OUR TEETH AND OUR SOILS

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The knowledge about the human body and its many functions has been accumulating seemingly very slowly. The additions to our information have awaited the coming of each new science and the contributions by them in their respective fields. Dentistry as well as the medical profession has been ready and quick to accept and use any new knowledge that might alleviate human suffering. In medicine, for example, one can list the major successive additions almost as separate sciences coming at the slow rate of about one per century. Anatomy was the beginning one making its debut in the sixteenth century. The seventeenth century brought us physiology; the eighteenth added pathology; and the nineteenth emphasized bacteriology, all these for our better health.

Very probably the twentieth century will be credited with the addition of the science of nutrition as a major contribution to the better life of our people. Better nutrition is leading us to think less about medicine as cures and less about fighting microbes with drugs. In a more positive way it is helping us to think more about helping the body defend itself by being well-fed and therefore healthy.

If we are to bring about good nutrition by means of good food, to build up a good defense for the body, that defense must be strong, not only against enemy invasions, as it can be against tuberculosis, but also against the degenerative diseases like the heart troubles, cancer, diabetes, etc. For such defense then of necessity, the science of the soil and its fertility, by which alone high quality foods can be provided, may well be an addition during the present century to our knowledge of the better functions and better health of our bodies. It is proposed therefore in this discussion to lead you to think about the health condition of only one part of our body, namely, our teeth as they are related to the fertility of our soils.

SOME BASIC FACTS INVOLVED

In dealing with the subject of soil fertility and its implications for our teeth, or for any other part of our anatomy and our physiology, it is essential that one establish certain facts and principles at the outset and then follow through as these seem to have causal connections with the phenomena under consideration.

The first fact that may well be considered is the observation that under moderate temperatures the increase in annual rainfall from zero to 60 inches, for example—as is the range in going across the United States from near the Coast Range eastward—gives first an increased weathering of the rocks. That change represents increased soil *construction*. Going east from zero rainfall means increasingly more productive soils until one reaches about the mid-continental area. Then with still more rainfall, there comes excessive soil development under the higher rainfall which means increased soil *destruction* in terms of soil fertility considered both in quantity and in quality.

The second important fact in connection with this climatic pattern of soil development is the observation that at the maximum of soil construction (and in the

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approach to it), which is near the 100th meridian of longitude, there is a wide ratio of the exchangeable calcium to the exchangeable potassium on the colloidal clay of the soil. There is a similar ratio of these two in the chemical composition of the crops and other vegetation grown thereon.

Then there is the third significant fact, namely that calcium is associated with the synthesis of proteins by plants, while potassium is associated with their synthesis of carbohydrates. The latter process, which is commonly spoken of as "photosynthesis", may well be considered a supra-soil performance. This classification is proper since photosynthesis is a compounding of carbon, hydrogen and oxygen—all weather-given elements taken from the air and water—into carbohydrates by sunshine energy. The process of synthesizing proteins is a biosynthetic process, that is, one by the life processes of the plant. It seems to be a case in which some of the carbohydrates serve as the raw materials out of which the proteins are made. This is brought about by combining with these carbohydrates some nitrogen, some phosphorus, and some sulfur, all coming from the soil. At the same time, some calcium, and possibly several other soil-borne nutrient elements are required, while more of the carbohydrates are consumed as energy materials for this conversion process.

The fourth significant truth that brings the soil fertility into control of the composition of our food, and therefore of our health, comes out of the facts (a) that in soils under construction by the limited climatic forces, or those with a wide calcium-potassium ratio, proteinaceous and mineral-rich crops and foods as well as carbonaceous ones are possible, and (b) that in soils under destruction by excessive climatic forces, or those with a narrow calcium-potassium ratio, protein production is not so common while production mainly of carbohydrates by the crops is almost universal.

Out of these climatic, pedologic, and physiological facts there comes the major principle of concern to the dentists, namely, we have in the regions of higher rainfall the excessive carbohydrates in Nature and therefore may expect them in the human diet. Where rainfall is high enough to encourage vegetation in abundance there we have a hindrance to sound teeth from Nature herself, because of too much carbohydrate, or conversely, insufficient proteins and minerals, a fact—all too familiar to those in the dental profession—that militates against sound teeth. We need then to realize these facts and consider them by remembering our geographic location and in our management of the soil with human nutrition in mind.

Excess of carbohydrates is natural

In considering soil fertility as it provokes excessive carbohydrates but deficiencies of proteins and minerals, we need only to look at the chemical composition of the human body in comparison with that of plants (Table 1). From these analytical data we can see that potassium is taken into the plants in largest amounts of all the mineral elements from the soil, while calcium and phosphorus are next in that order. In the human body, these same elements are the major three, but calcium is first, phosphorus second, and potassium third. Of amounts

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still higher than any of these in the human body is nitrogen. This is the key element distinguishing protein synthesized as amino acids from the elements only by plants. Plants offer us mainly carbohydrates with only small amounts of proteins. Plant composition, considered as our food, represents possible shortages of proteins, of calcium, of phosphorus, and of probably other essential elements. We, like other animals, are constantly in danger of deficiencies of proteins and minerals, especially as we are more vegetarian. By the very nature of

TABLE 1

Chemical Composition of the Human Body in Comparison with that of Plants and of Soils

SOURCE	ELEMENTS*	HUMAN BODY % WEIGHT	VEGETATION % DRY WEIGHT	SOIL† % DRY WEIGHT	
Air and water	Oxygen	65.00	42.9(2)*		47.3
	Carbon	18.00	44.3(1)		.19
	Hydrogen	10.00	6.1(3)		.22
Air and soil	Nitrogen	3.00	2.63(4)		
Soil	Calcium	1.50	.88(6)	0.30‡	3.47
	Phosphorus	1.00	.34(8)	0.0075	.12
	Potassium	.35	2.14(5)	0.03	2.46
	Sulfur	.25	.30(10)		.12
	Sodium	.15	.70(7)		2.46
	Chlorine	.15	.70(7)		.06
	Magnesium	.05	.31(9)		2.24
	Iron	.004	.0251(11)		4.50
	Manganese	.0003	.01(12)		.08
	Iodine	.00004	.00004		—
	Copper	Very small amount	.0011		—
	Zinc	Very small amount	.0041(13)		—
	Fluorine	Very small amount	.0005		.10
	Aluminum	Very small amount			7.85
	Boron		.004(14)		—
	Silicon				27.74

* Order of magnitude.
† Collected from various sources.
‡ % readily exchangeable in soils.

the creative processes that start with the soil, carbohydrates are plentiful while there are deficiencies of minerals and proteins. Man is therefore always faced with the shortages of minerals and proteins relative to the carbohydrates and fats. It is this nutritional need that encourages his carnivorousness and his use of animal products such as eggs and milk.

Excessive carbohydrates are invoked by our fertility pattern

That these shortages of minerals and proteins vary according to the pattern of soil fertility is demonstrated very clearly by the soils of the United States. The lower rainfalls of the western half of our country (the area of sparse population)

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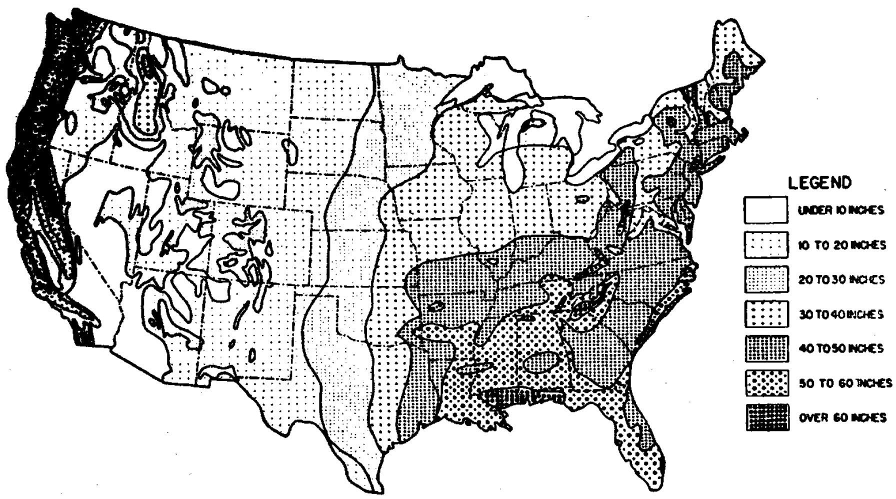

FIG. I. The higher rainfalls in the Eastern United States have leached the minerals from the soils, hence forests in early days and carbohydrate-producing crops today more than protein-rich and mineral-rich products grow there. Distribution of mean annual precipitation in the United States (44).

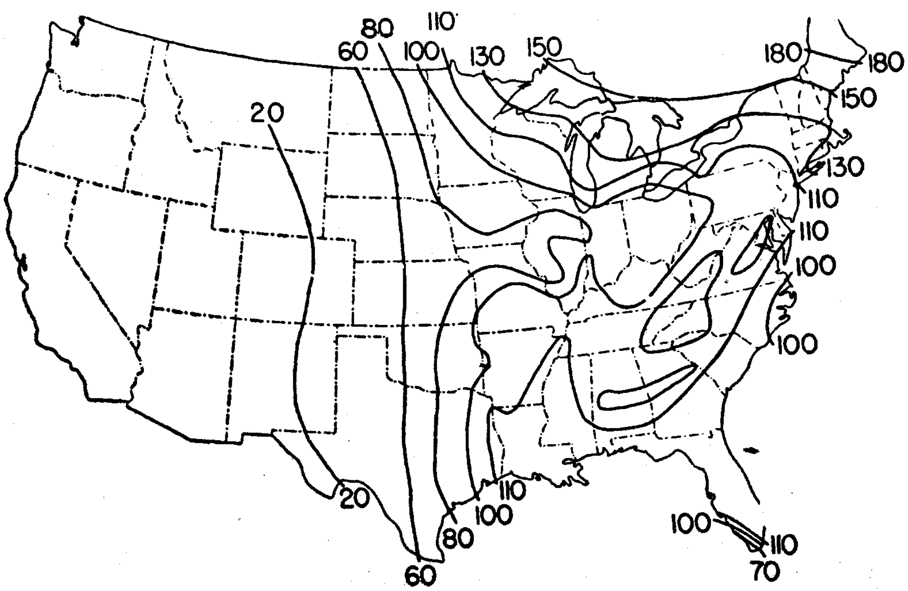

FIG. II. The lines of constant ratios of rainfall to evaporation (times 100) give pattern to the fertility of the soils. They tell us, for example, that the Cornbelt soils are similar to those farther west under less leaching. They are, therefore, still well supplied with minerals. (According to Professor Transeau, Columbus, Ohio.)

have not removed the calcium and the other nutrient cations from the surface soil. These lime-laden, mineral-rich areas have been the prairie soils. It is on

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these that the legumes as protein-rich, mineral-providing forages flourish widely and profusely. It is these soils that were feeding buffaloes in the early days by

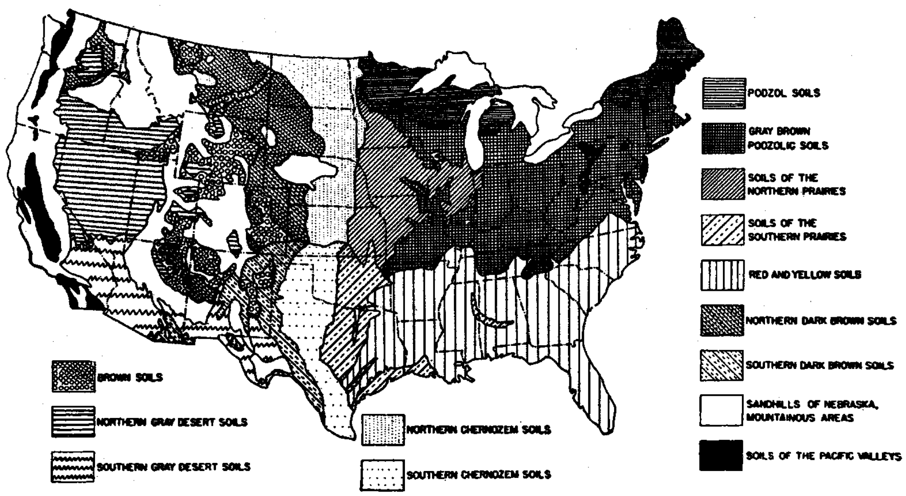

FIG. III. The soil map shows itself a composite of the map of rainfall and that of rainfall-evaporation ratios. It is the soils that give us an East and a West, and divide the East into a North and a South. Climatic and vegetational soil groups in the United States. (After Marbut, 1935)

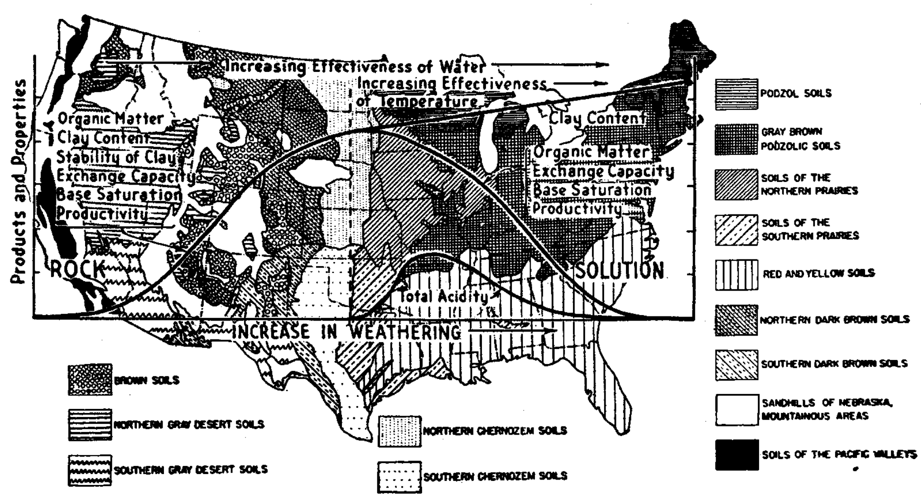

FIG. IV. The pattern of soil development of the United States shows the maximum of soil construction in the mid-continental area. It is on the soils there that maximum of protein and mineral delivery by crops is possible as good feed and food. Climatic and vegetational soil groups of the United States. (After Marbut, 1935)

their grass without purchased protein supplements. It is these soils that are giving us protein products in beef and lamb today.

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When one looks at the eastern half of the United States (the area of dense population) this part of our country with its higher rainfalls has soils leached so highly

Photo Mo. Agr: Expt. Sta.

FIG. V. "To be well fed is to be healthy" in the case of plants as well as humans. More clay, though acid, put into the sand (from left to right) made healthier plants.

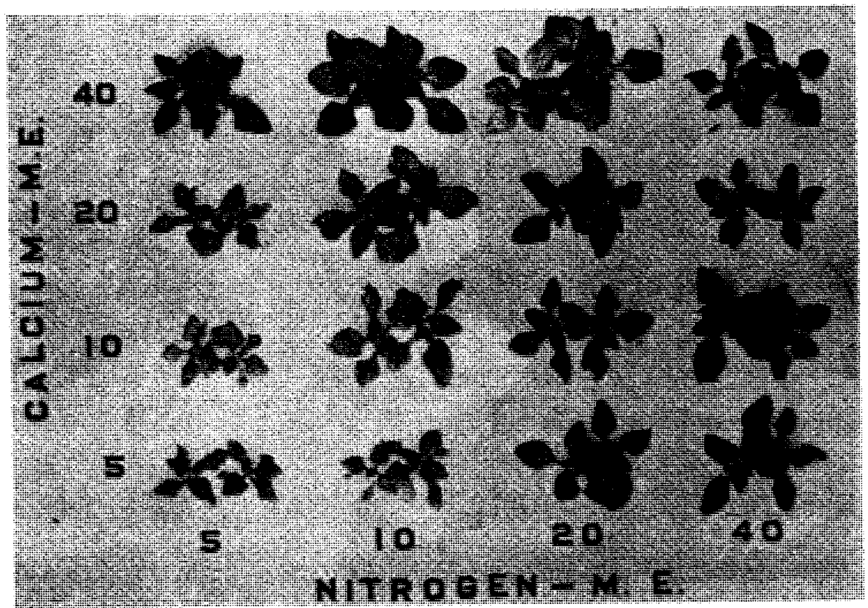

Photo by Mo. Agr. Expt. Sta.

FIG. VI. Spinach fertilized with more nitrogen and calcium, to make it more proteinaceous (right two rows) was protected against the attack by the thrips insects, while that less rich in proteins (left two rows) was not.

that most of the calcium has gone from these to the sea. In fact, that loss of calcium has made us classify them as "acid soils", as though the acidity rather

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than the shortage of fertility were responsible for their failure to grow protein-rich legumes. They were originally growing only wood as forests. When cleared

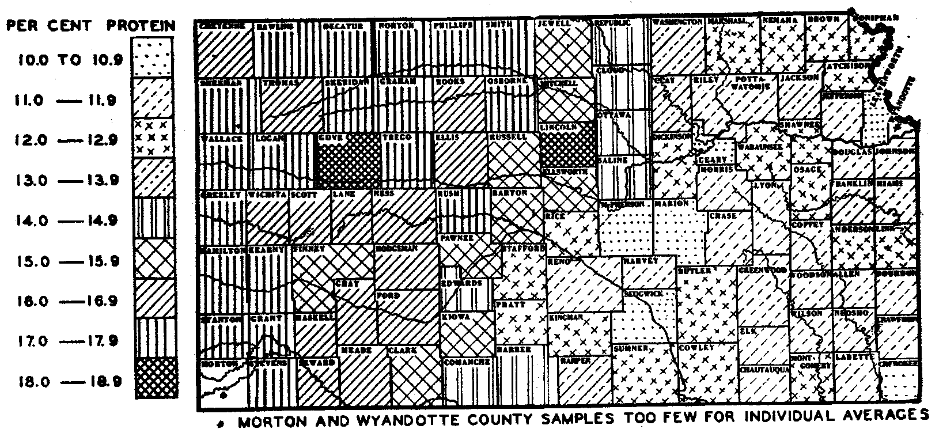

FIG. VII. The protein concentration in wheat of Kansas increased from ten to eighteen percent in going from the Eastern part of the state with 37 inches of rainfall to the Western part with only 17 inches. Plants can manufacture proteins only as the fertility of the soil permits. Protein content of Wheat.—Kansas 1940. As indicated by pre-harvest survey conducted by agricultural marketing service, United States Department of Agriculture.

Photo Courtesy Univ. of Minnesota Press

FIG. VIII. Wild life struggles desperately to get its calcium and phosphorus as shown by this porcupine consuming the antlers in the northern woods.

of these they have been growing starchy crops. It is on these eastern soils that we fatten the cattle that are born and grown on the soils farther west. These eastern soils can still grow hogs whose carcasses are mainly fat. Such soils if given fertility treatments can produce proteins by reproducing and growing the

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animals themselves but usually only with much help by attending veterinarians. Eastern United States is the area of increasing troubles with our dairy cattle, such as what is called "brucellosis" when affecting the cows and "undulant fever" when a disease of the human. Both of these diseases are still baffling to the diagnostic efforts aiming to locate their fundamental cause. If the Creator himself was making only such carbonaceous products as forests on those soils shall we not believe that such products must represent about the limits of our possibilities when we take over and grow crops on them without adding fertility to the soil?

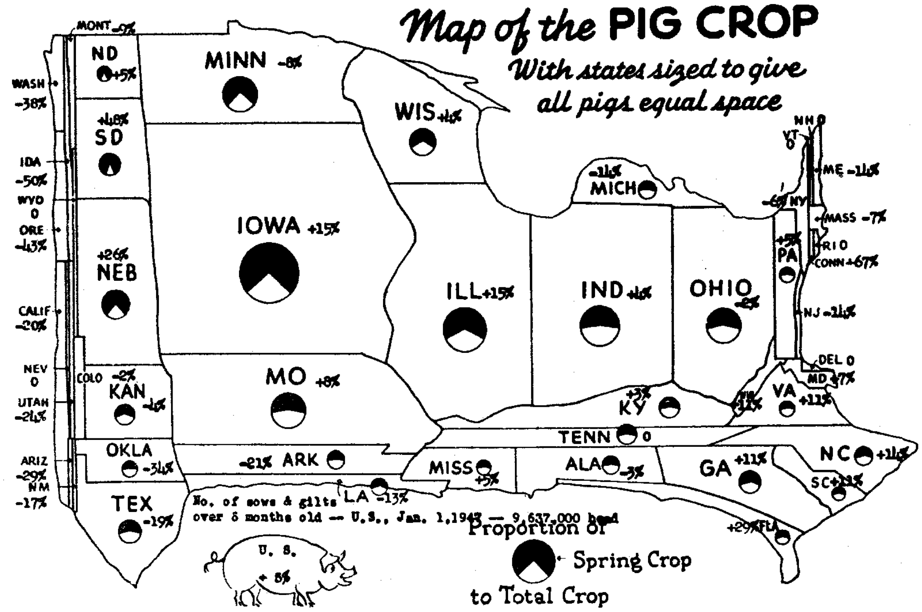

FIG. IX. The Eastern States produce carbohydrates more than proteins to make our animals those with more fat rather than protein. Number in each state shows per cent increase or decrease in number of sows and gilts over 6 months old on Jan 1, 1947, from pre-war years 1939–41. Prepared by American Meat Institute. Source of Data: U. S. D. A.

Soil exhaustion spells deficiencies of proteins and minerals but excess of carbohydrates

Soils naturally highly weathered are no longer well stocked with nutrient mineral reserves in their sand and silt fractions, nor with mineral fertility adsorbed on the clay. Such soils must of necessity give crops and foods which are mainly carbohydrates and are therefore deficient in proteins and minerals. But quite the opposite, the less weathered soils under low annual rainfalls are mineral-rich in the silt and sand reserves, and on the clay. Hence they give both proteins and minerals along with the carbohydrates in the plants grown on them.

In these facts we have the suggestion that any soil undergoing exhaustion of its fertility, whether by Nature or by man, is bringing about a change in the chemical composition of any plant species growing on it. This change means that the

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plant species become more carbonaceous, less proteinaceous, and less mineral-rich. These changes occur within any single plant species, too commonly believed constant in its chemical composition regardless of the soil growing it.

Surveys and experiments demonstrate the facts

That we may well take cognizance of this as a principle, has been demonstrated by the study of the chemical composition of the many crops and other plants as they are native to soils that are (a) slightly, (b) moderately, and (c) highly de-

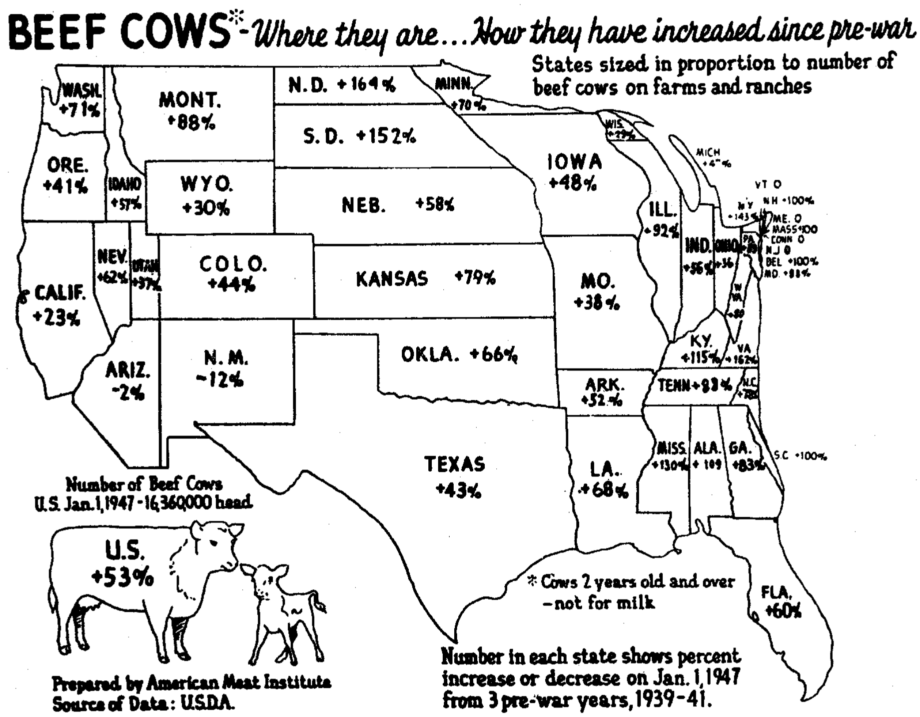

Fig. X. The Western States produce mineral-rich, proteinaceous forages to make our animals those with protein more than fat.

veloped under increasing rainfall and temperature. While some thirty plant species, common on the *slightly* developed soils, contained enough calcium, phosphorus and potassium in total to make up almost five percent of their dry weight, this figure dropped to four percent in going to a similar number of plants native to *moderately* developed soils. Then it dropped to less than two percent in going to plants natural to *highly* developed soils. As the soils are more highly developed then, or farmed under higher rainfall and temperature, they can provide us, through the plants on them, less and less of these minerals essential for bone growth and less of those associated with synthesis of proteins by the plants.

Experiments by Dr. E. R. Graham at the Missouri Agricultural Experiment Station have demonstrated how less calcareous soils make less of proteins and

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more of carbohydrates; or that the changing calcium-potassium ratio of higher development of the soil brings corresponding decreases in the protein and mineral contents of the same kind of vegetation. He grew soybeans on soils with (1) a wide, (2) a medium, and (3) a narrow ratio of the calcium to the potassium. He reproduced the conditions of soils under increasing weathering or under increased experience with rainfall and temperature. These three soils represented increasing encouragement for the plants to produce carbohydrates more than to synthesize proteins.

This narrowing ratio of the calcium to the potassium resulted in an increase of vegetative bulk by one-fourth. Such an increased tonnage would warrant agronomic applause. But this increase in vegetative mass represented a reduction in the concentration of protein by one-fourth, a reduction in the concentration of phosphorus by one-half and a reduction in the concentration of calcium by two-thirds of that in the smaller tonnage yield.

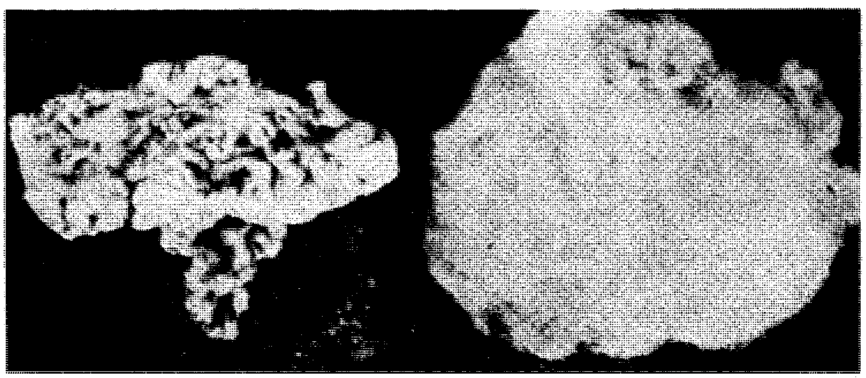

FIG. XI. Animal products, more than the animal body or the plants, reflect soil deficiencies. The wool on the left, which could not be carded, was grown by sheep fed lespedeza fertilized by phosphate only. The wool on the right, which carded nicely, was from sheep fed similar hay grown on soil given both limê and phosphate.

By modifying the relative amounts of calcium and potassium in the soil much as they are modified under increasing weathering of the soil, the physiology of the plant was shifted to the production of less protein and to the production of more carbohydrates. Higher soil development and more rainfall and temperature, then, bring less protein production by any crop and therefore less proteins and minerals in our feeds and our foods.

Concentration of protein in our food crops is being lowered by soil exhaustion

As our soils are being exhausted of their fertility by cropping under the intense economic pressure now being put on them, a single grain crop like wheat is producing itself of less protein and of more starch as time goes on. We say "wheat is becoming soft where once it was hard". In our near-colonial days we produced hard wheat in the valley of the Geneseo River of New York. That wheatbasket, or breadbasket of this country at that time, made Rochester the "Flour City".

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Today Rochester is still the "Flower City" with its many parks. But the "hard" wheat has moved westward across the United States, while the "soft", starchy wheat—which we seemingly desire for our pastries—is crowding along in its wake. "Soft" wheat has now gone so far west that even in Kansas the millers and bakers are complaining about its low protein content and their low volume of bread output per unit of flour used. The farmers of Kansas, however, are delighted with their high volumes of output as bushels per acre that are possible when the plants collect only carbohydrates instead of converting these into protein of much less bulk as plant output.

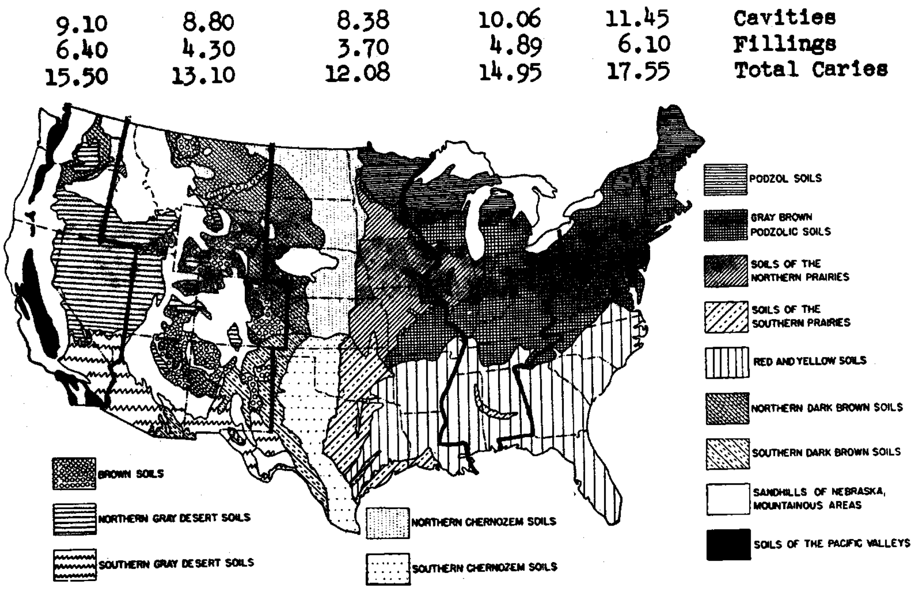

FIG. XII. The concentration of dental caries gives a reciprocal curve of that for soil development under the climatic forces. The minimum of caries are in the mid-continental area of maximum soil construction. They increase in going westward from there to soils less developed, and more so in going eastward to soils more highly developed.

Corn, too, is doing less in its synthesis of proteins. While we have pushed up the volume of its output as bushels per acre by hybrid vigor, we have not realized that the concentration of protein in our corn grain was dropping from a mean figure of about 9.5 percent to only 8.5 percent during the last ten years.

Forage crops, as well as grain crops, have been going to lower concentrations in minerals and proteins. They have been going lower in giving us what may be called the "grow" foods but have been holding up in supplying for us what may be called the "go" foods, namely carbohydrates. But while this is happening there is greater deception by the crop of which only vegetative mass is of concern or is measured, than when the harvest taken is the seed or the plant's efforts for its own reproduction and continuance of the species. As we harvest vegetative bulk we fail to note the low delivery of protein which reports itself as lowered grain yield more noticedly than as less vegetative bulk.

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As we mine the soils of their fertility so that the output by one crop as bulk goes down, we search the world and bring in some exotic crop because it can make tons or bushels where the preceding crop failed. If this imported crop makes vegetative tons where the others failed, it must be putting out it products with less of soil fertility in them and therefore they must be more carbonaceous and probably of deceptive nutritional values.

As a consequence of the lowered protein concentration in grains and grasses under soil fertility depletion, we have not only had the westward march of "hard" wheat, and the clamor for more "grass" agriculture, but also a westward march of our protein in beef and lamb. Chicago is no longer the major beef cattle market.

Photo by Post

FIG. XIII. Human health goes with the soil and its fertility. Courtesy F.S.A. Scene from Wadesboro, N. C.

That honor now rests on Kansas City. Even the hog market, a trader mainly in fat products, has moved to central United States when it once was farther east. These movements have been under the force of a declining soil fertility and are not merely the result of man's wanderlust or his nomadic nature.

Here, then, in the soil fertility is the pattern of the nutritional values of our foods and feeds pointing out their lowered concentrations of minerals and proteins. Here is the lowered power of growth and lowered capacity for reproduction. Life is not passed from one fat globule to another, nor from one starch grain to another, but only from one protein to another protein molecule. Can a dentist see good permanent teeth being laid down in the jawbone of a foetus when the mother's diet is deficient in minerals and protein? Can he find sound teeth in school children when carbohydrate bulk predominates in their diet because of its lesser cost and easier storage than that of milk and meat? Is it any wonder

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that we were startled when COLLIERS told us of "The Town Without a Toothache" located in the region of lower rainfall?

Geography of dental defects in the United States and the pattern of soil fertility

That Hereford, Texas, is in the part of the United States of highly fertile soils is not so startling when the geography of dental defects on a larger scale is considered. The recent physical examinations of the millions of men taken into the Army and the Navy give a wealth of data in relation to the many possible factors in control of our health and of the condition of our teeth. These data may well be correlated with the fertility of the soil for their suggestive value in listing many of our health troubles as possible deficiencies originating in the soil. In these data and records there is an opportunity to relate the caries of the teeth to the soils of the United States according to their pattern of fertility, or to their degree of development by the climatic forces.

Very recently Comdr. C. A. Schlack and Lt. Birren of the Navy Medical Research* Institute presented some data by regions of the United States which represented the condition of the teeth of 69,584 men coming on active duty in the Navy in 1941–42. These represented 93 percent of a lot from which 7 percent had already been eliminated for dental reasons. This screening reduced the regional differences, but even in spite of this, those regional differences show a decidedly interesting relation to the development of the soil.

From the report of these naval officers, one is almost astounded at the poor dental condition in this sample of our people. It is especially serious when these naval inductees represented the mean, youthful age of 24 years with 82 percent of them below the age of 30 years. For the group as a whole the report reads as follows: "The mean number of simple and compound cavities was found to be about ten per person . . . and five fillings per person." "Few teeth required extraction, despite the large number of carious teeth, the mean number per person being about 0.2. In contrast, the mean number of missing teeth was 4.7 at the time of the examination."

This is a sad commentary on the dental condition of our young men when the statistics list them for an average of 15 carious areas each, in spite of the regular encouragement by the radio to use the tooth brush daily and to "see your dentist twice a year." But when the chemical composition of our teeth tells us that they consist mainly of calcium phosphate, and when the foremost fertilizer treatments needed to grow even carbonaceous vegetation on our soils are lime (calcium) and superphosphate (phosphorus), there is good reason that the poor dental condition of these naval inductees should be connected with the low fertility of these soils. When soils need lime and phosphate to grow agricultural vegetation much more will they need these fertilizer additions of calcium and phosphorus in order to pass these nutrient elements on to the animals and the humans in the chain of decreasing chances to get these soil-borne requisites for good sound teeth.

By recalculating the dental data of these naval inductees so as to make them

* C. A. Schlack and J. E. Birren. Influences on Dental Defects in Navy Personnel. Science 104:259–262, 1946.

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represent more nearly the soil areas according to increasing degrees of soil development in going from the arid West to the humid East, the correlation is very striking. It is highly significant that the lowest numbers of carious teeth are in the longitudinal belt of dual-state width just west of the Mississippi River. Hereford, Texas, is included in this belt. As one goes either westward or eastward from this belt to other similar belts, the tooth troubles increase. This increase, however, is much larger in going eastward, that is, to the excessively developed soils under higher rainfall and temperatures, than it is in going westward to the underdeveloped soils.

Here is a clear indication that those soils with a high capacity for protein production, because of their high mineral fertility, are the soils that have also grown better teeth. These are the soils of the open prairies.

Quite differently, however, those soils that have a low capacity for producing legumes, beef, and mutton and have been growing starchy grains and fattening the livestock, have a much higher number of carious teeth per person. These are the soils of the forested areas or the potential producers of mainly fuel foods.

The maximum number of caries was exhibited by the men from the New England States where the cavities amounted to 13.5 accompanied by 7.8 fillings per person or a total of 21.3 carious areas per mouth. With such numbers of defects it seems a pity that we can't have more than 32 adult teeth. In the Middle Atlantic States just south of New England, the total figure was 19.6. Still farther south the corresponding value was 13.4 of which 9.7 were cavities and 3.7 were fillings.

In this case of the soil and teeth as one goes south from New England there are three factors that may help explain the decrease in caries. There is first, a decreasing ratio of rainfall to evaporation and therefore less relative leaching of the soil; second, there is less acidity to break down the mineral reserves because of the nature of the clay; and third, in the South there is the more general use of fertilizers consisting mainly of carriers of calcium and phosphorus.

In these regional data there are the suggestions that the curve of the condition of the teeth is the reciprocal curve of the fertility of the soil. We may expect also, from these relations, that the pattern of soil fertility is in control not only of the health of the teeth, but also of health in general. This is strongly suggested by a careful study, reported by Dr. L. M. Hepple of the University of Missouri, of the more than 80 thousand draftee rejections from more than 310 thousand selectees for the Army from Missouri alone. He points out, for example, that Kansas had lower rejection rates than Missouri. This is another way of telling us that the health troubles increase in going from the calcareous soils of Kansas to the lime-deficient soils of Missouri.

Equally as interesting in terms of the increase in draftee rejections as the soils are less fertile, are his data in going across Missouri from the northwest to the southeast, which means going from the legume and cattle area to that of cotton. His series of figures for draftee rejections in making that traverse of the state was 208, 247, 280, 339, and 368 per thousand selectees. Even for an area so limited

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as Missouri, the health condition in terms of Army standards reflects the pattern of the fertility of the soil.

From all of the data of the inductees into the Army and the Navy there is the suggestion that more of our so-called "diseases" may well be statistically mapped for the United States and compared with the map of the soil fertility. If all other body irregularities as well as those of the teeth were so viewed, it is highly probable that many of our diseases would be interpreted as degenerative troubles originating in nutritional deficiencies going back to insufficient fertility of the soil. Surely the millions of health records of the inductees into our national defense will not be left lying idle in Federal archives when they can be sorted out as specific diseases, plotted as densities over the soil fertility pattern, and possibly give suggestions for combating the failing health that rests on the great fact that degeneration of the human body goes with the exploitation of the soil.

If the decay of teeth is linked with the declining fertility of the soil, this concept of tooth troubles may well be a pattern to guide our thinking about other health troubles, not as calls for drugs and medicines, but for conservation in terms of a new motive, namely better health via better nutrition from the ground up.

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