating, and other factors have reduced per capita requirements of food-fuel; but such reduction in requirements is not yet sufficiently general and important to offset other tendencies toward increased per capita consumption.

Increase in total world consumption, or disappearance, of wheat (outside of seed) may be in one or all of four directions:

1. Increase in population of wheat-consuming countries.

¹ Definitive opinions on the trend of cereal culture of the world would best be deferred until after the census to be taken in practically all countries in 1930. Unusual preparations have been made for a world-wide census of agriculture, with the reports planned to be on a more comparable basis than has ever occurred before. The forthcoming census is not only highly important on account of improvements in census procedures, it is especially important because the census of 1920 was so unsatisfactory, following directly after the close of the war.

2. Increase in per capita consumption in wheat-consuming countries.

3. Increased use of wheat as animal feeding stuff and in industry.

4. Penetration of wheat into countries not now, or only in part, wheat-consuming regions.

The statistical material at our disposal does not now permit of segregation and measurement of these four directions of increase. The rate of increase of population is only approximately known for most countries. The difficulties in judging consumption are enhanced by the unsatisfactory state of the statistics of production. Nevertheless, one is justified in assuming that, for the world as a whole, consumption of wheat tends to increase. Population grows, though at a rate not accurately to be appraised. Per capita consumption, at least in post-war years, tends on the whole to increase, though not in all groups of peoples and not uniformly. The use of wheat is apparently expanding, both absolutely and per capita, in countries where wheat plays a relatively small part in the diet. Statistically, little is known of the use of wheat for animal feed and in industry; but nothing suggests that this use is tending to contract. One may properly

assume that the general trend of wheat consumption is upward, but at what rate it is impossible to say.

The question naturally arises whether supply precedes demand or demand precedes supply in the trend of expansion of wheat growing in the world. Are opening of new wheat land and improvement in yield and quality the primary factors? Or is the expanding demand of old wheat eaters and new wheat eaters the primary factor in stimulating production? In a certain sense such a question is both hypothetical and artificial; but if one poses the question as it ought to be considered for any commodity, it seems that increase in supply, with improvements in facilities of transportation and international exchange, is primary. Wheat has long been regarded as the premier cereal, except with certain rice-eating peoples. New purchasers of wheat can always be secured when an enlarged production enables wheat to be offered at a price regarded as competitive in communities accustomed to the use of several cereals. In this sense, it is to be said that the place of wheat in the diet of the world is expanding, and that the rate of expansion depends primarily upon factors of supply and price.

II. WHEAT IN THE FOOD SUPPLY OF THE UNITED STATES

QUANTITATIVE IMPORTANCE

Discriminatingly to appraise the importance of wheat in our diet, we must consider the intake of wheat and of other cereals, and the total ingestion of foodstuffs.

A forward-looking segregation of the food supply is to divide it into six classes, a grouping based largely on attributes rather than on derivation. This classification, though conveniently applied in the United States, is not as useful in judging the food supply of this country as in appraising the food supply of the world. Nevertheless, it may serve an introductory purpose on the present occasion.

1. Animal products, including milk, butter, cheese, beef, mutton, pork, poultry, fish.

2. Cereals, including wheat, rye, maize, barley, oats, rice, sorghum grains, and divers other seeds.

3. Tubers, roots, and stalks, including cane sugar, beet sugar, potatoes, cassava, sago, tapioca.

4. Oil seeds, including coconut, peanut, walnut, almond, pecan, cottonseed, olive, sunflower seed, palm and palm kernel, sesame seed, rape seed, flaxseed, and soy bean.¹

5. Legumes, including peas, beans, lentils, pulses of all kinds.

6. Fruits and vegetables of all kinds, outside of the above.

Employing figures of Pearl² for the six crop years 1911-12 to 1916-17, slightly adjusted and rounded, we have the following rounded percentages of the total calories

¹ Soy bean is a legume, but is classed with the oil seeds on account of its high fat content.

² Raymond Pearl, *The Nation's Food* (Philadelphia, 1920), pp. 252-57.

contributed to the American diet by these six classes of foodstuffs:

CLASS	PER CENT
Animal products	40
Cereals	34
Tubers, roots, and stalks.....	17
Oil seeds	5
Fruits and vegetables.....	3
Legumes	1

The figures are based on food purchased for use and thus include both ingestion and household waste.¹ Since waste is not uniform in the different groups, the figures for ingestion would be sensibly different, but the point does not concern us here. The figures are only approximate, but are nevertheless probably fairly illustrative of the diet of the period 1911-17. A similar analysis of the present diet would probably show some decrease in cereals and some increases in dairy products, sugar, and fruits and vegetables; but the changes cannot readily be measured and are not, for the most part, radical in character.

¹ Inedible refuse and waste have been subtracted, but edible waste in the foodstuffs as produced is included in consumption.

² Raymond Pearl, *op. cit.*, pp. 247-48.

³ In the statistical estimates of the food requirements of a country it is customary to recalculate the mixed population of men, women, and children into units of average adult men. One first determines the customary food requirements of each sex at different ages. Then one obtains the census figures for total population, age distribution, and sex distribution. From these data one then computes the number of average statistical adult males in the population. According to the census of 1919, in the United States 100 census individuals corresponded to about 85 average statistical adult males.

⁴ The word disappearance is in some ways better than consumption to express the disposition of food. Broadly considered, disappearance includes all ways in which a supply is reduced. Pearl attempted to make a separation between consumption (including ingestion and edible waste) and ingestion following adjustment for edible waste. This gave the following material for daily per capita consumption, which illustrates how large are the items of waste, particularly for fat and carbohydrate:

	Ingestion and waste	Ingestion
Protein (<i>grams</i>)	121	114
Fat (<i>grams</i>)	169	127
Carbohydrate (<i>grams</i>)	542	433
Total calories	4,290	3,424

When one regards these estimates of edible waste and considers also the inevitable errors of sampling and analysis, it becomes clear how unwarranted it is to set up supposedly precise figures for intake of protein, fat, and carbohydrate.

Of the total calories in the diet contributed by cereals (34.7 per cent unrounded), 25.9 per cent were derived from wheat and 8.8 per cent were secured from all other cereals. From this computation it would appear that fifteen years ago a little over one-fourth of the calories in our diet was secured from wheat. The figure is of course by no means exact, because the error in the estimates of total calories is much larger than the error in the estimation of the calories in wheat.

According to Pearl's calculations,² the food supply of the average adult male³ American corresponded to 4,290 calories per day, for the period 1911-12 to 1916-17, this including ingestion and waste in the household.⁴

The nutritional components were 542 grams of carbohydrate, 121 grams of protein, and 169 grams of fat. Of the total, cereals contributed 1,489 calories, or 34.7 per cent. Cereals stood second in order of magnitude; animal products stood first with 1,705 calories, or 39.7 per cent. Sugar stood third with 568 calories, or 13.2 per cent. In a contrast of these data with those of other countries, the outstanding features are the large figures for animal products and sugar and the small figure for cereals.

Rounded figures given in Table 1 show the approximate position of cereals and of

TABLE 1.—CEREALS AND WHEAT IN DIETS OF VARIOUS COUNTRIES BEFORE THE WAR*

Country	Percentage of total calories in cereals	Percentage of total calories in wheat	Percentage of total cereals in wheat
United States	34	26	75
Great Britain	35	31	89
Germany	39	16	40
France	55	50	91
Italy	64	47	73
Russia	73	19	26
Japan	87	6	7

* These figures apply to the years just before the war and were secured from compilations carried out during the war, largely for the purpose of determining the basis of rationing. Comparable figures for the same countries since the war are not available. Cf. T. B. Wood, *The National Food Supply in Peace and War* (Cambridge, England, 1917); *Rapport Général, Commission Scientifique Interallée du Ravitaillement* (Paris, 1918); *Die Deutsche Volksernährung*, edited by Paul Eitzbacher (Braunschweig, 1915); Carl Ballod, "Die Volksernährung in Krieg und Frieden," *Schmolters Jahrbuch*, XXXIX, 1915.

wheat in the pre-war diets of various countries.

The ascending percentage of the total calories contributed by cereals is strikingly shown. The low figure for wheat in Germany was due largely to the use of rye and potatoes and in Russia to the use of rye. The low figure for wheat in Japan was due to the use of rice. Probably the figures for cereals for Russia and Japan were too high. Except for the proportion of wheat to all cereals, the diets in the United States and Great Britain were similar. Conditions in Australasia and Canada resembled those in Great Britain and the United States.

In the pre-war diet of the average statistical adult male American, cereals contributed 56.1 per cent of the carbohydrates, sugar ranking second with 25.6 per cent. Striking are the low figures for legumes and for fruits and vegetables, illustrating how small is the contribution of carbohydrates by legumes and all the fruits and vegetables including the potato.

In the pre-war diet of the average statistical adult American male, cereals contributed 43.5 grams of the total of 120.7 grams of protein per diem, or 36.0 per cent. Animal products stood first with 67.4 grams, or 55.8 per cent. Striking is the low figure for protein contributed by legumes, 2.3 grams, corresponding to 1.9 per cent of the total. Nowhere else in the world (Eskimos and such peoples excluded), outside of Australasia and Canada, is such a relation between animal protein and cereal protein to be observed; it is just the converse of the common relationship in other countries, where the cereal protein exceeds the protein of animal products, usually by a heavy margin.

The pre-war diet of the average statistical adult American male contained 168.9 grams of fat per day, of which animal products contributed 140.2 grams, or 83.0 per cent. From oil seeds were secured 20.6 grams, or 12.2 per cent, while cereals contributed only 6.7 grams, or 4.0 per cent. Contrasting the carbohydrate and fat contributed by cereals, we realize how predominately starchy they are and how insignificant is the content of fat. Incidentally, outside of Australasia and Canada, no region approaches the United States in fat ration,

except near the poles where marine fats predominate and in the tropics where the vegetable oils predominate in the diet.

According to Pearl, of the 1,489 calories contributed by cereals to the daily food supply of the average statistical adult American male, 1,112 were in wheat. The wheat calories were roughly 75 per cent of the total cereal calories, and represented 25.9 per cent of the calories in the food supply.

Thus, of the total carbohydrate of the diet, wheat contributed 42.3 per cent; of the total protein, 28.9 per cent came from wheat; of the total fat, only 1.8 per cent came from wheat.

According to the recent estimates of the Food Research Institute, the per capita flour consumption is now about 0.9 barrels per annum.¹ Converting the per capita figure into that of the statistical adult male to make it comparable with the pre-war estimate of Pearl, this corresponds to 950 calories per day per statistical adult male in the form of wheat flour. This includes semolina going into alimentary pastes but does not include breakfast foods. The census reports on the manufacture of wheaten breakfast foods since the war lead to the rough estimate of 15 calories per statistical adult male per day consumed in this form.² The total, 965 calories, is to be contrasted with 1,112, the figure reached by Pearl, and represents a substantial reduction. If one were to assume that the total calories of the food supply per statistical adult male are now the same as computed by Pearl for the pre-war consumption, 4,290, it would follow that the wheat calories now represent but 22 per cent of the total calories of the food supply as bought. The low figure for wheat calories would seem to confirm the worst fears of the wheat grower and flour miller.

What, now, is the present food requirement of the statistical adult male? The figure of 4,290 calories including intake and waste is much too high—in the opinion of the writer 400–500 calories too high. Undoubtedly the intake of food has been declining, with decrease of manual labor, re-

¹ See WHEAT STUDIES, July 1926, II, 267, 279.

² Corresponding to 6,437,510 bushels of wheat reported as used in food preparations outside of flour mills. But flour mills also manufacture breakfast cereals.

duction in number of exposed occupations, improvements in housing, and average reduction of body weight. At the time when the food requirements of the allied nations were set as the basis of the program of provisionment, a safe figure for the caloric requirements of the statistical adult male was set at 3,000 calories per day. This corresponded to a per capita requirement of practically 2,500 calories per day. More recent estimates are substantially lower—indeed, it may not be much in excess of 2,000 calories per day per head of population.

If, now, the per capita ingestion of flour be taken at nine-tenths of a barrel, this would correspond to about 790 calories per day. If the total per capita ingestion be only 2,000 calories, then the flour calories would amount to 39 per cent of the total. But if the total per capita ingestion be 2,500 calories, then the flour calories would amount to but 32 per cent of the total.

Two things are rather surprising in this connection: first, the indefiniteness of our statistical information on average per capita supply and ingestion; second, the large figure for waste to be applied in any computation of the American food supply. This waste begins at the farm and continues through to the dining table, where it is peculiarly prominent. In fact, service waste and plate waste are peculiarly American defects. In no way are the luxurious habits of Americans more clearly revealed than in the wastes attending the preparation, the table service, and the table ingestion of foodstuffs.

FORMS OF INGESTION OF WHEAT

Wheaten products are used in this country in five ways: as yeast-risen bread and quick-rising bread; as crackers, cakes, and pastries; as flour used in sauces and gravies and in the preparation of meat and vegetable dishes; as alimentary pastes, in the various forms of noodles, macaroni, spaghetti, ravioli, and vermicelli; and as breakfast cereals. It is surprising how little we know of the several amounts of wheat that go into these five classes of foodstuffs.

Yeast-risen bread, of course, is the outstanding form in which wheat is ingested, but what proportion of domestically consumed flour goes into bread is not known.

One-half looks too low, four-fifths looks too high; probably one might guess somewhere between two-thirds and three-fourths. How much of the bread is baked in the home and how much purchased from bakeries remains curiously indefinite. The reports on purchase of flour by bakeries, as issued in the successive biennial censuses of manufacture since the war, give figures far below the estimates of millers and bakers, even when allowance is made for omission of reports of small bakeshops. Undoubtedly, bakery bread is superseding home-made bread, but how rapidly and to what approximate extent is not clear.

There has been an evident increase in the use of cakes, pies, and pastries, but it is not measurable; nor is it clear to what extent home-baked sweets are being replaced by the baked sweets of the shops. It seems probable that the increase in the use of cakes, pies, and pastries has been in part, possibly largely, at the expense of bread. In the use of baked sweets the price of flour is less important than in the case of bread.

The amount of flour used in sauces and gravies and in the preparation of meat and vegetable dishes cannot be large. In some ways, the development of home cooking under the influence of instruction of girls in home economics tends to favor such use of flour; but the preference for broiled meats is against it.

Alimentary pastes have become more popular in the diet, and they are now widely used even outside of the Latin populations in whose cuisines they are prominent. Alimentary pastes are prepared both from durum wheats and from bread wheats. In the trade, estimates of the wheat equivalent of the semolina used in alimentary pastes used in the country run from 20 to 30 million bushels; but the data are unsatisfactory in all directions, partly because pastes are made in small shops as well as in large factories. Also, it must be kept in mind that some durum flour goes into bread.

The amount of wheat used in breakfast cereals is not large and has not been shown to be increasing. There is certainly more consumption of toasted wheat bread than of wheaten breakfast cereals at the breakfast table. There are several prominent wheaten breakfast foods, but they find dif-

difficulty in increasing their trade in competition with preparations of corn and oats. To the making of breakfast cereals, gruels, and porridges, wheat lends itself in some ways less well than oats, corn, and rice, though better than rye and barley. Indeed, gluten may be a disadvantage in a breakfast cereal. Shredded wheat, puffed wheat, and cream of wheat are outstanding breakfast foods that have held public favor for many years; but there are preparations of oats and corn of equal if not greater prominence. According to the census of 1925, "food preparations" of wheat accounted for but 6,437,510 bushels of wheat, compared with 26,474,963 bushels of corn and 38,397,051 bushels of oats. But such a figure is too low for breakfast cereals because of the widespread use of bran in various cereal mixtures.

Any substantial gain or significant loss in use of wheaten foodstuffs is likely to apply largely to bread. When times are hard, more bread is likely to be eaten and less of cakes and pastries; with prosperity, the intake of wheaten bread is likely to be cut down and the use of cakes and pastries increased. In public eating places bread is often served free, but cakes and pastries are not; when the service of bread is charged for, this tends to lower consumption in public eating places. When wheaten breakfast foods or cakes and pastries are introduced into the meal, this is a selection; but the use of bread is largely an incident. Bread is a carrier for other foodstuffs, whose use rises and falls with any individual, depending upon the other components of the meal. The use of bread as a staple in the meal, an integral part of it like an order of meat, is peculiarly ill-defined on the American table of today.

It is to be kept in mind that to a substantial extent the different forms of wheaten products compete for the attention of the consumer. It is toast versus breakfast cereals; roll versus coffee-cake; spaghetti versus bread; and so on. Thus the drives in favor of consumption of wheat in one form have some effect on the use of wheat in other forms.

Bakers have learned that variety is the spice of life, and bread is now offered in a multiplicity of styles and made according

to different formulas. Increasingly the custom in public eating-places is to offer patrons a choice of breads; the breads of wheat, rye, and corn are often heaped together on the bread plate. The same use of variety is shown in the multiplicity of cakes and pastries offered in public eating-places. The breads containing fruits and nuts spring from the same motive. Undoubtedly, the appeal to the consumer has thus been heightened to some extent, and bread thus raised from the drab position of an unchanging staple. Did the present-day American have available only the breads, cakes, and pastries of his forebears, the consumption of wheat would have declined more than it has. The wrapping of bread and frequent delivery of wheaten products has aided the bakeries in replacing home-baked products; this has probably tended also to increase consumption, as compared with the use of home-baked products. But the increased cost through wrapping and delivery may have tended slightly to restrain consumption.

The relation of the price of bread to the price of flour, and to the prices of other baked wheaten foods, depends, apart from expenses of distribution and selling, upon the inclusion in the bread of other ingredients than flour. In Europe the standard bread is baked of dough containing only flour, salt, yeast, and water. In this country the standard bakers' formulas include shortening, milk, and often sugar or malt extract. European-type bread is still baked for our foreign population and French bread is served to some extent in public eating-places; but the prevalent American taste is emphatically in the direction of the bread whose texture and taste are modified by the addition of the other named ingredients. In Europe bread is much cheaper than cakes and pastries; in this country the relative difference is less pronounced.

There is much discussion on the digestibility of the different cereals, and of different preparations of the same cereal, most of which is not to the point. The digestibility of the milled preparation of any cereal depends upon the degree of extraction,¹

¹ By extraction is meant the proportion of the wheat berry recovered in the flour or other milled product.

the fineness of grinding, the proportion of fiber, and the method of preparation for the table. In all probability, the comparative digestibility of the different cereals rests upon the same factors. This would imply that comparable flours of the same

cereal or of different cereals, comparably prepared for the table, would be comparably digestible. In short, the question is not one of the digestibility of the digestible elements but is a question of the varying effects of the indigestible elements.

III. WHEAT AS A SOURCE OF NUTRIENT MATERIALS

The nutritional factors in the diet are the carbohydrates, the fats and oils, the proteins, the mineral salts (or, more technically, the cations and anions), the vitamins, and the roughage. In appraising the place of any foodstuff in the diet, one does so with reference to its constituents in relation to the nutritional requirements of the diet as a whole. To appraise the importance of any *one* foodstuff, one must have regard for the *other* foodstuffs in the diet to which the one in question is complementary or supplementary. In discussions of the physiology of nutrition, one must not rigidly separate the various factors concerned; nutrition is not a series of disconnected compartments. But in a discussion of the place of any foodstuff in the diet, it is convenient to resolve the foodstuff into the several factors, with the caution that the reader must not take the segregation too literally. How is the place of wheat in the diet to be appraised from the standpoint of its nutritional constituents in their relations to the constituents of the diet obtained or obtainable in other foodstuffs?¹

WHEAT AS A SOURCE OF CARBOHYDRATE AND FAT

Since wheat contains around 70 per cent of carbohydrate, and wheat flours from 69 to 73 per cent, wheat represents the most important source of carbohydrate in the diet. The carbohydrate is almost entirely starch, except for cellulose in the coat of the kernel. The concentration of starch is highest in the endosperm, where the fiber is lowest; the relations are reversed in the bran. On digestion, dextrin and maltose appear first, later glucose; a complete digestion converts the starch into glucose entirely.

¹ For an excellent popular presentation see C. O. Swanson, *Wheat Flour and the Diet* (New York, Macmillan, 1928).

The carbohydrate contained in the wheat content of the average American diet corresponds to 42.3 per cent of the total carbohydrate of the diet and represents 22.5 per cent of the total calories of the diet. Wheat is therefore the outstanding fuel food. In the hard-working classes in countries with a more vegetarian diet, the cereals are used as fuel much more than in the United States. To an extent equaled nowhere else in the world, we employ fats, sugar, and meat as fuels in place of carbohydrates. But wheat is still the chief single fuel.

The digestibility of the carbohydrates of wheat is highest in the endosperm and lowest in the coat. The cellulose of the bran and the fiber in the flour are practically not digestible at all; the digestible starch in the bran is protected by the fibrous elements and to some extent escapes digestion. Therefore the digestibility of the starch of different flours is reduced as the extraction rises and it is facilitated by the comminution. There has been a great deal of discussion as to the relative digestibility of different wheaten flours; in all probability, the fineness of the grinding and the extent of extraction explain the differences found in digestion tests. Raw starch is less digestible than cooked or baked starch; and to a considerable extent the digestibility of breads is dependent upon the physical characteristics of the loaf, the amount of water taken up in the dough, and the amount of shortening employed. The best white breads are considerably more digestible than the best whole wheat breads; indeed, whole wheat breads are preferred by some simply because of the large and indigestible residue.

Cereals, with few exceptions, are poor in fatty substances. Wheat contains from 1 to 2 per cent of crude fat, much less than corn and oats. Thus, the wheat fat furnishes less than 1 per cent of the calories of wheat

flour. The fat is largely in the germ; rancidity of the fat is the most obvious expression of decomposition of whole wheat flour containing the germ. The fat is of little nutritional importance, so far as is known, and the intake of fat in wheat corresponds to only 1.8 per cent of the fat content of the American diet. The fat of the germ is the carrier of two vitamins—A and E; wheat germ fat is, indeed, the best known source of vitamin E.¹ Outside of the commercial importance of the fat as the basis of decomposition, the fat of the wheat has no known practical significance in nutrition outside of its fuel value.

Combining the carbohydrate and fat of wheat, we obtain the factor which gives to bread its outstanding position as a fuel food. Taking the per capita consumption of flour as nine-tenths of a barrel of average analysis, the wheat flour contributes close to 800 calories per person per day, the largest contribution of any single foodstuff. Of this, some 670 calories are contributed by the carbohydrate and the fat and some 130 calories by the protein.

WHEAT AS A SOURCE OF PROTEIN

A people must secure protein for the most part either in cereals, legumes, or animal products. Americans secure their protein largely from animal products and cereals, only to an insignificant extent from legumes. In most parts of Asia, on the contrary, protein is secured largely from legumes and cereals, to a small extent only from animal products. The European diet stands nearer to the American than to the Asiatic diet, in total intake of protein and in dependence on animal products for protein rather than on legumes and cereals; the total protein intake is lower than in the United States, but higher than in Asia.

Protein is burned in the body like any other nutrient and is, therefore, a source of energy.² A small amount of sugar is known to be formed from protein; and from this sugar, fat may subsequently be formed. But these are subsidiary reactions and do

not express the importance of protein in the diet of normal persons.

Protein is composed of amino-acids, which serve for the growth and maintenance of the tissues of the body. They are often termed the "building-stones" of the tissues. The number of amino-acids in protein is large—nearly 20; all of them are not equally important, because some may be formed in the body, while others cannot be so formed and must be supplied in the diet. We speak of a protein as "competent" or "balanced" when it contains the amino-acids, the "building-stones," necessary for the tissues; we speak of it as "deficient" when certain of the indispensable amino-acids are absent. Balanced and deficient protein are relative terms. The best proteins for use in the body are contained in milk, in eggs, and in the edible visceral organs. The proteins of the skeletal muscles, the common meat of our table, are less competent. Still less competent are the proteins of cereals which, as a class, are inferior to the proteins of legumes, some of which indeed are competent. Among the cereals, the protein of corn is perhaps the poorest, which explains why supplementary feeding with protein concentrates is so important when raising hogs on corn. Wheat ranks relatively high in the nutritional quality of its protein, but is relatively poor in two indispensable amino-acids, lysine and tryptophane.

As a source of protein, wheat stands above most of the other cereals. Oat meal, it is true, ranks as high in protein content as wheat flours; but the milled preparations of corn, rye, barley, rice, and sorghum grains run in protein content from one-half to three-fourths of the protein content of hard wheat flour. Some of the softer wheats, however, yield flours containing no more protein than the other cereals. The point is of little importance in this country. The protein content of wheat is a matter of significance to vegetarians; also, in other groups it is important. In a diet heavy in cereals and light in legumes or animal products, a heavy content of protein in any grain would be an asset; but with the prevalent heavy protein intake in the American diet, the extra protein of wheat has little use but as fuel and is there-

¹ See below, p. 159.

² A part of the heat set free when protein is burned is utilizable only for warmth of the body and not for support of work.

fore comparable with the corresponding amount of starch. Indeed, by some who regard our protein intake as excessive, the protein of wheat is regarded rather as a disadvantage, so long as we consume so much animal protein.

Judged by animal experiments, all cereals are incomplete foodstuffs. But conclusions drawn from the behavior of animals fed solely with one cereal find no application to the use of the cereal in a mixed diet. Nutritionally, wheat protein has not been shown to present any advantages, other things being equal, over the proteins of rye, oats, barley, or rice, in a mixed diet. If the cereal in the diet is important as a source of protein, then wheat is better than corn and probably better than rice, rye, and barley, but perhaps not as good as oats.

The proteins of cereals are all more or less unbalanced and incompetent. This is a defect only when cereal protein predominates heavily in the diet. Where a food supply contains only 36 per cent of the protein in the form of cereal protein, the unbalanced nature of such protein has little importance. Indeed, it is easily possible to have cereal protein constitute two-thirds of the total intake if the remaining protein is adequately balanced, e.g., if it is drawn from meat and milk.

Thus, the importance of the quality of the protein of a cereal depends upon the proportion of that protein in the total protein of the diet. In the case of wheat in the statistically average American diet, its protein is only around 29 per cent of the total ingestion of protein. Human experience and experiments on animals make it clear that with the appropriate use of milk and meat, wheat could be depended upon for half of the protein of the diet without approaching the danger line. Under these circumstances, the nutritional quality of the protein of wheat has little practical bearing on our diet, except for vegetarians and underfed persons.

The protein of the germ and coat is somewhat superior to that of the endosperm. If bread were a crucially important source of protein and if the protein of whole wheat bread were crucially superior to that of white bread, then it would be important to use whole wheat bread instead of white

bread as the source of protein. But this is not the case; and incidentally, the protein of the customary white milk-bread is superior to that of whole wheat bread.

The outstanding advantage of wheat protein lies in the gluten, which adapts wheaten flour to the making of yeast-leavened loaf bread. By virtue of the gluten, wheaten bread may be mixed, kneaded, baked, wrapped, and delivered at low cost with the methods of mass production. This commercial advantage is not detracted from by demonstrable nutritional disadvantages. Whether baked preparations of oats, barley, corn, and rice—biscuits, scones, cakes, pancakes, steam bread, or other forms—are less digestible than yeast-risen wheaten bread is not definitely known. Much depends upon the varying excellence of different preparations. In all likelihood, the difference in digestibility in properly made preparations of the different cereals is inconsequential in a mixed diet.

WHEAT AS A SOURCE OF MINERAL ELEMENTS

The animal body contains certain mineral elements: of importance here are calcium, sodium, potassium, magnesium, and iron of the cations; and phosphorus, sulphur, chlorine, iodine, and fluorine of the anions. These elements exist in varying combinations and proportions in the skeleton, in the fleshy tissues, in the circulating fluids, and in the coverings of the animal body. The requirements are relatively heaviest during the period of growth; the maintenance requirements are, however, considerable. For no one of these substances can the rate of requirement for growth or maintenance be stated upon a quantitative basis per day, per week, or per year. But whatever the requirements, these substances must be introduced with the diet. As a rule, too much is better than too little, though this is not the case with the iodine, which has a peculiar influence on the activities of the ductless glands.

These inorganic elements, varying from element to element, are present in all natural foodstuffs, varying from product to product. In the refining of sugar, the mineral elements present in the juices of the cane and the beet are eliminated. Also, in the rendering of animal fats and

oils and in the refining of vegetable fats and oils, the mineral elements are practically eliminated. There is little loss of mineral elements in the commercial canning of fruits and vegetables, except with certain processes. In the curing of animal products on the other hand, mineral salts are usually added. In the milling of grains for the production of bolted flours, the content of mineral salts is reduced.

It has long been urged, as a part of the whole-grain doctrine, that the cereals of the diet should be milled whole in order to retain all the mineral elements. In all cereals, the deposition of mineral elements is larger in the coat than in the endosperm; and the distribution of the different elements is different in coat and endosperm.

During the growth of the child, the turnover is rapid in the mineral metabolism. Something more is involved than the deposition of mineral elements in the skeleton; there is also a metabolic turnover, in which the mineral elements are taken into the body and eliminated with the excrements. In the forced feeding of young animals for market, it is now established practice to add a mineral ration, since it has been found that animals raised on corn grains, plus protein concentrates like tankage, even with the inclusion of green feed lay on flesh faster if given a supplementary mineral ration.

So far as human beings are concerned, our information on deficiency in mineral elements seems to be limited to calcium, phosphorus, iron, and iodine, of which the latter may be disregarded since cereals are not a source of iodine. The deficiencies involving calcium and phosphorus (also possibly fluorine) are connected with the skeleton and the teeth. The defects include imperfect structure formation, defective deposition of salts, fragility of the bones and teeth, and decay of the teeth.

The question arises to what extent these deficiency conditions are due to shortage in calcium and phosphorus, rather than to disturbances in the processes of deposition in the bones and teeth. A skeleton may be structurally weak in substance because lime and phosphate were not available; or it may be weak in substance because, with the mineral elements freely available, the

bone-building tissues did not function normally. For illustration, there is a disease associated with deficiency of haemoglobin in the red cells of the blood; is this due to lack of iron or to inability of the haemoglobin-forming tissues to build haemoglobin even when iron is available? The same question applies to the bones and teeth—are the defects due to scarcity of the inorganic elements or to improper working of bone- and tooth-building functions, even when the mineral elements are freely available?¹

For the United States, it is to be concluded that defects in bones and teeth, so far as they are of dietary origin, are due predominantly not to shortage of mineral elements but to disturbances of function associated with shortage of vitamins, and are provoked also in other ways.

If it were desired to avert a possible deficiency in mineral elements, do the cereals offer the best method of achieving this? The cereals show no outstanding superiority in mineral equipment. Calcium and phosphorus are not present in cereals in the proportions best adapted for use in the skeleton; also the potassium is greatly in excess of the sodium, the magnesium greatly in excess of the calcium. The mineral salts in milk, in fruits and vegetables as a class, and especially in the leaf vegetables, are better proportioned to the needs of the animal body. Medical experience in the rearing of children, and experiences of animal husbandry in the rearing of animals, agree in the view that the mineral elements in cereals are not ideally proportioned and are not to be relied upon for the best development of the body.

Coming, now, to the mineral elements in white flour and whole wheat flour respectively, the flour is lower in mineral elements than is the wheat offal; indeed, one of the purposes of fine milling is to reduce the mineral ash of flour. According to analyses of Forbes,² the elements are distributed in the wheat berry in something like the following percentages:

¹ See discussion of vitamin D on page 162; D is apparently a regulator of the calcium metabolism.

² E. B. Forbes, F. M. Beegle, and J. E. Mensching, "Mineral and Organic Analyses of Foods," *Ohio Agricultural Experiment Station Bulletin 255*, January 1913.

Element	Wheat	Wheat flour	Wheat bran	Wheat shorts	Wheat germ
Potassium	0.520	0.050	1.320	1.021	0.296
Sodium	0.310	0.110	0.201	0.165	0.721
Calcium	0.050	0.019	0.125	0.096	0.071
Magnesium	0.130	0.016	0.531	0.383	0.340
Phosphorus	0.373	0.088	1.110	0.876	1.050

From this it is apparent that both the germ and the coat hold more mineral matter than the endosperm.

How important is this difference in a mixed diet, in the average American diet? Other things being equal, would it be worth while to use whole wheat flour instead of white flour in order to obtain the difference in mineral elements?¹ If one were subsisting largely, or even heavily, on wheat flour—yes; but otherwise—no, not for people whose food consists of wheat to the extent of one-fourth to one-half of the total. If bread were a crucially important source of minerals in relation to the total mineral requirement, and if the minerals of the wheat offal were inherently superior to the minerals of the white flour, then it would be important to use whole wheat flour instead of white flour. But no such situation obtains. It is far better to seek the mineral elements in milk, vegetables, and fruits. The outstanding importance of milk as source of calcium and phosphorus is one deserving of the widest recognition. To secure really needed mineral elements by the use of wheat bran and wheat germ would be a makeshift, contrasted with the advantages to be secured when the mineral elements are obtained in milk and vegetables. In the same sense, it would not be worth while to use molasses or raw sugar instead of refined sugar in order to obtain mineral salts, since these are more readily obtainable in milk and other foodstuffs. The mineral content is one of the numerous factors, the others to be mentioned elsewhere, in the outstanding importance of milk in the human diet.

We conclude, therefore, that in the statistical average American diet the mineral elements in wheat offal are of subordinate

¹ A diet should yield an alkaline ash; acidosis is the term applied to symptoms due to relative shortage of alkali. From the standpoint of acidosis, the white flour would be superior to whole wheat flour, since the ash of the latter, when burned, yields more acid.

practical importance since they constitute in no sense a preferred source of supply. The statistically average intake of milk, fruits, and vegetables makes the mineral elements in wheat offal dispensable. In consequence, in the average diet there is no purpose in consuming any other flour than white flour, so far as the mineral elements are concerned. Under peculiar and isolated circumstances in the diet, associated with a shortage of milk, fruits, and vegetables, the mineral intake may become so reduced as to indicate the use of whole wheat bread instead of white bread. The proper disposition of such an abnormal set of circumstances, however, is not to be content with such a makeshift as wheat offal, but to secure the adequate amounts of milk, fruit, and vegetables in the diet. The mineral elements might be secured by use of appropriate salt mixtures; but this also would be a makeshift. The correct solution is to secure and maintain the adequate use of milk, fruits, and vegetables.

WHEAT AS A SOURCE OF VITAMINS

For a long time certain diseases have been recognized as peculiarly dependent on the state of nutrition. Such are scurvy, pellagra, beriberi, and rickets. By some regarded as due to poisons and by others regarded as bacterial infections, they are now recognized as due to deficiencies in the diet. Within the function of nutrition are the chemical elements of the body (inorganic and organic) and also regulatory substances by which the utilization of the nutrient materials is directed and controlled. To one large group of regulatory substances that influence various functions of the body, the term hormone has been applied. The members of a special group of regulatory influences related to nutrition are called vitamins.

The subject of vitamins—their nature, origin and distribution, relation to growth and nutrition, and the results that follow their withdrawal from the animal body—lends itself poorly to nontechnical discussion. In the first place, intricate concepts of physiology are involved. Secondly, the factual material consists more of experimental results on animals than of clinical observations on human beings. The at-

tempt is being made, through animal experimentation, to secure information with which deficiency diseases in human beings may be identified and explained. In what follows, only the barest outline can be presented, and this represents in part an interpretation of conflicting views. All that is here attempted is to make clear what is known of deficiency diseases in relation to the vitamins contained in wheat.

We have information tending to indicate the occurrence of five vitamins, arbitrarily called A, B, C, D, and E. Vitamins are as yet best understood by what happens when they are withdrawn. Their mode of action is as yet not open to hypothesis; but the deficiency diseases that follow their withdrawal from the diet are used to identify them. No vitamin has been yet isolated. Vitamin A has a determining influence on growth and tissue resistance. Vitamin B is the vitamin whose absence leads to beriberi. Vitamin C is the vitamin whose absence leads to scurvy. Vitamin D is the vitamin whose absence, it is now inferred, leads to rickets. Vitamin E is the vitamin whose absence leads to sterility. These designations are all too abrupt and inconclusive, but will suffice us here. Future investigations may expand the number of the vitamins and much is still needed in the direction of precision of our information.¹

Vitamins are widely distributed but vary greatly in the degree of concentration in foodstuffs. The vitamin contents of different foodstuffs are being standardized by feeding experiments on animals. Some vitamins are stable, others highly unstable—factors of great importance experimentally and nutritionally. The vitamins are widely synthesized in plant life; for the most part, animals secure their vitamins from plants in the diet and do not synthesize the vita-

mins in their own bodies. Many microscopic forms of plant life synthesize vitamins and thus vitamins may be formed by fungi in the intestinal tract of animals, a point of practical importance in herbivora. But it is not proved that animals do not synthesize vitamins in their tissues. For illustration, the liver of the cod is rich in vitamins; is it to be supposed that these were synthesized by marine plants and taken in with the food supply of the fish, and not synthesized in the tissue of the fish? The relation of light to the synthesis of vitamins is now being intensively investigated. Wherever the ultimate source, one by one the vegetables, fruits, cereals, legumes, and edible animal products are being graded on the basis of vitamin content, both as to kinds and amounts of vitamins present.

The approved method of investigation is to use the white rat, whose rate of growth and nutritional requirements have been standardized. A basal diet is prepared, free of vitamins, but containing the necessary salts, protein, fat, and carbohydrate. Through the period of test, the animals are fed with the standardized diet, plus known amounts of the particular food under investigation. It is sometimes practicable to check such tests with the use of standardized concentrated preparations of vitamins. Rapid advances are being made in the production of concentrated preparations containing vitamins, and the day is probably not distant when standardized preparations of active vitamins will be available on the retail market.

So far as wheat is concerned, we are practically concerned only with vitamin B. Wheat ranks relatively low as a carrier of vitamin, excepting B and E, being therefore low in vitamins A, C, and D. Vitamin E is present in the wheat germ in high concentration; indeed, in the oil of the wheat germ is found the highest known concentration of the fecundity vitamin. A dietary deficiency in vitamin as a practical problem, so far as wheat is concerned, involves only vitamin B. The vitamins B and E are mostly in the germ; the bran is not rich in B and it has little E. The endosperm is low in vitamin. Since there is no known disease involving vitamin E,² it follows that only

¹ Lay readers desirous of familiarizing themselves with the subject of vitamins will find an excellent presentation in *Your Weight and How to Control It*, edited by Dr. Morris Fishbein and published by the George H. Doran Company in 1927. An exhaustive technical discussion is to be found in *The Newer Knowledge of Nutrition*, by E. V. McCollum and Nina Simmonds, 3d ed., published by the Macmillan Company in 1925. The conflicting interpretations of animal experiments and clinical observations are brought clearly to light in the last named book.

² Recent observations lead one to suspect that vitamin E may act as a regulator of the iron metabolism, as vitamin D is believed to act for the calcium metabolism.

under peculiar and exceptional circumstances are the vitamins of wheat of practical importance in the diet.

The classical illustration of a vitamin-deficiency disease is beriberi, a disease long known in the Orient which at times has expanded to the dimensions of a scourge. It is a degenerative disease, of which inflammation of the nerves and spinal cord is the outstanding symptom. As beriberi occurs in the Orient, it is the result of eating a diet consisting predominantly of polished rice. The mere eating of polished rice does not cause the disease; nor are all cases of beriberi provoked by the eating of polished rice. Only when the diet consists largely of polished rice, does beriberi develop. Beriberi may be caused by an exclusive diet of salted fish; it may also be provoked by patent wheat flour or corn flour, when these are the predominating articles of diet.

In the parts of the rice berry removed by polishing is vitamin B, whose withdrawal provokes the disease.¹ The polished rice is not itself injurious; it merely lacks an essential element. The B is present to much larger extent in the germ than in the bran, and a small amount of the rice germ will prevent the disease. When the victims are fed unpolished rice prompt recovery ensues, unless the affliction has been extreme. Also, recovery may be brought about with vitamin B contained in other sources. Finally, beriberi may be prevented without disturbing the use of polished rice by the administration of vitamin contained, for example, in yeast.

The endosperm of any grain may be compared with polished rice as a possible cause of beriberi. We have no records of beriberi produced with the use of white flour. Since the endosperm of wheat and of rice seem equally devoid of vitamin B, there must be some determining reason why polished rice in the Orient has caused beriberi while white wheat flour in Europe and North America has not caused beriberi. The answer lies in the other components of the diet. In the Orient, the foodstuffs in the

diet outside of polished rice were deficient in vitamin B; in Europe and in North America, the foodstuffs in the diet outside of the white flour were not deficient in vitamin B, but contained enough to maintain health. If, instead of white wheat flour in the proportions in which it has occurred in the diet in Europe and North America, polished rice had been used in identical amounts, beriberi would not have occurred because of the protective action of the vitamin B in the other foodstuffs.

In every question of deficiency disease due to lack of a vitamin, the outcome is determined not by the absence of the vitamin from a particular foodstuff, but by the absence of that vitamin from the entire diet. If the diet contains enough vitamin B to be adequately protective, it is immaterial whether this is obtained in all of the foodstuffs or in only a few of the foodstuffs. It is when one foodstuff, deficient in vitamin, constitutes practically the entire food supply, or is combined with other foodstuffs deficient in vitamin, that the vitamin-deficiency disease arises. One of the most impressive facts in our knowledge of vitamins is the striking action of a small amount of the vitamin-carrying foodstuff. Vitamin B is widely distributed. All the fruits and vegetables contain it, it is present in milk, eggs, and meat, and is absent or deficient only in the rendered animal fats, the refined vegetable oils, in sugar, and in the finely milled cereals. There has never been a clear-cut beriberi problem in the United States.² No one could develop beriberi on the average mixed diet of this country; indeed, the average mixed American diet would act as a rapid cure for beriberi. Doubts concerning the use of white flour in our diet cannot be based on fears of beriberi, as customarily understood.

Pellagra is a complex degenerative disease, associated with pronounced weakness of the muscles, digestive disturbances, skin eruptions, polyneuritis, and often terminating in insanity. It is usually most marked in early summer. Long before it was recognized in the United States, pellagra was common in Europe, particularly in Spain and Italy and in the Danube countries, where it was commonly ascribed to the use of immature or decomposed corn.

¹ Vitamin B seems also to exert a stimulating action on appetite and digestion.

² Possibly, before the Civil War beriberi occurred among plantation negroes subsisting largely on polished rice. Rice offal is very rich in vitamin B.

It is now recognized that corn as such has nothing to do with the disease.

Pellagra in the United States is associated with what might be termed a general depravity of the diet, occurring in underpaid and underfed classes living under bad conditions of sanitation; it is more common in the South, though by no means confined to the southern states. Pellagra in institutions, jails and asylums, has sometimes been the result of graft. The pellagra diet consists usually of degerminated corn meal or white flour or both, molasses or syrup, lard and salt pork, salt fish, potatoes, and dry beans. Conspicuous is the absence of or shortage in milk, eggs, and fresh meat, and the diet is low in protein. Such a diet is deficient in all vitamins, but especially in B; it is deficient in balanced protein; and it is deficient in roughage. Persisted in, the disease progresses slowly but progressively, with notable seasonal exacerbations.

Pellagra does not directly respond to treatment with vitamin B, as does beriberi. The patients recover promptly when milk, eggs, and fresh meats are added to the diet; and under these circumstances, preparations containing vitamin B seem to accelerate the recovery. Milk is a specific, especially in early cases.

Neither the experimental nor the clinical investigations are satisfactory. Some clinical investigators regard pellagra as a combination of beriberi and protein starvation; others, as a combination of protein starvation with scurvy. Certain symptoms of the disease strongly resemble war dropsy, regarded as the result of protein starvation. Lastly, other investigators regard pellagra as an independent deficiency disease, of which the specific factor has not yet been determined. Of the importance of shortage of milk, eggs, and fresh meat in the etiology of pellagra, there can be no question. Recently attention has again been directed to vitamin B.

It is to be conceded that if an American is trying to live on wheat and corn flour, baking powder, lard, molasses, sow belly and salt fish, the corn meal should be fresh whole corn meal and the wheat flour should be fresh whole wheat grist flour. Whether this would prevent pellagra and maintain nutrition, in the absence of improvement in

the protein ration, remains, however, doubtful. Judged by the clinical results, the restoration of a proper protein intake through the use of milk is far more important than the use of whole grain flour. Obviously pellagra is the result of degraded diet peculiar to isolated circumstances of poverty and ignorance (or criminality), and no lesson to be drawn therefrom ought to be imposed upon the intelligently diversified American diet. The reform of the diet in pellagra does not apply to the average statistical American diet, which is better than the diet used to cure pellagra in institutions. What is required for the elimination of pellagra is elevation of social standards and of the level of earnings, with the education and improvement in the scale of living that go with them.

Rickets has been regarded as a disease associated with vitamin deficiency and shortage of mineral elements and thus possibly dependent on the use of finely milled cereals instead of whole cereals. More recent investigations, however, and especially the studies on the effects of light on rickets, have changed the views of the medical profession. All cereals are low in lime and phosphorus; the milled flours are merely more deficient than the whole grain. In rickets, something prevents the skeletal tissues from building sound bone and depositing the lime salts properly. In the blood serum of rickety children, the lime content is little changed from normal, but the content of inorganic phosphorus is peculiarly low. Cod liver oil contains the factor determining the normal function of the skeletal tissues; when it is administered, the local disease is arrested and the normal relation of calcium and phosphorus in the blood serum is restored. Exposure to sunlight, and also to ultra-violet light, has the same effect. Finally, selected rays of light will "activate," i.e., endow certain otherwise inactive fats with the protective property naturally possessed by cod liver oil—that is, the protective factor can be synthesized in an appropriate foodstuff by exposure to light. Inferentially, the natural occurrence of the anti-rachitic vitamin, as in cod liver oil (and other fats and oils) rests upon activation, or synthesis, by light.

The cereals do not contain the anti-

rachitic factor, and it would be to no purpose to use whole grains, rather than white flours, on that account. Nor is the calcium content of whole grain sufficiently higher than that of flour to warrant the change. The conclusion to be drawn from recent work on rickets is that milk and the green leaf vegetables are the indispensables in the diet of growing children, and beyond this no dietary adaptations are indicated. Incidentally remarked, the old-fashioned doctors, who used to give children a course of codliver oil treatment during the winter, have been convincingly vindicated.

Recent investigations, confirming old but poorly defined medical opinion, indicate in respect to vitamin D that activation by light may be secured in the living body. In other words, rickets may be prevented and cured by sunshine. Also, the vitamin D content of cow's milk is dependent both on the diet and on the exposure of the animal to light. The milk of dairy cows housed in barns during the winter is inferior to the milk of cows kept outdoors during the daytime; in protecting the milch cows from the rigors of winter, they are also protected from the beneficent action of sunshine. It is gradually becoming apparent that the production of milk under high-pressure dairy methods, involving the forced use of concentrates with animals kept in barns, may yield a milk normal in protein, sugar, and fat, but deficient both in vitamins A and D and possibly in minerals also. Since milk is being relied upon to keep the diet competent, the milk must be kept competent by appropriate feeding and care of milch cows.

Apart from pellagra, as stated above, there is nothing to indicate that the current American use of white flour threatens us with any deficiency in vitamin. There are so many other foodstuffs containing vitamins that a shortage seems practically impossible, when the diet contains milk and fresh fruits and vegetables. This is particularly the case when one recalls that wheat flour composes only one-fourth of our diet. If wheat flour were three-fourths of our food supply instead of one-fourth, it would be necessary to use whole wheat flour instead of white flour. But with the diet composed, to the extent of three-fourths of its

calories, of diversified foodstuffs, many of which are rich in vitamins, especially milk, the wheat in one-fourth of our diet is not to be regarded as a necessary source of vitamin. If one is after vitamins, whole wheat flour is a poor makeshift.

It may be urged that all individuals, and especially children, do not receive their share of milk and fresh vegetables, and that the deficiency in milk and fresh vegetables might well be made up by the use of whole wheat bread. This would represent an obvious and lamentable makeshift in a country with the diversified agriculture and dietary standard of the United States. The suggestion might have some validity if only vitamin B were involved; but when one considers the other nutritional attributes of milk, the suggestion fails to meet the case. What is wanted is not arrangements for doing without milk, but arrangements for securing milk.

On technical grounds, there is no effective way of retaining the vitamins of the wheat kernel except to include the germ in the flour. With the germ included, the flour is prone to decomposition. The baking quality of flour depends upon proper maturing after grinding. The flour trade and baking industry of the country depend upon flour being so made as to keep sound and sweet, over many months with ordinary precautions. It is technically impossible to provision the country with a flour containing the germ, since it cannot be sterilized, or kept in cold storage to retard decomposition. If it were desirable, on economic or other grounds, to have the vitamins of the germ, specifically vitamin B, retained in the bread, it would be far better to have the baker add it artificially than to have the miller keep it in naturally.¹ In recognition of the unbalanced nature of wheat protein, the addition of milk protein to bread has become practically standardized in the baking formulas in this country. Vitamin B could be similarly added, if regarded as so advantageous as to appear commercially necessary. Animal tests indicate that white milk bread is as competent as whole wheat bread, but more

¹ The now prevalent use of large amounts of yeast substantially increases the content of vitamin B in white bread.

vitamin B could be added if thought advantageous. If bread were a crucially important source of vitamins, and the vitamins of grain offal were crucially superior to the vitamins of white flour, then it would be important to use whole wheat flour instead of white flour, but such is not the case.

To see the effete clubman, seated at a table covered with foods drawn from all regions and loaded down with vitamins, ordering whole wheat bread in order to secure vitamin B, is strikingly illustrative of the carrying power of propaganda.¹

WHEAT AS A SOURCE OF ROUGHAGE

Wheat is a source of roughage in the diet only to the extent to which bran is used in whole wheat flour, whole wheat breakfast cereals, and bran breakfast cereals. Though foodstuffs containing bran are prominent among the advertised foodstuffs, the amount of roughage thus introduced into the average diet is small. For practical purposes, the roughage in the American diet is obtained from fruits and vegetables.²

We have, however, a bran cult, proclaiming with insistence for all the use of bran in the diet. To the extent that public agitation on behalf of bran merely represents advertising copy, it may be dismissed. There is no way of knowing whether the bran fad has increased in number of adherents dur-

ing the past generation, since we possess no trustworthy records of the proportions of wheat flour consumed respectively with and without bran. In publicity the fad has increased, in consequence of the larger public attention now being given to all health aspects of the diet, promoted in addition by interested parties. The advocates of the use of bran in the diet support their arguments in favor of bran as a roughage by invoking also the proteins, the minerals, and the vitamins contained in the covering of the wheat. We have discussed these in other sections, and limit the discussion here to the factor of roughage.

The advocates of bran as roughage assume either that roughage is lacking in the average diet; or that the roughage intake in fruits and vegetables is inadequate and bran should be used in addition thereto; or it is implied that the roughage of fruits and vegetables is inferior and that bran roughage ought to be used in substitution therefor.

The wheat berry may be roughly divided into the endosperm, the germ, and the coat. The endosperm comprises about 82 per cent of the weight of the kernel, the coat around 16 per cent, and the germ only 2 per cent, the proportions varying from variety to variety of wheat and from year to year. The bran is composed largely of fiber, i.e., cellulose.

The roughage requirement of the diet varies from person to person, and is not relatively the same at different ages or in the two sexes. It varies from season to season, also with occupation and physical activity. Discerning physicians have long recognized that the roughage requirement is distinctly an individual variable.

The most effective roughage is to be obtained in raw bran and in raw fruits and vegetables. In cooked or baked bran, fruits, or vegetables, of the same fiber content, the roughage is less effective. The more effective the roughage, the more likely it is to irritate the alimentary tract and provoke digestive disturbance. Among the different kinds of roughage, for most persons bran is likely to be found less acceptable than the fibers of fruits and vegetables; and in particular, among the numerous fruits and vegetables, each individual is likely to find

¹ "The attitude which one should take toward the discussion of the relative merits of bolted as against whole wheat flour is now easy to understand and appreciate. The latter is decidedly more suitably constituted to maintain well-being for a short time if it serves as the sole article of diet, as it might under famine conditions. Whole wheat flour is an incomplete food and must be supplemented with other foods in order to compensate for its deficiencies. The unfortunate individual, who through faulty habits of living finds at an age at which he should be still in possession of the full vigor of middle life that his efficiency is diminishing and the joy of living slipping away, has not infrequently turned for relief to substituting whole wheat flour for the staple white variety. As a rule those who advocate this practice exhibit in some degree the spectral mien of the dyspeptic. They would gain much more through adhering to a diet well balanced than through adopting this or any other dietary whim or fad." E. V. McCollum and Nina Simmonds, *The Newer Knowledge of Nutrition*, 3d ed. (New York, 1925), p. 132.

² It is erroneously assumed that the laxative action of bran and of fruits and vegetables is due solely to roughage. But in fact phytin aids in the action in the case of bran, while in the case of fruits and vegetables, organic acids and fermentative products contribute to the effect.

that certain of them prove best adapted to his alimentary tract.

There are many degrees of the bran cult, some of which border on mysticism. Some extreme advocates of whole wheat wish to use no flour, but only coarse grits instead; some insist that the wheat kernels shall not be rolled but only cracked; still others insist that the wheat kernels must be cut. If bran is desired as roughage in a mixed diet, it would seem preferable to use blended flours, made by sifting bran back into white flour. Such a blended flour keeps well, in contrast with whole wheat flour. In such a flour it is possible, with special milling or with the use of sieves of different mesh, to have the bran particles finer or coarser, as desired. Also, the proportion of bran may be modified at will—for example, all the way from 10 to 50 per cent. If bran is to be rationally employed in bread as roughage, this is the best way of using it. If bread were a crucially important source of roughage and the roughage of grain offal were crucially superior to the roughage of other foods, then it would be important to use whole wheat flour instead of white flour. But such is not the case. In special cases where bran acts well, it is best used as breakfast cereal and this use is growing.

The advocates of so-called health breads fall into five groups. First we have the teachers of home economics and nutritional experts engaged in education, both of whom naturally tend to exaggerate their specialty. Secondly, we have food faddists, who are prone to support new projects, or take extreme positions on old topics, in order to appear advanced and esoteric. Thirdly, we have food cranks, often dyspeptic and neurasthenic, who magnify their personal idiosyncrasies to racial proportions. Fourthly, we have the quacks—medical, semi-medical, pseudo-medical, and anti-medical—who extol health breads for fees. Lastly, we have the writers of advertising copy being put out by acquisitive manufacturers of whole grain products. Of the followers, some use whole wheat bread because they like it, but more use it because they have read or heard that it is good for this, for that, or for the other ailment.

The tone of advertising copy and the extreme claims of purveyors of special food-

stuffs are certain to be moderated in consequence of mergers of food manufacturing establishments. When a concern sells, side by side, a coffee substitute, a decaffeinated coffee, and a national brand of natural coffee, the advertising of the coffee substitute is certain to be less extreme than in the case of a manufacturer whose sole business is making coffee substitute. When a bran breakfast cereal, a whole wheat breakfast cereal, and a refined white wheaten breakfast cereal are marketed side by side by the same concern, the advertising of bran is certain to be more restrained than in the case of a manufacturer whose sole product is bran breakfast food. Special factories devoted to one wheaten product are tending to disappear, being taken over by manufacturers who market many products. Thus, the commercial incentive of unbridled advertising will decline; gradually the propaganda in favor of bran will be confined to the faddists and will not become supported by the manufacturers. With the faddist will remain the medical quack. It is fair to conclude that the deceptive propaganda on white bread versus whole wheat bread, when confined to quack physicians and food faddists, will decline to small dimensions.

Nothing in the above reflections applies to those who use whole wheat bread because they like it. What is objected to is that advocates of bran try to impose their hobby on society as physiological doctrine applicable to all. As a matter of personal taste, the bran diet is unobjectionable; as a nutritional system for all persons, it is devoid of foundation.

To the vast majority of Americans it is not a matter of indifference, nutritionally or esthetically, whether their table has whole wheat bread or white bread. The appearance of white bread is more attractive, the texture is finer, it toasts better. Whole wheat bread has a pronounced taste of its own; white bread has a bland wheaten taste that lends itself well to spreading materials. That whole wheat bread has made so little progress since the day of Graham, is due to the weak appeal it makes to the taste. Certainly the place of wheaten bread in the diet will not be enlarged by insistence on the use of whole wheat bread.

IV. GENERAL OBSERVATIONS ON NUTRITIONAL COMPETENCY OF FOODSTUFFS

No foodstuff should be appraised by itself, apart from the other foodstuffs. Not what a food is good for alone, but how good it is in combination with other foodstuffs, is the measure to be applied. Otherwise an article like lard or sugar would find no place in the diet. And the best single food, milk, lacks qualities that in the long run are found to be essential in the diet. Such a correlated appraisal should be both qualitative and quantitative, and done with sound physiological perspective.

Practically all foods are deficient in one direction or another; no single foodstuff can be depended upon indefinitely to sustain nutrition in a normal manner. In addition, certain foodstuffs as they appear in trade have by processing been made more deficient than they were naturally. The conspicuous illustrations are refined sugar, polished rice, white flour, corn flour and hominy, rendered animal fats, refined vegetable oils, and starches, including products like sago and tapioca. For natural reasons, the customary cuts of meat (muscle meats) are relatively deficient in dietary factors, being far inferior to the visceral organs; as a class they stand somewhat above the cereals. Provisioning a people, or rationing a group, involves combining in appropriate proportions, to make a balanced whole, the relatively competent foods with the relatively deficient foods.

It is possible, but not desirable, to incorporate all the elements of nutrition into a single food. With development of chemical and manufacturing technique, it is now possible to prepare the perfect biscuit for man, just as it has been possible to prepare the standard diet for the white rat. Several years ago, a large baking company put out a mixed bread that contained (or was supposed to contain) all the elements essential for satisfactory nutrition, a single food capable of sustaining growth and health. This perfect bread proved a commercial failure. Such a food is of interest to explorers, surveyors, and prospectors; but it holds no appeal to people who wish, quite naturally, to please their tastes with diverse foods in varying combinations of preparation and service. Man does not choose to live by

bread alone—or by any other single article of diet, no matter how competent. Such rationalization may be applied to industry, but not to nutrition. A diet has esthetic and psychological values, as well as physiological values.

It is neither necessary nor desirable to have the foods so combined as to make every meal nutritionally complete; it is enough to have the food of the day competent. Indeed, in view of the storage of vitamins in the tissues, it seems that it might be sufficient to have the food of the week competent.¹ But though this might hold for balanced protein and vitamins, it would not hold for roughage or energy foods, which ought to be held close to an average intake. Beyond this, the concept of balance and competency tends to be exaggerated. Nutritional doctrines must be kept in harmony with economic considerations. The art and science, and also the social economy, of the diet lie in combinations: "The keynote to the discussion of the individual foods entering into the diet of man is the importance of using proper combinations of foods."²

Looking back over the past half-century, we observe a decline in the per capita intake of all food, decline in per capita intake of cereals,³ and increase in per capita intake of sugar. Corn has suffered greater decline than wheat, both relatively and absolutely. With appropriate qualification and adjustments for other foodstuffs, it may fairly be stated that the decline in use of cereals has been effectuated mostly by substitution with sugar. Sugar contains no protein, vitamin, or mineral elements; it is strictly an energy food, which owes its popularity largely to its taste and to the flavors developed when it is added to other foodstuffs. The expansion in the use of sugar has been in part associated with expansion

¹ It would not be sufficient to have the ash of the diet alkaline for the week; this ought to be secured for the day.

² E. V. McCollum and Nina Simmonds, *The Newer Knowledge of Nutrition*, 3rd ed. (New York, 1925), p. 132.

³ See WHEAT STUDIES, July 1926, II, No. 8, and December 1927, IV, No. 2.

of the use of fruits and vegetables. The protein, vitamins, and minerals in the cereals displaced by sugar have been in part replaced by protein, vitamins, and minerals in fruits and vegetables. The net effect is not measurable, but there can be little doubt that the level of competency in intake of protein, vitamins, and minerals has improved during the past fifty years.

Modern flour milling, like sugar refining and the refining of fats and oils, is based upon mass production, uniformity of product, cheap distribution, and low price to consumers. The savings thus made available to society are to be secured only if these foodstuffs are employed in proper combinations with other foodstuffs that are complementary to them. The problem is to secure the adequate and competent national diet at the lowest cost, and the true solution is to be sought only by proper combination of highly manufactured foodstuffs with other foodstuffs in their natural states. The heart of this problem lies in the milk supply of the country—and it is not extraneous to the subject under consideration to urge that the milch cow is in the van of the agricultural progress of the country. So long as the consumption of wheat in this country stands at the present level, or anything approaching it, the outstanding objective in the use of wheat is to secure heat units. Wheat is primarily a fuel food. A distinctly secondary purpose is to secure protein. The mineral salts and vitamins of wheat scarcely enter the picture of the national diet; certainly they need not enter unless milk, fruits, and vegetables are deficient. The roughage of wheat is needed only by those who prefer wheat roughage to that of fruits and vegetables. The use of wheat for any other purpose than to secure starch and protein is uneconomical, in view of the advantages that would accrue from the use of other foodstuffs to supply vitamins, minerals, and roughage.

THE APPEAL FOR INCREASED CONSUMPTION

Are there nutritional reasons for appealing for a larger consumption of wheat? Do we stand too low in the wide range of wheat consumption, compared with other countries—not for reasons of price and

convenience, but for reasons of physiology? The answer is in the negative.

There are no nutritional reasons for urging an increased consumption of wheat and a lessened consumption of other cereals, or an increased consumption of wheat and a lessened consumption of meats and vegetables. In the declining trend of consumption of cereals over recent decades, corn has lost most, and apparently all the cereals combined have lost more than wheat. This is exactly what would be expected with the gradual transfer of baking from the home to commercial bakeries. But there is no nutritional ground for urging the further substitution of wheat for the other cereals. Our use of meat is probably declining and that of vegetables is certainly increasing. There is no nutritional reason for checking the growing use of vegetables or accelerating the declining use of meat in favor of wheat.

We conclude, therefore, that there is no physiological reason why the customary intake of wheat in this country, howsoever ingested, should be regarded as too low. There is no reason why it might not be somewhat lower; indeed, millions of Americans consume less wheat than the average of wheat in calories, as computed by Pearl. On the other hand, there is no nutritional reason why the consumption of wheat should not be substantially increased, no nutritional reason why the use of white flour should not be substantially increased. But the reasons must be those of taste, convenience, and price, not of physiology.

What might be termed the customary range of use of cereals in the diet would be from 30 to 60 per cent of the total calories. Whether a particular diet with a cereal proportion at any point within this range is competent or incompetent, advantageous or disadvantageous, would depend less on the cereal fraction itself than upon the other components of the diet. The lower the proportion of cereal in the diet, the easier to include the various indispensable elements. When diets contain cereals in ascending proportions, beyond 50 per cent of the total calories, it becomes increasingly difficult to secure the indispensable elements in adequate amounts.

The American diet may be termed lux-

urious in that meats are used for fuel instead of cereal; or, to be more specific, protein is used for fuel where carbohydrate would serve as well. On account of the fact that proteins are burned in the body with an acid ash and the end-products entail a renal elimination, while starch is burned in the body without ash and with no end-products to entail any such elimination, it has been widely urged that the use of protein should be limited to the protein need of the tissues and not employed as a fuel. From this point of view, it would be advantageous to have a larger use of cereals, provided this implied a lower intake of protein. Whether this implication holds, is, however, not so easy to determine, since the caloric content of meats is largely due to fat, while the cereals themselves are relatively heavy in protein.

Since fats may leave an acid residue when burned in the body, while starches do not (except in the sense that carbonic acid is an acid), it has been urged, other things being equal, that it would be better to use cereals freely and fats sparingly as fuel instead of fats freely and cereals sparingly. Thus, it would follow, since the American diet is heavy in fat and light in cereals, that increase in intake of cereals and decrease

in intake of fat might be advantageous. The physiological reasoning may be sound, but it is not clear how important it is in practice.

Possibly, perhaps probably, the consumption of wheat in the United States has declined to a position of stable equilibrium. Milling journals seem to hold the view that the bottom has been reached and an upturn is in prospect. We do not believe consumption will be increased in response to appeals by producers. We do not anticipate that such fluctuations in wheat prices as are likely to occur would make any sensible difference in consumption. If the prices of meats and sugar, of fruits and vegetables, were to rise substantially, this would influence people to consume more wheat. If the prices of meats and sugar, fruits and vegetables, should decline substantially, which is improbable, the effect might fall more on other cereals than on wheat. Should the prices of foodstuffs, the outlay, and the proportion of the income expended for foodstuffs become matters of substantially larger concern than they are today, the net result, we feel, would be a noteworthy increase in the consumption of wheat; otherwise, there is little incentive to change the current practice.

V. THE ECONOMIC BEARINGS OF WHEAT CONSUMPTION

WHEAT CONSUMPTION IN RELATION TO PRICE

The price of foodstuffs is important in this country, despite the small proportion of the average American income that is expended for them. Whenever a foodstuff is universally liked, covers nutritional needs appropriately, meets with established taste and custom, is convenient in use and service and not exposed to conspicuous waste, that food enjoys substantial additional esteem when the price is low. This is the position of wheat flour and of bakers' bread. Yet despite relatively low price, the consumption of wheat has slowly declined over several decades. The per capita decline has been due in part to per capita decline in total food intake in terms of calories: in part it has been due to substitution. To some extent, wheat has replaced corn and the other cereals; but to a greater extent,

wheat has been replaced by sugar, and to some extent by fruits and vegetables.

Demand for wheat is relatively inelastic. Bread is often used as illustration of inelasticity of demand. But the reaction of the consuming public varies widely from country to country, and from class to class. If demand for wheat is relatively inelastic in the United States, then in Europe it would be comparably more elastic and elsewhere still more elastic. But general statements mean little and statistical studies of the demand for wheat in relation to price are singularly lacking.

Individual reactions vary widely. If two persons of whose diets bread constitutes a fourth were suddenly confronted with extraordinary increase in the price of bread, the one might respond that since bread is so small a part of his diet he would not give it up but would pay the price, the other

might respond that since bread is so small a part of his diet he would not pay the price but would drop it entirely. Much depends upon purchasing power, upon proportion of the income spent for food, and upon custom and convenience. In every community are persons for whom price will modify the effective demand for wheat, and others who will show no such reaction. The behavior of a population as a whole would represent an averaging of plus and minus adjustments. Probably a discerning student of home economics could better judge the outcome in a particular case than an authority on theoretical economics. Side by side, one finds it preached that hard times in this country increase the consumption of wheat and that hard times reduce the consumption of wheat; the first is undoubtedly the more correct teaching, but the latter persists. When wheat stands low in a diet, hard times will tend to enlarge the use of it; when wheat stands high in a diet, hard times will tend to lower the use of it.

In dealing with this subject since the war one must use retail, not wholesale, prices. This makes the question much more difficult, because comprehensive retail prices are difficult to assemble, they lag behind wholesale prices, and to a considerable extent wholesale prices fail to register on the retail market at all. But only from retail prices may trustworthy inferences be drawn.

The cheapest foodstuffs (not including vegetable oils in this discussion) are wheat flour, rye flour, corn meal, rolled oats, rice, and sugar. These are all highly concentrated starchy foods and relatively non-perishable. In order to secure an idea of the price of these staples, we may use averages of the retail prices reported for fifty-one cities in the United States.

Table 2 contains for the past five years, as reported by the Bureau of Labor Statistics of the United States Department of Labor, the average retail prices of cereal preparations and sugar.

Rye flour is not reported. We know, however, that rye flour is somewhat cheaper than wheat, near the rye-growing areas if not in distant regions. Very little rye flour is sold as such at retail; possibly the price for rye flour where sold at retail would be

in the neighborhood of that of corn meal. Whole wheat flour (not reported) costs more than comparable white flour, because the losses due to spoilage and to weevils must be paid for, the volume of sales is small, and demand is inconstant.

TABLE 2.—AVERAGE RETAIL PRICES OF VARIOUS ARTICLES OF FOOD, 1924-28*

(Cents per pound)

Year	Wheat flour	Bread	Wheat cereal	Corn meal	Corn flakes	Rolled oats	Rice	Sugar
1924....	4.9	8.8	13.9	4.7	20.0	8.9	10.1	9.2
1925....	6.1	9.4	14.2	5.4	22.0	9.2	11.1	7.2
1926....	6.0	9.4	14.5	5.1	21.8	9.1	11.6	6.9
1927....	5.5	9.3	14.6	5.2	20.2	9.0	10.7	7.3
1928 ^a	5.4	9.2	14.6	5.3	19.1	8.9	10.0	7.1
Average 1924-28.	5.6	9.2	14.4	5.1	20.6	9.0	10.7	7.5

* Data from *Retail Prices 1890 to 1926* (U.S. Bureau of Labor Statistics Bulletin No. 445), August 1927, pp. 48-49 and 56-57; also from *Monthly Labor Review*.

^a Ten months' average; data for November and December 1928 not yet available.

That corn meal is so little cheaper at retail than wheat flour is at first glance surprising. This is due to the fact that the milling of corn is more regional and less widespread than the grinding of wheat; therefore, in many cities relatively high freight charges are incorporated into the retail price of corn meal. Also, corn meal is more prone to decomposition than wheat flour, which has the effect of enlarging the waste and increasing the price. Rolled oats and rice are also manufactured regionally, rather than generally, and the retail prices over the country are heightened by transportation charges. The net result of the above price comparisons is to emphasize the relatively low price of wheat flour per pound. Table 2 illustrates, incidentally, how much more expensive is wheat cereal than wheat flour and corn flakes than corn meal.

But one may go further and adjust the prices to the calorie basis. On the basis of the average prices given above, the number of calories purchasable for one dollar was about as follows:

Corn meal (1,625 calories per lb.).....	31,900
Wheat flour (1,640 calories per lb.).....	29,300
Sugar (1,790 calories per lb.).....	23,800
Rolled oats (1,795 calories per lb.).....	19,900
Rice (1,610 calories per lb.).....	15,100

These figures indicate how much cheaper is wheat flour than rolled oats and rice and how little cheaper is corn meal than wheat flour. When one considers the characteristics of the two preparations—the limited uses of corn meal and the tendency to decomposition, the large number of uses of wheat flour, the characteristics of its gluten, and the keeping qualities—wheat flour is the cheapest of the group. The first cost of wheat flour is slightly higher than the first cost of corn meal, but the net cost is probably as low and possibly lower.

It is interesting to ponder on the annual monetary outlay for wheaten products. If the nine-tenths of a barrel of flour used by each American per annum had been purchased as flour at the average retail price of the past five years, the annual flour bill would have been \$9.88, or 19 cents per week, per person. If the same flour had been purchased in the form of bread (176 pounds of flour equals 240 pounds of bread) at the average retail bread price of the past five years, the annual bread bill would have been around \$22.08, or 42.5 cents per week, per person. Large proportions of the purchases are in the form of flour and bread, but considerable wheat is purchased in the form of cakes and pastries, which are more expensive than bread. Perhaps it may be assumed that the higher prices of sweet baked goods balance the lower price of flour and that the price of bread gives a fair figure for the average cost of wheaten products. However viewed, the low sum represented in the money spent for wheaten foodstuffs is striking enough, particularly in view of the fact that around one-fourth of the calories of the diet are thus obtained. Since the sum spent for breadstuffs is so small, there is little incentive in making a saving by lowering it still further; also little is lost if it rises somewhat. In addition, any foodstuff priced in pennies tends to receive secondary attention from even the saving housewife. This all tends to make demand for wheaten products inelastic.

The wheat flour of course is raw and as such is inedible, whereas the sugar is ready to eat. But, in fact, only a small part of the sugar consumed is utilized without putting it through one or another form of cooking in conjunction with other foodstuffs. With

full allowance for the facts that sugar is ready to eat, is practically nonperishable, and contains no water, it is certain that the net cost is not so low as the net cost of wheaten flour.

Since the war, several special developments have tended to influence the use of wheat. The first is the industrialization of the South. This has been accompanied by increase in the consumption of wheat and decrease in the use of corn. A second factor has been the disappearance of the western frontier, which has been accompanied by a reduction in the consumption of wheat and beans and an increase in use of other foodstuffs. A third factor has been restriction of immigration. The immigrants are our heaviest bread eaters, especially the Slavs and Italians. Assimilation of the immigrant carries with it the gradual assumption of the American diet; the children of the immigrants adopt the eating habits of the children of the native stock. Lastly, the widespread increase in consumption of cakes and pastries of all kinds has involved a reduction in the use of wheat. Superficially considered, it is often assumed that the contrary is the effect, since persons often eat pastry who would refuse bread. But broadly considered, it is not to be doubted that the addition of 20 pounds to the annual per capita sugar intake has been accompanied by a substantial, if not by a corresponding, reduction in the use of flour. To these special factors must be added the more general influences—a decline in per capita food requirements, the reduction of the average body weight, the change in the age distribution of the population due to increased longevity, and the expanding use of fruits and vegetables.

Despite low price, the consumption of wheat remains low. Whether it would remain low in hard times is not known from comparable experience. Much would depend on how hard the times. Presumably, in some regions and with some classes, corn meal would replace wheat; in other regions and with other classes, wheat would replace meat and vegetables. What the net result would be, only the countrywide test would tell; but if the writer judges American consumers correctly, the net result would be in favor of wheat. Apparently, it

is to no purpose to appeal, on behalf of the producing class, for increased consumption of wheat on the basis of the low price of wheaten foodstuffs. For the time being, consumers make their decisions on other grounds.

Bread suffers at the hands of consumers, not from aversion or opposition, but from indifference and neglect. There are too many available foodstuffs, too many attractive dishes on the table. Bread is always on the table and is an old story to the eye and to the taste. Bread must be chosen or not chosen each meal in competition with dishes that are more or less different at each meal. In short, at each meal bread, the stand-by, has to compete with novelties for the attention of the consumer. With a large proportion of the population trying to reduce rather than increase their diet and their body weight, bread has come to occupy almost the position of a nominal filler. Today there is no one staff of life. Bread remains a highly important foodstuff, common to a great variety of diets, but its basic importance has greatly diminished.

INFLUENCE OF USE OF WHOLE WHEAT ON ANIMAL HUSBANDRY

Wheat offal is a specialized concentrated feeding stuff, one of the best from any standpoint and in certain ways the very best. It is largely employed in the ration of the breeding stock during gestation and lactation, also in the growth ration during the suckling period and for a time after weaning. It is most prominent as a dairy feed, and its value to animal husbandry may be fairly judged in terms of equivalents of milk.

Used as a supplementary protein ration in the dairy, the protein of wheat offal is to a large extent recovered in the protein of the milk. The milch cow has a protein metabolism for maintenance and tissue growth; she has a special protein metabolism devoted to the milk secretion. After the other requirements of the body of the milch cow have been fully covered, when the added feeding stuffs designed for milk production are appropriately proportioned, the energy is largely recovered in the milk.¹

In part, wheat offal is used as food for growth and maintenance, in part as a

purely supplementary protein ration for milk production. Just what is the milk equivalent of the wheat offal, applied to the country as a whole, would depend upon many factors. It is probably a safe illustration to use the figure of 38 per cent derived by Forbes,² i.e., 38 per cent of the protein of wheat offal is converted into the protein of milk of the usual composition. This may be too high or too low; but as illustration of the importance of wheaten mill feed in milk production, it may fairly be trusted.

Let us assume that we grind 520 million bushels of clean wheat for domestic consumption of flour. This would yield about 4.6 million tons of offal, containing around 650 thousand short tons of protein. Using the factor of conversion mentioned, this would be equivalent to about 15 billion pounds of milk, which is approximately one-eighth of the milk supply of the country, and perhaps one-sixth of the milk supply used as human foodstuff.

From this rough computation, the enormous importance of wheat offal to animal husbandry is apparent. Wheat is not merely our most important cereal food; also it yields one of our most important cereal feeds. To transfer the population of the United States over to whole wheat bread would provoke a revolution in agriculture. With this, however, we need not concern ourselves, because it will never happen.

Another phase of the situation merits attention. The 520 million bushels of wheat now ground for domestic consumption of flour are grown on something like 36 million acres of wheat land. With the country transferred to whole wheat bread, with the same intake as at present, this would involve setting free 10 million acres of land now devoted to the raising of wheat for domestic consumption. The 10 million acres would of course have to be used for the raising of feeding stuffs to replace the mill feed; but this, for much of the wheat land of the United States, would not be a com-

¹ E. B. Forbes, J. August Fries, Winifred W. Branman, and Max Kriss, "The Relative Utilization of Feed Energy for Maintenance, Body Increase, and Milk Production of Cattle," *Journal of Agricultural Research*, September 1926, XXXIII, 483.

² E. B. Forbes and R. W. Swift, "The Efficiency of Utilization of Protein in Milk Production, as Indicated by Nitrogen Balance Experiments," *Journal of Dairy Science*, January 1925, VIII.

mercially profitable alternative employment. In short, if the country consumed whole wheat bread instead of white bread, this would reduce the acreage planted to high-priced wheat and increase the acreage planted to low-priced coarse grains, to the commercial loss of the producing class.

In conclusion, it is pertinent to revert to the biological importance of milk in the human diet. The researches of recent decades have made evident the fact that milk is the heart of the American diet. The balanced protein of meat and eggs is important; the vitamins of the green leaves and the fruit juices are very important; the mineral constituents of fruits and vegetables are important. But milk combines so many of the indispensable constituents of the diet, especially for the young, that it is veritably the keystone of the arch of nutrition. It would be technically possible for the country to maintain the milk supply without grain offal, using grains and other concentrates instead; but it would be technically more difficult and certainly more expensive.

In the broad sense, the decision between whole wheat bread and white bread is a choice between bran and milk, representing the alternative uses of wheat offal as feeding stuff or foodstuff. The bran has no unique qualities in the human diet, and for the homely virtues it possess there are many substitutes available. Milk has unique properties and there is no substitute. It may be urged that some peoples live practically without milk, as in India and China. But that rejoinder yields the point at issue, because we are not trying to imitate the diets of India and China.

In countries with a low protein intake, the superiority of wheat protein—especially over corn and millet—is nutritionally important and speaks there in favor of an enlarged consumption of wheat. In countries like India and China, where dairying is but slightly developed, wheat should be consumed as whole wheat flour, to secure the full benefit of the protein. Indeed, in India and China cereals as a class ought to be consumed whole and not milled fine, because grain offal is not converted into an equivalent of higher-value foodstuffs. The very reasons that speak against

consumption of wheat offal in the United States speak in favor of it in India and China; or, better put, the reasons that speak for consumption of grain offal as foodstuff in India and China do not apply in the United States.

NATIONAL ECONOMY OF WHOLE GRAIN CONSUMPTION

It is sometimes urged that cereal consumption in the form of whole-grain meals, instead of in the state of extracted flours, is quite generally in the interest of the national economy. In view of the emphasis laid upon economy in calories during the war and the ease with which war experiences are misinterpreted and misapplied in peace times, the topic merits examination.

Experiences the world over illustrate three sets of circumstances under which enforced national saving of calories imposes on the human population the necessity of consuming cereals as animals do. Under necessity, we include economic compulsion or advantage as well as sheer physical need.

A state at war is frequently under the necessity of compelling the population to subsist as much as possible on domestic production. This usually involves a shift toward vegetarianism, and the transition from the accustomed diet may be both sudden and extreme. Under stress of war, little attention is paid to nutritional considerations. Great Britain and Germany, at the opening of the Great War, were heavy net importers of animal products; they imported animal products in large amounts and also imported feeding stuffs out of which further volumes of animal products were secured. The blockade prevented both animal products and the feeding stuffs from entering Germany; that country was thus compelled to make compensatory adaptations in agriculture and dietary, including the compulsory use of long-extraction flour and whole-grain meal instead of bolted flour. Submarine warfare and shortage of ocean tonnage enforced the same measures in Great Britain. The exigencies of war and consequent adaptations in all the belligerent states of Europe held also for the neutral states to a considerable extent. Even in the United States, straight

flour was substituted for patent flour in order to conserve wheat for shipment overseas. The circumstances will vary from case to case; but in the state at war, the human population will usually be compelled to adopt a coarser diet, tending more toward vegetarianism, in order to save calories and increase production of food calories per unit of area. Indeed, the exigency may be so extreme as to compel the slaughtering of domesticated animals and the use of fodder stuffs as foodstuffs for the human population. In Europe during the recent war, the offal of the bread grains, the coarse grains, and fodder roots were used as foodstuffs to an extent never before known. Use as food was even made of grass meal, prepared by grinding hay stuffs; there is in fact no nutritional reason (apart from the content of fibre) why alfalfa meal should not be as good a foodstuff as mill feed. In short, under stress of war, fine flours are abolished; bread grains are consumed as whole-grain meals, more or less coarsely ground. But the population in Europe paid a heavy price when bran was consumed as food instead of the milk that could have been secured from it, since deficiency diseases developed to a widespread extent. Since the war few in Europe have been in any doubt as to which is the better—a unit of bran or its equivalent of milk.

In a country where population presses continuously and sensibly on the food supply, it may be necessary in the saving of calories to consume whole grains instead of flour. China furnishes a good illustration. The offals of wheat and rice fed to animals are worth less when returned in the form of animal products than when consumed directly, on account of loss of calories. In addition, the cereal offals represent there an important source of vitamin B; vitamin A must be secured largely from green leaves, and protein largely from legumes.¹ Under extreme pressure of population on food supply, the calories assume greater importance even than the so-called indispensable factors of nutrition—the vitamins, mineral salts, and balanced protein.²

The death-rate in such a country is already so high that malnutrition merely makes a bad situation somewhat worse. In a country where porter labor largely re-

places beasts of burden, the calories in grain offal cannot be dispensed with. There is of course widespread use of flour and polished rice in China; but if the country were rationed on a strictly animalistic basis, it would be found preferable to have the cereals milled whole.

Thirdly, a country without continuous and sensible pressure on food supplies, but still a heavy net importer, might perhaps find it economically advantageous to consume cereals in the form of whole-grain meal rather than in the form of bolted flour. The decision would depend upon the agriculture of the country and upon the cost of producing the exports required to pay for the imports of cereals. Consider Great Britain. The wheat imports of the country are about 225 million bushels annually. These could be reduced by a fourth if graham bread were to supplant white bread and brown flour to replace white flour. Would this be in the interest of their national economy? Up to the present, certainly not. Great Britain is largely a region of grass. Only in certain areas do bread grains thrive and even here yields are conditioned on the use of chemical fertilizers. Beyond a certain minimum, domestic production of cereals encounters increase in cost; but the grass lands are unusually productive on account of the climate, and under these circumstances mill feed and other concentrates find favorable utilization by pastured animals. From the standpoint of agriculture, diversification based on the use of grain offal, oil seed meal, and coarse grains represents the best utilization of the grass lands.

The industrial productivity of Great Britain is such as to enable the population to choose between consuming mill feed in bread or converting it into dairy products

¹ The soy bean, whose protein is of excellent quality, is the outstanding source of protein in Japan and China. This utility of the soy bean is enhanced by the high oil content and its peculiar adaptability to culinary manipulations.

² J. B. S. Haldane has remarked that "about half the human race at the present moment is suffering from partial starvation, and the first requisite for them is to eat more of the cheapest food they can get, vitamins or no vitamins." *Possible Worlds and Other Papers* (New York and London, 1928), p. 59. This comment is probably overdrawn for the world as a whole; certainly it is devoid of application to the United States.

and meats. A highly industrialized nation is not driven towards vegetarianism. It employs its efficiency in manufacture and commerce, in order to secure a more diversified diet with a larger proportion of animal products. If Great Britain were to lose her export markets and if the invisible items in her international trade did not suffice to balance the excess of imports of goods over exports, she might feel herself compelled to go from white bread to graham bread and in other ways to approximate the wartime diet. But so long as Great Britain expands annually her new investments abroad, it is not to be urged that the country stands under the economic necessity of using grain offal as foodstuff. Doubtless the physiologists, on the basis of experiments on the standardized diet of the white rat, would be able to devise for the people of Great Britain a competent diet that would cost the country less than the present diet. Such a human diet, standardized on the white rat, and reinforced by experiences with domesticated animals, would contain graham bread instead of white bread; but it would subordinate appetite to hunger and disregard the psychological factors of nutrition. Important as saving is to an individual and to a nation, there is a point beyond which it is not worth while. And until a country faces such a pressure of population on food supply as to enforce a low standard of living, the impulse to save is not strong enough to make an unsatisfactory diet acceptable for that reason. In effect, an industrialized people employs its talent in part for the very purpose of securing the purchasing power to pay for a better diet. When a country is rich enough and earns enough to choose between foodstuffs, it is idle to suggest how much might

be saved if it continued to use the diet of a poor people not in position to choose between foodstuffs. If one shows how much the British might save by using graham bread instead of white bread, one should also show how much might be saved by using cotton instead of wool, and jute instead of cotton.

Arguments advancing the use of whole wheat flour would imply for Europe the reduction of herds of domesticated animals. When Europe imports wheat and mills it into white flour, in effect she imports bread and milk and meat. The use of whole wheat bread tends toward vegetarianism. Europe, with the use of her manufacturing facilities, is headed in the opposite direction.

For the country that is a net exporter of cereals the problem is not how to use less, but how to dispose of more. If the people of the United States were to use graham bread instead of white bread and wheat meal instead of wheat flour, this would diminish the home market for wheat by something like 150 million bushels. Unless eliminated by adjustment in acreage, the wheat thus saved would need to find an export outlet or be degraded to a feeding stuff at home. It is not obvious that it would be in the interests of the national economy to feed 150 million bushels of wheat to animals at home instead of feeding to animals the wheat offal corresponding to that amount of wheat. Indeed, it is probable that the animal products to be secured from wheat offal equal in calories to 150 million bushels of wheat would exceed those to be secured from the wheat directly. The export problem of the wheat grower would certainly not be lightened by increasing the exportable surplus.

VI. CONCLUSION

Biologically considered, the place of cereals in the diet depends largely on the pressure of population on food supply. A heavy intake of cereals is the most effective expression of vegetarianism; and thus, in congested countries, like China and India, cereals occupy by far the most prominent position in the food supply. Broadly speaking, the lower the income of a nation,

group, or family, the higher is the proportion of cereals in the diet.

The place of wheat among cereals must ultimately rest to some extent on comparative prices. Apparently, the per capita use of wheat in the world is increasing; but for the time being this is probably the expression of greater freedom of choice rather than the result of lower price.

The place of wheat in the American diet rests for the present on a different basis. In this country there is no pressure of population on food supply; and in the national sense the choice between foodstuffs is not determined by prices, though it is somewhat influenced by them.

The use of wheat in the American diet has declined during the past half century and now stands close to nine-tenths of a barrel of flour per person per year. Whether wheat has reached a stable position in our diet is not established; but impending changes can hardly be of significant proportions.

Wheat now contributes about one-fourth of the calories of the American diet and is therefore still the outstanding single staple foodstuff. The meaning of wheat for us lies primarily in the starch content. It is the starch, which comprises about 70 per cent of the weight of wheat flour, which is the major source of the energy on combustion of wheat flour in the body.

Wheat contributes around one-fourth of the protein of the national diet; in consideration of the quality of wheat protein contrasted with the quality of the protein in the animal products in the diet, the wheat protein is distinctly of subordinate importance. Only for vegetarians and for persons subsisting on a sub-standard level of protein intake, is wheat a significantly important source of protein.

Of the five known vitamins, only one is of possible importance in relation to wheat—namely, vitamin B. It is largely localized in the germ. This vitamin is present in so many other foodstuffs in the diversified American diet as to make the use of the wheat germ dispensable to the average individual. Only where peculiar and, indeed, relatively abnormal conditions obtain, is vitamin B of the wheat germ essential.

Like cereals in general, wheat is not especially rich in mineral elements. These are present in such amounts in milk, fruits, and vegetables as to make the mineral elements of wheat dispensable except under exceptional circumstances of deprivation.

Wheat bran is one of the several avail-

able forms of roughage, but in no way a necessary or even a relatively advantageous component of the average diet. For most individuals, the roughage in fruits and vegetables is superior to that of bran. In addition, fruits and vegetables contribute at the same time a more competent supply and assortment of mineral elements and of vitamins than are available in bran.

Nutritionally considered, the place of wheat in the diet may be anywhere up to, let us say, two-thirds of the calories of the diet. The higher the proportion of wheat, or other cereal, in the diet, the greater the care necessary to secure the indispensable elements in order to avoid deficiency diseases. In the United States, it is only where the statistically average diet is not had that the possibility of deficiency diseases arises.

A broad survey of modern knowledge of nutrition, in a country with the agricultural characteristics of the United States, indicates that nutritional security in the diet is to be sought in the milk supply and that wheat (and other cereals) ought to serve us as fuel food. To consume our bread as whole wheat bread instead of white bread would make no essential contribution to the national health, and would not be in the interest of national economy. American agriculture is based on the diversified diet, and any step in the direction of vegetarianism is not in the economic interest of the present population as related to land area.

Apart from nutritional considerations, the place of wheat in the diet depends on taste, custom, convenience, and price. Wheat is now one of the cheapest foods and under conditions of prosperity there is little incentive further to cheapen the diet by increasing the consumption of wheat. Other things being equal, there is little reason to expect that consumption of wheat may be expanded by appeals on behalf of producers. With national income where it stands and a wide diversity of foodstuffs freely available, the present place of wheat in the diet has been arrived at through a series of adjustments and interactions which are not likely to be notably modified in the near future.

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